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OF THE

UNITED STATES COMMISSIONERS

TO THE

UNIVERSAL EXPOSITION OF 1889

AT PARIS.

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VOLUME III.

APPARATUS AND PROCESSES OF MECHANICAL INDUSTRIES,
CIVIL ENGINEERING, ETC.

SIXTH GROUP.

Edited by CHARLES B. RICHARDS, M. A., United States Expert Commissioner for Sixth Group.

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GENERAL REVIEW

OF

THE SIXTH GROUP.

BY

CHARLES B. RICHARDS, M. A.
United States Expert Commissioner for the sixth group.

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GENERAL REVIEW OF THE SIXTH GROUP.

By CHARLES B. RICHARDS, M. A.

INTRODUCTION.

(1) Recognizing the inability of one person to report with sufficient etail upon any large proportion of the whole ground covered by the reat variety of subjects to which the exhibits in the sixth group elate, the Commissioner-General authorized the expert assistant ommissioner for this group to limit his work to a general review of ie group and a more particular examination of a single class under , and to distribute the remainder of the work to a number of exerts who volunteered or were employed to furnish particular reports n the special subjects of which they were competent to treat.

Among those who volunteered this assistance were several of the xpert assistant commissioners for the other groups, who assumed ie responsibility of examining those classes of the sixth group hich bore close relations to the classes of their own groups, or to hose subjects the professional work of these gentlemen relates.

The kindness of those who have thus willingly given their valuale time and labor, has made it possible to present a collection of pecial reports relating to a variety of subjects which must otherise have been entirely neglected or very superficially presented, the round to be covered being so vast and the difficulties in the way of athering information during the Exposition so great.

Following are the names of the gentlemen who have contributed pecial reports, or included matter relating to the sixth group in e reports of their own groups :

Commissioner Chandler, for the fourth group, took the following bjects : Apparatus for compressing fuel and economizing smoke ; so certain appliances for metallurgical work, in Class 48 ; chemical pparatus and gas manufacture, in Class 51 ; processes for the presvation of wood, in Class 63, and hygiene, hospitals, etc., in Class 64.

Commissioner Clark, for the seventh group, took into his own roup Class 50, relating to the manufacture of food products.

Commissioner Newbury, for the fifth group, took the subject of the manufacture of chemical and pharmaceutical products, in Class 51.

Mr. C. R. Dodge, special agent of the U. S. Agricultural Department, took agricultural appliances, in Class 50, and certain subjects relating to textile manufactures, in Class 54.

The following gentlemen contributed special reports. The arrangement is in the order of the classes to which the reports relate:

Mr. Henry M. Howe, on mining and metallurgy; Class 48.

Prof. John H. Barr, on machine tools; Class 53.

Mr. J. M. Merrow, on knitting and embroidering machinery; Class 55.

Mr. H. D. Woods, machinery for making brick and tiles; in Class 57.

Prof. L. M. Haupt, Class 61, railroad appliances.

Mr. Carl Hering, Class 62, electricity.

Prof. William Watson, Class 63, civil engineering, public works and architecture.

Commissioner Lyle, Class 66, art of war; also life-saving, in Class 65.

The regulations of the Exposition prohibited visitors from making sketches, or even taking notes, without special permission from the exhibitors in every case, a rule which was rigorously enforced by the attendants; and although, through the courtesy of M. Berger, Director-General of the Exposition, the Commissioner and his assistants received letters intended to secure special privileges, the suspicion with which attempts to make memoranda were regarded, and the consequent interruptions that occurred, put many and very serious difficulties in the way of getting the information necessary for a sufficient knowledge of the exhibits.

The exhibitors were, as a general rule, exceedingly courteous and quite willing to give all the information requested, but they could seldom be found except at times when the buildings were thronged with visitors. In a few cases exhibitors of extensive collections of machinery stated, in answer to inquiries, that it was not for their interest to be public instructors, and refused all opportunity for getting information respecting their exhibits.

In this connection it is a pleasure to acknowledge the value of the services rendered by Mr. H. D. Woods in corresponding with the exhibitors and in collecting much of the information which served as the basis of several of the special reports.

Messrs. Vuillet and C. Morin, attachés of the administration of Machinery Hall, also rendered service in gathering information.

Frequent reference is made to descriptions and comments found in the leading journals of engineering science and practice. It is natural to expect that nearly all the strikingly interesting features of a great international exhibition would be promptly noticed and de scribed in the enterprising special technical journals of the various countries. In the present instance these journals have vied with each other in giving to the public information respecting the details of the Paris Exposition, and many of them have published different illustrated descriptions of the same exhibits.

The publishers of the English journals "Engineering" and "Industries" cordially gave full permission to have their illustrations and descriptions used to any extent in the reports. A limited use of this privilege has been made, credit being given in each case to the source from which material is taken. In referring the reader to publications of descriptions not inserted in the report, those references have been chosen which seem to give the fullest information on the subject.

GENERAL CHARACTER OF THE EXPOSITION IN THE SIXTH GROUP.

(2) On making a careful survey of the machinery and other objects classed under the sixth group one fact soon became strikingly apparent, that, notwithstanding the great extent and variety of the display, the number of new inventions of importance—except perhaps certain applications of electricity—was very small.

Throughout the entire French, Belgian, English, and Swiss sections there were to be seen, with but few exceptions, only machines and apparatus which, in similar forms, have long been familiar to experts in the different arts represented.

It seems to have been necessary to make a similar criticism in relation to the Vienna Exposition of 1873, and at the Paris Exposition of 1878 a like condition was recognized and very ably commented upon by M. Hirsch, the accomplished reporter for the jury of Class 54 of that Exposition, who in his exhaustive report says, in effect:

> With respect to machinery the Exposition of 1878, compared with those which have preceded it, seems to present a clearly distinctive character. In former expositions new inventions occupied a considerable place; in the exposition of 1878 it is quite otherwise. Few absolutely original ideas are to be found. The machinery and apparatus exhibited are little more than recombinations of principles already well known and applied. Not only would we seek in vain in the vast buildings for some one of those great discoveries which change the character of an industry, but even, in a far more limited sense, inventions which possess a moderately important scope are absolutely wanting.

He then remarks that progress had nevertheless been made, and says:

> The machines exhibited are, as a whole, better designed and more intelligently combined than those shown in the former expositions; their proportions are better, their workmanship more perfect. In fact, considerable advance has been made.
>
> But it is not by great inventions that this progress has been effected; it is rather by a thousand improvements which relate to the details of the machinery, and if the results thus attained seem less brilliant their importance is not the less enormous. It may be said that the mechanical industries have advanced out of the embryonic period, have rested from putting forth germs, but are becoming developed by a vigorous growth.

The improvement in the detail and design of machines commented upon in 1878 by M. Hirsch has continued to advance rapidly since then, and it may be safely said that there is now comparatively little to choose between the productions of the several great nations who exhibited in Machinery Hall.

So far as style, proportions, convenience, completeness of detail, and adaptation to the purpose in view are concerned, the machinery was in general admirably well designed and executed.

The several great international expositions which have been held in the last two decades and the increased intercommunication of engineers and manufacturers resulting from them have had the effect which might have been anticipated: Each nation, gradually losing its prejudices, has adopted the improvements which have enabled another to take the lead in any particular direction, whether in matters of practical importance or of good taste. A general uniformity of excellence, amounting indeed to a certain lack of individuality in the design of the machinery of any one class, was a marked feature of the Exposition of 1889.

The doctrine of the survival of the fittest was here illustrated in its application to inanimate objects.

Light and flexible frameworks with tortuous contours, formerly approved and admired, have yielded place to substantial forms with severe rather than fanciful outlines well suited to the material employed, and designs have been adopted which exhibit a judicious directness in the application of material so as best to resist the stress to which it is subjected, and a distribution of mass well adapted for the absorption of vibrations.

Complex and indirect apparatus for transforming movement, the result of ingenuity misapplied or unskillfully directed, is replaced by simple and compact mechanism, the product of careful study and of the judicious application of the principles of kinematics.

Frivolous ornamentations and a profusion of highly polished surfaces are rarely found, their bad taste and inappropriateness being universally recognized, and the outlay formerly wasted in this direction is now applied to procuring neat castings and securing coincidence of the places where parts meet each other.

Another quotation from the report of M. Hirsch is apt in its application to the Exposition of 1889, and conveys suggestions so noteworthy that it will be given here:

> An interesting fact to notice is the absence of those eccentric and irrational inventions which too often mar an exposition, machines conceived in a contempt for fundamental mechanical principles and which betray the lack in their authors of the most elementary knowledge of science.

He goes on to say that the severity of the inspection of the jury for the admission of exhibits has much to do with this—

> But it is equally certain that the diffusion of technical instruction has played the more important part in this purging; exact ideas, so indispensable to the mechani-

cian, are widely popularized: they form the basis of professional teaching, not only for the education of the superintendent and the engineer, but also of the foreman and the operative. Furthermore, in proportion as the teachings are extended among those employed in an industry, in that proportion do the sciences themselves gain in breadth and solidity and in their foothold in the shops.

It is gratifying to be able to record the evidence of general progress thus shown by the Exposition of 1889. To those familiar with the condition of the mechanical industries in the countries of Continental Europe in former times one thing must have been strikingly evident: that these countries have recently made rapid strides in the direction of substantial progress, and that their manufacturers are fast assuming a position in the foremost rank among the producers of well-designed and well-executed machinery of all kinds. While, therefore, the United States has hitherto exercised, and, as will be shown, continues to exercise a very marked influence upon the improvement which is noticed in the products of the continental engineer and his shops, yet in order to continue to maintain in the future the creditable place in the advance which the younger country now occupies, unremitting attention must be given to increasing facilities for the best scientific and technical training of youth, a training superior in its methods to the European systems which, though faulty in many respects, have been such an important factor in the progress of the mechanical industries there.

(3) THE UNITED STATES SECTION.

The position held by the United States in the sixth group of the Exposition was a very honorable one.

Without particular mention here of the exhibits most deserving of attention, it is sufficient to say that no part of Machinery Hall was examined with greater interest and approval, by European engineers, than was the United States section. The general verdict of these men was that the greater proportion of those machines in which freshness and originality were shown was found in this section, and that here the interesting new idea and useful invention were conspicuous above the uniform grade of general excellence everywhere found in the mechanical exhibits.

The juries for the classes of the sixth group performed their duty in a thoroughly conscientious and painstaking manner, and their decisions afford the best criterion for judging of the excellence of the United States exhibit.

The high awards which were so liberally distributed to our exhibitors were generally given on the ground of the originality and utility of the exhibit rather than its fine appearance or great extent, and never simply because the exhibitor was a successful manufacturer or engineer, a course which for good reasons was not always pursued in distributing awards to the French exhibitors.

(4) The representation of the United States was by no means how-

ever confined to its own section; its proudest display was in fact seen outside of the actual exhibits made by its own citizens. Much of the machinery exhibited by the other nations was either admitted to be of design belonging to the United States and advertised to be this, or else was a close imitation of forms which have originated with its engineers and inventors.

A large proportion of the steam-engines were of the Corliss type. Porter's steam-engine governor was seen on most of the engines; the influence of Porter's life work in the development of the high-speed engine was everywhere apparent. The Wheelock, and Armington & Sims engines were exhibited in the sections of every nation; examples of pumps and water meters embodying Worthington's duplex system were numerous; the windmills exhibited were of types belonging to the United States; our forms of wood-working machinery have been adopted; our steam-boilers are closely copied, and the rapid working and yet safe passenger elevators so common in the United States are being introduced.

To substantiate this statement of the prevalence of American influence which the Exposition shows to exist in Europe it is well to quote from an unprejudiced writer.

In an article in the Revue Universelle des Mines, etc., on the steam-engines of the Exposition, Professor Dwelshauvers-Dery, of the University of Liége, the learned vice-president of the jury of Class 52 of the Exposition, says:

> One of the most striking facts that the Exposition of 1889 brings into relief is that, with respect to machinery, American influence is extending more and more, and gaining a stronger foothold day by day in Europe. The United States has imposed upon us its forms, its methods of execution, even the organization of work by which more perfect precision is obtained in the production of its workshops, and in the case of steam-engines it has imposed its types.

After giving numerous examples of the adoption by the largest manufacturing establishments of systems introduced from the United States, and of forms and devices imported from there, he continues:

> The question may well be put, whence comest this exuberance from one side of the Atlantic, that kind of relaxed condition on the other? How does it happen that the master thought is sent across the ocean to Europeans, who, so to speak, are reduced to the rôle of manufacturers only?
>
> Perhaps the answer would be more easily found if we were to quit the domain of the mechanic arts to examine from a higher standpoint the social status of the old and the new continents. It would be a digression of great value, but space is lacking, and we will speak only of machinery, and particularly of the steam-engine, born in the old continent, having there received at the outset its first applications, and whose fundamental theory has been based on the work of Europeans—Régnault, Mayer, Joule, Rankine, Clausens, Hirn. If we say that the Americans have a more practical mind, that is to say, more logical habits of thought, this is begging the question, for the American race has little blood foreign to Europe, and other reasons than that of race must be given to account for this practical superiority.
>
> Does not the difference we find lie in the education? In the United States it is free everywhere, everywhere creative and expansive as liberty itself. In Europe it

is regulated, powerfully organized, the work of a despotism smacking of the barracks; its aim seems to be to reduce to uniformity all the members of the social body, to cast them all in the same mold, to make them, so to speak, interchangeable. It is forgotten that the trees of a forest can be brought to equal height only by cutting off the higher ones to the level of the lower; that the education of organisms is not accomplished under the hammer, at the anvil, in the mold, or by a milling process, and that the first of its duties is to respect individuality while developing it at the same time.

Often, without consulting special aptitudes, a young man is brought up to make a mechanician by inculcating in his mind, in a methodic manner, a certain number of sciences, well classified, well graded, according to a well-defined programme, which leaves nothing for him to originate; the courses of study teach him everything; the young man need only learn, let himself be led. Periodically he is examined as to what he has absorbed; he is overworked, if it is necessary to do so, to deprive him of time for reflection; then a diploma is given to him, and he is consecrated a mechanical engineer, warranted by the Government. Happily there are vigorous temperaments which resist even this prolonged compression and burst the mold, resuming their own forms more or less speedily. But how much time is wasted?

Let us have less, much less, dogmatic teaching; ' * the youth be brought up in the laboratories, as is already done nowadays in England and America; let the schools and laboratories be opened widely, leaving the young people free to consult their aptitudes, without compelling them to submit to a series of examinations by means of which their knowledge is appraised to the hundredth of 1 per cent., and without dismissing them from the school because they have failed in a branch the study of which repels them, and which perhaps they will never in their lives make use of.

Public prosperity is interested in a reform which has the respect of individual freedom for a foundation. This would be the simple consecration of the revolution which the Paris Exposition celebrates, and whose results are even to-day compromised by the kind of education which is applied to those of whom it is desired to make leaders in movements relating to social interests. The true democratic principle is to give to each one the place which his personality merits, with the air free about him for his development; "the right man in the right place."

The quotation has been given thus in full in order to add force to the words already said in connection with the quotation from M. Hirsch respecting the influence technical education has had upon the progress shown in the mechanic arts.

(5) *Classification:* In the Exposition of 1889 the classification of the objects exhibited did not differ greatly from that of 1878, and, with one exception, all the classes relating to plant, apparatus, and processes used in mechanical industries were assigned to the sixth group, which, therefore, comprised Class 48 and Classes 50 to 66, inclusive; Class 49 which relates to agriculture and forestry, having been taken from the sixth group and set off to the eighth and ninth groups.

The general subjects to which the plant, implements, apparatus, and processes under the eighteen different classes of the sixth group relate, respectively, are:

Class 48. Mining and metallurgical operations.

Class 50. Food industries and the preparation of agricultural products.

Class 51. Chemistry, pharmacy, and tanning.
Class 52. General mechanics.
Class 53. Machine tools.
Class 54. Spinning and the manufacture of cordage.
Class 55. Weaving.
Class 56. Sewing and the manufacture of articles of clothing.
Class 57. Furniture, joinery, and the manufacture of building materials.
Class 58. Paper making, dyeing, and printing.
Class 59. Miscellaneous industries and arts.
Class 60. Carriage and wagon making and wheelwright work.
Class 61. Railways.
Class 62. Electricity.
Class 63. Civil engineering, public works, and architecture.
Class 64. Hygiene and public charities.
Class 65. Navigation and life-saving.
Class 66. The art of war.

(6) The number of exhibitors of different nationalities in the different classes of the sixth group is given approximately in Table I, compiled from the French official catalogue, in which there were some errors. Changes in the classification were, in many cases, made by the juries after the publication of the latest editions of the catalogues, so that awards were given to exhibitors whose names were listed in classes different from those in which the awards were granted. As the purpose of the table is only to give a general idea of the distribution of the exhibits, its accuracy is practically sufficient.

TABLE I.—*Number of exhibitors in the sixth group, by nations and classes.*

Class.	France and colonies.	Belgium.	United States.	Great Britain.	Switzerland.	Other countries.	Total.
48	146	28	4	12	3	16	209
50	250	23	12	16	17	21	339
51	175	13	1	16	3	10	218
52	483	42	34	63	17	38	677
53	96	10	20	17	8	23	174
54	81	19	2	6	3	44	155
55	102	5	2	5	8	14	136
56	104	2	12	9	....	7	134
57	65	1	9	....	2	1	78
58	164	11	13	11	3	21	223
59	93	2	26	12	5	10	148
60	247	18	9	21	5	69	369
61	162	37	23	19	8	16	265
62	293	15	33	18	10	21	390
63	798	77	17	39	12	88	1,031
64	274	21	2	32	10	66	405
65	209	5	8	36	6	40	304
66	187	18	2	4	....	12	223
Grand total	3,929	347	229	336	120	517	5,478

(7) The field covered by this group was very great, and the floor space devoted to it, which was crowded with exhibits, had an extent of about 100,000 square metres, or 1,000,000 square feet—nearly 25 acres. The following table shows how this space was provided for by the different buildings:

TABLE II.—*Space occupied by the sixth group.*

	Square feet.	Total square feet.
Boiler houses in the boiler courtyard:		
Babcock	1,500	
C. Knapp	645	
Daydé & Pillé	1,775	
Roser	2,225	
De Naeyer	4,900	
Belleville	2,174	
Weyher & Richmond	1,690	
Dulac	1,076	
Fontaine	1,076	
		17,061
Other buildings in this courtyard:		
Steinlen & Co	13,778	
Two bakehouses	2,734	
Megy's building	1,291	
		17,803
Electrical Court:		
Gramme station	7,750	
Syndicate station	3,875	
Le Couteux station	6,296	
		17,921
Class 61, Annex:		
First building	60,548	
Second building (Suffren avenue)	21,958	
		82,506
Class 60, Industrial Arts Building Annex		26,000
On the Champ de Mars:		
Goldenberg	538	
Asphalt	322	
Forges St. Dennis	1,610	
Montechamin	259	
Stoker's Society	4,305	
Royaux	538	
Lacour	603	
Etablissement Cail	7,535	
La Buire	5,274	
Annex for Class 52	8,270	
Solvay	1,054	
Mariemont Collieries	3,762	
Forges du Nord	4,843	
Edison Station	4,843	
Perrusson	1,549	
Telephones	3,762	
State manufactures	4,358	
Eiffel Pavilion	699	
Gas Pavilion	4,036	
Pavilion Coignet	387	
		58,547
Carried forward		219,838

TABLE II.—*Space occupied by the sixth group*—Continued.

	Square feet.	Total square feet.
Brought forward		219,838
On the Quai d'Orsai:		
Annex for Class 52	19,375	
Annex for Class 65	30,189	
Pumping stations	3,647	
Serpollet	1,054	
Electrical stations	13,238	
Petroleum	10,676	
Annex for Class 58	12,817	
		90,996
Buildings on the Esplanade des Invalides:		
Ministry of War (ground floor)	35,527	
Ministry of War (second story)	32,292	
Powder and saltpeter	3,358	
Aerostation	6,048	
Tollet tents	2,270	
Collat tents	1,667	
Walker tents	387	
Sanitary service	304	
Yvose tents	484	
Colombier Militaire	587	
Sanitary train	18,298	
Wagon shed	9,687	
Military bakery	1,076	
Public assistance	20,558	
Hygiene (Class 64)	15,069	
Mineral waters	10,764	
Help for the wounded	12,593	
English mill	1,098	
		172,067
Surface occupied by exhibits of the sixth group in Machinery Hall		565,147
Total		1,048,048

(8.) *Machinery Hall.*—It will be seen that more than one-half of the total area occupied by the sixth group was furnished by the great Machinery Hall, the general arrangements and dimensions of which will be stated here, the description of the structure being given in the report on Class 63. A general view of the interior is given in Plate I, the frontispiece of this volume.

This building, which perhaps is the boldest in design of any hitherto attempted, and the largest one of its general kind yet constructed, consists of a central nave 1,360 feet long, covered by a glass roof in a single span of 375 feet, with its peak at a height of nearly 160 feet from the ground. On each side of the nave, extending its whole length, is a lateral extension or wing 48 feet wide, forming a part of the great hall, not in any way partitioned off from it, but having a roof much lower than that of the nave. These wings expand the ground floor of the great room to a width of 471 feet in all, and also have floors 26 feet above the ground floor which form galleries 48 feet wide along each si le of the hall; galleries 59 feet wide are also carried across the ends of the nave at the same level. The whole ground floor of Machinery Hall thus affords an area of 640,000 square feet, and the galleries an additional area of 176,000 square feet; total, nearly 19 acres, which, after deducting thoroughfares and passageways, left about 565,000 square feet of floor room available for the exhibits.

(9) The allotment of the space according to nationalities is shown in Table III.

TABLE III.—*Allotment of space in Machinery Hall.*

Countries.	Ground floor. Nave.	Ground floor. Wings.	Galleries.	Total.
	Sq. feet.	*Sq. feet.*	*Sq. feet.*	*Sq. feet.*
United States	18,298	6,877	3,552	28,727
Great Britain	18,513	14,196	10,586	43,295
Switzerland	12,916	3,745	6,813	23,474
Belgium	24,972	9,364	3,229	37,565
France:				
Class 48	14,800	8,880	3,229	26,909
50	23,680	8,880	4,306	36,866
51	16,070	....	2,153	18,223
52	35,865	12,797	6,782	55,441
53	30,268	2,140	3,230	35,638
54	17,222	....	2,153	19,375
55	16,070	....	2,294	18,364
56	....	....	10,764	10,764
57	17,222	....	2,153	19,375
58	22,013	11,893	3,050	36,956
59	5,597	....	1,940	7,537
61	....	66,995	17,568	84,563
62	14,208	4,648	2,906	21,762
63	....	21,986	18,324	40,310
Grand total	287,714	172,401	105,032	565,147

The French exhibits covered three-fourths of the area of Machinery Hall; the remaining fourth, namely, the corner of the building nearest the avenue de la Bourdonnais and the main exhibition building for the industrial groups, was assigned to the only four foreign nations who made any considerable exhibition of machinery, namely, United States, Great Britain, Belgium, and Switzerland.

The French exhibits were divided in accordance with the official classification, and all the objects in a class were grouped together in one place, so that the exhibits of any class could be studied together and be compared with each other.* In the foreign sections, however, there was little attempt at an arrangement in classes, the limited

* The general arrangement of the ground floor of Machinery Hall is well shown on the plan of the Champs de Mars, in vol. I of the reports.

dimensions of the space and the character and extent of the exhibits making it impracticable to effect a systematic grouping.

(10) As an exhibit of bold engineering enterprise, and as a work of art in iron construction, Machinery Hall was magnificent, but it is questionable whether it was so well adapted for its use as other buildings for the same purpose in former expositions have been.

As is the case with all noble buildings, the fine proportions of this immense hall prevented its size from being appreciated at a glance, and the height and great width of the arched nave had the effect to dwarf the contents of the building sadly, so that even the noblest exhibits and the largest machines (such, for example, as the blowing engine, 40 feet high, exhibited by the Cockerill Company, and the large horizontal engine with a pulley 33 feet in diameter, shown by Farcot) failed to appear impressive.

Provisions for ventilation were practically entirely wanting, only a few very insufficient inlets and outlets for air having been provided. It was supposed that the great height and volume of the inclosed space would make it unnecessary to provide for rapid renewal of the confined air, but the heat, even in moderately warm weather, was almost intolerable, and the air was close except in cold and windy weather.

The great width of roof and the consequent movements caused by expansion and contraction from change of temperature made trouble with the glazing, so that occasional showers of broken glass from the great height, and the arrangement for extensive repairs which the breakages involved, made it necessary at times to rail off large areas of the floor in order to prevent access to places where it would be dangerous for visitors to pass.

The provisions for the circulation of visitors in this great hall were well considered, and proved as liberal as could be demanded for even the vast crowds which at times filled the Exposition. Two main avenues, 26 feet wide, one lengthwise and one crosswise through the center of the building, divided the ground floor into four equal parts, and an avenue also 26 feet wide crossed the building midway between each end and the middle. These four thoroughfares, with a passage across each end of the building and eight others running lengthwise, all from 10 to 13 feet wide, formed the main channels of communication and circulation. Railway tracks were laid in these passageways, and turn-tables provided at crossings for use in placing and removing the exhibits; they were covered by the floor during the Exposition.

(11) Nearly all the machinery in motion, or that which required a supply of steam, was located in the nave, although motion was communicated to some of the very light machinery in the upper gallery, and to some of the machines under the galleries, by means of special lines of shafting. The principal lines were four in number, extend-

ing from end to end of the hall. They were placed in the middle of the spaces for the exhibits, between the passageways, and supported at a height of 15 feet above the floor by the heavy double columns and lattice girders which sustained the tracks of two traveling cranes of 60 feet span, which were used for placing heavy machinery, and afterwards employed as traveling galleries for conveying visitors from end to end of the building, and affording points of view of the building and contents. At the places where the power was transmitted from the engines to the shaft the columns were from 6 to 12 feet apart, according to circumstances, elsewhere 36 feet apart with two intermediate hangers in the space. Where the shaft received the transmission from an engine it was 5¼ inches in diameter, elsewhere 3½ inches. The speed was 150 revolutions per minute. It was assumed that about six-tenths of a horse-power per foot in length might be required. Each line was divided into seven independent lengths, driven by separate engines, but the lengths could be coupled by sleeves in case of the failure of any engine. There were several supplementary lines of shafting in different parts of the building, notably three under the galleries, where they were sustained by substantial hollow iron posts, having an elliptical cross-section and a base broad enough to afford rigidity without bracing ; a neat arrangement.

(12) The line shafting, without pulleys or hangers, was rented in thirty lots from several large engineering firms, who also furnished attendance, oil, etc., necessary to keep it in running order, on terms as follows :

First. For supplying the shafting, and for the service of keeping it oiled and in running order during the entire term of 180 days, which is the official period of the Exposition, at the rate of 7 hours of working time per day, 64 francs per running metre, or about $3.90 per foot of the 3½-inch shafting, was paid.

Second. If service additional to the above should be required in consequence of an extension of the daily running time beyond 7 hours, then an additional payment was to be made, at the rate of about one-quarter of a cent per foot of shaft for each additional hour, to cover extra expense for attendance, oil, etc.

Third. If additional service should be needed in consequence of a continuance of the Exposition beyond the official period of 180 days, then 2¼ cents per foot of shaft was to be paid for each day of 7 hours running time thus added to the term, to compensate for the continued use of the shafting and the expense of keeping it oiled and in order.

The total length of shafting thus supplied was about 5,000 feet.

(13) For driving the shafting there were thirty-two steam-engines, and these were scattered in all parts of the building, a distribution which necessitated an extensive system of piping for the supply of steam, for carrying the cold water used for condensation, and for the re-

moval of the hot water discharged from the condensers—a system the magnitude of which will be appreciated when the great volume of steam and water which the engines required is considered.

The pipes were contained in substantially built arched subways of masonry, which extended beneath the floors of the thoroughfares. The main subway, which extended the whole length of the building, between the lines of shafting nearest the boiler court, was 8 feet wide by nearly 7 feet high and 1,100 feet long. Another subway, of nearly the same size but half this length, was placed in the quarter of the building occupied by the foreign exhibitors, while a cross-subway of the same size as the latter connected these two. Openings were provided 14 feet apart for access to joints and for making connections, the distance of the openings from each other being determined by the standard length of the pipes used for the Paris water supply. Six smaller subways led to the main subways from the six groups of boilers which supplied the steam. The hot and cold water pipes, one of each, in the main subway, were 24 inches in diameter. In the subway for the foreign sections these pipes were reduced to 16 inches. The steam pipes were comparatively small, as they led independently from the different groups of boilers to limited sections of the building, and were not connected with each other, so that the repairs of a break or leak in one of the pipes would not interfere with the running of any large number of machines. The branch pipes from the lines of the subways to the engines were supplied at the expense of the exhibitors.

All steam pipes were well covered with nonconducting clothing, but notwithstanding this the heat radiating from them contributed greatly to the discomfort experienced in this building by the exhibitors and visitors.

(14) The motive power for the shafting in Machinery Hall was, as has been stated, obtained from thirty-two engines. These were furnished by exhibitors. Each of the twenty-eight lengths into which the four main lines of shafting were divided and each of the three lines under the galleries was driven independently by one of these engines, the remaining engine being employed to drive a dynamo from which power was transmitted to the Agricultural Building.

The names of the exhibitors, the nominal power of each engine, the power bargained for by the administration, and the length of shaft driven by each is given in Table IV.

TABLE IV.—*Particulars of the steam-engines employed for driving the main lines of shafting in Machinery Hall.*

Names of the exhibitors.	Length of 3½-inch shaft driven by each engine.	Power the shaft was intended to transmit.	Power requested by the exhibitors of machinery.	Power of the engines furnished by the contractors.	Power contracted for or actually exerted.
	Feet.	*H. P.*	*H. P.*	*H. P.*	*H. P.*
Powell	110	90	48	150	90
L'Horme	110	67	45	240	80
Ateliers de Vierzon	132	79	50	50	40
Schnieder & Co	165	100	226	300	110
Windsor	165	100	46	150	90
Chaligny	118	72	22	60	50
Boulet	120	73	60	100	75
Anciens Etablissements Cail	85	51	30	200	40
Darblay	80	50	....	30	....
Biétrix	180	110	75	120	85
Weyher & Richmond	165	100	226	150	100
Lecouteux & Garnier	165	100	47	300	110
Société de Fives-Lille	185	112	38	100	75
Douane, Jobin & Co	165	112	60	100	75
Davey, Paxman & Co	165	100	46	150	90
Straight Line Engine Company	145	89	89	100	90
Société Phœnix	135	76	85	190	100
Société de Winterthur	160	100	74	120	85
Sulzer Frères	165	100	20	150	90
Berger-André	185	112	50	100	75
Société Alsacienne	......	......	....	200	60
Davey, Paxman & Co	145	89	89	150	90
Brown	145	89	89	100	90
Carels	130	78	85	350	110
Société d'Oerlikon	165	100	93	300	110
Escher, Wyss & Co	165	100	20	150	90
Olry Grandemange	118	72	16	80	55
Cassé et fils	185	112	36	600	110
Berendorf	75	45	21	50	40
De Quillacq	110	67	60	160	90
Buffaud & Robatel	75	45	12	75	40
Brasseur	110	67	60	520	110
Total	4,363	2,657	1,918	5,595	2,545

It will be seen that 2,500 horse-power were required by the administration, while the actual power of the engines in motion made over 5,000 horse-power available.

(15) For providing the engines and connections, including pulleys and belts for transmitting power to the line and all valves and pipe connections with the hot and cold water and steam mains; also for running the engines continuously at the power required and furnishing attendance necessary for this purpose, the following prices were paid:

First. For power supplied in the amount contracted for, during the whole official period of 180 days, at the rate of 7 hours working time per day:
For each indicated horse-power $8.00

Second. For extra power beyond that contracted for if required in the regular working hours:
For each indicated horse-power, per hour.. .0064

Third. For power if supplied in overtime, in consequence of the daily working time being extended beyond 7 hours:
(a) For each indicated horse-power, per hour of overtime, for oil, wear and tear, etc.. .0064
(b) For each hour thus added, for labor.. .40

Fourth. For power if needed in consequence of the continuance of the Exposition beyond the official period of 180 days:
For each indicated horse-power, per hour.. .01

Steam for running the engines, and water for condensation were supplied to these contractors without charge.

(16) The steam supply for Machinery Hall was furnished by certain exhibitors, who contracted to erect boilers, connect them with the water supply, and provide chimneys not less than 100 feet high, without expense to the administration; also to supply steam during the exposition, on terms which were alike for all the contractors.

It was agreed that the administration would deliver water in the main under the boiler court without charge to the contracting exhibitors, who on their part were to be at the expense of the fuel and all attendance, of whatever character, required for the maintenance of a continuous supply of steam at a specified pressure, in quantity as required. There were ten of these exhibitors whose boilers were used for Machinery Hall alone. The boilers were separated into seven groups, six of which occupied buildings in the boiler court, which extended the whole length of one side of the hall at the extreme end of the Champs de Mars, the seventh group being in the electrical station on the other side of the hall.

(17) The exhibitors in the several groups, with the number, heating surface, and water capacity of the boilers, the quantity of steam demanded of the contractors, and the quantity actually supplied, will be found in Table V.

TABLE V.—*Particulars of the boilers for supplying steam for the Machinery Hall.*

	Names of the exhibitors to whom the contracts were awarded.	Number.	Steam pressure. Licensed per square inch.	Steam pressure. Actually used per square inch.	Total water-heating surface.	Water contents.	Weight of steam contracted for per hour.	Weight of steam supplied per hour.	Actual working capacity as determined by trial, per hour.
			Pounds	*Pounds*	*Sq. feet.*	*Cu feet.*	*Pounds.*	*Pounds.*	*Pounds.*
I.	Fontaine	1	90	75	1,076	387	2,200 }	7,700	4,400
	Dulac	1	120	75	930	421	2,200 }		
II.	Weyher & Richmond	2	120	95	1,850	676	4,400	4,400	......
	Companie Fives-Lille	1	130	90	1,000	296	1,364	1,364	......
III.	Belleville	8	150	100	6,400	620	22,000	29,700	34,000
IV.	De Nayer	5	150	100	15,130	3,070	22,000	22,000 }	36,500
V.	De Nayer	1	150	100	2,710	525	5,500	5,500 }	
	Roser	5	150	100	5,970	1,250	18,700	18,700	20,000
	Daydé & Pillé	2	150	100	2,370	387	6,600	6,600	10,000
VI.	Conrad Knapp	1	130	100	1,350	277	3,300	3,300	......
	Babcock & Wilcox	2	130	100	5,540	1,400	15,400	15,400	24,200
VII.	Davey, Paxman & Co.	4	150	100	2,844	......	11,000	14,300	......
	Total	31	......	......	47,170	9,309	114,664	128,964	......

NOTE.—The water-heating surface and water capacity given in the table for the Babcock & Wilcox boilers do not include the surface and contents of the "economizers," but for the De Nayer boilers the surface of two economizers which were used is included, as the aggregate surface only could be ascertained from the data procurable.

It should be stated here, that the engines by which the line shafts were driven used less than half the entire steam supply, the larger part being required for the numerous other engines which were connected with special exhibits, particularly those for giving motion to dynamos and other high-speed machinery not driven from the lines. In addition to this large supply of steam demanded for Machinery Hall, there was nearly an equal amount required for supplying the engines in the electric-light stations, the pumping engines, and one or two of the large isolated exhibits of machinery driven by special engines; the supply required for these, about 100,000 pounds per hour, was furnished by other boilers than those specified above.

(18) The prices paid the exhibitors who contracted to supply steam were as follows:

First. For steam supplied in the quantity contracted for:

For each 2,200 pounds, say 1 ton, of water evaporated every hour (or for 7 tons per day of 7 hours actual working time), during the whole official period of 180 days $1,700.00

Second. For extra steam supplied during the regular working term of 7 hours:

For each ton of water evaporated .... .60

Third. For extra steam supplied in consequence of an extension of the daily working time beyond 7 hours:

(*a*) For each ton of water evaporated in this additional time .... .60

(*b*) For each hour thus added (to pay for the labor) .... .60

Fourth. For extra steam supplied in consequence of the continuance of the Exposition beyond the official period of 180 days:

For each ton of water evaporated in the additional time	$1.00

A single example of the application of the contract for supplying the steam will enable all the contracts to be understood.

Suppose an agreement to have been made with a contractor to supply steam at a rate equivalent to the evaporation of 22,000 pounds, or say 10 tons, of water per hour, under the conditions of the first clause of the contract. Suppose also that the demand for steam required that he should increase the supply to 12 tons per hour, or 2 tons per hour more than agreed for, beginning the thirtieth day after the opening of the Exposition. Also suppose that, from the date just mentioned until the Exposition closed, the daily working hours were increased to 8 instead of continuing at 7. Finally, suppose that the Exposition had continued open 6 days beyond the official period of 180 days. Then at the end of the Exposition the amounts to the credit of the contractor would be as follows:

I. Under first clause of the contract:	
For 10 tons, at $1,700	$17,000
II. Under the second clause:	
For 2 tons per hour extra during 150 days and the regular working time of 7 hours per day, being 2,100 tons extra, at 60 cents	1,260
III. Under the third clause:	
(*a*) For 12 tons per hour during 150 extra hours (1 hour per day for 150 days), being 1,800 tons extra, at 60 cents	1,080
(*b*) For 150 extra hours, at 60 cents per hour (to cover labor of all kinds in whatever quantity)	90
IV. Under the fourth clause:	
For 12 tons per hour during 6 extra days of 8 hours running each, being 576 tons, at $1	576
Total	20,006

The following additional particulars of the arrangements made with the contractors are extracted from the published regulations and the blank forms for the contracts:

The payments under the contract were to be made in three equal installments; the first, as soon as a test of the quality and capacity of the apparatus should be made after its completion in full working condition; the second, on the 31st of August, 1889; the last, one month after the close of the Exposition, but not later than November 30, 1889.

In the event of a delay by the contractor in having his apparatus in complete working order at the time specified in the contract, he was to suffer a forfeit for each day of such delay, in the amount of one-half the daily allowance provided for his service, the amount forfeited to be deducted at the time of payment of the first installment.

It was provided that the contractor might take one day each month, called a day of rest, for the repair, adjustment, or other attention which the apparatus might need, during which time he could discontinue the service; but the time when this discontinuance should occur must be fixed by the administration, when not determined by an accident which should necessitate a stoppage.

Recording steam-gauges and feed-water meters, the keys of which were held by the administration, were to be applied to the boilers of each contractor, and the indications of these instruments read daily by an inspector.

All materials furnished by a contractor, as for buildings, chimneys, etc., belonged to him, and after the close of the Exposition could be removed or left, as he preferred.

It has been thought best to give an account of these contracts, because their terms were carefully considered, and they enabled the administration to estimate closely the cost of the various parts of the service and to avoid the expense of an extensive corps of assistants to take charge of the details which fell to the care of the contractors, who, as exhibitors, were willing to make terms exceedingly favorable to the administration, for there was active competition to secure the contracts, which were distributed to as many different persons as practicable.

The working of all the details of the executive business relating to the mechanical service was exceedingly satisfactory. There was no confusion whatever in the conduct of this important branch of the great enterprise; almost every contingency seems to have been foreseen and provided for, and there was no confusion when they had to be met. The employés were not so numerous as to appear obtrusive, and yet an admirably thorough supervision of everything was maintained.

GENERAL REVIEW OF THE CLASSES OF THE SIXTH GROUP.

(19) A general review of the sixth group properly includes separate notices of the several classes it includes. Under the conditions already explained these are necessarily brief and superficial. In some cases reference merely is made to the special report which relates particularly to the class, in others a brief review of the standing of the United States relatively to the other exhibiting nations is given, and wherever it is practicable mention is made of our own exhibitors who received the highest awards, or whose exhibits attracted such favorable attention as to show that they were features of the national display which added essentially to its credit; while in a few cases it has been possible to give descriptions of interesting exhibits which are not described in the special reports.

The notices are arranged in the numerical order of the classes.

CLASS 48, MINING AND METALLURGY.

(20) Many of the individual exhibits in this class were on a large scale, particularly those entered by the great mining companies of France and Belgium. Besides machinery for facilitating the various processes of mining, the space allotted to these companies contained large models showing sections of the mines and illustrating the methods employed in working them. Some of these models were made of transparent material and others built up of removable layers, by means of which the geological formation of an entire mining district was shown, and in which the location of the mineral veins and the mines with their various shafts and galleries could be easily traced. The ingenious devices by which the different features were displayed enabled the visitor to obtain a clear conception of the extent and character of the different mining enterprises represented.

France and Belgium necessarily filled the most important place in the space occupied by the mining exhibits. The collieries of Mariemont and Bascoup, Belgium, were placed in a large special building outside of Machinery Hall, where were shown large models of their mines with the breakers and other structures, and miniature machinery in motion.

Two diamond mining companies exhibited models of their South African mines, and displayed the product in all its forms. They also exhibited the processes of mining, washing the dirt, collecting the stones, and finally that of cutting them. Their exhibits were among the most attractive of the whole Exposition and were crowded with throngs of visitors every afternoon.

Only four exhibitors from the United States were represented in the catalogue for this class. All of them received awards. The Cyclone Pulverizer Company and the Ingersoll Rock Drill Company, both of New York, received gold medals; Mr. Theodore Blake, of New Haven, received a silver medal for his exhibit of a multiple jaw crusher;* and a bronze medal was awarded to Elmer Sperry & Co., of Chicago.

(21) An important exhibit from the United States was placed in the section after the awards had been declared and, consequently, too late to be entered in any of the catalogues or to receive the official notice of the jury of awards. It was a gyrating screen for coal or ore, exhibited by Mr. Eckley B. Coxe, of Drifton, Pennsylvania, the invention of Mr. Coxe and Mr. Samuel Salmon, of Drifton.

This screen is intended for screening and sizing ore on a large scale and is a remarkable machine in many ways. It attracted much attention and favorable comment, and its advantages were so highly appreciated that a license to manufacture and sell the machines for

* This crusher is described in Mr. Henry M. Howe's report.

certain of the European countries was at once sought and contracted for by one of the most reliable of the French firms, who manufacture mining machinery on a great scale, and who expect the extensive introduction of this machine in European countries, especially in the collieries of France and Belgium.

The improvement affords a solution of the difficult problem of the practical adaptation of flat horizontal screens to the handling of large quantities of heavy material. The advantages of the horizontal screen over those of cylindrical form are well known to experts in mining processes, but hitherto the cumbrous form they have assumed, and the great power required to overcome their friction in working, have made their use unprofitable, except on a small scale. The Coxe & Salmon screen is a compact cluster of flat rectangular screening plates, one above another, which receive a rapid circular motion of translation in horizontal planes by means of an eccentric on a vertical revolving shaft. Figs. 1 and 2 show respectively one of the rolling bearings on which the screen is supported, and a perspective view of the complete apparatus.*

The principal feature of the invention is the manner in which the screens are supported and at the same time guided in their movements. The supports are shown in Fig. 1. They consist of rollers in the form of two cones placed base to base, guided between slightly dishing conical bearing plates: the upper one, A, being fastened to the screen beneath the corners, while the lower plate, B, is stationary and fastened to the bed-plate of the machine. There is one roller under each corner of the screen.

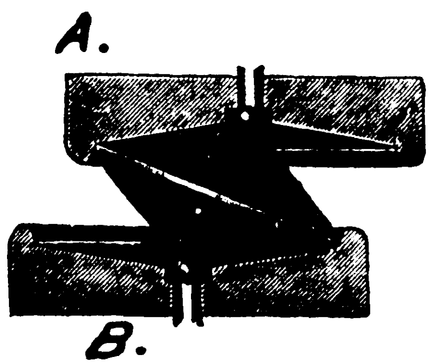


FIG. 1. Roller bearing of Coxe and Salmon's gyrating screen.

These anti-friction roller bearings guide and restrain the movements of the screen, as well as sustain its weight, in such a manner that every part of all the screens receives a circular movement of equal extent in horizontal planes without rising or falling.

Fig. 2 shows the general arrangement. In the form shown, two sets of screens are placed side by side and driven by the same shafts. In this case the eccentrics for giving movement to the separate sets are placed with their centers on opposite sides of the shaft, so that they stand exactly 180 degrees apart. By this arrangement the centrifugal force developed by the gyration of one set is balanced by that of the other. This balance is so nearly perfect that,

* These illustrations are taken, by permission, from "Engineering," London, August 30, 1889, where the invention is described more fully than in this report.

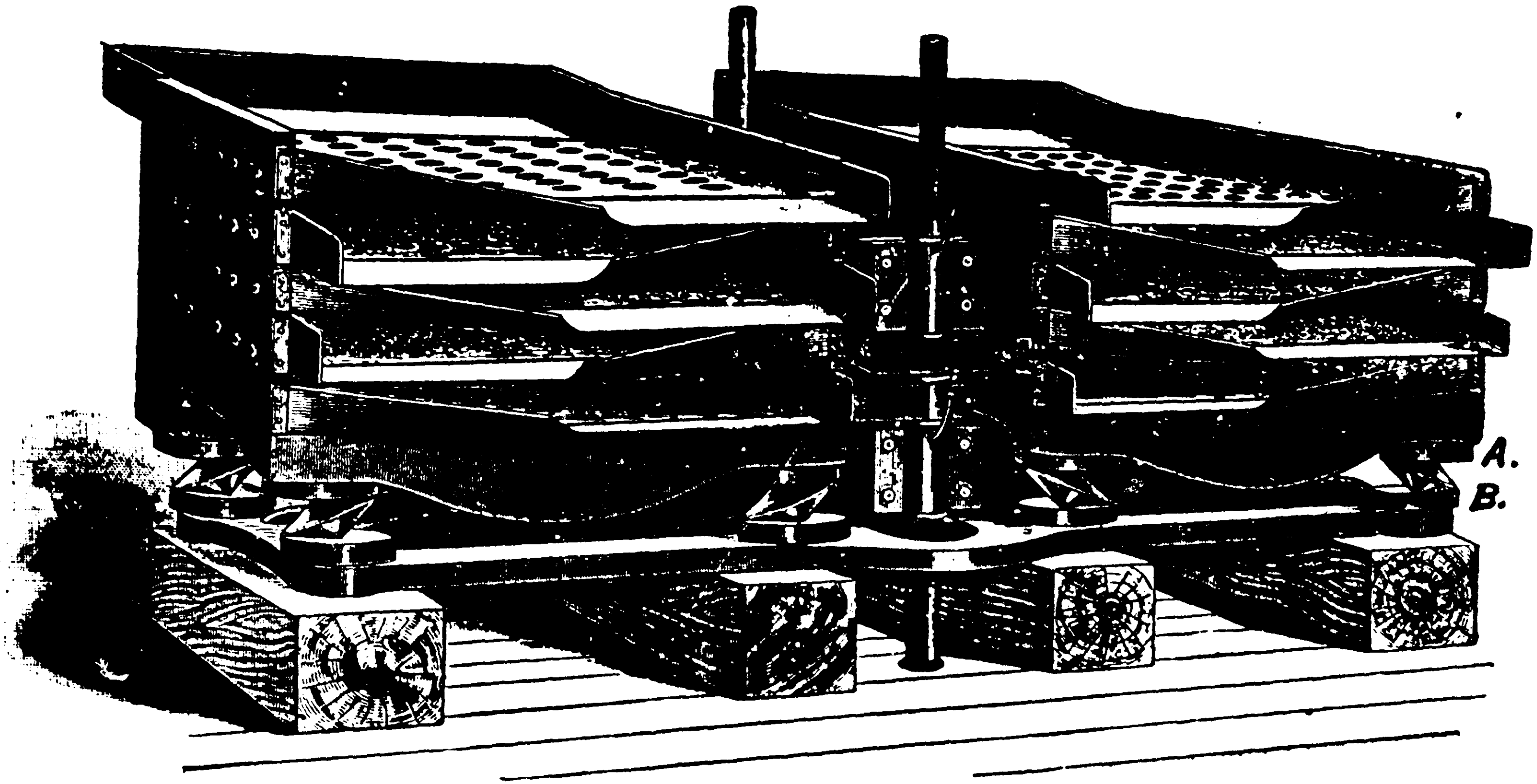


FIG. 2. Perspective view of Coxe and Salmon's gyrating screen.

with the machine shown in the Exposition, the heavy screens, when empty, could be run at about 200 revolutions per minute without sensible tremor.

By the use of these roller bearings the power required to run the machine is reduced to a minimum and is only slightly in excess of that necessarily absorbed by the action of the screens upon the material which is thrown upon them, because almost the whole of the frictional resistances occasioned by the weight of the screens and their centrifugal force are those resulting from the rolling of the smooth cones on the smooth surfaces which form their tracks, even axle friction being avoided in these places.

Two vertical driving shafts with their eccentrics, one at either end of the screens, are employed when two sets of screens are combined in one machine.

(22) Many interesting objects exhibited in Class 48 are described in the special report on Mining and Metallurgy, by Mr. Henry M. Howe, contained in this volume.

CLASS 49. FARMING AND FORESTRY.

(23) In the classification by the French authorities this class, which was at first included in the sixth group, was afterward transferred to the eighth and ninth groups, covering agriculture and horticulture; the objects exhibited are therefore noticed in the reports relating to those groups, and will not be referred to here.

CLASSES 50 AND 51, AGRICULTURAL WORK, FOOD INDUSTRIES, AND CHEMICAL MANUFACTURES.

(24) The reports of Commissioners Chandler, Clark, Newbury, and Riley contain notices of the exhibits in this class.

(25) The exhibitors from the United States numbered only twelve in Class 50 and five in Class 51. These seventeen exhibits received four gold medals, two silver medals, six bronze medals, and two honorable mentions; fourteen awards in all. The ratio of number of awards to number of exhibitors is 0.825.

There were 895 exhibitors from all nations in the two classes.

The awards were: Grand prizes, 12; gold medals, 81; silver medals, 119; bronze medals, 135; honorable mentions, 74; in all, 421; the ratio is 0.47.

If, however, the awards are weighted according to the values which Mr. Carl Hering, in his report on electricity,* has given to them; namely, 20, 10, 5, 2, and 1, for the different grades, respectively, beginning with grand prizes and ending with the honorable mentions, and if we divide the sum of all these values by the number of exhibitors, we find the average value of all the exhibits from

* Mr. Hering's report is contained in this volume.

all nations to be represented by the number 2.33, and those from the United States by 3.76. The number of exhibitors from the United States was so small that this comparison does not really represent the relative importance of the display, but goes to show the appreciation in which the articles exhibited were held by the jurors of these classes.

CLASS 52, GENERAL MECHANICS.

(26) The special report on this class is contained in this volume.

CLASS 53, MACHINE TOOLS.

(27) Of twenty exhibitors from the United States seventeen received awards, of which two were grand prizes and nine gold medals. There were one hundred and seventy-four exhibitors from all nations, and the United States, with less than one-eighth of this representation, received two-fifths of all the grand prizes allotted to the class, one-eighth of the gold medals, and one-sixth of the silver medals.

The Brown & Sharpe Manufacturing Company, and William Sellers & Co. received the grand prizes. The gold medals were given to the American Screw Company, G. F. Simonds, Stiles & Parker Press Company, American Tool and Machine Company, E. W. Bliss & Co., Morse Twist-Drill and Machine Company, H. J. Sternberg & Son, the Tannite Company, and Warner & Swasey. This showing gives a good idea of the standing in which American machine tools and their appliances are held in Europe. Professor Barr, in his special report, which is contained in this volume, has noticed many of the exhibits in this class.

In general the display was attractive and instructive as showing great progress on the part of the continental builders of machine tools. The English and American styles are generally adopted, and excellent workmanship is a characteristic of the machinery exhibited in this class. The machines constructed by the builders of best repute are massive and with outlines which suggest strength and rigidity. Those features of American machine tools which relate to convenience of manipulation, and have made our machinery so popular in Europe as to have obtained a large market for it there, have been adopted by the manufacturers of machine tools in France, and these manufacturers are, therefore, more formidable competitors than heretofore.

(28) The commissioner for the sixth group visited the works of the Messrs. Steinlen & Co., in Mulhouse, Alsace, who also have a manufactory in Belfort, France, and found the methods employed in building their machine tools to be of the most advanced character.

Milling processes are employed in that shop on a larger scale and for a greater number of general purposes than is usually the case in our own shops, and often take the place of operations ordinarily performed by the planer. It is claimed that the work is equally well done by less skilled workmen than are required to manage the planer, and that the product is consequently cheaper. The finished work and work in progress shown in the shop and at the Exposition were certainly excellent and left little to be desired. The surfaces as the cutter leaves them are remarkably smooth and regular, so as to require but little subsequent filing or scraping in fitting.

The shops of the Messrs. Steinlen are excellently organized, and the small tools, the system for their distribution, and the arrangement of their tool rooms are of the best. They reproduce American machine tools of the most popular designs, and advertise this fact as their recommendation. But in addition to these reproductions Steinlen & Co. are introducing a line of well-designed large lathes, horizontal boring machines, and other machine tools, in which original and improved features are introduced.

The special building on the exhibition grounds in which the Messrs. Steinlen placed their exhibit was one of the largest of the buildings erected by exhibitors, and contained a magnificent display of machine tools, machines for engraving printing rolls, calico printing machines, calendering machines, dynamos, shafting and its accessories, and steam-engines. Six of the latter were shown, all of the "straight line" type, a license for the manufacture of which this company has obtained from the United States patentee. Steinlen & Co. received a grand prize.

Grand prizes were also awarded to two French exhibitors, Bariquand & Son and Bouhey & Son, the most interesting of whose machines are described elsewhere in Professor Barr's report, which also contains notices of the English, Belgian, and United States exhibits of machine tools.

There were two exhibits of special machines in the United States section which did not come within the scope of Professor Barr's special report and must be noticed here.

(29) The American Screw Company, of Providence, had a well-arranged space in which they exhibited in operation a set of machines for making wood-screws on a new system, which has been adopted by them in the United States, and by means of which it is said one-third of the enormous output of their shops is now being manufactured. The screw produced by the machines is in itself a new article of manufacture. It is a wood-screw, of which the thread is raised on the outside of the wire, so that a screw of size No. 13 outside the thread is made from wire as small as that required for a No. 9 screw of the usual kind; the head, however, is as large as that of the No. 13 screw. The nick is indented in the top of the head and does not extend all the way across it; the head is therefore not weakened by

the nick. The screw itself is better than the old form, and there is much less waste of material in its manufacture. The wire is cut off, headed, pointed, and nicked in a machine resembling a common heading machine, but in which the blank receives three blows from three separate punches successively so as to produce the large head on the small wire without displacing too much metal in each process. The indentation of the nick also helps to spread the head and fill the heading die. The blanks, after being headed, are placed in the hopper of the threading machine and fed to the dies, where the thread is raised by a process of rolling. The following brief description and illustrations of this process have been taken from Engineering, London, November 22, 1889:

The blank drops vertically into a short guide, with the greater part of its length protruding below, like a skater who has gone through a hole in the ice and is supporting himself on his outstretched arms. The blank is then seized between the dies and the thread is rolled onto it; during this process the blank rotates, but has no movement of translation. As soon as the rolling is complete the screw falls through the guide into a hopper below and a new blank takes its place.

The dies are two flat plates, standing face to face, and having lengthwise reciprocating horizontal motions in opposite directions. Ribs corresponding to developed screw threads are formed on their faces, as shown by the sections, Figs. 4, 6, 7, and 8, and in elevation and plan, Figs. 3 and 5. These ribs all stand the same height from the back of the plate (Fig. 4), but the grooves between them gradually decrease in depth. At the entering ends of the dies (Fig. 5) the ribs are narrow and immediately penetrate the blanks to the full depth of the thread. The ribs grow gradually wider, and as the blank rolls between the dies the metal, caught between one rib and the next, is gradually compressed and made to flow outwards, until at the point *oo*, Fig. 3, it has assumed the form shown in Fig. 7, and is filling the grooves *bb*. As the rolling proceeds this action continues, and at *pp* (Fig. 3) the screw is partly formed (Fig. 8). When the process ends the die has the section shown in Fig. 6, and the screw thread is complete. There is no cutting of the blank whatever, neither is it lengthened nor shortened; its skin is made to flow endwise and outwardly by means of a pressure which is mainly longitudinal instead of being radial.

These two machines constitute a set and produce the finished screw.

(30) George F. Simonds of Fitchburg, Massachusetts, exhibited a forging machine operating on the same principle as the threading machine just described. It is for forging pieces which are solids of revolution, such as the balls for bicycle bearings, certain parts of carriage trimmings, small handles, the blanks for screws or round-headed bolts, and a variety of objects employed in the arts.

In this machine the piece is forged on the end of a heated rod, or from a detached piece, by being rolled between straight-grooved dies one or both of which have reciprocating movements. The grooves have the shape of the profile of the finished forging. Repeated rollings reduce the piece to its form with great accuracy, leaving nothing to be desired in smoothness and uniformity.

The exhibit deservedly received recognition by the awarding of a gold medal.

AMERICAN SCREW COMPANY'S PROCESS FOR THREADING WOOD SCREWS.

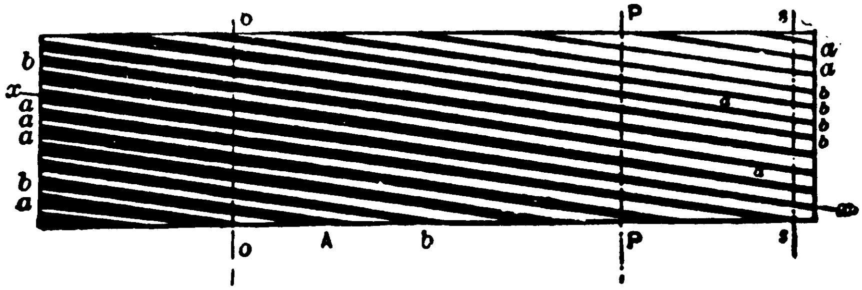


Fig. 3. Elevation of one of the dies.

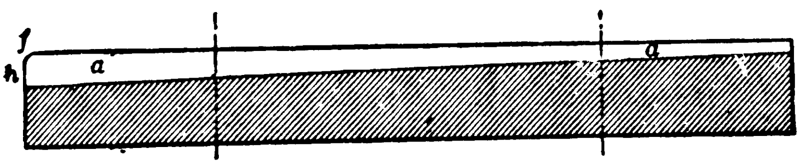


Fig. 4. Longitudinal section of the die.

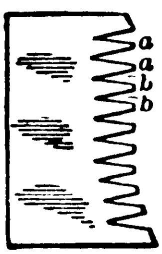


Fig. 5. Entering end of the die.

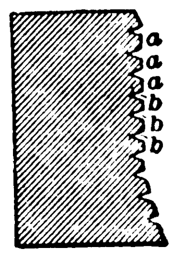


Fig. 6. Finishing end of the die.

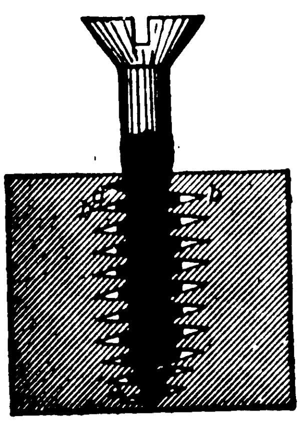


Fig. 7. Cross section of die, at o. o. Fig. 3, showing the beginning of the threading process.

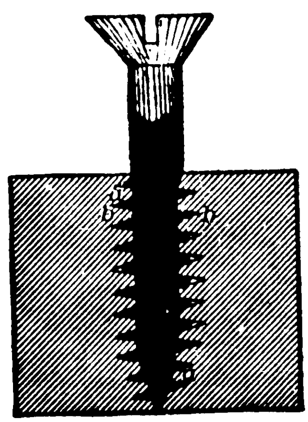


Fig. 8. Cross section, at p. p. Fig. 3, showing a screw nearly threaded.

(31) For particulars relating to the different displays of machine tools the reader is referred to the special report by Prof. J. H. Barr, contained in this volume.

CLASSES 54 AND 55, MACHINERY AND PROCESSES FOR THE TEXTILE INDUSTRIES.

(32) No improvements of special value or novelty were noticed in the machinery for spinning and weaving cotton and wool. This review of the class is therefore limited to the mention of those exhibitors whose displays obtained the highest awards, and who may be regarded as representative foreign manufacturers of the kind of machinery in question. There were large displays in the sections of all the great nations excepting that of the United States, which was represented by only three exhibitors in each of the two classes. Of these the National Cordage Company of New York received a gold medal for their exhibit of rope and cordage, and the Eureka Fire Hose Company a gold medal for a loom for weaving fire hose.

In the French section the finest display of pickers, carding and combing machines, and spinning frames was made by the Société Alsacienne, Mulhouse, Alsace, to whom a grand prize was awarded. They exhibited a picker with Lord's apparatus for regulating the speed of the feed apron. the operation of which is to deliver the material to the picker at a uniform rate, so many pounds per minute, whether it be spread thickly or thinly, evenly or unevenly, on the apron; it also contained a safety arrangement for preventing the covers from being opened while the machine is in motion.

Carding and combing machines, spinning frames, and looms of different kinds, all of excellent design and workmanship, were also exhibited by this company.

A grand prize was awarded to the De l'Horme Company* for a great collection, in their own special building, of a variety of looms for weaving fine goods, velvets, damasks, foulards, and other silk goods.

Lenique, Piquet & Co., of Calais, France, exhibited lace looms which were deemed worthy of a gold medal.

A German firm, the Saechsische Webstuhl Fabrick, Chemnitz, Saxony, one of the very few German exhibitors in the sixth group, displayed looms for weaving cloth, velvet, silk damask, etc., and received a gold medal.

In the British section, Mr. George Hodgson, Bradford, England, made a fine display of excellent looms, for which he received a grand prize. A wide loom, capable of being adapted for goods 3 yards wide, was shown by him, also a "Revolver" loom for six shuttles, and several improved Crompton looms for cloths and cassimeres.

* Companie des Fonderies et Forges de l'Horme, Chantiers de la Buire, Lyons.

Paget's warp-weaving loom is noticed in Mr. J. M. Merrow's special report.

Three grand prizes were awarded to Belgian exhibitors, as follows: To Célestins Martin, of Verviers; to the Société Verviétoise pour la construction de machines, and to V^ve Mathieu Snoeck, Verviers, all of whom exhibited wool-working machinery, either for carding and combing, spinning, or weaving. Four gold medals were also awarded to other Belgian exhibitors in the two classes.

In the Swiss section the Ateliers de Construction de Ruti (successors of Gaspard Honegger) received a grand prize for looms of excellent design and construction, while Jacob Rieter & Co., of Winterthür, made an equally fine display of machinery for carding and spinning. The only self-acting mule for cotton spinning shown in the Exposition was in this space. Several mules for woolen yarn were, however, shown elsewhere. The carding machines shown by Rieter & Co., like those of other exhibitors, embodied the English system of movable top cards fastened to an endless chain, by which they are automatically and successively removed, cleaned, and returned to place; the modifications applied by the different Continental manufacturers relate chiefly to improvements for facilitating the adjustment of the movable cards.

Reiter & Co. also exhibited self-acting embroidering machines, and machines for threading the double-pointed needles used in the embroidering machines.

The Fives Lille Company* presented an ingenious machine for netting fish nets, which attracted much attention.

(33) The special report of Mr. J. M. Merrow contains an account of knitting machines and power machines for embroidering, which were included under Class 55; and in the report of Mr. C. R. Dodge, in vol. II, may be found a notice of machinery and processes for the preparation of ramie, and of the new processes for making artificial silk.

CLASS 56, SEWING AND THE MANUFACTURE OF CLOTHING.

(34) Besides sewing machines this class contained machinery for making buttons, hats, etc., and apparatus for cutting out stuffs for making articles of clothing.

The one hundred and thirty-five exhibits may be divided as follows:

Sewing	40	Stamping	9
Making shoes	40	Covering buttons	5
Measuring and cutting	30	Hat making	6
Embroidering	5		

There were many appliances for the use of tailors and dressmakers, for taking measures for clothing, or for laying out work,

* Compagnie de Fives Lille, Paris.

which were not remarkable in any respect. Several presses for forming felt into hat bodies were shown, all of simple construction, without important novel features.

The most interesting displays were those of sewing machines and shoe machinery, of which there were numerous and extensive collections.

In this class the machinery in the United States section held a most creditable position. There were but fourteen exhibitors from the United States, of whom eight made attractive displays of sewing machines, including machines for sewing leather, making fancy stitching, embroidering, working buttonholes, etc.; two showed special buttonhole-working machines; three exhibited lasting machines or other machinery used in manufacturing shoes, and one a machine for cutting out work.

(35) The favor with which the machines from the United States were regarded is indicated by the awards of the jury. The grand prizes and gold and silver medals were distributed as follows:

	France.	United States.	Great Britain.	Other countries.
Grand prizes	2	2	0	0
Gold medals	6	5	*1	0
Silver medals	17	2	1	0
Bronze medals	31	0	5	4
Honorable mention	11	3	1	6
Total	67	12	8	10
Number of exhibitors	104	14	8	13

*To the Howe Machine Company, Glasgow.

There were in addition four noncompeting French exhibitors, members of juries, who would doubtless have received gold medals if their exhibits had been in competition.

(36) Of the exhibitors of the United States, the International Buttonhole Sewing Machine Company, Boston, and Wheeler & Wilson Manufacturing Company, Bridgeport, Connecticut, received grand prizes. The Davis Sewing Machine Company, Watertown, New York, the New Home and Singer Sewing Machine Companies, New York, the White Sewing Machine Company, Cleveland, Ohio, and the Paine Shoe Lasting Machine Company, Rochester, New York, obtained gold medals.

Nearly all the sewing machines were placed in the gallery of Machinery Hall, where those from the United States were arranged in tasteful pavilions which attracted many visitors, although the location was not where the general public would be the most likely to find its way, and consequently not altogether favorable.

(37) The exhibit of the International Buttonhole Sewing Machine Company was in the body of the hall with the shoe machinery, and

attracted as much attention as any single machine in the Exposition, the rapidity with which it performed its work and the perfection of the product were so remarkable. The machine is so well known and extensively used in the United States that a description of the mechanism in detail is not needed. A general view of the machine which formed the principal feature of the company's display at Paris is given by Fig 9.

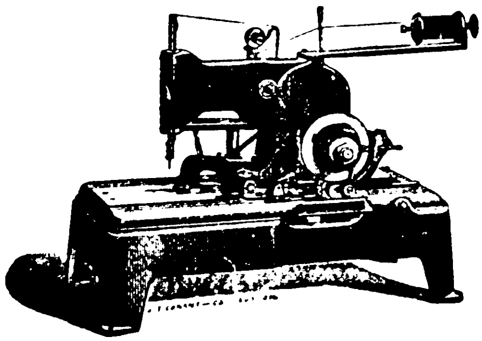


FIG. 9.—The Reece buttonhole sewing machine; by the International Buttonhole Sewing Machine Company, United States.

It works a regular eyelet buttonhole, with a cord set in the stitching around the hole, and makes a square bar across the small end. The work is clamped immovably to a stationary bed, the machine then cuts the buttonhole, after which the needle and other stitching mechanism travel around the hole automatically. The needle works along one side of the hole, then around the eyelet end, turning about its axis meanwhile, then works back along the other side of the hole, and finally moves back and forth crosswise of the end several times to form the bar, and stops automatically. When stopped the needle stands out of the cloth, so that the work can be shifted or removed without obstruction. The movements of the stitching mechanism are given by cranks, and very quiet working is obtained at a high rate of speed.

The loose ends of thread and cord are fastened by hand, or, on shoe work, the ends are stitched to the inside of the buttonhole pieces by a special machine, which will do the finishing for eighteen or twenty cases of shoes in a day.

(38) The exhibit for which the Wheeler & Wilson Company received a grand prize contained a buttonhole machine, which is also automatic in its action, stitching along the sides of the hole and across the end, but not around either end.

The company also exhibited several interesting special sewing machines, among which was one for making automatically a great variety of zigzag rows of stitches for ornamenting cloth, leather, etc. Also a twin needle machine for making simultaneously two rows of stitches interlocked by a single shuttle thread. By means of this machine a rib, with or without a cord inserted in it, can be formed in the goods and a row of stitches made on each side of the rib at once. The stitching is like that made on the backs of gloves. Machines with four needles, for making simultaneously two rows of stitches on both sides of the rib, are also made.

The machine, however, which won for this exhibit its greatest prestige was the new high-speed family machine, used also for manufacturing, in which the rotary hook—the original distinctive feature of the Wheeler & Wilson machine—is applied with an improved and very simple device for giving it a variable instead of uniform motion of rotation, by which less of the upper thread is drawn through the goods by the hook in forming the loop. This machine works with a straight needle, and has a take-up on the arm above the goods. The feed is in the direction away from the operator, instead of from left to right, resembling the shuttle machines in this respect.

A large manufacturing machine on the same principle, to which a wheel feed is sometimes applied, was also shown. It works at a high speed, has a large bobbin in the hook, and is adapted for heavy tailoring work and to be run by power.

The rotary hook is adopted by several of the largest of the French manufacturers of sewing machines, and seems to be preferred to the shuttle; in fact, modifications of the hook, having vibratory movements instead of complete rotation, are being adopted by manufacturers of shuttle machines.

(39) In the pavilion of the Singer Company were also a great variety of special sewing machines, among which may be mentioned a buttonhole machine; a machine for overseaming and zigzag stitching; a machine for working eyelet holes, used in shirt manufacturing, etc.; cylinder machines for sewing hollow goods, sleeves, trouser legs, bags, etc.; a high-speed chain-stitch machine with automatic devices for trimming the edge of the material, for knit goods; a portable machine for sewing carpets, and a gigantic machine with roller feed for sewing canvas, leather, and rubber belting up to three-quarters of an inch in thickness.

In the Singer buttonhole machine the work is clamped to a plate and the hole spread open for stitching; it is then fed in the direction of the length of the buttonhole, while the needle stitches along one edge; the whole work is then turned around automatically and fed in the opposite direction while the other edge is stitched, and in one form of machine the end of the hole is finally barred. A cord is inserted and inclosed in the stitching.

The smaller forms of the Singer machine, for family and manufacturing use, have an oscillating shuttle, consisting of a hook vibrating about a horizontal axis and containing the bobbin, which is eccentric to the axis, so that the action is that of a hook and shuttle combined.

(40) The Davis Sewing Machine Company, Dayton, Ohio, and Watertown, New York, exhibited machines which have long been known in the markets of the United States and Europe. The feed is the distinctive feature of these machines, being a top feed. When the needle descends into the cloth the presser foot is lifted slightly, and at this time the feeding is produced by means of a feed bar alongside of the needle, with a toothed foot which is forced downward upon the cloth and moves laterally together with the needle, pushing the cloth along. This simultaneous movement of the feed foot and needle insures that all the plies of the cloth through which the thread passes shall be moved equally without relative displacement. The mechanism of the machine is simple.

The shuttle of the manufacturing machine which they showed carries a bobbin holding a large supply of thread. An automatic bobbin winder, by which the thread is laid evenly in winding, is applied to these machines.

The exhibit of the New Home Sewing Machine Company contained a large assortment of machines of various styles of finish.

This is a shuttle machine, with an under "drop" feed. In the family machine the shuttle is thrown by a combination of levers beneath the plate. In the manufacturing machine the shuttle oscillates about a horizontal axis, and its arrangement allows a short, stiff needle to be used.

(41) The White Sewing Machine Company entered only family machines in competition, and showed an assortment of excellent work produced by them, the exhibit bringing them a gold medal, as has already been said.

(42) In the French section there were few interesting displays of sewing machines, although much space was covered.

The most important was that of Messrs. Hurtu & Hautin, who have built up a large business in machines of their own manufacture. They exhibited more than thirty varieties of sewing machines. Their latest pattern is a lock-stitch machine for family and manufacturing use, having a revolving hook of which the rotative movement is, like that in the Wheeler & Wilson machine, variable, instead of uniform; in fact, this variable movement is produced by mechanism resembling that employed for a similar purpose in a machine introduced many years ago by the Wheeler & Wilson Company, but displaced by later and simpler contrivances. The bobbin for the under thread is in a case. The speed is said to be as high as 2,500 stitches per minute.

Among the machines exhibited by this French firm was a waxed-thread machine, for operating on harness and saddlery work, machine belting, etc., capable of sewing through a thickness of leather as great as 1¼ inches. This machine is provided with an awl for perforating automatically the hole in the work through which the needle descends. The needle thread loop is spread by a hook at the end of a revolving cylindrical shell, which forms part of a shuttle race through which the shuttle is driven without contact with the waxed loop. A small lighted lamp beneath the hook, near where the needle comes down, keeps the waxed threads warm and prevents them from sticking in the leather.*

In a machine, "La Comtesse," made by Leconte, Paris, the under thread is on a spool which stands in a spool case at the top of an upright revolving shaft bearing a hook by means of which the loop is spread and carried around the spool case. A great length of the upper thread is required for the loop, which is drawn up by a take-up on the arm.

(43) *Embroidering machines.*†— Nearly all the American and foreign sewing machines have special attachments for embroidering. Elegant specimens of work were shown, executed on the Davis, the Singer, and the Wheeler & Wilson machines. Several French manufacturers, however, exhibited machines made particularly and solely for this kind of work, and it is to these that this notice relates.

E. Cornely exhibited several types of an embroidering machine called the "Couso-Brodeur." It is a chain-stitch machine, in which the design is brought out by the chain itself; that is, the chain is shown on the right side of the material. This machine was invented originally by Bonnaz in 1863, and was first exhibited in 1867, coming into practical use soon after. Mr. Bonnaz exhibits machines of this kind at the present time. Mr. Cornely has made several improvements on the original machine.

In sewing, the thread lies on the under side of the machine, and the needle, which is hooked like a crochet needle, passes through the material and draws up a loop of thread, then passes down again through the first loop, brings up a second loop, the material having been fed ahead, and the first loop is tightened around the second one, and so on. The movement of the treadle is communicated to the machine through a sliding clutch in the head of the machine, and a spring throws this clutch out, unless it is held in place by means of a handle placed under the table. This allows the foot gear to work continuously, and yet the needle is controlled so that it can continue stitching, or make only a few stitches in succession, or even only a single stitch, and be stopped instantly by simply letting go the handle. Where the machine is run by power the engaging mechanism is worked by a pedal with the left foot. For foot-power machines both feet work on the machine treadle, and the clutch is worked by the hand.

In order that the work need not be turned around in following a

* Both kinds of Hurtu & Hautin machines mentioned above are very clearly illustrated and described in Armengaud's Publication Industrielle, vols. 27 and 29 (2d series, vols. 7 and 9).

† Mr. H. D. Woods collected the greater part of the information relating to embroidering and straw-braid machines

design, the Couso-Brodeur has what is called the "universal feed," which is Bonnaz's ingenious invention. This is a top feed in which the feeding surface is an annular serrated presser foot, surrounding the needle and receiving its vibratory movements from a small lever jointed to a sleeve which is concentric with the needle bar. The sleeve, carrying its lever, can be turned about the needle bar as about an axis, so as to give the vibratory movements to the presser foot in any desired direction, the end of the lever, when it is turned, traveling around within a ring attached to the vibratory bar of which the presser foot forms the lower extremity. By turning the sleeve, therefore, the feed may be made to operate in any direction which the pattern of the work may require. This turning can be produced while the machine is in motion, by means of a crank, beneath the machine, with which the sleeve is connected through a train of bevel gears, and by changing the direction of this crank the direction in which the work is fed may be changed at will, the movement of the work being always in the direction in which the crank is pointed. So long as the directing crank remains pointed in one direction, the feeding continues in a straight line in that direction, while by revolving the crank continuously the feeding is in a circular direction, and thus the machine can be made to produce any desired pattern in a more definite way than by turning the work about in the usual manner. The stitching can be stopped and started at any instant by lifting or pulling down the handle of the crank, which is connected by levers with the clutching mechanism.

The machine is said to work at the rate of 1,200 stitches per minute.

Mr. Cornely exhibited five different styles of this machine:

1. A single-thread single-needle machine, such as the one described, intended for plain chain-stitch embroidery, but which, by allowing the hook to miss stitches, will also make moss embroidery, which consists of a series of loops very close together.

2. A two-thread single-needle machine, in which a second thread, placed on a spool above the work, is wound around the loop of the chain stitch as it is made. In addition to the parts of the first machine this one has a thread guide that revolves around the needle holder.

3. A three-thread, single-needle machine, in which a thread or cord passes down through the needle holder and forms a core around which the second thread is wound, and makes a much more raised figure. This machine can be used with two threads, or with only one if desired.

4. A single-thread machine with several needles. This is for forming several parallel or concentric rows of chain-stitch embroidery, as for edges of muslin curtains, etc. The needles are placed side by side in the needle-bar, and as they pass through the work the thread is forced into engagement with the needles by a fork which transfers it from a toothed holder, after which the thread is

brought up through the work in several loops side by side. The work is like several rows of chain stitch, except that all are formed from one thread. By setting one needle higher than the others it can be made to skip the stitches and leave a row of loose loops on the edge.

5. The last machine is a Couso-Brodeur, combined with scissors, by which the tops of the loops are sheared off as they are formed above the work, and thus an appearance of velvet or chenille s given to the work. A novel feature is a pair of pliers, by which the portion of the loop that is cut off is picked up and brought around in front of a tube through which it is blown away from the work, a small air pump being attached to the head of the machine, and a rubber pipe led from it to a nozzle in front of the needle. This machine can be operated as the simple Couso-Brodeur if desired.

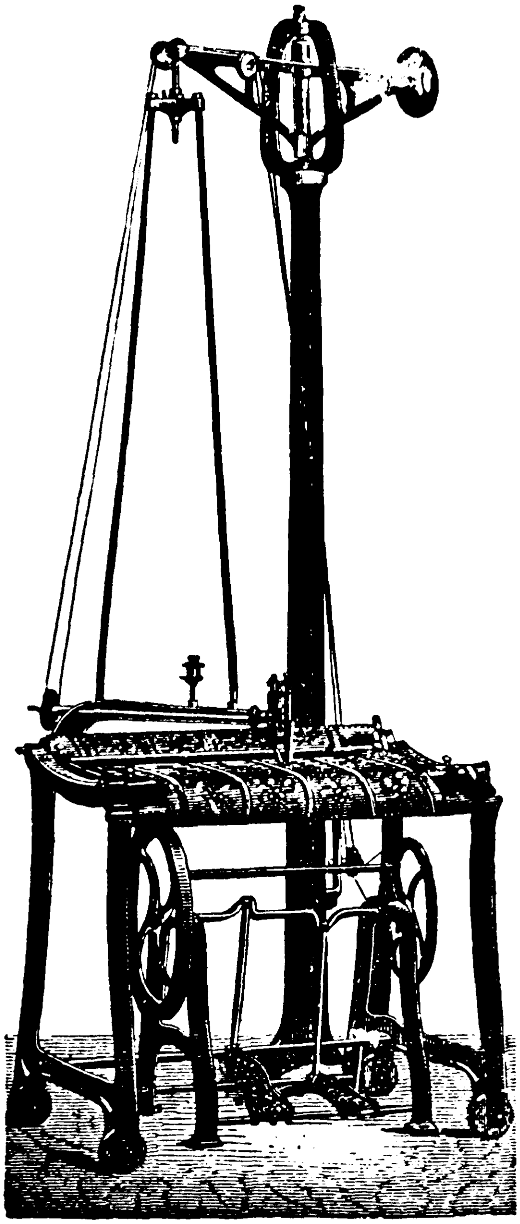


FIG. 10.—Hurtu & Hautin's embroidering machine.

(44) Mr. Jules Derriey exhibited a large embroidering machine which works fourteen needles on fourteen repetitions of the same pattern at once. The stitch is the same as with the Couso-Brodeur. It is designed to embroider muslin curtains, etc., and is used by manufacturers in the north of France, at Tarare, St. Quentin, and other places. It will do the work of five of the Bonnaz machines. The machine was invented by Mr. Klaus and improved and brought into working shape by Mr. Derriey.

(45) Messrs. Hurtu & Hautin showed an embroidering machine that will take in any length of work, and is made in different widths up to 6 feet and over. It is formed of two distinct parts: the table or frame that holds the work, and the sewing arm or machine proper, which is suspended from a standard or crane, allowing the whole thing to swing in any direction. Fig. 10 shows this machine.

The table is an iron frame with rolls on either side to fasten the work to, and having four casters allowing it to be moved laterally.

The working mechanism consists of a ⊃-shaped frame, containing all the mechanism of an ordinary sewing machine. The upper limb of the ⊃ carries the main shaft, terminating at the head which holds the presser foot and needle mechanism. This head can tip about the main shaft as an axis so as to allow it to swing past the roll of work. It also has a handle by which the operator guides it over the work as desired. The lower arm of the U contains a smaller shaft to drive the shuttle, which oscillates about a horizontal axis. The treadles and driving pulley are attached to a separate frame made fast to the floor, and the belt passes over a series of small pulleys on the standard or crane, and is then brought down to the pulley on the main shaft of the ⊃ frame. The operator guides the needle over the design, regulating the speed of the feed according to the kind of work to be done. When the arm can not reach the design, either the work table is moved along latterly or the work is rolled up on the upper roll and released on the lower one.

This machine is used for different kinds of imitation lace work, as well as embroidery, and for overlaying, applying braid, etc. A large size, run by power, is made for sewing coverlids, counterpanes, blankets, etc.

(46) *Machines for sewing straw.*—There were several machines exhibited for sewing straw braid for the manufacture of straw hats. For the most part these are adaptations of the ordinary single-thread Wilcox & Gibbs sewing machine, with a special feed arranged for feeding the straw. On these machines the straw is very apt to get broken. The stitches are the same size on both sides, so that to have a fine and almost invisible stitch on the right side the stitches must be very near together. They usually have a drop leaf in front to allow the hat to pass around as the work progresses.

One of the principal exhibitors in the French section was the firm of Legat & Herbet, of Paris, who showed D. Legat's straw-braid sewing machine. In this machine the needle has a hook near the point like a crochet needle, and takes the thread from a shuttle beneath the work. The machine is quite intricate in respect to the moving parts that help to make the stitch, which, although formed of a single thread, will not ravel easily. The machine is worked by foot power or by machinery. The shuttle is contained in a cylindrical box on the front of the table, just below the needle, in which all the parts that need frequent attention are contained. This can be seen in the general view of the machine, Fig. 11.

The operation is as follows:

The needle passes down through the braids, catches the shuttle thread in its hook and rises, bringing the doubled thread up with it; the braid is then fed forward about one-sixteenth of an inch and the needle again descends, while, in order that the thread may be carried down through the straw by the needle, a wire finger comes forward so as to hold the thread in the hook until the needle has again penetrated the straw, after which the finger retreats and when the needle rises the second time it fails to bring up the thread, leaving a loop below the braid through which the shuttle glides and thus forms a knot; then the braid is fed ahead about half an inch, and the needle descends again to pick up the thread for forming a new stitch; the thread is put on the needle by three arms that come forward below

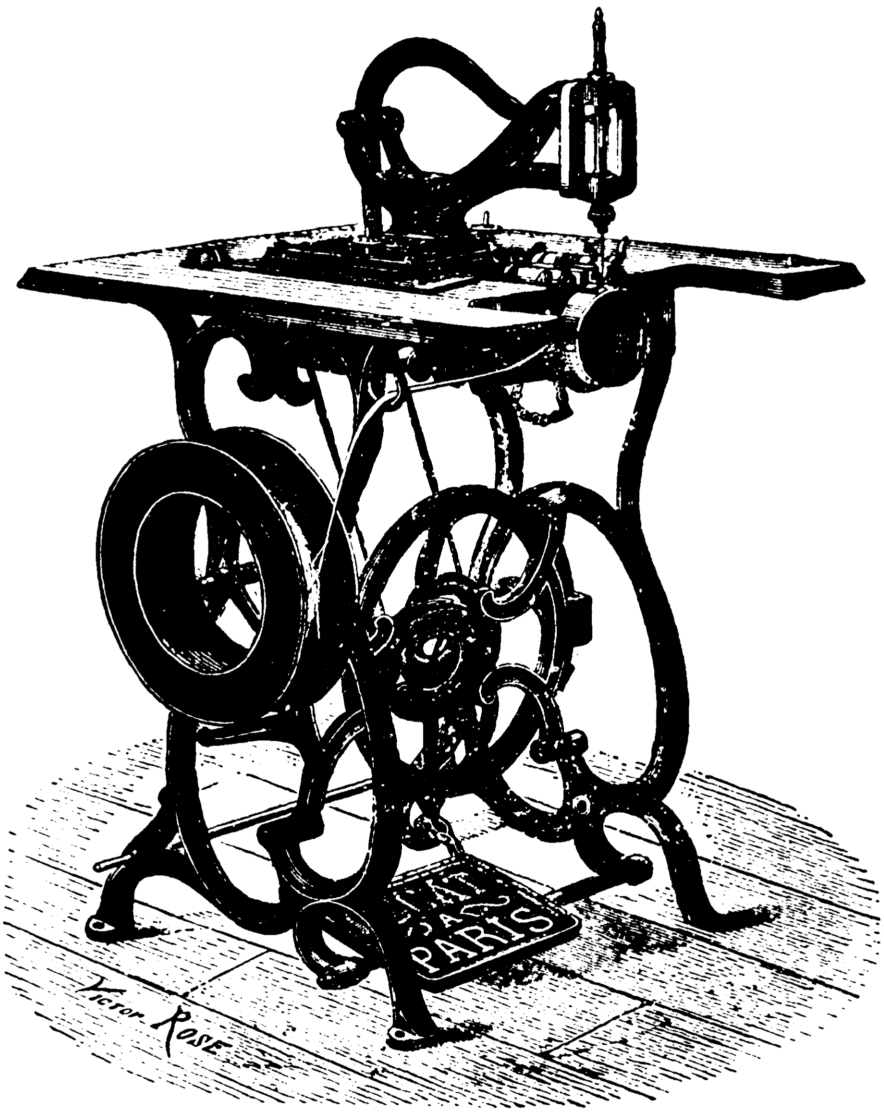


FIG. 11. Legat's machine for sewing straw braid.

the braid, opposite the thread as it is stretched from the shuttle to the last stitch made; the thread is again drawn up through the straw, the braid is fed ahead one-sixteenth of an inch and the needle descends again. There is thus made a short stitch on the face of the work and a long one on the back. The length of each of these can be varied according to the class of work and the fineness of the straw. The top stitch shows the thread doubled, while underneath it is single.

This machine uses only one-third as much thread as the ordinary two-thread machines, and only one-fifth as much as the regular chain-stitch machines. From 650 to 900 yards of braid can be sewed on this machine in 10 hours.

(47) *Paine's shoe-lasting machine*.—Among the exhibits of shoe-manufacturing machines that of the Paine shoe-lasting machine, the invention of Mr. S. White Paine, of Rochester, New York was probably the most interesting. The machine has been introduced only recently, and performed its work in so excellent a manner during the Exposition that it received the highest award given to that class of machines, although in competition with several others that were better known.

An illustration and description of the machine can not be given here.*

No lasting tacks are used in working with it. A "rubber" cement is applied to the insole, and then, by the aid of the machine, the upper, to which the lining has previously been stitched, is tightly and very uniformly stretched over the last by means of pinchers, the tension of which is limited by springs and thus made independent of the judgment of the operator, after which, by a very ingenious mechanism, the edges of the upper are turned over upon the insole and pressed firmly upon the cemented surface of the latter; this operation fastens the upper and insole together and completes the lasting.

The machine is adjustable to almost any desirable extent for the accommodation of shoes of different shapes and sizes.

CLASS 57. MANUFACTURE OF ARTICLES FOR FURNITURE AND DWELLINGS.

(48) This class contained wood-working machinery of all kinds; machines for making papier mâché, and working in bone and horn; tools and machines for carving in stone, engraving, and engine turning; also machinery for making brick and tiles, and for molding and pressing porcelain, pottery, terra-cotta, etc.

There were fewer exhibitors in this class than in any other, but some of the exhibits were hardly exceeded in interest and extent by those of any class.

In the United States section the space occupied by the wood-work-

* A general view of the complete machine, and a notice of its operation, somewhat in detail, can be found in the "Boot and Shoe Recorder," Boston, December 19, 1888.

ing machinery exhibited by Messrs. J. A. Fay & Co., Cincinnati, of which Mr. W. H. Doane, the president of the company, was the representative, was, with the exception of the Edison Company's space, the largest in the section, and one of the largest devoted to any single display in machinery hall.

Plate II shows a view of the exhibit.

Only three grand prizes were awarded in this class to exhibitors of all nations, and Messrs. Fay & Co. received one of them.

In general appearance and character of the machinery, this exhibit was incomparably superior to any other in the class, and it afforded an excellent example of representative American practice in wood-working machinery.

The style and finish of the machines, their handiness, and special adaptation to the purposes of their use, were excellent, and a number of important improvements, new in the European market, attracted the attention of visitors and made the exhibit particularly interesting to the expert, so that the attendants were kept constantly employed in explaining and demonstrating the operation of the various machines.

The space contained about twenty different machines, driven from countershafts beneath the floor by power derived from a special "straight-line" engine placed within the inclosure.

Much of the machinery was of the kind used in the manufacture of railroad cars, and adapted for working large timber.

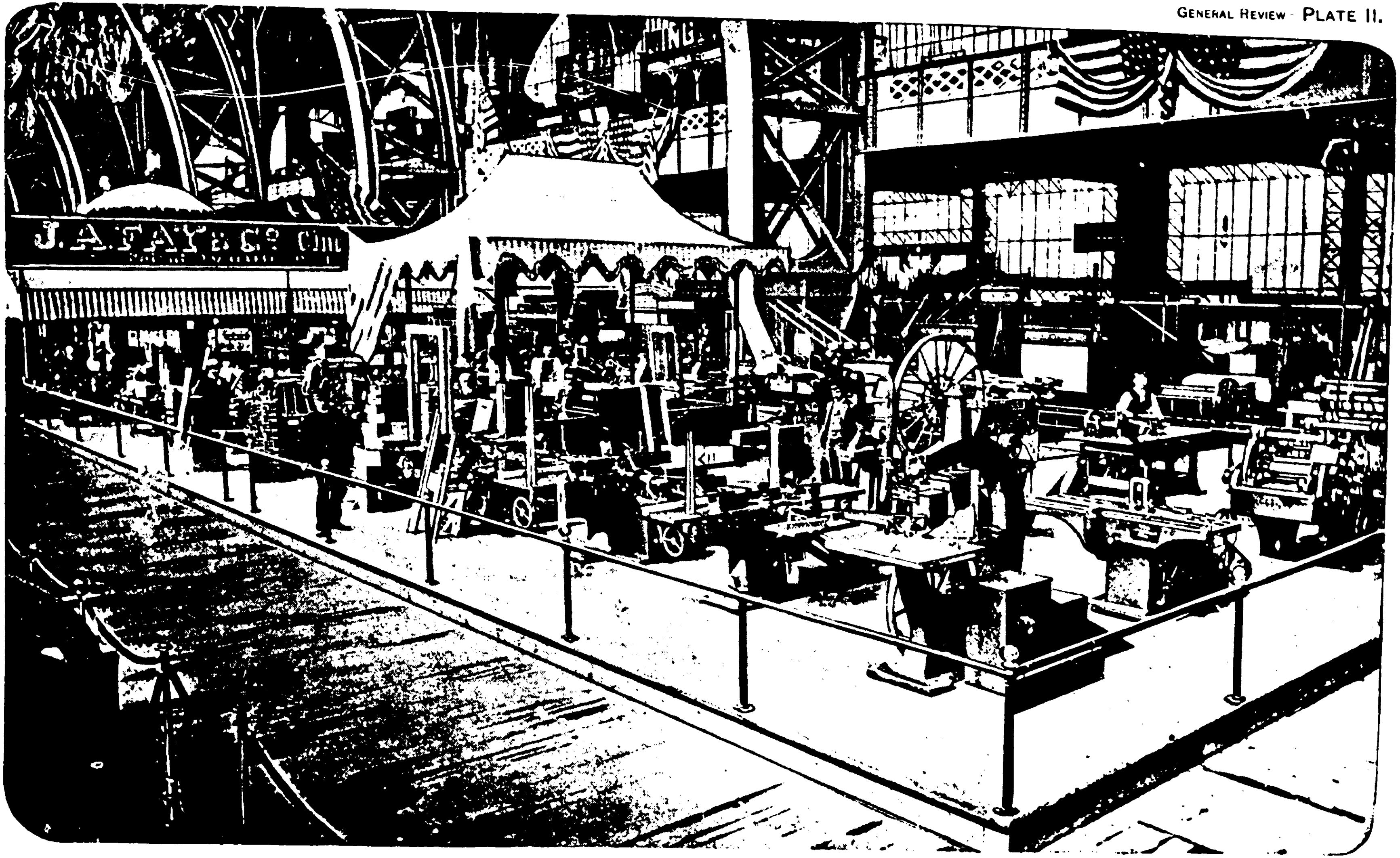
This class of machinery, while it is comparatively new in Europe, is extensively introduced in the United States, and its general character is quite familiar to all who are interested in the class of work for which it is used, so that the machines in general need not be described.

In a series of illustrated articles in Engineering on the wood-working machinery of the Exposition, thirteen of Messrs. Fay & Co.'s machines are shown and described.*

Two rapid-working mortising machines attracted more attention than any of the other machinery.

They operated by making square holes side by side, so close together as to open into each other. The holes were cut by means of a hollow tool in the form of a square chisel-edged pipe with an auger revolving at great speed inside it. The chisel removes only the corners of the hole left by the augur which does the bulk of the cutting. In the United States this device is not new. In the larger of the two machines the back-and-forth lengthwise movements of the boring chisel were automatic, but capable of being regulated by the operator by means of a treadle. This machine was adapted for

* Engineering, London, July 1, August 2 and 23, September 6 and 30, and October 4, 1889.



J. A. FAY & CO.'S EXHIBIT OF WOOD-WORKING MACHINERY.

making mortises as wide as 1½ inches and of any length. The smaller machine, which was not automatic, was adapted for mortises from three-eighths to three-quarters of an inch wide. The larger machine is shown in Fig. 12.

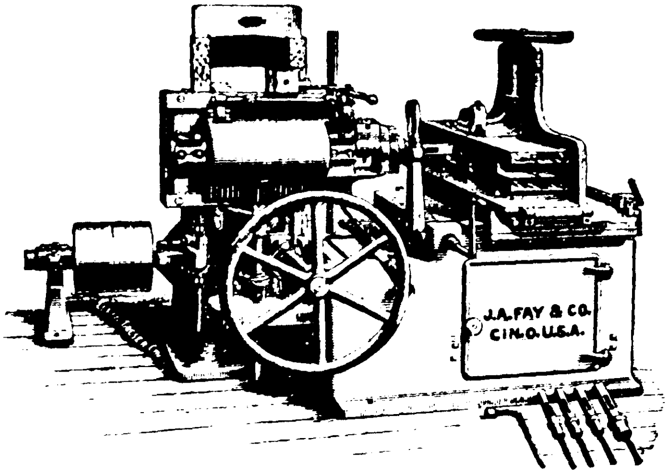


FIG. 12—Large mortising machine; by J. A. Fay & Co., United States.

A mitering saw bench, of which the table is stationary and the saw arbor adjustable in a vertical plane to any angle with the horizontal up to 45 degrees, seemed to have novel features. It is particularly adapted for cabinet work and manufacturing. Its general appearance is shown by Fig. 13.

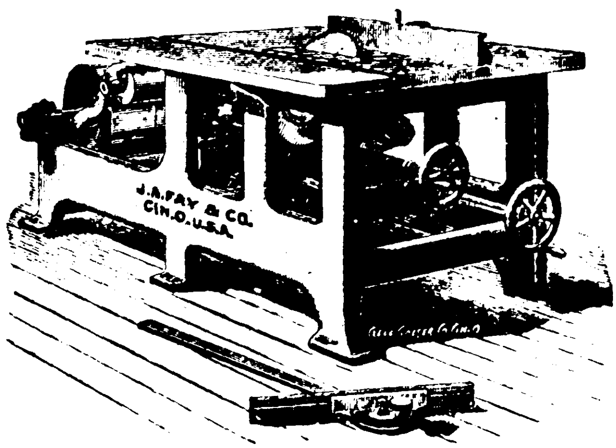


FIG. 13.—Saw bench for mitering; by J. A. Fay & Co., United States.

A noticeable feature of the machines in this inclosure was the care which had been taken with the patterns. The designs were studied with a view to the appearance of the machines, as well as to their mechanical features. The machines looked substantial, and yet there was a tastefulness and elegance about them which was not seen in the machines of the same class in the other sections.

(49) A number of French manufacturers of wood-working machin-

ery made extensive exhibits. Several of them showed special machines for making wooden shoes, and lathes for turning irregular forms. The lathes were modified Blanchard lathes, with arrangements for making one pattern guide the movements of the cutters for a number of different pieces, none of them new. One of these exhibitors of special machines received the award of a grand prize.

Messrs. Thomas Robinson & Son, Rochdale, England, exhibited band saws, molding machines, and special machines for dovetailing, etc., for which they received a gold metal.

(50) An interesting hand tool for smoothing, shaping, and sculpturing stone—applicable also to a variety of other uses—was shown by its inventor, Mr. S. McCoy, in the United States section. It is a pneumatic tool, consisting of a cylinder of convenient size for holding in the hand, containing a reciprocating piston of very short stroke which is worked at a great speed, say ten or fifteen thousand strokes per minute, by means of compressed air. The piston delivers its shower of blows upon a loose tool-holder at the end of the cylinder, and the point, chisel, or other tool required for the work is fastened in the holder and receives exceedingly rapid vibrations of very short range. The fundamental principle of this instrument is similar to that employed in dental pluggers and rock drills. The compressed air is conducted to the tool through a flexible pipe, and the tool is held in the hand while the point is applied to the work with firm pressure, the sharp, short strokes of the tool point performing the cutting with great rapidity.

Because of the rapidity and minuteness of the movements of the tool point its action is almost continuous, and in cutting with it the process is more like that of paring than like the working of a chisel driven by a mallet. The touch with the tool is thus rendered so delicate that the finest work can be executed with it, while with the larger forms of the tool heavy cutting can be done rapidly. The applicability of the tool for chipping cast-iron was demonstrated at the Exposition.

These tools, especially arranged for snarling or embossing hollow-ware, were shown; also tools for executing fine repoussé work. Calking tools on this principle, for calking the seams of boiler and tank work, are made and in successful use.

(51) A large proportion of the space given to class 57 was occupied by machinery for making brick and tiles, and for molding and shaping articles of pottery and porcelain, and for the preparation of the materials for making them.

One of the most striking of the exhibits was by Mr. Pierre P. Faure, who showed in operation a complete series of machines used in the manufacture of fine porcelain. He exhibited filtering presses in which the mixture of clay and water is forced through wire gauze and the clay delivered in the required state of fineness and homogeneity.

He also exhibited a number of machines for shaping plates, saucers, and cups, in some cases by pressure in molds, to give the first approximately correct shape, and in others by means of templets, by which the roughly molded piece, placed in or on a revolving chuck, is scraped to exactly the proper form and thickness. The mechanism by which the templets are held, adjusted, and applied constitutes the chief feature of these last machines; and, while simple, they are so efficient that by their use an excellent quality of work can be turned out rapidly, and with less skillful labor than by the old processes. For oval dishes the upper part of the revolving vertical spindle, by which the work is held, receives its elliptical movements from a combination of an eccentric and slides resembling the oval chuck used in lathes for turning ovals and fancy work, while the templet receives a slight vertical motion from a cam, the shape of which can be made so as to give different thickness to different parts of the work as desired.

Mr. Faure's machinery is used in all countries where porcelain is manufactured and its utility is widely recognized.

A grand prize was awarded to him by the jury.

A special report by Mr. H. D. Woods on machinery for the manufacture of brick and tiles, will be found in another place in this volume.

CLASS 58. PAPER MANUFACTURE AND PRINTING.

(53) The display in this class was extensive and covered much space, forming probably the largest collection of paper-making and printing machinery and appliances ever brought together. The collection was far from complete, however, and there was but little which was new to be found among the machines exhibited.

(54) *Paper machines.*—Four complete Fourdrinier paper machines were set up in Machinery Hall; one from France, by the Messrs. Darblay, of Essonnes, two from Belgium, by De Nayer & Co., Villebroek, and Dautreband & Thiry, of Huy, and one from Switzerland, by Escher, Wyss & Co., Zurich. The two first mentioned were in motion.

The mills of the Messrs. Darblay are among the most important for the manufacture of paper in Europe. More than 2,000 hands are employed, and eighteen or twenty paper machines kept running. They make paper of all grades. No definite information respecting the paper machine exhibited could be obtained. It does not seem to have important advantages over machines in use in the United States. The wire web was about 6 feet wide and 35 feet long. Eleven cylinders are used for drying the paper and felt. The beating engine, from which the machines are fed with pulp, was made of concrete.

The De Nayer machine was designed for making wider paper than the Darblay machine, and had a web 9 feet wide and 35 feet long. The couch rolls are of bronze and 18 inches in diameter. The upper rolls of the felt presses, of which there are three, are also bronze. There are fifteen cylinders for paper and felts. The beating engines connected with the machine are of cast-iron, and the pulp before being pumped to the machine is well stirred in large receivers by rotary agitators.

The Messrs. De Nayer also exhibited a glazing calender of the usual construction, having twelve rolls 8 feet long, of chilled iron and paper alternately.

The other Belgian machine presented a fine appearance. The following description of some of its features is taken from Engineering, London, November 22, 1889:

Before the wire there are two flat strainers, having a cam motion. The continuous wire has a length of 40 feet, and will make paper, cut and dried, 6 feet in width. Noticeable here is a flat, narrow plate of gun metal immediately after the breast roll, which serves for the better regulation of the flow of pulp onto the wire. There are three vacuum boxes under the wire, the tops of which are covered with wood. The couch rolls are both about 15 inches in diameter: the upper one is of cast-iron, the lower of hard rubber. Following these are the three two-roll felt presses of cast-iron. The diameter of the rolls is about 14 inches, and the first wet felt is provided with an apparatus for washing it continuously. In this part of the machine is the chief novelty, to which we would direct special attention. Instead of having four separate standards for the four presses, they are placed on strong cast-iron vertical frames or columns, which are mounted together, the whole forming one solid erection, somewhat similar to the framing of the drying machine. On the whole, this seems a good arrangement, and possesses several advantages. By these means the press rolls can either be kept vertically above each other or slightly inclined.

The drying machine proper consists of fourteen drying cylinders for paper and felts, arranged in such a way that each group of one or two cylinders (with the exception of the first) has its felt and felt dryer. The diameter of these cylinders is about 4 feet; that of the felt dryers is rather smaller. Each cylinder is provided with its doctor. Here we observe that the steam is sent into the drying cylinders and the condensed water let out on the same side, and not at opposite sides of the machine, as is often the case. The framing is very well arranged for leading the paper quickly through the machine, and there are many points of detail which have been well studied. After the drying cylinders there is a set of three-roll glazers 14 inches in diameter. The cooling cylinder comes next, and is followed by an arrangement for damping both sides of the paper. It is then cut with circular cutters and reeled.

The last great paper machine to be mentioned is the one in the Swiss section. The whole length of this machine is about 90 feet. It will make paper 7 feet 3 inches wide, the length of the wire web, under which are three separate vacuum boxes, being 42 feet.

The diameter of the upper couch roll is 1 foot 8 inches, that of the lower 1 foot 2 inches. Next come the felt presses, of which there are three; each has two rolls and is arranged with the upper roll slightly inclined, or not quite vertically over the lower. All the presses are of cast iron, and each has its separate strong standard. The top rolls of the felt presses are 16 inches and the bottom 1 foot 2 inches in diameter, and the sides being open the felts can easily be renewed. Pressure is given by means of levers and weights.

The drying machine consists of ten cylinders for drying the paper and six for drying the felts. It is divided into two parts, with a two-roll damp press between them. In the first part are seven drying cylinders and four felt driers, arranged in four groups, each provided with its felt. The second part consists of three drying cylinders and two felt driers. All the cylinders but one are felted, and every felt has its drying cylinder. These vary in diameter from about 3 feet to 4 feet; most of the felt driers are about 3 feet 3 inches in diameter, but some are smaller. The shafting has the usual conical pulleys. In this drying machine a style of circular framing has been adopted, which allows the various small rolls to be easily and quickly adjusted as required. The drying cylinders have doctors, as also the damp press, each provided with a to-and-fro motion. Immediately after the drying machine comes a cooling cylinder, and next a calender for glazing the paper, consisting of six rolls of various diameters. Finally, the paper is slit longitudinally with circular cutters and reeled in the usual way.

The machine was not in motion.

(55) M. Débié, of Paris, exhibited a machine for making millboard, consisting of an endless wire web 5½ feet wide and 46 feet long, with couch rolls and press, but without a drying machine. The pulp sheet from the wire is wound on a cylinder until sufficient thickness is obtained, when the cylindrical board thus formed is cut open and removed to give place to another accumulation of sheet pulp on the cylinder. The cylindrical board thus formed is afterward flattened in a press and the water squeezed out. A uniform quality of board is made by this process.

The same exhibitor shows in his catalogue millboard machines resembling the ordinary paper machines, and having a succession of drying cylinders and roller presses. This more complete machine is capable of producing 10 tons of board per day.

(56) *Printing presses.*—There were several good displays of printing presses in the United States section. The Campbell Printing Press Manufacturing Company, New York, exhibited the well-known Campbell cylinder press; the Casey Machine and Supply Company, New York, showed a double job press; Golding & Co., Boston, showed several examples of American presses; the Liberty Machine Works, of New York, had several of the Liberty presses at work, and Mr. John Thomson, of New York, exhibited the Universal presses, one of which was adapted for embossing, cutting out, and creasing, and is much used by manufacturers of paper boxes.

The awards for these exhibits were of less value than the merits of the several objects displayed would have warranted. Messrs. Golding & Co. and John Thomson received silver medals, and the others only mention or no notice at all, while the extensive introduction of all these presses and the favor with which they are regarded in the United States, testify to their excellence so conclusively that their neglect by the jury appears the more surprising. The work produced by the American jobbing presses is superior to that of other presses designed for the same kind of printing, and the handiness of the presses in our section was in contrast to the more cumbrous machines exhibited elsewhere. The elegantly printed books issued by the French publishers show that the foreign printing presses designed for use in that branch of the art are well adapted for it; but if the vast number of ill-printed cards and circulars distributed at the Exposition, and the almost entire absence of a high grade of such examples of the printer's art, afford evidence of the capabilities of the European jobbing presses, then it would appear that our own greatly excel them in efficiency, and a critical examination of the mechanical features of the presses themselves strengthens this impression.

(57) In the French section the firm of V^ve. Alauzet & Tiquet exhibited a high-speed rotary newspaper press for printing in black and colors. Editions of the "Figaro" newspaper were printed on this press and distributed in the Exposition. On one side of the sheet the headings of the various articles were printed in five different colors, and the advertisements displayed in the same varied way. The whole paper is printed on both sides in passing once through the press. The press has two type cylinders, serving to print that part of the text which is in black, and one other type cylinder for the several different colors. So far, then, as the black impression is concerned the machine is a perfecting press, while the color printing is necessarily limited to one side of the sheet. The forms for the type cylinders are bent so that the lines of type encircle the cylinders, and the columns lie parallel with the axes. The sheet, therefore, runs through the press sideways instead of in a direction from top to bottom. This enables the single color cylinder to be used for all the colors, and yet the advantage is obtained of having as many of the colors appear in the same column of the printed sheet as may be desired; all five may in fact be distributed with the black in different parts of a single column, or their distribution among the columns be varied at will. The color printing appears in horizontal zones of considerable width, but the appearance of uniformity in this respect can be avoided by a judicious distribution of the variously colored headings or cuts. The colors are applied to the single cylinder from an ink tray divided into as many compartments as there are separate bands of color on the cylinder. The two stereotype plates for the black impression and the single one for the color printing are cast from the same form, and the removal of those parts of the faces which are not required to produce the impressions is effected by routing them away, or preferably by filling up parts of the mold. In the plates for the black impression the face is removed in the places which correspond to all the color impressions, and in the plate for the color cylinder only those parts of the face are left which are required to make the color impressions in the desired

places. An electrical stop motion is applied to this press to stop the press whenever the paper becomes torn. The speed of the press exhibited is said to be 12,000 to 14,000 copies per hour.

Another press shown by this firm was for printing two colors on one side of a sheet only; it is not new. The press has a reciprocating bed, on which four forms may be fastened—two at each end of the bed. The impression cylinder makes two revolutions, one for each form, at each stroke of the bed. The means provided for registering are efficient, and the press was at work on four-color work, printed by running the sheet through the press twice in successive movements of the bed: applying it the first time to the pair of forms on one side of the bed and the next time to the pair on the other side.

The same firm also showed lithographic, and phototype and copper-plate presses which produced work of remarkable excellence and delicacy.

(58) Messrs. Kientzy Brothers, of Paris, exhibited a simple machine for printing children's school copybooks on both sides of the sheet. The paper, in a continuous strip, passes under an engraved roll at one end of the machine, by which a series of impressions are produced on one side, the paper being pressed upward against the engraved roll by a roller lifted by a heavy weight. The strip then passes over guide rollers, which lead it first upward and then horizontally, through quite a distance, to the other end of the machine, where it is printed on the opposite side. The ink on the side first printed becomes partly dried before the second impression is produced.

(59) *Type and printing material.*—Many extensive displays of type were made in the French section. The jury indicated its high appreciation of the exhibit of type in the United States section by awarding a gold medal to the MacKellar, Smiths & Jordan Company, of Philadelphia.

(60) *Type-setting and distributing machines.*—These were assigned to this class, and were represented by five or six different machines. Several of them were of the Delcambre type, one of the oldest of all. This style of machine, though simple, is necessarily cumbrous and slow.

(61) An ingenious machine for putting the type in line when selected from the case by the compositor was exhibited in the British section. It is the Lagerman machine, a Swedish invention. It is not practicable to describe it here, but a complete description can be found in the United States Patent No. 362751, to A. Lagerman, dated May 10, 1887. The compositor selects the type from the case and simply drops them in rapid succession into a hopper in front of the case. If a type drops sidewise the machine rights it, if wrong end up turns it end for end, but if right end up it retains it so. The machine also

turns the type about its vertical axis, when it falls in such a way that the character would print upside down, and finally places the type in line properly righted in every way. Spaces of one thickness only are put in by the compositor.

The justification is effected in a separate machine, which was exhibited by the same inventor. This supplementary machine greatly facilitates the operation of justification. A line of matter from the galley is pushed into its place in the machine, an index then shows how much too long or too short the line is, the compositor moves a lever to the proper position, and the machine pushes out the spaces already in place and substitutes others of proper thickness. The machine seems to work satisfactorily, and would doubtless be a valuable accessory to any composing machine.*

The type used in the Lagerman machines are of the usual form, with a single nick in the side. There is therefore no special provision for distribution, and no distributing machine was shown by this exhibitor. The system as a whole is therefore very deficient, as the process of distribution requires as much skill and care as that of setting, though it involves less time.

(62) Fraser, Alexander, Neill & Co. exhibited in the British section a pair of machines for type setting and distributing, both of the Delcambre type. The principal feature of each is a vertical or inclined glass-covered plate called the type board, having numerous type-converging channels, which in the setting machine converge from the type reservoirs at the top of the board and meet at the bottom, where they discharge the type through a single spout into a galley. In the distributing machine they diverge from a single receptacle at the top, and end in a number of type reservoirs at the bottom, the type from the receptacle falling through one or another of the slanting grooves and into one or another of the reservoirs at the will of the operator. The Delcambre composing machine has often been described. Ordinary type, having only the printer's nick, are used in both machines. The distributing machine is not automatic. The matter from the form is placed before the compositor, who has to read it and distribute it character by character, one at a time, by touching successively those keys of the keyboard which correspond to the proper characters. The action of depressing a key pushes a type from the matter into the receiving groove or receptacle of the keyboard, and at the same time turns a switch which throws the type into the channel leading to the reservoir containing that kind of character only. The reservoirs are narrow brass troughs into which the type fall so as to stand against one another, flatwise, and are the reservoirs adapted for use in the composing machine. As a means of placing the type in line in a special reservoir adapted for a setting machine, this distributor does its work more rapidly than the

* For a description of the justifying machine see "Engineering," London, March 7, 1890.

same work could be done by hand, but the distribution is not so rapid as that done by a compositor in distributing to a case.

(63) *The Thorne combined type setting and distributing machine.*—This remarkably simple, ingenious, and efficient machine was exhibited in two places in the United States section: in the space allotted to the Thorne Typesetting Company of Hartford, Connec-

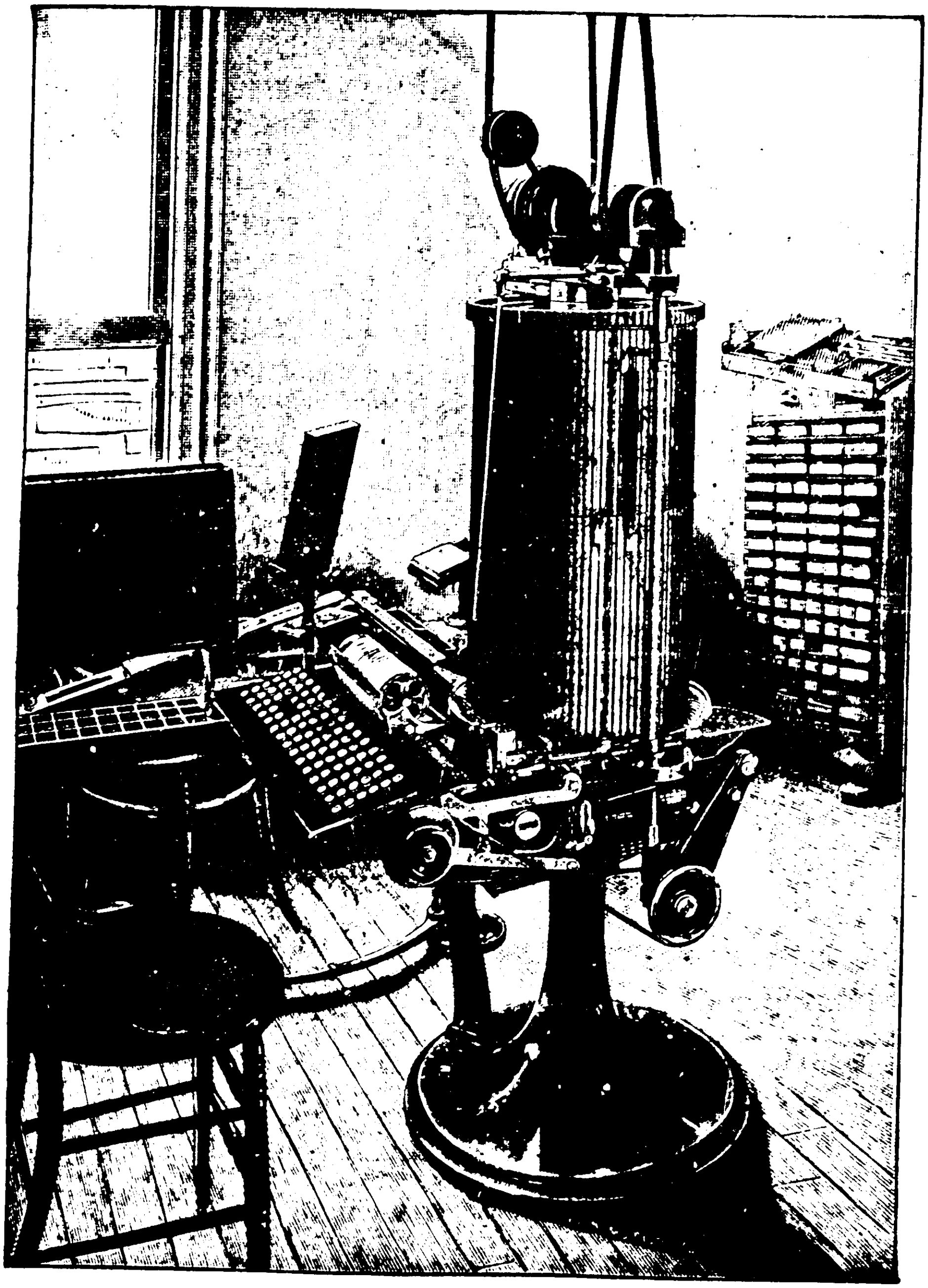


FIG. 14.—The Thorne type setting and distributing machine.

ticut, and in the Edison space, where it was shown in use in connection with a phonograph, the utterances of which served in the place of copy for the compositor.

A general view of this machine is shown in Fig. 14. Only a brief and very general notice will be given here, as the machine, which has become known in our own country within the past two years, can be seen in operation in many printing offices, and accounts of it have been published in our journals. The following is taken from one of the company's circulars:

The Thorne typesetting machine consists of two iron cylinders, about 15 inches in diameter, placed perpendicularly one above the other, in the external surface of each of which are cut longitudinally ninety channels or receptacles for the types which are to be used in it. Within the channels of the lower cylinder are inserted "wards," or small steel projections extending in various relative positions through their entire length, which correspond respectively with "nicks" specially made in the type, the purpose of which is, in distributing the letters, to automatically divert each letter from the mass of letters in the upper or distributing cylinder to its appropriate place in the lower or setting cylinder, so that each channel in the latter shall receive types of only the particular character intended for and adapted to it. The work of distribution is thus carried on automatically by the revolution of the upper cylinder upon its axis, which in rapid succession places the various types in position to be released from the distributing cylinder, when they instantly drop of their own weight into orderly position in the proper grooves of the setting cylinder, as above indicated. The typesetting is performed by manipulations upon a keyboard on which the characters of the language are represented, very much as upon an ordinary typewriter. These keys communicate directly with the setting cylinder above mentioned, each stroke of a key releasing a letter, and, by the aid of a revolving disc, transferring it from its channel in the cylinder to its place in the continuous line of reading matter which the operator is "setting." This continuous line is broken up into shorter lines and justified to a proper length for the columns of a newspaper or the pages of a book, according to the work on which the machine is employed.

The process of distributing the types is carried on, as before indicated, automatically, and with very much greater rapidity than and at the same time with the setting. When the setting cylinder is full the distributing cylinder ceases to revolve, but may be started again instantly at the will of the operator whenever it becomes necessary to replenish the former; and thus the distributing mechanism is active or at rest according to the demand made upon it by the activity of the operator. It is an exceedingly interesting feature of the machine, which alone gives it great advantage over hand work, that no time is required to "fill the cases," the automatic distributing cylinder rendering the supply of types in the setting cylinder continous and inexhaustible.

Three persons are required to operate each machine: one at the keyboard, a second to break up and justify the lines, and the third to keep the distributing cylinder "loaded" and maintain a general supervision. With expert help one machine will set and distribute 6,000 ems per hour, or from five to six times as much as the most rapid hand compositor. The work is not particularly laborious, and it is found by experience that intelligent girls are fully as well adapted as men to become efficient compositors. * * * The machines are so light running that a single horse-power is sufficient for half a dozen of them.

The type board is skillfully arranged. Some of the letters are repeated several times, and their arrangement is such that the keys for the letters forming certain prefixes and terminations of words that are most frequently used, such as *re*, *con*, *ed*, *al*, *ion*, etc., and short words that are often needed, such as *an*, *at*, *in*, *the*, etc., can be touched simultaneously and yet the type follow each other in the proper succession, one movement of the hand only being required in setting such combinations.

This machine was not properly presented to the attention of the jury, and failed to obtain the award it deserved. None of the other machines exhibited could be compared favorably with this one, either in scope or rapidity of working. It is thoroughly practical.*

CLASS 59.

(64) Under the denomination "Machines and implements for miscellaneous industries and arts," this class contained those machines and tools, adapted for a great variety of manufactures, which were not named under the more general heads which designated the subdivisions of the other classes. It embraced typewriters, paper-bag machines, cash registers, etc., and to it were also assigned numerous ingenious machines and implements used by those manufacturers who work on a limited scale, and are engaged in making the great variety of articles known in the French market as "article de Paris," and the different articles formerly known in the United States as "Yankee notions," as, for example, toilet pins, hair pins, brushes, combs, eyelets, covered buttons, match boxes, keys for musical instruments, corkscrews, and a multitude of objects difficult of classification except as "miscellaneous."

The extensive displays made by the departments of the French State manufactories and the mint were assigned to this class; they included machines and tools for the manufacture of tobacco, also coining presses, and machines for weighing and sorting coins. These two great government exhibits were the only ones which received grand prizes in the class.

(65) Twelve gold medals were awarded in all; of these France received seven, the United States three, and Great Britain two.

The limitations which prevent a full report in detail upon the objects in every class apply also here, and a few only of the most important exhibits, particularly those which gave the United States a representation in Class 59, will be noticed.

(66) *Typewriters.*†—Few exhibits attracted more general interest than the typewriting machines. During the busy hours of the day, from 2 until 6 p. m., the portion of the United States section devoted to typewriters was blocked by eager and curious spectators, some seeking for specimens of work, others bent upon an investigation of

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*The company has sold ninety machines within the last 6 months, and the demand is increasing so rapidly that facilities for producing twenty machines per month have been provided.

†The greater part of the notes on typewriters was furnished by an expert in this specialty.

the relative merits of the different machines now presented to most of them for the first time. Of these the following were represented:

Keyboard machines.	1.—Remington typewriter.	Type-bar machines. (One movement.)
	2.—Caligraph typewriter.	
	3.—Bar Lock machine.	
	4.—Hammond typewriter.	Type on one piece. (Two-movement machines. Excel in quality and variety of work.)
Single-key machines.	5.—Hall typewriter.	
	6.—Columbia typewriter.	
	7.—Mercury typewriter.	
	8.—World's typewriter.	

The above indicated groupings are, it will be seen, made from two points of view. First, with regard to the speed or ability of the machine to compete with the pen in ordinary writing. In the first class of this group belong naturally the machines which are operated from a keyboard or series of finger keys; the second class being represented by machines that are operated by means of a single key, or like the Mercury, which, although provided with a keyboard, effects its impression, nevertheless, by means of a separate key. The grouping from the second point of view is based on the question, whether the type are placed on separate pieces (type-bars), which move individually to a common point when a letter is to be printed, or whether the types are grouped together upon a single piece and require an additional movement to print any letter when brought to position.

Of the differences existing between the machines which employ the type-bar we will speak briefly. They consist: First, in the manner in which the type-bar is jointed or hung, and in its mode of connection with the key-lever. In the Remington machine the type-bar is hung from a "trunnion-like bearing." In the Caligraph the trunnion-like bearings are transformed into pivots with adjustments for taking up wear. In the Bar Lock machine a ball-and-socket joint performs the same function. Whether these differences, which form the subject-matter of patents, are of as much practical importance as their respective representatives maintain, it is not necessary to discuss. The second difference noticed between the type-bar machines is that two of them (Caligraph and Bar Lock) have a separate type-bar for every character, while in the Remington two characters are placed upon each type-bar, which reduces the number of hammers, pivots, and connections, as well as finger keys, about one-half, but requires some additional adjustments with the carriage that are unnecessary with the Caligraph and Bar Lock.

It is evident that the multiplication of type-bars demands a larger circumference in which the bearings are hung, or else a diminution of the space allowed for the hangers of each individual type-bar. An increase in the number of type-bars consequently involves a longer type-bar, and, with equal solidity, a correspondingly greater weight, with greater liability of collision in rapid work. From a theoretical point of view it would seem that the reduction in the number of type-bars, and consequently in the number of finger keys to be operated, is in the line of progress, and as the manufacturers of the Remington typewriter control a patent covering this peculiarity, it would appear as if the other systems, which are later, were adopted rather of necessity than of choice. It may be said, however, that the double keyboards of the Caligraph and Bar Lock machines, if open to the theoretical charge of unnecessarily multiplying similar parts performing the same function, are, nevertheless, so thoroughly mastered by expert operators as not to leave much choice between the two systems.

The Bar Lock machine (type-bar) has some characteristics which distinguish it broadly from the Caligraph and Remington. First, the type-bars are so hung that they strike downward instead of upward. This enables the work to be seen without lifting the carriage. Second, only a portion of the circle, and that on the same side of the machine as the operator, is employed for hanging the type-bar. This admits of providing a solidly fastened piece (bar-lock), upon which stand several wires arranged in a circular arc, serving as guides to the type-bars at the moment of impression, to avoid the danger of bad alignment. Critics of this machine raise the question whether these guides, if sufficiently close together to secure the great accuracy required in typewriting, are not likely to lock the type-bars so as to prevent them from moving freely to position; and, on the other hand, suggest that use might easily wear the guide-pins so as to impair their utility. The care and ingenuity displayed in the construction of the Bar Lock machine gives promise that it may occupy an important place among the typewriters.

It must be remembered that the type-bar did not originate with the inventors of either of the machines in question. John Bain, the Scotch inventor of the printing telegraph, was the first to use a series of type-bars striking at a common center. The Francis patent of 1850, and some other subsequent American patents, also antedated the modern type-bar machines. Nevertheless, to the "Remington" belongs the unquestioned and distinguished honor of being the first typewriter brought into general use.

In considering those machines in which the type are placed on a single piece, and therefore all move together whenever a letter is brought to position and printed, the Hammond first claims attention, as the only one to be classed among the fast machines. It would be natural to suppose that a machine which is so constructed that ninety characters, or even half that number, must be moved every time a letter is printed, would require so heavy a type-carrier and coöperating parts that its action would be necessarily slower than that of a machine in which a single type only has to be moved at every impression. And when it is further considered that in a type-bar machine only a single movement is required to bring the character into position and produce the printing, while in the Hammond machine the character must first be brought into position by one movement, and dwell in that position until the printing is effected by another movement, namely, that of the impression hammer, it would be still more natural to conclude that it must be impossible to attain so high a speed with this machine as with those employing type-bars. Experience, however, shows that this is not the case; for, in the Hammond machine, the ingenious devices by which a perfect coöperation of the different parts and their prompt response to the touch of the operator are secured, have made it possible to reach the almost incredible speed of more than eleven impressions per second in writing actual matter, a higher speed than has been reached by other machines. Even at this great speed, involving what would seem to be a bewildering flight of small letters, capitals, punctuation marks, etc., the quality of the work remains excellent, the alignment and spacing being practically perfect and the impression uniform.

Like the other machines which operate with two movements, the "Hammond" allows of an indefinite number of changes in the style of the characters, or in their nature; as, for example, in the substitution of characters adapted for one language to those required for another.

Concerning those machines in which the type are carried upon a wheel or single piece, but have no keyboard connection, little need be said in general. The broad principles involved in these machines are common property, and no great originality is observable in any, excepting perhaps in the Hall machine, in which one important feature in typewriting machines, viz. the elastic platen, was first introduced. The machines exhibited show some interesting peculiarities, but are not designed for serious competition with the pen, and much less for competing in speed with the principal keyboard machines. It can, however, be said of this entire class that the slowness of their operation, and the fact that the type comes first to a definite position while the printing is produced afterward, and also that a change of type-wheel or type-plate can easily be made, adapt them for doing work of great variety and excellent quality where speed of operation is not essential.

Finally, one familiar fact observable in the domain of natural history may be noted also in the development of typewriting machines: viz. that the reduction of the number of similar parts, where each performs the same functions, appears to be in the line of progress, while at the same time two distinctly different functions, such as the presentation of the type and the production of the impression, are executed best when the separate functions are performed by separate parts.

Gold medals were awarded to the American Writing Machine Company, of Hartford, Connecticut, for the "Caligraph" machine: the Hammond Typewriter Company, of New York, for the "Hammond" machine; and Wyckoff, Seamans & Benedict, of New York, for the "Remington;" silver medals to the Columbia Typewriter Manufacturing Company, New York, who exhibited the "Bar Lock" and "Columbia" machines; Frederick Myers, New York, for the "Mercury;" and the World Typewriter Company, New York, for the "World" machine. The Hall Typewriter Company received a bronze medal for the "Hall" machine.

(67) A typewriter of Danish origin, of somewhat ancient date, was also shown in Machinery Hall. The type are applied to the lower ends of converging rods, which are guided in a hemispherical keyboard, from which they stand out like pins from a pin-cushion. Button heads on the upper extremities of the rods form the keys, which are pushed by the fingers in writing. The rods all point toward the center of the sphere and the type all strike in the same spot to print. The paper carriage is semicylindrical and swings on its axis in printing a line, but moves longitudinally in spacing from line to line.

Maskelyne's typewriter, exhibited by G. N. Maskelyne & Son, in the British section, is a machine having horizontal type-bars radiating to a common point where the impression is printed. When not in action the type, which are on the ends of the lower edges of the bars, rest on an inking pad. When a key is touched the end of the corresponding type-bar is lifted slightly, then the bar is thrust forward to the printing place, and, finally, the type is brought down upon the paper to produce the impression. The spacing is different for the different letters, so as to give a better appearance to the work than is obtained by uniform spacing. The machine is said to work rapidly, noiselessly, and with a very light touch.

The Messrs. Maskelyne exhibited cash registers also, and received a silver medal.

A typewriter was exhibited in the Swiss section. It is a dial machine, called the Velograph, and received a bronze medal.

68. *Machines for making paper bags.*—A very ingenious and practical machine now extensively used in the United States for making an excellent form of paper bag was exhibited in operation in the United States section by Mr. M. F. Leinbach, of Bethlehem, Pennsylvania.

The product of this machine is itself a new article of manufacture, being a bag which is folded flat and has all four side corners creased lengthwise, so that when the bag is inflated by being held by one edge of the mouth and swung with a quick motion through the air,—it opens out so as to assume a square, parallel-sided, flat-bottomed form, and will stand erect when set on a counter or table and remain wide open, so that it is in the best form for receiving what is poured into it. The bag when opened is also free from reëntrant folds which would form pockets inside the bag and afford places of lodgment for the contents; it can therefore easily be emptied completely. As they come from the machine the bags are folded flat and narrow, and take up less shelf room than square-bottomed bags of equal capacity made on other machines. The folded bags need not be inflated in order to be opened, but can be spread wide open by pulling slightly on one edge of the mouth and one fold of the bottom, when two hands can be spared for the purpose. One edge of the mouth is left slightly longer than the other, so that it can be grasped with one hand when the bag is tightly folded, without the necessity of unfolding it far enough to insert the fingers. The machine makes the bags from a continuous strip of paper of any quality, and turns them out at an exceedingly rapid rate.

The Leinbach machine is the outgrowth of a necessity for supplying the market with this greatly improved form of bag, and is the successor of other machines long used in the United States by the same company that now employs the Leinbach machine, but who formerly manufactured the form of square-bottomed bag shown in the British section, as the product of a machine in operation there which will be mentioned further on.

The Leinbach machine is made in several sizes, one for each different width of bag, and there are no adjustments for enabling bags of different widths to be made on the same machine. The length of the bag can, however, be varied at will. This limitation of the variety in the product of a single machine is not deemed an objection, for the demand for paper bags of all sizes is so enormous, particularly in the United States, that companies for manufacturing them seldom make so few bags of any given width that one machine is not constantly employed in making them. It is also a well-recognized fact that machines adapted for a definite kind of manufacture are unreliable, in respect to quality of product and certainty of action, almost in direct proportion to the variety of adjustments that are provided for changing the character or proportions of the work produced.

The Leinbach machine unfortunately failed to receive proper recognition from the jury; for the value of the award given for it, when compared with other awards for the same class of machinery, was very far from being proportioned to its merits.

(69) The paper-bag machine shown in operation in the British section was exhibited by Messrs. Bibby & Baron, of Burnley, England. This machine, and the bag made by it, are said to embody as many as twenty-two patents originally obtained in the United States and worked there. The machine is simple, efficient, and rapid working, but the product is inferior to that of the Leinbach machine. The bag has a folded bottom and can be opened out so that the bot-

tom will be square and the bag stand upright, but as it is creased lengthwise on two opposite sides the mouth tends to remain closed and must often be opened with the hand to receive the contents. A simple machine for making a similar form of bag was exhibited by Planche Brothers, of Saliens, France, and another different machine by Claude Rochette, Paris.

A very simple and ingenious machine for making small cork-screws wholly from wire was exhibited by Messrs Clough & Maconnel, of New York, and received a silver medal.

(70) Silver medals were also given to the Lamson Consolidated Store Service Company, Boston, for their exhibit of cash registering and adding machines, and to the John R. Williams Company, New York, for machines for finishing and bunching cigars.

CLASS 60, CARRIAGES, WAGONS, HARNESS WORK, AND SADDLERY.

(71) The greater part of the display in this class was placed at the side of the main building devoted to the various groups, adjoining Machinery Hall. It occupied about 26,000 square feet of floor space, and was remarkable for the striking appearance presented by the great variety of handsomely finished coaches, carriages, wagons, etc.,

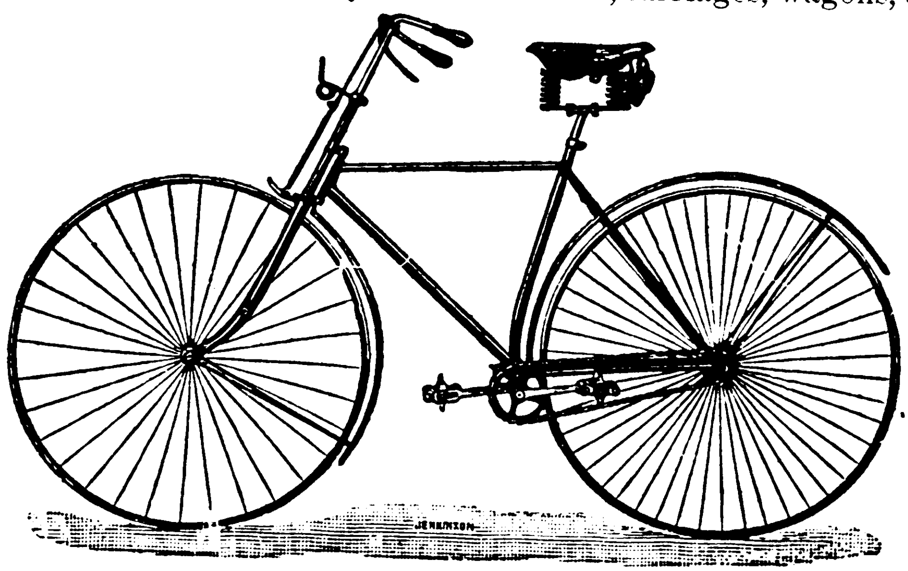

FIG. 15.—Bicyclette; Howe Machine Company, Glasgow.

In the United States section the dispay of fine carriages by Messrs. Healy & Co. of New York, was so favorably regarded as to receive the distinction of the only grand prize awarded to a foreign exhibitor in this class; only four other grand prizes having been awarded in all, one of which was for articles of saddlery.

It must be said, however, that several of the most prominent French exhibitors in the class were members of juries, and consequently noncompeting.

The report of an expert in the particular specialties of this class could not be obtained.

(72) The display of "cycles" in the British section was large and interesting. Humber & Co. and the Rudge Cycle Company received the only gold medals awarded for cycles. There were but few large-wheeled bicycles, but a great variety of bicyclettes, or "safety" bicycles, none, however, having strikingly novel features. Fig. 15 shows one form made by the Howe Machine Company, Glasgow, and gives an idea of the shape of frame which is the most in favor.

(73) A great variety of single and tandem trycicles were shown. Fig. 16 gives a view of a form different from the others, made by Humber & Co. The crank and transmitting gear are connected with the two driving wheels, which are in front instead of behind. The rider sits well over toward the front axles, so that his position is much the same as on a bicycle. The arrangements permit of steering without the use of the hands.

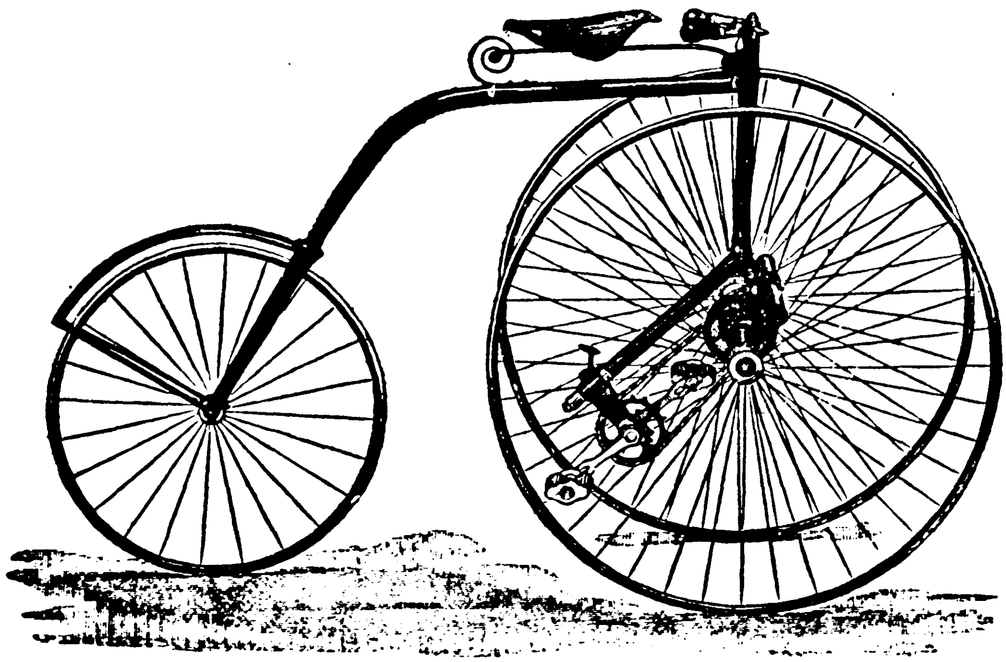

FIG. 16.—Tricycle ; Humber & Co., London.

Humber & Co. publish the "Amateur's" records of the several types of their machines, which are interesting as showing how little practical advantage one form has over another in speed.

The records are :

	Bicycle.		Bicyclette.		Tricycle	
	Min.	*Sec.*	*Min.*	*Sec.*	*Min.*	*Sec.*
Twenty miles	56	$58\frac{3}{5}$	56	$58\frac{2}{5}$	59	$10\frac{3}{5}$
One mile	2	$31\frac{1}{5}$	2	$36\frac{2}{5}$	2	$41\frac{2}{5}$
One-fourth mile	0	$33\frac{1}{5}$	0	$37\frac{3}{5}$	0	$37\frac{1}{5}$

(74) Fig. 17 shows a steam tricycle constructed by the Messrs. Serpolet Brothers, Paris. It will run with considerable speed, climb

quite steep grades, and, though not light, is not excessively heavy, weighing 400 pounds when loaded with enough fuel and water to last for a trip of several miles. The speed is regulated by limiting the supply of feed water to the boiler by means of a cock in a by-pass from the feed pump. The boiler is practically safe, containing only the quantity of water that can be held in a capillary opening which forms the inside of a thick, flattened pipe of which the boiler is made.

The boiler is described in the report on Class 52.

FIG. 17. Serpolet's steam tricycle.

CLASS 61. RAILWAY MATERIAL.

(75) For this class see Professor Haupt's special report in this volume.

CLASS 62. ELECTRICITY.

(76) Mr. Carl Hering's report on this class contains a full account of the exhibits, and will be found in Vol. IV.

CLASS 63. CIVIL ENGINEERING, PUBLIC WORKS, AND ARCHITECTURE.

(77) Prof. William Watson's special report in this volume, on this class, and Professor Chandler's report, in Vol. II, on the preservation of wood, cover ground occupied by this class.

CLASS 64. HYGIENE AND PUBLIC CHARITIES.

(78) Professor Chandler's report on hospitals, in vol. II, is referred to as treating of the most important subject in this class.

CLASSES 65 AND 66. NAVIGATION, LIFE-SAVING, AND MILITARY MATERIAL.

(79) For these classes see Capt. D. A. Lyle's reports in Vol. IV.

REPORT

ON

MACHINERY AND APPARATUS ADAPTED FOR GENERAL USE IN MECHANICAL ENGINEERING

BY

CHARLES B. RICHARDS, M. A.,

Professor of Mechanical Engineering in the Sheffield Scientific School of Yale University.

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REPORT ON CLASS 52: GENERAL MECHANICS.

By CHARLES B. RICHARDS, M.A.

I.—General remarks.

(1) This was the most extensive of all the classes of the sixth group, both in the scope of subjects covered and in the space occupied by the exhibits, while the number of exhibitors was greater than in any other class except No. 63.

The space allotted to it was distributed as follows:

	Square feet.
In Machinery Hall:	
Grouped French exhibits	55,000
Exhibits of other countries	10,000
Annex on the quay	19,000
Boiler houses	17,000
Pumping stations	13,000
Annex on the Champs de Mars	8,000
Megy's pavilion	1,000
Serpolet boiler house	1,000
Total	124,000

This does not include the space occupied by the thirty-two large steam engines and numerous gas engines employed for driving the shafting and special exhibits, nor that required to accommodate the lines of shafting, the pumping apparatus for the Eiffel Tower, and the numerous elevators in the tower, Trocadero, Machinery Hall, etc. It may be assumed that Class 52 alone required one-seventh of all the space devoted to the eighteen classes which composed the sixth group.

(2) In the United States section the display in this class was not extensive; the quality, however, was good—a fact attested by the number and value of the awards the jury felt justified in giving to our exhibitors. Out of 677 catalogued exhibitors from all countries, only 34, or about one-twentieth of the whole number, were from the United States. These exhibitors received 1 grand prize out of a total of 16 awarded, 7 gold medals out of 73, and in all 26 awards of different kinds.

The grand prize was given to the Worthington Pumping Engine

Company, New York; the gold medals to the American Elevator Company, New York; Armington & Sims, Providence, Rhode Island; C. H. Brown & Co., Fitchburg, Massachusetts; Crosby Steam Gauge and Valve Company, Boston, Massachusetts; Otis Bros. & Co., New York; Straight Line Engine Company, Syracuse, New York; and Jerome Wheelock, Worcester, Massachusetts.

Another of the grand prizes was awarded to the English representatives of the firm of Babcock & Wilcox, of New York, and yet another to a French firm for steam engines manufactured under licenses from Corliss & Wheelock; while four other manufacturers of engines originally patented by citizens of the United States were represented on the juries, and thus held posts of honor which prevented them from competing for awards.

(3) The jury for Class 52 consisted of twenty members, thirteen of whom were from France, two each from Belgium, Great Britain, and the United States, and one from Switzerland. In examining the exhibits for the purpose of making the awards the jury estimated their comparative values and rated them according to a numerical scale ranging from 0 to 20. A definite numerical value was also given to each of the five varieties of awards, which were distributed in accordance with the valuation of the exhibits; the ratings which entitled the exhibits to the particular awards being as follows:

20 to 19, a grand prize.
18 to 17, a gold medal.
16 to 15, a silver medal.
14 to 13, a bronze medal.
12 to 11, honorable mention.

Exhibits rated below 11 failed to receive an award.

In this class, twenty-eight of the most prominent French exhibitors, and one from Switzerland, were placed out of competition because of their positions as members of juries. A careful comparison of the exhibits thus deprived of awards with those of a similar character which received them, shows that it is fair to assume that ten of these noncompeting exhibitors would have been entitled to grand prizes, and the others to gold medals.

(4) The following table shows the distribution of awards to exhibitors of various nationalities:

Awards.	France.	Belgium.	Great Britain.	Switzerland.	United States.	Other countries.	Total.
Grand prizes	8	2	2	2	1	......	15
Gold medals	52	5	5	2	7	2	73
Silver medals	93	6	6	4	4	......	113
Bronze medals	89	9	10	3	12	3	126
Honorable mention	97	9	10	1	2	15	134
Total	339	31	33	12	26	20	461
Number of exhibitors	469	42	63	17	34	52	677

To these should be added the estimated awards for noncompeting exhibitors: For France, ten grand prizes and eighteen gold medals, and for Switzerland one gold medal.

If we give to the different awards for each country the values assigned them by the class jury, and divide the sum of the values thus obtained by the number of exhibitors in each section, the relative standing of the several countries, as determined by this estimate of the mean value of the exhibits, is:

Switzerland	1.55
France	1.54
United States	1.54
Belgium	1.43
Great Britain	1.00

If the values adopted by Mr. Hering for the awards in Class 62 were used, the standing would be:

Switzerland	2.44
France	1.55
United States	1.55
Belgium	1.47
Great Britain	1.00

If, finally, we estimate the relative importance of the collective exhibits by comparing the whole number of the awards, without reference to their value, with the number of exhibitors, the standing is:

France	1.48
United States	1.46
Switzerland	1.46
Belgium	1.41
Great Britain	1.00

(5) The descriptive title given to Class 52, "General mechanics," hardly indicates the ground it covers, which, indeed, is difficult to define. The other classes related to specific manufactures, industries, or trades, while to Class 52 were assigned machines, apparatus, and objects which are adapted for the use of the mechanical engineer in general work, in distinction from special.

The subjects to which such machines and objects relate are given in some detail in the prospectus of the French official classification, a translation of which will be found in the first volume of these reports. Nearly all may, however, be advantageously grouped under the following more general heads:

I. Prime movers, their accessories and appliances.
II. Steam generators and condensers, their parts, and accessories.
III. Apparatus for moving, forcing, and obtaining force from water and air.
IV. Machines for lifting and shifting heavy loads.
V. Apparatus and parts of mechanism for transmitting, modifying, and regulating motion and power.
VI. Apparatus and instruments for measuring weight, speed, pressure, and power, and meters for measuring fluids.

VII. Printed publications relating to general mechanical engineering, and to technology.

VIII. Apparatus and material for navigating the air.

The last heading relates to a subject, which, like marine engineering, is more special than general, but was included in this class for lack of another place for it. As technical literature did not find a place elsewhere, it was put, with engineering literature, in this class.

Class 52, however, was not intended to receive all the exhibits which might come under these general divisions; those only were assigned to it which had no special adaptability for a single industry, art, or special branch of engineering; and, further, motors and other machinery of a general kind in which electricity played an important part did not find place in this class, but were assigned to Class 62.

A few examples will illustrate the principles applied in admitting some exhibits of a certain class of objects and rejecting others of the same type which differed from the former only in certain modifications, which, while they did not prevent or even lessen the utility of the object for general use, were yet intended to fit it for a more special application.

Steam engines in general belonged in Class 52, but marine engines were assigned to Class 65 (Navigation and Life Saving), and steam fire engines, to the same class. Only a few of the many portable engines were admitted to Class 52, for the greater number had special features which rendered them particularly useful for agricultural work, and were properly included in Class 49.

Pumps for general use came into Class 52, while fire pumps were placed in Class 65, and pumps for agricultural use, in Class 49.

Apparatus for utilizing compressed air for general motive power was in Class 52, but many air compressors were transferred to Class 48, as they were fitted for use chiefly in mining and metallurgy; and some to Class 50, which contained ice machines.

Balloons in general were shown in Class 52, but some large balloons designed for military reconnaissance were exhibited in Class 65.

Windmills which were combined with pumps for irrigation were in Class 49, while other kinds appeared in Class 52.

The French authorities were exceedingly judicious in their classification of the exhibits, and showed rare judgment in their distribution to the various classes.

(6) A point worthy of notice in connection with the jury work in Class 52 is the character of the written or printed circulars of information furnished by the French exhibitors to the members of the jury of awards. They were in most cases very complete and satisfactory, and in some instances no pains were spared by the exhibitors to give the fullest possible explanation of their exhibits, by means of drawings and clearly printed descriptions, accompanied by statements setting forth the special features of the objects and their

claims to attention. These presentations were noticeable for their clearness and good form.

Usually twenty copies of these documents, one for each member of the jury, were furnished by the exhibitor, and thus each juror was enabled to understand quickly what he was shown at the time of the jury's visit to the exhibit, and to act intelligently in determining its merits.

This desirable feature was the result of the efforts of the French authorities to remedy difficulties which had been experienced in all previous expositions. They endeavored to have the exhibitor understand that the manner in which his case was presented to the jury of awards could not fail to have its effect upon the decision reached, which must, to a great extent, be based upon knowledge obtained before the visit of inspection, rather than upon information gathered during the necessarily limited time that could be devoted to the examination of the exhibit.

The Belgian exhibitors followed the course of the French in this particular, but those of other countries were less generally and fully prepared with such descriptions; a deficiency for which the French members of the jury generously made allowance, and which they counterbalanced by more prolonged and patient personal examinations of the exhibits themselves, and by listening to such advocacy of them as the jurors representing those countries could give.

In future expositions important advantages may be gained by the adoption and development of the system suggested by this example. The formal statement usually filed by an exhibitor, often consisting of obscurely expressed answers written indistinctly in the blank spaces of a list of printed questions—alike for all the exhibitors of a class—should be supplemented by a more precise explanation of the distinctive features of the exhibit, and its claims to importance, as shown by the extent to which the articles exhibited have been introduced into public use, or by records of the results of such tests of their excellence as may have been made. This should be concisely but clearly presented, with suitable illustrations when the subject admits of them, so that the exhibitor's case may be set in a proper light before those whose duty it is to pass judgment upon it. The decisions respecting awards can then be made intelligently and satisfactorily, and much valuable information be collected which might otherwise be withheld. Each exhibitor should be made to understand that, as a competitor for recognition or award, it is for his interest to furnish a proper presentation of his case.

The remarks made in the general review of the sixth group, respecting the scarcity of new inventions which promise to be of any considerable importance, and the absence of those that are likely to revolutionize present practice or methods, apply with force to the display in Class 52. Many of the exhibits were remarkable for their extent, and the excellent design and workmanship of the objects shown, but, with few exceptions, there was little to be found which was new or instructive.

In the report on this class no attempt is made to mention any large proportion of the exhibits displayed. Only a few which presented features of special interest are described, and the distinctive characteristics of some others mentioned, in cases where the reputation of the exhibitor, or the relation of the object exhibited to similar machines known in the United States, makes it desirable to refer to it.

The immense number and variety of the objects displayed made it impossible to avoid leaving unnoticed many which were undoubtedly quite as interesting and important as some that are described. It was necessary to make a selection of such subjects as could be best dealt with under the circumstances which limited the time and resources of the reporter.

II.—Steam boilers.

(7) *Sectional steam boilers.*—In the display of steam generators which the Exposition presented, boilers of the tubulous sectional type were far more numerous than all other forms together.* A large proportion of the steam employed for different purposes in Machinery Hall was supplied by boilers of this kind, those in active operation representing 3,000 horse-power in steam actually supplied, and a total steaming capacity of more than 5,000 horse-power.

The number and variety of the exhibits of this type of boiler, the extent to which capital is invested in their manufacture, and the enactment of laws which enforce their use in certain cases, indicate a tendency toward their very general adoption in Europe.

The growing demand for steam pressures much higher than those hitherto generally employed, and the peculiar adaptation of the tubulous steam generator for use under this condition, is one of the chief reasons for its approval, but the increased use of elevators, and the introduction of isolated plants for electric lighting, which have brought about the more general employment of steam power in large and valuable buildings and its wider introduction in cities, in districts devoted to dwellings, have also tended to extend the adoption of a form of boiler in which safety from destructive explosion is the quality most valued.

The influence which the introduction of sectional boilers in the United States has had upon their adoption in Europe may also very properly be referred to here: The immediate causes for the present

* The term *tubulous boiler* is applied to a kind composed chiefly of tubes which contain the water to be evaporated and are surrounded by the flame and hot gases, in distinction from a *tubular boiler*, which consists of a shell containing the water and traversed by tubes which form flues for the hot gases and are surrounded by the water.

demand for a type of boiler possessing the qualities specified have been suggested, but the extensive and rapidly increasing use of the sectional boiler in England and on the Continent has undoubtedly been greatly hastened by the fact that Harrison, Root, and notably Babcock & Wilcox, long since made a practical and commercial success of this general type of steam generator in the United States, thus demonstrating its value. The enterprise of the last-mentioned firm has so extended the use of water-tube boilers as to popularize them to a degree which has made the type favorably known all over the world.

Fortunately, in tubulous boilers of the best type, an immunity from the danger of widespread destruction of property or life, in case of accident to the boiler, is secured without the sacrifice, to a serious extent, of other necessary or desirable qualities.

It is well known that the frightfully disastrous effects which sometimes result from the explosion of a boiler which contains a large quantity of water, are produced by the breaking open of the boiler in such a way as to instantly set free the entire contents, and thus permit the sudden destructive action of the energy which, before, was pent up in the large mass of highly heated water the boiler contained. The amount of this energy is in almost direct proportion to the quantity of the water and to its temperature, but the suddenness of the application of the power developed is the most important factor in the result of an explosion of the character referred to. The volume of steam which is suddenly generated from a large mass of highly heated water instantaneously relieved from confinement is enormous, and yet this steam possesses for a short time sufficient pressure to wreck the structure it penetrates, while the energy suddenly developed by the explosion is sufficient to project large fragments of the ruins to a distance. On the other hand, when the fracture of a boiler is of such a character as to permit a gradual relief of pressure, the pent-up energy developed in this manner is dissipated gradually, and often harmlessly.

In the tubulous sectional boilers shown in the Exposition, the features which are to be noticed in considering the question of safety are:

I. Comparatively small water capacity—not exceeding from one-third to one-tenth that of many other types of boilers in general use.

II. The division of a great proportion of this water into small portions, contained in numerous small receptacles the walls of which may be made sufficiently strong without requiring such thickness as to involve their injury from overheating.

III. Small communications between the different receptacles, and between the receptacles and the steam reservoir of the boiler, by which the instantaneous escape of any great quantity of hot water is prevented in the event of a local breakage.

IV. Numerous joints where the parts are united, affording places at which yielding under excessive pressure may occur and allow a gradual escape of the contents instead of its sudden release.

Theory, confirmed by experience, shows that the outflow of highly heated water, even when the water is subjected to the great pressure which is due to its high temperature, is comparatively slow if the escape takes place through orifices of moderate size; and, if such openings are the only kind which are presented when the rupture of a boiler occurs, the escaping contents fail to produce the widespread ruin so much dreaded as the result of a boiler explosion.*

* When an outlet is opened below the water level of a boiler under steam, the water which issues into the atmosphere is at the high temperature due to the boiling point which corresponds to the pressure in the boiler.

In consequence of this, a portion of the water, varying from 4 to 16 per cent. of the whole, depending upon the pressure, is converted into steam when it reaches the orifice, where the pressure necessarily becomes reduced from that of steam in the boiler to that of the atmosphere outside. The volume of the steam thus generated is great compared with that of the water, and the steam in escaping fills the orifice to such an extent that the outflow of the water is greatly retarded. This fact, which corresponds with conclusions deduced from theoretical considerations, must have been observed by every one who has had to do with the management of a boiler, as he can not have failed to notice the surprising length of time required to empty a boiler under steam when the blow-off cock is opened ; for, although, from the high pressure which the steam exerts on the water, and the force with which it tends to drive it out, the rapid expulsion of the water might be expected, yet its level in the boiler is lowered but slowly, and its escape is gradual, no matter how great the steam pressure may be.

Professor Zeuner, in his Warme Theorie, has given formulæ and tables for the computation of the outflow which will take place from a boiler under steam at various pressures, and the following short table, giving roughly approximate results, has been computed from his formulæ:

Rate of discharge of the hot water of a steam boiler through an orifice below the water line.

Steam pressure above the atmosphere	20	50	100	150	pounds per square inch.
Rate of outflow per square inch of the orifice.......	1.04	1.05	1.06	1.07	cubic feet per minute.

This shows that the contents of the boiler escape only very little faster when the pressure is high than when low. The higher temperature of the water under the greater steam pressure causes a greater volume of steam to be generated in the orifice than is produced at the lower pressure, and the outflow of the water is more obstructed in consequence.

Cold water subjected to the same pressure would be discharged many times more rapidly, as the following table shows.

Discharge of cold water under pressure.

Pressure..................	20	50	100	150	pounds per square inch.
Corresponding head........	46	115	230	346	feet.
Discharge per square inch of orifice..................	15.9	25.1	35.5	43.5	cubic feet per minute.

The discharge given in these tables is 30 per cent. less than the theoretical discharge, this allowance having been made for friction, contraction, etc.

It is true that by the failure of one or more of the sections of a tubulous boiler small fragments may be hurled to a distance and cause damage or destroy life, or the escape of steam may do injury by scalding persons in the immediate neighborhood of the boiler, but the destruction of a building and the great loss of life which may thus be entailed are not to be feared as a consequence of such an accident.

The steam reservoirs or drums of sectional boilers often contain a considerable proportion of the heated water. The remarks made above do not apply to this part of the apparatus; but, as the reservoir is not necessarily subjected to intense heat, the thickness and strength of its walls may be made as great as is necessary to secure strength, and the effect of heat upon them need not be considered. The reservoirs are generally made far stronger to resist bursting than the joints at the connections of the tubes are to resist yielding. Disastrous explosions of such reservoirs of sectional boilers have, however, occurred.

The evaporative efficiency of the different types of boilers in general use—that is, their economy with respect to the quantity of water evaporated in proportion to fuel consumed—depends chiefly upon the quantity of water evaporated in a given time by a given extent of heating surface. Under the conditions usually found, the economical efficiency diminishes with an increase in the rapidity of this evaporation. Unless, then, the general arrangement be very faulty, a boiler of one type may be so proportioned as to be as economically efficient as a boiler of another type. There is, however, an advantage in this respect in favor of boilers having furnaces entirely surrounded by heating surface, that is, in favor of internally fired boilers as they are called, of which the locomotive, marine, and Galloway boilers are examples which were represented in the Exposition. In this kind the economical efficiency is somewhat greater, with a given rate of evaporation, than in boilers of other types, because a larger proportion of the heating surface is favorably situated for the reception of radiant heat from the incandescent fuel and flaming gases, and also because the loss of heat by radiation from the exterior surfaces can be made less than in the others.

The table on page 21 gives certain general information respecting the boilers used to supply steam for the Machinery Hall. The interesting features of a few of these and other boilers exhibited, and some facts relating to their use, will be noticed, but no attempt will be made to name all the exhibitors of boilers, and many of the exhibits which may merit attention will have to remain unnoticed, the number displayed was so great.

With a single exception the sectional boilers shown in use at the Exposition were either of the Root, or Babcock & Wilcox tubulous type, pure and simple, or else more or less close imitations of these.

(8) *The Babcock & Wilcox boilers.*—These were exhibited in the British section by the Babcock & Wilcox Company, of New York and Glasgow, to whom a grand prize was awarded.

The general arrangement and features of construction of these boilers, as they are made in the United States, have become so well known through their extensive introduction that it is unnecessary to describe them here.

Two of the boilers exhibited by this firm were used at nearly their full capacity for supplying steam to the hall; they differed from the form usually seen in the United States in a few details only, but chiefly in having all the connections made of wrought iron instead of cast iron, a change which was made because the employment of cast metal for any important component part of a boiler is disapproved of, and in some cases prohibited by law, in European countries.

The nearly vertical connecting pipes or headers, of rectangular cross section, by which the adjacent ends of the inclined water tubes are united with each other and with the steam and water reservoir, were forged in a single piece having the usual undulating or sinuous form, so that the tubes they hold are staggered, that is, so that tubes in one layer lie over the spaces between the tubes of the layer next below.

These headers at each end of the tubes communicate directly with the bottom of the reservoir by means of nearly vertical tubes expanded into the tops of the headers and fastened, also by expanding, into the flat bottom of a wrought iron inverted saddle piece, or cross box as it is called, which extends across the bottom of the reservoir, near each end. The direct communication thus afforded between ends of the inclined water tubes and the interior of the reservoir avoids impediments to the water circulation.

Fig. 1 is a longitudinal sectional view of the front end of the upper part of the boiler, and shows the cross box for that end and the way the headers communicate with the reservoir by means of it; and Fig. 2 exhibits a front view of the boiler with part of the front casting removed so that the sinuous form of the wrought-iron headers can be seen.

The headers and cross boxes are forgings of remarkable excellence, and afford good examples of the progress which has been made in England in the art of working wrought iron and steel; they illustrated the fact that the production in these materials of forms which have hitherto been made only of cast metal is now practically carried on as a manufacture, so that the products are supplied at prices which make it profitable to employ them. These and other examples of admirably executed work in wrought metal, particularly in metal plates, show that the processes and apparatus employed by the English manufacturers of these specialties are superior to those in use in the United States.

The usual hand holes in the fronts of the headers, opposite the end of each tube, are closed by hand-hole plates on the inside, and disk-like covers on the outside, which are seated on the faces of the headers and clamped in place by means of wrought-iron bolts. The faces of the cover and plate are dressed and the seats on the headers also faced, so that the parts are in contact, metal on metal, and no destructible packing is employed for making the joints tight.

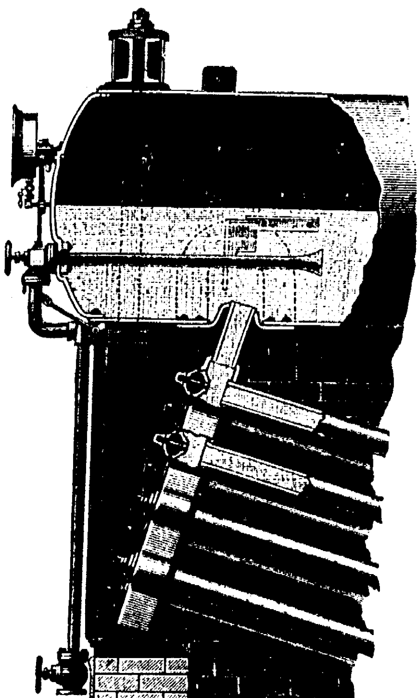


FIG. 1.—Babcock & Wilcox boiler. Section of upper part of front end.

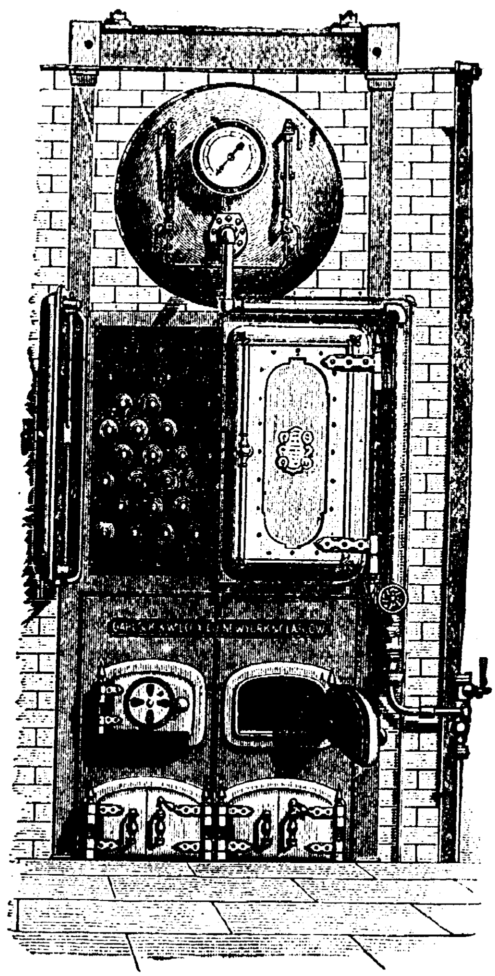


FIG. 2.—Front view of the Babcock & Wilcox boiler.

A test of the steaming capacity, made by the administration, demonstrated that the boilers of the set exhibited were capable of yielding 24,200 pounds of steam hourly, with fuel of the quality obtainable at the time, and under the working conditions. This gave a rate of evaporation of about 4.4 pounds of water per hour per square foot of heating surface of the boilers proper. An economizer with 1,425 square feet of heating surface, placed in a chamber in the smoke flue, was used in connection with the two boilers.

The Babcock & Wilcox Company, in the printed catalogues which formed part of the evidence presented to the jury of Class 52, gave a list of about 4,000 of their boilers, representing nearly half a million horse-power, sold in the last fifteen years; also a list of over 100 boilers, representing more than 15,000 horse-power, sold by them in the first three months of 1889 in countries other than the United States.

(9) *The Root boiler.*—Conrad Knap & Co., of London, England, exhibited in operation Knap's improved Root boiler.* To indicate the differences between the various modifications of the Root type of boilers shown in the Exposition, a brief description of Knap's boiler is given first; a longitudinal section is shown by Fig. 3.

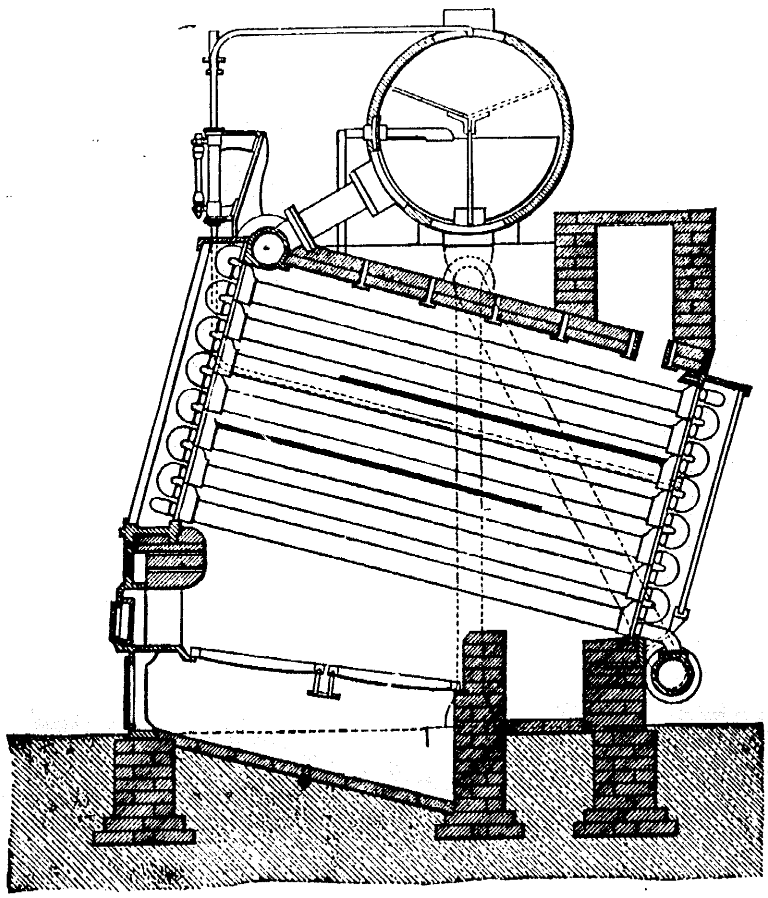


FIG. 3.—Knap's modification of Root's boiler. Longitudinal section.

A number of pipe elements, all inclined in one direction, as in the Babcock & Wilcox boilers, are piled one above another in vertical zigzag rows, a single vertical row of elements constituting what is called a section, or a series. A number of these sections standing side by side compose the entire heating surface of the boiler, and contain the greater part of the water from which steam is generated. Each element of a section communicates with those next above and

*The Root boiler originated in the United States, where it has been introduced extensively.

below it in a manner that will be described later, and the upper front ends of all the sections are put in communication with each other by a cross pipe, forming a steam collector, from which a riser leads to a large cross drum or steam reservoir located above the boiler, the place of entrance of the riser being at the level of the surface of the hot water which partly fills the reservoir. The lower rear ends of the bottom elements of the sections are also united by a cross pipe forming a hot-water collector, the two ends of which turn upward and enter the bottom of the reservoir. An element of the boiler consists of a single 5-inch tube 11 feet long, having at each end a cast metal mouth piece, or junction box, with two circular apertures in its face. The end of the tube is fastened in the box by expanding. The outer faces of the boxes are rectangular and lie one upon another. The elements of a section thus piled are united by return bends which slant right and left alternately and connect the apertures of each box with those of the boxes lying next above and below it; as shown in Figs. 4 and 5, which represent, respectively, an end view of three elements, and a sectional view of their ends.

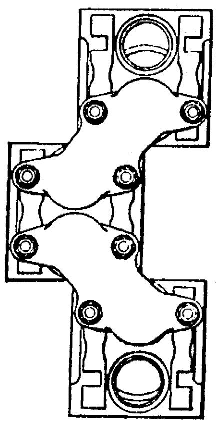


FIG. 4.—End view of three elements.

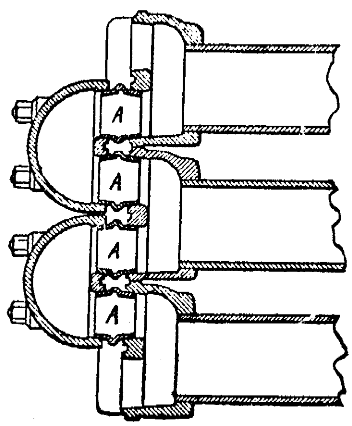


FIG. 5.—Section of the ends of three elements.

The joints between the mouths of the return bends and boxes are formed by short pipe nipples, A, which are turned tapering at each end and fit accurately into the mouths, which are smoothly bored. Four bolts in the corners of the return bends afford means for forcing the nipples into the mouths and clamping them in place.

The front end of the uppermost element of each section is united to the steam collector above it by one of the return bends, and the back end of the lowest element is connected with the hot-water collector beneath it by an elbow, all these joints being made by means of the tapering nipples.

The tapering nipples are bulged in the middle so that a single corrugation is formed around them. This corrugation of the nipple is the novel feature of the joints of the Knap boiler; it makes the joint somewhat elastic and serves to secure permanent tightness.

Access may be had to the interior of a tube by removing a return bend, and, if repairs are needed, any single element or section can be removed and replaced quickly by loosening a few bolts.

The feed water is delivered into the reservoir at the place where the hot water and steam from the tubes enter it; its water is thus instantly heated to a high temperature, which occasions the deposition in the reservoir of certain salts of lime and magnesia liable to be contained in the water, their action in forming scale in the tubes being thus prevented.

One of the boilers exhibited was set in brickwork; another smaller boiler of portable form was cased with brick-lined plates. They were good specimens of workmanship.

(10) *The De Nayer boilers.*—Messrs. De Nayer & Co., of Willebroeck, Belgium, had in operation a battery of six boilers of excellent appearance and careful construction.

The performance of these boilers in supplying a large quantity of steam for the Belgian, Swiss, and French sections in Machinery Hall was exceedingly satisfactory.

The capacity of the boilers was tested by the administration of the Exposition, and the six boilers were found capable of evaporating 36,500 pounds of water per hour under the usual working conditions.

The form and structural features of this boiler are essentially like those of the Root boiler shown in Fig. 3 and just described.

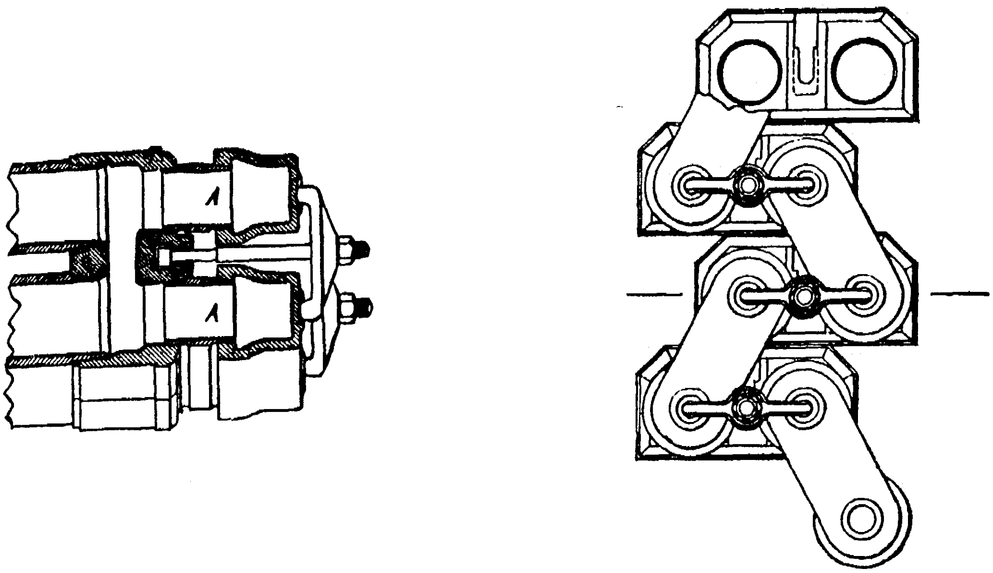
It consists of inclined tube elements united by return bends and communicating with a steam reservoir above the boiler by means of risers leading from cross pipes which form collectors for steam and hot water. The steam reservoir, however, lies lengthwise of the boiler instead of crosswise.

An element of this boiler, instead of being a single tube, consists of two parallel 5-inch tubes coupled at each end by rectangular headers, or junction boxes, in which the slightly tapering ends of the tubes are made fast by having been forced into the tube holes and expanded in them. Each junction box has two apertures or mouths in its outer face, in line with the tubes. The elements are piled flatwise one upon another, and coupled to the elements next above and below by return bends, in the manner shown by Figs. 6 and 7.

Pipe nipples, A, with tapering ends are used in this boiler, as in the Root boiler, to form the joints between the boxes and return bends; but the nipples are without the corrugation used in the Knap joint.

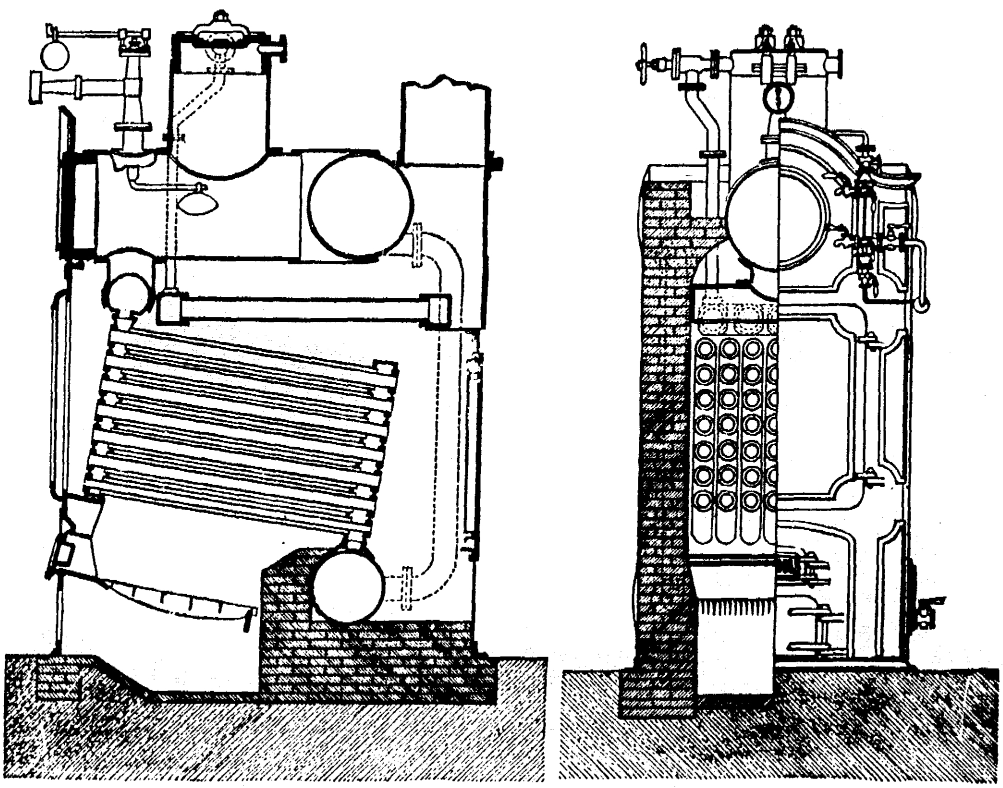
The return bends are clamped to the junction boxes by a single bolt and a brace which bears on the backs of the bends.

The steam reservoir contains but little hot water, for steam is set free in the tubes, and discharged into the reservoir above the surface of the water. The hot water descends from near the bottom of the reservoir to the cross collector beneath the back ends of the lowest water tubes. The steam is dried by being forced to pursue a circuitous course, with sudden changes of direction, in its discharge



FIGS. 6 and 7.—Horizontal section of a single element, and end view of four elements of the De Nayer boiler.

from the reservoir, the deposit of the moisture taking place on the surfaces which deflect the flow of the steam.



FIGS. 8 and 9.—The Roser boiler.

The De Nayer boilers are used extensively in Belgium and France, and their use is increasing. A grand prize was awarded for the exhibit.

(11) *The Roser boiler.*—Five boilers exhibited by N. Roser, of St. Denis, France, were employed to furnish steam for sections in Machinery Hall, and seven others were in use in different parts of

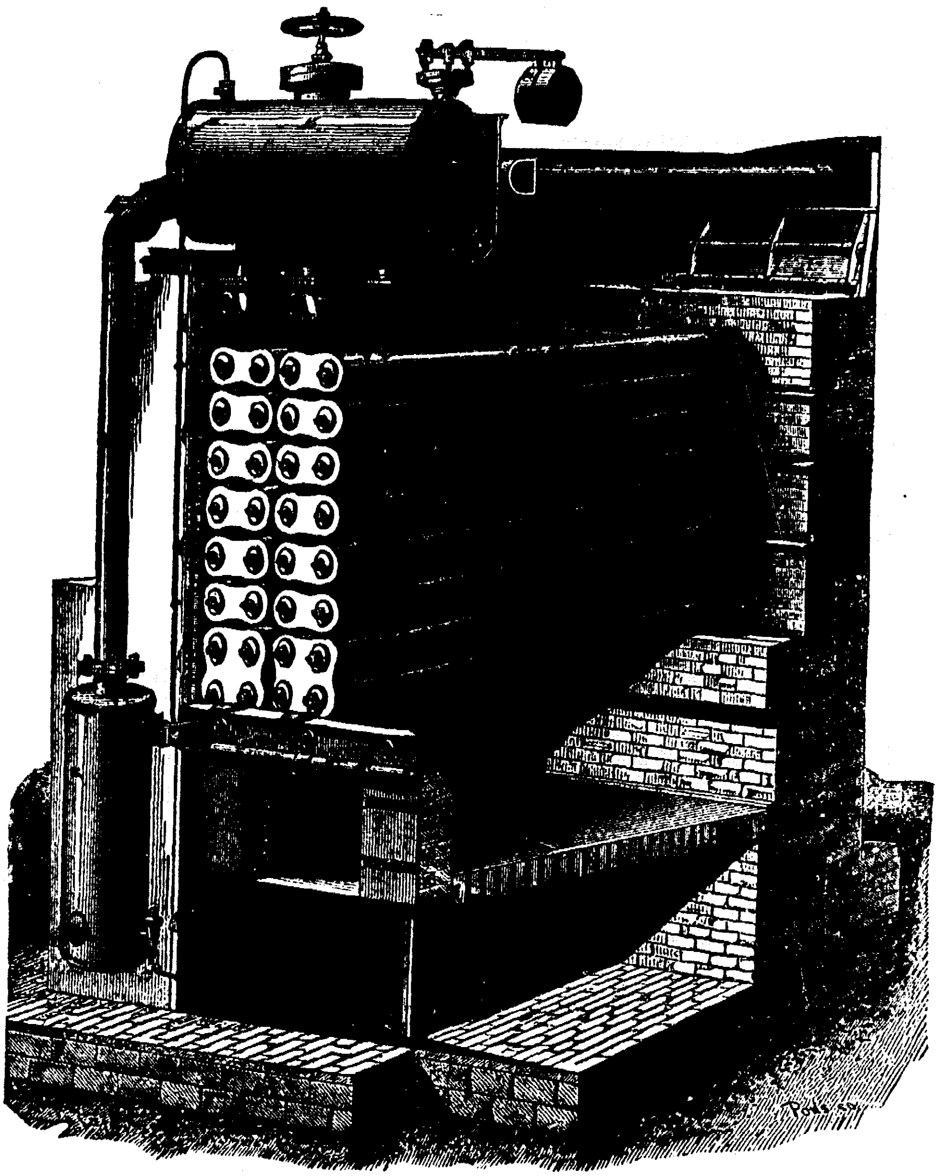


FIG. 10.—View of two elements of a Belleville boiler, with their connections. Stationary type.

the Exposition; over 2,000 horse-power in all. Two kinds were exhibited. Figs. 8 and 9 show one form, in which the hot gases after passing around the water tubes return through smaller fire tubes, which pass through the axes of the water tubes. In another kind the return fire tubes are omitted and the water tubes made long enough to furnish the required surface.

It will be seen that this boiler is a combination of the Babcock & Wilcox, and Root types, with the return fire tubes added in one of the forms. The tubes are in vertical rows and not staggered; an arrangement which is not favorable for efficiency.

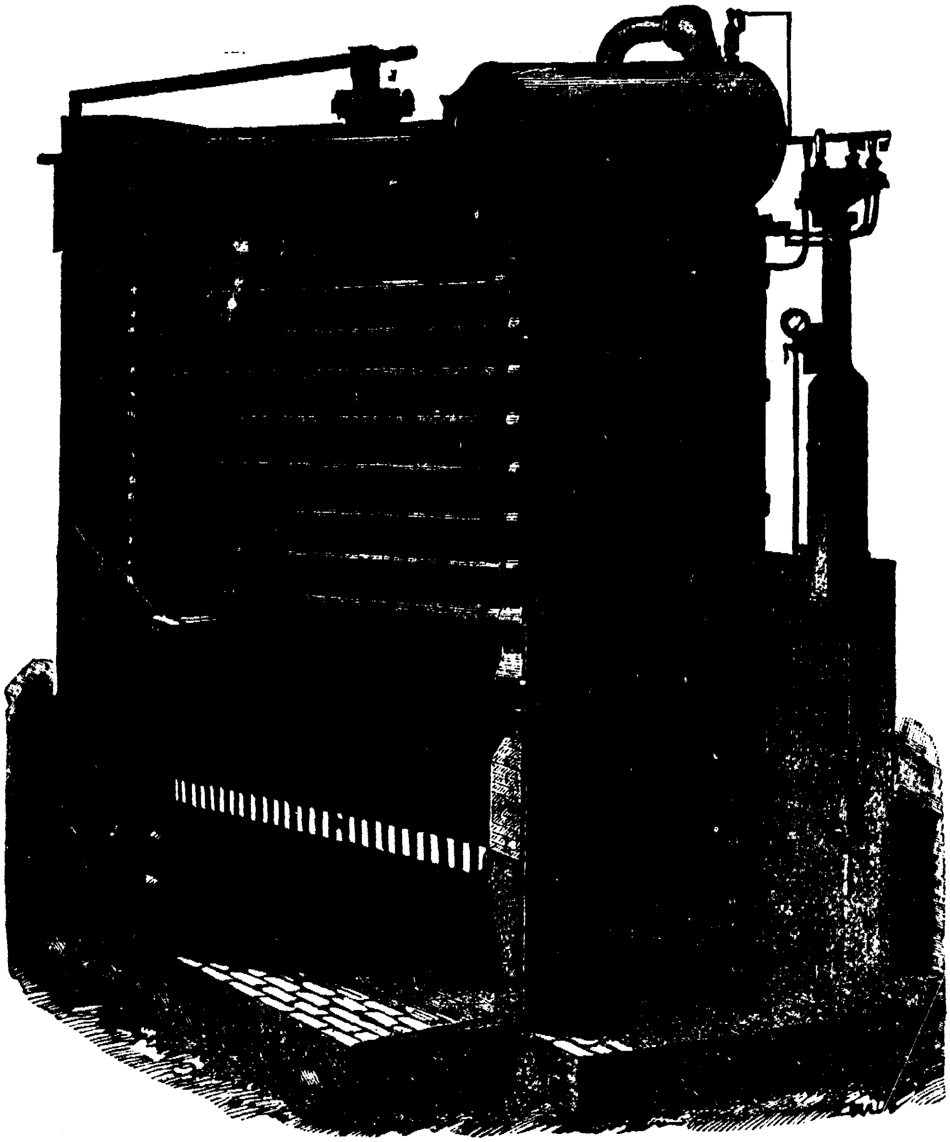


FIG. 11.—Belleville boiler, stationary type, with parts of the setting removed.

(12) *The Belleville boilers.*—These were exhibited by J. Belleville & Co., St. Denis, Seine, France, and, in extent, formed the most important of the boiler exhibits. There were four distinct displays:

I. A group of boilers of 1,000 horse-power, furnishing steam for Machinery Hall.

II. A group of 700 horse-power, in use for the central electrical station.

III. One of eight groups of marine boilers, for a naval cruiser of 8,000 horse-power.

IV. A large number of marine, stationary, and portable boilers, set up in Machinery Hall and in the building for maritime exhibits, but not in operation.

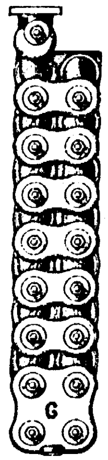


FIG. 12.—End view of a single element of the Belleville boiler.

The Belleville boiler has attracted much attention in France, and in detail is essentially different from the other boilers exhibited.

Figs. 10 and 11 show a stationary boiler in which the characteristic features may be seen.

An element consists of a double vertical row of nearly horizontal pipes, G, united by return bends, called "junction boxes," which connect the end of one tube with the adjacent end of the tube next to it in such a manner that the element takes the form of a continuous pipe doubled upon itself so as to constitute a narrow flat-sided coil. See Fig. 12.

A number of these elements stand, side by side, directly over the fire grate, K. They contain nearly all the water there is in the boiler, together with a portion of the steam, and afford the entire heating surface.

The front upper end of each elemental coil leads directly into the bottom of a small cross drum, C, above them, which forms a steam receiver supplementary to the space for steam afforded by the upper folds of the elements. Beneath the front lower ends of the elements is a cross pipe, F, of rectangular cross section, forming a feed-water distributer by means of which the hot water is distributed to the coils. A pipe, D, descends from near the bottom of the steam receiver, C, to a sediment collector, E, which stands in front of the boiler at one side, just below the elements, and a short pipe leads from the top of this collector into the feed-water distributer, F.

The feed water is injected into the lower part of the steam receiver C, just over the inlets from the coils, so that it is immediately brought into contact with the hottest products of the boiler. This causes a precipitation of salts contained in the water, and they are carried by the downward circulation through the pipe D into the lower part of the sediment collector E, from which the sediment can be blown out, while the purified water is delivered to the distributer F from the top of the collector.

The steam which enters the receiver C from the elements is in the condition of foam, and contains a large proportion of water. It impinges against a shell of peculiar form inside the receiver C, and, being driven around this shell, and again deflected by a shelf projecting into the shell, the steam eventually finds its way into a collecting pipe through which it is drawn off in a dry condition even when the boiler is forced. If superheated steam is desired it is obtained by passing the steam through a coil, H, which is exposed to the hot gases.

The water passes to each coil through a nipple screwed into the top of the distributer. The upper end of the nipple is tapering and enters a bored hole in the bottom of the lowest junction box, the joint being made tight by a short thin steel ferrule around the nipple, which makes a kind of packing between the tapering nipple and the edge of the bored hole. A single bolt, passing through an ear projecting from the face of the junction box, and also through a projecting flange on the distributer, clamps the joint tightly enough to maintain it steam tight under the greatest pressures, even when the bolt is tightened by the fingers alone, and yet permits sufficient yielding to accommodate movements produced by unequal expansion of the elements. By removing this bolt, and two others at the flange joint where the upper end of the coil is united to the steam collector—all at the front of the boiler and easily accessible—the element can be drawn out forward and a new one be put in to replace it, the elements being made interchangeable in every respect.

The joints between the tubes and junction boxes are screw joints. Parallel threads are cut on the pipes, and the joints made tight by means of lock-nuts. A coupling with lock-nuts, at one end of each tube, permits the removal of any tube from an element without disturbing the other tubes.

The Belleville boiler contains very little water in proportion to its steaming capacity, and is, therefore, essentially a safety boiler; but this feature involves the inconvenience of a certain want of steadiness in maintaining the water level constant and keeping a uniform steam pressure when the boiler is left to the control of an attendant. The boiler is, however, intended to be worked under very high steam pressure—at a pressure, in fact, which greatly exceeds that at which the steam is delivered or used; the small mass of water in the boiler is, therefore, at a comparatively high temperature, and a certain store of heat is thus afforded, which is drawn upon, replenished, or increased when irregularities of steam production or delivery take place. This compensates to a certain extent for the lack of water and steam capacity.

To remove the difficulty which would be involved by a necessity for the constant attention of the fireman, the following automatic regulating devices have been provided as integral parts of the Belleville boiler: An automatic damper regulator, shown at J in Fig. 11; a feed-water regulator, B′, operated by a counterpoised solid float in the water column B; and an automatic pressure reducer, not shown.

It is natural that critics of the boilers should denounce these automatic devices, as innumerable instances of failures of other contrivances for the same purposes form a part of the experience of every engineer.

These boilers, however, have passed beyond the experimental stage, for they have been in use in France during many years and are highly praised in some quarters, particularly in some branches of the marine service of the government.

From information obtained from reliable sources it is ascertained that over 200 stationary Belleville boilers, representing 30,000 horse-power, and 330 marine boilers, corresponding to 35,000 horse-power, are in use. The greater number of the latter are used in the French navy, the regulations of which require that a boiler for that service shall be capable of operating continuously for six weeks while fed with sea water only.

The jury awarded a grand prize to the Belleville Company.

(13) *Shell boilers.*—Except in connection with portable or semi-portable engines, but few varieties of boilers were shown that had shells of considerable diameter in which the water was evaporated, a form so universally known and generally employed.

Messrs. Davy, Paxman & Co. exhibited a battery of nine locomotive boilers in the building of the electrical syndicate, of which four were employed for delivering steam to the United States section in Machinery Hall. They were provided with the Godillot grate and an automatic stoking device, but otherwise had no novel features that need to be noticed. A few other important exhibits of shell boilers are worthy of attention.

(14) *The Galloway boilers.*—W. & J. Galloway & Sons, Manchester, England, exhibited in the British section of Machinery Hall a partly finished boiler of their well-known type, with two cylindrical furnaces united and continued by a broad elliptical flue, braced by Galloway's cross tubes, which afford a great extent of exceedingly effective heating surface.

The boiler that was exhibited was left in an unfinished condition to show its internal arrangement and the features of its construction; an opportunity was thus afforded to admire the excellent workmanship, and the perfection with which the difficult flanging at the ends of the cross tubes is accomplished by the system of machinery and tools employed in their manufacture.

Experiments in England and the United States have demonstrated a very high economical efficiency for these boilers, even when the rate of evaporation is great. Their general excellence is attested by the fact that the works of the Messrs. Galloway doubtless form the largest boiler-making establishment in the world. Over 7,500 boilers of the Galloway type have been constructed in England, and 338 boilers, weighing, on an average, 11 tons each, have been turned out from the Galloway shops in a single year. The firm keeps in stock from 30 to 50 boilers ready for delivery.

The award of a grand prize by the jury proved their appreciation of the importance of the firm and the value of its productions.

The boiler is manufactured in the United States by the Edgemoor Iron Company.

(15) *Dulac's boiler with Field tubes.*—L. L. Dulac exhibited a novel boiler set in brickwork, from which steam was taken for Machinery Hall. Other boilers of the same type were shown without the setting, to exhibit their construction.

A view of this boiler is given in Fig. 13.

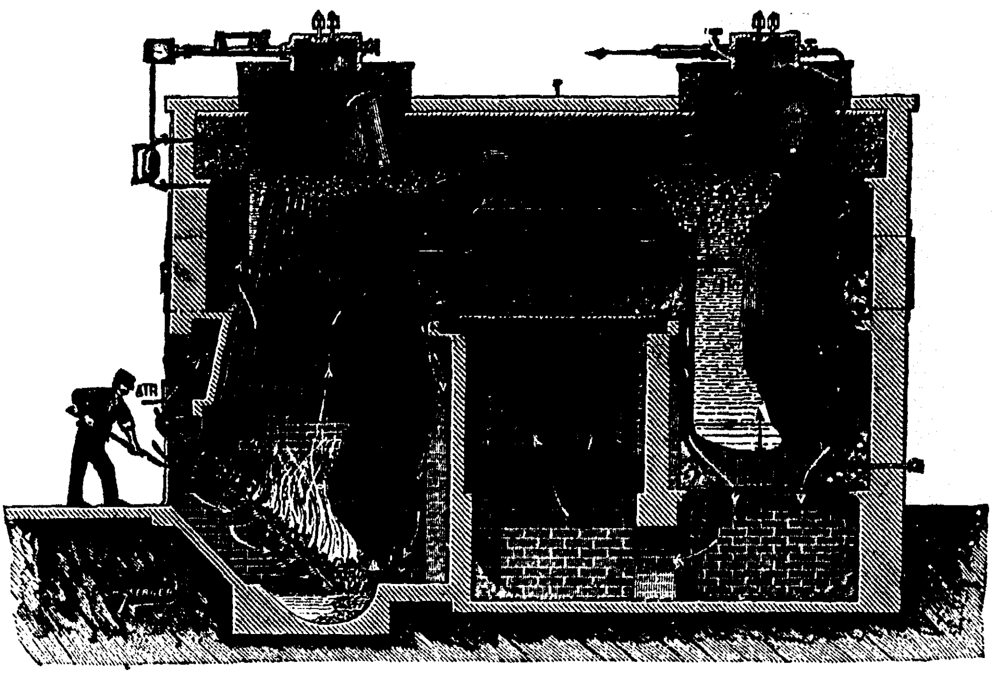


FIG. 13.—Dulac's boiler.

It consists of two vertical cylindrical shells, of unequal height, united by a horizontal barrel. The shorter vertical shell stands in the furnace, over the grate, and is provided with "Field" tubes hanging from its bottom; the higher shell, at the back of the boiler, stands behind the furnace bridge wall and forms a mud drum into the bottom of which the feed water is pumped. The water becomes heated gradually as it rises in this shell, and travels forward toward the tubes in a direction opposed to the current of the hot gases.

Each of the Field tubes is provided with a device for preventing a deposit of sediment in the tube, constructed in the following way: The inner pipe of the tube extends to a considerable height above the mouth of the outer pipe, and the upper part of the inner tube is surrounded by a can-like receiver of considerably larger diameter than the pipe, which serves as a receptacle and collector for the sediment which the circulation of the water would carry down into the tube, unless prevented in some manner.

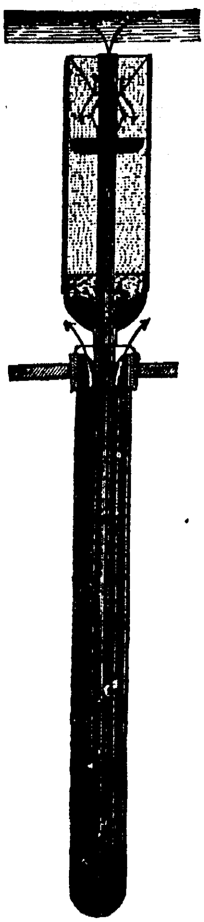


FIG. 14.—Field tube with sediment collector; Dulac's boiler.

Fig. 14 is a section of one of the tubes, showing the arrangement of the sediment collector.

The grate of this boiler was inclined at an angle of about 45 degrees, and formed in steps, the fuel being supplied at the top through a sort of lock consisting of a box of segmental shape hinged by its lower edge to the boiler front casting, and taking the place of a fire door. The box was tipped forward or outward to be filled with coal, and then tipped inward to discharge its contents on the grate, the inclination of which secured a favorable distribution of the coal. The jury's award was a gold medal.

(16) *Boiler with removable furnace.*—A type of boiler much used in parts of France where the water is hard, was set up and used in the boiler court by Messrs. Weyher & Richemond (Société Centrale Pantin), for supplying steam to the hall.

It is an internally fired, return tube boiler, constructed in such a way that the furnace, back connection, and tubes can be easily disconnected from and drawn out of the shell, in order to give free access to all these parts, and to the interior, for cleaning or repairing.

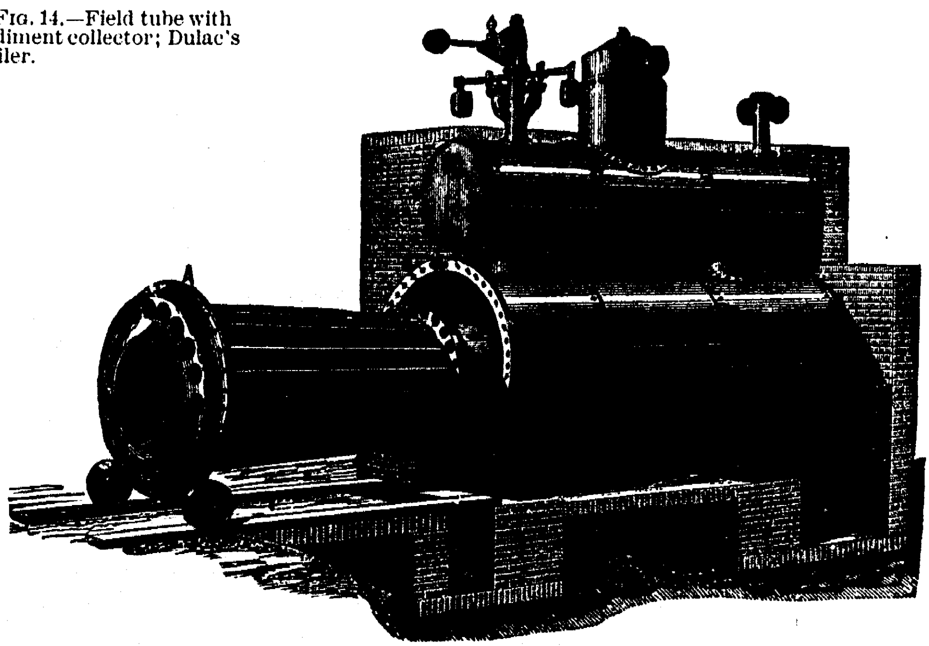


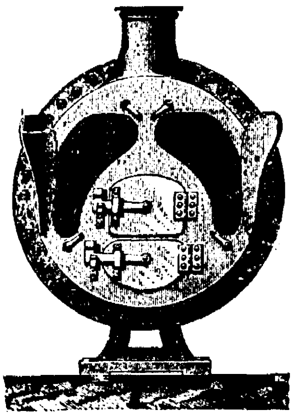
FIG. 15.—Stationary boiler with removable furnace. Weyher & Richemond, France.

Fig. 15 shows the arrangement of the particular boiler referred to, with the furnace drawn out, and without the smoke breeching, while

Figs. 16 and 17 show, respectively, a front view and a section of another boiler having similar features, in which all the parts are shown in place.

The furnace, the return tubes which surround it, and the back connection are all attached to a short section of the shell, which forms the extreme front end of the boiler proper, and is united to the rest of the shell by means of flanges which form a girth joint, made tight by means of a rubber gasket and bolts.

The smoke breeching containing the furnace doors is bolted to the front of the boiler, and the gases from the tubes pass through it to a smoke pipe, as in Fig. 17, or else are delivered by the breeching to a flue beneath the boiler, as would be the case in the boiler set in brickwork, which is shown by Fig. 15.



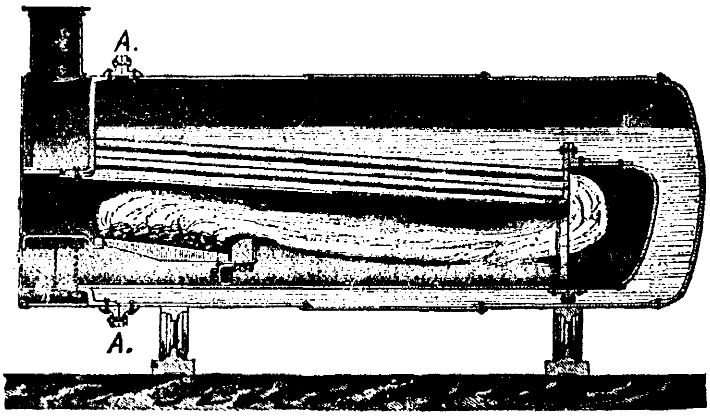


FIG. 16.—Front view. FIG. 17.—Section.
Semi-portable boiler with removable furnace.

This kind of boiler was shown by several different exhibitors in the French section, and is very often used with semi-portable engines; a brief statement of the performance of one of them is given in this report in connection with the description of Weyher & Richmond's semi-portable compound engine.

(17) *Serpolet's instantaneous steam generator.*—This is a novel kind of boiler which was exhibited in several forms and applications by the Society for Serpolet's System of Instantaneous Steam Generators, 27 Rue des Cloys, Paris.

The boiler, as now constructed, is intended for engines of small power, although the inventors claim that their experiments indicate a promise of the successful application of the principle to larger sizes.

An element of the boiler consists of a capillary tube formed of a thick pipe of large bore, which is flattened so that the sides of the bore nearly touch each other, a cross section of the tube showing the capillary opening as a slit, which in some of the tubes was scarcely visible, and in others about three one-hundredths of an inch wide. See Fig. 18.

The tube is variously made. In some examples it was formed wholly of steel, and bent into a flat coil (Figs. 18, 19, and 20 show this form); in others the coiled tube was of thick copper, and

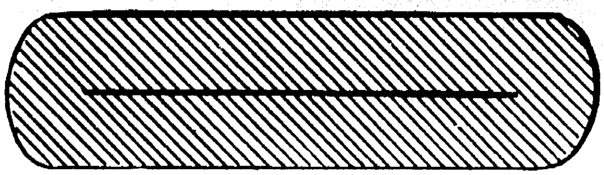


FIG. 18.—Cross section of a tubular element of Serpolet's steam generator.

in one form consisted of a thin, flattened steel tube inclosed in a mass of cast iron which was formed around the coiled tube by casting.

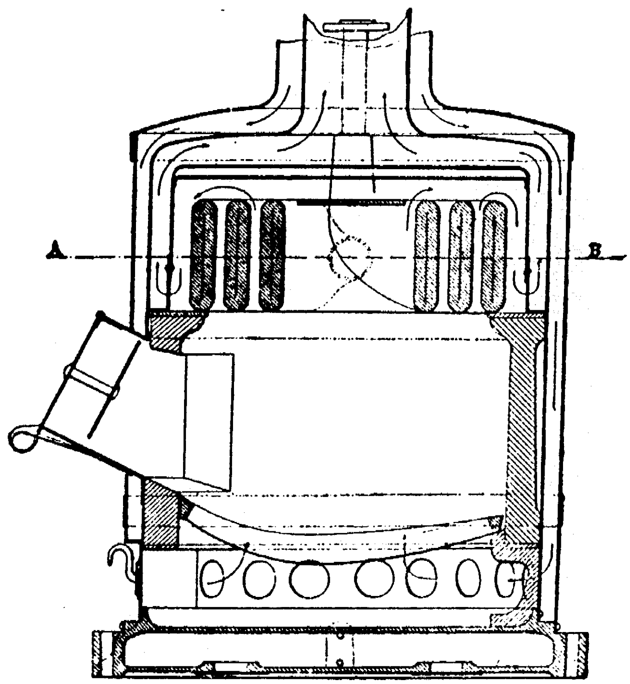


FIG. 19.—Vertical section of Serpolet's steam generator.

The length of the tube of a single element was $6\frac{1}{2}$ to $7\frac{1}{2}$ feet, the width of the capillary slit $1\frac{1}{2}$ to $2\frac{1}{4}$ inches, and the evaporating surface 1.6 to $2\frac{3}{4}$ square feet.

One or more of these elements are placed in a stove, where they are highly heated. Figs. 19 and 20 show a boiler consisting of a single element, and Fig. 21 one in which three elements are placed one above another and coupled together.

When water is forced into one end of the capillary tube, steam instantly issues from the other end, the appearance of steam occurring almost simultaneously with the injection of water, and ceasing as soon as the supply of water stops; facts which, it is claimed by the inventors, indicate that the water does not assume the "spheroidal" condition when in contact with the highly heated surfaces of the tube.

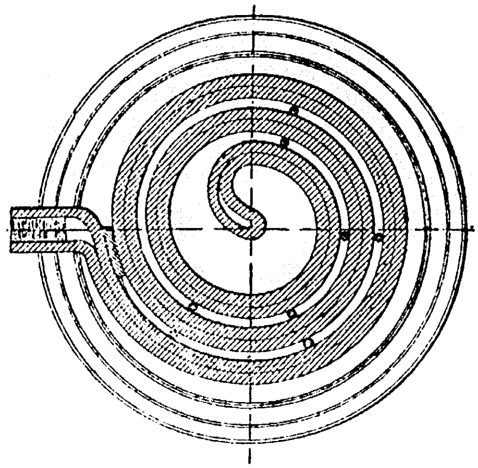


FIG. 20.—Cross section at A B in Fig. 19.

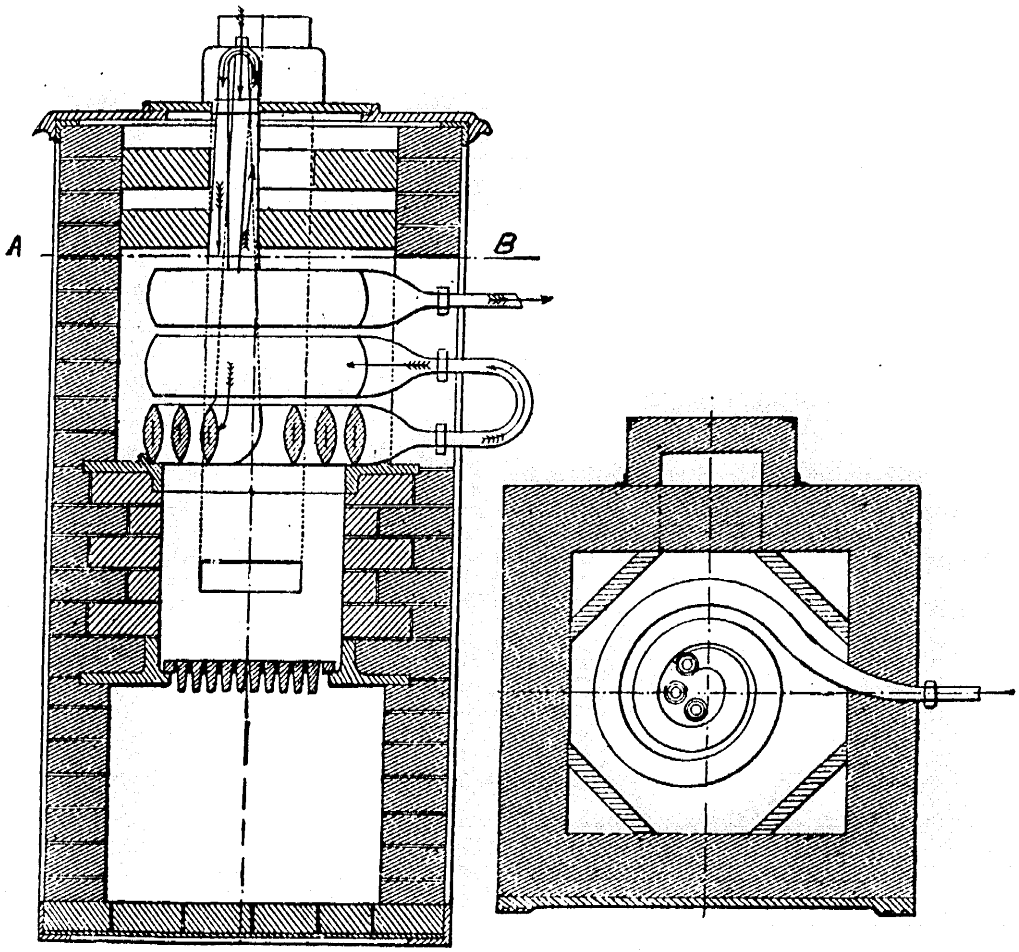


FIG. 21.—Serpolet steam generator with three elements.

The boiler has no steam receiver, contains almost no water, has no safety valve nor steam gauge, and there is no stop valve nor throttle valve between the boiler and engine, the supply of steam to the engine being regulated entirely by the quantity of water pumped into the boiler. A few strokes of a small hand pump serve to start the production of steam necessary for getting the engine in motion, after which water, in quantity sufficient to maintain steam of the required pressure, is injected continuously by a feed pump driven by the engine. The action of this feed pump was, in most of the exhibits, regulated by a centrifugal governor, connected with the pump in such a manner as to regulate the length of the stroke of the pump plunger in accordance with the demand for steam.

A single tubular element of the smallest size is used for an engine of 1 horse-power, one of the larger elements for 1½ horse-power, and several elements are united for engines of greater power. The weight of a small element of thick steel pipe is about 70 pounds, and that of one of the cast-iron elements, described above, nearly 165 pounds. The heat stored in this mass of metal secures a certain regularity in the production of steam under varying conditions.

The Serpolet Company had a special building for the display of their boiler, containing a number of examples, and they also exhibited a steam launch on the Seine, in which was a boiler of three steel elements, whose evaporating surface was 4.8 square feet, external tube surface 11 square feet, and weight 515 pounds. The boat was 33 feet long by 4½ feet beam, and a speed of 9 miles per hour could be maintained.

A steam tricycle for two persons was also shown in operation.

(18) A test of one of the boilers was made at my request, and in accordance with my directions, by Mr. Carl Hering. The data, conditions, and results of this test were as follows:

The boiler was of a size which is built and sold for 1 horse-power, and embodied a single element made of a thin steel capillary pipe, coiled and inclosed in a perforated cast-iron disk having corrugated edges.

The dimensions of the boiler, and areas of the surfaces were:

Diameter of the cast-iron element	inches	17.00
Depth of the cast-iron element	do	3.94
Length of the inclosed capillary tube	feet	7.54
Thickness of the walls of this tube	inches	0.08
Height of the capillary opening	do	2.24
Width of the opening	do	0.035
Weight of the whole element	pounds	164.00
Height of the boiler	inches	35.00
Diameter of the boiler outside	do	24.00
Diameter of the grate	do	16.14
Area of grate surface	square feet	1.41
Area of the surface of the inside of the tube (evaporating surface)	do	2.80
Area of the outside surface of the cast-iron element (surface exposed to the flame and hot gases)	square feet	6.90

The steam was used in a small and uneconomical engine which was employed to run a dynamo, and the power delivered at the belt was ascertained by electrical measurements, very carefully and skillfully made by Mr. Hering; but it is not necessary to give the results of this part of the trial in dealing with questions relating to the boiler; it is enough to say that the power was in excess of the nominal horse-power.

A pressure gauge was applied to the feed pipe as well as to the steam pipe, so that the pressure required to force the water into the capillary pipe could be observed.

A fresh fire was started about an hour after a previous fire had been drawn from the furnace, and the tubulous element was so far cooled by pumping water into it, that steam ceased to issue from the outlet and water appeared instead. The test was commenced about half an hour (28 minutes) after the new fire was started, and was continued during 4½ hours, with occasional interruptions.

Total running time, 3 hours 57 minutes.

Data and results.

[Mean of the observations.]

Temperatures:		
Feed water	deg. F	43.7
Exhaust steam	do	275.0
Chimney gases	do	700.0
Pressures:		
In steam pipe	pounds per square inch	112.2
In feed pipe	do	130.0
Fuel:		
Coal fed to furnace	pounds	52.8
Wood for kindling	do	6.6
Coal equivalent to this wood, say	do	2.2
Ashes remaining after test	do	11.6
Combustible consumed, total	do	43.5
Per hour of running time:		
Total	do	11.0
Per square feet of grate	do	7.8
Per square feet of evaporating surface	do	3.9
Water evaporated:		
Total	do	236.0
Per hour:		
Total	do	59.7
Per square feet of evaporating surface	do	21.3
Per pound of fuel	do	4.29
Per pound of combustible	do	5.42
Equivalent evaporation from and at 212° F. per pound of combustible, neglecting the superheat of the steam	pounds	6.59

The steam was superheated to such a degree that paper touched to the steam pipe became charred in a few seconds.

It is not known whether the capillary elements can be made durable, or whether in continued use they will remain unobstructed by sediment.

A bronze medal was awarded by the jury.

III.—STEAM ENGINES.

(19) A collection of engines, representing a capacity of more than 10,000 horse-power, were grouped in the space devoted exclusively to Class 52. These were in the French section alone; other steam engines were shown in the Belgian, British, Swiss, and United States sections, and, besides all these, the thirty-two large isolated engines employed in driving the lines of shafting were included in the exhibits assigned to Class 52. Outside of this class were also a number of portable engines adapted for agricultural work, and a very few marine engines of small size, the absence of marine engines being a rather remarkable feature of the display in steam engineering.

The agricultural engines were in Class 49, and the marine engines found their place in Class 65.

(20) A large proportion of the stationary engines were of the compound type, of which the greater number were coupled engines with cylinders of unequal diameters. Compound semi-portable and portable engines were also shown; in fact a number of these were of considerable size and adapted for working with a high degree of economy.

The following table shows the number and collective power of the engines and the number that were compound. This table includes the thirty-two isolated engines, the capacities of which are given separately in the table of engines which will be found in the general notice of the sixth group.

(21) TABLE.—*Compound and noncompound steam engines; not including agricultural engines.*

Description of engines.	France.		Switzerland.		Belgium.		Great Britain.		United States.		Alsace.		Total.	
	No. of engines.	Horse-power.	No. of engines.	Horse-power.	No. of engines.	Horse-power.	No. of engines.	Horse-power.	No. of engines.	Horse-power.	No. of engines.	Horse-power.	No. of engines.	Aggregate horse-power.
20 horse-power or over:														
Compound	50	6,050	13	1,400	3	750	4	850	....	......	....	.....	70	9,050
Noncompound	46	5,200	2	60	7	410	3	260	4	320	4	400	66	6,650
Less than 10 horse-power, of all types	39	350	2	10	3	20	5	10	1	10	...	......	50	400
Total	135	11,600	17	1,470	13	1,180	12	1,120	5	330	4	400	186	16,100

Nearly all the engines, except the portable engines, were fitted with condensers and air pumps; condensation being more generally employed in Europe than in the United States, and used for engines of even very moderate power, for preventing the discharge of steam into the air, if not for obtaining an effective vacuum.

Steam jackets are almost universally applied to all cylinders, of either compound or noncompound engines.

(22) The influence that the practice in steam engineering in the United States has had upon European practice has already been referred to in the quotation from Professor Dwelshauvers, in the general review of this group; it was certainly marked. The very general introduction of the Corliss cut-off and of the Corliss type of engine in various forms, was a noticeable feature of the display; the Porter governor was almost universally adopted, and was applied in one form or another to nearly every engine having a governor detached from the main shaft; and many of the high speed engines with shaft governors embodied features originally introduced in the Porter-Allen engines.

(23) The design and workmanship of the great number of engines exhibited were with very few exceptions excellent. But few novelties were, however, noticed; even in details, familiar forms, perhaps as good as any we may expect to reach, are perpetuated.

A few monstrosities were seen, but on the whole fewer than have hitherto appeared in similar great collections.

A very few rotary piston engines show that a charm still attaches to this form, and a remarkable steam turbine, Parsons's, gives promise of a possible simple solution of the problem of a direct application of steam to the production of rotary motion with satisfactorily economical results.

In the following pages a few only of the engines that were exhibited are described.

(24) *Weyher & Richemond's engines.*—Messrs. Weyher & Richemond (Société Centrale), of Pantin, near Paris, made an extensive exhibition of excellent and interesting compound engines, many of which were in operation.

The first to be noticed are their vertical triple-expansion engines, one of which was employed to give motion to the machinery of Class 50. Fig. 22 shows a general view of an engine of this kind; Fig. 23, a vertical section through all the cylinders, in a plane, X X, passing through the axis of the shaft; Fig. 24, a section, in a horizontal plane, Z Z, through the high-pressure and medium-pressure cylinders; Fig. 25, a vertical section through the medium-pressure cylinder and one of the low-pressure cylinders, in a plane, Y Y, transverse to the shaft.

The frame is of the form usually employed for marine engines, and the machine is composed of two tandem engines standing side by side, with cranks set 90° apart. The lower cylinders are both low pressure. The high-pressure cylinder is placed directly over one of these, and the medium-pressure cylinder over the other; an arrangement not unusual in marine engines.

Steam from the boiler enters the jacket of the high-pressure cylinder, and from there passes through a butterfly throttle valve *a*, stop valve *b*, and piston valve *c*, to the high pressure cylinder I. The exhaust steam from I is distributed by the piston valve *d* to the intermediate cylinder II, and, after further expansion in that cylinder

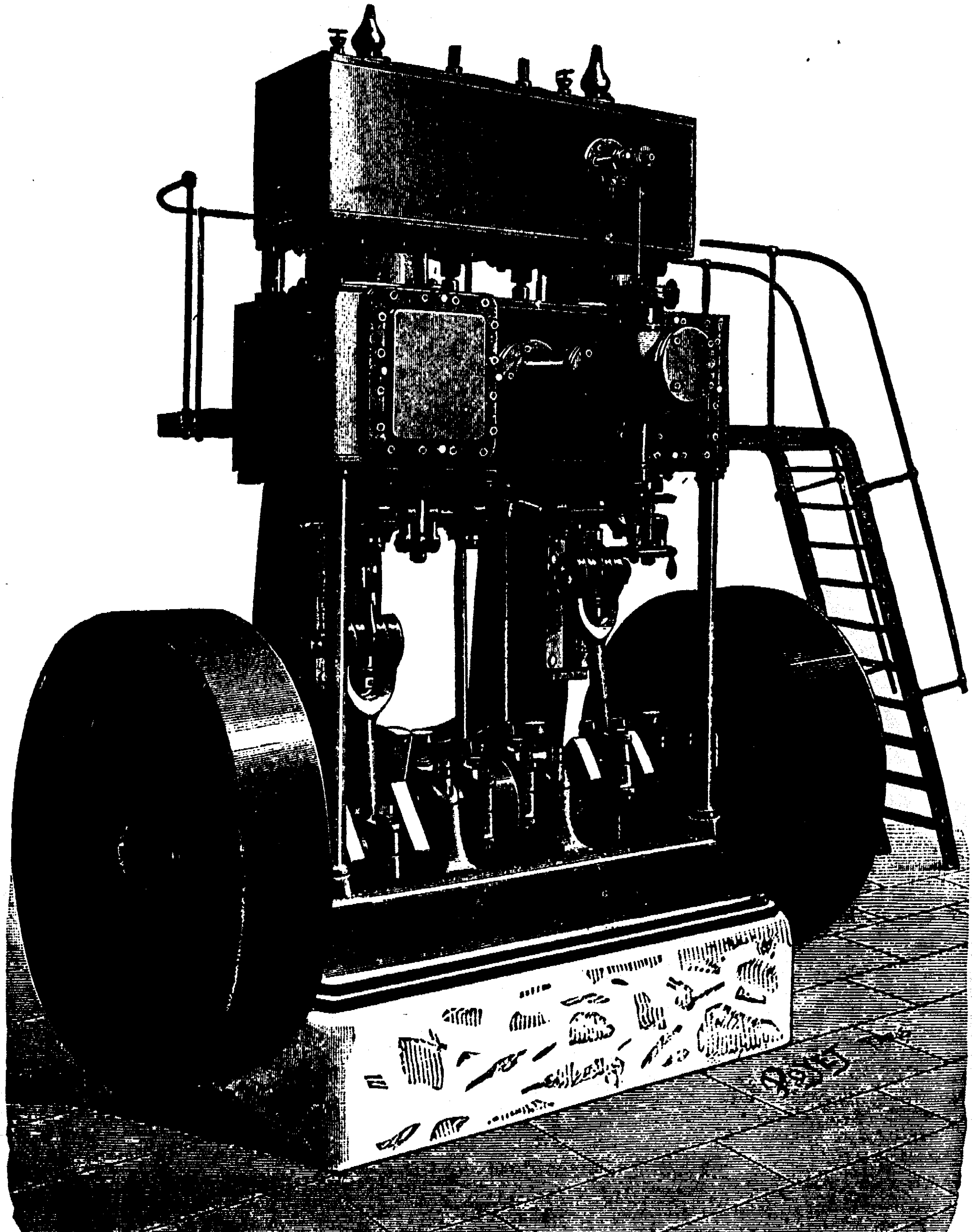


FIG. 22.—Triple-expansion vertical engine by Weyher & Richemond, France.

is exhausted through pipes into the steam chests of the two low pressure cylinders III, in both of which cylinders the steam acts by yet further expansion, and then escapes to the condenser. All the cylinders are jacketed, and each jacket first receives the steam with

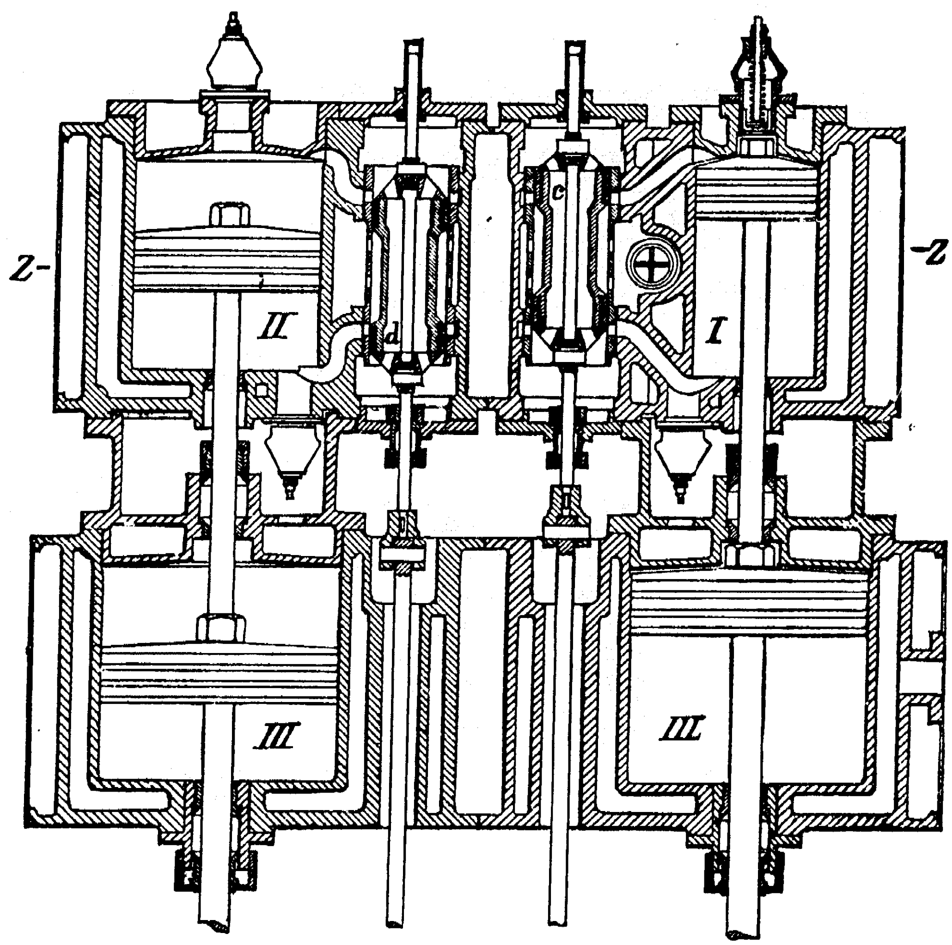


FIG. 23.— Vertical section at X X, Fig 24.

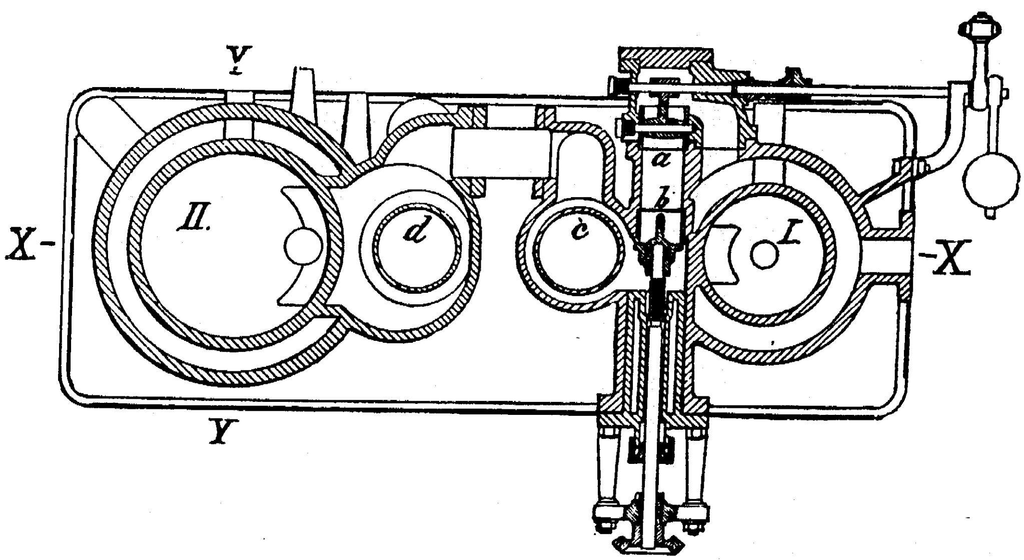


FIG. 24.—Horizontal section at Z Z, Fig. 23. Weyher & Richemond's triple-expansion vertical engine.

which the cylinder to which that jacket belongs is supplied; that is, the jacket of I contains steam taken from the boiler direct, while the jackets of II and III are filled with exhaust steam from I and II, respectively. The stroke of the pistons is 18 inches, and the diameters of cylinders I, II, and III are 15.3, 22.8, and 28.3 inches, respectively. The steam is cut off invariably at about half stroke in

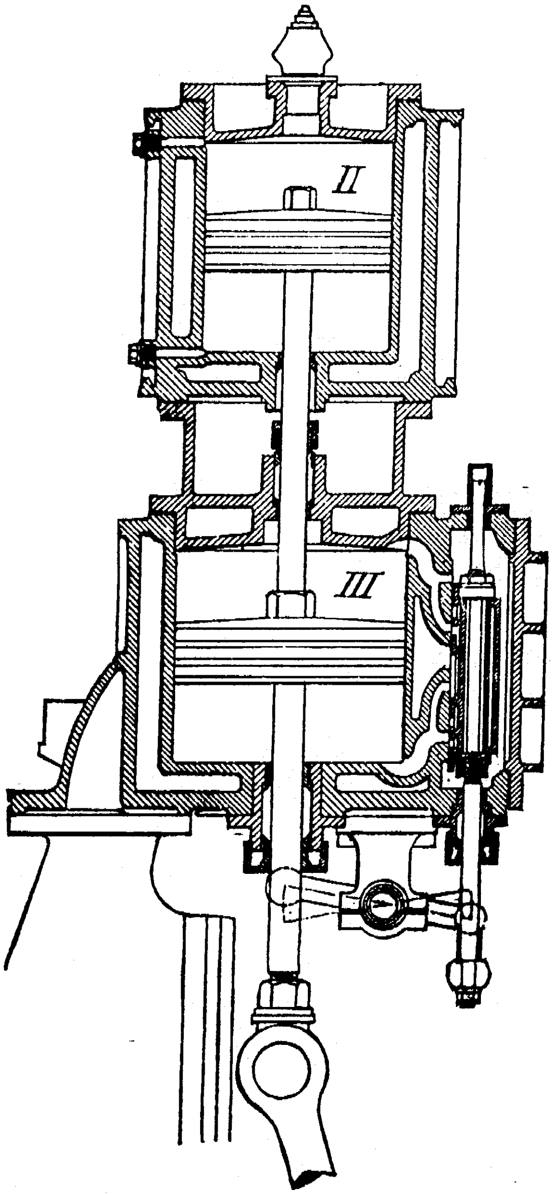


FIG. 25.—Weyher & Richemond's triple-expansion engine. Vertical section at Y Y, Fig. 24.

the high-pressure cylinder, and the total ratio of its expansion is therefore nearly 12. The engine is intended to use steam at 150 pounds pressure, and to run at a speed of 130 revolutions per minute, under which conditions the steam consumption is said to be about 15½ pounds per effective horse-power per hour.

Piston valves are employed for the upper cylinders, and a double-ported slide valve for each of the lower cylinders. All four valves are driven by two eccentrics, through two rock shafts, one for each component engine, arranged so that the weight of the piston valve balances that of the slide valve.

The governor is attached to the shaft, and regulates the speed by means of the throttle valve *a* (Fig. 24). It does not communicate motion directly to the valve, but acts through an intermediate device, of old design, consisting of a screw which may receive either right-hand or left-hand rotation, from a pair of clutches revolved in opposite directions by bevel gears which are driven from the engine shaft. The governor causes the engagement of the screw with one or the other of the clutches when the speed of the engine becomes less or greater than the nominal speed, and thus occasions the movements of the screw by which the throttle is opened or closed as required. It is claimed that the variation of speed does not exceed one-half of 1 per cent.

An independent jet condenser and a double acting vertical air pump, worked by a small beam engine attached to the condenser, are used to obtain the vacuum.

Four engines of this type, of 150 horse-power each, were employed in the central electrical station for driving the large Edison dynamos. They were in constant operation during the whole term of the Exposition, and were very remarkable for smoothness and regularity of running.

(25) This company also showed several horizontal engines, compound, and single cylinder; also a number of portable engines and several double cylinder semi-portable engines. The last mentioned are worthy of notice because of the careful trials to which in 1879 an engine of this type was subjected in deciding the award of a prize offered by the Société Industrielle de Mulhouse, for the first engine of new type which should be put at work in Upper Alsace and realize a steam consumption not exceeding 20 pounds per horse-power per hour; the power being measured by a friction brake on the fly-wheel shaft, after the engine had been regularly at work during at least one year.

The trial was made by Messrs. Meunier, Keller, Grosseteste, and other eminent engineers and scientists, with the care and precision for which experiments conducted under the auspices of the Mulhouse Society are noted. The trial forms the subject of an exhaustive published report, and demonstrates the following results:

Weight of steam, coal, and combustible consumed per hour.

	Steam.	Coal.	Combustible.
	Pounds.	*Pounds.*	*Pounds.*
Per indicated horse-power	16.3	2.45	2.02
Per brake horse-power	18.8	2.83	2.33

These figures represent the average results of three trials of about 3½ hours' duration. The steam consumed could be accurately ascertained, by the methods employed, from trials of even shorter duration than these, but confirmatory trials lasting 12 hours were afterward made. The consumption of fuel was also ascertained with sufficient accuracy to determine what the economical efficiency of the engine and boiler together was. The conditions of running were the same as in the everyday working of the apparatus.

The following data are selected from the report:

Boiler pressure, 95 pounds; vacuum, 26 inches; diameters of high-pressure and low-pressure cylinders, 11.2 inches and 18 inches, respectively; stroke, 19 inches; speed, 88 revolutions per minute; indicated horse-power, 79; brake horse-power 68½; ratio of expansion, about 8½.

The steam from the boiler passed around the jacket of the high-pressure cylinder before entering its steam chest. The exhaust steam from this cylinder passed over the high-pressure jacket and then over the upper part of the low-pressure cylinder into the steam chest of that cylinder. The lower part of the low-pressure cylinder was jacketed by steam from the boiler direct. The waste room in the high-pressure and low-pressure cylinders was 6.4 per cent. and 5 per cent. of the piston displacement, respectively.

Fig. 26 shows a side elevation of this engine mounted on its boiler. The condenser, and the air pump and feed pump stand at the side of the boiler, the pumps being worked from the crosshead of the engine by means of a three-armed lever. They are shown in the foreground of the engraving.

The boiler has a furnace with return tubes surrounding it, all removable from the shell. The smoke breeching, shown at the right-hand end of the boiler, surrounds the mouth of the furnace and leads the hot gases from the tubes to an underground flue, but can be arranged for use with an upright smoke pipe. This type of boiler has been described elsewhere in this report.

The arrangement of the whole apparatus is a good one for places where the water for condensation can be obtained, and is a type of semi-portable engine which is extensively used in France. Its economical performance is excellent for an engine of comparatively small power, and the first cost to the users is moderate, because expensive foundations and settings are unnecessary.

Messrs. Weyher & Richemond exhibited also Parsons's steam turbines, which are described on page 126.

As the administrator of the company was a juror, their exhibit could not be put in competition for an award.

(26) *Farcot's engines.*—One of the largest exhibits of steam engines was by Joseph Farcot, of Rouen.

His single cylinder horizontal Corliss engine, of 1,200 horse-power, was the largest engine in the Exposition. It covered an extensive floor space and presented a comanding appearance, but did not compare favorably with the large beam engine exhibited by Corliss in the Centennial Exposition of 1876.

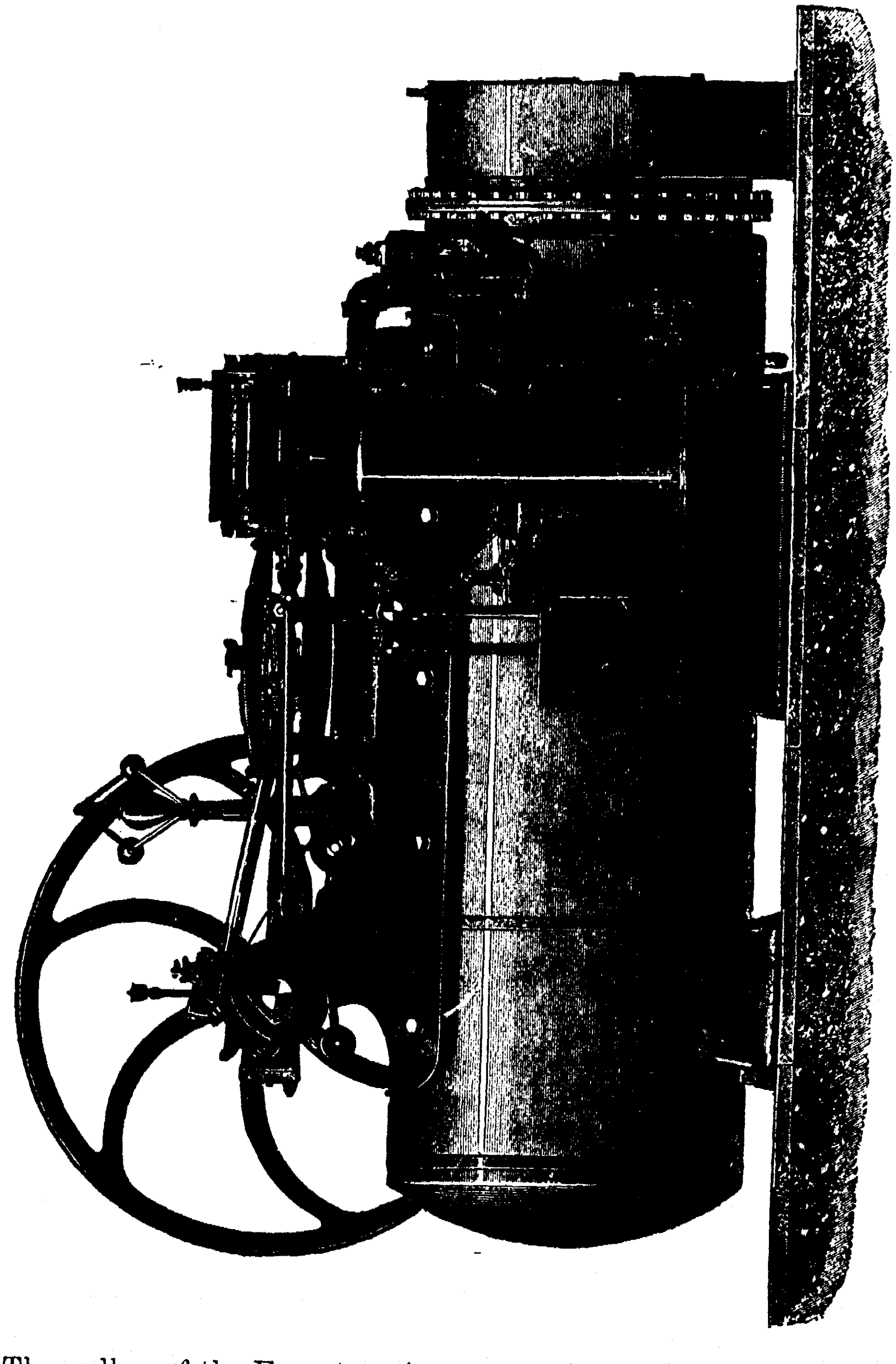


FIG. 26.—Weyher & Richemond's compound condensing semi-portable steam engine.

The pulley of the Farcot engine was 32 feet 10 inches in diameter, with a face about 5 feet broad, and a rim weighing 21 tons. The rim was cast in a single piece and afterward separated into four parts. The wheel had two sets of riveted plate-iron arms of elliptical cross section.

The noticeable feature of this engine is the location of the valves, all four of which are placed in the cylinder heads in such a manner that the waste room filled by steam is very small. The arrangement of valves in the vertical cylinder of the beam engine shown by Corliss in 1876 was the same as this.

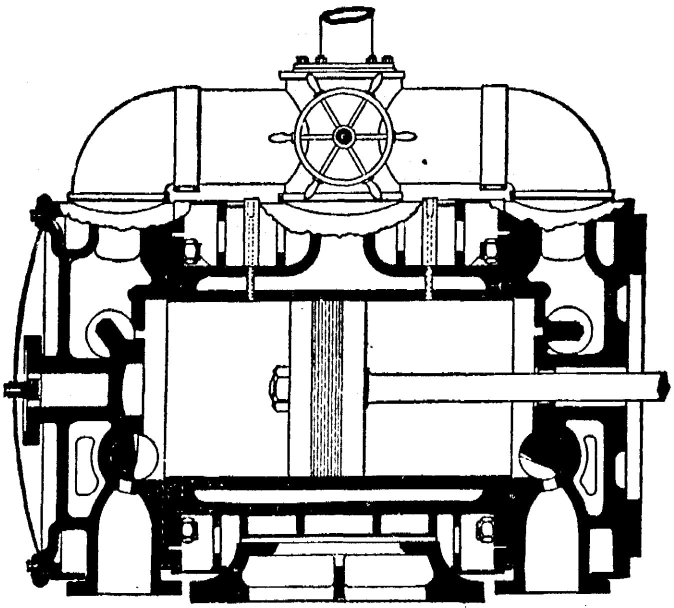


FIG. 27.—Farcot's Corliss engine. Vertical section of cylinder.

Fig. 27 shows a longitudinal vertical section of the cylinder of the Farcot horizontal engine.

It will be seen that the large steam pipe located over the cylinder is branched so as to lead to each cylinder head, and also supplies steam to the steam jacket by a direct connection in line with the main vertical pipe, so that the jacket, which is of liberal dimensions, receives the steam in such a way as to maintain a good circulation.

A smaller Corliss engine, of 200 horse-power, stood by the side of the large engine.

The valve gear of the Farcot engines is a modified type of the Corliss gear, and is so arranged that the admission of steam is regulated by the governor up to about three-fourths of the piston's stroke, instead of only to about three-eighths of the stroke, as in the older forms of the Corliss gear. Farcot's arrangement is, however, more complicated than other devices that were shown for effecting the same result, and will not be described here.

(27) Farcot also exhibited three vertical engines:

I. A high speed compound engine of 100 horse-power.

II. A compound engine of 200 horse-power, with a radial valve gear, in which the force of the governor to regulate the point of cut-off is not applied directly, but through an intermediate apparatus consisting of a steam actuated piston the movements of which are controlled by a hydraulic cylinder forming a kind of cataract. This regulating apparatus is so constructed as to give a definite position to the valve gear for every different position of the governor sleeve. It was invented many years since by Joseph Farcot, and is called the "servo-moteur." A similar arrangement, adjusted by hand, has long been in use in connection with nearly all large marine engines as a means of moving the link to vary the cut-off and reverse the engine, and it is unnecessary to describe it here.

III. The third engine shown by Farcot in his space in Machinery Hall was a triple expansion vertical marine engine of 400 horse-power, and was the only marine engine of any considerable size shown in the Exposition. This engine had three cranks set 120 degrees apart. The three cylinders were side by side in the usual way.

A radial valve gear was used, and this was adjusted, or the engine reversed, by a hydraulic servo-moteur so arranged that the engine could be controlled from a distance, as, for example, from the bridge or pilot house of a steamer.

J. Farcot was a member of the jury, and therefore not a competitor for an award.

(28) *Brasseur's compound engines.*—Victor Brasseur, of Lille, France, to whom a grand prize was awarded, is a licensee of Corliss, and also of Jerome Wheelock.

He builds engines of the Corliss type of 1884, also the Wheelock engine with turning valves. (He has not adopted Wheelock's new application of flat sliding valves.)

The valve spindles are self-packing and separate from the valves, to the ends of which they are coupled or clutched.

A large compound engine and a noncompound single cylinder engine of each of the above types were exhibited in operation.

The compound engines were composed of two horizontal engines acting on a common shaft. A reheating receiver was used between the high and low pressure cylinders. The steam jackets of all the cylinders were independent of the steam chests, and heated by steam at boiler pressure. The ratio of the capacity of low-pressure cylinder to high-pressure was 2½ to 1 in each case.

The firm has built about four hundred engines of the two types since 1880, and eighteen orders were taken within the first six weeks of the Exposition.

(29) *Lecouteux & Garnier's Corliss cut-off gear.*—This is the Corliss gear of 1868, to which an improvement is applied which permits the governor to vary the point of cut-off from the beginning of the stroke up to within three-tenths of the end; a much greater range of automatic action than it is possible to have with the older forms of the Corliss gear.

In the original and usual forms of the Corliss motion the eccentric requires to be set more than 90 degrees in advance of the crank, an arrangement which compels the eccentric rod and the parts which receive motion from it to complete their movements in the direction of opening the valve, and begin their movements in the contrary direction, before the crank reaches a vertical position, and before the piston performs half its stroke. Ordinarily, it is the movement of the valve rods in the direction of opening only which occasions the release and closure of the admission valve, by bringing the trip gear into contact with the stop which the governor controls: if, therefore, in any stroke of the engine the governor falls so low that the release does not occur before the return movement of the valve rod begins, the valve does not become detached at all in that stroke of the piston, and the admission of steam continues to the end; the range of variation of the point of cut-off which is within the control of the governor does not therefore extend quite up to half the stroke, and usually falls considerably short of that extent.

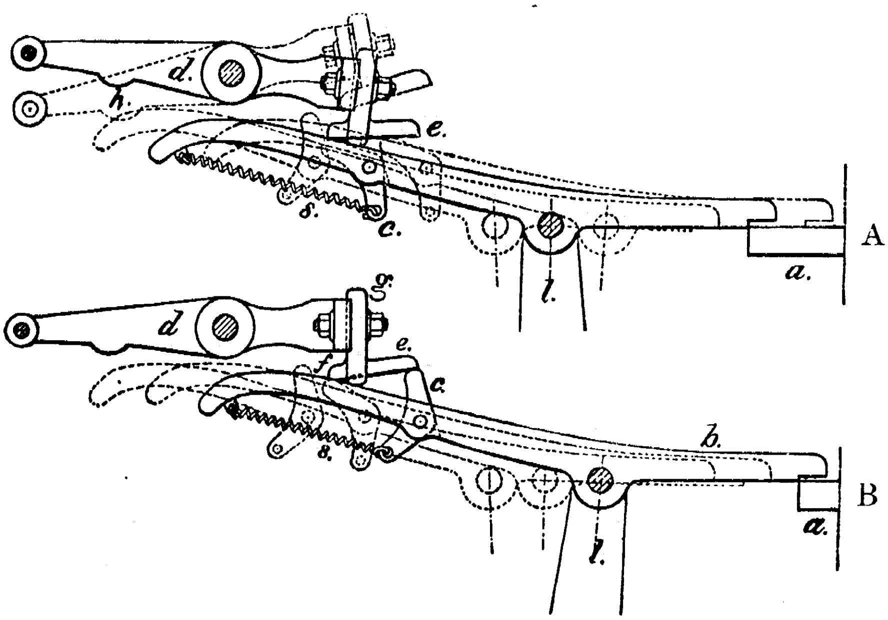


FIG. 28.—Lecouteux & Garnier's Corliss valve gear, with device for prolonging the admission beyond half s'roke.

Fig. 28, A and B, show the device employed on the Lecouteux & Garnier engine.

a is one of the two rods which are connected with the steam valves; *b* is one of the opening and releasing latches, the fulcrum of which is carried at the end of the vertical spring lever *l*, whose spring is not shown, and *d* is the tappet lever actuated by the governor.

All these parts are substantially the same as the corresponding parts of the Corliss gear of 1868, modified only as follows:

The tappet plate, *g*, of the governor lever *d*, is provided near its lower end with a narrow inclined prong whose point is at *e*, and heel at *f*. The tail of the latch *b* is forked, and in the fork a tongue, *c*, is hung, which tends to stand erect, being held upright against the bottom of the slot in the fork by the action of the spiral spring *s*; but the tongue may be folded forward and downward into the slot, as shown in the figure, by dotted lines, for several positions of the latch. The direction of the movement of the latch in the act of opening the valve is from left to right in the figure.

If the tappet plate *g* is depressed so far by the governor that the latch is detached in its forward movement, as in A, then the disengagement is caused in the usual way, by the plate *g* acting on the tail of the latch *b*, as shown, the tongue *c* being folded down into the slot by the heel *f* of the tappet, which strikes it from behind. But if the tappet is raised so high that the plate *g* fails to trip the latch in its forward movement, it then stands so high that the tongue *c* can spring up beneath the tappet into its erect position, sometime in the forward movement of the latch, or else just when this movement is completed, and the parts are then in such relation that, when the return movement of the latch occurs, the latch is tripped by the ac-

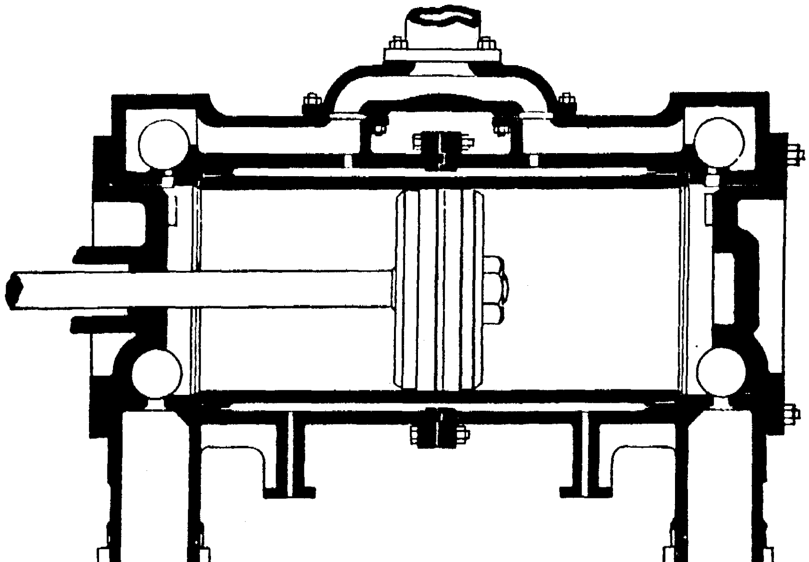


FIG. 29.—Steam jacketed cylinder of the Lecouteux & Garnier engine.

tion of the inclined prong *e f* on the point of the tongue *c*, which, as it is now acted on from in front, will not be folded downward by the contact of the prong, as shown in B. The higher the tappet stands, the later will the tripping take place. In A it occurs at the middle of the forward, or opening movement; in B at the beginning of the return movement, and may occur even later than this, when the tappet is raised higher.

A safety device is provided for stopping the engine when the governor falls too low, as from the breaking of the governor belt or other cause. It consists simply in forming a lug, *h*, on the tail of the lever *d*, in such a position that, when this lug is depressed below the point corresponding to the longest period of steam admission, the lug strikes the end of the tail of the latch just before the termination of its return movement, and, by thus holding the point of the latch up, prevents its engagement with the rod *a*, and consequently prevents the opening of the steam valve.

(30) Fig. 29 shows the construction of the cylinder of Lecouteux & Garnier's engine. The outer shell, containing the valve chests, is made in two parts, bolted together in the middle of the length of the cylinder, where a girth joint is thus formed. The space between this outer shell and the liner forms the steam jacket.

Messrs. Lecouteux & Garnier received a gold medal.

(31) *Bonjour's engine.*—The "Compagnie des Fonderies et Forges de l'Horme" displayed a number of single cylinder and compound engines to which Bonjour's valve systems were applied. There are two types of valve motions called Bonjour's, both of which are automatic and applied to driving two valves: a main slide valve, and a piston-shaped cut-off valve on the back of this slide.

It is not necessary to give a description in detail of the valve mo-

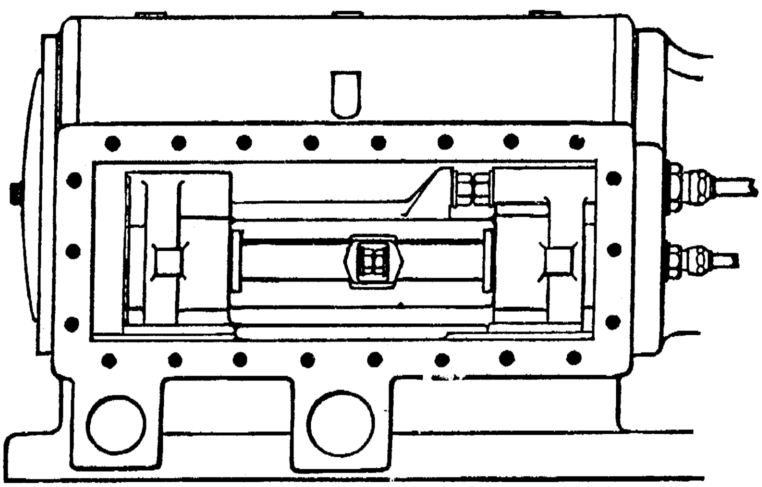


FIG. 30.—Side view of cylinder of Bonjour's engine, showing interior of steam chest.

tions themselves, but an unusual arrangement of the main valve and its seats in the steam chest was exhibited, which deserves notice.

A side view of the cylinder, with the steam chest cover removed, is given in Fig. 30, and a cross section of cylinder, steam chest, and valves, in Fig. 31.

There are two seats in the steam chest, at each end; one on the bottom of the chest, having in it a port leading to the exhaust chest beneath; another on the cylinder wall, perforated by the cylinder port and inclined at an acute angle with the chest bottom. The valve also has two working faces at each end, one of which rests on the bottom of the chest, while the other finds its bearing on the inclined seat. The valve is therefore wedged into the angle between the seats by the action of whatever unbalanced pressure the steam in the chest exerts on its back.

There is a steam port in each end of the main slide which is closed by a piston valve, the cut-off valve, which works in a small cylinder contained in the slide; there are also ports, and a cavity, in the slide, at each end of the cylinder, by which communication is opened at the proper times between the cylinder port and the port in the chest bottom through which the exhaust escapes.

This arrangement of a supplementary seat for the exhaust outlet, permits the main valve face to lie close to the bore and reduces the waste room in the ports.

In the engine illustrated by the Figs. 30 and 31 the main valve and cut-off valve are both operated with positive movements, derived from a peculiar kind of radial valve gear having a single eccentric

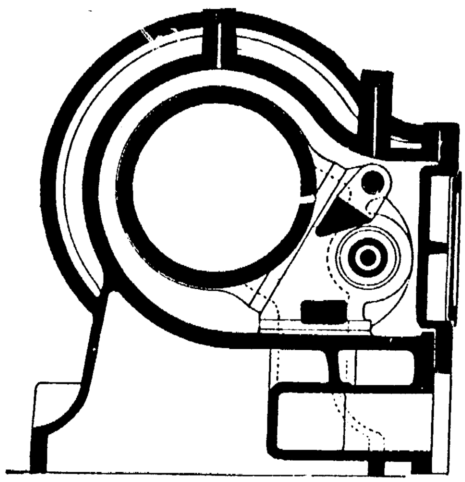


Fig. 31.—Cross section.

whose strap has two points of attachment at which the separate rods from the two valves are jointed to it. At another point the strap is pivoted to a pendulum bar, the point of suspension of which is movable by the governor.

In the other type of cut-off motion with which some of the Bonjour engines are furnished, the main valve is worked by a single eccentric made fast on the engine shaft, and the cut-off valve is thrown periodically by steam, by means of a small steam piston working in a cylinder whose valve is operated by simple mechanism controlled by the governor; an arrangement which is by no means new.*

(32) *Fricart's releasing valve gear.*—The "Société Alsacienne de constructions mécaniques," of Belfort, France, and Mulhouse, Alsace, received a grand prize for their exhibit, which included an excellent

*An automatic steam actuated cut-off was patented in the United States in 1866 by Babcock & Wilcox, who introduced quite extensively engines having this feature. Illustrated descriptions of their system can be found in Engineering, of January 1, 1869, and August 26, 1870.

compound engine to which the Fricart releasing valve gear, shown by Figs. 32 to 36, was applied. This is a modification of the Corliss gears of 1851 and 1879; the wrist plate, which is in the form of a rocking five-armed frame, being placed at the side of the cylinder, centrally between the four valves, which are of the Corliss type with Wheelock's self-packing stems.

The motion of the wrist plate is derived from a single eccentric, *b*, which is keyed on the main shaft of the engine nearly at right angles with the crank; an intermediate lever, *c*, being interposed between the eccentric and the wrist plate near the place where the governor stands. (See Fig. 32.)

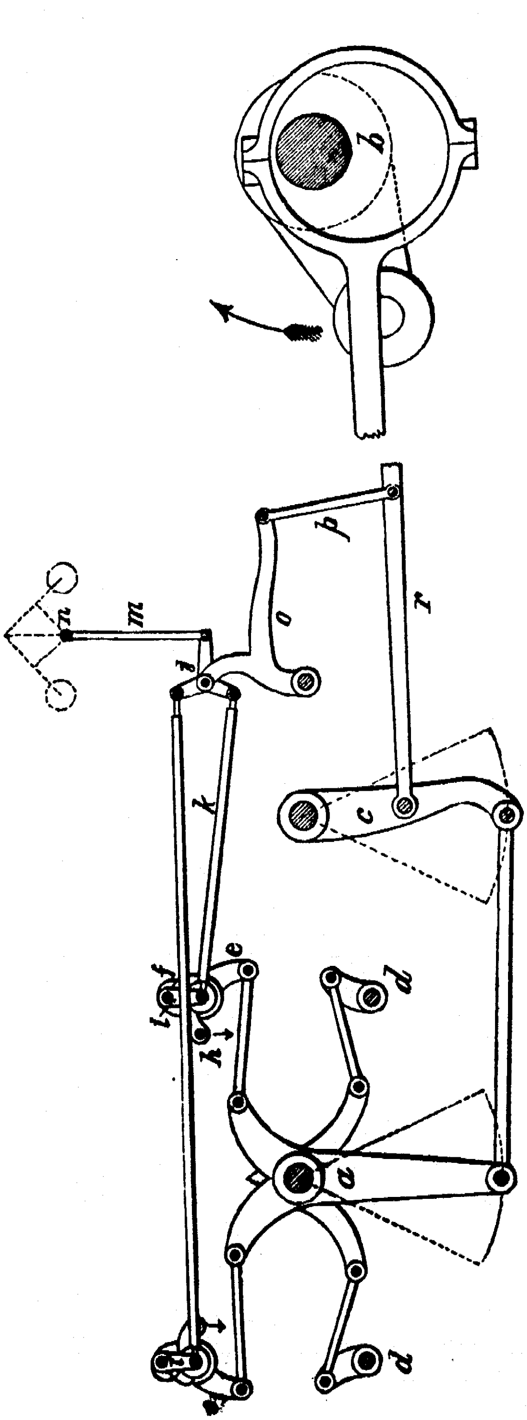


Fig. 32.—Fricart's releasing valve gear. General arrangement.

The exhaust valves, at *d*, are opened and closed with positive movements derived from the wrist plate in the usual manner, while the wrist plate also gives positive rocking movements to two levers, *e*, one at each steam valve, which turn on the sleeves which support the valve spindles.

The description which immediately follows refers to the mechanism connected with the forward admission valve. A pawl or latch, *f*, is pivoted to a branch of the rocking lever *e*, and the end of this pawl pushes the steam valve open by abutting against a toe, *g*, keyed fast on the valve spindle. (See also Figs. 33 to 36.)

To effect the discontinuance of steam admission before the end of the stroke, the pawl is caused to swing outward from the spindle so far as to clear the end of the toe *g*, and the valve thus released is pulled shut by the action of a weight, vacuum spring, and dash pot, in the usual way. The weight and dash pot are suspended from a lever, *h*, forming one piece with the toe *g*.

The peculiar and distinctive feature of Fricart's gear is an ingenious arrangement by which positive movements are given to the pawl *f*, in such a way that its engagement with the toe for opening the valve will occur at the proper instant, and yet so that the action of the governor will vary the point of cut-off through the desired range; namely, from no steam admission whatever, up to an admission which continues during three-fourths of the piston's stroke.

The arrangement is as follows: An arm, *i*, which is in one piece with the pawl *f*, is connected, through a rod, *k*, to the lower one of two short vertical arms of a three-armed lever, *l*, the extremity of whose horizontal arm is connected by a rod, *m*, with the sleeve of the governor *n*. The fulcrum of the three-armed lever is carried by the vertical arm of a bell-crank, *o*, the horizontal arm of which is coupled by a link, *p*, to the eccentric rod *r*, at a place where the rod has a certain extent of vertical vibration. This vibration communicates horizontal reciprocating movements to the three-armed lever and the rod *k*, by means of which the pawl is made to swing to and fro about the pivot by which it is hinged to the lever *e*.

This swinging motion of the pawl carries its point inward and outward, toward and away from the valve spindle, while at the same time the oscillation communicated by the wrist plate to the lever *e* carries the whole pawl back and forth around the spindle, and the combination of these movements causes the point of the pawl to traverse peculiarly shaped curved paths, shown in Figs. 33 to 36.

The paths that the pawl point traverses and the shape of the toe are such that the valve always begins to open a little before the commencement of the piston's stroke, and the path of the pawl point may be such that the point of the pawl will remain in contact with the toe until after its return motion in the direction of closing the valve has commenced; but whenever the path carries the pawl point so far outward from the valve spindle that the point clears the end of the toe, the valve, which is thus liberated, is suddenly closed by the action of the weight and dash pot. The time of continuance of the steam admission is determined by the continuance of the contact of the pawl with the toe after the valve begins to open, and this is regulated by the governor in the following way: As has been explained, the rod is connected with the governor sleeve by means of the three-armed lever *o*. When the governor rises or falls, from changes of the engine's speed, the lever is tipped, and this has the same effect that shortening or lengthening the rod *k* would have. When the governor rises the effect is as if the rod were shortened, so that the whole path which the pawl point follows is displaced outward from the spindle, and may be carried so far outward that the pawl fails to continue in contact with the toe long enough to open the valve at all, or else ceases contact soon after it begins to open. When, on the other hand, the governor falls, the path of the pawl point is brought nearer to the spindle, and in consequence of this the continuance of the contact of the pawl with the toe is prolonged, so that the release is delayed more or less, or indeed may be postponed until after the pawl has begun its return movement, or

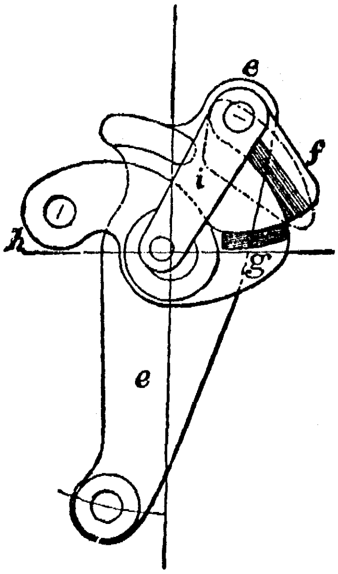


FIG. 33.—Valve being released at 0.1 of the stroke.

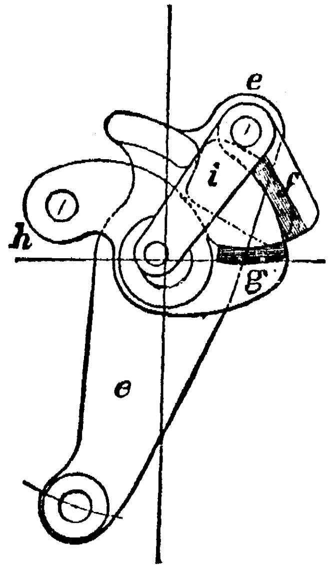


FIG. 34.—Valve being released at 0.4 of the stroke.

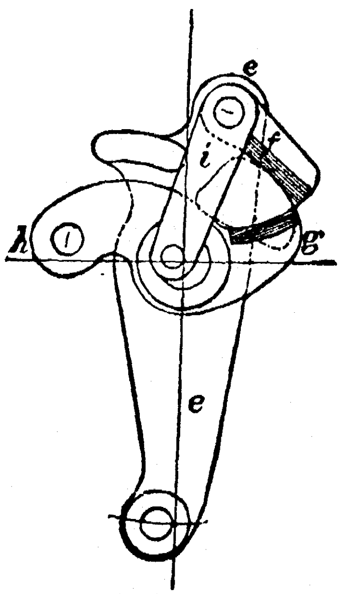


FIG. 35.—Valve being released at 0.7 of the stroke.

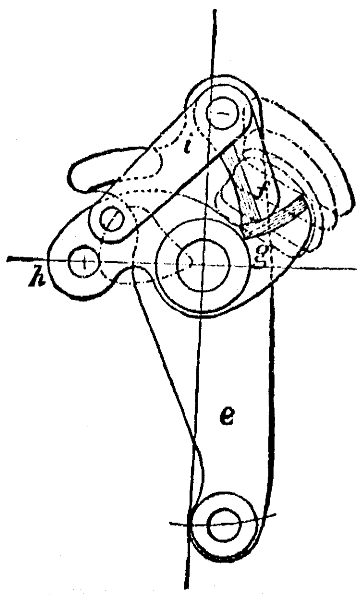


FIG. 36.—Valve beginning to open when cut-off occurs at 0.7 of the stroke.

even until it has returned to any desired point. When the governor is at its lowest point the valve will not be released at all, but will follow the retrograde movement of the pawl in closing.

Figs. 33, 34, and 35 show the relations of the parts connected with the valve spindle, and the paths which the pawl point follows, when the cut-off of steam occurs at 0.1, 0.4, and 0.7 of the stroke, respectively, the pawl point being shown in the position where it is about to release the toe *g*; and Fig. 36 shows the parts in the position where the valve begins to open when the cut-off takes place at 0.7 of the stroke. The several paths of the point of the pawl shown in the other figures are also all shown in this one.

As the action of the rear admission valve is the same as that of the front valve, no further explanation is needed.

FRICART'S RELEASING VALVE-GEAR.

Fig. 37 is a diagram showing the position of the rear steam valve relatively to its port, for different positions of the piston in the forward and return stroke, when the conditions are such that the valve is not released by the pawl; and Fig. 38 is a similar diagram for the rear exhaust valve. The numbers from 0 to 10 indicate consecutive equidistant positions of the piston in the forward stroke, and those from 10 to 20 consecutive positions in the return stroke. The edges of the ports are shown by the horizontal straight lines, while the

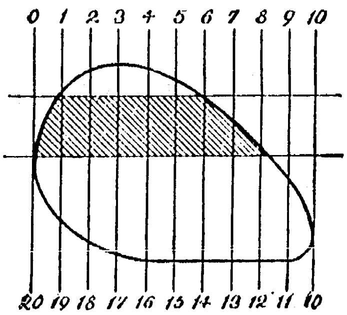


FIG. 37.—Steam valve diagram.

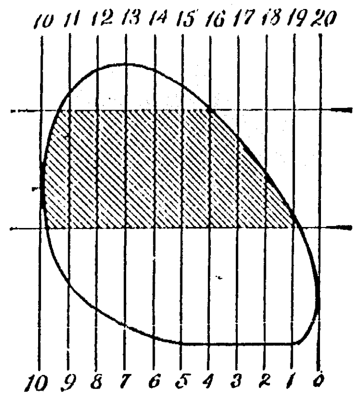


FIG. 38.—Exhaust valve diagram.

curves show the positions of the opening edges of the valves. The opening movement is upward in these diagrams. It will be seen that the full opening of the valve is promptly obtained.

(33) *De Ville-Chatel & Co.'s compound engine, with Fricart's positive movement valve gear and balanced valves.*—H. DeVille-Chatel & Co., of Brussels, exhibited a small high-speed tandem condensing engine, of 80 horse-power, fitted with a positive movement valve gear and balanced turning valves; also Fricart's invention.

The cylinder diameters were 8.7 and 15.75 inches, with 15¾-inch stroke, and the speed 175 revolutions per minute.

Four turning valves are used for each cylinder, worked by a Corliss wrist frame on the side of the cylinder, and all the valves receive positive movements from the wrist frame in the same way that the exhaust valves derive their movements in the Corliss gear. The wrist plates for both cylinders are vibrated by a single movable eccentric on the main shaft of the engine, in the fly wheel of which is the governor, which regulates the engine by shifting the eccentric so that its eccentricity and angular advance are changed to vary the steam distribution; an arrangement of eccentric and governor now seen on nearly every form of small high-speed engines.

The valves of the high-pressure engine are balanced and give four openings simultaneously for the admission or escape of steam, as the case may be. In this last respect these cylindrical valves resemble the flat balanced valves of the Porter-Allen engine.

A section of one of the valves and its seat is given in Fig. 39.

The valve shown is one of the exhaust valves, which are placed at the top of the high-pressure cylinder. The valve has a port, B, extending from end to end and passing directly through it. The two cups or cavities, S, are also connected by a port, shown in dotted lines. D is the cylinder port, and E a port leading into the exhaust chest. Two cavities, *d* and *e*, corresponding in width to the ports D and E, respectively, are made in the seat, diametrically opposite

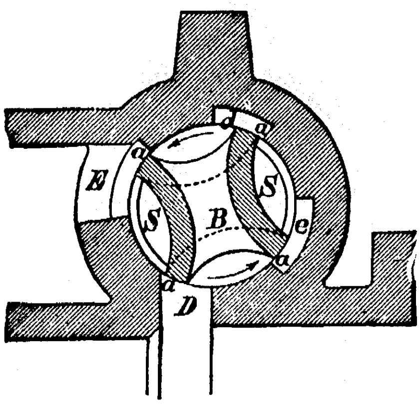


FIG. 39.—Fricart's balanced valve, by DeVille-Chatel & Co., Belgium.

those ports. The valve is shown as if moving in the direction indicated by the arrows and in the act of opening. It will be seen that communication will be opened between the ports D and E, through the ports in the valve and cavities in the seat, at the four edges of the valve marked *a*. The form of the valves and their relation to the seat are such that the valves are placed in perfect equilibrium.

The quadruple opening admits of the use of short valves, and secures liberal opening even when the valve moves only a short distance, as, when the throw of the eccentric is shortened by the governor action to diminish the power of the engine.

Ordinary Corliss valves with self-packing stems, Wheelock's, are applied to the low-pressure cylinder.

(34) *The Sulzer engines.*—The establishment of the Messrs. Sulzer Brothers, of Winterthur, Switzerland, whose exhibit was one of the most striking in Class 52, affords a notable example of the growth in prosperity which the fostering of the mechanic arts by the Government has made possible in Switzerland.

Founded in 1834, this firm commenced with a small machine shop, employing 12 workmen. In 1850 the number was increased to 136, and in 1860 the reputation established by the Sulzer Brothers for well-designed and well-built machinery had increased the business to an extent which warranted the employment of 450 men. The manufacture of the type of automatic engine which is now one of the chief specialties produced by this firm, was taken up in 1867, and this, with the collateral branches of industry it brought, furnished employment in 1870 to 1,000 men, increased to 1,250 in 1880. A branch establishment has been opened at Ludwig Shafen, on the Rhine, and to-day over 2,000 operatives are employed, 1,300 in the machine shops, and 750 in the foundries.

The ground covered by the establishments amounts to about 25 acres, of which over 8 acres are under roof. The product for 1888 included 213 steam engines, representing 18,500 horse-power, and weighing 2,800 tons; 237 boilers, representing 66,000 square feet of heating surface, and weighing 1,100 tons; and steam-heating apparatus weighing 700 tons.

In 1877 the Messrs. Sulzer were among pioneers in the introduction of compound stationary engines, and of late have been forward in introducing triple expansion engines for use in shops and manufactories.

The award of the jury was a grand prize; well deserved.

(35) The engines exhibited by Sulzer Brothers were:

First. A compound horizontal condensing engine, of 400 effective horse-power, consisting of two engines of equal stroke standing side by side, and having a common shaft with the cranks set 90 degrees apart.

The diameters of the high-pressure and low-pressure cylinders are 19.7 and 31.5 inches, respectively, and the stroke is 55 inches; the speed 75 revolutions per minute. The steam pressure with which the engine is intended to work is 100 pounds.

The diameter of the fly-wheel pulley is 14½ feet, and its face, which is 37 inches wide, is grooved for 14 ropes of 2¼ inches diameter.

Both cylinders of this engine are steam jacketed. The steam from the boiler flows through the high-pressure jacket on its way to the admission valves, and the exhaust steam of the high-pressure cylinder heats the low-pressure cylinder before entering the valve chambers. The Messrs. Sulzer claim that their experiments indicate this to be the best system of jacketing. They have also dispensed with a "receiver," the exhaust pipe from the high-pressure cylinder and the low-pressure jacket forming the only intermediate reservoir. The governor is of the Porter type.

As the balanced puppet valves and the peculiar valve gear of the Sulzer engine have been described in United States reports of former expositions (Vienna, 1873, and Paris, 1878) a description will be omitted here. They have been applied to more than 1,000 engines built by Sulzer Brothers. Valves and seats were exhibited which had been in use 14 years without refitting and were tight.

(36) A certificate was furnished to the jury, showing that the results of a trial of one of these engines in Milan demonstrated a steam consumption of 14.06 pounds per hour and per indicated horse-power, when the engine was working with steam at 90 pounds boiler pressure and developing 267 horse-power. The statement was also made that one of their triple expansion engines running in Hungary developed on trial results as follows:

Boiler pressure	152	151	152	pounds per square inch.
Power developed	383	387	316	indicated horse-power.
Consumption of steam per indicated horse-power per hour, condensation in jackets included.	11.66	11.86	11.95	pounds.

A certified official report of this test could not be obtained; and no particulars of the engine or trial were given. The results stated are extraordinary, though possible.

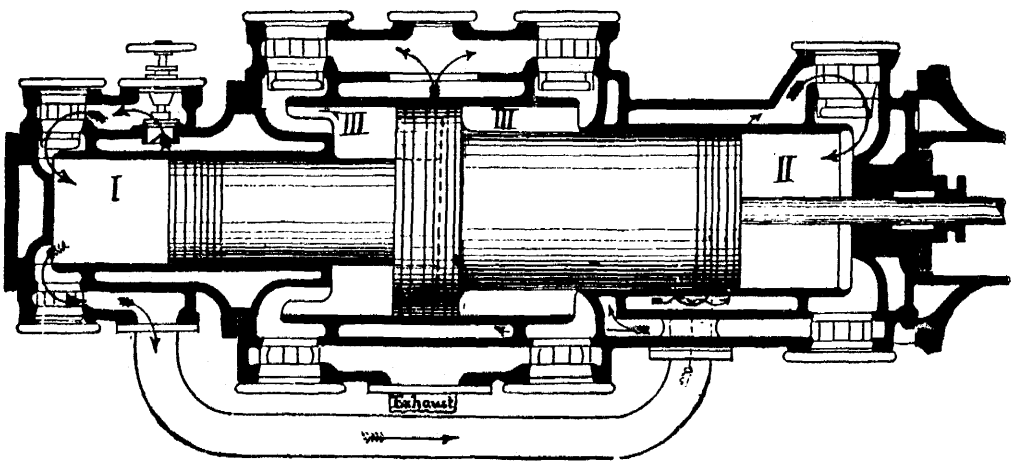


FIG. 40.—Sectional view of the cylinders of Sulzer Brothers' tandem triple-expansion horizontal engine.

(37) Second. The Messrs. Sulzer also exhibited a new type of tandem triple-expansion compound engine having only one piston rod, one connecting rod, and one crank. It is composed of a single-acting high-pressure cylinder 13.8 inches in diameter, a single-acting medium-pressure cylinder of 20.7 inches, and a double-acting low-pressure cylinder of 27.6-inch bore, all having a piston stroke of 29½ inches. The speed of the engine was 85 revolutions per minute. Fig. 40 is a longitudinal section through the common axis of the cylinders and shows their arrangement.

Steam from the boiler is admitted to cylinder I after having traversed the jacket of this cylinder; after doing its work in I the steam is exhausted into the jacket of cylinder II, around which it first passes and then enters the cylinder through the admission valve; after acting on the piston in cylinder II the steam is discharged into the jacket of cylinder III, which serves as a reservoir from which the steam passes alternately into the annular spaces in the back and front ends of cylinder III, as the admission valves for that cylinder are opened. From cylinder III the steam passes to the condenser.

It will be seen that there are eight valves for the three cylinders; they are double-beat puppet valves of the Sulzer type. The engine is intended to work with steam at 150 pounds pressure, and when cutting off at 0.3 of the stroke in the first cylinder gives a power of 118 indicated horse-power. Porter's governor is used.

Fig. 41 shows the indicator diagrams obtained from the three cylinders of this engine, and Fig. 42 the tangential pressures on the crank pin for the forward and return strokes, under the conditions stated above.

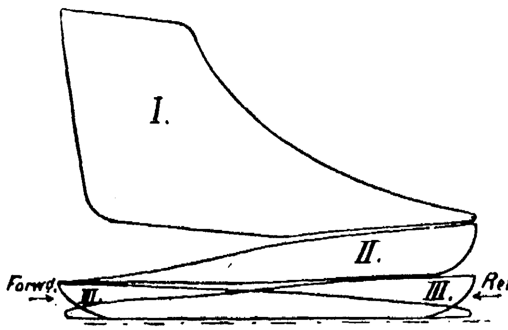


FIG. 41.—Indicator diagrams from all three cylinders of Sulzer's tandem engine.

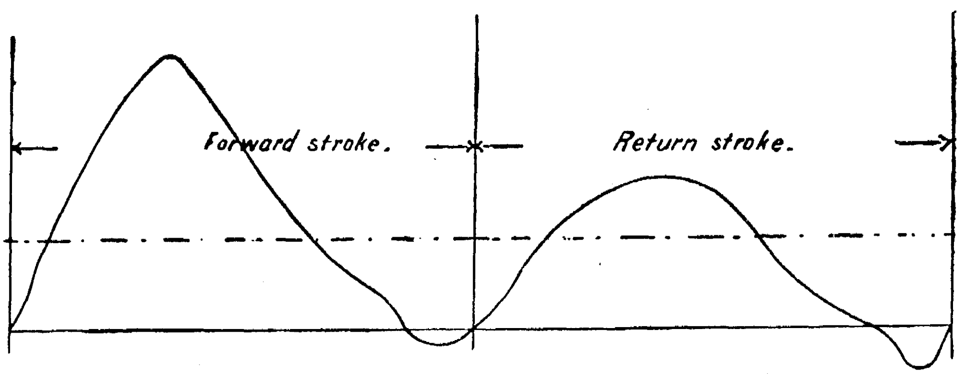


FIG. 42.—Diagram of tangential pressures on the crank pin of Sulzer's tandem engine.

The rotative effect is not so uniform as with triple-expansion engines of the usual type, and the effect in the forward stroke is different from that in the return stroke, but this irregularity is compensated for by a heavy fly wheel. The engine is comparatively cheap to build.

(38) Third. Another engine in this exhibit was a large vertical triple-expansion engine with three cranks set 120 degrees apart. The cylinders were 16, 24, and 36 inches diameter, the stroke was 2 feet, and the speed 100 to 125 revolutions per minute, giving 300 to 350 effective horse-power.

The frame was of the marine type, the valves of the Sulzer double-beat type, and the governor, Porter's. The valve gear and appliances were complicated, but the appearance of the engine was fine and the workmanship could hardly be excelled.

Two well finished high-speed vertical compound engines of 100 horse-power and 40 horse-power, respectively, which it is unnecessary to describe, completed the exhibit of steam engines made by this firm.

(39) *Escher, Wyss & Co.'s engines.*—Escher, Wyss & Co., of Zurich, Switzerland, showed a compound engine of 150 horse-power, consisting of a pair of single-cylinder horizontal engines, having cylinders of unequal diameters but equal stroke, with a shaft in common, and cranks set 90 degrees apart.

The diameters of the high-pressure and low-pressure cylinders are 14.6 and 21.7 inches, respectively, the stroke 31½ inches, and the normal speed 80 revolutions per minute.

The jacket for the high-pressure cylinder forms part of the steam chest of that cylinder, and consequently is filled with steam coming from the boiler. The low-pressure cylinder has two jackets, one entirely encircling the cylinder and containing steam at boiler pressure, the other partly surrounding the inner jacket, forming part of the low-pressure steam chest, and receiving steam exhausted from the high-pressure cylinder.

The exhaust steam from the first cylinder passes through a steam-jacketed horizontal tubular reheater, located between the engines and beneath the floor. The steam is partly dried in circulating through this reheater, the tubes of which are filled with steam at boiler pressure, and it is still further dried on its way to the second cylinder, by passing through the outer jacket of that cylinder, where it is warmed by contact with the outside of the heated inner jacket. The capacity of the reheater is about three-quarters that of the low-pressure cylinder, and this space, added to that which is in the pipes forming the connections with the two cylinders, and in the low-pressure steam chest, gives a total receiver capacity about five times the piston displacement of the high-pressure piston per stroke. The area of the heated surface thus provided for drying the steam amounts to about 60 square feet.

The four valves are of the Corliss type, with Jerome Wheelock's self-tightening stems. The valve gear for both cylinders is of the Fricart-Corliss type, which is described elsewhere.

A Porter governor, with a spring inside the sleeve to increase its preponderance, is used to regulate the point of cut-off for the high-pressure engine, the low-pressure valve gear being adjustable by hand.

The low-pressure steam chest is furnished with a safety valve, by which the pressure of the steam admitted to the cylinder is limited.

The diameter of the fly-wheel pulley is 12 feet, and its face, which is grooved for the reception of eight ropes of about 2 inches diameter, is 21 inches wide.

The general form of the engine frame resembles the Corliss somewhat, but is cylindrical from the steam cylinder to the end of the guides, and the back brace is tubular, of rectangular cross section. Beneath the guides there is a stand resting on the foundations.

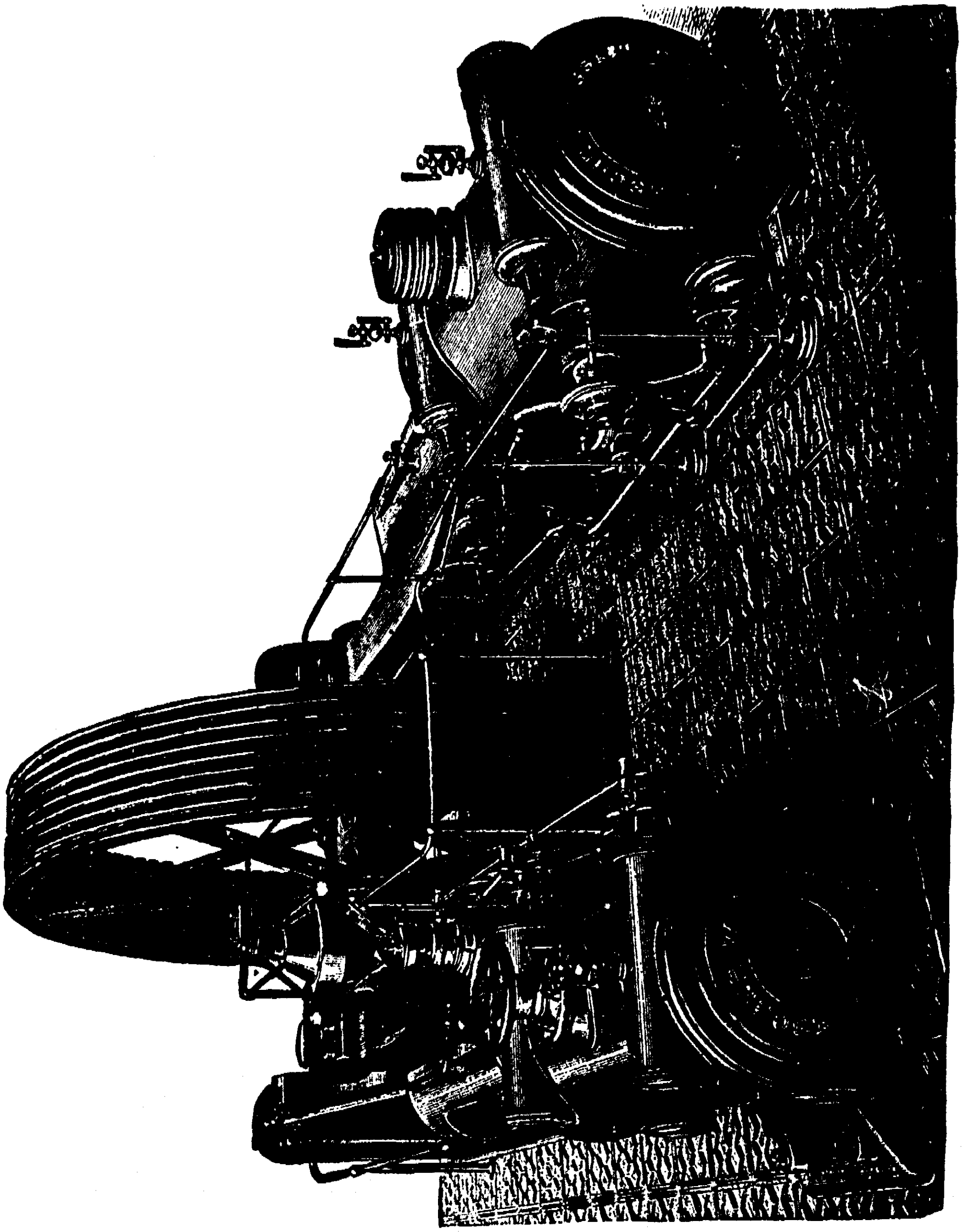


FIG 43.—Compound engine with Fricart's releasing valve gear, by Escher, Wyss & Co., Zurich.

This engine presented a fine appearance, and as there are some peculiarities in the design and outside finish of the cylinders and frame, a perspective view is given in Fig. 43.

(40) A 25 horse-power single-cylinder self-contained engine, with the Ryder cut-off gear, regulated by a governor the axis of which was horizontal, was exhibited by this firm. It had a 10-inch cylinder, a stroke of 16 inches, and a speed of 150 revolutions per minute.

A yet smaller plain slide-valve horizontal engine, running at a high speed for driving dynamos, was also seen in their space; the speed was regulated by a throttle valve actuated by a governor in the fly wheel of the engine, through very direct mechanism. It had a cylinder 6 by 6 inches, and ran at 250 revolutions per minute. The estimated effective capacity was 6 horse-power.

Messrs. Escher, Wyss & Co. made numerous exhibits in other classes than Class 52, and all the machines they displayed were interesting and admirable; a fact attested by the award of a grand prize by the jury.

(41) *Carels Brothers' compound engine.*—The large compound engine (350 horse-power) exhibited by the Messrs. Carels Brothers, of Gand, Belgium, presented the most elegant appearance of any engine in the Exposition, and is particularly interesting because of the exceptionally good economical results which have been obtained from a similar engine of their construction.

This firm is a licensee of the Sulzer Brothers, and the engine is a pair of horizontal single-cylinder engines arranged like the Sulzer compound engine in nearly all particulars.

The low-pressure cylinder had the usual Sulzer gear, set to cut off at half the stroke. The valve motion of the high-pressure cylinder was a simplified modification of the Sulzer gear, producing an unusually rapid opening of the valves, which were of the Sulzer double-beat type. The diameters of the cylinders were 20.7 and 32.5 inches, and the stroke 47¼ inches; speed 65 revolutions per minute.

The steam was cut off at one-fifth of the stroke in the high-pressure cylinder and at two-fifths in the low-pressure, making the number of expansions 12½.

The finish of the engine was plain, and entirely in black and white. The lagging of the cylinders was covered with planished iron without bands; all fittings were nickel-plated, and where the connecting rod brasses showed, they also were plated. Nothing could be more elegant than the appearance of simplicity this finish gave.

(42) As the following certified report of a careful test of one of the Messrs. Carels' engines by Mr. R. Vincotte, engineer of a Belgian Association for the Inspection and Care of Steam Apparatus, shows a remarkable result, it is given nearly in full with Mr. Vincotte's remarks:

BRUSSELS, *June* 9, 1888.

Monsieur VERTONGEN-GOENS, *à Termonde:*

I have the honor to send you the results of tests made of your Sulzer engine December 19, 1887, and January 10, 1888.

The test of the 19th of December is the only official one, and that only ought to serve as a basis for the payment for the engine. The trial of January 10 was only made as a check upon the preceding one.

As I have explained to you, this is the first time that a steam engine has given me so favorable a result, and although the experiments of December 19 left nothing to be desired it seemed to me useful to repeat it and to verify it anew in all respects. The second experiment gave the same results as the first. I, however, thought it best to undertake lengthy theoretical verifications before admitting such novel results.

Having reviewed the question from all sides, I believe the following results to be very accurate, and, if they do necessitate the payment of a large bonus to the constructors, they afford a guaranty that you have the most economical engine in Belgium.

Size of engine.

	Inches.
Diameter of large cylinder	35.4
Diameter of small cylinder	22.7
Stroke of pistons	59.0

Chief results of the trials.

	Dec. 19, 1887.	Jan. 10, 1888.
Duration of first test—from $8^h\ 49\frac{1}{2}^m$ a. m. to $7^h\ 0\frac{1}{2}^m$ p. m., with stops from $12^h\ 1^m$ to $1^h\ 2^m$ and from $3^h\ 5\frac{1}{4}^m$ to $4^h\ 30^m$	$8^h\ 39\frac{1}{2}^m$	.....
Duration of second test—from $8^h\ 30^m$ a. m. to $6^h\ 59^m$ p. m., with stops from $11^h\ 57\frac{1}{2}^m$ to $12^h\ 57^m$ and from $3^h\ 58^m$ to $4^h\ 27\frac{1}{2}^m$	.....	$9^h\ 0^m$
Mean pressure of steam ... Pounds.	85.3	88.2
Weight of water pumped into the boiler ... do	29,710.1	29,428.1
Correction for difference of water level in boiler ... do	—152.1	+146.1
Correction for water of condensation in the steam pipe, which was collected, pounds	—960.1	—1137.2
Total weight of steam used in the engine ... Pounds	28,597.9	28,437.0
Water collected from the steam jackets of the small cylinder and the receiver, pounds	3,026.1	3,191.6
Temperature of this water ... deg. F.	306.3	306.3
Temperature of the condensing water ... do	73.4	73.4
Mean horse-power developed (indicated)	248.1	235.8
Total number of horse-power hours	2,148.0	2,121.9
Consumption of steam per indicated horse-power per hour ... Pounds	13.3	13.4
Weight of steam to be deducted from the consumption, in taking account of the benefit derived from the water from the steam jackets used in a small pump ... Pounds	—617.7	—651.4
Consumption per indicated horse-power per hour when this correction is taken into account ... Pounds	13.0	13.1

From a scientific standpoint the consumption is 13.3 and 13.4 pounds.

From the standpoint of the contract the consumption is 13 and 13.1 pounds.

* * * * * * *

R. VINCOTTE.

The Carels Brothers received a grand prize as their award.

(43) *Engines in the United States section.*—The steam engines in our own section were all noncompound. Messrs. C. H. Brown & Co. of Fitchburg, Massachusetts, exhibited an engine of 100 horse-

power of the well-known type manufactured by this firm. It was employed nearly up to its full capacity in driving one of the main lines for the section, and did its duty well without signs of laboring.

A gold medal was awarded for this engine.

The Straight Line Engine Company, of Syracuse, New York, to whom a gold medal was also awarded, showed a 100 horse-power Sweet straight line engine of new pattern, in which a separate slide valve worked by an independent eccentric was used for the exhaust, the two valves, steam and exhaust, being placed on opposite sides of the cylinder; otherwise the engine was essentially like the smaller engines hitherto built by the company. Another of their engines, of 35 horse-power, was employed to drive the J. A. Fay & Co.'s wood-working machinery; and Messrs. Steinlen & Co. of Mulhouse, Alsace, who have taken a license to build the straight line engine, exhibited four, of 100 horse-power each, which were employed in driving large dynamos for lighting a portion of the Exposition.

An Arnington & Sims engine of 75 horse-power, for which a gold medal was awarded, was used to drive the dynamos of the Thomson Electric Welding Company, and a 25 horse-power Westinghouse engine for driving another dynamo. French and Belgian firms are manufacturing both these last-named engines under licenses.

The Colt's Patent Firearms Manufacturing Company, of Hartford, Connecticut, displayed a Baxter engine of 5 horse-power.

As all the engines just named are well known in the United States, and have been extensively published in the technical papers and business circulars, they will not be described.

(44) Jerome Wheelock of Worcester, Massachusetts, who received a gold medal, did not exhibit an engine, because there are several prominent French manufacturers working under his licenses who displayed the engines.

He did, however, show in the United States section a new system of valves, adapted for substitution in the place of the Corliss turning valve, particularly in engines of the Wheelock type. This system is comparatively recent, and will therefore be illustrated.

Fig. 44* shows a section of the lower part of one end of a steam cylinder with the valve seats and valves in place, and Fig. 45 a perspective view of one of the plug-shaped seats, having the valve, its stem, and their connections applied to it, the whole apparatus being in condition for insertion into the bored hole which is provided in the cylinder end for its reception.

The seat plug is long and tapering, and is cut away at one side so as to form a flat face which is perforated with several ports. A flat slide valve, also having several ports, rests on this face and receives motion from the valve stem, which has a bearing in each end of the plug. Short cranks, with links coupling them to lugs on the back

*This figure is copied from Engineering.

of the valve, give sliding movements to the latter when the stems are turned back and forth. The plugs occupy the places filled by the turning valves in the Corliss engine, and are driven into holes in the cylinder which correspond to the holes made for the seats of the turning valves, but are bored with a slight taper corresponding to that of the plugs. The plug fits tightly in the hole and is fastened so as to be made steam tight by driving. There are no bolts to hold the seats in, and no bonnets to cover them.

The valve stems are turned back and forth by the valve gear in essentially the same manner as that hitherto employed in the Wheelock engine, and the steam valves are tripped and closed in the usual manner.

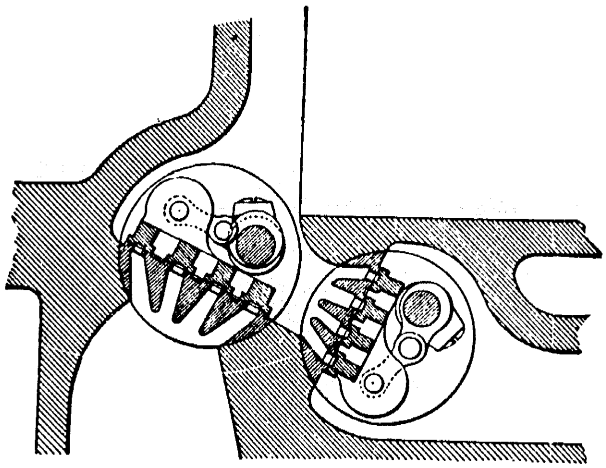


FIG. 44.—Section of end of cylinder, showing Wheelock's new system of valves.

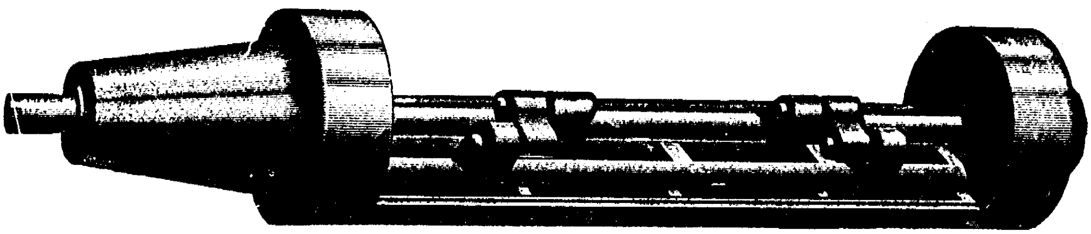


FIG. 45.—Wheelock's valve seat and valve.

This new valve arrangement is manufactured under license by De Quillacq, of Anzin, France, who manufactures largely the older type of Wheelock engines.

(45) *Steam engines in the British section.*—Several quite small engines for steam launches, air compressors, etc., were shown by British exhibitors, but Messrs. Davey, Paxman & Co. of Colchester, England, exhibited the only engines of large size; two of about 140 horse-power each, one of which was compound, gave motion to sections of the shafting in Machinery Hall. Three compound engines, of 360, 200, and 120 horse-power, respectively, were employed for driving dynamos in the "Central Electrical Station of the Syndicate." All these engines were furnished with the Paxman auto-

matic expansion gear, in which a cut-off valve works on a plate, perforated with ports, which lies upon the back of the main slide valve and is prevented from endwise movement. The main valve is operated by a single eccentric, and the cut-off valve by two other eccentrics and a shifting (Stevenson) link, the position of which is adjusted by the governor, which thus regulates the point of cut-off.

(46) *Parsons's compound steam turbine.*—One of the most interesting novelties in the Exposition was Parsons's steam turbine, an English invention exhibited in the French section by Messrs. Weyher & Richemond.

It is shown in Figs. 46 to 48, which, with the greater part of the following description, are taken from a paper presented by the inventor to the Institution of Mechanical Engineers, London, October 25, 1888.

The steam turbine is combined with a dynamo of small diameter, and the whole apparatus is called a "Turbo-Electric Generator." Its high speed adapts it peculiarly well for driving dynamos directly, and, while the turbine is useful for other purposes, its applications hitherto have been made chiefly in this way.

The machine shown in the Exposition ran at about 10,000 revolutions per minute with perfect silence and steadiness. In fact, except for the slight sparking shown at the commutators of the dynamo, it would have been difficult to tell whether the machine was running or not.

In 1888 the inventor made the following statement:

The first turbo-electric generator, completed in 1882, ran at 18,000 revolutions per minute, and gave 6 electrical horse-power; it has been in almost constant use since that time, and has done a large amount of work. The second, made shortly afterwards, runs at 10,000 revolutions per minute; it was placed on the Tyne Steam Shipping Company's steamer *Earl Percy*, and has worked her 60 lamps ever since to their entire satisfaction; the cost of fuel and maintenance is very small, and the light remarkably steady.

Theory based on the authenticated performances of water turbines and the laws of the flow of steam and gases showed that the turbo-electric generator possessed the elements of the highest economy, not merely comparable with the best-known performances, but even superior to them. How far practice has come up to theory may be judged by the results given at the end of this extract, and it will be seen that they approach nearly the best results of ordinary engines working with the same steam pressures.

The compound steam turbine T, Figs. 47 and 48 consists of two series of parallel-flow or Jonval turbines, set one after the other on the same spindle S, so that each turbine takes steam from the preceding one and passes it on to the next. In this way the steam entering all round the spindle from the central inlet I, Fig. 47, passes right and left through the whole of each series of turbines to the exhaust E at each end. The steam expands as it loses pressure at each turbine, and by successive steps the turbines are increased in size or area of passage-way, so as to accommodate the increase of volume, and to maintain a suitable distribution of pressure and velocity throughout the whole series of turbines. The areas of the successive turbines are so arranged that the velocity of the flow of steam shall have throughout

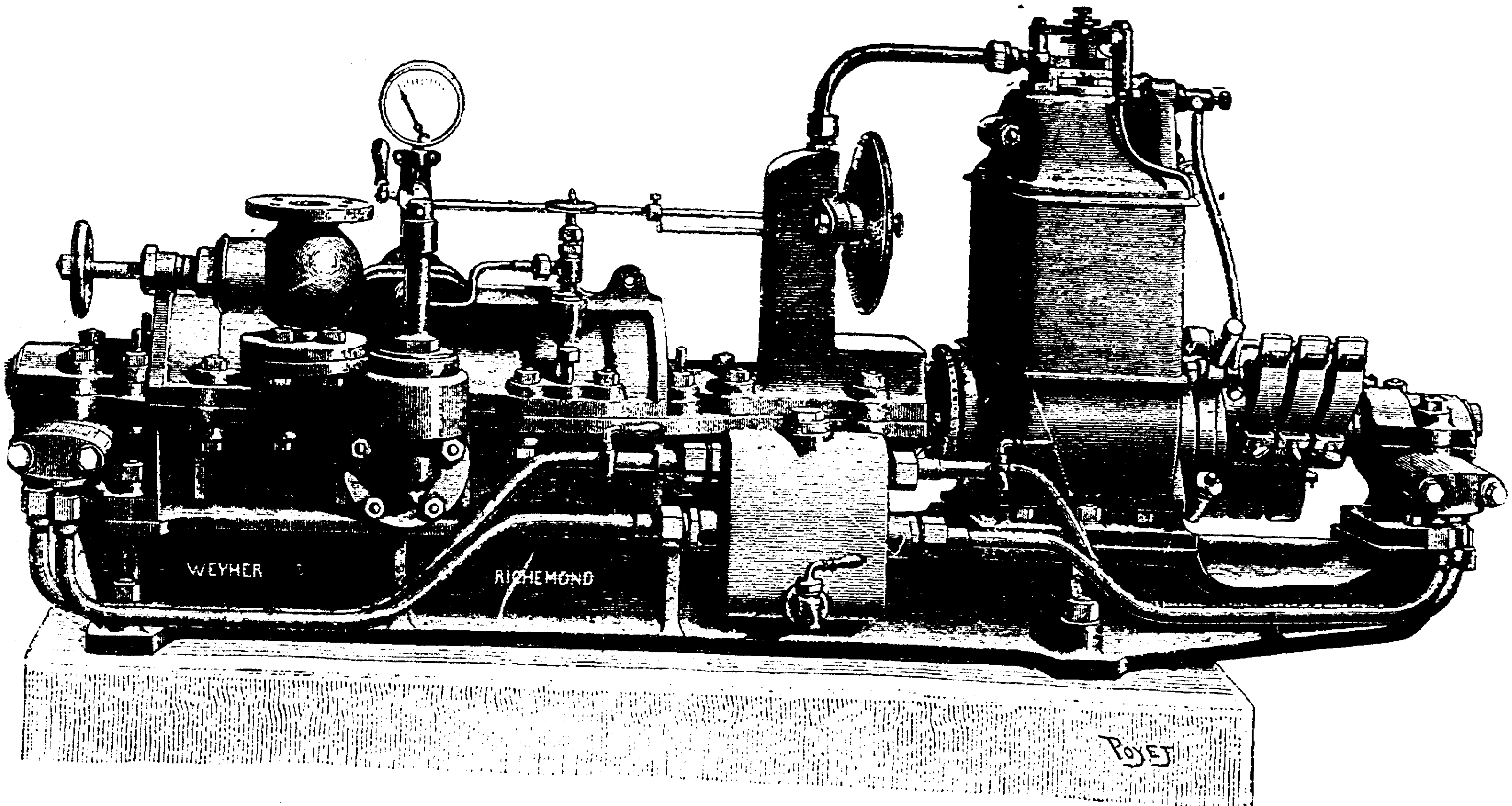


FIG. 46.—Parsons's compound steam turbine, as applied for driving a high-speed dynamo. General view.

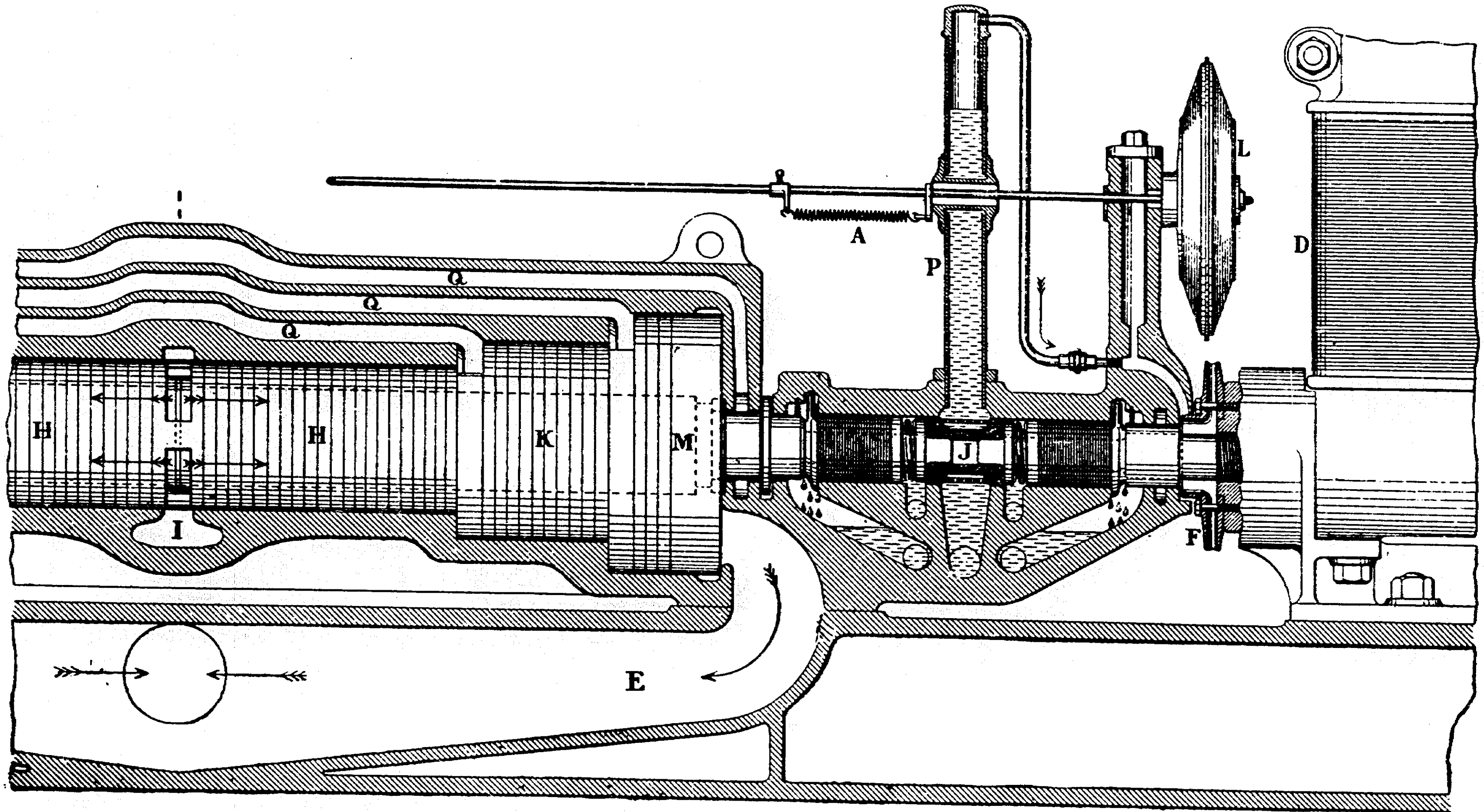


FIG. 47.—Longitudinal section of Parsons's compound steam turbine.

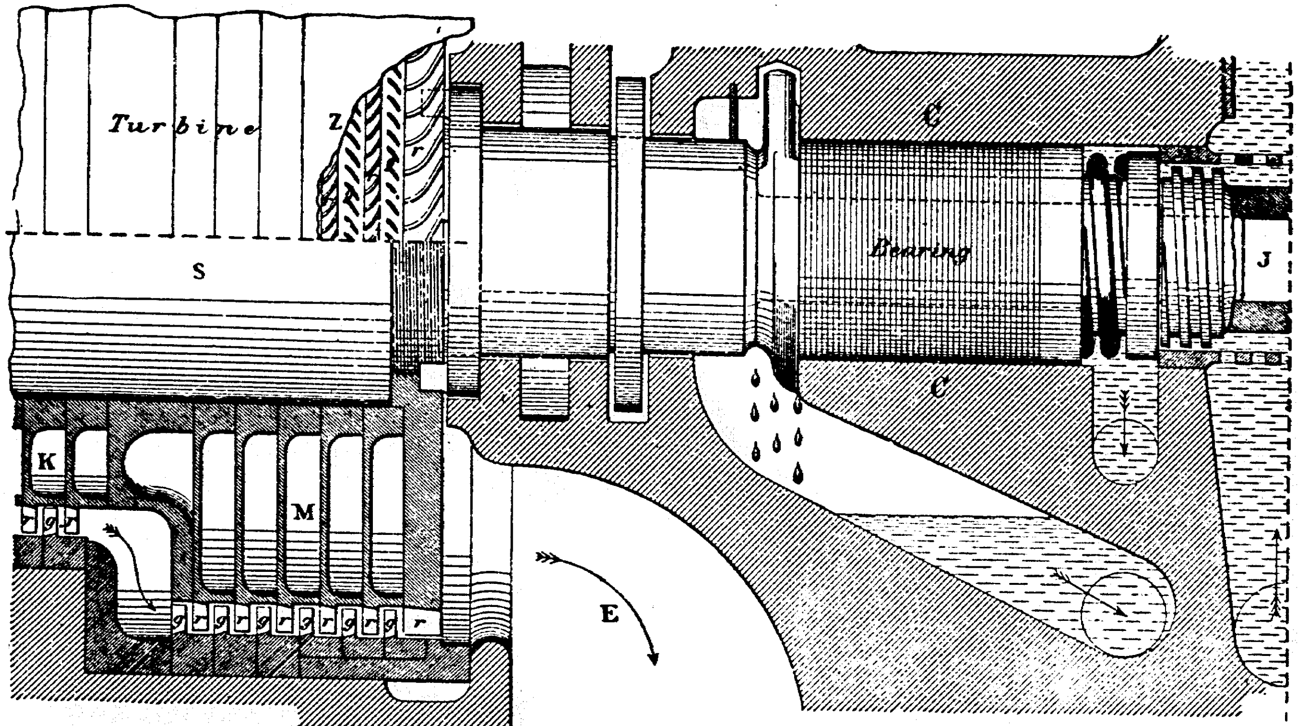


FIG. 48.—Section of, one end of the turbine, and of the bearing, of Parsons's compound steam turbine.

the series a nearly constant ratio to the speed of the blades; and as far as possible this ratio of velocities is so fixed as to give each turbine of the series its maximum efficiency. The two equal series of turbines on each side of the central steam inlet I balance each other as regards any end pressure on the spindle of the motor, and thus remove any tendency to undue wear on the collars of the bearings B.

The turbines are constructed of alternate revolving and stationary rings of blades. The revolving blades *r*, Fig. 48, are cut with right or left hand obliquity on the outside of a series of brass rings, which are threaded upon the horizontal steel driving spindle S, and secured upon it by feathers; the end rings form nuts, which are screwed upon the spindle and hold the rest of the rings upon it. The stationary or guide blades *g* are cut with opposite obliquity on the inside of another series of larger brass rings, which are cut in halves, and are held in the top and bottom halves of the cylindrical casing by feathers. The set of blades on each revolving ring runs between a pair of sets of the stationary or guide blades. The passages between the blades in the alternating rings form a longitudinal series of zigzag channels when the machine is standing still, as seen at Z in Fig. 48.

Bearings.—As it is impossible to secure absolute accuracy of balance, the bearings are of special construction so as to allow of a certain very small amount of lateral freedom. For this purpose the bearing is surrounded by two sets of steel washers one-sixteenth of an inch thick and of different diameters, the larger fitting close in the casing C and about one thirty-second of an inch clear of the bearing, and the smaller fitting close on the bearing and about one thirty-second of an inch clear of the casing C. These are arranged alternately, and are pressed together by the spiral spring N. Consequently any lateral movement of the bearing causes them to slide mutually against one another, and by their friction to check or damp any vibrations that may be set up in the spindle. The tendency of the spindle is, then, to rotate about its axis of mass, or principal axis as it is called; and the bearings are thereby relieved from excessive pressure, and the machine from undue vibration. The automatic oiling of the bearings by the screw J almost entirely prevents friction and wear. The circulation is continuous, the oil being used over and over again; and as it deteriorates very slowly and there is little waste, the consumption may be said to be unusually small. The oil is raised up to the screw J by the suction of the fan F acting upon its free surface in the standpipe P. By the screw J it is fed into the adjoining bearing, and is also forced along a pipe to the two other bearings of the spindle. After passing through the bearings the oil flows back along a pipe to a reservoir, to be again drawn up thence through another pipe by the fan and fed into the bearings by the screw. The throttle valve is worked by the movement of a leather diaphragm L, which the suction of the fan F tends to close against the tension of the spring A.

Durability.—After 3 years' working, 10 hours daily, the wear on the bearings has been found to be very small, in some cases almost inappreciable. The blades or vanes of the turbines show no cutting action from the steam. The commutators in the larger sizes have stood this amount of work well, and when carefully looked after have suffered very little wear.

Steam consumption.—As the result of careful tests, made when exhausting into the atmosphere and giving off 32,000 watts, the consumption of steam per electrical horse-power per hour has been found to be 42 pounds with a steam pressure of 61 pounds at the inlet; and 35.1 pounds with a steam pressure of 92 pounds at the inlet. Tests made at Portsmouth Dockyard, and at Messrs. Weyher & Richemond's, in Paris, have agreed closely with the tests made on the same turbo generators before they left the works at Gateshead. These tests have therefore confirmed the accuracy of the figures above given.

IV.—Gas engines.

(47) It is interesting to note the great development in the use of gas engines which has taken place within the last few years, as shown by the large number displayed in the Exposition of 1889, in contrast to the scarcity of such engines in the French exhibition of 1878. The character of the engines shown at the Exposition of 1889 is also remarkable. For a long time after Otto by his practical inventive genius and his researches had developed a useful and economical motor, gas engines were used only for small powers, their application being limited to from 1 to 10 horse-power for many years; and the engineer would have been bold indeed, in 1878, who had advocated building, or predicted the use of, gas engines of such great power as some of those exhibited on the Champs de Mars ten years later. Single gas engines of 25 horse-power followed a long trial of the smaller sizes; those of 50 horse-power were ventured upon later, and in the Exposition of 1889 we find two different engines capable of exerting 100 horse-power. One of these was of the greatest simplicity, having a single cylinder only and yet being in every way a thoroughly practical operative machine; the other consisted of a group of four engines of 25 horse-power each, combined on one bed and actuating a single crank shaft; an arrangement adopted in order to secure great uniformity of motion.

(48) Although there are several classes of gas engines and hot air engines—for both these belong to the same general group of motors—and although each class has from a theoretical standpoint its distinctive advantages, yet only two kinds have proved successful for general application and for the production of power on a considerable scale. They are:

I. Gas engines in which a mixture of gas and air, previously compressed, is heated by the ignition of the mixture, and produces power by its expansive action;

II. Gas engines in which the mixture of gas and air is exploded without previous compression.

Motors of the last class are not economical, but are simple and strong, and serviceable for moderate powers.

The first class is, then, the one which, because of its practicability as a motor of considerable power, has been introduced into a field which, until very recently, was occupied by the steam engine only.

Of the second class there were four types exhibited; of the first class, more than twenty.

It is the first class only which will be considered here. Of these there were three distinct systems represented.

First. That in which a cycle, constituting one complete operation, consists of four distinct processes performed in a single cylinder.

Second. A kind in which two processes complete the cycle.

Third. One in which two cycles are completed by three processes.

(49) The first of these systems includes the well-known Otto engine, which takes its name from its inventor, who discovered and applied the system it embodies. It has, however, been found that the four-process cycle employed by Otto was previously, though independently, invented and fully discussed by another scientist,* and this system, formerly attributed only to Otto, is therefore known as the cycle of Beau de Rochas, the earlier discoverer.

The four processes may be described as follows:

First. The drawing of the explosive mixture into the cylinder during the whole of the first forward stroke of the piston.

Second. The compression of the mixture by the piston's first return stroke.

Third. The ignition of the mixture and its expansive action in producing the power in the second forward stroke.

Fourth. The expulsion of the products of combustion and other contents of the cylinder during the second return stroke of the piston.

As the cylinder in this kind of engine is only single acting, the ignition of the mixture and exertion of power in the cylinder can occur only once in every two revolutions of the crank shaft, and consequently a heavy fly-wheel must be used to obtain regularity of motion.

Beau de Rochas specified certain conditions as essential for obtaining the best results from the use of the gas; these are, substantially:

1. That the admission of the explosive mixture must be cut off after the least practicable proportion of the filling stroke has been performed, so that after the ignition in the acting stroke the expansion may be as great as possible.

2. That the pressure of the mixture at the moment of ignition, and consequently at the beginning of the acting stroke, must be as great as practicable, by which a high initial pressure resulting from the ignition is obtained; a condition implied by the first if considerable power is required.

3. That the speed must be as high as possible.

4. That, for a given power and speed, the cylinder diameter should be as great as possible.

The last two conditions bear upon the loss of heat by conduction through the cylinder walls, which must necessarily be kept cool enough to permit of lubricants being used effectively, this cooling being usually effected by a circulation of water around the cylinder.

Beau de Rochas concludes that all these conditions are more nearly realized in a single-acting single-cylinder engine than in any other form of motor. The grand success which resulted from the embodiment of these ideas in a useful form by Otto, and the experi-

*See Beau de Rochas's French patent of 1862.

mental investigations which have followed, show this form to be quite as economical as any that has thus far been produced, and the conclusions Beau de Rochas reached to be well founded.

No greater proof of the success of this system can be presented than the fact that within 10 or 15 years 30,000 engines of this type, representing an aggregate of over 100,000 horse-power, have been sold. Seventeen different varieties of engines embodying this system were exhibited.

(50) The second system referred to was represented by three varieties of engines only. The system is carried out by drawing in and partly compressing the air by means of a piston working in a cylinder separate from and auxiliary to the working cylinder, or else by employing one end of the working cylinder for these processes, while the compression of the mixture is completed, and the power developed, in the opposite end of the same cylinder. This last plan is the one which is adopted for the three varieties of engines just referred to.

Air, and usually gas also, is drawn into the front end of the working cylinder by the backward or inward motion of the piston, the contents of the opposite end of the cylinder escaping at the beginning of this stroke, or being expelled during the stroke. At the beginning of the forward stroke a charge of compressed air and gas is admitted behind the piston and ignited, by which the piston is propelled forward and the contents of the front end of the cylinder compressed into a receptacle from which the charge is delivered into the back end of the working cylinder as needed. One ignition, therefore, takes place at each revolution of the engine, and for this reason more power can be obtained from an engine of this kind than from one of the same size and weight of the first system.

The third system was represented by a single example only.* In this the engine is double acting, and the ignition and motive effect occur twice in six strokes, that is, twice in three revolutions of the crank shaft. Let us consider one end of the cylinder only—for the processes are the same in both ends: The mixture is drawn in by the first direct stroke of the piston, compressed by the first return stroke, ignited in the second direct, and expelled in the second return stroke; a charge of fresh cool air, to clear out the products of combustion and cool the cylinder, is drawn in by the third direct stroke, and expelled in the third return stroke, which completes the cycle of processes.

A number of the gas engines exhibited were adapted for working with the vapor of petroleum, a few of them being fitted specially with vaporizers for producing the inflammable vapor in the quantity required, as regulated by the action of the engine.

*The Griffin engine, exhibited in the British section.

(51) In a number of the Otto engines the ignition of the charge was effected by the transfer of a small portion of the flaming gas from an igniting burner to the interior of the cylinder containing the charge, a plan which has long been in use; in other cases a tube heated to incandescence fired the charge, a portion of which found entrance to the tube; but in the greater number of engines exhibited, other than the Otto, the ignition was produced by an electric spark. The various devices for producing and regulating the spark are described in the report on Class 62.

(52) The improvement which has been made in the economical efficiency of the gas engine since its introduction is noteworthy.

In 1881 a test of the Lenoir gas engine, of one-half horse-power, one of the first brought into practical service, gave a consumption of 124 cubic feet of gas per effective (brake) horse-power per hour. In another trial of the same kind of engine, of 1 horse-power, the consumption was reduced to 95 cubic feet. In 1878 the consumption in the Otto engine had been reduced to 36 cubic feet per hour per effective horse-power. The practical working results of the Otto engine may now be estimated at 30 cubic feet, although recent experiments, in which rich gas was used, have shown that the consumption may be reduced to 24.5 cubic feet or less. A 10 horse-power "simplex" gas engine, when tested in 1885 by M. Wirtz, gave each horse-power with a consumption per hour of 20 cubic feet of gas having a heating power of 605 heat units per cubic foot. A small Charron engine, according to the same engineer, consumed 19.5 cubic feet of gas per hour per brake horse-power, with gas having a heating power of 670 heat units per cubic foot. This last test was made in 1889.

Results are published giving a working performance of a 50 horse-power "Simplex" engine, using Dowson gas which was made and used for the supply of gas to the engine only. Less than 1.3 pounds of anthracite coal were consumed per hour, per effective horse-power; a better performance than this is, however, claimed in England for the Crossley Otto engines of large power.

The engines employed during the Exposition do not seem to have given good economical results, if the performance of all is considered, and if the statements of the gas consumption are correct. About 300 horse-power is said to have been supplied by gas engines, and the hourly supply of gas for these to have been 14,000 cubic feet. The price charged for the gas was $1.10 per thousand cubic feet.

(53) *Compagnie Française des Moteurs à Gaz.*—This company, which controls the Otto patents, showed a new small vertical engine of admirably simple design, in which the distribution is effected through puppet valves instead of by a sliding bar, and in which the ignition is produced by means of a red-hot tube instead of by the transfer of a portion of flaming gas. The whole apparatus is sup-

ported by a large hollow frame which envelopes the cylinder and allows the circulation of water for cooling. See Figs. 49 and 50.

One of the novel features is a regulator which operates by the inertia of a weight in the following manner: For opening the exhaust valve and the gas supply valve there is a cam rod, *a*, which is supported by the spring *s*, which also bears up the exhaust valve *m*; this rod is driven down at every alternate revolution of the engine by a cam and lifted to place again by the spring. At the lower end of the rod *a* is an arm, *b*, which carries the regulator proper. This latter is composed of a right-angled lever pivoted to the arm at *c*. The horizontal branch of the lever carries a weight, *d*, counterbalanced by the spring *p*, and the vertical branch ends in a hook.

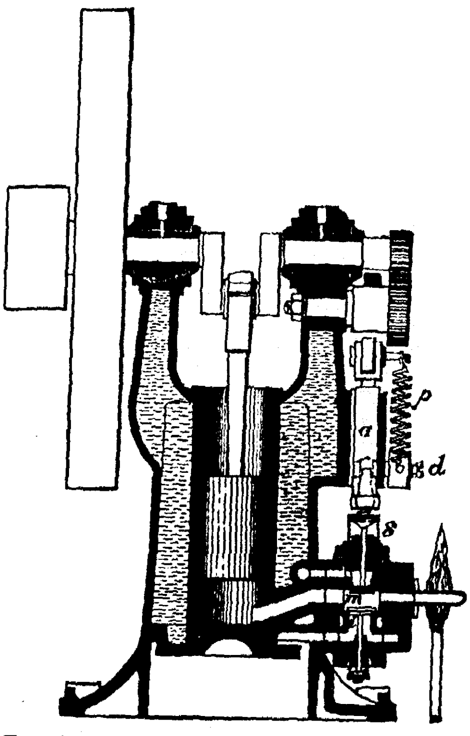


FIG. 49.—Sectional view of a vertical Otto gas engine.

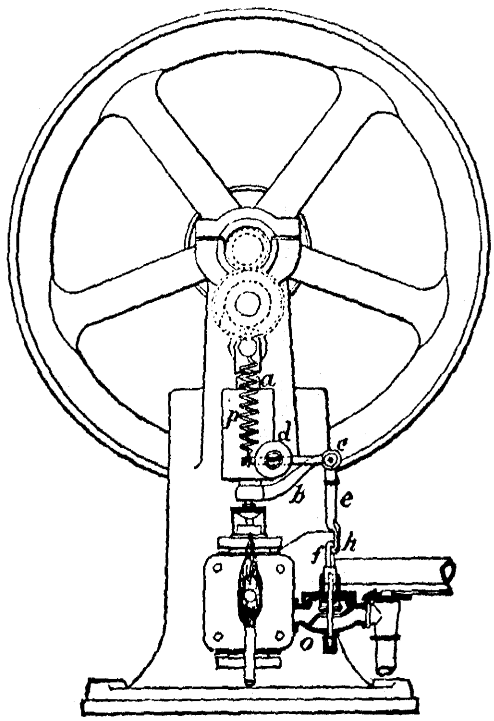


FIG. 50.—Vertical gas engine, Otto type.

This whole system moves up and down with the rod *a*, and, when the engine runs at the normal speed, the admission valve *o* is opened during every sucking stroke of the piston by means of the hook *h* on the arm *e* of the regulator lever, which engages with a hook on the top of the valve stem *f* when the rod *a* rises, the valve being closed when the rod descends.

If the speed of the engine increases, the weight *d* is, by virtue of its inertia, retarded in the upward motion of the cam rod, and the fulcrum *c* rises in advance of the weight, thus causing the vertical arm *e* to swing away from the rod *f* of the admission valve, which it therefore fails to lift. As soon as the speed is reduced, the lever returns to its place and raises the valve on the up stroke of the rod.

The gas valve *o* is therefore closed only during the period of exhaust, or whenever the cam rod in ascending fails to lift it. The mixture from the cylinder can not, however, escape through the valve *o* during the period of compression, because the automatic valve *i* is then closed and covers the holes with which the seat is perforated—for these are uncovered only while the valve *i* is lifted automatically, that is, during the period when air (or air and gas) is being sucked through it into the cylinder by every alternate upward stroke of the piston. The ignition is effected by means of a heated tube, placed in front of the cylinder, into which the compressed explosive mixture penetrates at the proper time and is ignited.

One form of this ignition tube is shown in the views of the engine, Figs. 49 and 50, but an improved arrangement has been adopted which is very satisfactory in its operation, and has been applied to the larger engines manufactured by this company. It consists of a vertical iron tube heated nearly to incandescence, so applied to the cylinder that it receives a portion of the explosive gas and ignites it, whenever the tube is brought into connection with the interior of the cylinder by means of a valve or slide which opens the communication when the moment for ignition arrives.

The iron tube is heated by a Bunsen burner, in the flame of which it is entirely immersed. The burner is not, however, sufficiently supplied with air to produce its full oxidizing effect, being surrounded with a concentric chimney perforated in such a manner that the air supply is directed to the outside of the flame, producing perfect combustion and intense heat at the surface, but leaving the interior of the flame lacking in oxygen. The tube is in some cases protected with a fire-clay coating. It lasts about 6 weeks and then costs but little for renewal, being a piece of half-inch pipe 5 inches long, capped at the end.

The action of this igniter is very sure and regular. The tube is screwed into the channel which forms the communication with the cylinder, but not at the end of this channel; the part of the channel beyond the tube forms a small reservoir, which first receives the products of combustion of the previous ignition, after which the pure mixture follows and enters the tube, where it is ignited; the explosion producing a reaction in the reservoir formed by the channel, which throws the flame into the cylinder and insures ignition of the main charge.

The length and arrangement of the tube have such an effect upon the time required for the reception of the gas, its ignition, and the travel of the flame to the cylinder, that, in the small engines, the igniting tube can be so adjusted that neither valve nor slide is needed between it and the cylinder to regulate the instant of ignition.

An illustration of a similar igniter, used in the Crossley engine, is given on page 150.

(54) The Compagnie Française exhibited also the well-known horizontal Otto motors of moderate size, and a few 40 and 50 horse-power engines specially built for electric light purposes and used for driving dynamos; these last consist of a pair of coupled engines, an arrangement which is preferred because regularity of speed is obtained without running the engines rapidly.

The same company also shows a 100 horse-power engine. It is really four 25 horse-power engines united on the same frame; there are four cylinders just alike, each with its special distributers and regulators, all working under the same conditions. The cylinders are placed in pairs on either side of the main shaft. There are but two cranks on the shaft, to each of which is attached two of the engines, and these cranks are set opposite each other. Slide valves of the necessary size being too large, they were replaced by puppet valves, the slide being retained only for the ignition, which is produced as in the common engines, by a transfer of the flame. A small engine is used to start the large one by means of a pulley on the flywheel shaft, a loose pulley being provided to receive the belt as soon as the large engine is running. A transverse section through the breech of the cylinder of one of the horizontal engines having an arrangement of puppet valves is shown in Fig. 51.

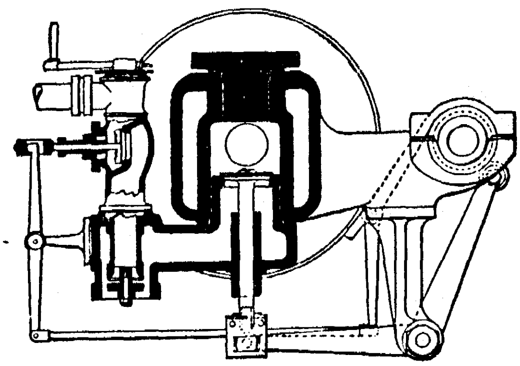


FIG. 51.—Vertical transverse section of breech of a horizontal Otto gas engine with puppet valves.

The company had twenty-seven motors, representing 360 horse-power, working in different parts of the Exposition. Since 1878 it has built 3,018 Otto engines of 8,252 total horse-power. It received a gold medal, as high an award as was given for this class of exhibits.

(55) *Delamare-Deboutteville & Malandin's "simplex" engine.*—This engine was exhibited by Mr. Thomas Powell, of Rouen, France. Its operation is on the Beau de Rochas system of four processes in one cycle, and the engine is provided with a slide through which the gas and air are admitted to the cylinder. In these respects it resembles the Otto engine of the usual form, but it differs from the latter considerably in several features of arrangement and detail, and is particularly interesting because the largest single cylinder gas engine ever exhibited is of this kind and was shown in operation in the Exposition.

This was a motor of 100 horse-power with a cylinder 22.6 inches in diameter and a stroke of 37½ inches.

Fig. 52 shows a side view, and Fig. 53 an end view of the large engine.*

*These figures were taken from Industries, London, Aug. 2, 1889.

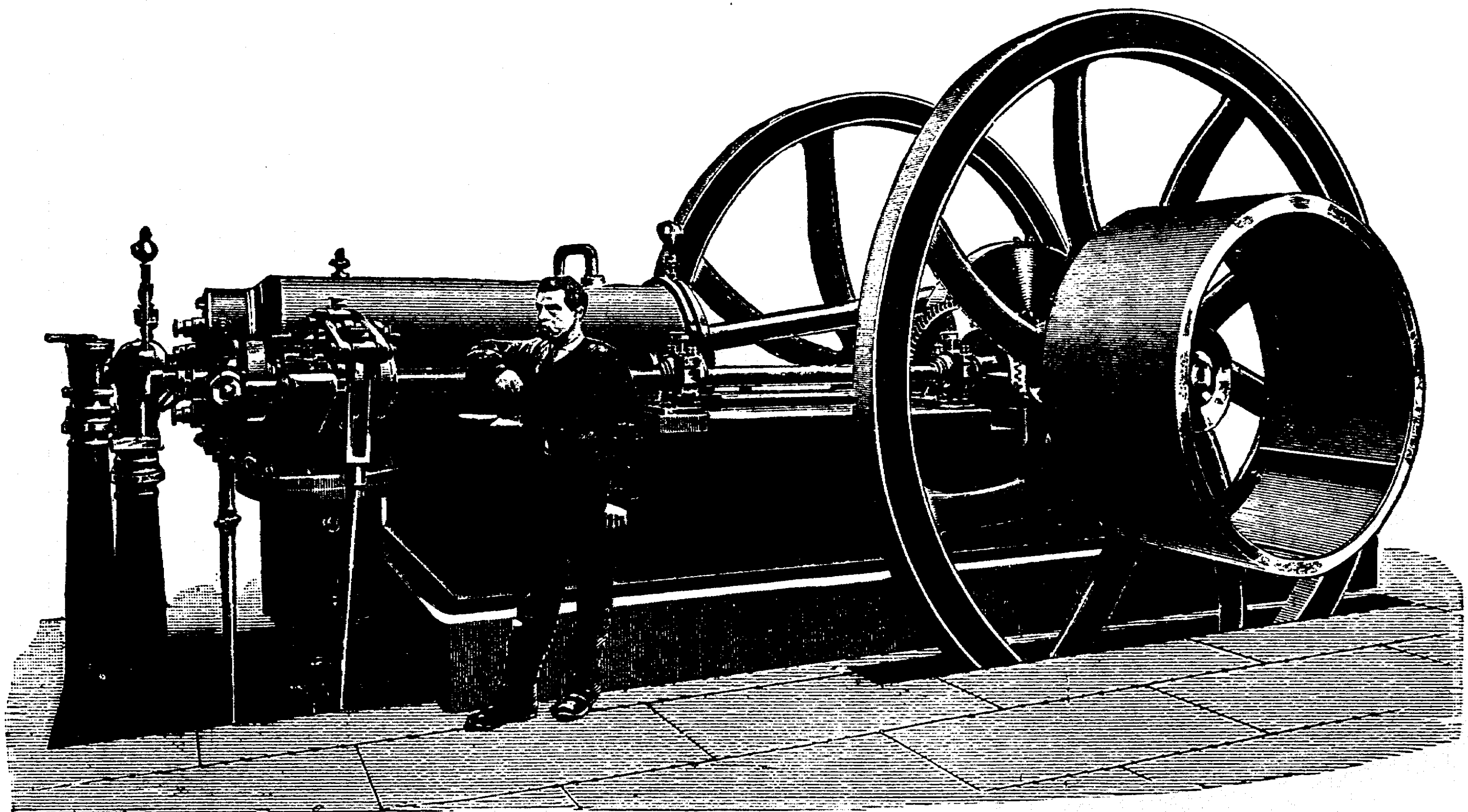


FIG. 52—The "Simplex" gas engine of 100 horse-power, exhibited by Thomas Powell, France.

The mixture of air and gas occurs in a receptacle fixed on the cover of the slide, instead of in the interior of the slide where mixture is made in the Otto engine. The air enters at one side of this receptacle, which is globular, and meets the gas as it enters through a valve on the opposite side. At the proper time a port in the slide opens communication between the mixing receptacle and the breech of the cylinder, and the mixture is then drawn rapidly through a passage way of varying cross section into the cylinder by the ad-

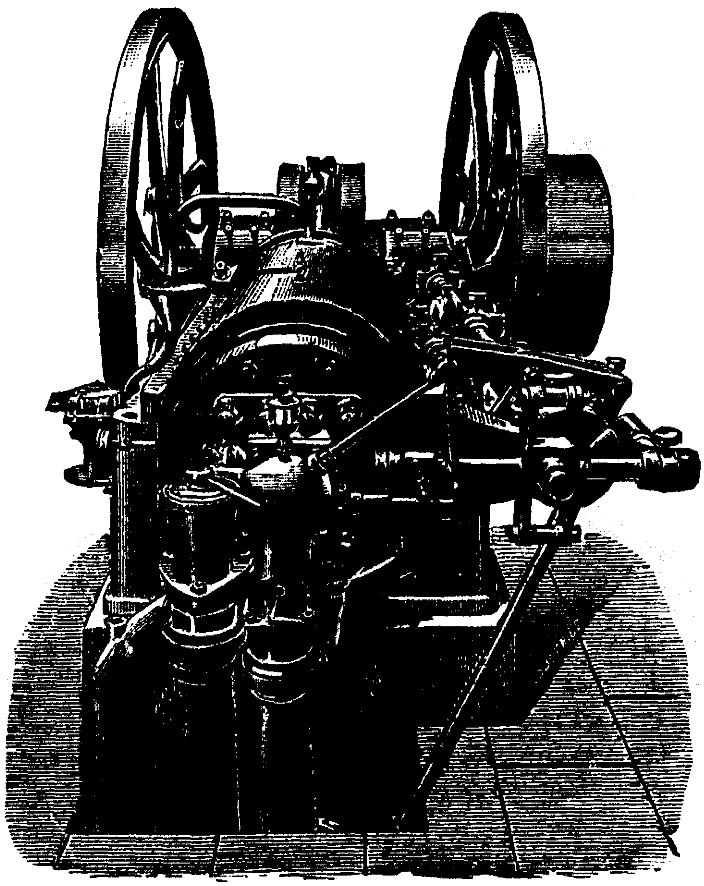


FIG. 53.—End view of 100 horse-power "Simplex" gas engine.

vancing movement of the piston, a complete mingling of the air and gas being thus produced.

The quantity of mixture admitted is constant, and its quality always the same whenever gas is admitted at all; the power of the engine being regulated, as in the Otto engine, by entirely suppressing the admission of gas, and admitting air only, during one or more revolutions, at times when an increased speed indicates that less effort upon the piston is required. The construction and action of the pendulum governor which determines the periods of opening the gas valve are novel and will be described further on. The exhaust takes place through a puppet valve lifted by a lever which has a creeping fulcrum, so that the valve is raised slowly and forcibly at first, but is lifted rapidly and widely after the pressure which holds it shut is relieved, and thus occasions but little resistance to the outflowing gases.

The ignition is by an electric spark produced in the interior of the admission slide, in a chamber which comes in communication with the cylinder port at the proper moment for ignition. The ignition does not take place at the instant the acting stroke of the piston begins, but at a point somewhat later, as shown by the indicator diagram in Fig. 54.

The first inch or two of the stroke is made under the pressure of the mixture in expanding from a condition of overcompression produced by the previous return stroke, and the mixture is then ignited; by this means a less violent shock is given to the joints of the connecting rod and shaft journals, while but little if any diminution of power is occasioned by the retarded ignition.

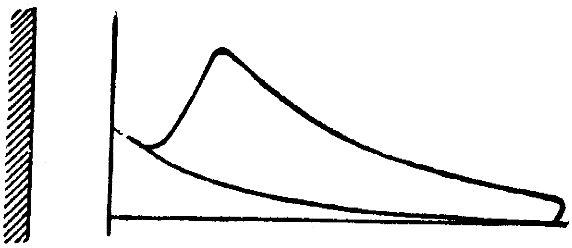


FIG. 54.—Indicator card from the "Simplex" gas engine.

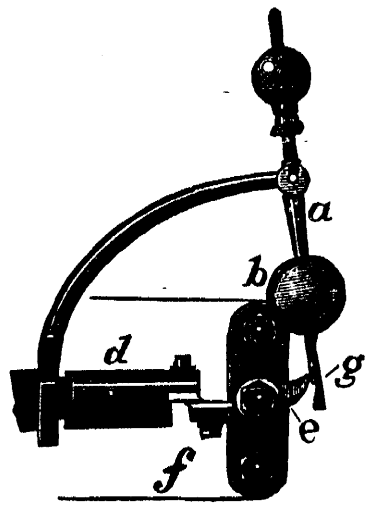


FIG. 55.—Pendulum governor of the "Simplex" gas engine.

Fig. 55 shows the arrangement of the governor and the parts connected with it by which the gas valve is opened.

The pendulum is a rod, *a*, with a heavy bob, *b*, near its lower end, and having at its upper end a counterweight the distance of which from the point of suspension is adjustable, so that the period of oscillation of the compound pendulum thus formed can be made to coincide with that of the reciprocating movement of the admission slide. The fulcrum of the pendulum is between the two weights, and is upheld by a fixed arm attached to the cover of the slide. The gas valve, whose stem is shown at *d*, is on the side of the cover nearest the pendulum, and is kept closed by a spring, but is opened at times by a dog, *e*, which is pivoted near the middle of its length to the slide *f*, and travels back and forth with the slide. The dog *e* is so acted upon by a spring that it is held nearly horizontal with its point falling somewhat below the valve stem *d*, so that, unless its point is tipped upward when it is carried forward by the inward movement of the slide, the point will clear the end of the valve stem and fail to engage with it; but if when the slide moves inward the tail of the dog *e* is slightly depressed, the point comes in range with the end of the stem, and, engaging with a notch which is in the end, pushes the gas valve open.

When the engine is running at its normal speed—that is at the speed for which the oscillations of the pendulum are adjusted—or at a slower speed than that, the tail of the dog *e*, by which the pendulum is pushed backward in the outward movement of the slide *f*, remains in contact with the lower end of the rod of the pendulum during all the time that the slide is moving inward and the pendulum swinging forward, or at least during the greater part of that time. In this condition of affairs a small shoulder, *g*, on the pendulum rod comes in contact with the tail of the dog some time before the pendulum has reached a vertical position, and depresses the tail so that the point of the dog engages the valve stem and pushes the valve open. If, however, the speed of the engine is so great that the strokes of the admission slide are more rapid than the oscillations of the pendulum would be if unchecked, the inward movement of the slide will carry the dog forward so rapidly that the pendulum will lag behind and the projection *g* of the pendulum fail to strike the tail, so that the point of the dog will not be lifted but will pass beneath the gas-valve stem, and the valve will consequently remain closed for that stroke of the engine.

(56) The great difficulty usually experienced in starting large gas engines has been overcome in this engine by very simple means, made possible by the peculiar method of ignition employed. The inventor's own description of the arrangement is given:

The arrangement for engines of 20 horse-power and under will first be described, and its increased simplicity for engines of larger power will then be pointed out. For an engine of 16 horse-power, for example, a small gas pipe furnished with a three-way cock is fitted on the igniting apparatus: an admission passage for gas traverses the barrel of the cock, and a small hole of suitable section communicating with the outer air is pierced in this passage. An india-rubber tube connects this gas pipe with the gas supply of the engine, and at the point of junction is fixed a small graduated cock (which may be called the gas cock), the degree of opening of which regulates the proportions of the explosive mixture. The method of starting is as follows: The engine must previously have been stopped at the ignition point, which is easily done by means of the three-way cock. The induction coil is fitted with a contact breaker, which interrupts the flow of sparks between the platinum points. When this is done the three-way cock is first opened, and then the gas cock to the marked position. The fly wheel is now slowly turned to draw in the explosive mixture, and when the piston has made two-thirds of its stroke, the three-way cock and gas cock are closed; then the plug of the large gas cock used when the engine is running is turned, and set at the position convenient for starting; the fly wheel is turned backward to compress the charge, the electric current switched on, the spark produced, the charge ignited, and the fly wheel receives an impetus sufficient to start it. For motors of 20 horse-power and under, it is necessary to compress the charge slightly (as just described), because the passive resistances are proportionately great; but with larger engines this is not necessary, and the operation is as follows: A small pet cock is fixed on the cylinder above the compression chamber, forming a communication between its interior and the outer air. The engine must be stopped, not at the point of ignition, but somewhat in advance, with the crank at an angle of 90 degrees, which, as before described, is easily done by means of the three-way cock. The piston has then made about half its stroke; the gas cock is opened to the marked position as before, as is also the three-way cock. As the gas is under slight pressure, it enters the cylinder through the seating, and draws in air with it by the small oblique hole. The explosive mixture thus formed gradually fills the space behind the piston, expelling the burnt gas by the cock at the top of the cylinder, which must be opened previously to that for the admission of the gas. In about a minute (for a 50 horse-power engine) the cylinder is full of explosive gas, and the cock above the cylinder, the gas cock, and the three-way cock are then closed. As before, the large gas cock is opened to the starting position, the electric current switched on, the charge ignited, and sufficient impetus thus given to the fly wheel to start the engine.

(57) In using petroleum vapor instead of gas, a peculiar carburetter is used, which is described by M. Delamare-Deboutteville as follows:

A receiver containing products of low density is placed immediately above a spiral horsehair brush, fixed in a jacketed chamber heated by the hot water from the motor, which neutralizes the refrigeration due to evaporation. Below this receiver is fixed a cock, with a graduated disk, by which the supply of the liquid is regulated according to the consumption of the engine. Close to this is another cock, admitting the hot water coming from the cooling jacket of the engine, and this water, at a temperature of about 122 degrees F., mixes intimately with the petroleum vapor, which it carries along with it in its fall on to the brush, and by the time that it reaches the lower receiver the complete evaporation of the light essence has been effected. A safety valve, through which the gas is admitted to the motor, obviates any backward ignition. It might be thought that the water would absorb a part of the light essence, and so cause a considerable loss; but this is not the case, and experience shows that the whole of the carburetted vapor is volatilized. The only constituents absorbed by the water are the mineral and vegetable substances before named, and all incrustation from this cause is completely prevented. After several months' working the engine is in as good condition as on the first day. Moreover, there is no fear of the gradual impoverishment of the liquid, as the whole of the volatile constituents are evaporated from each part as it flows through; so that the working is always regular from beginning to end, and the power given off is always the same.

(58) *Tests of gas consumption.*—Trials have been made by Dr. Aimé Witz, of Lille, the data and results of which, certified to by him, were as follows:

Leading dimensions of the engine: Diameter of cylinder, 7¾ inches; stroke, 15¾ inches; speed, 160 revolutions per minute. The effective work given off by the motor was measured by a Prony brake. The ordinary lighting gas used contained about 600 heat units per cubic foot at constant volume; the Dowson gas, comparatively rich in carbonic oxide, about one-fourth of that quantity. Mean pressure of the town gas, three-fourths of an inch of water; of the Dowson gas, 2½ inches. Trials of November 7, 1885: Duration of trial, 1 hour; effective horse-power, 6.70; consumption of town gas per effective horse-power per hour, 22.09 cubic feet; reduced to 32° F. and 30 inches barometer, consumption 21.55 cubic feet; water per effective horse-power per hour, 5.47 gallons; temperatures, entering 51° F., effluent 135° F. Duration of trial, 2 hours; effective horse-power, 8.67; consumption, 20.66 and 20.12 cubic feet; water per effective horse-power per hour, 4.44 gallons; temperatures, 51° F. and 144° F. Duration of trial, 1 hour; horse-power, 9.28; consumption, 21.23 and 20.73 cubic feet; water, 4.38 gallons; temperatures, 50° F. and 172° F. Trials of November 8, 1885: Dowson gas; duration of trial, 2 hours; horse-power, 7.12; consumption, 89.97 and 88.03 cubic feet; water, 5.83 gallons; temperatures, 48° F. and 144° F. Duration of trial, 30 minutes; horse-power, 3.61; consumption, 188.14 and 114.85 cubic feet. Duration of trial, 30 minutes; horse-power 5.26; consumption, 100.71 and 97.88 cubic feet; consumption of oil (Moehring), 5.68 ounces per hour. The inventor states that other trials of the Simplex motor have given the following results: A 50 horse-power engine, working with a load of 35 to 40 effective horse-power, consumes daily, with a Dowson generator rather underpowered, 51 pounds of English anthracite coal per hour, equivalent to a consumption of from 1.148 to 1.30 pounds per effective horse-power per hour, inclusive of everything. A 16 horse-power engine, supplied with coal gas and working with a load of 12 effective horse-power, uses 2,327 cubic feet per day of ten hours, or 19.4 cubic feet per effective horse-power per hour. These two engines are in constant work, and their consumption is calculated from the daily records kept for several months, and not from experiments.

(59) *Louis Charon's engine.*—Messrs. L. Charon & Co., of Solre-le-Chateau, France, exhibited a small motor which has interesting features, although the engine has as yet attracted but little notice.

It is a horizontal engine with a four-process cycle, but differs from others of that kind in that the compression of the explosive mixture, and, consequently, the expansion of the ignited gases, are varied by the action of the regulator; an advantage which has been attained without complicated mechanism.

The admission of the mixture and its ignition are never omitted, and its quality remains nearly the same, but the quantity is graduated according to the power required. Two puppet valves, regulated by the governor, control this admission; the first is the valve for admitting the gas, and the second a valve through which the air mixed with the gas passes. This second valve, which serves also for retaining the mixture in the cylinder, remains open during the entire forward or suction stroke of the piston, and also during a certain part of the time when the piston is returning to compress the mixture, so that a portion of the mixture is then allowed to escape. The quantity which thus escapes is regulated by the governor, which controls the time of closure of the valve, this closure taking place early when the engine runs too slowly, and late when the speed is greater than necessary. The compression is therefore feeble, and the explosive force consequently comparatively small, when but little power is required, but becomes increased when there is a greater demand for power, because the earlier closure of the retaining valve causes a greater quantity of the mixture to be retained in the cylinder and subjected to greater compression, which determines a much higher acting pressure and greater development of power when the ignition takes place. The portion of the explosive contents of the cylinder which is thus ejected by reason of the delay of the retaining valve in closing is not wasted, for this portion of the mixture is forced into a coil of pipe through which the air supply for the cylinder is drawn, and the rejected gaseous mixture which the coil receives is again taken into the cylinder, unchanged in quality, when a supply is needed for subsequent strokes of the piston. The coil thus serves as a temporary reservoir for the supply of explosive mixture whenever it contains any, and also acts as a pipe for conveying air to mix with the gas whenever there is no mixture remaining in the coil. The gaseous mixture received by the coil does not escape at the lower end, which is open to the air; the stratification of the gas and air seems to remain undisturbed, and diffusion does not take place to a degree sufficient to permit the odor of gas to be perceived at the open end of the coil.

The governor regulates the extent or time of opening of the gas valve in such a manner that the gas supply is proportioned to the quantity of air drawn through the coil, so as to maintain the quality of the mixture practically constant.

The arrangement of the exhaust valve is essentially the same as in the Otto engine. The ignition is produced in a small chamber in the breech of the cylinder by means of an electric spark, by an ingenious arrangement described elsewhere.*

A 4 horse-power engine tested by M. Witz gave the exceedingly good economical results stated in the introduction to this chapter; namely, a consumption of 19½ cubic feet of gas per hour per effective horse-power.

(60) *The Lenoir engine.*—The Parisian Company for lighting and heating by gas, and Messrs. Rouart Bros. & Co. made a very extensive exhibit of Lenoir engines of an improved type.

Lenoir was one of the early inventors of the gas engine. The engine which now bears his name is of the four-process cycle type with a few peculiarities. The rear part of the cylinder in which the compression is effected is surrounded with broad thin circular wings

*See the report on Electricity, by Mr. Carl Hering, in this volume.

which form extended cooling surface in contact with the outside air, while the front part of the cylinder has a water jacket or reservoir in which, in some cases, no provision is made for the circulation of water, a quantity of the water contained in the jacket being boiled

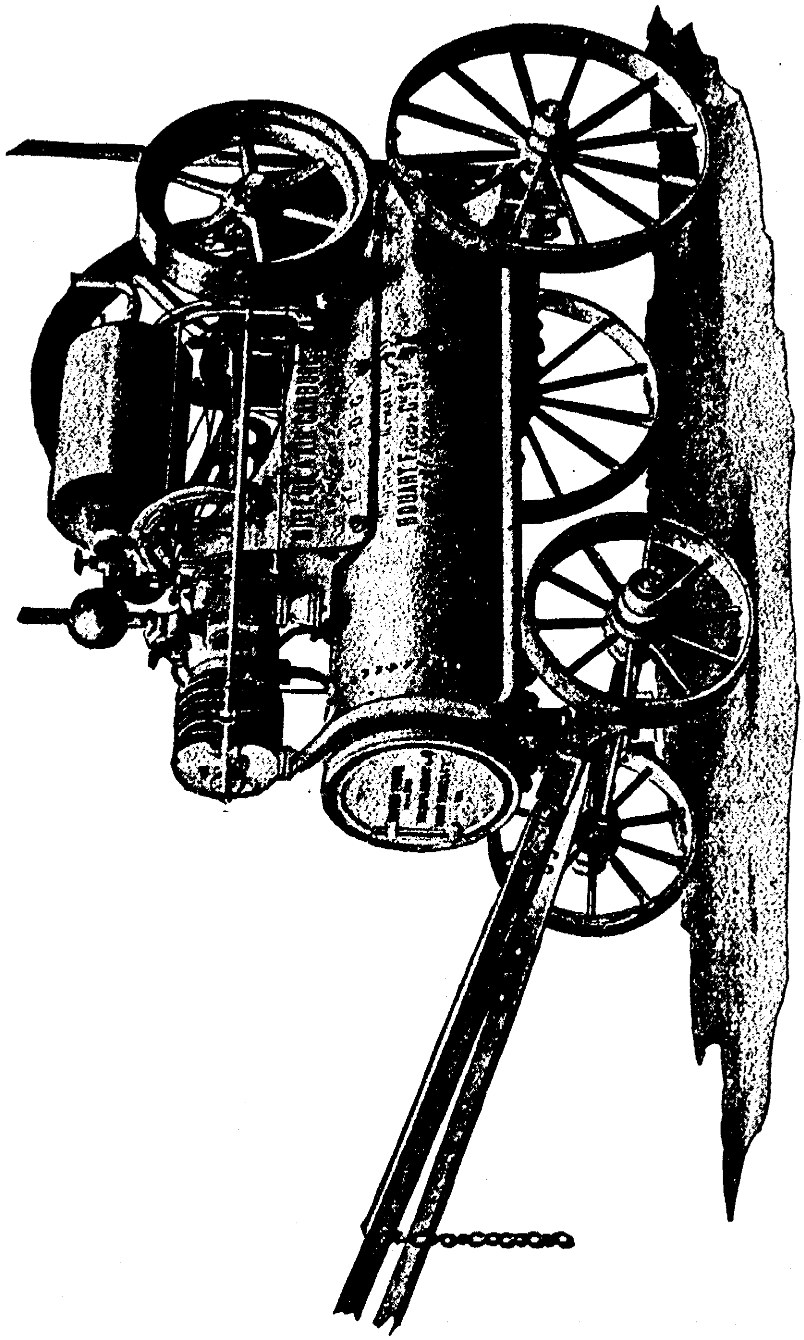


Fig. 56.—Agricultural gas engine, with carburizer; by Rouart Bros., France.

away by the heat generated in the cylinder; and, although the water remains at 212° enough heat is absorbed by the vaporization to keep the cylinder sufficiently cool.

Puppet valves are used for the distribution. The ignition is by means of a spark from an induction coil.

In some of the engines a device is provided for calling attention to a neglect to regulate the gas admission cock properly. It is an electric alarm placed over the gas bag and so adjusted for a gas pressure of about five-eighths of an inch of water as to continue ringing a bell whenever the pressure is of the desired degree or greater than that. If, then, the bell rings continuously the gas cock must be closed slightly, but if the ringing ceases entirely the cock must be opened by degrees until the ringing is intermittent, in which condition the adjustment is correct.

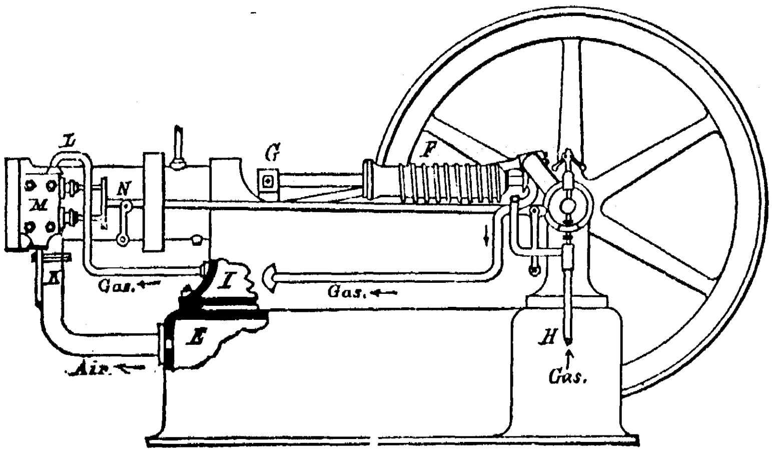


FIG. 57.—Ravel's gas engine.

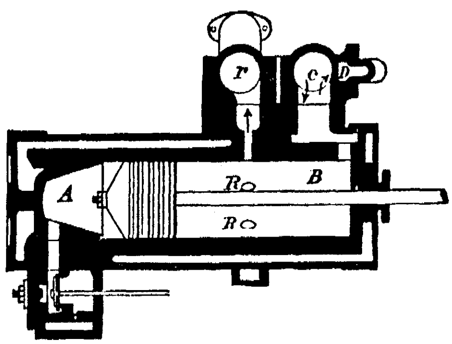


FIG. 58.—Horizontal section of the cylinder of Ravel's gas engine.

(61) The Messrs. Rouart employ carburizers and apparatus for petroleum vapor in connection with these engines, and adapt them for agricultural use. They showed an engine and apparatus of this kind mounted on wheels for use in the field (Fig. 56), and also exhibited a petroleum launch, in the Seine river.

The economy of these engines is good, a 2 horse-power engine having consumed about 25 cubic feet of gas per effective horse-power per hour during a test made by M. Tresca in 1885.

(62) *The Ravel gas engine.*—This is exhibited by the Société des Moteurs à Gaz Français, Paris.

Fig. 57 shows a side view of the engine, and Fig. 58, a horizontal section of the cylinder.

It works upon essentially the same principle as the Baldwin engine, of which a full description is given, receiving an impulse at every revolution of the shaft. There are some differences which will be noticed. Air is drawn into the front end of the cylinder through a puppet valve, the chamber of which is at C, and is forced at a pressure of 4 or 5 pounds per square inch into a reservoir, E, in the sub-base of the engine. Gas is taken through the governor valve V into a small pump, F, worked from the crosshead G, and is forced into the reservoir, I, in the frame of the engine, where it is kept separate from the compressed air and maintained at about the same pressure as the air. Puppet valves in the valve box M admit the air and gas to the rear end of cylinder whenever they are opened by the eccentric rod N. The exhaust takes place through ports, R, in the cylinder walls, which are uncovered by the piston at the end of the forward stroke, but, as the piston is made quite short, a puppet valve, the chamber of which is at *r*, is used to prevent the escape of the compressed air from the front end of the cylinder, and this valve has to be raised by a lever worked from the shaft just before the ports R are uncovered, in order that the exhaust from the back end may take place. The products of combustion are expelled from the cylinder by the entrance of the mixture, which takes place at the end of the forward stroke through a passageway leading from the box M and entering the cylinder breech tangentially, so that the mixture shall not be projected toward the exhaust ports and wasted by escaping from them. The mixture is compressed by the returning stroke of the piston and then ignited by an electric spark. The gas pump, and separate reservoirs for gas and air, are the features which attract attention. The consumption of gas in this kind of engine is somewhat large.

(63) *The Ragot petroleum engine.*—This engine was exhibited in the Belgian section by the Société Anonyme des Moteurs Inexplosibles, of Brussels. It is shown in Fig. 59.

The engine is of 5 horse-power, is on the same general principle as the Otto gas engine, has puppet valves by means of which the distribution is effected, and the ignition is by an electric spark.

It is fed with liquid petroleum of ordinary density, which is vaporized in a generator, shown at A in the figure, consisting of a conical casing of cast iron which incloses a smaller concentric cone of copper provided with wings to increase the heating surface. The interior of the copper cone receives the hot gases exhausted from the engine cylinder, and is thus heated, while the space between the cones communicates by a pipe with the governor valve, through which the air and inflammable vapor are drawn into the cylinder of the engine. A small pipe at the apex of the outer cone admits petroleum from a reservoir to an atomizer, through which drops of petroleum and a small current of air are drawn by the vacuum produced in the space between the cones by each suction stroke of the piston. The petroleum, which is thus converted into a fine spray, is vaporized by contact with the copper cone, and permeates the air which has entered with it and become highly heated. The necessary quantity of this mixture of air and vapor, which is inflammable but not explosive, passes to the governor valve, through which it is drawn into the cylinder together with additional air in quantity sufficient to make an explosive mixture. The mixture thus introduced into the cylinder is compressed by the return stroke of the piston and ignited in the next outward stroke.

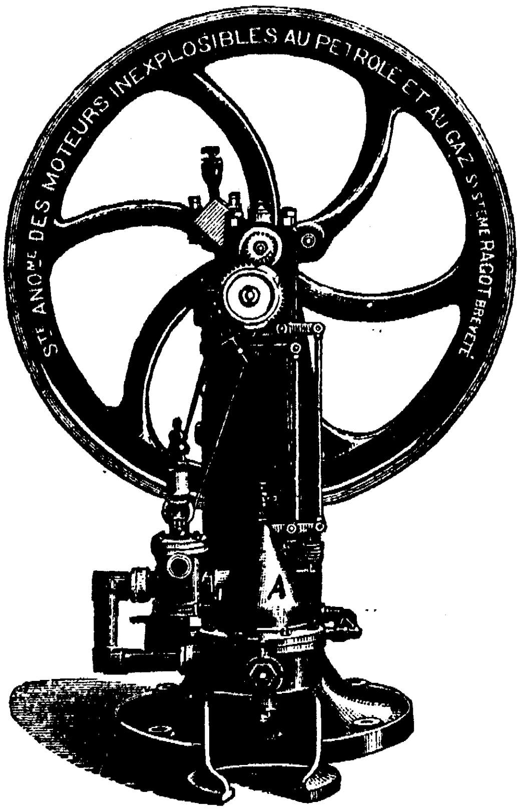


FIG. 59.—Ragot's petroleum vapor engine.

To start the engine the vapor is produced by heating the copper cone by the flame of an oil lamp placed beneath the vaporizer.

From 300 to 500 grams, say about a pint, of petroleum per hour is required for the production of each horse-power.

(64) *The Taylor engine.*—Messrs. John Taylor & Son, of Nottingham, England, exhibited horizontal and vertical gas engines with two cylinders side by side, one of which acts as a pump to transfer the gas and air to the other cylinder, in which the ignition occurs once in every revolution of the shaft.

The engines are compact and exceedingly well built. They run at a high speed.

(65) *The Griffin engine.*—This was exhibited by G. C. Bingham, of London, England.

The peculiar cycle of processes employed in this engine has been described in the introduction to this chapter, and a further notice is unnecessary.

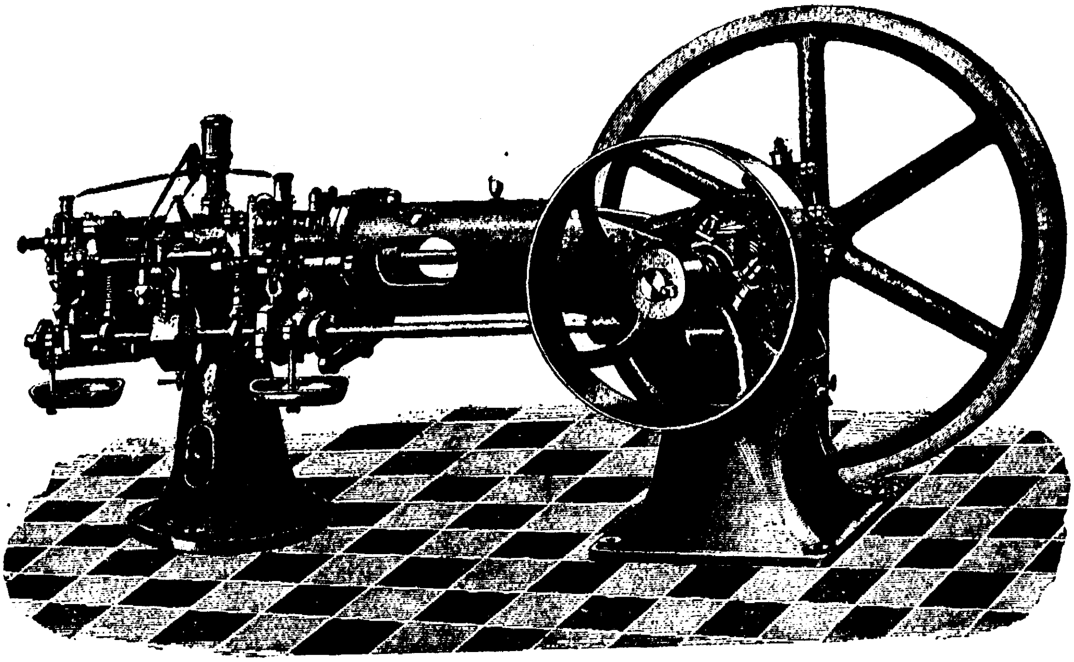


FIG. 60.—General view of the Griffin gas engine.

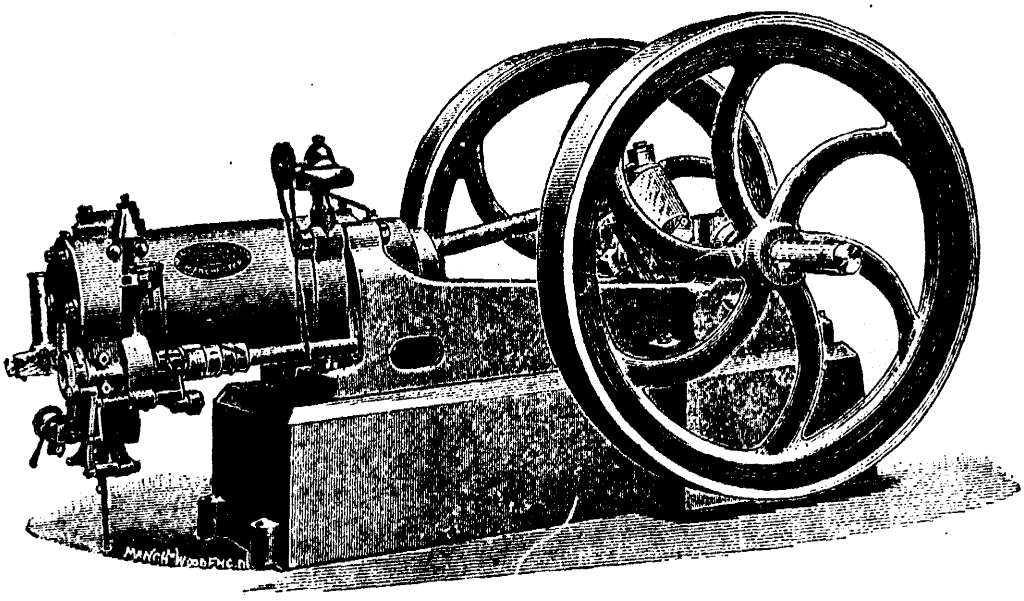


FIG. 61.—Crossley's gas engine, Otto type, with puppet valves and tube igniter.

The general appearance of the engine and the arrangement of the valve gear can be seen in Fig. 60.

(66) *The Crossley Brothers' Otto engines.*—In the British section

Messrs. Crossley Brothers, of Manchester, England, made a very striking display of gas engines of the Otto type, for which they received a gold medal. They exhibited eight engines, some horizontal, others vertical, varying from one-half horse-power to 25 effective horse-power.

These engines do not differ, in any of the essential principles of operation, from the Otto engines manufactured on the continent. Their design, however, is much more elegant, and some of the arrangements are more convenient. The general appearance of the 25 horse-power engine is shown by Fig. 61.

Puppet valves were employed for the distribution and the slide was dispensed with in one or two of the engines exhibited.

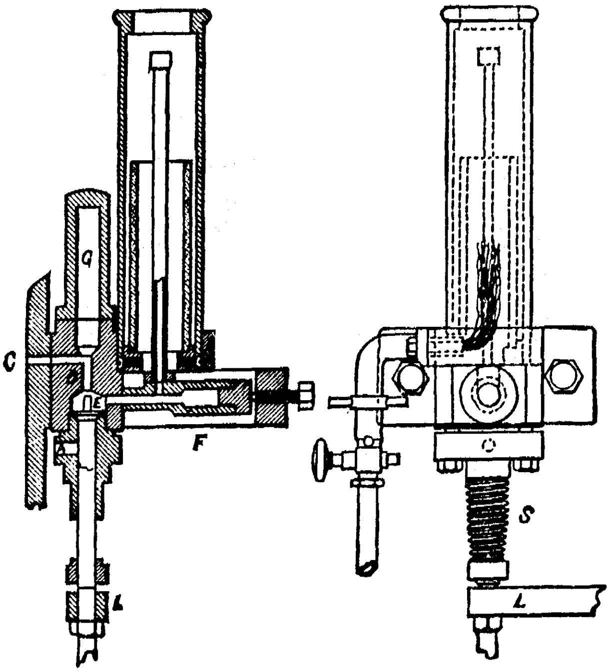


FIG. 62.—Igniting apparatus used in the Crossley Otto engines.

Fig. 62 shows the arrangement of the tube by which the ignition is produced. A similar method of ignition has been described in connection with the Otto engines manufactured by the Compagnie Française.

C is the port from the cylinder, G the chamber for the reception of the burned gas from C; E a small puppet valve which is worked by a lever and determines the instant of ignition by opening and closing the passage D and outlet A alternately; T the igniting tube kept hot by a Bunsen burner; and F a pocket to receive a portion of the inflammable gas which, when ignited, blows the flame into the cylinder. An asbestus chimney surrounds the burner flame.

It was stated that the Messrs. Crossley had built a vertical gas engine of 120 horse-power which was working with the remarkably small consumption of 15 cubic feet of gas per hour per horse-power.

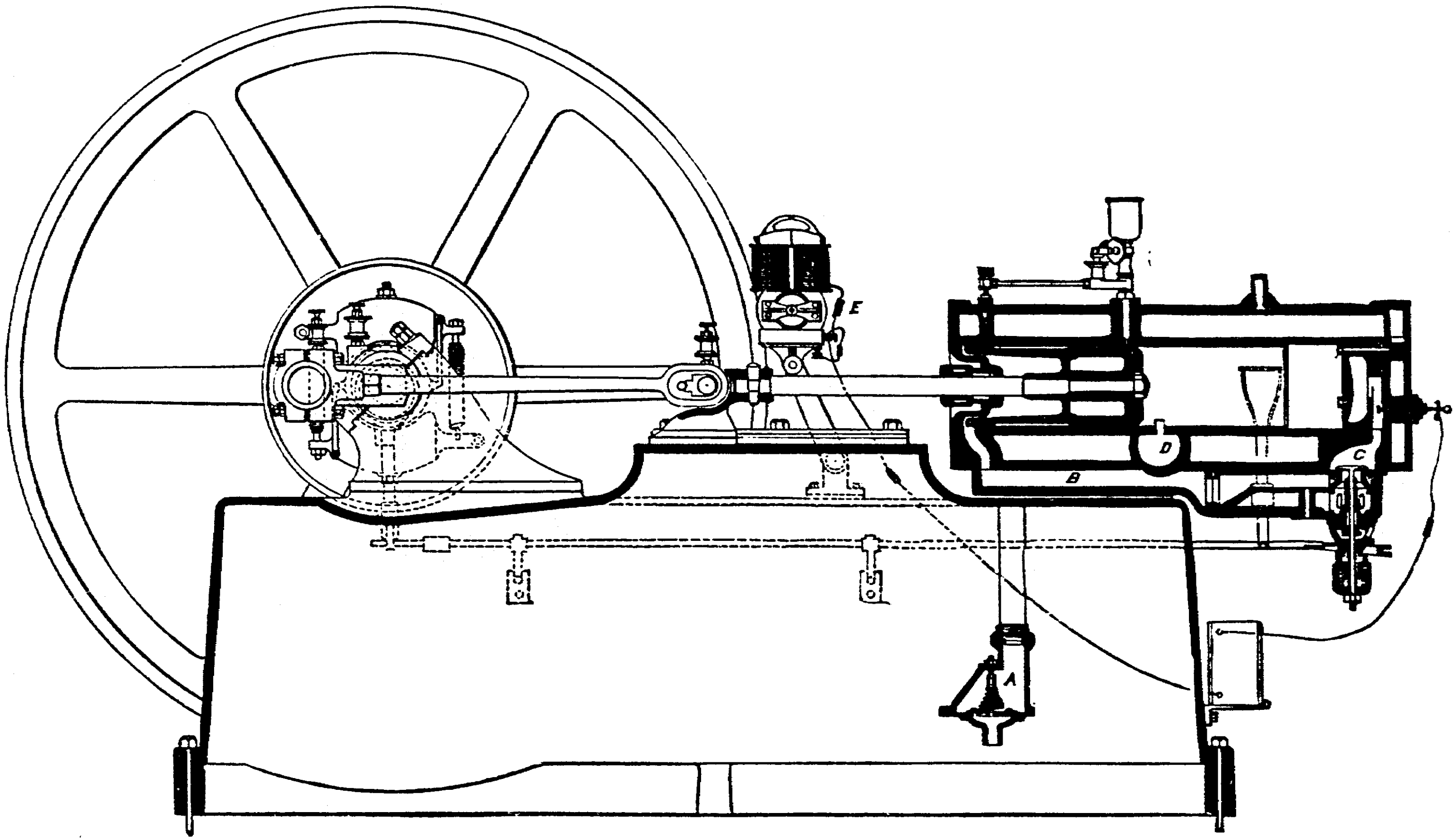


FIG. 63.—Sectional view of Baldwin's gas engine.

This engine was not exhibited and no official certificate of its performance was presented.

(67) *The Baldwin gas engine.*—Two of these engines were exhibited in the United States section by Messrs. Otis Brothers & Co., of New York, who received a gold medal.

The engines are of very neat form, are simple in construction, and run with great regularity and steadiness.

This motor belongs to the second of the classes into which the gas engines have been divided; namely, to that class in which an ignition occurs once in every revolution of the shaft. In the Baldwin engine, as in most engines of this kind, the gas and air are taken into the front end of the working cylinder by the backward movement

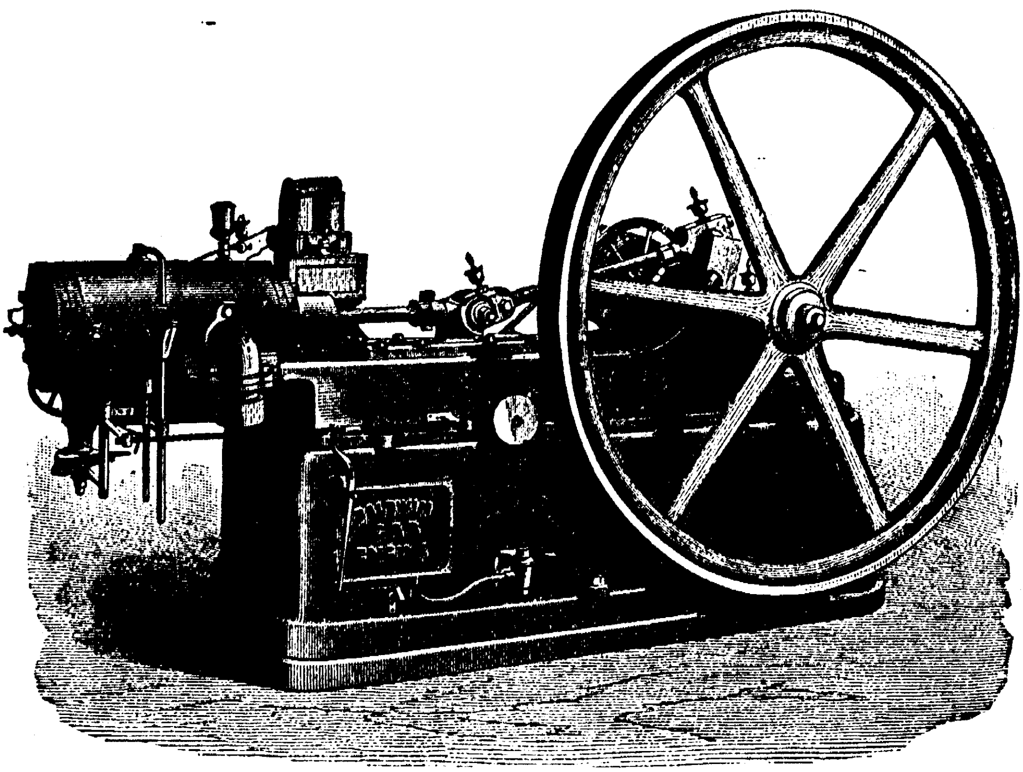


FIG. 64.—General view of the Baldwin gas engine.

of the piston, and are transferred to a reservoir from which a supply is taken into the rear end, which is the working end of the cylinder, as needed; but it differs from most, in that the inflammable mixture enters the working end of the cylinder at the end of the piston's forward stroke, and is compressed by the piston on its return.

A longitudinal section of this motor is shown in Fig. 63, and the general appearance of one of the earlier forms of the engine by Fig. 64.

The gas and air are drawn into the front end of the cylinder, through a valve box, A, in the engine bed, by the backward movement of the piston, the forward movement of which compresses the mixture in the reservoir B which lies beneath the cylinder. The mixture passes from the reservoir through the valve C into the rear of the cylinder, where it is ignited. The exhaust takes place through a port, D, which is located nearly midway between the ends of the cylinder, and is uncovered by the piston just before the forward stroke is completed. At the instant the pressure in the cylinder is relieved by the opening of the exhaust ports, the valve C is lifted automatically by the excess of pressure which then exists in the reservoir B, and the inflammable mixture enters the back end of the cylinder and displaces the burned gases, without, however, having time to escape through the exhaust ports, which are covered by the piston as soon as the return stroke begins. The backward stroke of the piston compresses the mixture in the back end of the cylinder to prepare it for ignition, and at the same time draws fresh mixture into the front end for transfer to the reservoir in the next revolution of the shaft.

The ignition is produced by sparks from a small dynamo, E, driven by the contact of its pulley with the periphery of the engine fly wheel.

The speed of the engine is controlled when too rapid, not by omitting the admission of gas, nor, generally, by reducing the quality of the inflammable mixture, but by limiting the quantity admitted. To accomplish this the lift of the valve C is regulated by the action of the governor in the following way: The valve C is held down to its seat by a spring which is not too stiff to prevent the pressure of the mixtute in the reservoir B from lifting it; the height to which the valve can rise is, however, limited by a curved wedge against which a head on the lower end of the valve stem strikes when the valve lifts. When the engine runs more slowly than its normal speed the thin edge of the wedge permits the valve to rise to its greatest extent, but if the speed increases, the thicker part of the wedge is drawn forward so that the valve rises less and less, and the mixture enters the cylinder at a lower tension, and consequently in less quantity than before. This method of regulation is applied alone for moderate changes of speed, but when greater increase takes place an attachment to the governor, which then comes into play, closes by degrees a throttle valve in the gas pipe, and reduces the inflammability of the mixture as well as its quantity. To prevent the mixture from entering the acting end of the cylinder in such a way that it will flow directly to the exhaust port and escape with the products of combustion, the port into the cylinder breech is located in the axis of the cylinder, and a deflector, or "retarder," as it is called, consisting of a plate perforated with circular rows of holes near its outer edge, is placed in front of the entrance port to produce a uniform distribution of the mixture in the cross section of the cylinder.

The regulator is an ingenious application of a shaft governor, which moves an oscillating lever laterally in such a way that one or the other of two pawls at the end of the lever engages with a ratch on either side of the rod by which the curved wedge is moved, so that the rod is worked one way or the other, or left standing still, according to the change or uniformity of the speed of the engine, the teeth of the ratches on the opposite sides of the rod being inclined in opposite directions.

The engines worked exceedingly well and quietly during the Exposition. One of them was used for driving a dynamo, and produced light from incandescent lamps remarkable for its steadiness; the other was a self-contained pumping engine. As the engines have an ignition every revolution, they exert large power in proportion to their dimensions.

V.—HYDRAULIC MACHINERY.

(68) Although no inventions of marked importance relating to hydraulic apparatus were presented, yet there were many exhibits in this class of machinery that were interesting either for boldness or skill in conception, or as examples of the application of hydraulic power on a very large scale. Others were noticeable for neat design and good execution.

More than 50 years ago France was the birthplace of the modern turbine,—that type of hydraulic motor which has practically displaced all that preceded it. It was interesting on this account to look for the evidence the Exposition afforded of improvement in the form of this remarkably efficient and convenient machine for utilizing the power of water, and to learn which of its numerous forms is standing highest in popular favor, or whether any one form is asserting a marked superiority over others. This class of machinery, then, deserves the first consideration.

TURBINES.

France and Switzerland were the two nations which vied with each other in the display of turbines, and it is just to say that the Swiss section contained the most extensive and most interesting exhibits of this kind.

(69) Notably there were only two general types of turbines extensively shown; the Jonval or Fontaine parallel flow pressure turbine, and the Girard turbine. Both varieties are of French origin, and are held in nearly equal favor, the former kind for low falls where the wheel is submerged and the head variable, the latter for higher falls or great heads, and where the variation of head is slight, but where the resistance, and consequently the quantity of water used, is variable. The pressure turbine is extensively used in the United States, in a great variety of forms. The Girard turbine is less known here. It is essentially an impulse turbine, and differs from the pressure turbine in that the water, which is delivered to the

wheel through a series of guides or spouts, as in all other turbines, does not fill the buckets of the wheel after entering them, as it does in the pressure turbine, and is not confined by the backs and sides of the buckets, which, in the Girard turbine, are expanded so as to permit the streams from the spouts to spread laterally in the buckets with perfect freedom. The water imparts its energy to the wheel by the continuous deviation in the direction of its motion which it suffers in gliding over the front curved surface of the bucket against which it is impelled through the guide curves or spouts. The surfaces of the buckets which receive the impulse are so curved, and so directed in relation to the spouts and to the circular path in which the buckets travel, that the water leaves the wheel with a velocity only sufficient for its removal, as is the case with the water in all well-designed turbines. This kind of turbine, because of the freedom from confinement under which the water acts in the wheel bucket, is called a turbine of "free deviation" to distinguish it from the pressure turbine, in which the water is forced through the buckets, the cross sections of which are contracted so as to completely regulate the shape of the streams which pass through them, and slightly restrain the outflow of the water when the wheel is fully supplied with water. The Girard turbine is nearly, if not quite, as efficient when exerting its full power under a constant head, as the best pressure turbines are when they also are placed under the conditions of water supply and resistance for which they are designed, and is far more efficient than these when a varying resistance demands a diminution of the quantity of water supplied to the wheel; that is to say, the regulation of the Girard turbine is effected with little or no loss of economical efficiency, while the regulation of the pressure turbine, the buckets of which must be full in order to act efficiently, is attended with diminished economy. While the power of a Girard turbine may be reduced one-half, by a reduction of its water supply, without a diminution of its economical efficiency, a similar reduction of power in the best pressure turbines lessens the economy in the application of the water by 10 or 15 per cent., and in the case of a still greater reduction of power a greater proportional loss occurs.

It has been said that the Girard turbine is better adapted for high heads than for low. This is true, because in order to secure a good performance of this wheel it is necessary to place it so that the water shall issue freely from the buckets into the air, and the wheel ought therefore to stand above the level of the highest back water in the tailrace. This condition involves a small loss of head, which is not suffered in the use of a submerged, or drowned wheel, and it is only when the head becomes considerable that this loss is insignificant. The same condition makes it impracticable to place the wheel at the upper level of the fall or at an intermediate level, and prevents the use of a draft tube.

It is a distinctive feature of the Girard turbine that the efficiency of the wheel is not diminished materially by limiting the admission of the water to a few of the buckets instead of applying it to the entire circumference. The series of guide spouts for delivering the water to the buckets may advantageously be limited to a short segment of the circle which a complete series of guide blades would form, and some of the spouts may be closed while others are left open, without a material reduction in the economy with which the water is applied. There were numerous examples of these "partial delivery" or "partial injection" turbines, in which a single set of inlets consisting of a few guide spouts are used on one side of the wheel, or two sets, one on either side of the axis; in fact, this is the favorite form of turbine for very high heads, or for motors of small power, for it admits of the use of a wheel of large diameter with a proportionally slow speed of rotation, and yet the stream of water required for its economical supply is not large.

(70) A few tangential wheels were shown, in which a single stream from a spout outside the wheel is directed against spoon-shaped, or inward-curved buckets. This form has been extensively used in Europe for small powers where the head of water is great, but it is uneconomical as usually constructed, and is being abandoned in favor of the Girard wheel. In the western regions of the United States, however, the Pelton wheel, which is a peculiar form of tangential wheel, is successfully used for obtaining power under very great heads, with satisfactory economy of water. This wheel, which is of large diameter, is driven by a jet of water from a round nozzle, and the shape of the buckets is such that the impulse of the water is utilized with but little loss.

The variety in the forms of the Girard turbines exhibited was considerable. They were represented by horizontal wheels with parallel or axial flow of the water, and by horizontal wheels with an outward flow; also by vertical wheels with an outward flow.

The pressure turbines were all, or nearly all, horizontal, with parallel flow, or, as has been said before, they were of the Jonval or Fontaine type. They differed from each other chiefly in the arrangements for regulating the admission of the water; that is, in the apparatus for opening and closing the inlets.

(71) Several interesting applications of turbine wheels to pumps for city waterworks were exhibited. Two of these, with the systems of water supply of which they form a part, will be described here.

Messrs. Escher, Wyss & Co., of Zurich, Switzerland, exhibited a large Girard turbine coupled to a pair of pumps, all complete and in working condition. This exhibit was one of a set of seven pumping turbines, three of which are already in operation for supplying water to the town of Chaux-de-Fonds for domestic use and, to a limited extent, for motive power. The arrangement of this whole system of water supply is so interesting that it deserves special attention.

Chaux-de-Fonds is a town with a population of about 25,000 inhabitants, in the Jura Mountains, near Neufchatel, at a level of nearly 3,000 feet above tide, 1,000 feet above the part of the river Reuse from which the water power for driving the pumping machinery is derived, and about 1,200 feet above the pumping station. The receiving and distributing reservoir into which the pumps deliver is at a height of 400 feet above the lowest parts of the town. The supply obtained from the three pumps which are now working is at the rate of something over 1,000,000 gallons in 24 hours, and, with the four additional turbines which will complete the works, the supply will be increased to more than 2,500,000. The water that is pumped is collected from springs which formerly emptied into the river, but are now intercepted and diverted into the pump pit by means of four horizontal galleries or tunnels driven through the clayey soil through which the water percolates.

For driving the turbines water is taken from the Reuse at a place above the falls of that river, and about a mile upstream from the pumping station, where a head of 170 feet above the tailrace of the turbines is obtained.

The rising main, leading from the pumps to a receiving canal which is at an elevation of 1,600 feet above the pumping station, is a galvanized welded pipe about 10 inches in diameter and 4,000 feet long. The canal into which this pipe discharges, and the conduits with which the canal is connected, carry the water about 10 miles to the reservoir, which is still distant three-fifths of a mile from the town. It will be seen that the work was an important engineering undertaking.

The whole cost was about 1,800,000 francs, or, say, $360,000.

(72) The turbines are of the Girard type, with horizontal axes, partial injection, and outward flow. At each end of the turbine shaft is a disk crank which actuates a double-acting plunger pump with a plunger 4.4 inches in diameter and a stroke of 19.7 inches. The plungers are pointed; they work in opposite ends of pump barrels which are placed back to back, and are coupled with each other by crossheads and side rods. Metallic packing is used in the stuffing boxes to reduce the friction to a minimum. The frames on which the pumps lie, and at the ends of which the turbine shaft is supported in bearing boxes, resemble the bedplates of the Porter-Allen engines.

The diameter of the turbine is 15 feet 8 inches, its speed fifty-six revolutions per minute, and the power demanded of it 140 horsepower.

The water is delivered to the wheel at its lowest part, and on the inside of its rim of buckets.

The guide curves, or properly the guide spouts, are only eight in number.

The dimensions of the parts of such a turbine wheel under these particular conditions are computed in the following way:

The total quantity of water the wheel receives is about 10 cubic feet per second, and the head 170 feet. Assuming a coefficient of discharge of 83 per cent., the velocity of discharge will be $0.83\sqrt{64.4 \times 170} = 86.3$ feet per second, and with this velocity the cross section of the orifices required to deliver the 10 cubic feet will be, collectively, $\frac{10}{86.3} = 0.115$ of a square foot, or 16.6 square inches nearly. There are eight guide spouts, the mouths of which are actually each 2.36 inches across the face, and 0.944 of an inch wide in the direction of the circumference of the wheel; their collective area is therefore $8 \times 2.36 \times 0.944 = 17.8$ square inches, which is but little larger than the computed size of opening. The most advantageous speed of the inside edge of the wheel bucket which receives the water is one-half that of the water which strikes it, and should therefore be $\frac{86.3}{2} = 43.15$ feet per second. The wheel makes 56 turns per minute, or 0.933 of a turn per second; the circumference of the inside of the crown of buckets should therefore be $\frac{43.15}{0.933} = 46.25$ feet, and its diameter $14\frac{3}{4}$ feet. The inside of the crown is made 15 feet, and the outside diameter of the wheel very nearly 15 feet 8 inches.

There are 280 buckets. Their width across the inside of the crown of the wheel is $3\frac{1}{4}$ inches, somewhat greater than the width of the guide spouts, so that the water will not come in contact with the shrouding of the buckets in entering them, and the shrouding is made flaring, so that the width of the bucket at the outside face of the wheel is increased to nearly 8 inches, in order to permit the lateral spreading of the water to take place without restraint, on the curved surface on which it acts.

Fig. 65 is a vertical section of the lower part of the wheel, showing also the guide spouts and penstock.

The pumps are well designed for working under the great pressure they are subjected to from the lift of 1,600 feet which they have to overcome. A section of one pair of the pump barrels, showing the valve chest also, is given in Fig. 66.

The valves are direct-lifting, like puppet valves, and consist of two concentric flat annular plates connected with each other and with a central hub by radial wings. The hub is guided on a post projecting upward from the center of the valve seat, which is flat and perforated with two concentric annular ports that are covered by the concentric plates of the valve. The mean diameter of the outer port, is 6 inches, that of the inner, $3\frac{1}{2}$ inches, and the width of each port, 0.4 of an inch. The lift of the delivery valve is less than 0.1 of an inch, that of the suction valves about one-eighth of an inch. The valves and seats are of bronze, and springs are provided to press the valves to their seats. The mean velocity of the water in escaping between the delivery valve and its seat is somewhat over 10 feet per second.

As a safeguard against serious damage, which, on account of the length of the rising main and the great head, would be liable to

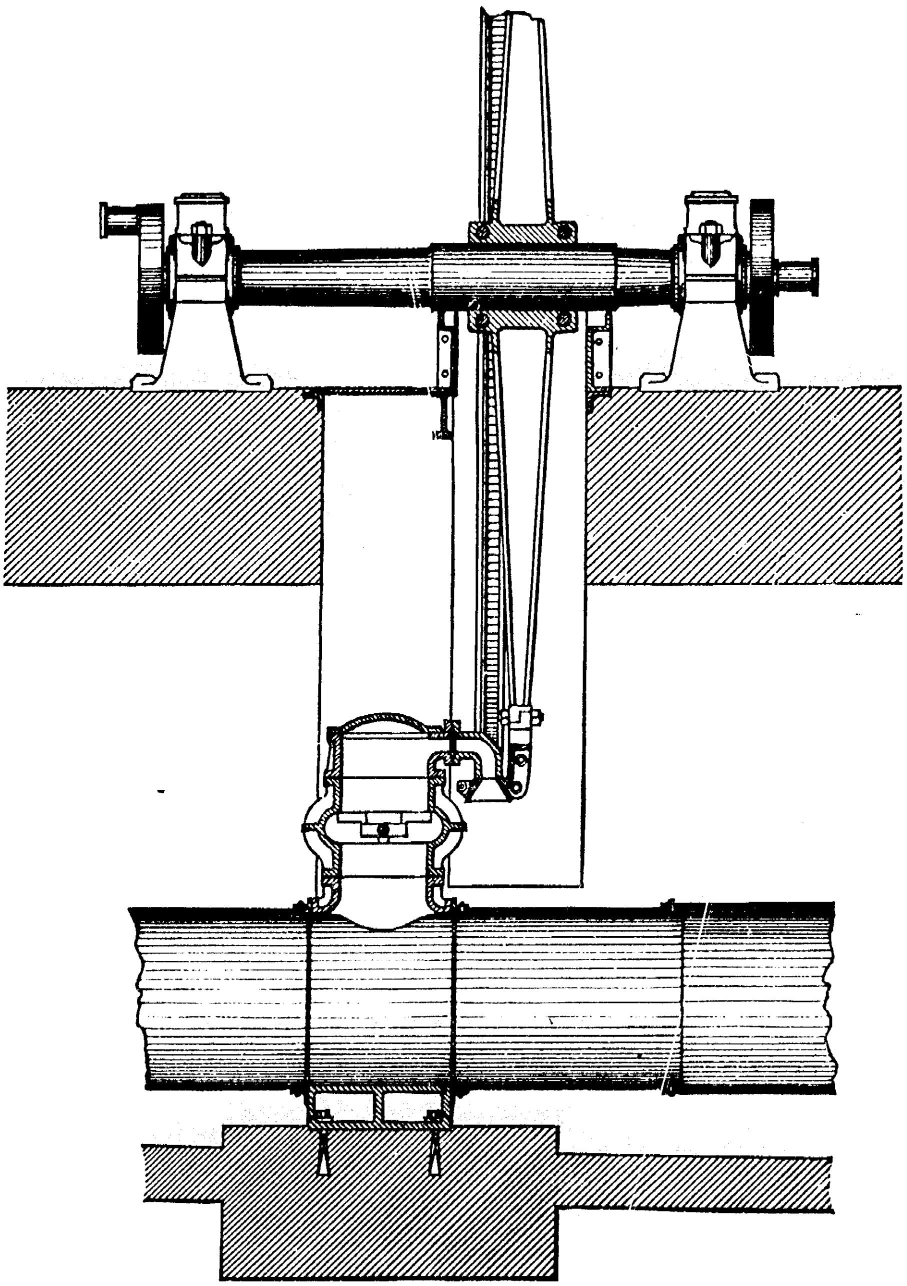


FIG. 65.—Sectional view of the penstock and lower part of one of the vertical Girard turbines of the Chaux-de-Fonds waterworks.

occur if there were a rupture of this pipe through which the pumps deliver the water to the canal 1,600 feet above them, the main is divided into four sections of equal length by means of three swinging check valves, which are pressed toward their seats by springs of

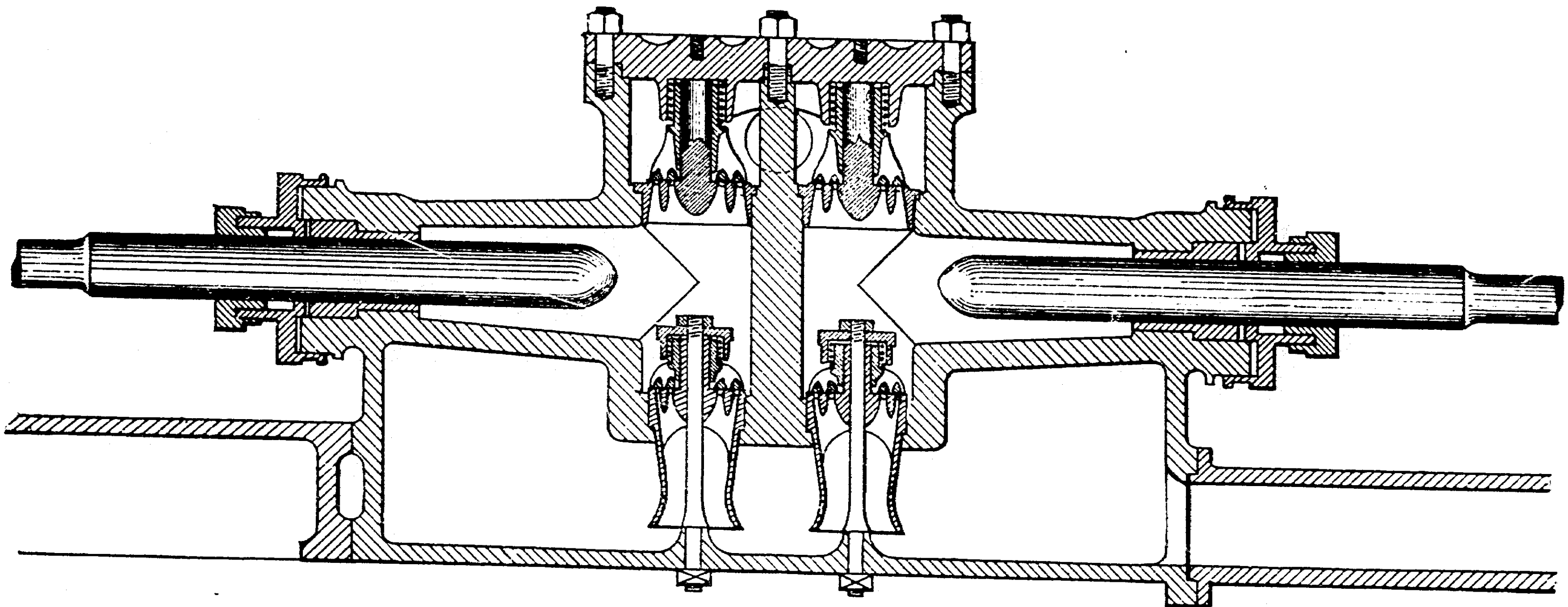


FIG. 66.—Sectional view of the plunger pumps of the Chaux-de-Fonds waterworks.

small tension, and are kept continually in slight motion by the passage of the water, so as always to be in good working condition.

The high economical efficiency obtained from this pumping machinery is by no means the least interesting feature.

The test made by the engineers for the town showed that 67 per cent. of the power due to the quantity of water delivered to the wheels under the head obtainable from the fall was returned in water delivered by the pumps into the reservoir. As it is improbable that the efficiency of the crank pumps is higher than 85 per cent., the economical effect of the turbine itself must be very nearly, if not quite, 80 per cent.; an excellent working efficiency, which demonstrates the truth of what has been claimed for the Girard turbine; namely, that its economy is excellent even when the water is distributed to only a small segment of the wheel.

All the machinery for this important work was designed and executed by Messrs. Escher, Wyss & Co.

(73) The same firm also exhibited a model, on a small scale, of one turbine and a set of pumps of the kind that are in use at Geneva for utilizing power derived from the river Rhone, and for distributing it to the manufactories and the small shops in the city where power is required, as well as for supplying water for ordinary uses.

These waterworks are interesting and instructive as an example of an extensive and successful system for the distribution of power.

(74) Before deciding upon the method of distributing the power various plans were considered; particularly, wire-rope transmission, transmission by electricity, by compressed air, and by water under pressure. In the report on this subject by Col. Turettini, the consulting engineer for the city, three tabular analyses of the cost of transmitting power by these various means were presented. They are given here with the costs in francs, as the figures are only comparative.*

TABLE I.—*Efficiency of different systems of transmission of power for different distances.*

Distance of transmission in yards.	Kind of transmission.			
	Electrical.	Hydraulic.	Pneumatic.	Wire rope.
100	0.69	0.50 to 0.65	0.55 to 0.60	0.96
500	0.68	0.50 to 0.65	0.55 to 0.60	0.93
1,000	0.66	0.50 to 0.65	0.55 to 0.60	0.90
5,000	0.60	0.40 to 0.55	0.50 to 0.55	0.60
10,000	0.51	0.35 to 0.45	0.50 to 0.55	0.36
20,000	0.32	0.20 to 0.25	0.40 to 0.55	0.13

* These tables were taken from a work by Beringer: "Kritische Vergleichung der electrischen Kraftübertragung." The costs, which were given in marks, were converted into francs, and the tables published in the Gęnie Civil of February 2, 1889.

TABLE II.—*Price to the consumer for each horse-power per hour for different systems of transmission and different quantities of power.*

Horse-power.	System of transmission.	A.—If steam is the original source of power. Distance of the engine from the consumer's premises, in yards. 100.	500.	1,000.	5,000.	10,000.	20,000.	Cost in the case of a steam engine used on the premises.
		Francs.	*Francs.*	*Francs.*	*Francs.*	*Francs.*	*Francs.*	*Francs.*
5	Electric	0.23	0.24	0.25	0.30	0.34	0.54	0.395
	Hydraulic	0.26	0.29	0.33	0.68	1.09	2.07	....
	Pneumatic	0.28	0.31	0.34	0.55	0.99	1.75	....
	Wire rope	0.12	0.16	0.19	0.57	1.08	2.37	....
10	Electric	0.21	0.21	0.22	0.26	0.32	0.50	0.273
	Hydraulic	0.25	0.26	0.29	0.53	0.80	1.49	....
	Pneumatic	0.26	0.28	0.30	0.47	0.65	1.08	....
	Wire rope	0.12	0.14	0.18	0.47	0.89	1.99	....
50	Electric	0.19	0.20	0.21	0.24	0.28	0.44	0.106
	Hydraulic	0.17	0.18	0.19	0.30	0.44	0.81	....
	Pneumatic	0.21	0.22	0.23	0.30	0.37	0.55	....
	Wire rope	0.11	0.12	0.13	0.26	0.47	1.16	....
100	Electric	0.19	0.19	0.19	0.23	0.27	0.42	0.106
	Hydraulic	0.17	0.18	0.18	0.30	0.43	0.71	....
	Pneumatic	0.21	0.22	0.22	0.27	0.32	0.47	....
	Wire rope	0.11	0.12	0.13	0.23	0.40	1.02	....

Horse-power.	System of transmission.	B.—If water-power is the original source. Distance of the wheels from the consumer's premises, in yards. 100.	500.	1,000.	5,000.	10,000.	20,000.
		Francs.	*Francs.*	*Francs.*	*Francs.*	*Francs.*	*Francs,*
5	Electric	0.036	0.037	0.038	0.046	0.054	0.087
	Hydraulic	0.030	0.040	0.050	0.144	0.260	0.499
	Pneumatic	0.041	0.048	0.060	0.132	0.250	0.464
	Wire rope	0.011	0.020	0.031	0.130	0.259	0.507
10	Electric	0.027	0.029	0.030	0.037	0.049	0.074
	Hydraulic	0.026	0.031	0.039	0.099	0.172	0.330
	Pneumatic	0.036	0.040	0.046	0.091	0.147	0.414
	Wire rope	0.010	0.017	0.026	0.100	0.199	0.416
50	Electric	0.023	0.025	0.027	0.030	0.032	0.057
	Hydraulic	0.016	0.019	0.022	0.047	0.080	0.149
	Pneumatic	0.022	0.026	0.029	0.046	0.067	0.112
	Wire rope	0.010	0.011	0.014	0.040	0.075	0.167
100	Electric	0.021	0.022	0.024	0.027	0.034	0.052
	Hydraulic	0.016	0.017	0.020	0.045	0.075	0.119
	Pneumatic	0.022	0.023	0.025	0.037	0.052	0.087
	Wire rope	0.008	0.010	0.011	0.029	0.052	0.112

TABLE III.—*Cost per horse-power of a plant for transmitting power to different distances.*

Horse-power.	System of transmission.	Distance of transmission in yards.					
		100.	500.	1,000.	5,000.	10,000.	20,000.
		Francs.	*Francs.*	*Francs.*	*Francs.*	*Francs.*	*Francs.*
5	Electric	1,917	1,987	2,075	2,775	3,645	5,045
	Hydraulic	1,053	1,693	2,492	8,893	16,893	32,893
	Pneumatic	1,876	2,482	5,382	12,837	27,887	52,887
	Wire rope	165	792	1,575	7,835	19,407	31,310
10	Electric	1,265	1,377	1,443	1,962	2,625	3,937
	Hydraulic	767	1,167	1,667	5,667	10,642	20,667
	Pneumatic	1,537	1,850	2,257	5,457	9,457	17,457
	Wire rope	126	637	1,195	5,925	11,837	23,662
50	Electric	1,015	1,038	1,076	1,382	1,757	2,507
	Hydraulic	392	552	765	2,327	4,352	8,352
	Pneumatic	805	925	1,075	2,250	3,775	6,775
	Wire rope	46	185	360	1,756	3,500	6,966
100	Electric	818	845	882	1,145	1,512	2,212
	Hydraulic	361	516	710	2,260	4,197	7,947
	Pneumatic	677	762	868	1,718	2,781	4,906
	Wire rope	27	111	215	1,043	2,080	4,152

(75) Although the cost of the hydraulic transmission is shown by these tables to be greater than by other methods, yet, under the circumstances, this system was recommended by Col. Turettini on the following grounds; namely, that the dependence which can be placed on the continuous working of the hydraulic system, the convenience of the service it affords, and its perfect safety in use, place it in the foremost rank when the transmission and distribution of power in a city are in question. The fact that a portion of the machinery and of the new works would in any event be required for the proper supply of water for domestic and public uses, afforded another reason for the adoption of this system in Geneva.

(76) The work was begun more than 10 years ago, and the pumps that are now in operation, together with the additions that are provided for, contemplate the utilization of the full power that can be obtained from the river at its low-water stage; namely, nearly 6,000 horse-power. Twenty turbines of 300 horse-power each will then be used. Of these, 8 are already in full operation.

The turbines are pressure wheels of the Jonval type with vertical axes. Each turbine, the diameter of which is 14 feet, and the speed 26 turns per minute, drives two double-acting pumps, through a single crank keyed fast to the upper end of the turbine shaft; the two pumps being set at an angle of 90° with each other in a horizontal plane.

Fig. 67 is a view of a sectional model exhibited by Escher, Wyss & Co., showing the general arrangement of a single turbine and set of pumps.

The dam used at Geneva for holding back the water of the Rhone is adjustable, so that, when the water is at any particular stage, the dam may be so adjusted that as great a fall as possible may be obtained, and yet the flooding of the low banks of the country about Lake Geneva be avoided.

The dam is in sections consisting of curtains formed of beams hinged together and resting against abutments, arranged in such a manner that the curtains may be unrolled downward to close the dam, or rolled up to open it. The dam may be wholly closed so as to direct all the water into the flume leading to the turbines, when the

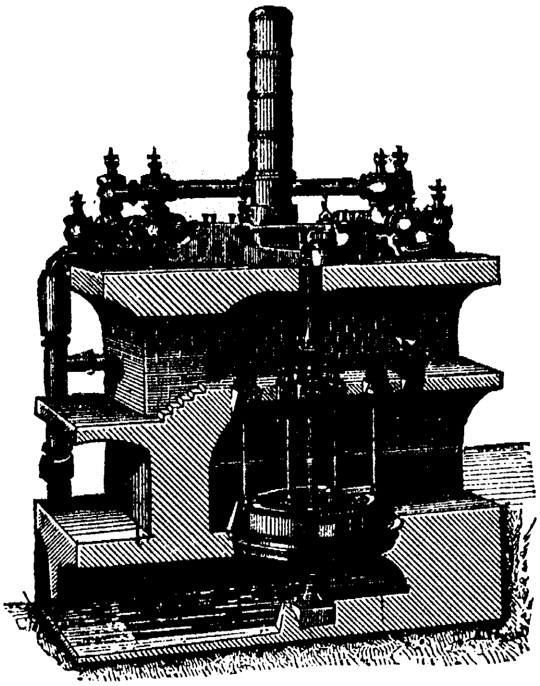


FIG. 67.—Sectional view of one of the Jonval turbines and a pair of the pumps used for the Geneva waterworks, Switzerland; showing the general arrangement.

water is low and the flow small; but when the flow of the river is great, as many sections of the dam may be opened as are necessary in order to let the surplus water flow away, and thus keep the level of the water in the lake from rising higher than before. At the time when the dam is thus opened the backwater below it is necessarily very much higher than at other times, because of the great quantity of water to be carried off by the river channel. The head available for the turbines is therefore much greater in low water than in high, and the quantity of water taken is inversely proportional to this head.

At low water the head is somewhat greater than 12 feet, but at high water is 5½ feet only; while the quantity of water which flows is 4,300 cubic feet per second under the former condition, and 9,500 cubic feet under the latter.

The turbines are so constructed that the number of buckets to which the water is admitted may be varied in a way that will permit the water to be employed economically under these very different conditions of supply.

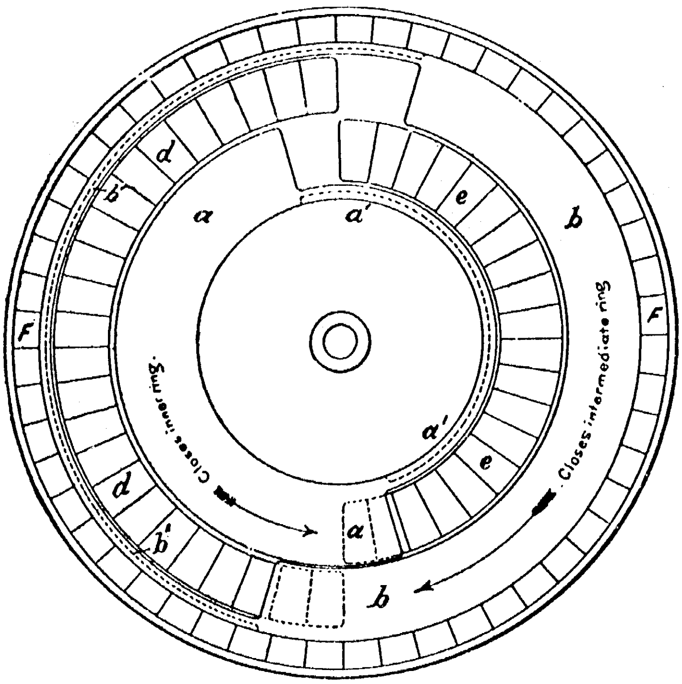


FIG. 68.—Plan of the guide-blade crown and annular gates of one of the turbines of the waterworks at Geneva, Switzerland.

Figs. 68 and 69 show a plan and section of the guide-blade crown and wheel crown of this turbine.

The crown of the wheel, containing the buckets, is divided into three concentric rings of buckets, the inner and intermediate rings each being 17¾ inches wide, measured radially, and the outer ring 11 inches, while the outside diameter of the wheel is 13 feet 11 inches. Three concentric rings of guide-blade channels, *D*, *E*, and *F*, form the guide-blade crown, and correspond to the rings of buckets.

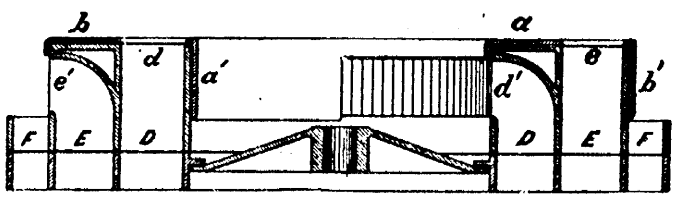


FIG. 69.—Section of the guide-blade crown and wheel-bucket crown of the turbine shown in Fig. 68.

The outer ring F of guide blades is not provided with means for excluding the water from the buckets, but the intermediate and inner rings can be entirely and independently closed by an arrangement which will be understood by the aid of Figs. 68 and 69. Half the channels between the guide blades, namely, those occupying a semicircle of the ring, are extended directly upward to the flat top of the guide blade crown, where the water enters their mouths, *d* and *e*. The other channels, contained in the opposite semicircle, are extended in the form of a quarter bend, so that their mouths, *d'* and *e'*, are at the side or periphery of the crown; the mouths *d'* of the channels for the inner ring being found in the inner periphery of the crown, while the mouths *e'* of the corresponding channels for the intermediate ring are in the outer wall or periphery of that ring. One-half of the flat top surface of each ring is therefore continuous and without openings, and the other half perforated with mouths, while the opposite halves of the peripheries of those rings are also perforated and continuous, respectively. The gate for closing the intermediate ring of guide channels consists of a flat plate, *b*, in the form of a half ring, which lies on the top of the crown, and a semicircular curtain, *b'*, which hangs from the ends of the plate and completes the closure by encircling that half of the outer periphery of the guide-blade ring which is opposite the part of the ring covered by the plate. When the gate is turned so that the plate *b* lies over the inlets *d* in the upper surface of the ring, and the curtain hangs in front of the inlets *d'* in the periphery, the water is excluded from the corresponding ring of channels. A half revolution of the gate uncovers all the inlets of this ring.

The gate for the inner ring is the same as for the intermediate, except that the curtain *a'* hangs inside the ring.

The advantage of this arrangement is that one, two, or all three of the concentric rings of the guide-blade channels can be opened to receive water, as the condition of the supply may warrant, so that the power may be kept nearly constant without closing the inlets of any single ring of channels to an extent which would seriously impair the economical efficiency of the wheel.

(77) In the water supply for Geneva there are two distinct systems of distribution: the *low-pressure*, with a head of 150 feet, and the *high-pressure*, with a head of 450 feet, each supplied by its own turbines and pumps independently.

Water is used from the low-pressure pipes for general purposes and for motors exerting only small power; that from the high-pressure system for power chiefly.

In December, 1888, there were 48 miles of pipe in use for distributing the low-pressure water, and 46 miles for the high-pressure water.

The power is taken by consumers representing seventy-six different industries.

At the beginning of 1889 there were 135 motors, nominally of 320 horse-power in all, driven from the low-pressure service, and 69 motors, nominally of 1,100 horse-power, from the high-pressure pipes. Three of these last are turbines of 200 horse-power each, used in an electric-light station.

(78) The charges for power in the industrial section of the city are established according to a sliding scale, and depend on the quantity of power and the time during which it is used. Curves representing the system by which these charges are computed are published in the annual report of the water department of Geneva, and the numbers in the following brief table have been computed approximately from the curves:

Price for each horse-power. per year, for different quantities of power and different hours of daily running.

	Horse-power.					
	5.	10.	20.	50.	100.	200.
For 10 hours daily	$94.00	$56.00	$43.00	$34.00	$27.00	$25.50
For 12 hours daily	105.00	66.00	50.00	37.50	31.50	27.50
For 24 hours daily	140.00	84.00	65.(0	50.00	41.75	37.00

The profits of the water department are considerable. In 1888, after paying all expenses, including interest at 4 per cent., and an annual assessment of 2 per cent. for a sinking fund to cancel all the indebtedness as it becomes due, there remained a net profit of nearly $30,000.

The rents received for water used during the year are as follows:

	Francs.
For public use by city	110,000
For domestic use	230,000
For sundry industries	25,000
For water-power	150,000

The daily water supply averaged about 11,500,000 gallons, 60 per cent. of which was low-pressure, and the remainder high-pressure. The city used about 40 per cent. of the low-pressure water for public purposes, about 30 per cent. was employed for motive power, and the remainder for domestic and industrial use. Ninety per cent. of the high-pressure water was used for motive power.

Various kinds of motors are used by the consumers. For quite small powers—1 horse-power or less—pressure engines are employed, but where considerable power is required preference is given to small high-speed turbines, either tangential wheels, or Girard turbines with partial injection.

Escher, Wyss & Co., of Zurich, Switzerland, to whom were intrusted the design and construction of the machinery for the Geneva and Chaux-de-Fonds water-works, just described, manufacture all kinds of turbines, from the largest to the smallest. Their catalogue shows a list of over 1,800 turbines, aggregating more than 100,000 horse-power, which have been placed by them.

(79) Fig. 70 shows a general view of a small and neat form of Girard wheel for moderate power, manufactured by this firm.

(80) J. J. Reiter, of Winterthur, Switzerland, made a fine display of turbines, of sizes varying from 200 horse-power downward. They were of various types. A number of different arrangements for controlling the admission of water to Girard turbines were shown. In one of these, for a parallel flow turbine, a plate, turning like a damper on a spindle pointing to the axis of the turbine, is placed in the mouth of each guide channel, and this is opened or closed by means of a cam groove in a ring, placed inside or outside the guide crown, as the case may be, which may be turned around the crown by means of gearing. The cam operates a little crank on the

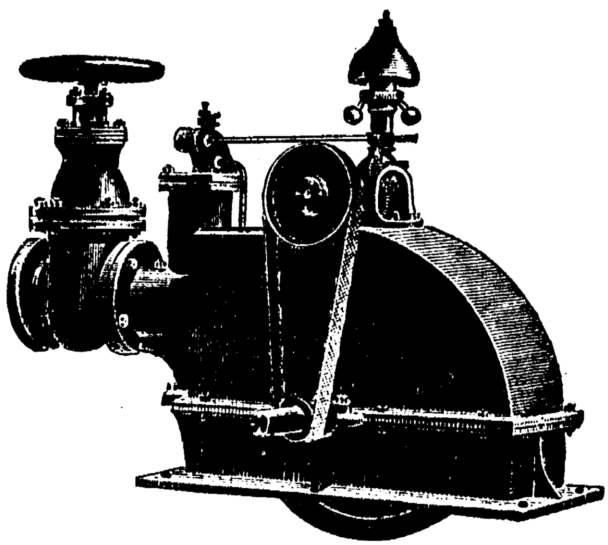


FIG. 70.—Small incased Girard wheel, by Escher, Wyss & Co., of Zurich, Switzerland.

end of each damper shaft in such a manner that the dampers are turned two at a time, one on either side of the wheel, successively, until the required number are opened or closed. By this arrangement very little strain is brought upon the gate mechanism, even when the water pressure is great.

A small, self-contained motor, containing a tangential turbine and furnished with a regulator, was exhibited. It is manufactured in more than seventy different varieties, adapted for heads from 30 feet to 500 feet, for speeds from 250 to 3,000 turns per minute, and for powers from one half of a horse-power to 25 horse-power.

In general outside appearance they resemble the small turbine shown in Fig. 70. Their efficiency is said to be as great as 75 per cent.; but this kind of wheel is going out of use in Europe.

The opening and closing of the spout through which the water is delivered to the wheel is produced by the action of the water pressure on a piston in a cylinder, the movements of which are controlled by a small valve moved by the governor.

(81) Brault, Tisset & Gillet, Paris, extensive manufacturers of water wheels, turbines, and mill machinery, are the successors of Fontaine, one of the pioneers in the improvement and introduction of the turbine. This firm has produced more than 8,000 wheels, representing collectively 200,000 horse-power; also 7,500 runs of stones and 2,500 roller mills. They employ 500 workmen.

Their exhibit included a variety of parallel-flow wheels, modifications of the original type of Fontaine's turbine. The opening and closing of the mouths of the guide-blade channels is by means of annular segments of some flexible material, as leather or vulcanized rubber, which lie on the flat top of the guide-blade crown, covering the mouths of the channels. One end of a segment is fastened to the crown, the other end is rolled upon a conical roller which travels around the crown and rolls up the segment, so as to uncover the mouths to the extent desired. The bottom of the leather segment is armed with metallic plates which correspond to the mouths of the channels; these serve to strengthen the segment while permit-

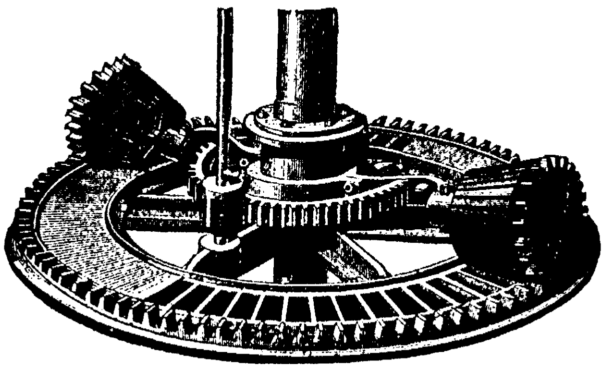


FIG. 71.—Guide-blade crown, and pliable roll-up gate, by Brault, Tisset & Gillet, France.

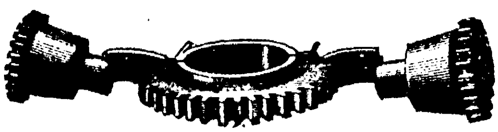


FIG. 72.—Segment and rollers for the pliable gate shown in Fig. 71.

ting a tight closure to be made by the contact of the pliant leather with the metal between the mouths. This arrangement in general is not new. Its application, as it was exhibited, was neatly designed, and is illustrated by Fig. 71, which shows the fixed guide-blade crown of a turbine with the apparatus for closing the openings in place.

Fig. 72 shows the rollers attached to the segment by which they are worked.

A Girard turbine with horizontal axis and partial injection, adapted for high falls and small power, was also shown by this firm.

Fig. 73 shows a view of this wheel, and Figs. 74 and 75 show sections of the water chest, the guide spouts, and part of the wheel, exhibiting the gate by which the guide spouts are covered and uncovered.

(83) *Bergès's installation of wheels under very great heads.*—A rather remarkable exhibit was made in Class 63 by Mr. Aristide Bergès, a civil engineer of Lancey, a town in the department of Isère, France, in the immediate neighborhood of the Southern

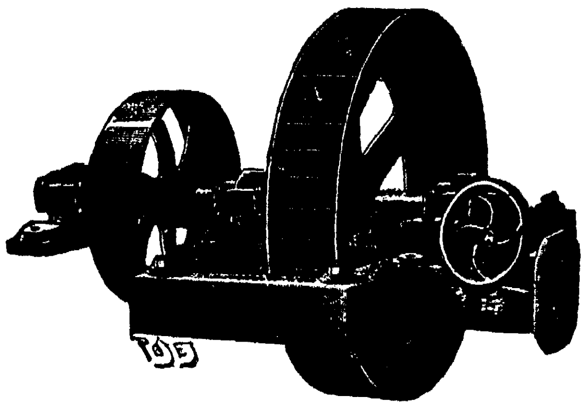


FIG. 73.—General view of vertical Girard turbine, by Brault, Tisset & Gillet.

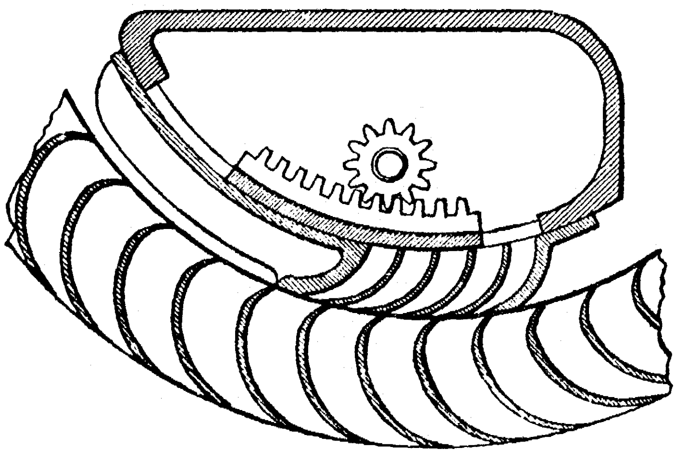


FIG. 74.—Section in plane of wheel.

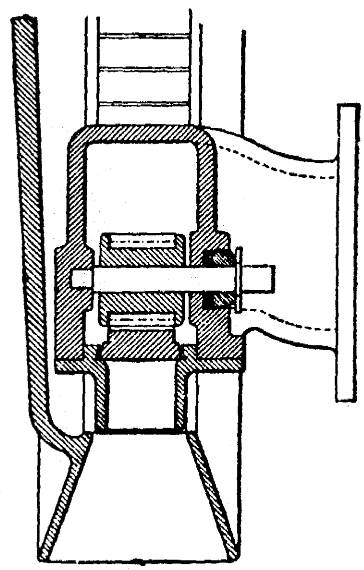


FIG. 75.—Section in plane of axle.

Water chest, guide buckets, gate, and lower part of wheel crown of the Girard turbine shown in Fig. 73.

Alps. He showed an impulse wheel of 6 feet diameter, and a model in plaster of the mountainous region in which he has established an extensive water-power derived from a small stream which is the outlet of lakes fed from the melting glaciers.

He called attention to his enterprise by a circular with the fanciful title "White Coal;" a title which he says he "employs to strike the imagination and to suggest in a vivid manner that the mountain glaciers can, if exploited for the development of motive power, render to the country in the neighborhood of the mountains a service as important as that derived from the coal extracted from its depths."

His model shows what he has done in obtaining a large water-power from a stream of insignificant volume. In 1869, when Mr. Bergès began his works, the flow of the stream was only about 3 cubic feet per second, and barely furnished power for a few small grist mills. Now the same mountain sources from which this stream flows, furnish the water-power for Mr. Bergès's large paper mill, requiring more than 2,000 horse-power.

This gain in power he obtains by taking the water from the mountain sources instead of the lower stream. Since 1883 his power has been obtained from water under a head of 1,600 feet, and the wheels, of various diameters, from 3 feet to 16½ feet, have been working, some of them regularly, during all these years. One of the wheels yields 1,200 horse-power, and is employed for driving wood-pulp machines; the others, varying from 20 to 500 horse-power, drive rag engines and other machinery.

Mr. Bergès describes his wheels as follows:

Not wishing to exceed 230 revolutions for my machines for making wood fiber, which are driven directly by the wheel, a diameter of 16½ feet had to be adopted.* After having witnessed the bursting of wheels which were made of so-called extra strong cast iron, and of wrought-iron wheels made too light, I was led to a type composed of steel plate 0.4 to 0.6 of an inch thick, forming two conical disks riveted together at the edges, and also riveted to a cast-iron hub. The crown of blades is made in segments about 32 inches long (20 segments), strongly bolted fast by steel or refined iron bolts. Neither the crown nor the disk is turned. The inevitable irregularities of the plate are corrected by packings of dry oak, which swell when wet and increase the pressure of the bolts. Extreme care has been taken to insure perfect balance with respect to the axis, and with care the blades may be made to revolve as truly as if the whole piece had come from the lathe. A turbine of this kind, weighing 10 tons, and capable of furnishing 2,000 horse-power, has been working since 1885, that is, for 4 years, and has not required repairs of any nature.

The 6-foot wheels require to run at about 600 revolutions per minute. I persevered for awhile in trying cast iron for these, but was forced to abandon it because of accidents from bursting. I can, however, say that two turbines of this type, of cast iron, did work for 5 years. They were two in which pains had been taken to cast slits through the hub, the hub being afterward secured by bands to insure the absence of initial strain in the arms.

In order, however, to avoid accidents, plate steel has been substituted for cast iron, in the form of a disk with the edge turned over to retain the crown of blades, which is made of white cast iron and fastened by bolts.

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*The circumferential speed of a 16½-foot wheel at 230 turns per minute, is about 65 per cent. of the velocity of flow due, theoretically, to a head of 1,600 feet.

Fig. 76 is a diametral section of the lower half of one of M. Bergès's large wheels.

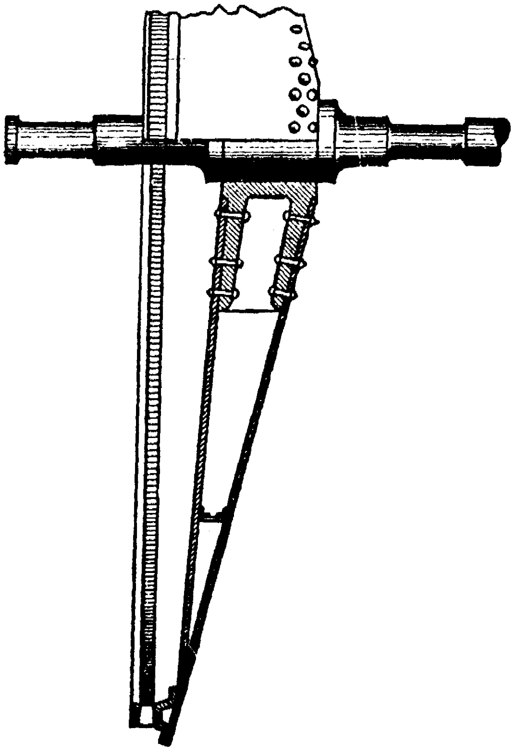

FIG. 76.—Section of lower half of Bergès's wheel for a high head of water.

The spout for delivering the water to the wheel is the same for all sizes of turbine. It is at the end of a delivery pipe in which the velocity of flow is 6 to 10 feet per second, and is a conical nozzle, like a hose nozzle, usually made with a diameter of about 1¼ inches, one of which is large enough to give 200 effective horse-power. The stream plays upon the inside of the crown of the wheel. For a 16-foot wheel six nozzles are used, each controlled by a cock in the pipe. Phosphor bronze or aluminum bronze is the best material for the construction of the nozzle, and as its weight is small, it can be renewed with but little expense when worn out. Cast iron lasts but a short time. Mr. Bergès says, "It wastes as butter wastes in the sun, and the water speedily hollows out caverns in it." The blades of the wheel wear rapidly also, unless cast thin and hard, and unless the original scale is left on the surface of the castings. If proper metal is used they last for years.

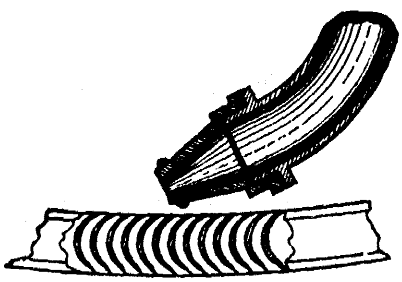

FIG. 77.—Spout and short section of buckets of Bergès's wheel.

Mr. Bergès states that he is now constructing works for a fall of 5,500 feet.

(84) Very high falls have been utilized in the Rocky Mountains and mining regions of the United States, by means of the "Pelton" wheel, which is exceedingly economical. It is believed, however, that Mr. Bergès is employing, on a large scale, a much higher fall than had been used before his undertaking was accomplished, and the project he is now beginning to carry out, for applying a fall of over a mile in height, is certainly remarkable for its boldness.

VI.—PUMPS AND PUMPING ENGINES.

(85) *Hand and Power pumps.*—Innumerable hand pumps of different kinds were shown in the French sections, and several exhibitors from the United States made fine displays of the different kinds of pumps for domestic and agricultural service which are universally employed here. The merits of these latter were recognized by awards to all the exhibitors. The French pumps have no marked advantages over ours, and except in the case of certain imitations of American pumps, they are inferior, particularly in those very essential, and often ingenious minutiæ of design, by which the manufacture is facilitated and cheapened without diminishing the excellence of the finished product in any particular.

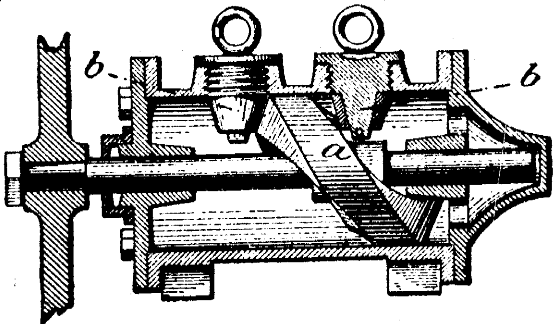

FIG. 78.—Horizontal section of Montrichard's valveless pump.

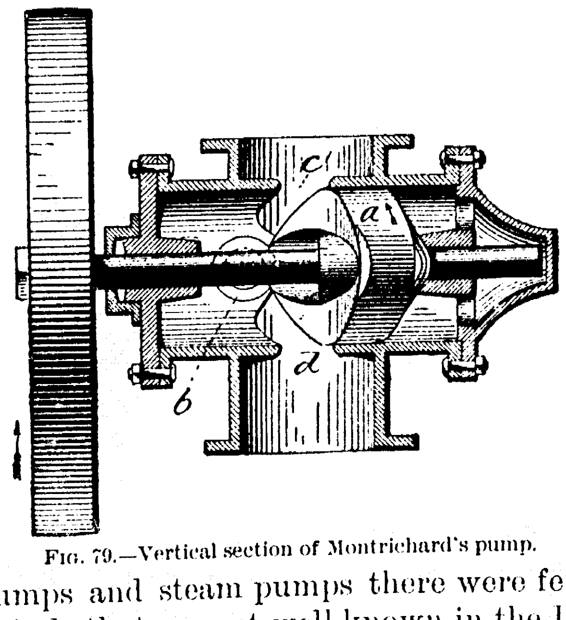

FIG. 79.—Vertical section of Montrichard's pump.

Of power pumps and steam pumps there were few showing novelty, and few kinds that are not well known in the United States, so that little of interest can be said about them.

(86) A pump without valves, having a piston which worked with combined movements of rotation and translation, by which the displacement of the water was produced, and the inlet and outlet openings opened and closed, attracted some attention. It is the invention of M. de Montrichard, of Montmédy, France. A power pump of this kind is shown in Figs. 78 and 79.

The pump is double-acting. Its piston, *a*, is a disk having the general form of an oblique slice cut from a solid right cylinder of the same diameter as the bore of the pump barrel.

A piston rod is made fast to the center of the disk, parallel to the axis of the barrel, through the heads of which it passes, where there are bearings in which the rod is free to slide lengthwise as well as to rotate. Two rollers, *b*, secured inside the pump barrel, on one side, at about the middle of its length, touch the edge of the oblique disk, one on either side, and restrain the movement of the edge in such a way that when the disk rotates, the part of the edge opposite the rollers traverses back and forth along the barrel by a distance measured by the product of the diameter of the barrel into twice the cosine of the angle which the disk forms with the axis of the piston rod; while the effective stroke, that is, the lengthwise movement of the piston rod, is equal to half the distance traversed by the edge. The capacity of this pump is the same as that of an ordinary double-acting piston pump of the same diameter and stroke.

The inlet port, *d*, and outlet port, *c*, are peculiarly shaped openings through the wall of the barrel, placed about midway between the ends, and reaching part way around the barrel on each side of the guide rollers *b*. The oblique edge of the piston as it rotates forms a movable partition between the ports, and alternately opens communication between them and the opposite ends of the barrel.

The pump is driven by a belt working on a pulley keyed to the piston rod and moving laterally back and forth with it; the pulley on the driving shaft having a straight face, wide enough to permit the lateral traverse of the belt.

It is said that an efficiency of 72 per cent. was obtained as the mean results of eight experiments made at the Conservatory of the Arts and Trades.

A steam pump embodying the same principles was also exhibited.

(87) *Direct-acting steam pumps.*—The name "direct-acting steam pump" is usually applied to steam-driven pumps in which the power of the steam in the steam cylinder is transferred to the piston or plunger of the pump in a direct line, and through a continuous rod, without the use of revolving parts, such as a crank and fly wheel, to continue, arrest, and reverse the motion of the piston and actuate the valves; and indeed it may be said to be limited now to a class of pumps in which the reversal of the movement of the pump is assured, and dead points avoided, even at the slowest speeds, by the use of an auxiliary steam piston or engine for throwing the steam valve. Engineers will recognize that this description covers all the numerous successful steam pumps well known in the United States. In the earliest forms of steam pumps, however, the auxiliary device for throwing the valve consisted of springs or weights which were set in operation by the movement of the pump, but were otherwise independent

in their action upon the valves. It is probable that in the Bull Cornish engine, an English direct-acting pumping engine of very early date, an auxiliary independent device for effecting or completing the movements of the valve was first embodied, but certainly not in a form which suggested the appliances by which the modern steam pump has been made so successful.

So far as the first production and introduction of the direct-acting steam pump in a practicable and successful form warrants the claim to priority of invention, the late Henry R. Worthington, of New York City, was the originator, in 1840, of such pumps, and his invention was followed immediately in the United States by numerous others; notably, first, that of Guild and Garrison, and afterward Wheeler's, under whose patent the greater number of the different manufacturers paid tribute. These inventions, followed by that of the Worthington duplex pump—consisting of two steam pumps of equal size, combined, side by side, and arranged so that the steam valve of either is worked by the movement of the other pump—formed the foundation upon which was built up the great business in the manufacture of steam pumps which is now carried on in the United States, and has spread to Europe, where the types which originated here are introduced, and are becoming universally known and adopted.

Although the number of steam pumps shown in the Exposition was large, there were but few different types. Duplex pumps seem to have been adopted almost to the exclusion of other kinds. These were shown in the sections of all the countries, but no novel or interesting features were noticed which merit a description.

(88) *Pumping engines.*—Four sets of pumping engines of considerable capacity were exhibited in operation, and employed in furnishing a large proportion of the water supply for the Exposition.

(89) Undeniably the most interesting of these was the new Worthington high duty direct-acting pumping engine of 6,000,000 gallons capacity, which was erected in a special engine house situated on the bank of the river Seine, within the Exposition grounds; it furnished a good example of a modern American pumping plant for the water supply of a city.

The highest award in the gift of the authorities, a grand prize, was justly given for this exhibit.

The invention which is the characteristic feature of this engine has made it possible to realize in the direct-acting pump nearly if not quite as great an economical efficiency as is obtained with the more complicated and cumbrous crank and fly-wheel engine, and it is a gratifying fact that this radical improvement in the direct-acting pump originated with C. C. Worthington, the son and successor of Henry R. Worthington, and is applied to the duplex pump of his father's invention.

Fig. 80 is a perspective view of this engine, Fig. 81 a sectional elevation, and Fig. 82 a diagram by the study of which the action of the "compensating cylinders," referred to in what follows, can be understood. The ordinates of the curved line in the upper part of Fig. 82 show the resisting force exerted by the compensating cylinders against the action of the steam pressure in the first half of the stroke, and the assisting force they yield up in the second half. The greater part of the following remarks upon this engine is derived from a special pamphlet circulated in the Exposition by the firm of Henry R. Worthington, of New York City, in whose publications a full description can be found.

The terms "high duty" and "low duty," as applied to pumping engines, are used mainly to distinguish between two different grades of performance with reference to the consumption of fuel.

"Low duty" is, generally speaking, held to describe engines upon which a guaranty of duty is made of from 50,000,000 to 70,000,000 pounds of water raised one foot for each 100 pounds of coal consumed. "High duty" describes engines of a guaranteed duty of from 95,000,000 to 110,000,000, and above.

The direct-acting pumping engine, although so widely used in waterworks stations for the past 30 years, was, owing to peculiarities which it is not necessary to discuss, comparatively limited in its capabilities of expanding steam; but even to-day, in view of the fact that higher duty in a pumping engine means higher first cost, and, in the case of fly-wheel engines, increased liability to derangement, it is more largely employed than any other type in existence.

This limilited ability to make use of high grades of steam expansion relegated the direct-acting pumping machine, as formerly constructed, to the class of "low duty" engines, and it is the invention of the devices by means of which the varying pressure in the steam cylinder, which is involved in the employment of steam extensively expanded, is made to produce a uniform effect in the pump, that has transferred the new Worthington pump to the class of "high duty" engines, without the sacrifice of the peculiar advantages which the direct-acting engine possesses over pumping machinery whose motion is controlled by the crank and fly wheel.

The problem presented is this: At the beginning of the stroke the steam, which is then at boiler pressure, exerts upon the pistons a force which is far in excess of that required for overcoming the uniform resistance in the pump; at the end of the stroke the force of the expanded steam is much less than that required for moving the load; the mean force during the stroke is sufficient to do the work, but its inequalities must be prevented from being transferred to the pump piston, or else the engine will start from the beginning of the stroke with a violent plunge, and stop short of the end of the stroke at a point where the driving force of the steam sinks below that required to overcome the resistance of the pump.

In the crank and fly-wheel engine the equalization of the force in the steam cylinder with the resistance in the pump, is effected by the ponderous fly wheel, which absorbs by its inertia the excess of energy developed in the steam cylinder in the first part of the stroke, and gives this energy out in the latter part. In other words, in the early part of the stroke so much of the force on the steam piston as is in excess of that required to overcome the pump resistance, is expended in accelerating the movement of the massive fly wheel, while in the latter part of the stroke the deficiency of force, which occurs when the steam pressure is diminished by expansion below the point necessary to overcome the resistance, is supplied by the action of the fly wheel, whose momentum is then available for this purpose.

In the Worthington high duty engine the effects of steam expansion are utilized, but the uniform distribution of the pressure is secured by an entirely different method, simple and effective, and embracing none of the objections of the fly wheel, while presenting many positive advantages.

This improvement in the construction of, or rather attachment to, the older form of the Worthington pumping engine, by means of which the cutting off and expansion of the steam is made possible, consists, briefly, of two small oscillating cylinders attached to the plunger rod of the engine. These cylinders and their connecting pipes are filled with water or other liquid and connected, either directly or through the medium of an accumulator, with the water in the force main of the pump. By this means a pressure on the pistons or plungers in these cylinders is maintained exactly equal to, or in proportion to, that in the force main. These pistons or plungers act in such a way, with respect to the motion of the engine, as to resist its advance at the commencement of the stroke, and assist it at the end; the water in the force main meanwhile exerting upon them a constant pressure at each end of the stroke.

Fig. 82 shows so clearly how this action takes place, that no description is needed; it is only necessary to call attention to the effect produced.

The two cylinders act in concert, and, being placed directly opposite each other, relieve the crosshead, to which they are attached, of any sliding frictional resistance, and relieve the engine of lateral strain.

By alternately taking up and exerting power through the difference in the angles at which their force is applied with respect to the line of motion of the plunger rod, these two cylinders, in effect, perform the functions of a fly wheel, but with the important mechanical difference, that they utilize the pressure in the force main instead of the energy of momentum. Whatever pressure is in the force main is directly communicated to the compensating cylinders, and any variation in the force-main pressure is followed instantly by a corresponding variation in the cylinder pressure. Thus a uniform relation is

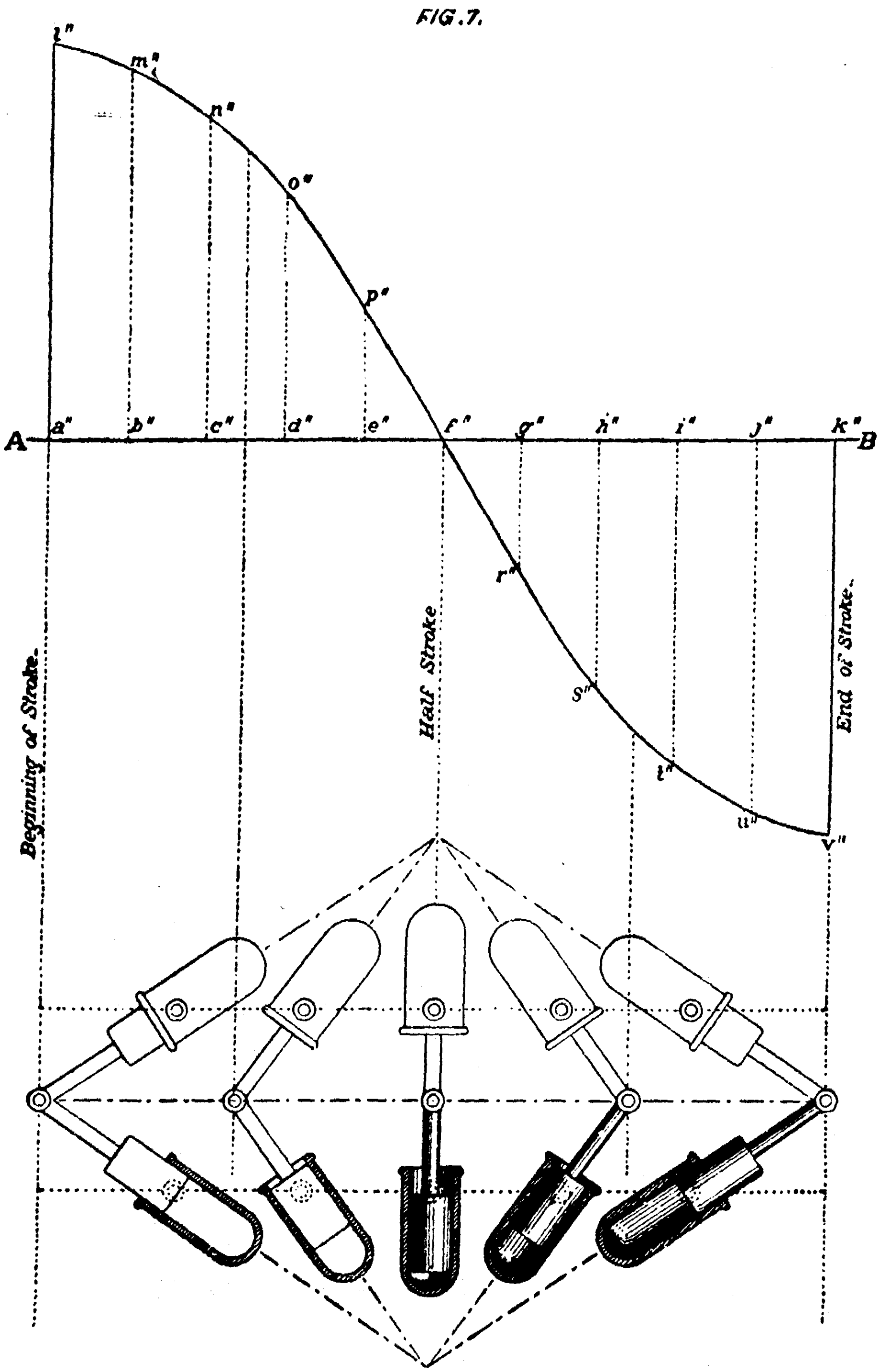

FIG. 82.—Diagram showing the action of the compensating apparatus of the Worthington high duty pumping engine.

maintained between the load on the pump plungers and the work performed by the compensators.

Their action is readily controlled, and their power is automatically proportioned to the work to be overcome, and is entirely unaffected by the speed of the engine. The same amount of expansion can be obtained in the same engine whether running at a piston speed of 10 feet per minute, or at 150. This latter feature is one of great importance, affecting, as it does so favorably, the economy of the engine when applied on any service where the demand is irregular or intermittent.

The value of the "compensating cylinder" feature in what is known as the direct-service system of waterworks can hardly be overestimated; for it must be plain that, as the momentum of a fly wheel rapidly decreases as its speed decreases, its available controlling power is so diminished that the grade of steam expansion, and hence steam economy, must be very materially reduced; whereas, with the Worthington compensating cylinders, whatever work is put into, and afterwards derived from them, does not vary with the speed, for the reason that pressure from the water column, and not inertia of mass, is the acting principle.

The economy of this engine is not appreciably affected by wide differences in its speed, as the rate of expansion in the steam cylinders is constant under all changes in the rate of delivery of the pump; the engine adapts itself exactly to the load: as the pressure in the compensating cylinders varies proportionally with the pressure in the force main, the result is a uniform propulsion of the water column and an absolute control of the speed of the engine, without dependence being had upon any automatic governor or other complicated device. Should the force main or distributing pipes burst from any cause, no accident can occur to the engine itself, as the loss of pressure in the main results in a corresponding loss of power in the compensating cylinders, until the pressure is entirely withdrawn from them, when the engine is unable to complete its strokes.

This important feature of the Worthington high duty engine was illustrated at one of the pumping stations of the National Transit Company's oil pipe lines, at Osborn Hollow, New York. The pump was working under a resistance of 900 pounds per square inch, and pumping at the rate of 26,000 barrels of oil per 24 hours, when it was observed to suddenly slow down and come to a full stop. Upon investigation it was discovered that the pipe line had burst a short distance from the station, thus relieving the pressure and robbing the compensating cylinders of their power. It was, therefore, impossible for the engine to make a stroke. This stoppage occurred notwithstanding the fact that the high-pressure steam cylinders were taking steam, up to quarter stroke, at a pressure of about 100 pounds per square inch. The high-pressure cylinders of this engine are 41 inches diameter, and the low-pressure cylinders 82 inches diameter. The engine, at the time the above accident occurred, was working up to 750 horse-power.

The work of the compensating cylinders can also, at the will of the attendant, be thrown on or off the engine instantaneously. Should they or the cut-off mechanism become in any way disarranged, or require overhauling or repairs, they can be quickly disconnected, so that the pump can then be run as a "low duty" engine, as satisfactorily as though originally constructed as such.

Worthington engines with this attachment have been fully tested under all the conditions to be met with in actual practice, and have achieved as high a duty as has heretofore been secured by an engine of any other type.

A duty of 100,000,000 foot-pounds, with the consumption of 100 pounds of coal (equivalent to 112,000,000 calculated on the English basis), can be considerably exceeded with an engine developing more than 100 horse-power.

The Worthington firm also furnished two large compound duplex high-pressure pumping engines, collectively of a capacity of 35,000 gallons per hour, which received water under a head of 650 feet, from the third platform of the Eiffel Tower, and delivered it under a head of nearly 1,000 feet at the top of the tower, for the supply of the Edoux hydraulic elevators.

(90) De Quillac and Meunier, of Anzin, the former of whom is the licensee of Jerome Wheelock, of Worcester, Massachusetts, supplied water for the Exposition by a crank and fly-wheel pumping engine. The engine was of the Wheelock type, and the pump a double-acting plunger pump situated directly behind the engine cylinder and coupled to the piston rod of the engine which extended rearward through the rear cylinder head. The capacity of this pump was about 5,000,000 gallons in 24 hours; the lift about 75 feet. It was placed in a special building located on the quay near the Worthington pumping station, and represented a type used largely in France for water supply.

The same firm also furnished a coupled pair of pumping engines of the same type to supply nearly 75,000 gallons per hour at a height of about 400 feet, for the Otis and Combaluzier elevators in the Eiffel Tower.

(91) *Centrifugal pumps.*—A large number of centrifugal pumps were on exhibition, only a few of which, however, possessed features worthy of notice.

Plans were exhibited in the Egyptian section showing a plant of very large centrifugal pumps established at Khatetbeh for taking water from the river Nile for the irrigation of the province of Béhéra. There are five centrifugal pumps at this station, each capable of delivering about 210 cubic feet of water per second, under a head which varies from 18 inches in high water of the river to 10 feet at low water. The machinery has therefore a pumping capacity of nearly 700,000,000 gallons every 24 hours, which is more than half the volume of water that flows in the river Seine, at Paris. Messrs. Farcot, of Paris, were the designers and builders of this immense pumping apparatus, and Mr. Joseph Farcot exhibited a model in plaster, of full size, of one of the great pump casings, which measures nearly 26 feet in its greatest diameter, that is, from the outer edge of the flange of the outlet to the opposite side of the case, which is in the shape of a snail shell.

The character of the foundations which were available for the pumps, the requirement that the engine must be placed above the high-water level of the river, and other considerations, made it necessary to place the axes of the pumps vertical; the plane of revolution of the runner or fan wheel is therefore horizontal.

The net power required to lift the quantity of water delivered by all the pumps when the river is at the low-water stage is 1,200 horse-power, furnished by five engines, one for each pump. Each engine is of the Corliss type, horizontal, but lies upon its side, so that the connecting rod swings in a horizontal plane and works upon a crank at the top of a vertical main shaft, which carries a fly wheel and is coupled at its lower end to the top of the axle of the pump runner.

Fig. 83 gives a general view of one of the pumps as it appears in place. The horizontal fly wheel of the engine is shown at the top of the picture and the delivery pipe of the pump may be seen in the foreground. The pipe slopes downward at first after leaving the pump, but rises afterward so that its outer end is at the level of the canal into which the water is delivered, and is there higher than the pump. A short bell-mouthed suction pipe is applied to the central inlet opening of the casing, and can be seen in the figure dipping beneath the surface of the water in the well.

A few dimensions of the machinery, and the weight of some of the parts are given below:

Diameter of runner, outside	inches..	150
Diameter of central opening in the runner, also diameter of inlet pipe	..do....	96.4
Width of runner blades—		
At the inlet	...do....	30
At the periphery	do....	27
Diameter of the delivery outlet of the casing	do...	63
Weights:		
Pump casing	tons...	30
Runner	do....	12
Engine shaft and runner axle	do....	12
Fly wheel	do....	22
Engine bedplate	do....	15
Steam cylinder	do....	5.5

The speed of the pump can be varied, or maintained constant at any speed between 16 and 40 revolutions per minute, the governor of the engine being made adjustable to meet the variation of speed demanded by the differences in the height of the lift which the pumps are required to overcome.

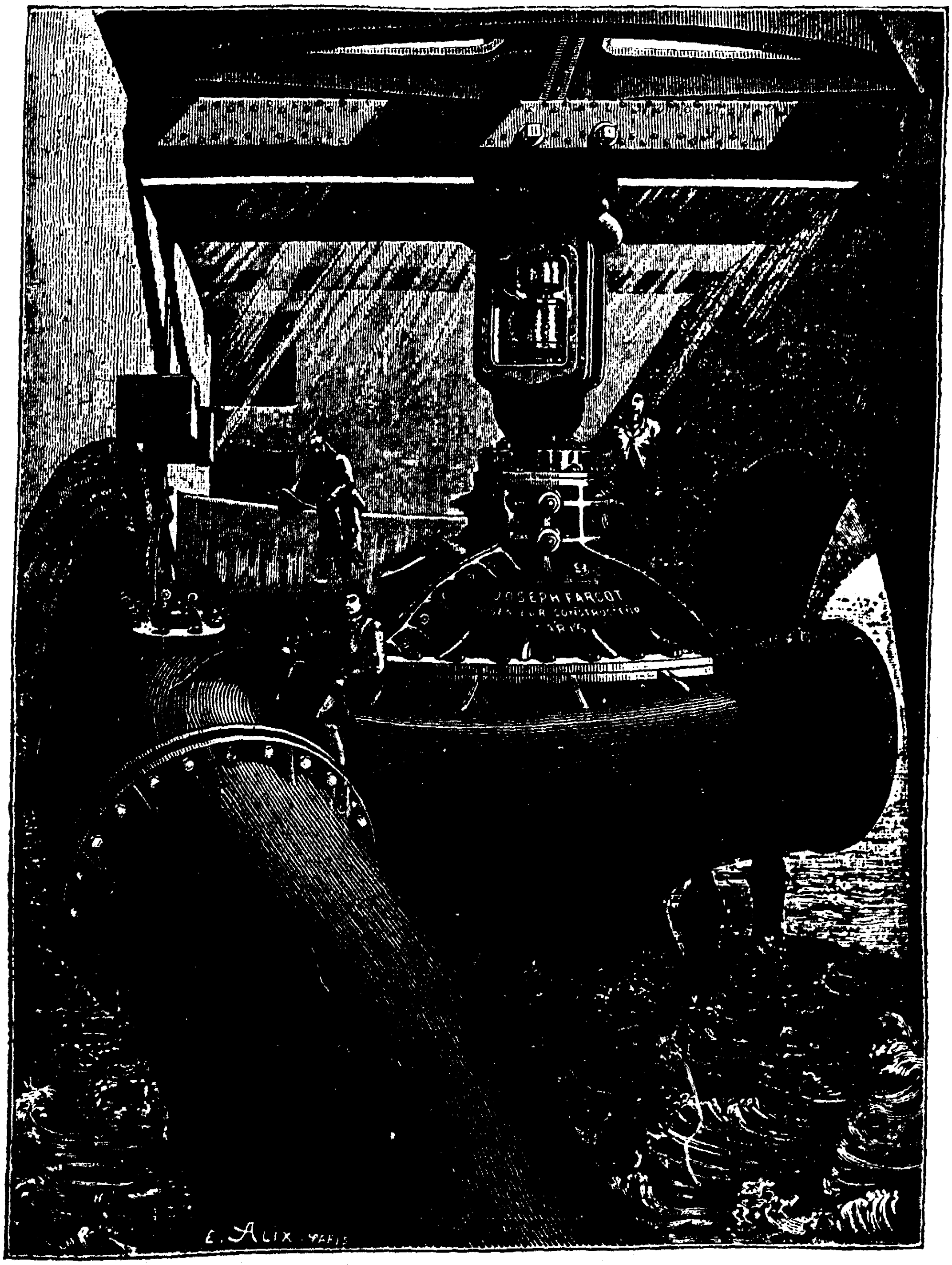

FIG. 83.—One of the great centrifugal pumps at Khatetbeh, Egypt, built by Farcot, France.

The weight of the revolving parts which the pivot of the vertical axle has to support amounts to nearly 110,000 pounds, and to insure the successful lubrication of this pivot it was necessary to place it above the level of the water; a large proportion of the weight the pivot bears is therefore suspended below it.

The intensity of the pressure to which the bearing surface should be subjected was limited to 2,850 pounds per square inch, and, as the oil channels required for the distribution of the lubrication take away from the area of the surfaces in contact, the diameter of the pivot was fixed at 8¾ inches.

If the coefficient of the friction of the lubricated surfaces is taken at 0.05, the work required to overcome the friction of the pivot when the speed is 35 turns per minute may be estimated at

$$110{,}000 \times .05 \times \frac{8.75}{12} \times \frac{2}{3} \times 3.14 \times 35 \div 33{,}000 = 8.9,$$

or, say, 9 horse-power.

This friction develops 6.3 heat units per second, and, as the air in which the machinery runs is warm, the cooling surfaces of the parts of the bearing are not extensive enough to enable the air to carry off the heat. This was anticipated, and an arrangement was made for cooling the oil, which fills a reservoir in which the pivot runs, by causing water to circulate around the outside of this reservoir; but

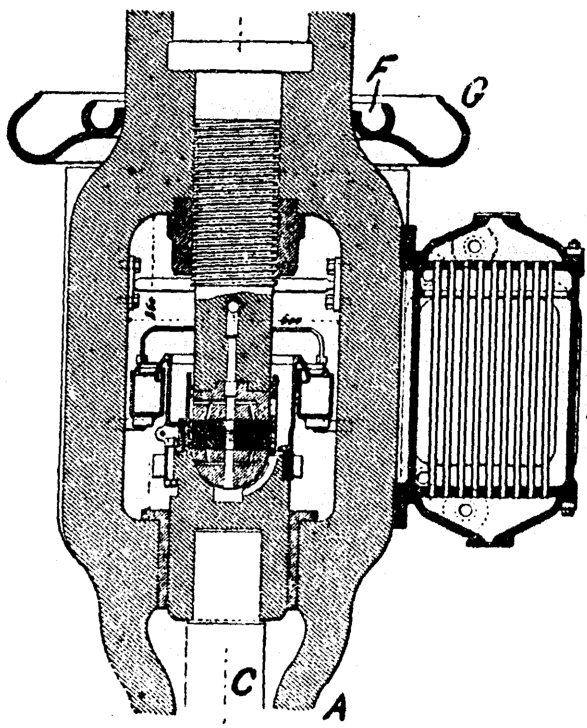

FIG. 84.—Vigreux's water-cooled step bearing for the centrifugal pumps at Khatatbeh.

even this arrangement proved insufficient, and failed to prevent the speedy heating of the parts, and the destruction of the bearing surfaces. A different arrangement was subsequently designed by Mr. Vigreux, the eminent hydraulic engineer, whose advice was obtained, and a step bearing constructed according to his plans is perfectly successful, so that since its adoption no heating has occurred.

Mr. Vigreux's step bearing, slightly modified by Messrs. Farcot, is shown in Fig. 84, while the arrangement of the principal parts surrounding the pivot—which were not changed in adopting the improvements—can be seen just above the pump, in Fig. 83.

A is the runner axle, made hollow and of cast iron, the runner being secured to its lower extremity; it is enlarged near its upper end and is mortised through and through, so that an open chamber is formed for the reception of the apparatus connected with the bearing. The lower end of the engine shaft is screwed tightly into the top of this hollow axle, so that the two are united as in one piece, while the pivot B is screwed into the axle at the top of the mortised chamber, in which it hangs; all these parts revolving together. C is a post which stands on the foundation and is fastened so that it can not turn; it rises through the hollow axle, and at its top, which is at the level of the bottom of the chamber of the axle, it carries a socket containing a stationary hemispherical bronze cup in which the lower bearing plate is held free to rock but not to revolve. The end of the pivot is also armed with a bronze plate which revolves with the pivot, and between these two plates is a third, of lenticular shape, which is unattached to either of the others and free to revolve or not. These bearing plates receive the whole weight of the engine shaft, fly-wheel runner, axle, and other revolving parts, and the post C sustains the load.

The oil for lubricating the bearing surfaces is contained in a reservoir fixed to the top of the socket. Mr. Vigreux's improvement is a device for keeping this oil cool by causing it to circulate rapidly in contact with surfaces cooled by water, situated apart from the reservoir, the oil being pumped from the reservoir by a small rotary pump which forces it through a tubular cooler made like a surface condenser, shown at E in Fig. 84, from which it returns to the reservoir. The cooler which revolves with the axle is kept supplied with water, and the surplus removed, by means of connections with the annular dishes F and G. As the cooler is outside the axle its dimensions are independent of the chamber in the latter, and the cooling surfaces can therefore be made extensive enough to produce the desired result.

The working of these great centrifugal pumps has been entirely satisfactory. They have exceeded the duty required of them. An official test of their efficiency demonstrated that the net useful work done, in water raised, amounted to 65 per cent. of the work indicated in the engine cylinders. No allowance was made for the resistance experienced by the water in the delivery pipe and tunnel, which are about 60 feet long. The pipe is about 5½ feet in diameter at the pump, and the tunnel expands gradually from this size to a rectangular cross section 11½ feet wide by 7 feet high at the outer end. Allowing a head of 1 foot for overcoming the friction in this channel when the pump delivers 250 cubic feet per second under a statical head of 10 feet, and assuming the power developed at the pump axle to be 90 per cent. of the indicated power of the engine—which the Messrs.

Farcot assume to be true—the efficiency of the pump alone is about 76 per cent. The pump efficiency is estimated by the Messrs. Farcot to be 79.6 per cent, but in their estimate too much allowance seems to have been made for the friction of the water in the delivery conduit. Their estimate of the engine efficiency is, however, high for an engine working under the existing conditions, so that it is perhaps safe to assume that the efficiency of these huge pumps approaches 80 per cent very closely. The consumption of coal is 3.3 pounds per hour, per horse-power of work performed, measured by the water actually pumped, without any allowance whatever for friction, etc.

(92) Before undertaking this great work, which involved guaranties of a certain economical performance, the Messrs. Farcot made a very complete series of experiments to determine the best form of centrifugal pump. These experiments are interesting, and the information derived from them is generally useful. Some of the particulars, derived from a description by Mr. J. Farcot,* are given below.

The power required to drive the experimental pumps was measured by means of a carefully designed transmission dynamometer, while the useful work done was ascertained by measuring the quantity of water pumped into two tanks which were filled and emptied alternately. The axes of the experimental pumps were vertical, in general, but experiments with one of them, with the axis horizontal, showed that the position does not affect the efficiency, when the lifts are as low even as 6 feet.

The first series of experiments, with lifts of from 3 to 10 feet, was directed principally to the determination of the best form for the passages for the water, through the runner, and in the casing around the runner. The run-

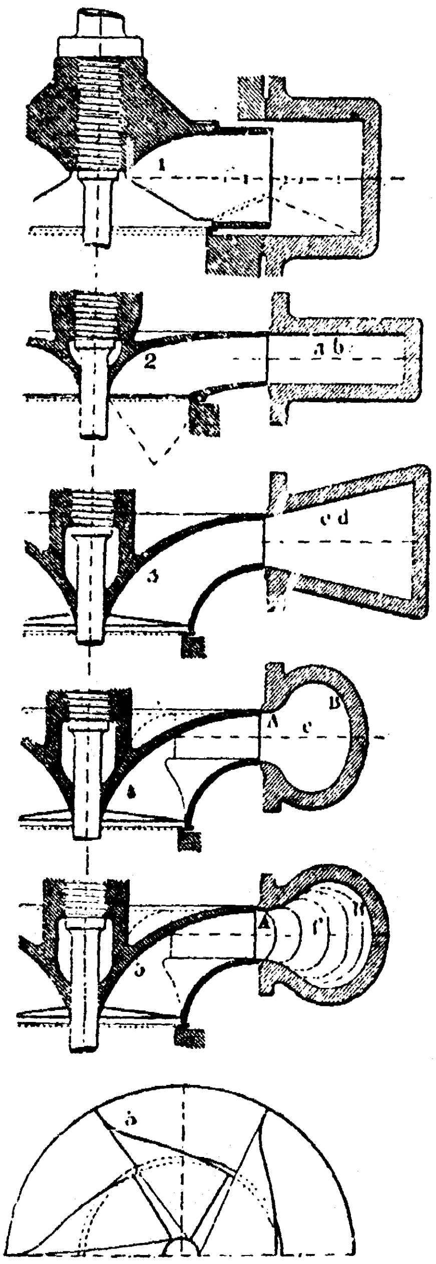

FIG. 85.—Different forms of runners and casings for centrifugal pumps; used in experiments by Joseph Farcot.

*Annales des Ponts et Chaussées, September, 1888.

ners were composed, as usual, of blades set between circular disks or side plates. The entrance for water was on one side only.

The disks and blades experimented upon are shown in Fig. 85 and were as follows:

1. A runner with plane radial blades and flat disks;
2. Plane radial blades, and paraboloidal disks but slightly dished;
3. Plane radial blades, and paraboloidal disks more deeply dished;
4. Helicoidal blades, alternated with half blades of the same shape, and paraboloidal disks;
5. Helicoidal blades, all alike, and paraboloidal disks.

Each of these was tried in six different casings, in which the forms of the annular conduits surrounding the runners were different; as follows:

(*a*) Circular conduit of rectangular cross section, concentric with the runner; Fig. 85 (2).

(*b*) Spiral conduit of rectangular cross section; Fig. 85 (2).

(*c*) Concentric; cross section trapezoidal: Fig. 85 (3).

(*d*) Spiral; cross section trapezoidal; Fig. 85 (3).

(*e*) Circular conduit, with cross section of curvilinear outline; Fig. 85 (4).

(*f*) Spiral; cross section curvilinear; Fig. 85 (5).

The efficiency of the pump improved as the forms stated above were used in the order given, and the best results were obtained by combining the runner (5) with the casing (*f*), with which combination an efficiency of 81 per cent. was obtained.

The same high efficiency was also obtained from experiments with runners shaped on the same principle as (5), for lifts of from 25 to 30 feet, and from 60 to 70 feet.

In the casings with spiral conduits the area of the cross section of the conduit was nearly proportional to the angular distance of the section from its starting place next the outlet.

In studying the form to be given to the passages through the runner, the movements which it was sought to give to each particle of the water passing through them were:

First, a uniform diminution of the velocity (v_0) which it has in the direction of the axis of the runner at entering;

Second, a constant angular acceleration of its movement in a circular path;

Third, a radial movement having a magnitude proportioned to the centrifugal force of the particle, resulting from its angular movement determined as above.

While the conditions prescribed by these principles can be realized practically only for those particles of water which continue in contact with the blades and disks, yet they formed the basis upon which the study of the problem was conducted.

Shape of the blades.—The form of the blade surface at each end was determined by the conditions:

(A) That the direction of the first element of the blade, at each point, shall be the resultant of the tangential velocity, v_t, of that point, and the axial velocity, v_o, of the particle of water which it picks up;

(B) That the last element of the blade, whose function is to impart the velocity of the tip of the blade to the issuing particle of water, shall be in the direction of the radius of the runner, the object of this condition being to obtain a maximum lift with a minimum speed of rotation of the runner.

Between the two limiting elements just described, the shape of the blades must be such as to make the passageway between them of such form that the extent of their surfaces will not be so great as to cause undue friction, while at the same time the flow of water through them will be free from eddies and not throttled. This is accomplished by determinating the two generating curves of the surface, that is to say, the two curves formed by the intersections of the blade with the disks, in the following manner: The curve on the lower disk; *i. e.*, the disk through which the water enters, is the intersection of the paraboloidal surface of this disk with a helicoidal surface—cylindrical or not—having an initial angle of inclination determined by the equation, tan. $a_1 = \frac{v_o}{v_t}$. The trace upon the surface of the upper disk is the intersection of its paraboloidal surface with a helicoidal surface whose generatrix, situated on the cylinder circumscribing the runner, satisfies the following two conditions:

First. That at its origin, the angle of entrance, a_2, shall be determined by equation, tan. $a_2 = \frac{v_o}{v_t}$.

Second. That, through an angular extent equal to that subtended by the lower curve, the change of curvature shall be as smooth and gradual as possible; the whole of the terminal element of the blade being on a line parallel with the axis of the runner, and at the periphery.

These two curves, traced in the manner described above, are united by a ruled, warped surface, which will be the surface of the blade.

Number of blades.—The experiments indicate that the number of blades, which should not be less than six, does not affect the efficiency materially. It does, however, produce a slight effect upon the mean velocity of outflow from the runner, and therefore causes a small difference in the height of lift corresponding to a given velocity of the periphery of the runner.

Speed of the periphery of the runner.—The experiments demonstrate that the velocity of the circumference of the runner is great enough if it is $v_t = 0.88 \sqrt{2gh}$; h being the height of the lift. Comparing this expression with that given by Professor Rankine—derived from his theoretical discussion of mixed molecular vortices constrained and free—which is, $v' = \sqrt{gh}, = 0.706\sqrt{2gh}$, it is to be remarked that the ratio $\frac{v'}{v} = 0.801$, and represents practically the efficiency of these pumps, as determined by the experiments.

Shape of the annular conduit of the case.—In flowing from the helicoidal blades of the runner, the water issues without eddies or loss of energy if the annular conduit is formed as in *e* and *f* of Fig. 85. The shape of the cross section of this conduit is the one which avoids abrupt changes in the direction of flow, and, while affording a given capacity of discharge, has the least wetted surface. It approaches a circle, but in reality its outline should be an "elastic curve" such as would be formed by an elastic strip fastened tangentially to the disk surface of the runner, as at AA', Fig. 86, and at the other end, as at B B', tangentially to a short circular arc selected so as to secure the least practicable wetted perimeter. This form was not determined arbitrarily and it contributes much to the efficiency of the pump. It forms a continuation of the paraboloidal

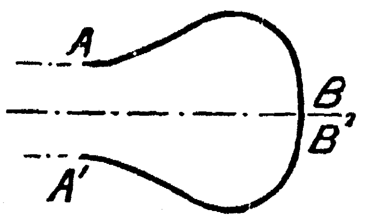

FIG. 86.—Outline of the cross section of the casing channel in Farcot's centrifugal pumps.

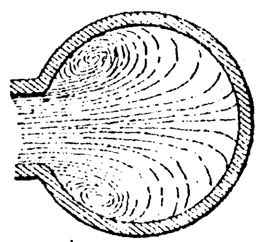

FIG. 87.—Showing the formation of eddies in a channel of circular cross section.

surfaces of the runner disks, and its principal advantage is that abrupt changes of the velocity and direction of the water in its flow do not occur, and eddies, such as are indicated in the sketch, Fig. 87, are avoided.

Mr. Farcot says that a concentric, instead of a spiral conduit for the case, gave nearly as good economical results, under certain conditions which he does not name. He says that the loss of head from the greater friction occasioned by the higher mean velocity of the water in the spiral conduit, appears to compensate nearly for the loss occasioned by eddies in the concentric conduit, but that an advantage of about 3 per cent. in favor of the spiral case was usually observable. By this is meant, that if the efficiency of the pump with the spiral case were 80 per cent., it would be reduced to 77 per cent. by using a concentric case.

(93) Centrifugal pumps of various sizes, in a series from small to large, are manufactured by the Messrs. Farcot. Their design is neat. Fig. 88 shows a general view of one of them.

(94) *Décour's centrifugal pump.*—This is manufactured by the Société des ateliers et chautiers de la Loire.

Fig. 89 shows a section. The feature of novelty is a diffuser, or, as it is called, an ejector, surrounding the runner and consisting of

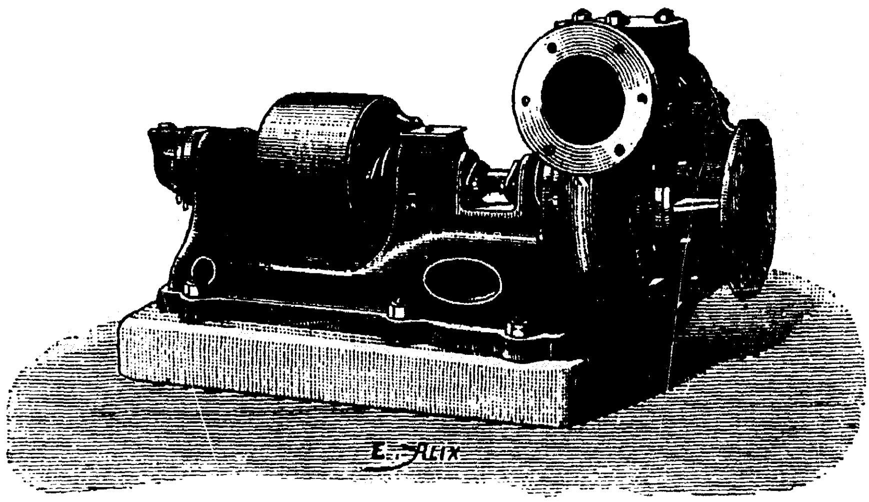

FIG. 88.—Farcot's centrifugal pumps.

two annular plates made in one piece with the case, and forming stationary expansions of the planes of the revolving runner disks. The passage way between the plates expands in width as it increases in diameter, forming a flaring outlet to the runner, through which the

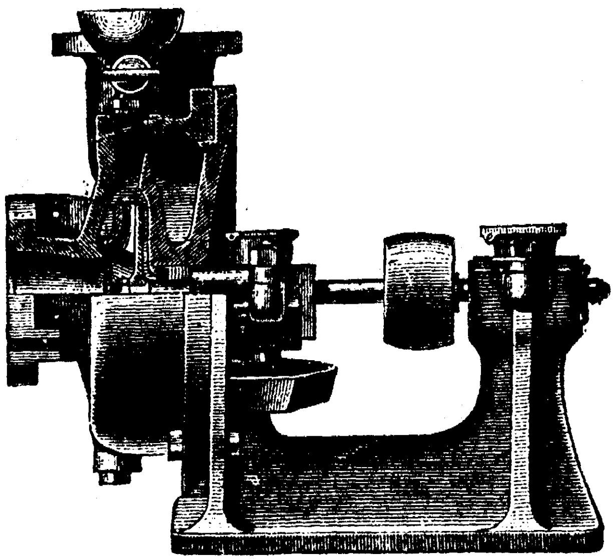

FIG. 89.—Sectional view of Décour's centrifugal pump.

water from the latter flows into the large annular chamber constituting the body of the pump, from which the discharge pipe leads. The action of this flaring annular outlet is the same as that of Boyden's diffuser, long since applied in the United States to turbine wheels—and the same as that of Venturi's tube—by which a part of the energy of the water, which would otherwise be lost in forming eddies, is utilized in such a way as to increase the discharge.

An official test of a 4-inch pump, made under the auspices of the Ministry of the Marine, at Brest, in 1886, showed an efficiency of 79 per cent., with a lift of 20 feet.

Nezeraux's centrifugal jet pump.—J. Casse & Sons exhibited this pump, in which the action of a centrifugal pump and that of a jet pump are combined in a novel way. It is designed for pumping water under a much greater head than can be advantageously overcome by centrifugal pumps of the usual construction, without running them at excessive speed.

Fig. 90 is a section of one form of this pump.

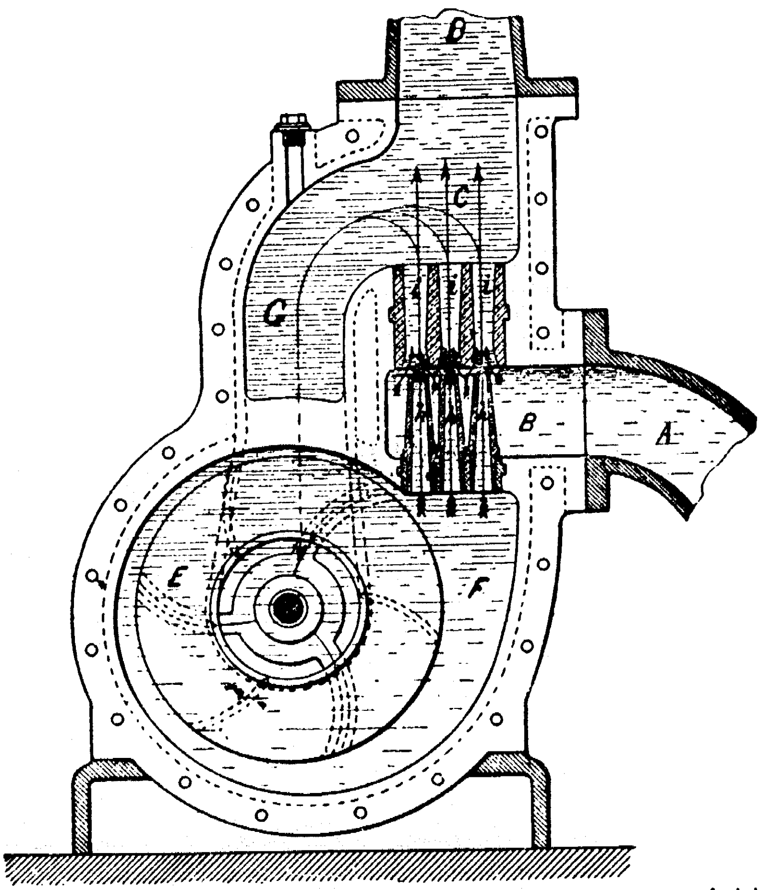

FIG. 90.—Nezeraux's centrifugal jet pump for forcing water to a great height.

A is the inlet pipe, or suction pipe; this enters the chamber B, which may be called the jet-chamber, for it contains a set of jet nozzles, *h*, leading from the chamber F, and a corresponding set of guide tubes *i*, leading from B, which, together, constitute a jet pump by means of which water, drawn in through A, is forced into a delivery chamber, C, and thence through the discharge pipe D to any desired height. From the chamber C a large passageway leads downward outside the pump case, on each side, and enters the case again opposite the central opening of the runner E, so that the two passageways form the inlet pipes of the centrifugal pump, of which F is the delivery chamber in which the runner turns.

By this arrangement, when the runner is stationary the pressure exerted by the head of water in the discharge pipe D is communicated through the passageways G and openings of the runner E to the water in the runner chamber F, and the pressure is as great in F as in C. When, however, the runner is made to revolve, the pressure in F will become greater than in C, and may be made as much greater as is desired, the increase being dependent upon the

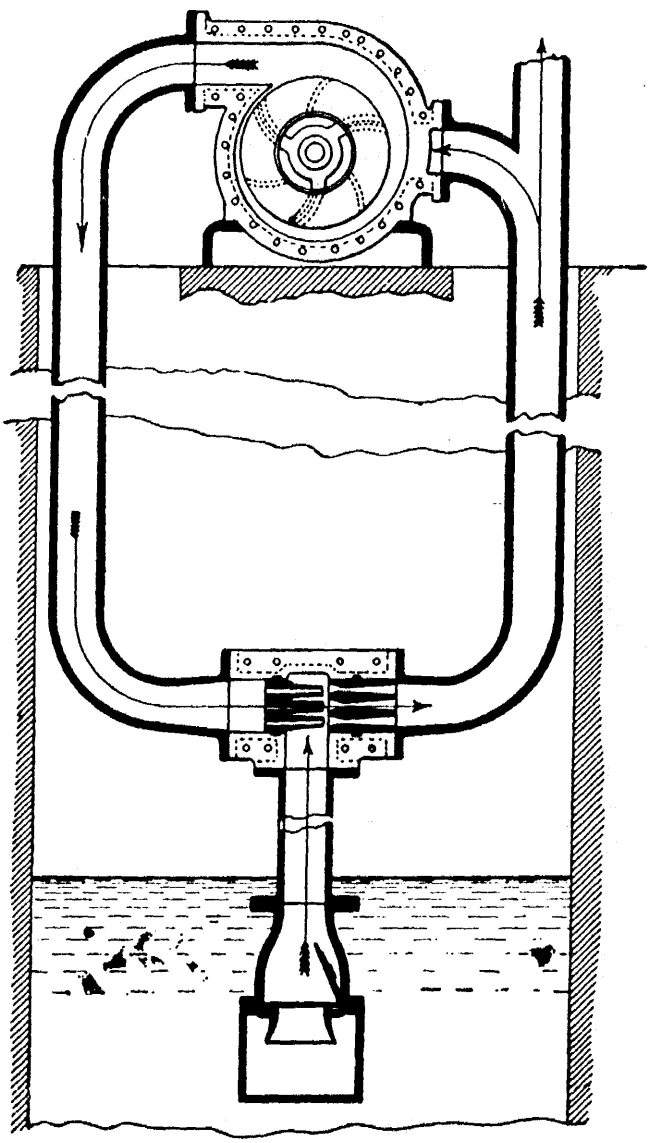

FIG. 91.—Application of Nezeraux's centrifugal jet pump to lifting water from deep wells.

speed at which the runner turns. This difference of pressure, when it becomes great enough, will produce in the jet pump a flow of water having sufficient velocity to entrain the required quantity of water from the chamber B, the nozzles and guide tubes being properly shaped and proportioned to produce this result under the prescribed conditions. When the head in the delivery pipe D is great, the larger proportion of the water which flows through the nozzles will circulate over and over again through the centrifugal pump, a small proportion only being drawn from the chamber B and delivered into the discharge pipe D.

With a centrifugal pump of a given size and speed, this apparatus will pump considerably less than $\frac{1}{n}$th of the quantity of water that the centrifugal pump alone would deliver, if running under the ordinary conditions and not under the excessive head, and will force this smaller quantity to n times the height to which the centrifugal pump running at the same speed would deliver its full volume of water.

Fig. 91 shows the apparatus arranged for drawing water from a depth of 80 or 100 feet below the place where the centrifugal pump is set.

The same system is also adapted as an air pump, for use with a jet condenser, and is said to produce an excellent vacuum. It is also applied in the same manner that ordinary jet pumps are used for exhausting air and gases.

No published results of tests of the efficiency of the Nezeraux pump could be obtained.

(96) *Hydraulic rams.*—Quite a number of these simple water elevators were shown by different manufacturers, the one first deserving notice being an unusually large machine of its kind, called the "Giant" ram by its maker and exhibitor, Mr. Ernest Bollée, of Mans, France.

A longitudinal section of this ram is shown in Fig. 92, while Fig. 93 is a cross section, in a plane passing through the escape valve.

The Giant ram embodies Mr. Bollée's latest improvements, and differs from rams exhibited by other makers in having the waste valve, A, of the battery, inverted with respect to the usual position of such valves, and counterpoised in such a manner that the valve rises in opening, and is closed by a downward movement. This arrangement admits of placing the valve seat at the bottom of the battery chamber, so that the escape of the waste water takes place downward through the bottom instead of overflowing the top of the chamber, and permits a more complete utilization of the full height fall than is obtainable with other forms, when the rams are placed above the tail water; in fact, in the new Bollée rams a short draft tube may be used beneath the escape valve seat, so that the ram may stand at a convenient height above the lowest water level and yet utilize nearly the whole fall.

The waste valve A is a puppet or pot lid valve, the stem of which is guided in the bonnet of the battery chamber in which the valve works. Its weight is overbalanced by means of two counter-weighted levers, B, which lift the valve from its seat when the reaction of the water in the battery chamber takes place, but are so adjusted as to permit the valve to close readily under the action of the escaping waste water as soon as this attains its proper maximum velocity of flow. The delivery valve C, through which the water is forced into the air chamber D when the valve A closes, is also a puppet valve, and is guided in its seat by wings. To prevent an injurious battering of the valve and seat faces, by blows occasioned by the sudden closing

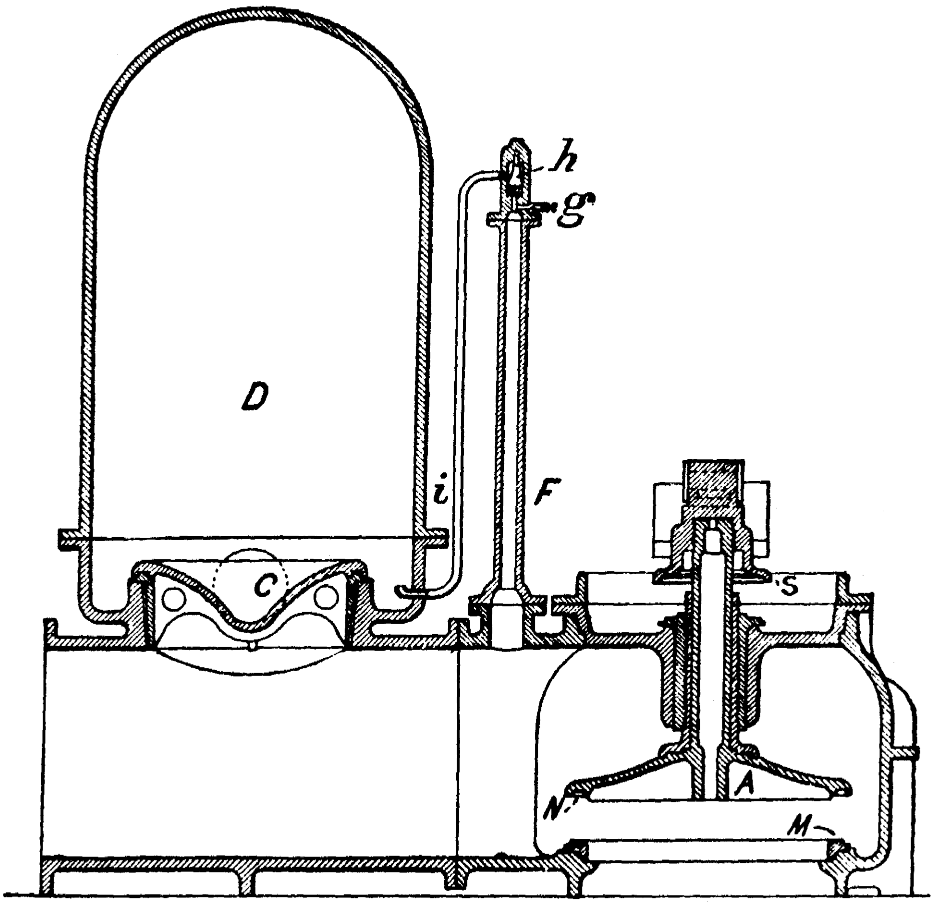

Fig. 92.—Longitudinal section of Bollée's "Giant" hydraulic ram.

of the delivery and waste valves, hydraulic cushions are provided, consisting of an annular tongue, M, on the top of the valve seat, and a corresponding circular groove or rabbet, N, in the bottom of the valve face. The projecting ring on the seat fits the groove in the valve, so that, when the valve shuts, water is inclosed in the groove N, and as this water can escape only gradually it prevents the metal surfaces from coming violently in contact with each other. An adjustable stop, D, is provided, by which the height to which the waste valve A may lift is regulated. The bottom of the stop S is recessed, and the top of the crown of the valve made to fit this recess, so that a water cushion is provided here also, to prevent shock when the valve is lifted suddenly so far as to strike the stop.

This great ram weighs about 8¼ tons, is 12 feet long, and its height is about equal to its length. The diameter of the supply pipe is 3 feet, that of the waste valve 40 inches, and of the delivery valve 30 inches. The lift of the waste valve is designed to be from 7 to 8 inches, and with this lift the valve is intended to pass 350 liters, or 12.35 cubic feet of water per second.

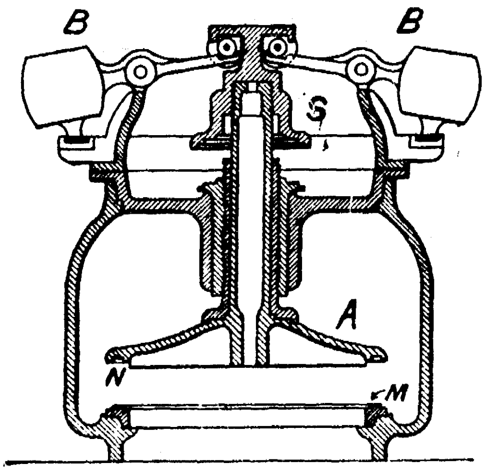

FIG. 93.—Transverse section of the battery chamber of Bollée's ram.

Mr. Bollée states that his Giant ram will deliver 150 liters, or 5 cubic feet, per second—or more than 3,000,000 gallons of water in 24 hours—to a height three times greater than the fall of the supply water; a duty which represents a high efficiency, even if, as must be the case, he assumes the lift of the water in the force pipe to be measured above the ram and not above the source of supply.*

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*The useful effect of a hydraulic ram is described in various ways in the circulars of the manufacturers of these machines; in fact, the efficiency, E, of the ram is assumed by the makers to be represented by one or the other of the following four different formulæ:

$$E = \frac{q(H+h)}{QH}; \qquad E = \frac{q(H+h)}{(Q-q)H}$$

$$E = \frac{qh}{QH}; \qquad \text{and} \qquad E = \frac{qh}{(Q-q)H};$$

in which Q denotes the whole volume of water taken from the supply pond, of which the portion q is forced up by the ram to a height, h, *above the level of the surface of the pond*, by the action of the quantity $(Q-q)$, which, falling from the pond to the ram, escapes from the waste valve under the head H, measured vertically from the water level of the pond down to the level where the waste water is discharged. Manifestly the last of the four formulæ given above is the only one which expresses the useful effect of the ram, if we estimate this according to the same principle as that upon which the efficiency of other machinery is estimated: for, if w denotes the weight of unit of volume of the water, then wqh is the useful work performed by the ram in taking the quantity q from the source of supply—which, in the oridinary ram, is the pond from which all the water is taken—and in forcing this quantity up to the height h above the source; while the energy expended in operating the ram is $w(Q-q)H$; namely, the energy exerted by that part of the water which falls from the pond to the ram, and is discharged there through the waste valve. The portion of water q which is not wasted also falls to the ram but rises again in the delivery pipe, as high as the level of the pond, without the action of the ram, and the water which is wasted is the only part of the whole quantity Q that is employed in doing the work of lifting the portion q through the vertical distance h to which it is forced above the level of the pond. The expression $\frac{qh}{(Q-q)H}$ then represents the ratio of useful work performed to energy expended, and is the measure of the efficiency E of the ram.

Etelwein long ago obtained from experiments, empirical formulæ for the efficiency

(98) An automatic air pump for maintaining the proper quantity of air in the air chamber is applied to this ram. It is shown in Fig. 92. F is a pipe rising from the top of the battery chamber, and having near its top a small aperture, *g*, for the admission of air. This aperture is partly closed by a screw by which the size of the opening may be regulated. Above the opening *g* is a small puppet valve *h*, which opens by lifting, and through which air is delivered into a chamber above the valve from which the air finds its way, through a small pipe *i*, into the main air chamber D. The action of this air pump is as follows:

Immediately after the shock of the supply water, occasioned by the closure of the waste valve, has produced the delivery of a portion of that water into the air chamber, a reaction of the water in the supply pipe takes place, which for a short time reduces the pressure in the battery chamber to less than that of the atmosphere. At this time a small quantity of air is sucked into the upper part of the pipe F through the hole *g*; but when the period of the next outflow of the escape water has ended, and the waste valve A closes, the shock, again produced by the arrest of the motion of the supply

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of well proportioned Mongolfier rams, and experience since his investigations has confirmed the general applicability of his conclusions.

The formula he gives as best representing the mean of the results for all different heads up to $\frac{h}{H} = 20$ is

$$E = 1.12 - 0.2\sqrt{\frac{h}{H}}.$$

The following table has been computed from this formula, and shows the duty that a well constructed ram may be expected to perform when the delivery pipe is of liberal size, and the diameter and length of the supply pipe, or penstock, properly adjusted to the conditions under which the ram is used.

Table of the efficiencies of hydraulic rams.

$\frac{h}{H}$	2	3	4	6	8	10	15	20
E	.84	.77	.72	.63	.55	.49	.35	.23
$\frac{q}{Q}$	.30	.20	.15	.095	.064	.047	.023	.011
$\frac{q}{Q-q}$	.42	.35	.18	.10	.07	.05	.023	.011

Example.—Bollée's Giant ram discharges 350 liters of water per second through the waste valve, in lifting a certain supply to a height above the ram three times greater than the fall, that is, to a height above the pond equal to twice the head of the fall. Here $\frac{h}{H} = 2$, and from the above table we have, for the quantity of water lifted, $q = 0.42\,(Q - q) = 0.42 \times 350 = 147$ liters per second. Mr. Bollée says that the ram delivers 150 liters. The efficiency of this ram in performing this duty would be $\frac{150 \times 2}{350} = 0.857$, or nearly 86 per cent. instead of 84 per cent., the efficiency computed from the formula.

water, compresses the air which has entered the pipe F to a pressure somewhat greater than that in the air chamber, because a greater pressure is needed to cause the opening of the main delivery valve than is required to lift the small valve *h*, and the air in the pipe F is therefore forced into the air chamber. The suddenness of the shock by which the compression of the air in the pipe F is produced prevents the loss of too great a proportion of the air through the hole *g*, which, though large enough to admit the required quantity of air under the comparatively slow aspiration which takes place, is not so large as to allow all that air to pass out again in the short period which its compression occupies. The action of this air pump is much more certain and efficient in keeping the ram in working condition than is the inlet valve provided for the same purpose by Montgolfier, the original inventor of the hydraulic ram.

An air pump similar to that shown by Bollée is applied to the rams displayed by other French exhibitors, and seems to be quite commonly used. (See Fig. 94.)

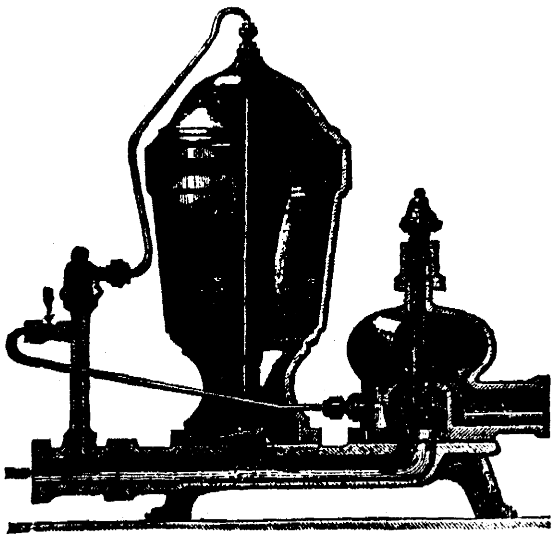

FIG. 94.—Durozoi's hydraulic ram with air pump.

(99) *Durozoi's ram pump.*—Mr. M. Durozoi, of Paris, exhibited a ram for using the motive force of river water or foul water under a small head, from one source, for taking purer spring water from another source and forcing it to a high elevation. The general form of this ram pump is not new, but there are unusual features.

Figs. 95 and 96 show sections of the machine.

It is a simple form of diaphragm pump, in which the diaphragm is worked by the shock and reaction, alternately, of the river water which flows into and out of the battery chamber containing the waste valve of the ram.

The water from the impure source enters the battery chamber at A and actuates the waste valve B, in the same manner as in the ordinary ram. A flexible diaphragm, D, of India rubber or leather, separates the battery chamber from a small chamber which is above the diaphragm, and beneath the delivery valve J. When the waste

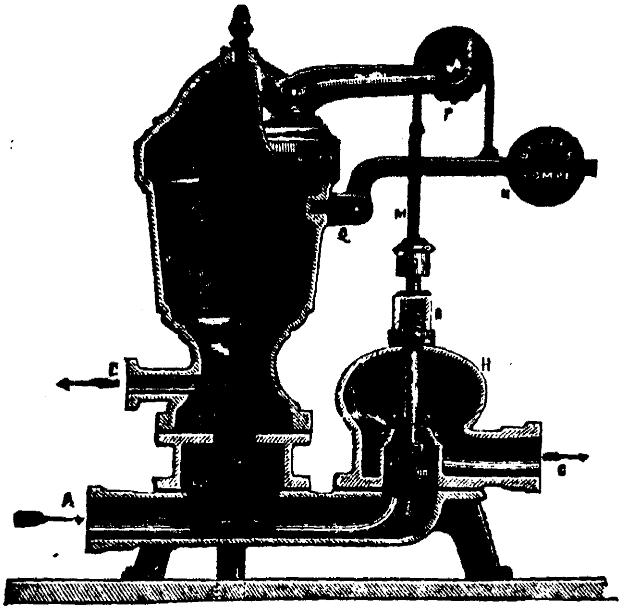

FIG. 95.—Longitudinal section of Durozoi's ram pump.

valve B opens, there is a partial vacuum formed for a time in the battery chamber by the flowing away of a portion of the water before the inertia of the mass of water in the main supply pipe is overcome;

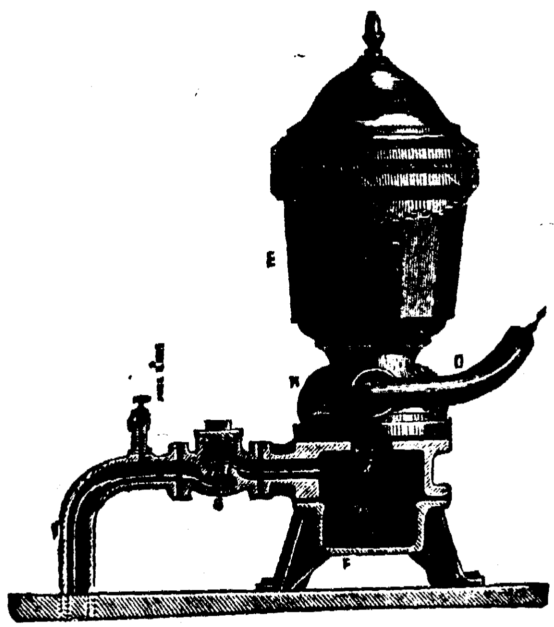

FIG. 96.—Transverse section of Durozoi's ram pump.

this occasions a downward flexure of the diaphragm D, by which pure water is sucked from its source of supply, through the pipe *i* and check valve *s*, into the chamber above the diaphragm. When the waste valve closes, the pressure which is then produced by the arrest of the motion of the outflowing impure water, instead of delivering a portion of this water into the air chamber, forces the diaphragm upward into the chamber above it, and thus forces part of the pure water contained in that chamber through the delivery valve J into the air chamber, and thence through the rising pipe to the desired elevation. The quantity of water thus raised by a ram of a given size depends upon the relation of the height of the fall of the motive water to the elevation to which the pure water is lifted above the source of its supply.

The same manufacturer showed a ram pump with a differential piston; that is, with a piston of large diameter working in a cylinder open to the battery chamber, and having a smaller piston attached

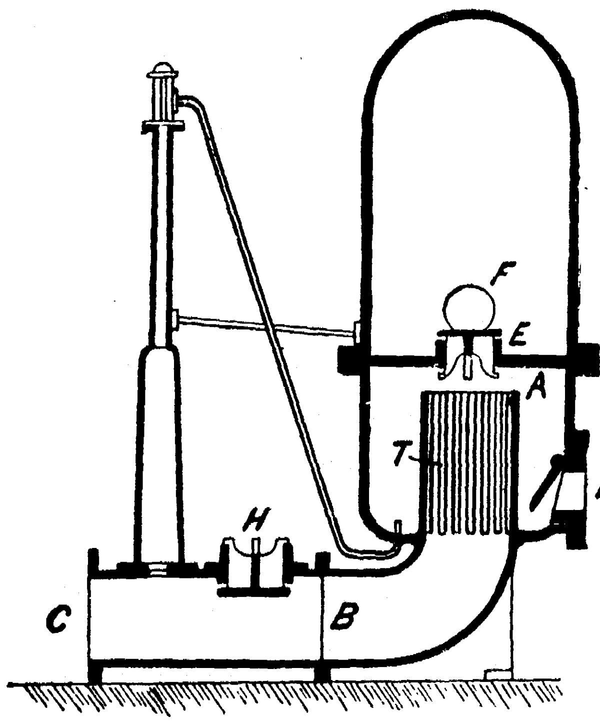

FIG. 97.—Bollée's ram pump without piston or diaphragm.

to it which works as a pump piston for raising the water which is to be lifted; by this means, with a given fall, water can be forced to a greater height than by using an ordinary ram.

(100) Mr. Ernest Bollée also exhibited a ram pump, for forcing pure spring water by means of river water or foul water, in which he dispenses with a diaphragm, piston, or any substance whatever for separating the foul water from the clear; depending for their separation upon the lack of a tendency of the waters to mingle when they are not agitated.

Fig. 97 shows a section of this ram. C is the inlet to the battery chamber B, which receives the river water and discharges it through the waste valve H. T is an upright pipe, forming a branch from the battery chamber. It is filled with partitions, which form narrow tubes passing through it and opening into a chamber, A, below the delivery valve E of the air chamber C. The inlet pipe and check valve for the clear water are at D, and the delivery outlet from the air chamber to the force pipe is at F. The upright branch T is of some height, and plays the part of a pump barrel. It is divided into numerous narrow vertical passages by small pipes which fill it. The changes of pressure which occur in the battery chamber are communicated to the chamber A through the open barrel T, and by this means the clear spring water is sucked in through the inlet-valve D, and forced into the air chamber, alternately. The narrow passages in the barrel T prevent such a commotion of the water in the barrel as would cause the spring water which is drawn into its upper part from mingling with the muddy or foul river water with which its lower part is filled from the battery chamber.

In the full-sized glass working model shown by Mr. Bollée a distinct horizontal plane of sharp separation could be seen in the barrel T, between the muddy water from the battery chamber and the clear water from chamber A. Whether the diffusion in the clear water, or mixture with it, of other impurities than those which were visible in the water would take place, could be learned only from trials and analyses under various circumstances.

When the difference between the fall and lift is quite small, Mr. Bollée dispenses with the partitions in the barrel T, finding that even then the waters have no tendency to mingle.

(101) Messrs. W. B. Douglass, of Middletown, Connecticut, Gould's Manufacturing Company, of Seneca Falls, New York, and Silver & Deming Manufacturing Company, of Salem, Ohio, exhibited in the United States section, well-constructed examples of hydraulic rams of the forms so well known here. They also exhibited ram pumps for two kinds of water.

(102) *Hydraulic elevators—Elevators in the Eiffel Tower.*—There were five elevators kept running continuously to their full capacity, for the conveyance of throngs of visitors to the three principal platforms of this gigantic structure, which formed one of the most attractive features of the Exposition.

Two elevators, of the Roux, Combaluzier, and Lepape system, in the east and west piers, carried passengers from the ground to the first platform, 187 feet above; two others, of the Otis type, built by Otis Bros. & Co., of New York City, were placed in the north and south piers, and ran from the ground directly to the second platform, with a landing at the first platform, and a total lift of 377 feet. Lastly, an elevator, on the Edoux system, carried visitors from the second platform to the summit of the tower, 905 feet from the ground, performing the lift of 528 feet in two equal flights of 264 feet each, the passengers being required to pass from one car to another at mid-height.

Water under pressure is the only motive power combining the precision and ease of management required for elevators under the conditions of these; and accordingly all the tower elevators are worked by water, which is supplied by pumps placed in the bottom of the south pier. Those by which the four lower elevators are fed pump the water through a pipe of 9.84 inches diameter into two cylindrical tanks, each 9 feet 10 inches diameter and 23 feet long, placed on the second platform. The two tanks are connected by a pipe 19.69 inches diameter, from which four branches are led down to supply the hydraulic cylinders at the foot of each pier. On leaving the cylinders the water returns through the underground pipes into the feed tank at the south pier, whence it is pumped anew into the upper tanks. The Edoux lift is supplied by two Worthington pumps, which deliver the water into a tank 9.84 feet diameter and 13 feet deep, placed on the third platform. A similar tank on the intermediate platform receives the discharge water, so that the pumps take their water from the height of 656 feet and deliver it to a height of 918 feet. The cast-iron pipes are made extra strong to resist so great a pressure.

The elevators in the piers are, essentially, inclined railways of very steep grade, the rails from the ground to the first platform having a rise of 1½ feet to each foot of horizontal distance, while their grade from the first platform to the second is 6 to 1.

The cars of these inclined railways are two stories high. Each car of the Roux elevators has room for 100 passengers—70 standing and 30 seated—while each of the Otis cars will accommodate 50 passengers, 25 in each story, all seated; the change of inclination of the car while in motion, in consequence of the change of grade at the first platform, makes it impracticable to allow the passengers to stand. The car of the Edoux elevator has room for 60 or 70 passengers, all standing. Twelve trips per hour are made by the cars on the Roux and the Edoux elevators, and eight by the Otis; the speed of running being 200 feet per minute for the Roux, 400 for the Otis, and 180 for the Edoux car. Twenty-four hundred persons per hour can therefore be carried to the first platform by the Roux elevators, 800 from the ground to the second platform, or from the first platform to the second, by the Otis lifts, and 800 between the second platform and the summit by the Edoux.

A brief description of each of the three systems will be given, but for more complete information the reader is referred to illustrated articles in Engineering of July 4, 1890.

(103) *The Roux, Combaluzier, and Lepape elevators.*—In this system the car, instead of being drawn up the inclined railway by means of wire ropes, is attached to the lower branch of a circuit formed

by an endless chain, running parallel with the rails on which the car runs, and passing over two large wheels, 12 feet in diameter, one at the head and the other at the foot of the lift. The wheel at the foot is a sprocket wheel, having recesses in its periphery for catching hold of the ends of the chain links. It is revolved so as to run the endless chain in the direction for moving the car upward, by means of a plunger which works in a horizontal hydraulic cylinder and is thrust outward for hoisting. The plunger carries a pulley sheave at its outer end, over which a pitch chain passes, one end of which is fastened to the framework holding the cylinder in place. This chain is led forward from its fastening and passes downward half around the sheave, then backward beneath the cylinder, and lastly, half around a sprocket pinion which is keyed fast to an axle on which the 12-foot sprocket wheel is also fastened. The loose end of this chain beyond the pinion is contained in a receptacle formed by a horizontal pipe, in which the chain slides back and forth as it is given out or taken in by the rotation of the pinion.

The length of pitch chain taken up or given out by each complete movement of the plunger is equal to twice the stroke of the latter, and as the diameter of the sprocket pinion is a little less than two-thirteenths of the diameter of the 12-foot sprocket wheel which drives the endless chain and car attached to it, the stroke of the plunger need be only about one-thirteenth as long as the travel of the car on the sloping railway, or about 16½ feet.

The endless chain for the car is composed of links formed of heavy bars about 40 inches long, jointed together by means of strong pins, and abutting against one another end to end. The chain runs in channels for its whole circuit, and is confined in these channels in such a manner that the chain can act by thrusting, as well as by pulling, without buckling. This affords double security against the falling of the car, the action of the chain being as follows: If the length of the upper branch of the chain circuit is so adjusted as to act in tension to draw the car upward, the tearing apart of a link would not result disastrously, as the car would then be held up by the part of the endless chain below it, that is, by the part which at the time lies between the car and the large sprocket wheel below; for this part of the chain, formed like the rest of links abutting against one another, and kept from flexure by the channels in which it is confined, would act as a solid bar on the end of which the car would be supported. If, on the other hand, the upper part of the circuit of the chain is slack, the car will not be pulled upward by the chain, but will be propelled by being thrust upward from below, by the chain acting like a continuously lengthening strut extending from the sprocket wheel to the car; now, if under these conditions the lower part of the chain should yield, then the car would remain safely suspended from the part of the chain which extends above it.

To lessen the enormous friction which would be occasioned by dragging this heavy chain, weighing 27 tons, through its guiding channels, it is supported on truck wheels which turn on journals on the two ends of each joint pin, and run, as upon rails, on the top or the bottom of the channels, as the case may be. There are about three hundred and fifty of these wheels in one endless chain. The car is supported by two of these endless chains, one on either side, each of which is provided with its own special hydraulic cylinder, and either of which alone is strong enough to sustain the car. The sheaves, pitch chains, and sprocket pin for each of the hydraulic cylinders are duplicated side by side, each set being of sufficient strength to sustain the load and leave a large margin of safety.

The Roux elevators were noisy in their operation, as might have been anticipated, but their security was beyond criticism, and their operation during the Exposition seems to have been satisfactory.

(104) *The Otis elevators.*—The problem which the Otis Brothers undertook to solve was more difficult than that presented by the other elevators in the tower. The continuous lift was much higher than those of the others, and the change of inclination of the track upon which the car ran—referred to elsewhere, and which occurred at the level of the first platform—increased the difficulty of designing efficient and safe elevators adapted to the service these were to perform. The Messrs. Otis overcame all the difficulties with great skill, and furnished elevators of the American type which were a credit to their firm and to the country it represented.

The hoisting apparatus of these elevators is of the type usually adopted by the Otis Brothers, and consists of a hydraulic cylinder bored throughout its length, and containing a piston whose rods pass through stuffing boxes in the upper cylinder head, and carry at their ends the movable sheaves of a purchase, by means of which the movement of the piston is multiplied sufficiently to give the required lift to the passenger car. The car is suspended by wire ropes passing over sheaves at the head of the lift and connected with the purchase. The piston rods act in tension, for, in hoisting, the pressure water is admitted to the top of the cylinder, and the water below the piston is allowed to escape and return to a tank at the foot of the lift. In lowering the load, the supply and escape valves are both kept closed, while a communication is opened between the top and bottom of the cylinder through a pipe connecting the ends, and the water displaced by the piston as it is drawn upward by the descending load passes into the part of the cylinder below the piston, an arrangement by means of which the cylinder is always kept full of water. In the Otis elevators for the tower all the apparatus is of unusual size; the hydraulic cylinders, 38 inches in diameter, are inclined at an angle of about 30 degrees with the vertical, and in each of these the two piston rods, of 4 inches diameter, are nearly 40 feet long. The upper ends of the piston rods are attached to a traveler sustained on trucks which run on rails parallel with the axis of the cylinder, and this traveler carries six 5-foot pulley sheaves, placed side by side, and acting in connection with six similar stationary sheaves, secured to the framing of the tower, so as to form an immense 12-purchase tackle. The length of the stroke of the piston in the hydraulic cylinder is therefore one-twelfth of the travel of the elevator car on its inclined track, or about 34 feet. To avoid inconvenience and danger from undue flexure of the inclined piston rods, ingenious provisions have been made to allow them to slide through two movable supports located outside and inside the cylinder—outside, between the stuffing box of the cylinder head and the end of the traveler to which the rods are attached, and inside between the cylinder head and the piston—in such a manner that the distance between two supports, that is, the distance between the piston and the stuffing box, or between the latter and the traveler, or between either of these and one of the movable supports, never exceeds half the length of the stroke. The outside movable support is a crosshead which slides on guide bars, and on which the piston rods lie as in a bearing box. The inside guide is a spider, or kind of open-work piston, which rests upon the lower side of the cylinder bore, along which it is free to slide; it is coupled to the crosshead by means of a rod passing through a stuffing box in the cylinder head, and stands midway between the upper cylinder head and the piston when the latter is at the bottom of its stroke, while the crosshead at this time lies just above the cylinder head. During the upward movement of the piston the spider and crosshead remain in the position just described until the piston has risen far enough to come in contact with the spider, which is then pushed upward by the continued movement of the piston, carrying the crosshead upward, away from the cylinder head, at the same time, until the upper end of the stroke is reached, at which time the spider is nearly in contact with the cylinder head, and the crosshead is midway between the cylinder head and the traveler. In this condition of the parts the piston rods are supported by the movable crosshead outside the cylinder, midway between the traveler and the upper cylinder head, just as they were upheld at mid-length by the spider inside the cylinder, when the piston was at the lower extremity of its stroke. In the downward travel of the piston, the spider and crosshead remain in the position they occupied when the upward stroke was completed, until the piston has descended through about half its stroke, when the traveler strikes the crosshead and forces it and the spider downward into the position first described.

The counterweight for the car consists of a long truck loaded with pig iron, and traveling on a straight track which has the same inclination as the main track on which the car runs, and is located beneath the latter, near the base of the tower. The counterweight is connected with the car by means of two ropes, arranged as a 6-purchase tackle, and passing over sheaves at the head of the lift.

To prevent the hoisting ropes from sagging, they are supported at intervals by grooved sheaves beneath them, except where the inclination of the rails gradually changes from the slope it has below the level of the first platform, to the much steeper slope above that level; here the pull upon the ropes tends to lift them, and, in order to have the line of draft continue nearly parallel to the track, it is necessary to place a series of guide sheaves above the ropes, so that the latter may be pressed downward, and be forced to lie in a concave plane curved upward. In order, however, to permit the passage of the fastenings by which the ropes are attached to the car, and in order to transfer gradually the direction of the pull of the ropes from the direction of the lower part of the track to that of the higher, the holding-down sheaves have to be lifted gradually, and successively, as the car approaches them in ascending, and must be depressed successively as the car passes them in descending; movements which are produced by inclined planes attached to the car and acting on cradles in which the bearings of the sheaves are held.

The usual safety appliances, consisting of clamps acting as brakes on opposite sides of the rail, for arresting the fall of the carriage in the event of the breakage of one or more of the ropes, are applied to this car. These are essentially modified from the customary form, and adapted to the peculiar conditions under which they have to work; but before the elevators were put into operation the efficiency of all the safety appliances was demonstrated by cutting apart the ropes, and thus setting free the loaded car, which descended only a short distance, and was brought to rest by the brakes without injurious shock. Safety brakes are also applied to the counterweight truck to arrest its fall in case of any failure of its ropes.

A fuller description than that given above, of the Roux and Otis elevators, may be found in a paper read by Mr. Ansaloni at a meeting of the Institution of Mechanical Engineers. This paper is published in full, with illustrations showing many details, in Engineering, London, July 5, 12, and 19, and in The Engineer of July 19.

(105) *The Edoux elevator.*—The Edoux hydraulic passenger elevator has been introduced to a considerable extent in Paris. It belongs to that class of elevators in which the car for receiving the passengers rests on the top of an upright plunger, whose length is equal to the height of the lift, and which works in a hydraulic cylinder as long as the plunger, and of considerably larger diameter. When an elevator of this kind does service for the lower stories of a building, the greater part of the upright cylinder must be buried in

the ground, so that when the height of the lift is great its penetration below the surface must be to a great depth; its establishment is consequently difficult and expensive in many cases. In the Trocadero the elevator cylinder penetrates 230 feet into the ground. It is a common practice to counterpoise a large proportion of the weight of both car and plunger by means of a weight suspended from ropes passing over sheaves at the head of the lift, the preponderance of the car and plunger being so adjusted as to be sufficient to overcome the friction and other resistances which would impede its motion, and therefore enough to insure the descent of the empty car. The car of the Edoux elevator is counterpoised in this way by an invariable weight, but a variable counterpoise also is provided for the plunger, in a manner, and for a reason which will now be described.

The effective weight of the plunger is less when at the bottom of its stroke and wholly immersed in the water contained in the hydraulic cylinder, than when it has risen out of the cylinder and stands at the top of the lift, by an amount equal to the weight of water displaced when the plunger is immersed; and its effective weight is diminished or increased in proportion as it is more or less immersed, differing, therefore, for every different position of the car. The effect of this variation of the virtual weight of the plunger on the operation of the elevator, is precisely the same as if the load in the car were uniformly increased from the time when the plunger starts to rise until it reaches its greatest height, when the excess of load thus added would amount to the weight of a column of water of the same diameter and length as the plunger. This varying load acts prejudicially in two ways: First, it tends to make the speed of the elevator diminish as the car rises; and second, it entails a waste of water; for the quantity used for each trip of the elevator must be sufficient to lift not only the maximum net load which the car is intended to carry, but also an additional load equal to the weight of the whole quantity of water displaced by the plunger.

The distinctive feature of the Edoux elevator is an arrangement for neutralizing this variation in the load, and rendering the pressure which the water is required to exert uniform throughout the whole lift. It consists simply in making the wire rope or chain by which the car and counterpoise are connected with each other, so large, that a length of rope equal to the lift of the plunger shall weigh just half as much as a column of water of the same diameter and length as the plunger. With this arrangement, when the car is at the foot of the lift the whole of the rope hangs above the car, and its weight is added to the load in the car which the plunger must lift; but when the car is at the top, all the rope has been transferred to the opposite side of the sheave, so as to hang above the counterpoise, adding its weight to the latter; the plunger is then only loaded with the load in the car diminished by the weight of the rope, the entire uniform change of load which is thus produced, by the uniform transfei of the rope as it passes over the sheave from the side occupied by the car to that of the counterpoise, being equal in amount to twice the weight of the rope transferred, and therefore exactly equal to the change in load which is occasioned by the change of the displacement of the plunger in the hydraulic cylinder, and in a direction opposed to this latter change; one change, therefore, counteracts the other, and the load to be lifted remains the same in whatever position the plunger may be. In practice four chains are often used, one for each corner of the car, so that their size does not become excessively large for elevators of moderate capacity, where a good head of water can be had. The wire ropes employed are flat, thin, and flexible, and yet of considerable weight per foot of length.

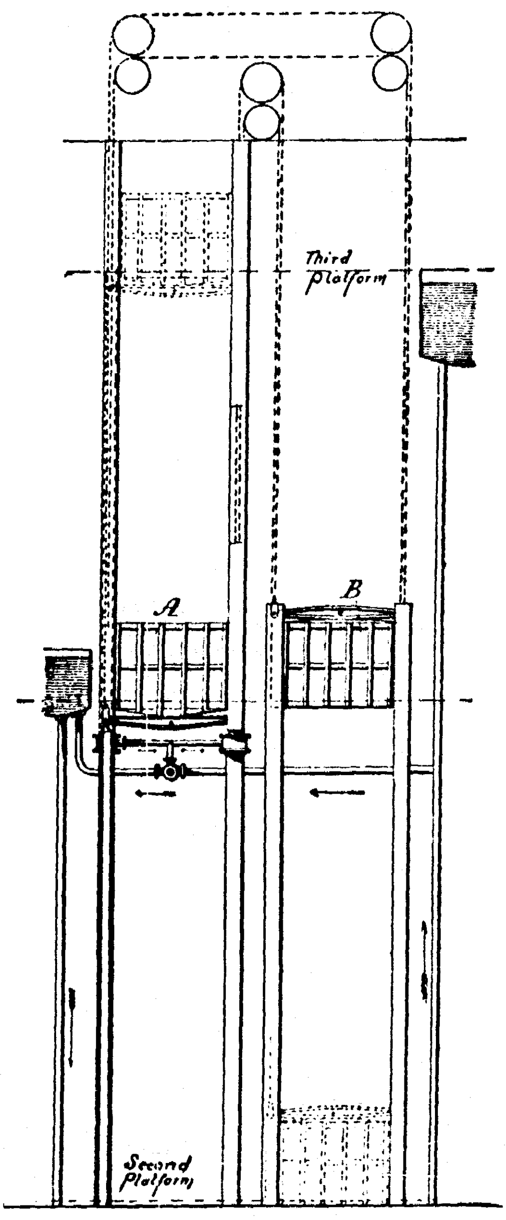

FIG. 98—The Edoux elevator in the Eiffel Tower.

In applying the Edoux system to the Eiffel Tower elevators for conveying passengers from the second platform to the third and highest, a condition which had to be met was that no part of the apparatus should extend below the second platform, a limitation insisted upon in order to avoid injuring the symmetry of the outlines of the structure. This difficulty and that of the great height of the lift were overcome, without sacrificing any essential feature of the system, by the expedient of dividing the lift into two equal flights. The vertical distance from the second platform to the third is 525 feet. Suppose a station for an elevator car to be located at half this height above the second platform, and that this is the starting point for a car A, Fig. 98, which rises from this place to the third platform, while at the same time its counterweight, consisting of a similar passenger car, B, descends from the same station, as a starting point, to the second platform; the car A, making its trips back and forth only between the mid-height station and the third platform, and the car B, between this station and the second platform. When the cars arrive at the mid-height station, which is the lower terminus for A and the upper terminus for B, the passengers who have come up from the second platform in B pass into A, while those who have come down from the third platform in A cross over into B, the upward-bound passengers completing the ascent to the summit in the car A, while the downward-bound passengers complete their trip in B. Two short, parallel platforms at the meeting station, afford separate passageways through which the passengers can change cars without interfering with each other.

By this arrangement the whole great lift is effected without the employment of any mechanism that had not already been tested by long use in the Trocadero, on a scale which afforded a safe precedent.

The cars are guided between vertical rectangular posts, of which there are three, one extending through the whole height of 525 feet, and two of half that height; the one on the left reaching from the second platform to the meeting station, and the one on the right extending from the meeting platform to the summit; all braced firmly to the framework of the tower at frequent intervals. The guides consist of cast-iron pipes, bolted to the posts, and having a slit all along the side next the car. The cars are moved by means of two plungers 12.6 inches in diameter and 265 feet long, working in hydraulic cylinders 15 inches in diameter, which reach from the second platform up to the meeting station. The plungers rise through the guide pipes, which steady them and protect them from the influence of wind. They are connected at their upper ends by an equalizing bar, on the middle of which the bottom of the car A rests. The hydraulic cylinders and rams are of steel pipe, riveted at the connections, except a portion of the length of the plungers, which is of cast iron made heavy so as to afford a preponderant force for lifting the suspended car B. Four flat wire ropes about 11 inches wide, two attached to the car A, and two to the plungers, are led above the third platform, then over sheaves, and downward to the car B, where they are fastened to the ends of an equalizing bar, from the center of which the car is suspended.

In the operation of the elevator four conditions occur:

First. Car A may be empty and car B loaded.

Second. Both cars may be loaded.

Third. Both cars may be empty.

Fourth. Car A may be loaded and B empty.

Only the first and last conditions need be considered.

Under the first condition, suppose car A at the top of its lift and B at the second platform. The car B and its passengers are now sustained by the weight of the plungers, and the weight of the latter must be as great as the weight of the passengers in the car, added to the unbalanced weight of the ropes hanging above the car B and to the weight required to overcome the frictional resistances. The last is assumed to be 5,250 pounds, and the weight of the passengers 8,800; as the water displaced by each foot of length of each plunger weighs 54 pounds, the weight of each rope should be 13½ pounds per running foot. The weight of the two plungers is, therefore, 8,800 + 525 × 4 × 13½ + 5,250 = 42,400 pounds.

Under the fourth condition, suppose A to be at the foot of its lift and B at its highest position, that is, suppose both cars to be at the mid-station; then, as the same length of rope hangs on the side of one car as on that of the other, the upward force required is equal to the weight of the passengers in A, added to that required to overcome friction, and to the weight of the plungers, diminishsd by the weight of water displaced by the latter; or in numbers, the force = 8,800 + 5,250 + 42,500 − 262½ × 108 = 56,550 − 28,350 = 28,200 pounds. As the combined area of the plungers is 250 square inches the head of water required above the top of the hydraulic cylinders, is $\frac{28,200}{250 \times 0.434}$ = 260 feet.

(106) *Work done and water consumed.*—(From Engineering, London, July 5, 1889.) Each of the Roux elevators consumes 1,925 British imperial gallons of water per trip, or the two together 3,850 gallons. Each Otis elevator consumes 1,728 gallons per trip, or the two together 3,456 gallons. The four elevators together consume therefore 7,306 gallons in one minute, since each of them takes one minute for the ascent; this is equal to 121.8 gallons per second. The difference of level between the pumping tank at the south pier and the supply tanks on the second platform is about 443 feet, after adding the loss of head. The power absorbed during the ascent of the four elevators from the ground level is thus equivalent to $\frac{7,306 \times 10 \times 443}{33,000}$ = 980.7 horse-power, or say 1,000 horse-power. The Edoux elevator consumes 31.69 gallons per second. The difference of level between the two tanks, adding the loss of head, may be estimated at 393.7 feet, which will give for the power exerted in the ascent $\frac{31.69 \times 60 \times 10 \times 393.7}{33,000}$ = 227 horse-power. The combined power thus amounts to over 1,200 horse-power, which, however, is in reality exerted only at intervals, namely, at the times of the ascents, or for about one-fifth of the time occupied in making the complete trip up and down. The power is accumulating in the tanks during the stoppages and descents, and consequently less than 300 horse-power is required to be developed continuously by the pumps.

(107) *Ellington's hydraulic balance elevator.*—An elevator designed for use in cities where hydraulic power is furnished by water under a pressure of 700 or 800 pounds per square inch, distributed through pipes in the streets, was exhibited in operation in the British section, by the Hydraulic Engineering Company, of Chester and London.

The elevator is of the direct-acting type, in which the cage is attached to the top of a plunger, which has a stroke as long as the height of the lift, in a hydraulic cylinder sunk in the ground. It is

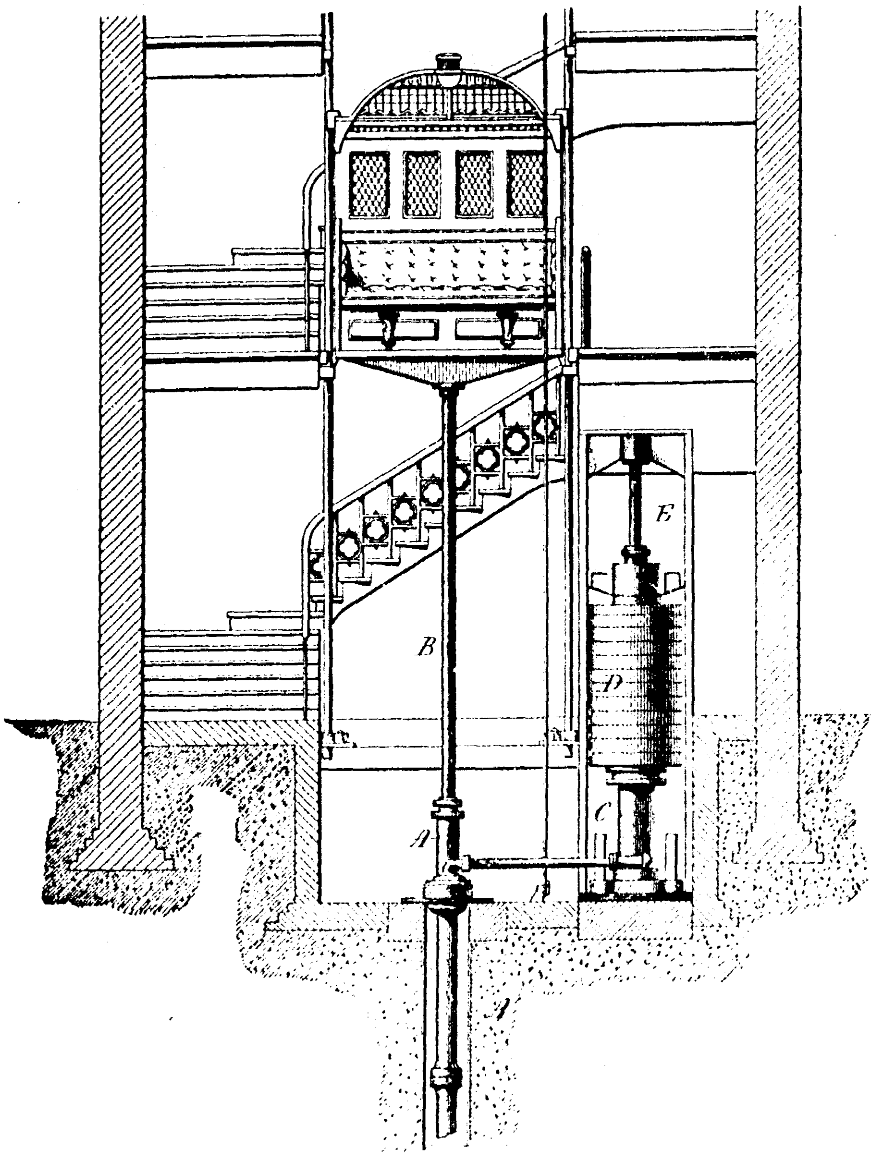

FIG. 99.—Ellington's balanced hydraulic passenger elevator, using water at a pressure of 700 pounds per square inch.

impracticable to apply directly to the lifting plunger of such elevators a pressure so great as that which the supply water exerts, because the cross section of the plunger would require to be so small, for an elevator of moderate capacity even, that it would be too slender to sustain the load. For example, if the water at 700 pounds pressure were admitted directly to the plunger, the diameter of the latter would not be greater than 1¼ inches for an elevator accommodating five passengers.

Mr. Ellington has made it possible to use a plunger of any desired size, by a device which affords at the same time a means of counterbalancing the dead weight of the cage and plunger, without employing a suspended counterpoise with its somewhat complicated accompaniments of sheaves and ropes. Referring to Fig. 99, the cylinder, A, in which the lifting plunger, B, works, is connected through pipes, and through a hollow plunger, C, with another hydraulic cylinder, D, of the same capacity as A but of larger cross section and proportionately shorter stroke. For convenience this larger cylinder is inverted and slides up and down over the fixed plunger C, which is fastened to a heavy base plate resting on a foundation. An invariable quantity of water is contained in the cylinders A and D and their connections, so regulated that D stands at the top of its stroke when the elevator cage is at the foot of the lift, and at the bottom of its stroke when the cage has risen to its highest point. The dead weight of the cage and plunger B is counterbalanced by weights attached to the cylinder D, and the load in the car is lifted by the action of the high-pressure supply water, applied so as to force the cylinder downward. This is done by admitting the supply water to a small hydraulic cylinder, closed at the bottom, which hangs down so as to form a deep pocket inside the cylinder D, and receives a fixed plunger, E, held in place by a crosshead at its top and by side rods which extend downward and tie the plunger to the foundation base plate. The plunger E is hollow and the water is conveyed through it to its cylinder. If water should leak from cylinders A and D or their connections, the cylinder D would descend lower than it should do when the cage is at the top of its lift; this action is taken advantage of to afford a means of supplying the deficiency by admitting some of the pressure water through a valve which is opened automatically by the cylinder D when the latter stands too low.

(108) *Otis passenger elevator.*—The American Elevator Company, of New York City, exhibited an Otis hydraulic high-speed passenger elevator, in the building in which the great terrestrial globe was displayed.

This elevator was used continuously for conveying visitors to the top of the building.

A gold medal was awarded for the exhibit.

VII.—THE TRANSMISSION OF POWER BY COMPRESSED AIR AND RAREFIED AIR.

(109) A problem of growing importance which presents itself to the engineer for solution, is the distribution of power in cities for use under circumstances where the establishment and care of a steam boiler on the premises is impracticable, or would be inconvenient or unprofitable. The cases where there is a demand for a distributed motive force from which power can be derived, are already very numerous; and the luxury of having a convenient, safe, and cheap source of power for domestic use, or for the use of the artisan who needs only a small supply, must, when once enjoyed, become a necessity, as the supply of gas for lighting and that of machinery for domestic use have become. There are cases where even very considerable power can be profitably derived from a motive force supplied from a distance, as, for example, for running isolated plants for electric lighting.

Several methods, direct or indirect, for effecting this distribution of power present themselves and have been more or less successfully employed. They all have their distinctive advantages for different circumstances of their use. Several will be enumerated.

1. The distribution of water power through the same mains as those through which the water supply of the city is obtained, and also through a separate system of pipes used especially for power supply, has been described in this report.*

2. Hydraulic power for the operation, chiefly, of hydraulic cranes, capstans, hoists, elevators, riveting, etc., has been very successfully distributed in several cities in England and on the continent of Europe, by means of a water supply under very high pressure—800 pounds per square inch—through pipes in the streets. This source of power is only applicable for special uses, and can not be profitably used for running machinery in general.

3. Electricity provides another means of distributing power.

4. Illuminating gas is available for the distribution of power, by supplying the fuel for the gas engine.

5. Steam distributed through pipes in the streets, used principally for heating, also furnishes a source of power; but hitherto has not been profitably applied.

6. Highly heated water, distributed in the same way as steam, has also been used.

7. Compressed air has been successfully distributed through pipes in the streets.

8. Rarefied air, also conveyed in pipes, finds its application for power distribution in Paris.

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* See page 161. The fact that the original source of power is derived from a fall of water makes these systems practicable in Geneva.

Both last-named systems were illustrated in the Exposition.

In discussing the availability of a particular medium for the conveyance of motive force, from the point of view of cheapness to the consumer, the questions which arise—after that of the first cost of obtaining or producing and storing the medium itself at the central or distant station from which it is distributed—relate to the cost of the channels for its distribution, and their maintenance; and in this connection the question whether the medium can be made useful for other purposes than for power is a vital one; for, if the cost of distribution can be paid for in great part, or wholly, by the charges for these other uses, the cost of the medium delivered for power may be reduced nearly to that of its production at the central station.

A comparison from this point of view, of the different systems enumerated above, is useful.

The several uses to which the medium can be applied are:

In system 1, water supply and power for general purposes.
System 2, hydraulic power only.
System 3, lighting and power.
System 4, lighting, heating and power.
System 5, heating and power.
System 6, heating and power.
System 7, cooling and power; ventilation incidental.
System 8, power only; ventilation incidental.

After the question of the cost of the medium through which the force is supplied—or often, indeed, independent of this to a considerable extent—the features of any system which are valued by the consumer are, safety in the use of the medium, small expense for attendance upon the motor, compactness of the motor and its availability for use in any given room or position, and, lastly (in many cases, a feature as important as any) convenience of use. With regard to the last the following conditions are to be considered: The absence of unpleasant smell or heat, the facility the medium affords for its disposal after it has been used, the ease with which the motor may be started, its reliability for constant service, and its simplicity of construction, so that it may not be liable to disarrangement if neglected or unskillfully managed.

It is not necessary here to compare the different systems in these respects, but it may be said that, except in the feature of costliness of the medium, the desired conditions are nearly all satisfied in the use of compressed air; while it must be admitted that the cost of the power to the consumer is quite high, at the rates at which compressed air is sold in Paris.

(110) The Popp system, exhibited in the Exposition by the Parisian Company for Installations of Compressed Air and Electricity—Vic-

tor Popp & Co.—is an example of a very extensive system for distributing compressed air in Paris.

It is the outgrowth of an enterprise started 20 years ago for supplying compressed air for operating clocks, so as to distribute uniform time throughout a large section of the city. At present, however, although about eight thousand clocks are operated by the air, its use for this purpose requires only a very small proportion of the power developed at the works of the company, where the air compressors in operation at the time of the Exposition were working at their full capacity of 2,000 horse-power. The demand for power in the district where the air is distributed was even then far greater than could be supplied, and the capacity of the works was being increased to 4,000 horse-power.

The works of the company are situated in St. Fargeau street, near the Buttes Chaumont, more than 2 miles from the center of the district where the greater part of the air supply is delivered, and nearly 5 miles from the most distant place to which the main pipes extend. The collective length of the pipes for distributing power exceeds 30 miles, and for the time service is about 40 miles, not including service pipes.

The company publishes a list of over two hundred streets in which its pipes are laid, and the names of three hundred and fifty consumers, employing the air in four hundred motors varying in size from one twenty-fifth of a horse-power to 50 horse-power or more. Some further particulars of the company's plant and the working of the system are given.

The air-compressing machinery is all at the St. Fargeau street station, and is operated by steam.

There is a small compressor for the time service, a 350 horse-power beam engine operating compressing cylinders, and six pairs of compound, coupled, horizontal, condensing, compressing engines, having an air cylinder behind each steam cylinder and in line with it. The diameters of the high and low pressure steam cylinders of the compound engines are 22 inches and 35 inches respectively, and of the air cylinders 23⅝ inches, the length of stroke being 48 inches; these six engines develop 340 indicated horse-power each, when running at 42 revolutions per minute, the steam pressure at the boilers being about 90 pounds.

As St. Fargeau street is situated at a distance from the river, the supply of water for steam condensation and for cooling the air in the compressors, has to be taken from the city mains, and is very expensive. To economize it the same water is used over and over again, and is cooled after each use by exposure to the atmosphere, a great extent—about 30,000 square feet—of cooling surface being provided, over which the water flows slowly, and to which the outside air finds free access. Water to supply waste from evaporation, and a small additional quantity needed in warm weather to keep the temperature of the condensers low, is all that has to be taken from the mains for daily use.

The compressed air is delivered at a pressure of 75-pound gauge pressure—6 atmospheres absolute—into reservoirs in the engine room, and from these it passes into the distributing mains. The total quantity of compressed air delivered daily corresponds to from 7,000,000 to 8,000,000 cubic feet at atmospheric pressure and temperature. The volume of the reservoirs is 9,000 cubic feet collectively.

The principal conduit for conducting the compressed air from the works was, at the time of the Exposition, a cast-iron pipe of nearly 11.8 inches diameter, having a uniform thickness of three-eighths of an inch. The lengths of pipe abut end to end, and the joints are made tight in the way shown in Fig. 100.

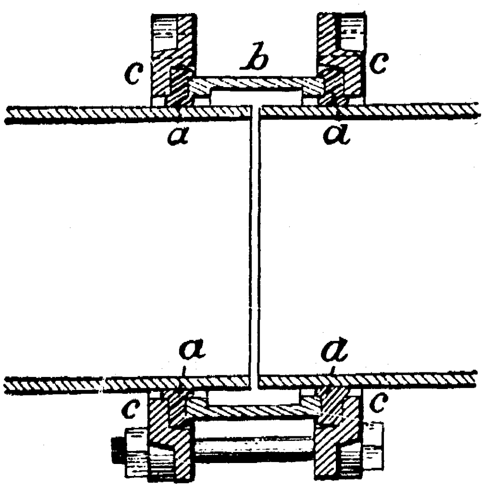

FIG. 100.—Section of pipe joint for compressed air.

a and *a* are rings of India-rubber packing, square in section, encircling the pipe; *b* is a short cast-iron sleeve against which the rubber rings are compressed, and made to embrace the pipe tightly, by means of two cast-iron rings, *c*, *c*, which are drawn together by bolts. This joint is efficient, and gives some elasticity to the lines of pipe; it is used on all the distributing mains, of whatever size.

The mains are led through the streets; part of the way through the great sewers, in which they are suspended, and part of the way under the roadways and sidewalk, where they are buried. At intervals automatic traps with floats are provided for the removal of water which condenses in the pipes.

The velocity of the air in the mains is at times as high as 45 feet per second, and yet the loss of pressure from friction is not great. Professor Kennedy found that, at a place 3 miles distant from the St. Fargeau Street station, and at a time when the indicated power there was 1,250 horse-power, and the velocity in the main 26 feet per second, the loss was only 4 or 5 pounds.

The air is used in various kinds of motors. A cheap, compact, rotary engine is employed for powers as small as from one-twelfth to one-half of a horse-power. For greater power than this the air is used in vertical or horizontal engines of the same kind as those in which steam is employed, without alteration of the engine in any way to adapt it for the new use; double cylinder, tandem or coupled, compound engines being used where the power required is very considerable.

To insure constant uniformity of pressure, the air is delivered to the consumer through a reducing valve which diminishes the pressure to about 65 pounds. Before entering the reducing valve the air passes through a meter, which consists simply of a fan wheel driven by the air flowing past it. These meters are tested under the same conditions as those of its use, and the rating thus obtained enables an estimate to be made, from the indications of the meter, of the quantity of air delivered to the consumer.

The air is not all used in motors, but is applied in a variety of ways: For raising liquids, as wine or beer, into tanks from which it can be drawn; raising water for domestic use into tanks in the attics of houses when the pressure in the city pipes is insufficient; operating hydraulic elevators, hoists, etc.; and furnishing blast for furnaces. It is also used for refrigeration. At the morgue the air is used for cooling the chambers where the bodies are exposed. At the Commercial Exchange air equivalent to 150 horse-power is employed for cooling refrigators in which meats, vegetables, butter, etc., are preserved. The air is also used in several places of amusement for driving ventilating fans, while parts of the building are cooled in hot weather by the cold air exhausted from the motors.

The demand for the compressed air, including that needed by the company for operating the dynamos in its electric-light stations, became so great that arrangments had to be made for doubling the capacity of the works and duplicating the large distributing main. This addition was in progress, but not completed, at the time of the Exposition. New compressors of improved construction were being built by the John Cockerill Company, of Seraing, Belgium, and one of them was exhibited in Machinery Hall. The makers of these new compressors guarantee an economical efficiency corresponding to the delivery of $12\frac{1}{2}$ pounds of air, compressed to 90 pounds gauge pressure—7 atmospheres absolute—for every pound of coal consumed under the boilers. These increased facilities for producing and delivering the air are now completed.

Wherever economy of the air used for power is an important consideration, it is heated just before being used, by means of a reheating stove on the premises where the motor is employed. This process not only secures an increased economical efficiency of the air and the motor, but also affords a means of avoiding the excessive cooling of the expanded air, and prevents the accumulation of ice in the exhaust pipes. The reheaters are compact, and the quantity of fuel required is small, so that it need be furnished only at intervals of several hours. Coke or coal is used for fuel in the stoves for the larger motors, and gas for the smaller sizes. The reheater for a 10 horse-power engine is about 20 inches diameter and 30 inches high, or for 1 horse-power 8 inches diameter and 12 inches high.

(111) The Popp system, as applied in Paris, has been made the

subject of careful experimental investigation at different times by Professors Radinger of Vienna, Reidler of Berlin, and Kennedy of London. The results of the different tests do not differ greatly from one another, and are favorable to the system.

Professor Reidler found that a 10 horse-power engine consumed per hour a quantity of air corresponding to 1,350 cubic feet at atmospheric pressure and 70° F. temperature, for each horse-power exerted at the brake, when the air was used without reheating; while this quantity was reduced to 780 cubic feet per hour when the air was heated to 320° F. before entering the motor. As the efficiency of the 10 horse-power motor was found by Professor Kennedy to be 67 per cent. in the first case, and 81 per cent. in the second, the above quantities correspond to the consumption of 900 cubic feet of cold air and 630 cubic feet of heated air per hour and per *indicated* horse-power.

The small motors in which the air is used in Paris are quite inefficient, so that the hourly air consumption rises to 1,060 cubic feet—estimated at atmospheric pressure and 70° F.—per brake horse-power, in the 4 horse-power motors, and 1,600 cubic feet in those of 1 horse-power, even when the air is heated; while the consumption of cold air in the small rotary motors amounts to as much as 4.9 cubic feet of atmosphere per hour for each foot-pound of work performed per second; which is at the rate of an hourly consumption of 224 cubic feet of air at atmospheric pressure, or 37 cubic feet of the compressed air—at 75 pounds gauge pressure—for a motor exerting, effectively, one-twelfth of a horse-power. The motors experimented upon were in some cases at a distance of 3 miles from the St. Fargeau street station, and the conditions under which all were tested were essentially the same.

Professor Reidler found that 320 feet of air at atmospheric pressure and temperature were compressed and delivered into the reservoirs for each indicated horse-power developed in the steam cylinders of the compressing engines at the station.*

The indicated power which must be exerted in the steam cylinders of the compressors at the St. Fargeau street station, in order to obtain each effective horse-power from the motors of different capacities using the air either at 70° F. or reheated to 320° F., has been computed, and is given, with other particulars, on page 217.

The prices charged by the company for the use of the compressed air vary according to circumstances. In some cases the power required to do certain work is estimated, and a certain gross sum is charged by the year for the use of the air to do the work. Where water is raised or elevators worked, the charge is by the cubic meter of water raised to a certain height, or per cubic meter of water used in raising the elevator cage through a certain lift. In general, how-

* Professor Kennedy's estimates give 348 cubic feet.

ever, 1.5 centimes is charged for a volume of air corresponding to 1 cubic meter at atmospheric pressure; that is, at the rate of 8.5 cents per 1,000 cubic feet, at atmospheric pressure, or about one-half of a cent for 40 cubic feet of the compressed air at 75-pounds gauge pressure.

Quantity of air required by the motors and cost of power to the consumer.

Grade of motor.	Condition of the air.	Volume of air required per brake horse-power per hour. At 75-pounds gauge pressure.	Volume of air required per brake horse-power per hour. Equivalent volume at atmospheric pressure.	Cost per hour, per brake horse-power, for the air, at the price charged in Paris.	Indicated power required at the station for each brake horse power obtained from a motor 3 miles distant.
		Cu. ft.	*Cu. ft.*	*Cents.*	*H. P.*
Large (10 horse-power)	Cold	225	1,350	11.5	4.2
	Reheated	130	780	6.7	2.5
Medium (4 horse-power	do	177	1,060	9.0	3.3
Small (1 horse-power)	do	267	1,600	13.6	5.0

With one of the small rotary motors, one-twelfth of a brake horse-power corresponds to the exertion of about 0.7 of an indicated horse-power at the station, and the cost per hour for the air necessary to run it to its full capacity is about 2 cents.

The motors smaller than 10 horse-power are very uneconomical in the use of air, but there is no reason why a great improvement should not be made in this respect, and the cost of the power to the consumer be correspondingly reduced.

The cost of reheating the air is very small; 2 or 3 cents per day of 10 hours, per indicated horse-power, covers the expense if coal is used, and eight or ten times this amount if gas is the fuel.

It is claimed that a very important increase of economy in the air required for the power can be obtained by intermixing with it water in the form of spray, which is injected into the reheated air as it passes to the motor. This process is not yet extensively employed, but Professor Reidler's experiments to test its efficiency indicate that the air consumption can be reduced by this means to 570 cubic feet, at atmospheric pressure, per hour and per brake horse-power, with the larger air engines.

The compressors in use at the St. Fargeau street station have not been economical in the use of steam, for their arrangement is such that the air is not properly cooled during its compression. In the new compressors this difficulty will be remedied.

(112) Mekarski's system for the application of compressed air as the motive force for locomotives and dummy cars for street railways, was shown in Class 61, and is described in Professor Haupt's report on that class.

(113) *Distribution of power by rarefied air.*—Another plan for the distribution of power in Paris, which is introduced to a limited extent, is by means of rarefied air—Petit & Boudenot's system—and was the subject of an exhibit by the "Société de distribution de force motrice à domicile," 41 Rue Beaubourg, Paris.

In their circulars it is stated that the company was established for the purpose of distributing motive force for very small engines—from one twenty-fifth of a horse-power to 3 horse-powers—and within a radius of half a mile of a central station. The present plant at the station consists of a number of air-exhausting pumps, actuated by three Corliss engines of from 75 to 100 horse-power each, by which a vacuum is maintained in large cylindrical reservoirs with which the distributing pipes are connected, the pressure in the reservoirs being kept at one-third of that of the atmosphere. The main pipes in the streets are carried through the sewers and under the sidewalks, are of cast iron from 4 to 8 inches diameter, and have a total length of about two-thirds of a mile. One-inch to 3-inch lead pipes are used for service pipes and risers to the motors.

It is stated that one hundred and forty subscribers take power from the company.

Rotary motors were at first employed for very small powers, but have been abandoned. Now the sizes of motors introduced are limited to three; viz., of one-half, 1, and 1½ horse-power respectively. They are all of the same type, a compact, vertical, double-acting trunk engine,* and are leased to the subscribers by the company.

The motors, which take air at atmospheric pressure from the room in which they work, discharge it into the exhausted service pipes, and are necessarily quite bulky in proportion to the power they can exert, because the effective pressure on the piston is necessarily small, being only that of the atmosphere less that in the pipes—not over 8 or 9 pounds per square inch.

The company publishes results of a trial of the efficiency of one of their one horse-power motors, from which the following figures are derived:

Results of the test of a 1 horse-power rarefied air motor.

Turns per minute	140	134	125	115
Mean effective pressure per square inch of piston area, pounds	2.12	4.15	6.08	7.95
Indicated horse-power	0.35	0.66	0.90	1.08
Brake horse-power	0.00	0.55	0.73	0.96
Consumption of air per hour:				
Total ....cubic feet	500	900	1,400	2,000
Per indicated horse-power ....do	1,400	1,370	1,550	1,850
Per brake horse-power ....do		2,000	2,100	2,100

* For an illustrated description of the engine see Engineering, London, June 14, 1889.

With the exhausting machinery in good condition, about 800 cubic feet of atmosphere per hour could be drawn into the pipes—and the required vacuum be maintained—for each indicated horse-power exerted in the steam cylinders of the engines at the station. The low effective pressure that must be made available makes it necessary to use large distributing pipes, and increases the first cost of this plant. The service given by the company is, however, very satisfactory to the subscribers, and the business has been developed to a profitable extent.

The award of the jury for this exhibit was a silver medal, the same as that given to the Victor Popp Company.

VIII.—Pneumatic postal dispatch.

(114) The Postal Dispatch and Telegraph Bureau of the French Government exhibited in their special building the apparatus of the pneumatic dispatch, which is so extensively employed in France as an auxiliary to the district telegraph or a substitute for it. While the pneumatic dispatch is not new, having been adopted in Paris as early as 1867, after many years previous use in England, yet a record of its present development and use in Paris is of sufficient interest to warrant its insertion in this report; and as it furnishes another example of the application of pneumatic force for distributing power, it may properly be described here.

A map, showing the network of dispatch tubes, the power stations, and the air and vacuum pipes connecting the stations with the dispatch tubes, as they were arranged in 1888, is given in Fig. 101.

In 1889 the total length of the dispatch tubes was 120 miles, and of the air pipes 18 miles, while the number of offices containing the apparatus for sending and receiving dispatches somewhat exceeded one hundred. There are seven power stations, containing machinery for furnishing compressed air through the air pipes and for exhausting the vacuum pipes. The largest station is at the main post-office, and contains a 60 horse-power Corliss engine, for operating compressors and air pumps having a collective capacity of 1,000 cubic feet of air per minute. From the seven power stations, the air and vacuum pipes connect with thirteen principal dispatch offices, from which the motive force is distributed throughout the whole system of tubing. These air and vacuum pipes are not used for the conveyance of dispatches, their function being simply to supply motive force to the principal offices for further distribution through the dispatch tubes. The messages, inclosed in leather-covered cases, are propelled from office to office through the tubes. Offices of secondary importance are connected with each other and with the principal offices by pairs of dispatch tubes, one for sending and the other for returning. Many such pairs of tubes radiate to a number of secondary offices from each of a few of the principal offices where the traffic is greatest. In many cases offices of minor importance are connected with each other, and with a main or secondary office, by means

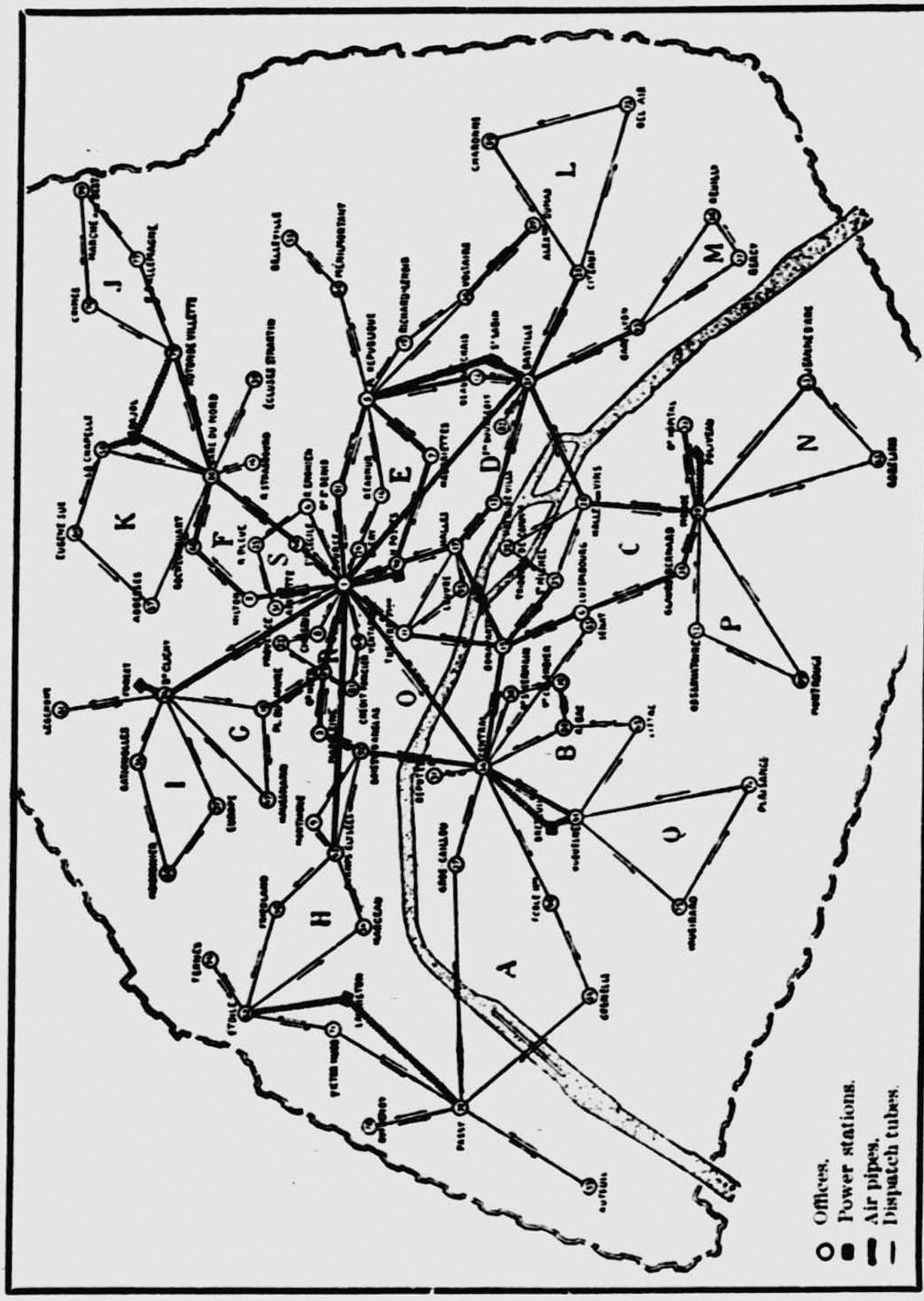

FIG. 101.—Map of the pneumatic postal dispatch system in Paris.

of a single line of tubes leading from office to office and forming a loop; that is, the line starting from the main office leads first to the nearest minor office, thence successively to a second and third or even a fourth office, and from the last leads back to the starting place.

In such a loop the transmission of the dispatches is usually in one direction only. For example, in sending from the main office to the fourth or last office in the loop, the dispatch, instead of being sent through the tube leading directly from the fourth to the main office, is sent to the first office and forwarded thence by way of the second and third offices, thus indirectly to its destination. In the same way, a dispatch is sent from the first office in the loop to the main office, by way of the second, third, and fourth offices successively, instead of being sent backward through the receiving tube which comes directly from the main office. The direction of transmission can, however, be reversed if necessary. In some cases an isolated minor office has only a single tube leading to it, through which the transmission of dispatches is made in both directions, backward and forward, compressed air being used for sending the dispatches outward, while the return trip is effected by forming a connection with a vacuum pipe in the main office. The tubes are of wrought iron, lap-welded, carefully drawn, smooth, and of very even size.

The greater part of the tubing is 2⅝ inches in diameter inside. A few of the tubes, however, through which the traffic is great, are half an inch larger; the exact sizes being 65 and 80 millimeters, respectively.

There are 110 miles of the smaller tubes, and only 10 miles of the larger. They are carried through the sewers in all directions. Where it is necessary to make a bend in the tube, for turning a corner, the radius of curvature of the bend is from forty to fifty times the diameter of the bore of the tube, and is so gradual as to prevent obstruction. The pressure in the air pipes is about 13 pounds per square inch, and the vacuum in the rarefied air pipes equivalent to 4½ pounds.

All the offices are connected by telegraph for signaling. The speed of transmission is at the rate of from 25 to 28 feet per second, 17 to 19 miles per hour. The dispatch cases can be sent in trains of two or three at once, and can convey fifty or more dispatches at a time. They are dispatched every three minutes through the tubes leading from the offices where the business is greatest; every fifteen minutes from any other office when there is anything to send. From this it will be seen that the sending capacity of the tube is very great, being many times that of a wire of the district telegraph, which may be said to be limited to about fifty dispatches per hour. The messages are written by the correspondents on small blanks, which can be closed securely and sealed for preserving secrecy.

(115) Figs. 102 to 105 show the fixtures used for receiving and sending dispatches. They form the termini of the tubes, and there are as many of them in each office as there are tubes connecting with that office. The fixtures usually stand side by side in pairs, one fixture for receiving dispatches from one direction, the other for send-

ing in the opposite direction. Those shown in Figs. 102 and 103 are used in the thirteen principal offices, which contain air and vacuum pipes.

A is the vertical end of the dispatch tube, terminating in the rectangular box B, which forms a receptacle for the dispatch case. C and D are the air pipe and vacuum pipe, respectively, and E and F pipes connecting C and D with the box B. I is a pipe connecting the boxes B of the two fixtures of the pair with each other: J, a branch from I, connecting with the open air; and G, H, K, and L,

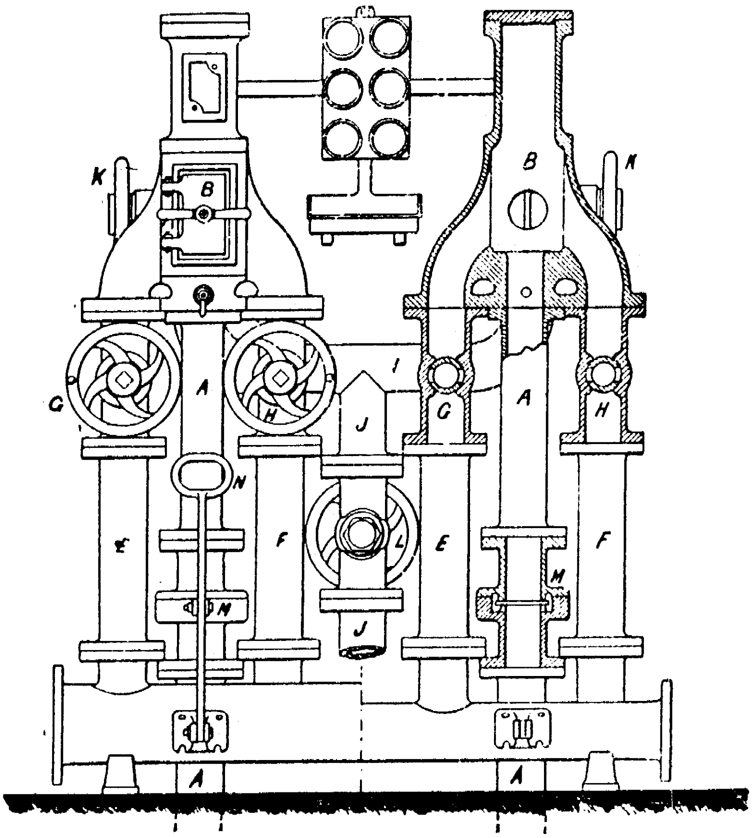

FIG. 102.—Front view of a pair of the pneumatic dispatch instruments used in the principal offices.

stop-cocks for opening or closing the pipes to which they belong. At the front of the box B is a door, which is kept closed air-tight except when opened for inserting or removing the cases. A rod, P, can be pushed inward to prevent the dispatch case from dropping into the tube when it is necessary to retain it in the box.

M is an air-tight sliding gate worked by a lever, N, for opening the dispatch tube to allow a case to pass, and for shutting it to prevent the escape of air when the box B is opened.

The fixtures shown in Figs. 104 and 105 are used in the secondary and minor offices. They differ from those described above only in the absence of the air and vacuum pipes and their connections.

Two posts which stand on the floor and support the box B take the place of the pipes E and F of Figs. 102 and 103. Corresponding parts in the several figures are indicated by the same letters, and the description need not be repeated. The compressed air is used in nearly all cases, and the vacuum only on the longest lines, the tubes being kept under pressure except in front of a case when the transmission is being made.

The operation of the apparatus can be understood from a single example. To send a dispatch case from a principal office, the attendant first signals the receiving station, then shuts the stopcock G (Fig. 102) and slide M, opens box B, inserts the case in the mouth

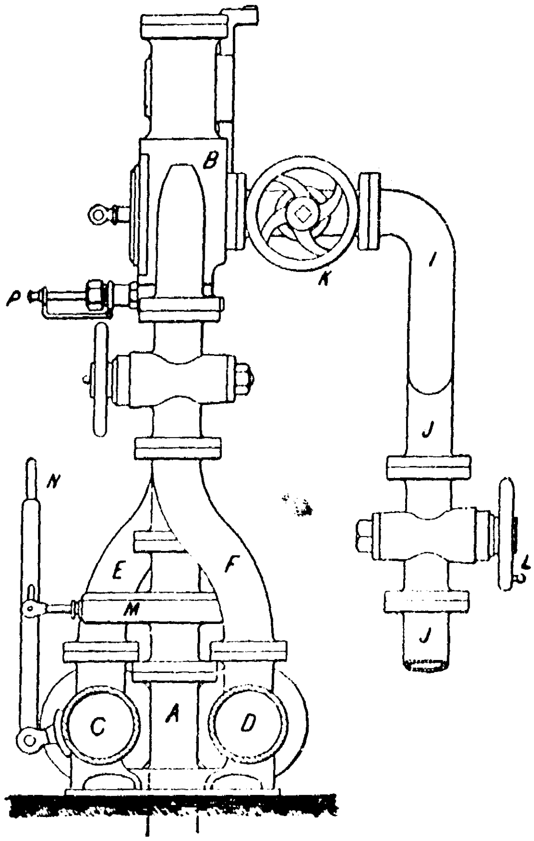

FIG. 103.—Side view of the instruments shown in Fig. 102.

of the tube A, closes the box, and reopens the cock G. He then pulls the handle N to open the slide M, and the dispatch case starts on its journey. At the receiving station, suppose the left-hand fixture in Fig. 104 to be the one at which the dispatch is to arrive. The attendant on receiving the signal shuts the left-hand cock and opens L, thus putting the right-hand box in communication with the open air. He then opens the slide M, and awaits the arrival of the case, which is announced by the sound of the case in striking the top of the box. He then closes all the stopcocks, and the slide, and opens the door of the box to remove the case, after which he closes the box and reopens the slide and the two stopcocks K, in order to maintain the pressure in the tube leading from the left-hand fixture, so that the other offices of that particular line of tubes may be supplied with air. To receive at a fixture in one of the main stations the communication is made between the box and the open air in the same way as with the simpler fixtures. Whenever it is necessary at any office to increase the propulsive force by making use of the vacuum, the tube or line of tubes to which that office belongs can be put in communication with the vacuum pipes through the receiving fixture at the main office of the line, by closing the cock L (Fig. 102) and opening H.

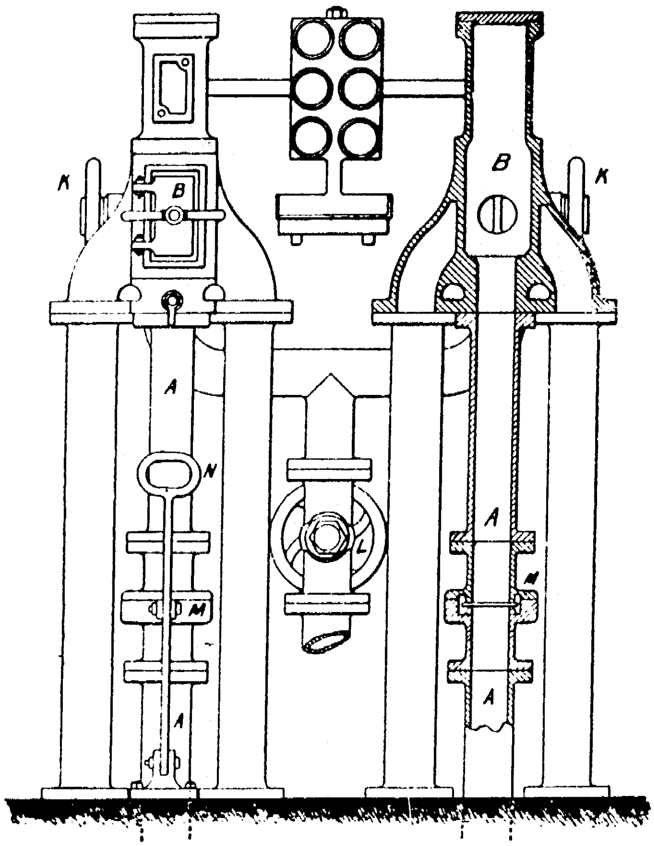

FIG. 104.—Front view of dispatch instruments used in the smaller offices.

IX.—INSTRUMENTS FOR MEASURING PRESSURE, SPEED, ETC.

(116) *Steam gauges.*—The most interesting and extensive display of pressure gauges was found in the space allotted to Mr. Edouard Bourdon, of Paris, who continues the business of his father, the late Mr. Eugene Bourdon, who in 1849 invented the steam gauge which bears his name. The value of the elastic flattened tube, as the pressure organ of a steam gauge, became recognized as soon as the invention was introduced, and has made Mr. Bourdon's name known in every land. Nearly all modern steam gauges embody his invention in forms that are but little if at all different from those in which it was originally introduced, or which were described in his patent, or early

tried by him. Few inventions of so novel a character have remained so little altered in essential details and methods of application, after such long and continued general introduction, as has this simple instrument.

The good reputation which the Bourdon type of gauge obtained for itself in Europe is to a great extent due to the conscientious care taken in its manufacture. It is safe to say that there have been, and are, no better Bourdon gauges made than those produced by the house established by their inventor; and the exhibit made by Mr. Edouard Bourdon showed that he feels it incumbent upon himself

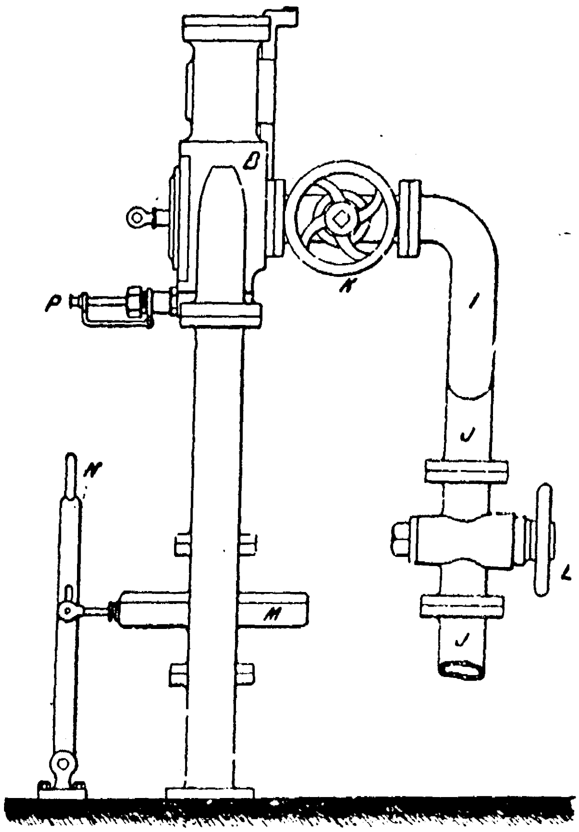

FIG. 105.--Side view of the instruments shown in Fig. 104.

to maintain the reputation his father established, by insuring that the product of his factory shall continue to be of the most excellent character.

Besides the large collection of gauges of all sizes, adapted for the great variety of uses to which they are applied, he exhibited an interesting series of sections of the tubes used in their manufacture. Mr. Bourdon uses more than seventy varieties of these tubes, for it is found that in order to attain the best results—that is, to insure uniformity and permanent accuracy in the action of the gauges, having regard also to economy of material—it is necessary to employ tubes of different cross sections for gauges of different sizes and ranges of pressure, and that a change in the length or curvature of a tube having the cross section best adapted for a gauge designed for a certain range of action, will not adapt that tube for acting equally well in a gauge intended for a different range; it is necessary to change also the outline of the cross section or the thickness of its sides. In Mr. Bourdon's gauges the tube sections are so related to the conditions the gauges are designed for, that the ultimate strain which is suffered by the material of the tubes, as the result of the distortion they undergo when subjected to the greatest pressure, is as nearly as possible the same in the different gauges. When the strain is thus properly limited the gauges are likely to retain their accuracy unaltered for a long time.

Phosphor bronze, having a tensile strength of 65,000 pounds per square inch, is the material used for tubes which are not subjected to extremely high pressures.

Of the bronze tubes, six patterns having different outlines of cross section are adopted, and each pattern is made in eleven different thicknesses, namely, from 0.008 inch for the thinnest, to 0.048 inch for the thickest, differing uniformly by 0.004 inch. It is found that sufficient uniformity of the material can not be obtained throughout the different parts of the cross section if the bronze tubes are made thicker than the limit named above.

For excessively high pressures, running up in some cases to 45,000 pounds per square inch, the tubes are made of Firminy steel of the quality used for piano wire. In one pattern of steel tube adapted for this great pressure, the sides were 0.12 inch thick, the cross section being nearly elliptical and measuring 0.64 by 0.44 inch outside.

(117) Mr. Edouard Bourdon makes these gauges for very high pressures the specialty of one branch of his business. He exhibited an interesting machine, invented in 1868 by Mr. Eugene Bourdon, for graduating and testing them, which is shown in its original form in Fig. 106.

It acts by hydrostatic pressure produced by a pump, and the pressure is weighed by weights suspended from a scale beam.

The gauge to be marked or tested is attached to a chamber, A, into which oil or water is forced from the pump cylinder B, whose plunger is actuated by the screw and hand-wheel below it. The intensity of the pressure in the pump, and consequently in the chamber A, and in the gauge, is measured by weighing the force it exerts in thrusting upward a small vertical plunger, *c*, of known diameter, which penetrates the upper part of the pump cylinder, B. The upper extremity of the small plunger *c* pushes against an inverted stirrup, *d*, from which hangs a steelyard, E, the fulcrum of which is at *f*. The force of the upward thrust of the plunger *c* can be weighed by weights, W, suspended from the free end of the steelyard.

The plunger *c* passes through cupped leather packings in the

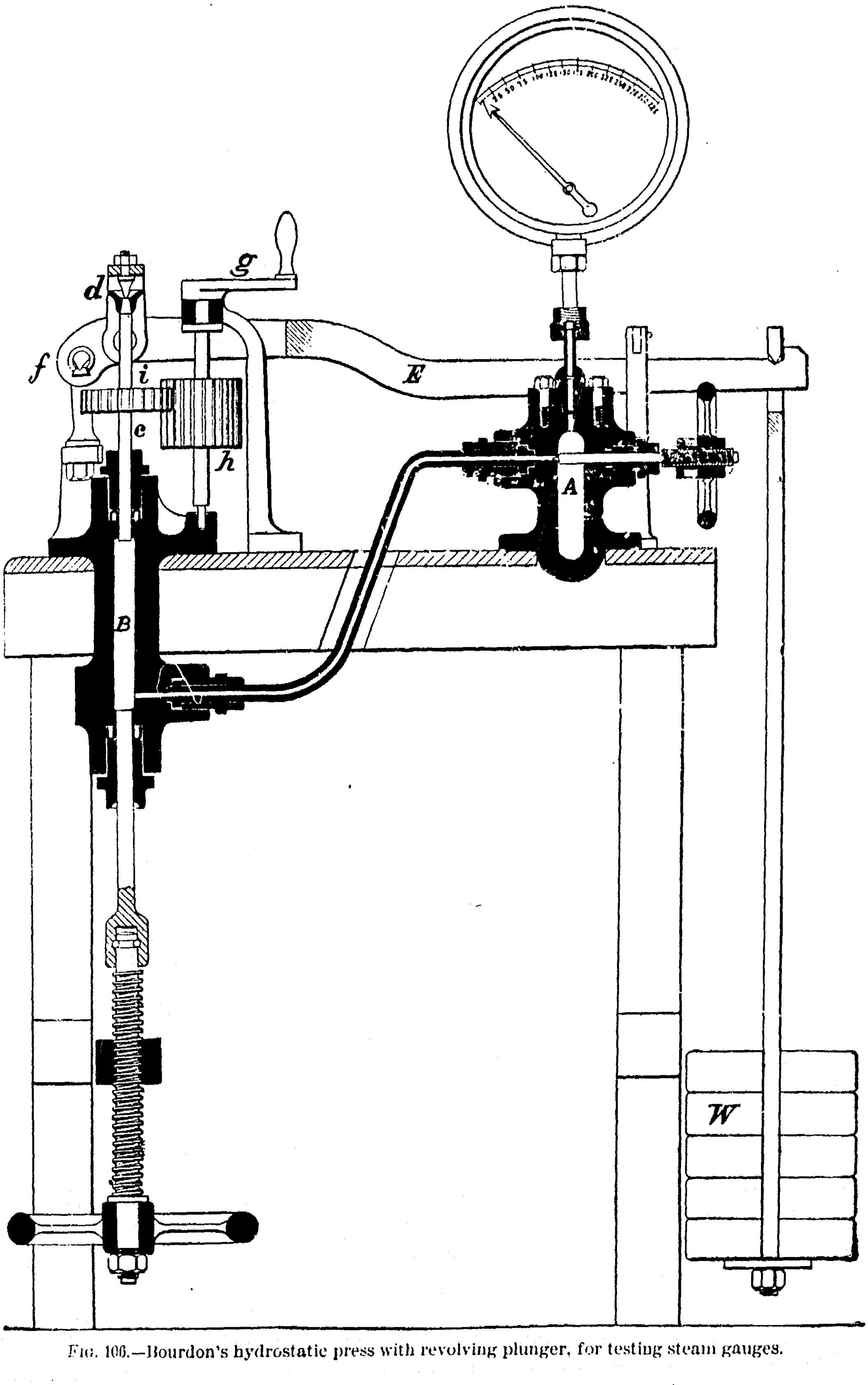

FIG. 106.—Bourdon's hydrostatic press with revolving plunger, for testing steam gauges.

top of the pump cylinder, by which leakage is prevented. The friction produced by the packing, and by the guide through which the plunger *c* passes, is liable to be considerable and variable, and its force in resisting the movement of the plunger can not be estimated accurately; if, therefore, means were not taken to neutralize the effect of this friction, so far at least as it affects the sensitiveness of the movement of the plunger *c* in the direction of its axis, the force exerted by the liquid in the cylinder B to thrust the plunger upward could not be accurately measured by weighing the force the plunger exerts to turn the steelyard. Mr. Bourdon overcame this difficulty by providing means for giving to the plunger *c* a rapid movement of rotation about its axis, by which the friction is so nearly overcome that the longitudinal movement occurs without sensible resistance. The rotation is produced by the crank *g*, through the gear wheels *h* and *i*.

The efficiency of this device is demonstrated by observing the action of the gauge while the process of weighing the force is carried on in the following way: The weight W, corresponding to a given hydrostatic pressure, is applied to the steelyard, and, without rotating the plunger *c*, the pump is worked until the weight W is lifted; the gauge needle assuming a certain position which is noted. A small addition to or diminution of the weight W under these conditions produces no change in the position of the gauge needle; if, however, the plunger *c* be rotated continuously by means of the crank, the needle will move slowly, and will finally settle in a position slightly different from that which it occupied at first; under these conditions, the rotation of the plunger *c* being kept up, if a very small change be made in the weight W, to either increase or diminish it, the gauge needle responds promptly to the change by moving slowly into a new position, and whenever the weight W is restored to its original condition the gauge needle settles back to the precise point which before corresponded to that weight, this correspondence taking place whenever the original weight is reached, whether it be arrived at by removing surplus weight or by supplying a deficiency. The sensitiveness of the apparatus is found to be very satisfactory, and the machine, slightly modified in form, is used for graduating and marking all the gauges that are intended for higher pressures than can be shown by a mercury column of practicable height.

It was invented and in use as early as 1868, for the Annales du Conservatoire des Arts-et-Métiers contain an account of a test of a gauge made November 20, 1868, by means of the machine.

It is an early example of the application of the principle of dividing the force required to overcome friction into two components, with the smaller one in the direction in which sensitiveness of movement is required; a principle embodied by Rider in his cut-off,

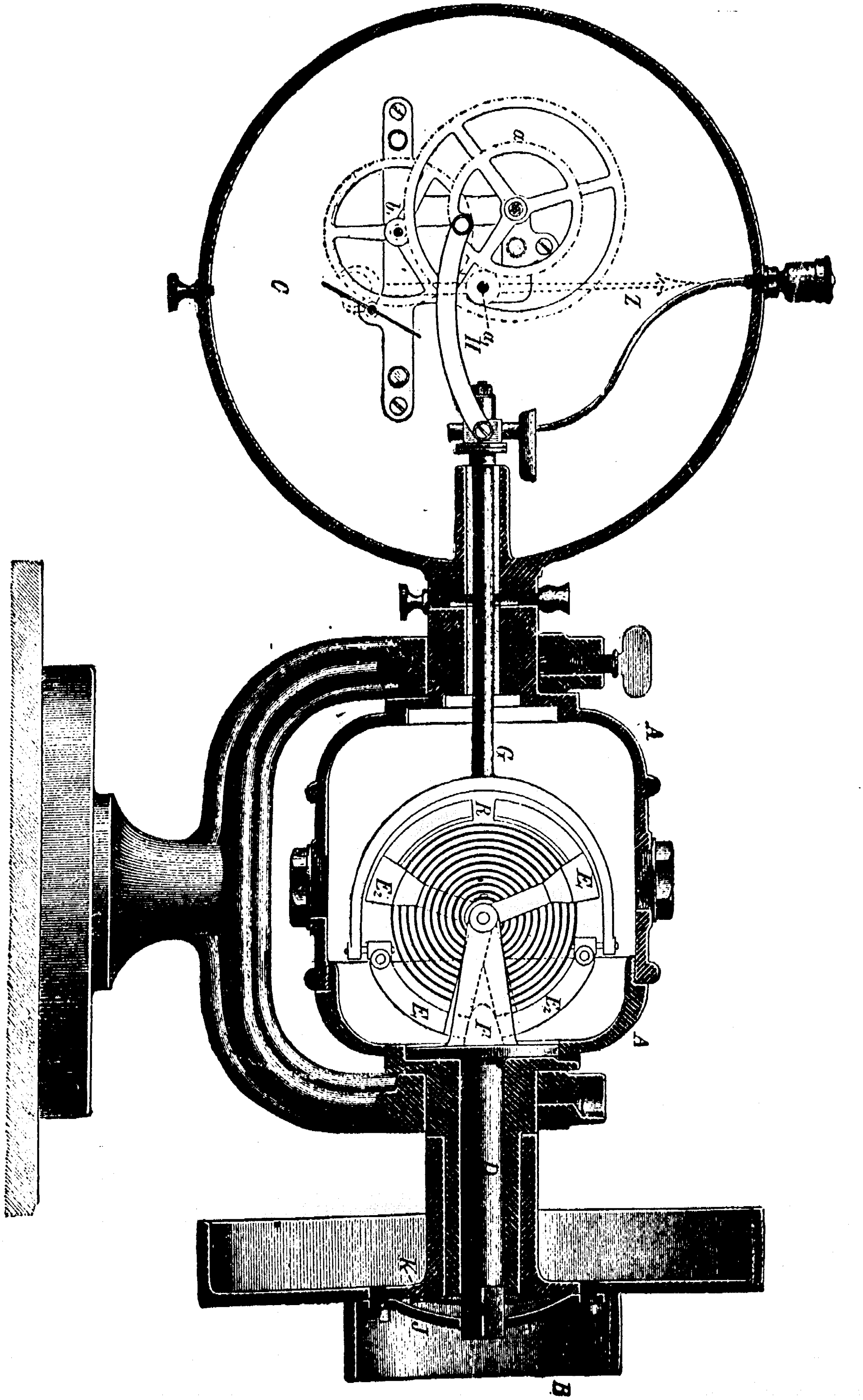

FIG. 107.—Sectional view of Buss's tachometer.

in which a semi-cylindrical cut-off valve, turned by the governor, slides lengthwise in a seat on the back of the main valve.

The gauges Mr. Bourdon exhibited did not offer any novelty of form.

(118) A gauge was noticed which is intended for use beneath railway cars, to show whether the pressure in the reservoirs of the air brakes is preserved. It can be read from either side of the car, the back of the gauge having a dial as well as the front, and can be read at a glance. The divided arc on which the pressure is read is short, and at one side of the dials, so that the pointer of the needle rises and falls to show change of pressure. The brakemen standing on either side of the car need only notice whether the pointer stands high or low to learn the condition of the pressure, and the mistakes are avoided which would inevitably occur if the pointer traveled from right to left, or the reverse; for it is liable to be looked at from opposite sides.

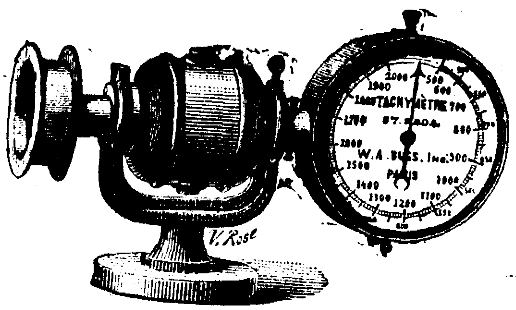

FIG. 108.—Front view of Buss tachometer.

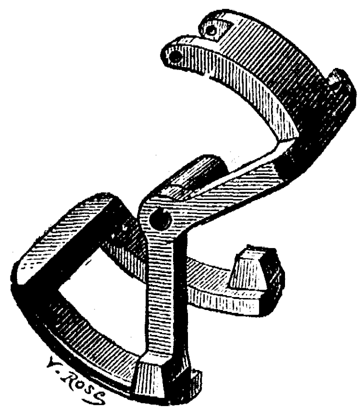

FIG. 109.—One of the pendulums of Buss's tachometer.

Mr. Bourdon also exhibited a great variety of safety valves, lubricators, etc., all of excellent workmanship and carefully studied design.

(119) *Buss's speed indicators and recorders.*—Messrs. Buss & Co., of Paris, exhibited Mr. Ed. Buss's instruments for indicating at once the speed of a revolving shaft—tachometers—also a speed recorder called by him a "tachygraph." The exhibit contained governors also, and received a gold medal.

Although not new, the Buss tachometer merits a description here. Fig. 107 shows the tachometer in section, and Fig. 108 is an outside view on a small scale, while Figs 109, 110, and 111 show details. It embodies the principles of a centrifugal governor.

The cylindrical box A (see Fig. 107) incloses the revolving centrifugal pendulums, while the drum-shaped dial box C contains the train of gearing for moving the needle Z, which indicates on the dial (see Fig. 108) the speed at which the pulley B revolves. The boxes A and C are hung in bearings on the stand which supports the instrument, so that the dial may be turned into a convenient position for reading.

D is the spindle carrying the centrifugal pendulums and driven from the pulley B through the coupling J. The two pendulums E and E_2, one of which is shown in perspective in Fig. 109, are suspended in a fork, F, at one end of the spindle D.

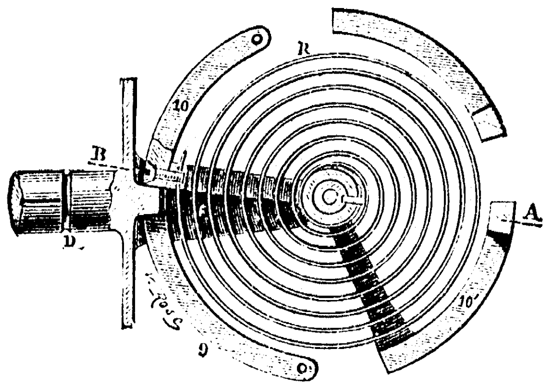

FIG. 110.—Section at C D Fig. 111.

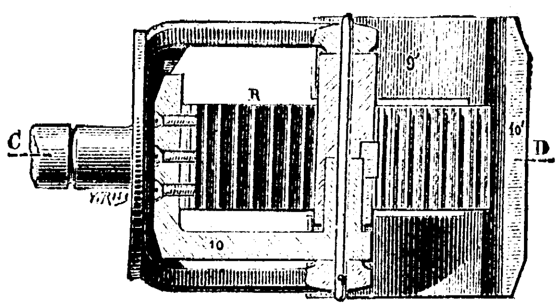

FIG. 111.—Section at A B Fig. 110.

END OF SPINDLE, AND PENDULUMS OF THE BUSS TACHOMETER.

One of the pendulums is attached to a stiff coil spring; see R—Figs. 110 and 111—which show the end of the spindle D with its fork, the weights, and spring.

The elastic force of the spring, which increases as the spring is deflected more and more, resists the varying effort of the pendulums to fly outward under the influence of the centrifugal force, and is in equilibrium with this effort at all speeds of the pendulums, thus determining different definite positions of the pendulums for different speeds of revolution of the spindle.

A sliding rod, G, is attached, by means of a yoke, shown in Fig. 107, to the pendulums E and E_2 in such a manner as to couple the pendulums together and make their movements coincident. The rod G receives longitudinal movements from the pendulums when they swing outward and inward about their points of suspension, and thus the rod has a different position endwise for each different speed at which the spindle D and its pendulums revolve; this endwise movement is made to turn the indicating needle Z by means of a pair of links, H, and a train of gearing; the speed at which the pulley D revolves at any instant can therefore be ascertained by noting the division of the dial toward which the needle points.

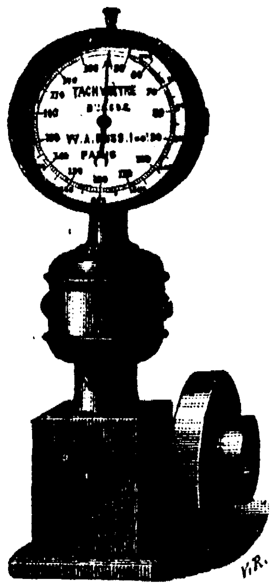

FIG. 112.—Upright tachometer.

The rod G, which rotates with the spindle, is coupled, by means of a sleeve, to the links H, which do not revolve.

Fig. 112 shows an upright form of the stationary tachometer.

A portable tachometer, in its case, is shown in Fig. 113. It has several little spindles projecting from one end, shown at the left-hand end of the figure; one of them is a prolongation of the main spindle of the instrument which carries the centrifugal pendulums, the others are so geared to this spindle that the velocity ratio is different for each.

The dial is marked with as many rows of divisions as there are spindles, and the whole is so arranged as to indicate speeds from 25 to 3,000 revolutions per minute.

This instrument is applied in the same way as the simple revolution counters so generally used, namely, by means of a pyramidal point applied to the end of one of the spindles, which is then inserted

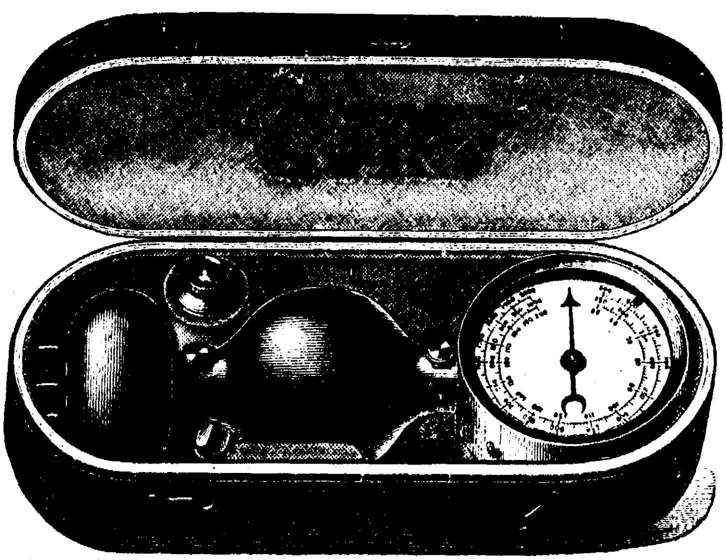

FIG. 113.—Buss's portable tachometer.

in the drilled end of the revolving shaft whose speed is to be indicated. It is intended for temporary use only, and for taking an observation lasting only a short time, as the means of lubrication are not such as to permit of continuous running for any considerable length of time.

The Buss "tachygraph" is shown in Figs. 114 and 115.

The front of this instrument has a dial which shows by the needle, at each instant, the speed of the machine to which it is applied, and in all respects the speed-indicating part of the instrument is precisely the same as in the tachometers already described. At the back of the dial box is a clock movement, shown in Fig. 115, which communicates a uniformly progressive lengthwise movement to a band of paper on which the speed is registered, at each instant, by a

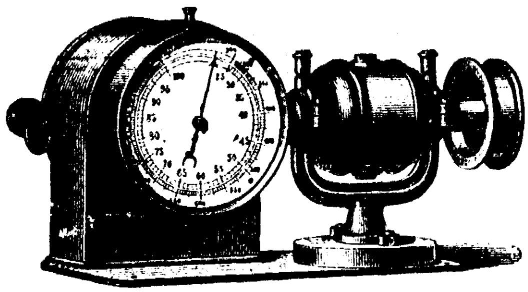

FIG. 114.—Front view.

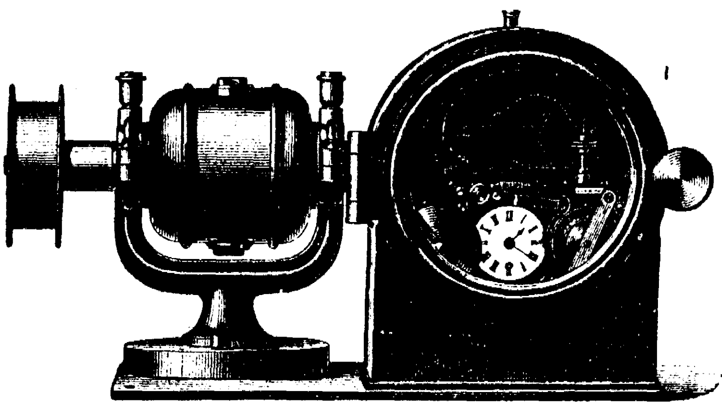

FIG. 115.—View of back.

BUSS'S SPEED RECORDER.

mark drawn by a pencil which is moved crosswise of the paper band, by means of a bell-crank lever connected with the sliding rod G of the tachometer.

The "tachygraph" performs the same function as Moscrop's speed recorder, an English invention well known in the United States, but is more compact.

Fig. 116 shows a short section of the diagram obtained from a Buss speed recorder applied to the drum of a winding engine in a colliery.

(120) *Steam-engine indicators.*—Nearly all the French indicators shown were of the Richards type without essential modification, this indicator being still almost universally used in continental Europe. It originated in the United States in 1859, was introduced

in Europe in 1862, and speedily displaced others, but in turn will be gradually displaced by later modifications of the principle which, since the expiration of the original patent, have come into use in the United States, having been made desirable by the conditions involved by the high rotative speed now often used in steam engines. These modifications relate chiefly to the method of guiding the magnified movement of the pencil in a straight line, and consist in more direct and lighter mechanism. A good example is the Crosby indicator, exhibited by the Crosby Steam Gauge and Valve Company, Boston, whose exhibit of indicators, steam gauges, safety valves, lubricators, etc., in the United States section, received the award of a gold medal; as high an award as was given for any exhibit of this kind.

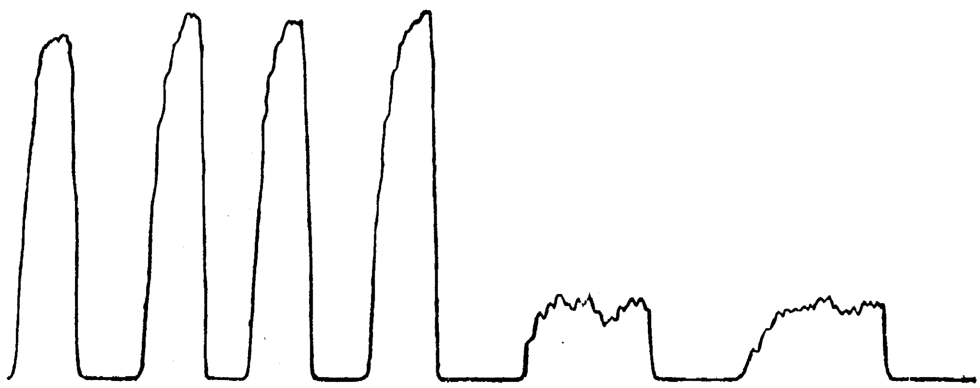

FIG. 116.—Short section of a record of the speed of hoisting in a colliery: made by a Buss speed recorder.

(121) *Water meters.*—A great number of water meters were exhibited; few, however, possessed novel or interesting features. Several of the meters were of the kind described as inferential, in which the impact of the water in flowing through the meter causes a small turbine or screw wheel to turn, and from the rotation of the wheel the rate of flow is inferred, and the discharge computed. The greater number of the meters, however, were of the piston type, and most of these duplex, involving the principle of the Worthington meter, in which the valve for distributing the water in either of the cylinders is actuated by the movement of the piston of its mate. Many of these duplex meters are arranged with the cylinders vertical instead of horizontal, a departure from the original form which is of doubtful value.

(122) *The Schönheyder meter.*—A very interesting meter was shown in the British section. It is the invention of Mr. W. Schönheyder, manufactured by Beck & Co., London. The description, partly taken from Engineering, was supplied by Mr. Schönheyder.

Figs. 117 to 119 show the meter, Fig. 117 being an outside view, Fig. 118 a transverse vertical section, and Fig. 119 a plan with the cover removed: one of the three cylinders with its piston being in section, and valve partly in section, while the outside of a second cylinder is shown: the third cylinder is omitted so as to show the piston and its tail rod complete.

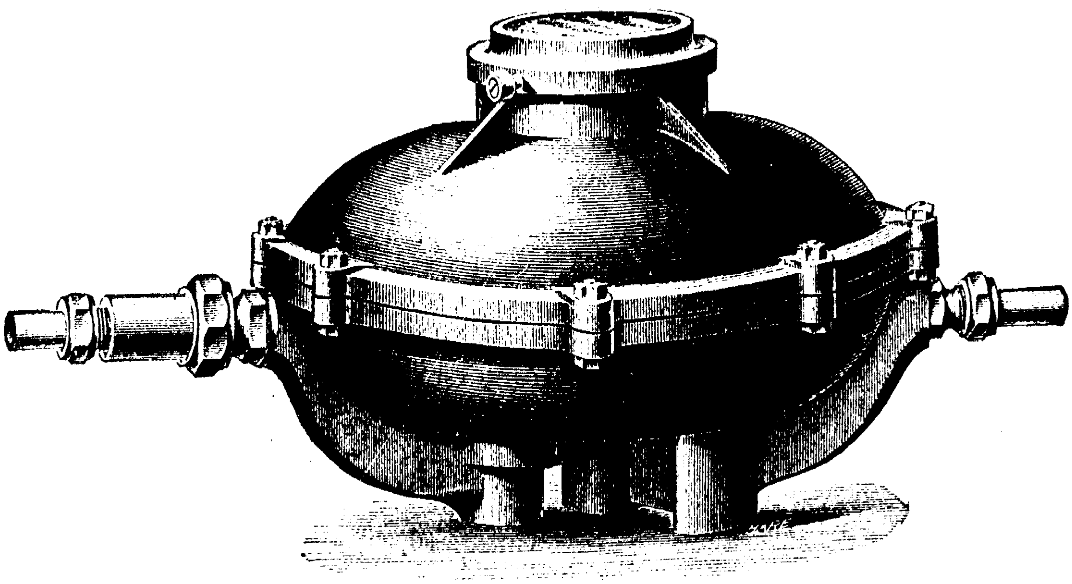

FIG. 117.—Schönheyder's water meter

The meter casing is in halves bolted together, with the joint made tight by a suitable packing ring. Within the casing are three cylinders, each capable of sliding to and fro against roller guides in a

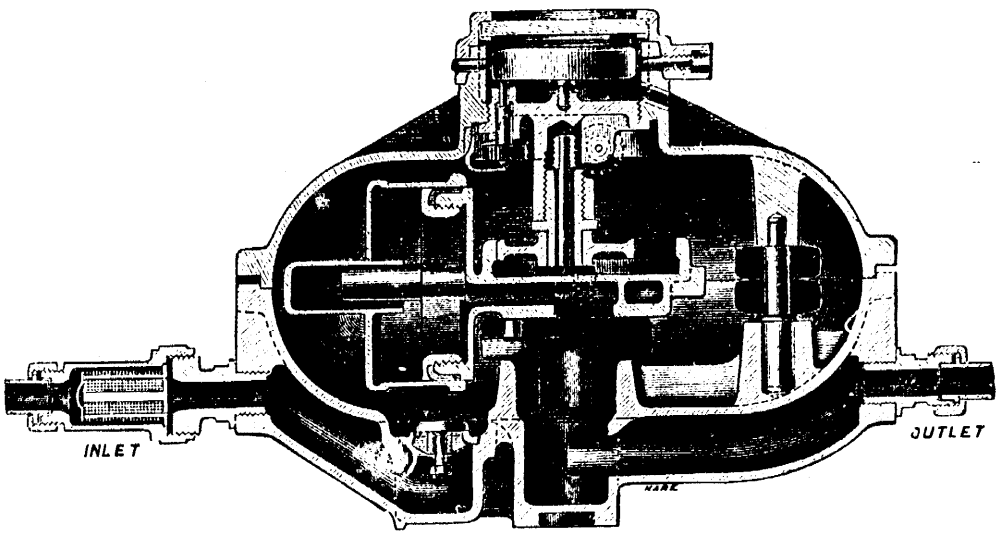

FIG. 118.—Vertical section of Schönheyder's meter.

line transverse to its axis. Each cylinder, which is open in front, is fitted with a piston with cupped leather packing and a tail-rod guide. All the three pistons are formed in one with a central valve having passages communicating with one side of the pistons, and, therefore, with the cylinders, and free to slide longitudinally and transversely on a facing in the center of the casing. Through this facing there are four ports, or passages, one in the center (triangular) acting as an eduction port, and three (oblong) acting as induction ports and arranged around the middle one. Each of the beforementioned passages in the valve has a port passing through the facing of the valve, so proportioned as to size and position that, by the to-and-fro and side movement of the valve over the facing, each port is alternately in communication with the induction and eduction ports, and the respective cylinders will, therefore, also be in alternate connection with induction and eduction. Water being admitted under pressure to the casing, after passing through a non-

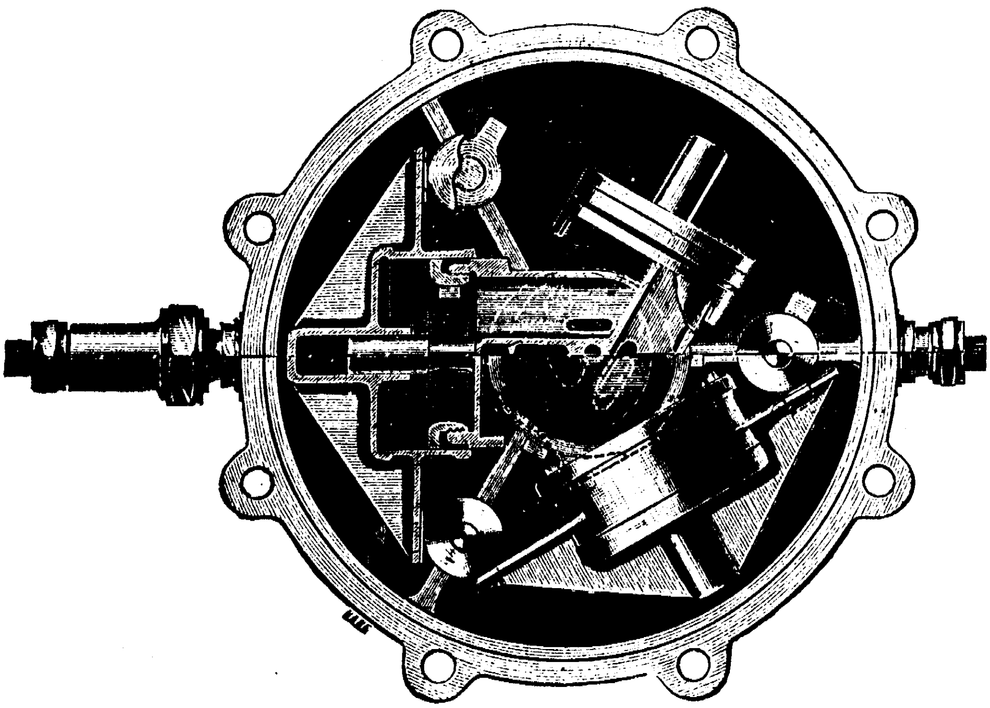

FIG. 119.—Plan of Schönheyder's water meter, with the tops of the case removed.

return valve, and being free to pass away from the eduction port to the outlet, the three pistons will be caused, by the pressure acting on their outer sides, to pass alternately in and out of their cylinders, while these reciprocate laterally. The path of the valve (with its attached pistons) is approximately circular, and the stroke is limited by a central roller depending from the cover and free to revolve on a stud: a ring or "roller path" being formed on the upper side of the valve.

The counter gear is worked by a crank, whose pin enters a hole in the top of the valve and is turned round through the said circular movement of the valve. The spindle of the crank passes through the central stud. The guide rollers are placed, one above the other, on suitable stationary pins guided both at top and bottom, and one wing of each cylinder bears against a bottom roller, while the other wing bears against a top roller.

The ports are not parallel to the center lines of their cylinders, but are placed at a slight angle, so as to compel the roller path to "cling" to the central roller even at low speeds; in other words, so as to make the machine always endeavor to take slightly longer strokes than it ought to do, the central roller in the roller path restricting this tendency.

The cylinders are prevented from twisting round on their pistons by suitable guides under the edges of the wings; but there is a slight clearance here, so that the valve will always bear on its face, even after some wear has taken place, and will not be held up by the cylinders. The counter gear is of simple construction, as shown; no small pins or screws are used in the arrangement, and the wheels are embedded in vaseline.

The stroke of the pistons being positive (being equal to the difference in diameter of internal ring, or roller path, and central roller), the meter is accurate at large and at small rates of delivery—even to a dribble; and, owing to the circular movement of the heaviest parts (pistons and valve), the meter will work, when called upon to do so, at exceptionally high speeds without injury, and with hardly any noise. Owing to the circular movement of the valve, its face and the face of the stationary seat wear each other to true and highly polished surfaces, hence tightness of the vital parts is insured.

The cylinders, being single-acting, will nearly always bear on their rollers, but at each turn of the center, when both the inlet and outlet ports are closed for a short time, the cylinders are slightly raised from the rollers, this action causing them (the rollers) to be always "traveling," and, therefore, to be continually presenting new wearing surfaces.

The meter is simple in construction and simple to repair; *not a single bolt, screw, or small pin is used anywhere, excepting only the cover bolts;* and when the cover bolts are removed all the working parts can be taken out by hand, even without disconnecting the meter from the service pipes.

The case is of cast iron, the rollers and the central face are of vulcanite, the pistons are packed with leather. All other parts are of gun metal, and the whole is water lubricated.

For boiler feeding, when hot water has to be measured, the vulcanite is replaced with gun metal and the leather cups with "quilted" cups—a kind of canvas pressed into cup shape, cut to lengths and sewed over. The meter can be used for measuring almost any kind of liquid, such as oil, beer, milk, cane juice, petroleum, etc.

The meter has been improved in some particulars lately. The inlet valve shown in the figure, for preventing the meter from being used if set up the wrong way, is now dispensed with. The worms and worm wheels are inclosed in a special chamber filled with vaseline, and water surrounds the counter gear, the cover of the counter box being made water-tight and strong enough to support the same internal pressure as that in the meter case. The glass lens is made tight by a rubber ring, and the casing being of gun metal, and the joint rings of canvas, all the surroundings are clean and will not discolor the water. As there is no "flow" through the chamber containing the counter gear, the water does not become fouled from the vaseline or from the (rusty) water in the meter. The advantage of this arrangement is threefold:

1. There is no end pressure on the spindle passing through the counter plate, hence diminished wear of worms and wheels.

2. The glass is never "foggy," hence the dials can always be easily read.

3. No dirty water, mud, or sand can enter from the outside through the usual leakage hole and clog the wheels.

Should the water, through some accident, become cloudy, the small cover can readily be unscrewed and the counterbox filled with clean water. On closing the cover down the air will escape by a small hole provided for the purpose. Should the glass break, no serious harm will result, a small leather collar on the through spindle preventing much waste of water.

The apparatus for holding the worms and wheels has not a single small screw or pin about it. By the peculiar form of the bearings holding the arbors, the wheels are locked in position. The end of the spring pressing on the through-spindle is slightly hollowed, so that it can not shift sidewise, and it is "hinged" to the plate by slightly indenting it after inserting it in a saw-cut made in a lug.

The only portion of the meter the wear of which will affect the registration, is the central roller and its pin. The periphery of the roller itself hardly wears, because its only motion is that of rolling; and the bearing wears but slightly because of the large diameter of the roller as compared with the stroke of the meter, which makes the motion very slow, and because of the very large surface of the bearing. The pin is of gun metal, and the roller is bushed with vulcanite. When wear does take place the stroke is slightly increased and the meter becomes a little "slow." It does not, however, become leaky, as most meters do, by wear.

As to durability: A number of meters have now been several years in use, and many attempts have been made to run them "to death" by working them at excessive rates for long terms, but without success. Of these cases, the tests at Birmingham, by Mr. Gray, should be mentioned. A one-half-inch meter was run for many hours at the rate of 1,500 gallons per hour without any visible injury or wear, and without affecting the accuracy of the registration.

(123) All the tests show that the meters are "slow" at large rates of delivery, and "fast" at low rates, owing, no doubt, to a slight increase of stroke when driven by high pressures, on account of the

springing of some of the working parts. At *very* low rates they again become "slow."

The results of a few tests are given:

Tests at Vienna waterworks, in May, 1889, of one-half-inch meter, No. 156 (Schönheyder's patent).

Pressure at inlet.	Outlet diameter "lines."	Time.			Tank.	Meter.	Slow.	Fast.	Gallons per hour.
Ats.	'''	*h.*	*m.*	*s.*	*Litres.*	*Gallons.*	*Per cent.*	*Per cent.*	
5	6		13	0	922	200	1.43	....	936
4	6		14	40	932	200	2.53	....	839
3	6		17	0	925	200	1.76	....	718
2	6		26	0	921	200	1.32	....	468
1	6		32	0	907	200	....	.22	374
0.5	6		41	0	907	200	....	.22	292
0.2	6	1	5	0	905	200	....	.44	184
5	5		15	0	928	200	2.05	....	816
4	5		16	0	932	200	2.53	....	769
3	5		19	0	923	200	1.52	....	641
2	5		33	0	921	200	1.32	....	368
1	5		50	0	920	200	1.20	....	243
0.5	5	1	0	0	910	200	.11	....	200
0.2	5	1	11	0	904	200	....	.55	168
5	4		18	0	924	200	1.62	....	678
4	4		19	30	923	200	1.52	....	615
3	4		22	30	921	200	1.32	....	540
2	4		27	0	912	200	.33	....	446
1	4		43	0	906	200	....	.33	278
0.5	4	1	0	30	905	200	....	.44	197
0.2	4	1	24	0	905	200	....	.44	142
5	3		25	0	917	200	.87	....	484
4	3		27	30	916	200	.76	....	440
3	3		33	0	910	200	.11	....	364
2	3		39	30	906	200	....	.33	303
1	3	1	2	0	902	200	....	.77	192
0.5	3	1	26	0	908	200	....	.11	139
0.2	3	2	40	0	898	200	....	1.23	74
5	2		47	0	908	200	....	.11	255
4	2		53	0	902	200	....	.77	225
3	2	1	0	0	903	200	....	.66	199
2	2	1	19	30	902	200	....	.77	150
1	2	1	58	0	903	200	....	.66	101
0.5	2	2	42	0	889	200	....	2.25	72
0.2	2	4	29	0	880	200	....	3.29	43
5	1	2	22	0	904	200	....	.55	84
4	1	2	33	0	892	200	....	1.91	77
3	1	2	53	0	888	200	....	2.36	68
2	1	3	31	0	870	200	....	4.45	54
1	1	5	7	0	868	200	....	4.72	37
0.5	1	9	55	0	860	200	....	5.39	19
0.2	1	35	13	0	873	200	....	3.96	5.45

Tests at the Berlin waterworks, in March, 1889, three-quarter-inch meter. No. 133 (Schönheyder's patent).

Trial No.	Time.		Compartive measure.		Slow.	Fast.	Gallons per hour.
			By tank.	By meter.			
	h.	*m.*			*Per cent.*	*Per cent.*	
....		12	100	101	....	1	1,100
11		15	100	101	....	1	880
10		21	100	101	....	1	629
9		29	100	102	....	2	455
8		36	100	102	....	2	367
7		49	100	102	....	2	269
6	1	7	100	102	....	2	197
5	1	56	100	103	....	3	114
....	2	2	100	103	....	3	109
4	2	54	100	103	....	3	76
3	5	36	100	104	....	4	39
2	9	17	100	1 5	....	5	24
1	15	23	100	103	....	3	14

Tests of water meters (Schnöheyder's patent).

NO. 202, 1-INCH METER FOR HOT WATER.

Pressure.		Time.		Tank.	Meter.	Slow.	Fast.	Gallons per hour.
Inlet.	Outlet.*							
Lbs.		*m.*	*s.*	*Gallons.*	*Gallons.*	*Per cent.*	*Per cent.*	
30	....	7	13	200	200	....	....	1,663
40	....	3	10	100½	100	.498	....	1,904
100	....	6	45	127	130	....	2.36	1,129
20	....	5	30	98½	100	....	1.52	1,075
10	....	7	0	98½	100	....	1.87	842
40	....	16	0	98½	100	....	1.52	369
50	....	6	30	30	30	....	....	277
30	....	24	0	98½	100	....	1.52	246
5	....	34	35	100½	101	....	.748	174
100	....	14	30	20	20	....	....	83
100	....	45	0	4	4	....	....	5.3
70	....	35	0	2	3	....	....	5.1
100	....	100	0	3.525	3.50	.71	....	2.1
40	....	....		1.000½	1.00	.05	....	....

*Six feet vertical, and about 10 feet of 1-inch pipe, and a 1-inch valve. The outlet was checked in many of these experiments. Owing to pipe resistances the capacity of meter is not fully shown. Thus with 40 pounds pressure and *free* outlet, discharge is over 2,500 gallons per hour.

NO. 142, ONE-HALF-INCH METER.†

40	....	9	0	102	100	1.96	....	680
25	....	11	0	100½	100	.498	....	548
10	....	24	30	98	100	....	2.04	240
50	....	177	0	2	2	....	....	.68

†Four feet head of water to drive slowly.

NO. 130, ONE-HALF-INCH METER.‡

Pressure. Inlet.	Pressure. Outlet.	Time.	Tank.	Meter.	Slow.	Fast.	Gallons per hour.
40	....	8 30	101	100	.99	....	713
25	....	10 30	99¾	100	....	.13	571
10	....	20 0	98	100	....	2.04	294
50	....	74 0	1.025	1.00	2.44	....	.83

‡ Five feet six inch head to drive slowly.

NO. 120, ONE-HALF-INCH METER.§

Pressure. Inlet.	Pressure. Outlet.	Time.	Tank.	Meter.	Slow.	Fast.	Gallons per hour.
40	....	7 30	101	100	.99	....	808
25	....	10 0	99¾	100	....	.756	596
10	....	20 30	98	100	....	2.04	287
50	....	290 0	1.00	1.00	....	....	.207

§ Four feet six inch head to drive slowly.

These tests were made by Beck & Co., London.

(124) *The Thomson water meter.*—Thomson's water meter, exhibited by the inventor, Mr. John Thomson, of New York, received a silver medal. The meter is shown by Figs. 120 and 121.

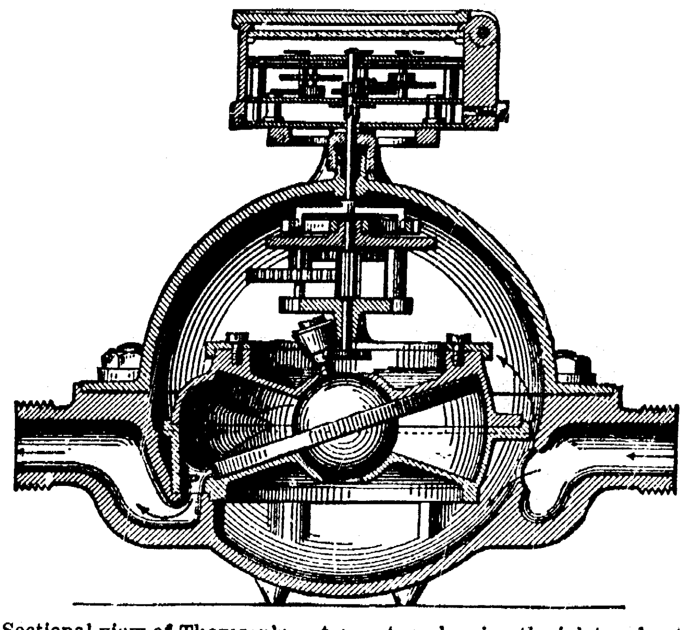

FIG. 120.—Sectional view of Thomson's water meter, showing the inlet and outlet ports.

Its principle is the same as that of the Davies and Bishopp disk steam engines, once quite famous in England for the novelty of their mode of action.

The measuring chamber of this meter is in the form of a central zone of a hollow sphere, having ends at top and bottom, which are conical frustums, whose sides slope inward toward each other, and hence toward the center of the sphere. At the center of each of these conical ends is a spherical socket with its center of curvature in the center of the spherical chamber.

In these sockets fits a solid sphere which forms the central boss of a thin, flat, circular disk, the edge of which exactly fits the interior of the spherical chamber. This disk constitutes the piston of the chamber and has a movement of nutation or wabbling about the center of the sphere as a center of motion, the charactër of the movement being such that the spindle in the axis of the disk receives a conical motion, so that its end sweeps around in a circular path. The chamber is divided at one side by a vertical radial septum or partition, extending from the periphery of the chamber to the central sockets, and the disk is perforated with a narrow radial slit so that it may straddle the partition. The whole measuring cham-

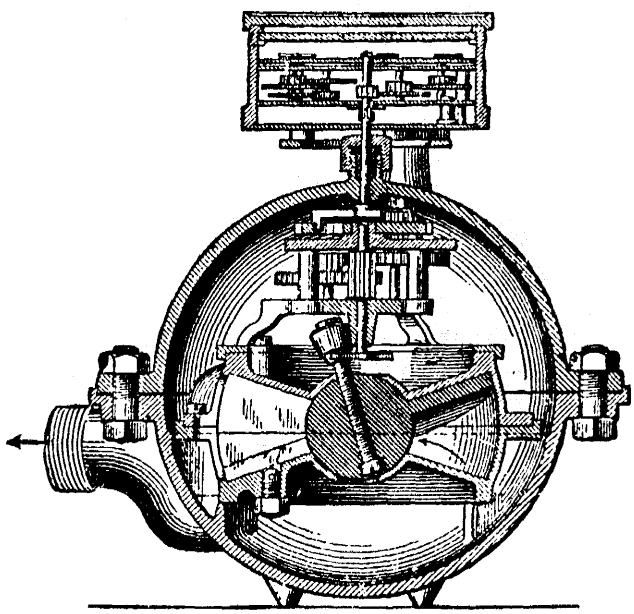

FIG. 121.—Sectional view of Thomson's water meter, showing the 'septum of the measuring chamber.

ber is inclosed in a globular case into which the water to be measured flows. From this the water enters the measuring chamber through an opening in the spherical wall on one side of the radial partition, and is discharged into the outlet pipe of the meter through an opening on the other side of the partition, the two openings in the wall of the chamber being close together, separated only by the thickness of the partition.

The water can not pass from the inlet opening to the outlet without so displacing the disk as to cause a complete oscillation and a single revolution of the end of the spindle, and each of these complete movements corresponds to a quantity of water equal to the whole contents of the measuring chamber. The disk spindle engages with a star wheel on the end of one of the arbors of a train of gearing forming a register, and turns it with a uniform motion. A small conical roller on the end of the disk spindle bears against the conical end of the bearing of the register arbor, which is exactly con-axial with the measuring chamber, and by this means the disk spindle is guided in its circular path in such a way as to insure the proper movement of the disk with the least possible friction.

The measuring apparatus is of elemental simplicity. Functionally it consists of only two parts, the chamber and disk, for no valves are required to effect the distribution of the water in the chamber.

More than two thousand of these meters are in use in New York City.

SPECIAL REPORT

ON

APPARATUS AND METHODS OF MINING AND METALLURGY,

CLASS 48,

BY

HENRY M. HOWE.

TABLE OF CONTENTS.

APPARATUS AND METHODS OF MINING AND METALLURGY.

By HENRY M. HOWE.

A.—Boring and shaft-sinking.

(1) *Lippmann's patent filtering column**—Figs. 1, 2, and 3—is a device for obtaining clear water from quicksands, etc. It consists of a thin-walled polygonal cast-iron column, in sections, bolted together tandem, made up of 6-inch square panels, as shown in Fig. 3. On the outer face of each panel are eight radial channels, leading to a 1-inch hole, A, Fig. 1, in the center of the panel, the hole passing completely through the wall of the column. A porous 6-inch square tile, *b*, is laid in each panel, as shown in Figs. 1 and 2, and cemented around its edges to the flanges which bound the panel. These porous tiles are the filterers; the channels in the face of the panels lead the water, which penetrates the tiles, toward the central hole of each panel, and through this hole to the interior of the column, whence the water is pumped to the surface.

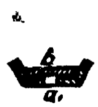

Fig. 1.

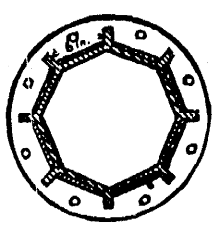

Fig. 2.—Cross section o filtering column.

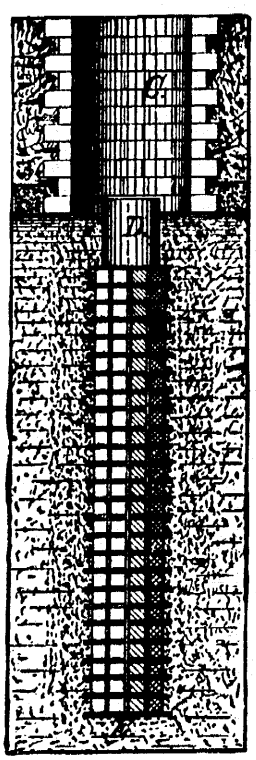

Fig. 3.

Lippmann's Filtering Column.

The procedure is as follows: First a well, C, considerably larger in diameter than the filtering column is to be, is sunk to the water-bearing stratum and lined with masonry or iron piping, as the case may be. Next, a common closed iron pipe, of diameter intermediate between this upper well and the filtering column, is sunk in the water-bearing stratum to the depth deemed suitable for the filtering column. The filtering column itself, its upper

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*See Le Genie Civil, XIII, No. 25, p. 390, October 20, 1883.

end preferably prolonged by a common closed pipe, D, as shown in Fig. 3, and its lower end closed with an iron plate, E, is next sunk within the temporary piping, which is then drawn up, leaving the filtering column in contact with the quicksand or other material of which the water-bearing stratum is composed.

This device was adopted at Rambouillet, near Paris, where the extremely fine Fontainebleau sands are said to contain very good drinking water, of which, however, the authorities were unable to avail themselves; for "in spite of all precautions and of many and varied experiments, the dangers and inconveniences due to the fluidity of the sand manifested themselves so intensely and persistently" as to defeat all efforts to obtain a water supply.

Here a filtering column, 15¾ inches in diameter and 11 feet 6 inches long with a filtering surface of 32¼ square feet, was sunk within a temporary tubing 22 inches in diameter. The base of the filtering column lies at a depth of 39 feet 5 inches, and is immersed 23 feet in water. Two pumps drew 3,000 gallons per hour from this filter, for several days in succession, without lowering the surface of the water below the limit of suction.

It is stated that the filter has now been in use for 18 months, and that, far from becoming clogged, it gives out 20 per cent. more water than at first.

(2) *New boring tools.*—The first four which will be described are shown by Lippmann,* following ones by Arrault,† the last by Becot.‡ We are indebted to these gentlemen for the cuts.

I. *Lifting-ram*, Fig. 4.—This tool is designed for freeing the trepan in case it becomes wedged in the rock at the bottom of the bore-hole. Should this occur, the rods are unscrewed from the trepan, the ram shown is then lowered through the tube, whose bore it almost exactly fits, so that the female screw *d* on its lower end readily catches the male screw on the upper end of the trepan, to which it is then easily attached by screwing.

The ram is then pulled up repeatedly by means of light rods reaching to the surface and attached to its ears *a a*. It is then hammered against the shoulder *c*, the blow thus delivered loosening and finally releasing the trepan from the crevice in the rock in which it has been caught.

The upward blows, delivered thus close to the trepan itself, are clearly much more effective than upward blows delivered at the surface, for the force of the latter is met and opposed by the resilience and inertia of the whole length of rods reaching from the surface to the bottom of the bore-hole.

II. *Reamer*, Fig. 5.—This is designed for reaming out the rock in the bore-hole immediately below the end of the tubing.

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* Edouard Lippmann et Cie., 36 Rue de Chabrol, Paris.

† A. Paulin Arrault, 69 Rue Rochechouart, Paris.

‡ H. Becot, 25 Rue la Quintinie, Paris.

e e are the cutting edges of the cutting tools, which are pivoted to the rod. As shown, they just fit easily in the tubing. Cords, h h and i, on each side of the rod are attached to little pins, k k, on the cutting tools. As the reamer is lowered through the bore-hole these cords grow wet, shrink, and thus act as strong springs to rotate e e about the pivot, throwing the cutting edges outward till their shoulders just above k k rest against the fixed flange above them on the rod.

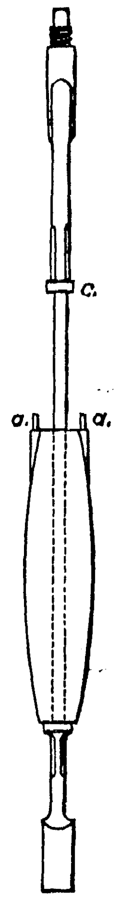


FIG. 4.—Lifting ram.

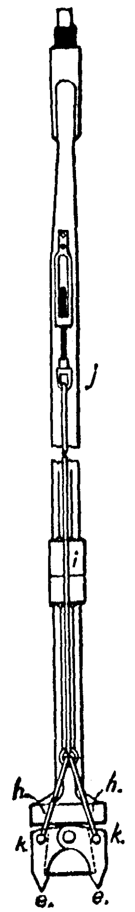


FIG. 5.—Reamer.

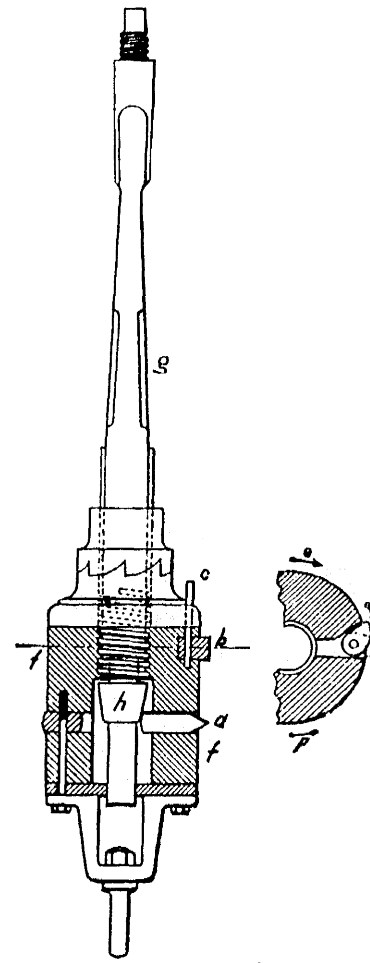


FIG. 6.—Pipe-cutter.

LIPPMANN'S BORING TOOLS.

The tool is readily withdrawn, for when it is drawn upward the outer edges of the cutting tools e e are pressed against the lower edge of the tube, and the tools are thus folded together again and brought into the position shown in the cut.

The cords h h and i of course play the part of very simple springs.

III. *Pipe-cutter*, Fig. 6.—This tool is designed for cutting the tubing apart at any depth in the bore-hole.

The tool is lowered to the proper position, and the cutting tool a is then driven outward till it bears against the walls of the tube, by turning the rod in the direction of arrow p (*i. e.*, to the left). In doing this the little cam *b*, by its own friction against the walls of the tube, is rotated in the direction of arrow *e*; *i. e.*, it is opened, for when closed it just fitted easily within the tube. When the cam is thus opened it jams against the walls of the tube and prevents the head *ff* from turning. Under these conditions the rod *g* alone turns, sliding over *ff* by means of the rachet *c*.

As the rod thus turns in the direction of arrow *p*, the conical head *h* is driven downward by the left-handed screw-thread shown just above it, thus forcing the cutting tool *a* outward a little, and by this means feeding the tool toward its work.

As the teeth of the rachet slip past each other each click is distinctly perceptible at the surface, by sound and feeling, as the workman holds his hand against the upper part of the rod. In this way

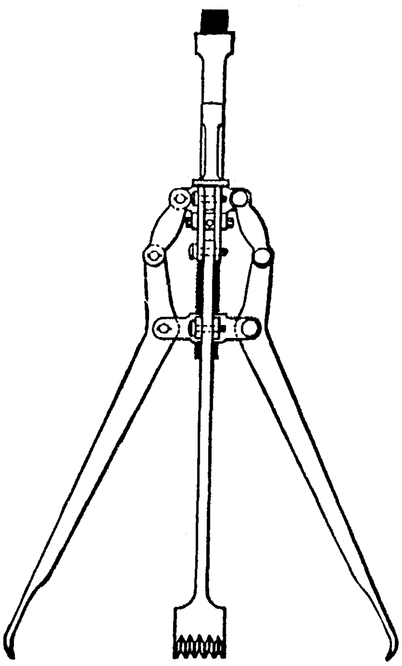


FIG. 7.—Side view.

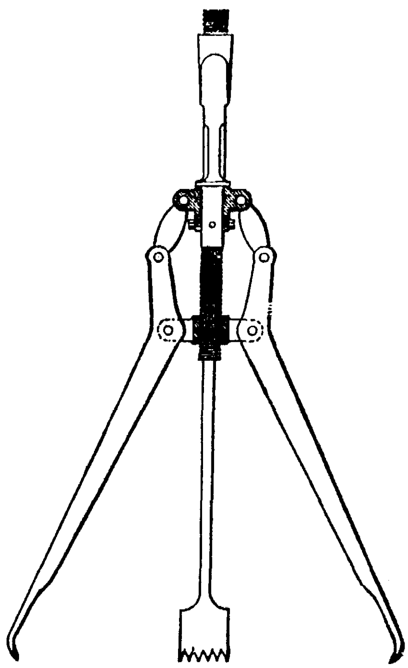


FIG. 8.—Section.

LIPPMANN'S NIPPERS FOR SHAFT SINKING.

he knows just how far the rachet has turned, and hence just how far the cutting tool *a* has been fed out, at any given instant. He can thus stop this left-handed rotation when *a* has been fed out far enough, and then proceed to turn the rod to the right in the direction of arrow *e*. This motion folds the eccentric *b* inward, so that it no longer jams in the tube, and *a* cuts into the tube as the rod continues to turn to the right.

When the cutter head has made a few revolutions the maneuver must be repeated, so as to feed the tool out a little farther, and these processes are repeated till the tube is cut through.

IV. *Nippers for shaft-sinking*, Figs. 7 and 8.—This tool is designed for gripping and lifting to the surface tools, etc., which have fallen to the bottom of a shaft which is being sunk by the Kind-Chaudron process, *i. e.*, while the shaft is full of water. It differs from the nippers used in bore-holes, chiefly in being of larger size and having four jaws instead of two.

V. *Light sinking outfit.*—Fig. 9 shows a light portable iron apparatus, by Arrault, suitable for sinking bore-holes to depths of from 50 to 65 feet.

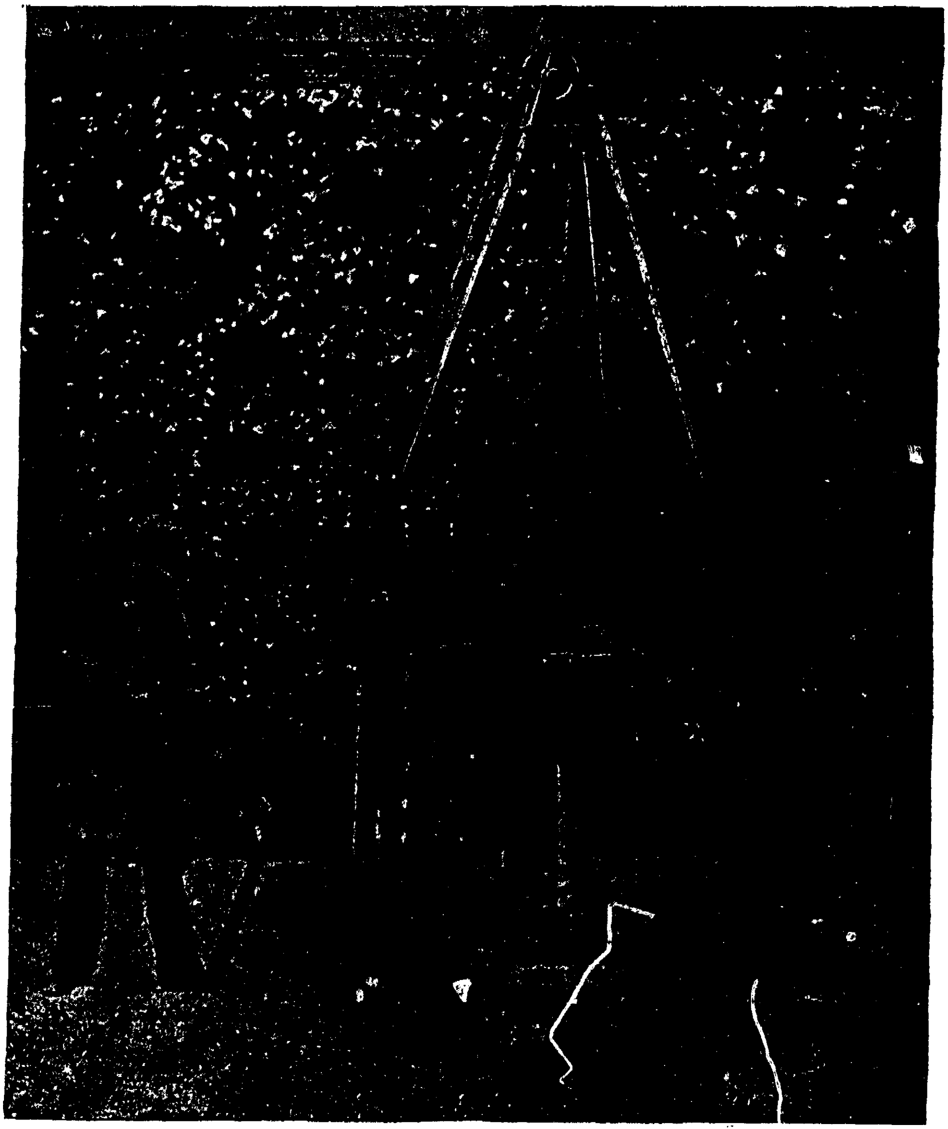


FIG. 9.—Arrault's portable sinking outfit, for holes from 50 to 65 feet deep.

The legs of the tripod are made of iron piping. Arrault shows or describes four other sizes of this apparatus, the largest suitable for sinking bore-holes to a depth of 650 feet. In all the sizes except the one shown, a hand-winch is used for raising the tools, etc., and the tripod is braced more or less strongly. I condense certain information concerning these sinking outfits in the following table:

TABLE I.—*Dimensions, etc., of Arrault's light boring outfit.*

No.	Depth for which the outfit is suited.	Weight, in pounds.				Cost at Paris.*		Number of men needed.	Diameter of bore-hole, in inches.
		Sinking apparatus.	Tools.	Piping.	Total.	All except piping.	Piping.		
	Feet.								
1	49 to 66	220	386	397	1,003	$130	$52	2	3.74 and 2.75.
2	66 to 82	672	1,091	926	2,689	340	1 0	3	5.11, 3.74, and 2.75.
3	115 to 197	1,390	2,469	3,086	6,959	780	390	4	8.07, 6.50 and 5.11.
4	197 to 328	2,006	7,473	7,716	17,195	1,800	770	5	9.84, 8.07, 6.50 and 5.11.
5	492 to 656	3,880	15,960	17,637	37,477	3,700	1,760	6	12, 9.84, 8.07, 6.50, and 5.11.

* At the rate of 5 francs=$1.

M. Arrault informs me that with this light outfit the distance sunk by hand per 10 hours should be about 2 feet to 2 feet 6 inches for limestone, 5 feet for very soft rock, and 6 to 12 for sand, etc.

Using steam a bore-hole 15 inches in diameter should, he states, be sunk at first at the rate of about 15 feet per 24 hours. He informs me that he has sunk through 197 feet of limestone, passing from a depth of 197 feet to one of 394 feet, in 15 days, the hole being driven true enough for piping.

Mr. Lippmann informs me that he sunk the Montron well (Loire), whose final diameter is 10 inches, to a depth of 1,650 feet in 16 months. He shows a collection of small crustaceans and fishes, some of which were 4 inches long, which have come up through deep artesian wells.

VI. *Solid trepans.*—Arrault shows a large trepan, with a cutting edge 39 inches long, cast as a single piece in chrome steel, and weighing about 1,000 pounds. These heavy trepans have hitherto usually been built up. For the single-piece trepan cheapness, strength, and simplicity are claimed.

VII. *Couplings for rods.*—Instead of having a socket and female thread on the lower end of each rod, which fits a male thread on the upper end of the next lower rod, Arrault joins the rods by couplings or sleeves, quite like the couplings of common wrought-iron pipes of small diameter. To diminish the wear he rivets the coupling to one, say the upper, of the two rods which it unites, the screwing and unscrewing thus taking place wholly between the coupling and the lower rod. After these threads are so far worn that they are no longer safe, he draws the pin by which the coupling was riveted to the upper rod, and then rivets the coupling fast to the lower rod, so that after this has been done the screwing and unscrewing take place between the coupling and the upper rod. In this way the threads on rod and coupling need not be renewed until this second set of threads has been worn out. In effect, this is substituting the wear of a coupling for part of the wear of a rod-end; and the advantage is that it is easier to replace a coupling than to replace a rod-end.

VIII. *Bell and cone joints.*—To compensate for the wear of the threads at the joints of boring rods, Becot makes the socket containing the female screw bell-shaped and the male screw cone-shaped, diminishing the diameter by 15 per 100 of the length of the screw. As the threads wear, they can always be made tight by screwing them together farther and farther. He also makes the section in the screwed ends considerably larger than in the shank, so that when rupture occurs it may always be in the shank, as this is far more readily repaired than the threaded ends.

M. Becot states that neither of these devices is original with him.

(3) *The Kind-Chaudron process* for sinking shafts through bad, and especially through water-bearing ground, consists first in sinking the shafts as one does a common bore-hole, *i. e.*, without pumping; the shaft while sinking remaining full of water, and the rock or earth driven through being removed by tools similar to those used in sinking deep bore-holes (trepans, etc.), but of course of diameter corresponding to that of the shaft. Secondly, in lining or "tubbing" the shaft before unwatering it, by lowering through the hole thus sunk a water-tight tubbing column composed of massive cast-iron rings or tubs, each ring cast in a single piece, flanged and accurately faced at each end, and bolted firmly to the adjoining rings. The annular space between this tubbing and the walls of the shaft is then filled from bottom to top with hydraulic cement, and not till then is the water pumped out of the shaft.

The tubbing column is bolted together ring by ring as it is lowered through the water. Its descent is facilitated by closing its lower end with a water-tight false bottom, A A, Fig. 10, so that the tubbing column floats in the water, the cast-iron walls of a ring of tubbing weighing less than the water which it displaces. In this false bottom is a pipe, B, which is continued up through the tubbing as, by the addition of ring after ring, the column grows; and, by means of cocks in this pipe, water is admitted from time to time into the interior of the tubbing in quantity sufficient to cause it to sink far enough to bring its upper end to a convenient height for attaching more rings. This false bottom is, of course, finally removed, after the tubbing has been made fast, the shaft being sunk through the good ground beyond by the usual methods.

I. *The joint* between the bottom of the tubbing and the surrounding rock is made tight, by a sort of gland and packing arrangement, much like that of a common stuffing box, so that the water may not leak into the shaft around and under the bottom of the tubbing. The gland-ring C C D D, Fig. 10, lies below the false bottom and within the lower joint of the tubbing; outside this ring, and between its lower flange C C and the flange E E, at the bottom of the tubbing proper, the annulus called the "moss-box" lies. In this annulus a quantity of clean dry moss is tightly packed, while the lower rings of the tubbing are still above ground. The moss is held in place by a stout netting while the tubbing is descending through the water. When the tubbing reaches the bottom of the shaft, the flanges C are first stopped as they strike against the ledge, *i. e.*, the bottom of the shaft, and as the column of tubbing continues to descend, the flanges

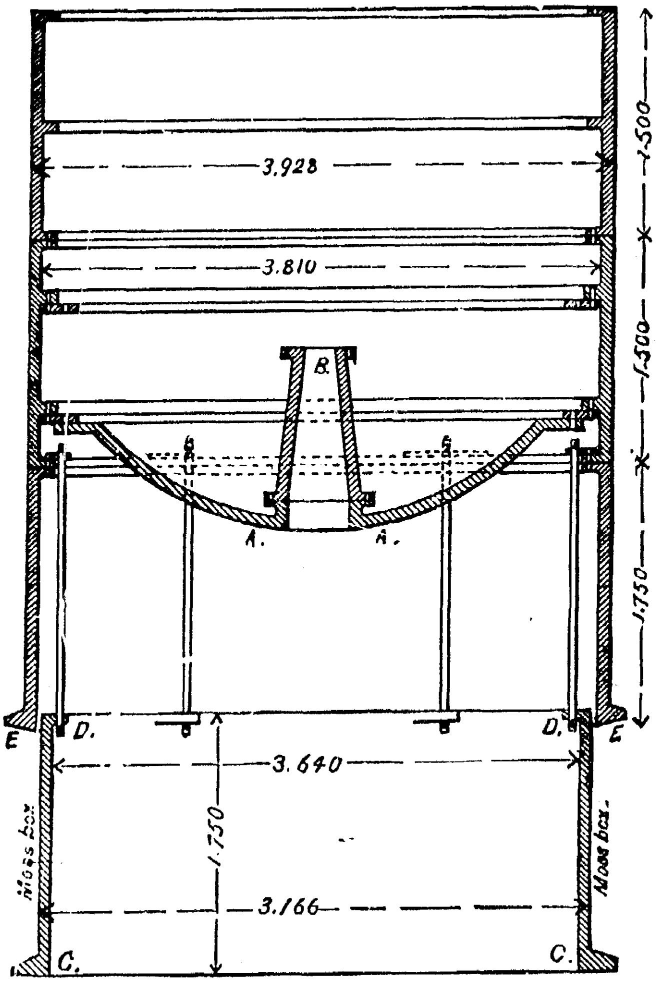


FIG. 10.—False bottom, moss box, etc., for the lower end of the tubbing column of the Kind-Chaudron process. Dimensions are in meters.

E E are brought nearer and nearer to the flanges C C, so as to compress the moss powerfully both outward against the rock which forms the walls of the shaft, and downward against that which forms its bottom, quite as the gland presses the packing in a common stuffing box against its walls and against the piston rod. When the tubbing column is completely lowered, its whole weight rests on this moss.

These details probably suffice to enable the reader to understand the following description of the progress made with the Kind-Chaudron process since 1878.* Further information is accessible to American readers in M. Deby's paper on this process.†

II. *Progress between* 1878 *and* 1889.—In this period sixteen shafts have been begun or finished by this process: In Belgium, 5; in France, 3; in Britain, 1; in Germany, 7.

The bottom of the tubbing of these shafts lies at a depth of from 303.4 to 1,066 feet below the surface, the sum of the depths of the bottoms of these sixteen tubbings being 9,076 feet. Three of these shafts are in course of execution.

Shafts of greater importance than those formerly sunk have been successfully sunk in this period, some of them through quicksand. I will now describe two of the most important of these.

III. *Sinking the Ghlin (Belgium) shafts.*—These two shafts, whose tubbing reaches to depths of 1,011 and 1,066 feet, respectively, were begun in May, 1873. The sinking and tubbing of the first shaft were finished in February, 1885, those of the second shaft in April, 1887.

The ground sunk through consists of—

First. Tertiary and Quaternary water-bearing strata, loose and quick, reaching from the very surface to a depth of about 65 feet.

Second. The marls, flints, and greensands of the Upper Cretaceous, apparently bearing much water.

Third. The Cretaceous quicksands, known as "sables achéniens," which present the real difficulty.

First a ring of masonry (see Fig. 11), 21 feet 4 inches in diameter inside and 2 feet thick, was sunk to a depth of 23 feet, by removing the sand and freeing its inner circumference as much as possible, while pressing downward on the upper surface of the masonry itself. At this depth serious difficulties arose, and it was therefore decided to drive the masonry no farther.

By this time the regular sinking plant was installed, and the engineers now proceeded to sink a cast-iron column, using a light trepan, dredging buckets, etc. With these tools and with the aid of presses placed above the shaft, a cast-iron column was sunk at No. 1 shaft through the upper water-bearing sands to a depth of 39 feet. Within this a second cast-iron column was farther driven to a depth of 59 feet, when it reached the upper part of the marls. The two cast-iron columns were much injured in this descent, and even cracked, for there was much difficulty in piercing the quartzose

*Condensed from an interesting paper by M. Chaudron; excerpt from "Industrie Moderne," A. D. 1889, 51 Rue Taitbout, Paris.

†Trans. American Inst. of Mining Engineers, v, p. 117, 1877. M. Deby here illustrates the tools used in this process. See also a paper by Mr. A. Demmler, read before the Manchester Geological Society, January 29, 1878. Fig. 10 is taken from this last paper.

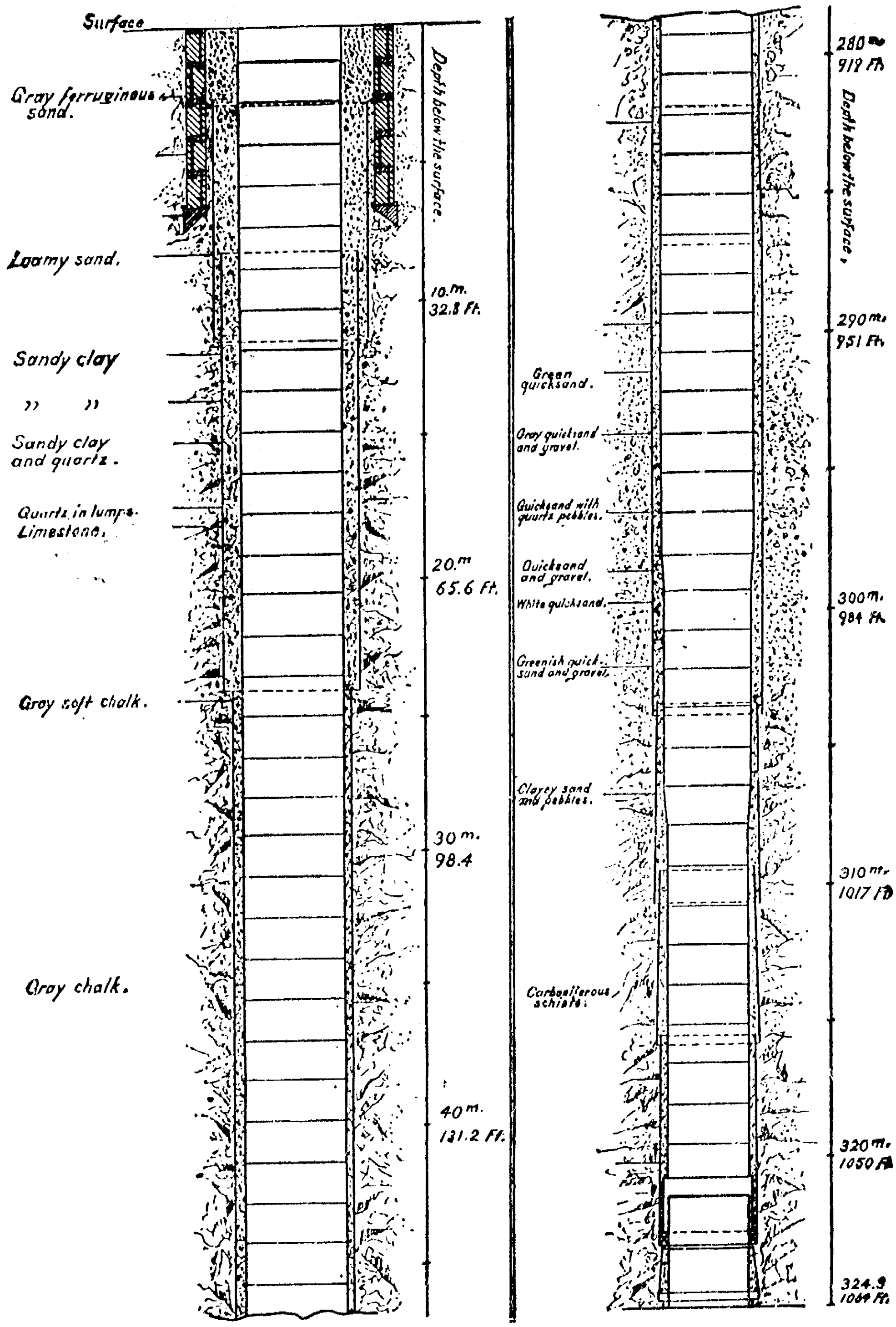


FIG. 11. FIG. 12.

Part section of No. 2 shaft at Ghlin, Belgium, sunk through quicksand by the Kind-Chaudron process.

masses which they met in the sands. The shaft, however, was still plumb, and had a clear inside diameter of nearly 19 feet. In view of the importance and depth of this shaft, and of the expected permanence of the workings, it was, of course, imperative to tub these upper water-bearing sands most securely, since any failure of the tubbing would deluge the workings below with avalanches of sand. A third cast-iron column was therefore sunk within the first two to a depth of 70 feet 6 inches beneath the water, its lower end resting in the marl. The annular space between this column and the two outer ones was then filled with concrete, and the water-bearing sands were thus firmly sealed up.

In the second shaft, profiting by the experience with the first, the engineers were enabled to reach the solid marl, at a depth of 78 feet 9 inches, with two columns of cast-iron instead of three, as shown in Fig. 11. This was accomplished toward the end of December, 1874.

Sinking through the marl.—Here a relatively narrow preliminary shaft was first sunk, and then reamed out to a diameter of 14 feet 5 inches. After some trials it was found that a diameter of 6 feet 6 inches for the preliminary shaft gave better results than a smaller one of, say, 4 feet 6 inches, a shaft of the former size sinking as economically and almost as fast as the smaller one, and being reamed out to the final size of 14 feet 5 inches much more quickly.

For sinking this large shaft a trepan was used which, without its accessories, weighed 20 gross tons, while the trepans for the preliminary shafts weighed from 10 to 12 tons. In 1876 relatively slight progress was made, as very compact silicious ground was met, which the trepans simply crushed instead of cutting. The engineers in charge were driven to trying the free-fall arrangement for the cutting tools, and finally developed a form of it which was easily applied, and which doubled the rate of sinking.*

After several years' work the water-bearing marls were successfully passed, impermeable ground was reached, and at a depth of 925 feet it was thought that the Coal Measures had been reached. What was their disappointment, however, on finding wholly unexpectedly, and at a depth of about 930 feet, a bed of quicksand some 50 feet thick (*sable boulant achénien*).

In shaft No. 1 three sheet wrought-iron columns were successively sunk in this quicksand, reaching comparatively firm ground in the Coal Measures at a depth of 984 feet. The dimensions of these wrought-iron columns were as follows:

Diameter.		Length.	Depth of lower end below surface.
Ft.	*In.*	*Feet.*	*Feet.*
13	8¼	17	961
13	2	28	974
12	11	26	984

*This form of free fall was invented by M. A. Vancranem, and patented (in Belgium) on April 18, 1879.

Unfortunately the schist on which the quicksand rested was itself very treacherous, and in order to find a solid base for the tubbing itself it was found necessary to sink with the trepan to a depth of 1,007 feet, following up this sinking with still another wrought-iron column, which extended to a depth of 997 feet from the surface.

In shaft No. 2, again profiting by the experience in shaft No. 1, they reached the coal-bearing strata with two wrought-iron columns; but a third and supplementary one had later to be placed above. But though they passed thus comparatively readily through these quicksands, new trouble arose in the coal-bearing strata. They found the schist at a depth of 1,007 feet, but they had to push down to a depth of 1,063 before finding safe foundation for the final cast-iron tubbing column, and to carry the wrought-iron tubbing to a depth of 1,050 feet. Thus the five successive columns of wrought-iron tubbing used in the lower part of shaft No. 2, as shown in Fig. 12, sealed up 126 running feet of treacherous ground.

Sinking the tubbing.—The shaft having thus been sunk to firm ground, and being still full of water, the relatively easy work of sinking the final columns of cast-iron tubbing, each of which was to tub one of the shafts from top to its present bottom as a single solid water-tight lining, now began. The tubbing column of No. 1 shaft, consisting of 214 cast-iron rings, with a total height of 1,007 feet, was lowered into place in less than 2 months; but an accident occurred which threatened most serious disaster.

In sinking the tubbing column through the water, as it floats on its false bottom, the latter has to support the whole weight of the column above, less the weight of the water admitted intentionally within the tubbing to enable it to sink, or, in the present case, some 2,200 tons. Now, when the tubbing had been lowered to a depth of about 740 feet, and while there were still 64 cast-iron rings to set and bolt upon its upper end, a leak occurred in the false bottom. Had the bottom itself broken, or had some joint sprung a leak?

Of course here was serious danger that the water would accumulate within the tubbing not only faster than they could pump it out, but so fast that the whole mass would sink to the bottom with a rush. There was nothing for it but to pump for dear life, and to bolt ring after ring to the top of the column as fast as possible, and so strive to keep its head above water, working without ceasing day and night. At length, after nine days of this peril and strain, the tubbing reached the bottom of the shaft and rested safely on the rock, its top still within reach. The shaft was saved.

To avoid the danger of another occurrence of this kind the tubbing of No. 2 shaft was provided with two false bottoms, one at its very base, the other about 250 feet higher up. Thus the first false bottom had to support only the first 150 rings of tubbing before being reënforced by the second. It is evident that, by admitting water into the space between the two false bottoms and thus compressing air between them the upper false bottom can be made to support as much of the weight of the whole as is desired.

The work of surrounding the tubbing columns with mortar (béton) presented no features of especial interest, though indeed it was no simple matter to place the little bucketfuls of mortar at a depth of over 1,000 feet. The work occupied about 2 months at No. 1 shaft. Four little steam engines drove double lines of wire rope, which took the full buckets to the bottom and brought the empty ones up.

IV. *Shaft at Gneisenau.—Sinking tubbing columns beneath the water level.*—The Kind-Chaudron tubbing column usually extends unbroken from the bottom of the water-bearing strata to the surface. At Gneisenau, in Westphalia, however, the water-bearing strata, some 140 feet thick, are overlaid by some 660 feet of good ground, in which a shaft could be sunk and lined in the usual manner without resorting to the Kind-Chaudron process. On piercing the water-bearing strata, however, the water gushed into the shaft, and filled it nearly to the surface.

To unwater the shaft was plainly impossible. It was therefore sunk while full of water, through the water-bearing ground, by trepan and sludge box. It was now clearly unnecessary to tub the whole depth of the shaft; the upper 660 feet were in good ground, and all that was necessary was to tub the 140 feet of bad ground, and to seal up the annular space between the tubbing and the rock at either end, so that water might not leak around the ends of the tubbing; for safety, however, the tubbing column was made 82 feet longer than the thickness of the bad ground, so that its ends might be the more securely sealed.

The tubbing column was put together in the usual way, setting ring after ring on its upper end, and sinking it little by little by admitting water from time to time into its interior, so that its head was ever at a level convenient for setting more rings. But in order that the tubbing column, some 220 feet long, might be readily lowered through the 600-odd feet of water which overlay the portion it was to occupy, it was closed at top as well as bottom, only enough water being admitted into it to enable it to sink at fair speed through the water.

It was thus lowered, being still controlled by rods which passed up through the overlying water to the surface. It was like lowering a gigantic closed can far below the surface of the water. When it came to rest at the bottom of the shaft a valve in the false top was pulled open by a wire which reached to the surface. The water now rushed into the tubbing column, and its weight pressed the moss box or stuffing box at its lower end hard against the rock walls of the shaft. The annular space around the tubbing, between it and the rock walls of the shaft, was now filled with béton, which was lowered by little buckets guided by wires which had been attached to the outer circumference of the tubbing at its lower end before lowering it, and which ran to the surface.

The shaft was now pumped dry, the water of the bad ground being effectually shut out by the tubbing, moss box and béton. The false top and bottom of the tubbing were removed, and the shaft was continued into the good ground beyond.

(4) *Lippmann's modifications of the Kind-Chaudron process.*—Lippmann has abandoned the moss-box arrangement, and instead places a ring of iron filings or turnings around the outside of the bottom of the tubbing, so as to form a species of rust-joint. The iron filings may be lowered quite as the béton is.

Instead of lowering this by little buckets he runs it down after mixing it with water, through sheet-iron pipes 4 inches in diameter, which reach from the surface to the bottom of the annular space between tubbing and rock. A little iron rod reaches down through each of these pipes. By moving it occasionally the béton is prevented from clogging in the pipe. The sheet-iron pipes are of course shortened as the work proceeds. After a little practice the men can fill about 50 running feet in 8 hours, which appears to be much quicker work than that accomplished by Chaudron's plan. We saw that 2 months were needed to back about 1,000 running feet of tubbing by Chaudron's method at Ghlin.

Lippmann further dispenses with the internal column of piping B, Fig. 10, with its series of cocks, and instead has a single cock in the false bottom itself. This cock is opened and shut by a lever moved from the surface. He objects to the internal column on the ground that it is liable to be broken, thus flooding and sinking the tubbing column.

We saw that Chaudron first sinks a preliminary shaft, which he later reams out to the full diameter sought. This is because a single straight-edged trepan works disadvantageously when of large diameter; for even if it be turned only through a very small angle between successive strokes, the distance between successive cuts near the circumference is very considerable.

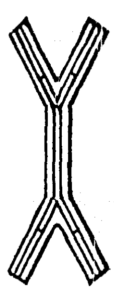


FIG. 13.—Lippmann's doubly Y trepan.

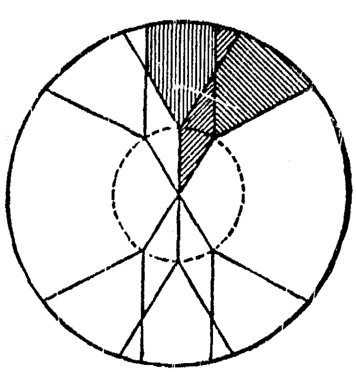


FIG. 14.—Shape of cuts made by Lippmann's double Y trepan.

To avoid this Lippmann uses a trepan like that shown in plan in Fig. 13, a sort of double Y, which, as shown in Fig. 14, cuts the rock up into a series of lozenges. With this trepan he sinks the shaft at once of full size.

B.—Rock drills and air compressors for mines.

(5) *The Bosseyeuse or wedging drill,* for drilling and breaking down rock.*—This machine is a rock drill, which can be swung easily either vertically or horizontally while working, so that it may cut at will either the common round holes or long slots. It is further provided with a ram-head (Fig. 22), for striking the wedges (Fig. 21), which are used for breaking down the rock. To use this ram-head we detach the common drill bit and attach the ram-head in its place.

The machine was devised for driving levels in coal mines without using explosives, breaking the rock down by wedging instead of by blasting. It is reported that eighteen out of the twenty-three explosions examined by the Belgian administration of mines in the three years ending in 1882 were caused by the use of powder.

I will first describe the machine itself and then its use, especially the system of wedging employed for driving levels, etc.

Fig. 15 shows the wedging drill and the wedges in place; Figs. 16 to 19 the details of the machine, Fig. 20 the bit, Fig. 21 the wedge and feathers, Fig. 22 the ram-head.

The drill itself is about 4 feet high and 2 feet 6 inches wide, and can drive levels from 4 feet high by 5 feet wide to 8 feet high and 11 feet wide.† "It is mounted upon a carriage running on wheels, G and H, and capable of being fixed by the screw J and sleeper K (Fig. 15). In the center of this carriage is an upright upon which is mounted a frame capable of being moved in all directions. By means of a hand wheel and a worm, M, it can be rotated in a horizontal plane; the screw N serves to tilt it, and the screw L to raise and lower it. In this frame are two long guides, B, upon which is mounted the motive-power cylinder A (Fig. 17), which can be moved along them by the screw O and hand wheel C. Compressed air is distributed to the cylinder by the slide valve C, the rod of which is enlarged at one end to form a plunger, D, working in a cylinder to which the air gains access through a leak hole in the plunger. This air is periodically evacuated by the opening of the air valve *a* by the tappet lever F, when the excess of pressure in one direction moves the valve. On the return stroke the piston is arrested by the counter piston K working in an extension cylinder to which air passes through the leak hole N.

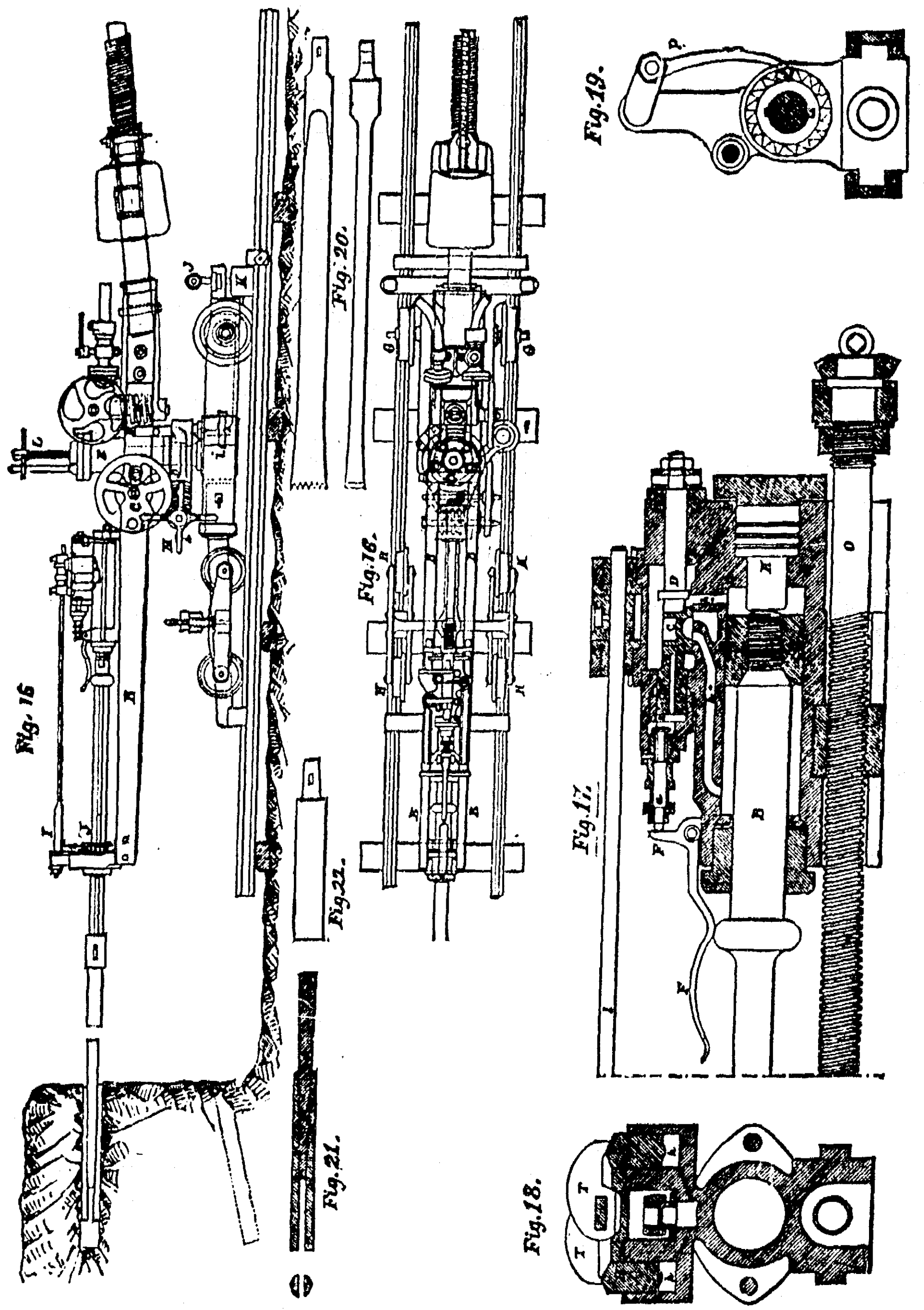
The boring bar J has a key groove down each side (Fig. 19), and passes through a ratchet wheel, which is partly turned at each stroke

* L'air comprimé et les Bosseyeuses aux charbonnages de la Société de Marihaye, à Flémalle-Grande, par Mr. Mathieu Dubois. Liége, Chas. Gordinne et fils. Date not given, but thought to be 1889. I venture to suggest the name wedging drill for this machine.

† Figs. 15 to 22 and the description of the drill given in quotation marks are from Engineering, July 12, 1889, p. 44.

of a pawl operated by the rod I, which has an oscillating motion imparted to it by the pistons H H."

Manner of driving.—In order to break down the rock by wedging we must first have an open space, or at least a cut, slot, or groove,



The Francois and Dubois Bosseyeuse or "ram drill."

toward which we may wedge the rock beside it. This slot may be either vertical or horizontal, according to the cleavage of the rock, etc. Once this slot is cut and holes drilled beside it, the rock is easily broken down by inserting wedges in these holes, and striking them with the ram, which is carried by the Bosseyeuse or wedging drill itself, the ram simply taking the place of the common bit used for driving holes.

Manner of cutting the slot.—Two ways are adopted, one for hard, the other for soft rock.

In case of hard rock, Figs. 23 and 24, a row of holes about 2½ or 3 inches in diameter, and as near together as possible, is first driven much as with a common rock drill. The spandrels between them are then cut out, replacing the common bit with a flat, chisel-like tool, which of course is driven without rotation.

In the case of soft rock (Figs. 25 and 26) two holes 2½ or 3 inches in diameter are first driven, one at either end of the proposed slot, and filled with wooden plugs. The slot between them is then cut

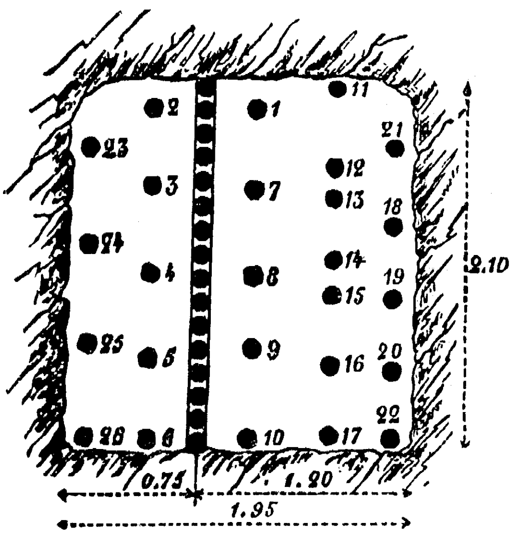


FIG. 23 (elevation).

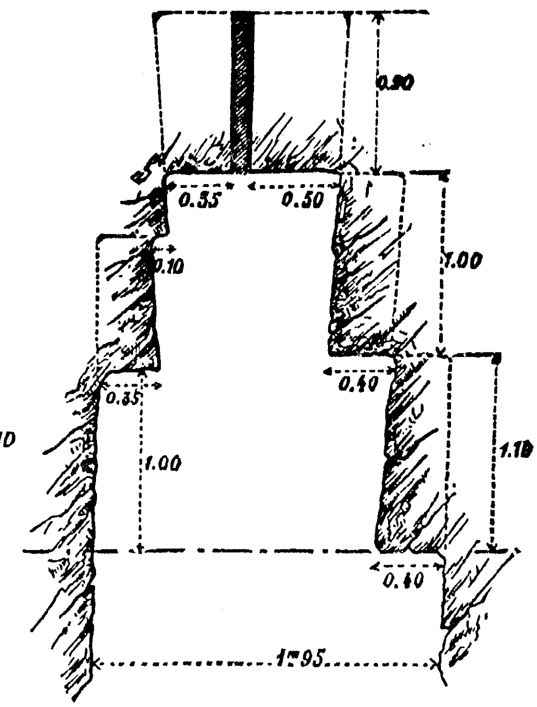


FIG. 24 (plan).

Driving in head rock with the ram drill. (Dimensions are in metres).

with a special bit, the machine working as in driving a common hole, but swinging back and forth from one end of the slot to the other continuously, by means of the worm M or the screw N (Fig. 15) already mentioned, so that it cuts a slot instead of a round hole.

It is recommended that the slot be at least 30 inches deep, the holes for wedging being from 4 to 6 inches deeper. The number and arrangement of the wedging holes must of course be governed by the hardness and cleavage of the rock, etc. These holes having been drilled, iron feathers are placed in them, and between these, steel wedges (Fig. 21). The cutting bit is now removed from the Bosseyeuse, and is replaced by a ram-head, which is driven against these wedges repeatedly, breaking down the rock by wedging it toward the slot.

Rate of progress and consumption of air.—Two test trials are reported, one for drifting in hard sandstone (grés), the other in

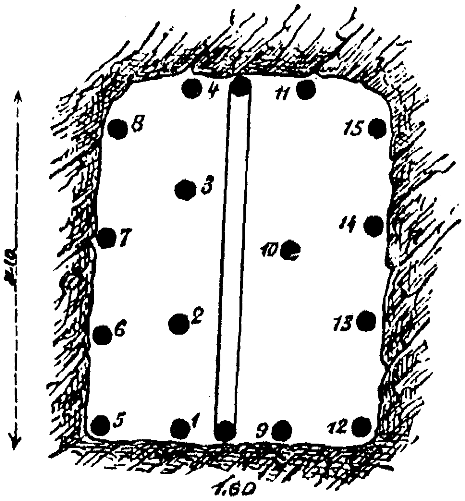


FIG. 25 (elevation).

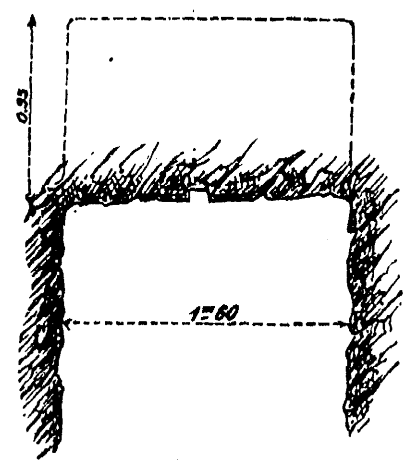


FIG. 26 (plan).

Driving in schist with the ram drill.

schist. Figs. 23 and 24 show the placing of holes, etc., for the former trial, Figs. 25 and 26 show the arrangement for the latter. The following details are recorded.

FIRST TRIAL; DRIFTING IN HARD GROUND.

Nature of rock: very hard compact sandstone.

Size of level (2.10 by 1.75 metres), 6 feet 10 inches by 5 feet 9 inches.

The slot was made by cutting fifteen holes (sixteen are shown in the illustration) 3¼ inches in diameter and 35½ inches deep (0.08 by 0.90 metres).

The intervals between the holes being (0.005 metre), $\frac{3}{16}$ of an inch.

Time occupied in drilling one hole, from 25 minutes to 1 hour.

Time lost between holes, from 0 to 7 minutes.

Time occupied in drilling fifteen holes, 9 hours 23 minutes.

Time per hole, 37 minutes, including time for placing and changing drills.

Time for drilling proper, 34.5 minutes.

Time for changing and placing drills, 2.5 minutes.

Total consumption of air, (189.77 cubic metres), 6,701 cubic feet.

Consumption of air per hole, (12.65 cubic metres), 446.8 cubic feet.

Pressure of air, (4.3 atmospheres) 63 pounds per square inch.

In cutting these holes the machine worked 8 hours 48 minutes.

Consumption of air per hour of active work (21.5 cubic metres), 759 cubic feet.

Cutting out the spandrels between the holes occupied 2 hours 15 minutes.

And consumed (37.2 cubic metres) of air, 1,314 cubic feet.

In cutting these spandrels the machine worked 1 hour 57 minutes, and 18 minutes were occupied in changing the machine from hole to hole.

Consumption of air per hour in cutting spandrels (19 cubic metres), 671 cubic feet.

Breaking down the rock after cutting the slot required twenty-six holes of about 39 inches deep.

To drill these holes occupied 16 hours.

Time per hole, 37 minutes.

Total consumption of air, (401.21 cubic metres), 14,162 cubic feet.

Consumption of air per hole (15.4 cubic metres), 543.8 cubic feet.

Wedging off the rock from these holes occupied of active work 2 hours 28 minutes.

Consumption of air, (33 cubic metres), 1,165 cubic feet.

Total time for drilling these wedging holes and breaking down the rock, excluding time occupied in cutting the slot, 25 hours 24 minutes.

There were thus 6 hours 56 minutes delay for cleaning up, etc., but cleaning up continued also while the holes were drilling.

Total length of drift, (0.87 metres), 2.85 feet.

Total consumption of air, (661.18 cubic metres), 23,344 cubic feet.

Total time occupied, all delays included, 45 hours 48 minutes.

Consumption of air per hour, (14.38 cubic metres), 507.8 cubic feet.

The machine was actually at work 30 hours 21 minutes.

Consumption of air per hour of active work, (22.04 cubic metres), 777 cubic feet.

Consumption of air per running foot, (816 cubic metres per running metre), 8,800 cubic feet.

Consumption of air per cubic foot, (223.052 cubic metres per cubic metre), 223 cubic feet.

SECOND TRIAL; DRIFTING IN SCHIST.

Dimensions of drift, (2.1 by 1.6 metres), 6.8 by 5.2 feet.

Two holes were first drilled, one at the top and one at the bottom of the face of drift as shown in Fig. 17.

Depth of holes (0.865 metre), 2.84 feet.

Time occupied in drilling holes, 6 minutes and 13 minutes, respectively.

Consumption of air in drilling holes (4.13 and 8.12 cubic metres), 146 and 286 cubic feet.

Time occupied in cutting slot from hole to hole, 2 hours 33 minutes.

Depth of slot, (1 metre), 39 inches.

Consumption of air in cutting slot, 54.46 cubic metres.

The rest of the time (active work) in drifting, after the slot was cut, was 15 hours 8 minutes.

During this time the wedging drill worked, in drilling, 4 hours 50 minutes.

In wedging down, 1 hour 7 minutes.

Air consumed in drilling, total (125.89 cubic metres), 4,446 cubic feet.

Per hour (27.97 cubic metres), 988 cubic feet.

Air consumed in wedging off, total (6.21 cubic metres), 219.3 cubic feet.

Per hour, (6 cubic metres), 211.9 cubic feet.

Distance drifted (0.95 metres), 3 feet 1.74 inches.

Consumption of air per running foot of drift (196 cubic metres per metre), 2,111 cubic feet.

Consumption of air per cubic foot of drift, 65.584 cubic feet.

RESULTS OF REGULAR WORKING.

During 6 consecutive months, in which twenty-five wedging drills were in use, the cost of operating one drill per diem was found to be as follows:

A drill with 4⅝-inch cylinder costs $1,200; one with 3½-inch cylinder costs $750, necessary tools included in each case. At 10 per cent. per annum the cost of amortization would be	$0.40 to $0.25
Cost of repairs to the wedging drill per diem (0.57 franc)	0.11
Cost of repairs to tools (0.31 franc)	0.06
Miscellaneous iron and steel used (0.30 franc)........	0.06
Drill-steel used (0.33 franc)	0.07
Oil, 0.13 gallon (0.35 franc)	0.07
	0.77 to 0.62

The cost of labor for driving the wedging drills was from $1.27 to $1.88 per diem per machine, and the average rate of driving in each of six drifts was from 18 to 25 inches per shift in schist, it being estimated that the rate of advance in sandstone is half that in schist.

After working for 10 years at Marihaye without burning a grain of powder, the engineers seem more than satisfied with the substitution of mechanical appliances for explosives, and they claim that, while offering greater security to their workmen and to the property, the cost of mining a ton of coal compares favorably with that at other mines under otherwise like conditions.

(6) *The Dubois & Francois air-compressor.*—This powerful compressor is built by the Cockerill Company of Seraing, where the classical air compressors for piercing Mont Cenis were built.

The compressor shown at Paris is horizontal, compound, condensing, with two horizontal air cylinders, each tandem with one of the steam cylinders. Beyond the steam cylinders is the crank shaft, the cranks standing at right angles, with a single fly wheel between them. The high-pressure cylinder has a Meyer cut-off, variable but not automatic. The governor simply controls the throttle valve, to prevent dangerous speed, since moderate changes of speed are of little importance.

The suction valves are flat steel disks faced with leather or rubber, and closed by spiral springs. The discharge valves are bronze puppets, seating directly on cast-iron, and held down not by springs but by a little piston, itself driven by the compressed air.

The distinctive feature of the Dubois & Francois compressor is the introduction of cooling water into the air cylinders in two distinct ways and for two distinct purposes. Above each air cylinder lies an open trough, into which a pipe about 1¼ inches in diameter discharges water. When I saw the compressor at work this pipe was discharging its so-called full capacity into this trough; this gives an idea of the quantity of water used by the compressor, as all that runs into the trough passes into the air cylinders. But I was informed that this was about double the normal quantity of water. The suction valves stand above the cylinders, with their stems horizontal and parallel with the axes of the cylinders; *i. e.*, the disks themselves are vertical. The lower edge of each valve is submerged in the water in this trough, so that, while the valve is open, the water simply gushes into the cylinder through it. The water thus introduced, while it, of course, exerts a certain cooling effect, is chiefly to fill the clearance, and to thus insure that all the air drawn in by the piston at each stroke shall be expelled during the return stroke.

In the second place a little of the water which has been thus drawn into the cylinder and again expelled, while still under pressure, is converted into spray by a special apparatus, and blown into the cylinder ends. Enormous surface of contact with the air of course makes it an excellent cooling medium.

Under these conditions it is stated that the volume of air drawn in is never less than 90 per cent., and may even reach 94 per cent. of the volume passed through by the piston; *i. e.*, the product of the area of the piston into its stroke.

The principal dimensions of the compressor are as follows :

	Feet.	Inches.
Diameter of high-pressure cylinder, 0.700 metre	2	3½
Diameter of low-pressure cylinder, 1.150 metres	3	9
Diameter of air cylinder, 0.60 metre	1	11½
Stroke of all cylinders, 1.200 metres	3	11¼
Revolutions, nominal		45
Revolutions, safe		50
Steam pressure, 8 atmospheres ....pounds per sq. inch.		118
Air pressure, 6 atmospheres..........................do....		88
Capacity of compressor at 40 revolutions, air at 88 pounds....cubic feet..		123,600

The compressor can, however, while running at 50 revolutions, compress air up to 114 pounds pressure per square inch. The fuel consumption for the five compressors of this type which the Cockerill Company is building for the Compagnie Parisienne (Paris Compressed Air Company) is guaranteed not to exceed 8 pounds of coal per pound of air delivered at a pressure of 88 pounds per square inch. The Compagnie Parisienne demands that the temperature of the air delivered at this pressure shall not be more than 27° F. (15° C.) above that of the surrounding air.

(7) *Cost of compressing air.*—In test trials at the Marihaye coal mines, lasting twelve days, the following numbers were arrived at as the cost of compressing 1 cubic metre of air (35.3 cubic feet, 1.3 cubic yards):

	Rate.	Amount.
Amortization of the compressing plant	5 per cent. per annum.	$0.00041
boiler plant	4 per cent. per annum.	0.00017
piping, etc	8 per cent. per annum.	0.00014
Coal	$2 per ton (2,240 lbs)..	0.00367
Oil, etc.		0.00008
Labor		0.00070
Total		0.00517

Each pound of coal evaporated 7.3 pounds of water. 7.7 pounds of coal were consumed per hour per 1 horse-power of the air cylinders. The labor of engineers and firemen is charged at the rate of from 60 to 65 cents per shift.

The report admits that the consumption of coal per 1 horse-power per hour may appear excessive, but points out that the trials were under far less favorable conditions than usual, for in most test trials the time is short and the compressor runs regularly. Here, however, the trials lasted 12 days, and the speed of the compressor varied greatly. Indeed, it often happened that the compressor stopped altogether, while the condensation in the pipes continued, the boilers being fired all the time to keep the steam pressure up. They claim that, under favorable conditions, the cost for fuel on a test trial could be reduced to but little more than half that found in this trial.

The compressors were of the Dubois & Francois type, with stroke and diameter of about 4 feet and 18 inches.

(8) *Ventilation by the Körting jet blower.*—In experiments at the Marihaye coal mines, in which Körting blowers were worked with compressed air, it was found that each blower furnished 106 cubic feet (3 cubic metres) of air per minute, and in doing this consumed (0.154 cubic metre) 5.4 cubic feet of air at a pressure of 68 pounds per square inch (4.3 atmospheres). Or, in other words, for every cubic foot of air at 63 pounds pressure delivered to the Körting blower 20 cubic feet are delivered by it for ventilating purposes.

(9) *Heating air for compressed-air motors.*—In describing the air compressor for the Compagnie Parisienne, the Cockerill Company states that the efficiency of compressed-air motors may be increased enormously by preheating the compressed air, and by injecting water with it. Thus, where dry air at 88 pounds pressure (6 atmospheres) and at 68° F. (20° C.) works with an efficiency of 46.7 per cent., if the air be preheated to 392° F. (200° C.) the efficiency rises to 64.8 per cent. ; and if water be injected simultaneously, the efficiency rises to 87 per cent., and that practically one may count on 80 per cent. efficiency. The expense of preheating the air and of injection they report as not more than 0.2 cent per horse-power per hour.

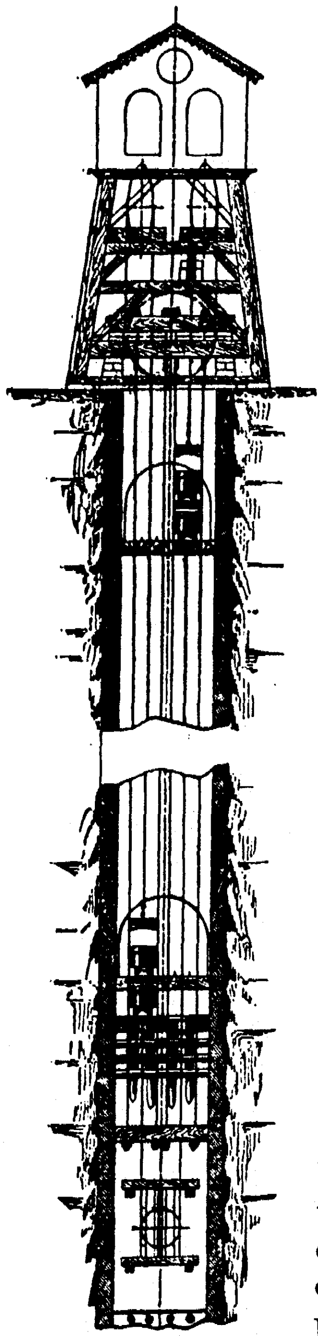


FIG. 27.—Arrangement for lowering filling at Lyons shaft.

C.—HOISTING MACHINERY.

(10) *Tail-rope counterweight at the Lyons shaft of the Montrambert et de la Béraudière Coal Mining Company.*—This counterweight regulates the speed of descent of the cages which carry filling to the

lower levels of the coal mine. As shown in Fig. 27, two cages, each carrying two filling cars, run in this shaft, and are suspended from either end of a common cable. We have in short a gravity balance, the weight of the descending full cars drawing up the empty ones. The problem presented was to devise a counterweight which would increase the average rate of descent, while decreasing the final velocity gently but surely.

This is very simply effected by hanging a cable or tail rope beneath the cages, each of its ends hanging down from one of them, so that when the two cages are midway down the shaft and therefore side by side, this cable forms a long narrow upright U, reaching to the bottom of the shaft. This tail rope is made 2.02 pounds heavier per running yard (1 kilogram per running metre) than the suspending cable, so that in a shaft 984 feet (300 metres) deep there is a difference of weight of 661 pounds (300 kilograms). At the beginning of the descent the whole of this excess, E, of the weight of the tail over that of the suspending cable reënforces that of the full over that of the empty cars, *e*, and accelerates the descent. But as the full cars descend, less and less of E pulls down on the descending cage and more and more of it pulls down on the rising cage; at mid-travel this excess E pulls equally on both cages; toward the end of the descent E pulls chiefly on the rising cage, and thus acts as a brake.*

This tail rope, then, is a differential counterweight. Over a simple counterweight (such as we would have, for instance, if the weight of the tail rope were equal to that of the suspending cable instead of being greater) it has a double advantage. With it the average velocity of descent and ascent is greater, so that more filling can be lowered per hour, while the final velocity is less; so that, in case the brakeman neglected to apply the brake promptly and firmly, the shock would be less than with a simple counterweight.

Clearly, if the excess E be fixed, the smaller the weight W of the filling in the descending cage the more slowly will the cages travel, till, when W becomes less than E, the weight of the tail rope pulling down on the rising cage would arrest it before it reached the surface. A series of experiments made with different weights of filling gave the results shown in Table 6, and represented graphically in Fig. 28, in which ordinates represent the distances passed through and abscissæ time.

* By addressing the Société Anonyme des Houillères de Montrambert et de la Béraudière, 4 Quai de l'Hôpital, Lyons, France, the reader can probably obtain a copy of their pamphlet distributed at the Paris Exhibition of 1889, and containing a fuller account and a mathematical discussion of this counterweight.

TABLE 6.—*Experiments with the tail-rope governor.*

No.	Weight of filling.	Maximum speed, per second.	Distance traveled at point of maximum speed.	Speed of arrival at surface, or at moment of applying brake, per second.	Distance traveled at moment of applying brake.	Time occupied by trip, including arrest by brake at surface.	Length of arrest by brake.	Distance traveled by cages.
	Kilograms.	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Seconds.*	*Seconds.*	*Metres.*
1	1,262	10.596	104.26	7.90	244	40.81	11.11	281
2	828	8.153	77.00	5.59	273	43.67	3.35	281
3	420	5.870	94.90	0.90	281	66.12	....	281
4	413	5.570	99.45	(*)	(*)	76.27	....	281

* The cages stopped automatically at 11 metres from the end of their normal trip.

Actual working.—As shown in Fig. 27, the weight of the two full cars has carried them to the bottom of the shaft, bringing the upper of the two down to the landing, and the lower of the two empty cars to the landing at the surface. At the bottom of the shaft a full car is replaced by an empty one; at the surface an empty car is replaced by a full one. Each cage now has one full and one empty car, and they thus balance each other. On withdrawing a bolt, the excess E of the weight of the tail rope hanging down from the upper cage over that of the suspending rope, added to that of the safety guard which the upper cage has lifted from the mouth of the shaft on arriving at the surface, suffice to overcome friction and to draw the upper cage down and the lower one up. They are arrested as soon as the upper car of the upper cage and the lower car of the lower cage have come opposite their respective landings, and again a full car is substituted for an empty one at the surface, an empty one for a full one at the bottom of the shaft. The bolt now being withdrawn, the weight of the filling plus E sets the cages in motion; the upper descends rapidly, pulling up the lower.

In practice, the load of filling in each car varies from 1,100 to 1,300 pounds (500 to 600 kilograms). The brake is applied lightly when the cages are within some 115 feet of the end of their travel. Under these conditions the average length of the trip is 41 seconds; that of discharging and recharging, 24 seconds, or, altogether, 65 seconds. 900 to 1,000 cars have often been lowered in 10 hours. 223,654 cars were lowered in 287 days in the year 1887, or, on an average, 779 cars per shaft.

(11) *Rossigneux's pump-rod balance.**—This is a very simple differential balance for Cornish mine pumps, which aims to increase the average while lessening the final velocity of both the up and down

*Described in l'Industrie Minerale, vol. VII, 2d series. The Bochkoltz, of which it may be regarded as a modification, is described in the same journal, vol. XIV, 1st series, and vol. I, 2d series. See also a pamphlet distributed at the Paris Exhibition of 1889, and probably to be had by addressing the Société Anonyme des Houilleres de Montrambert et de la Bérandiére, 4 Quai de l'Hôpital, Lyons, France.

stroke. The essential feature which distinguishes it from the common balance is that, instead of hanging from trunnions, it rests on a

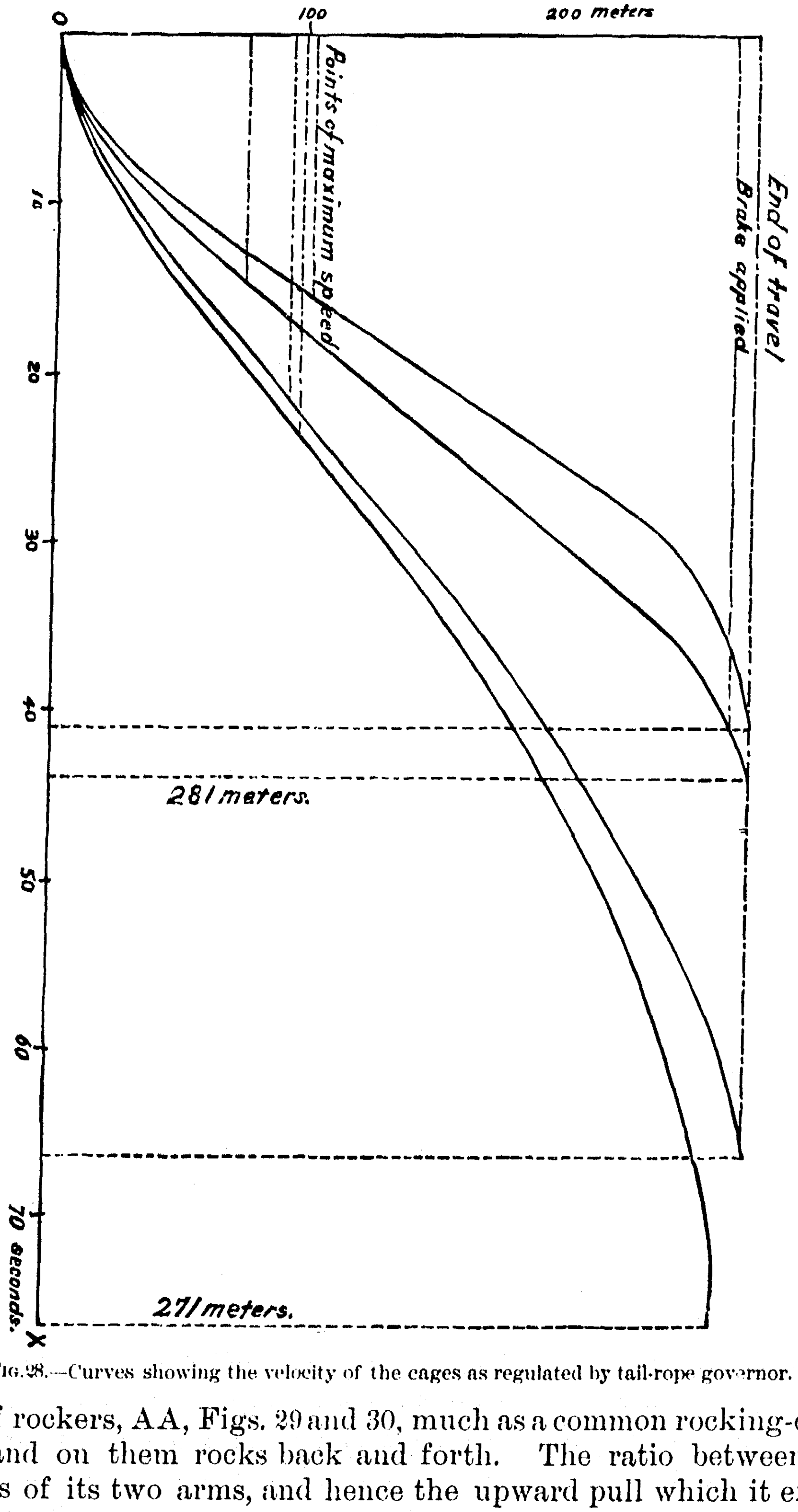
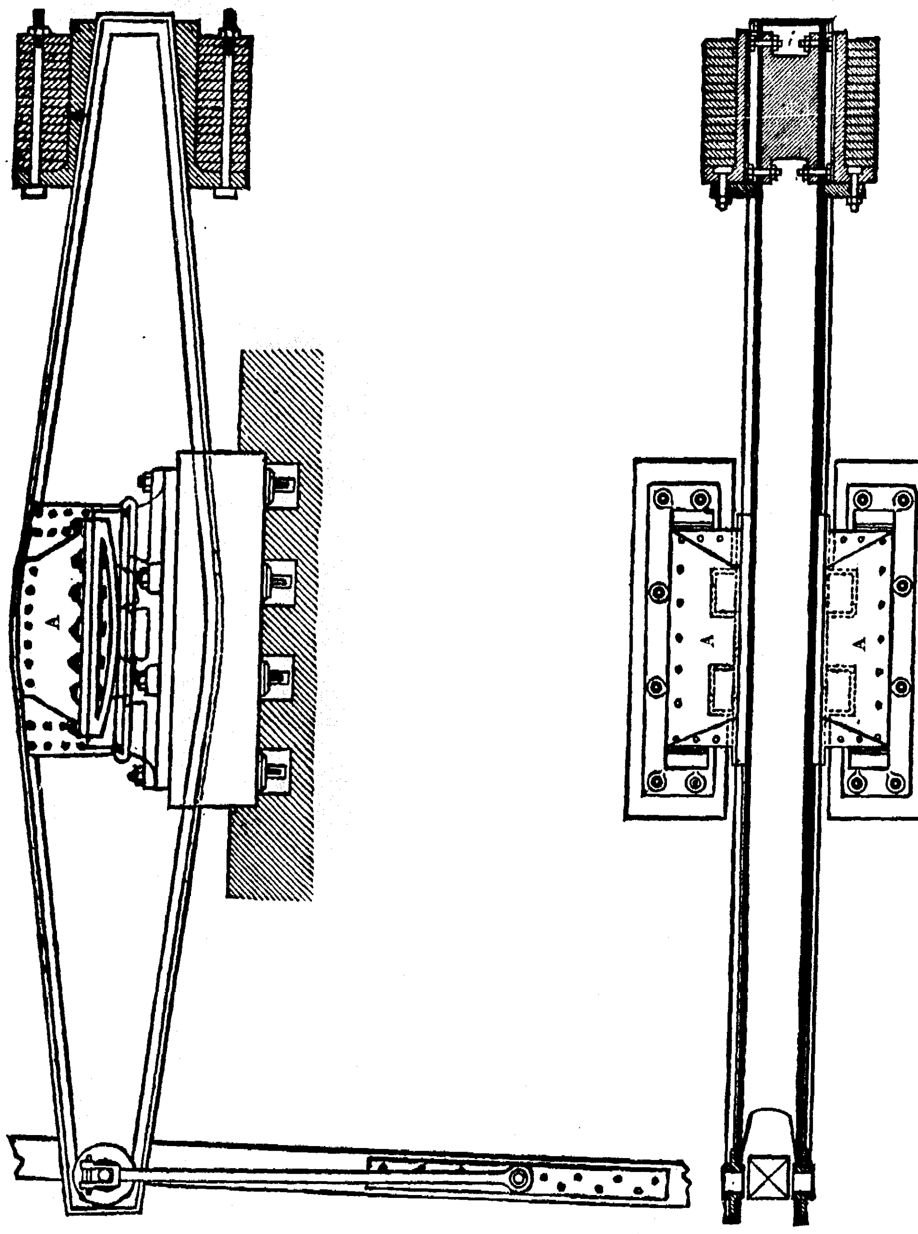


FIG. 28.—Curves showing the velocity of the cages as regulated by tail-rope governor.

pair of rockers, AA, Figs. 29 and 30, much as a common rocking-chair does, and on them rocks back and forth. The ratio between the lengths of its two arms, and hence the upward pull which it exerts on the pump rod, are constantly changing.

Thus at the beginning of the up-stroke it rests on the left-hand end of the rockers A A, the counterweight at its right hand end has the maximum moment, pulls up most strongly on the rod, and accelerates their rising motion greatly. As the stroke advances, the point of suspension of the balance moves to the right, the moment of the counterweight and the upward pull on the rods decline, reaching a



FIGS. 29 AND 30.—Differential balance for pump rods.

minimum at the end of the stroke, when the balance rests on the right-hand end of the rockers A A.

During the down-stroke the reverse occurs. The moment and hence the upward pull of the counterweight are at a minimum at the beginning of the stroke, so that the minimum resistance to the descent of the rods is now offered. As the stroke advances this resistance constantly increases. At the beginning of the stroke the resistance offered by the counterweight, plus the water, plus the friction, is less; at the end of the stroke it is greater than the weight of the pump rods.

In Fig. 31 ordinates represent weights, abscissæ the travel of the pump rods during the downstroke. The line A B C represents the resistance of the balance to the descent of the pump rod, M O represents their free weight (*i. e.*, the excess of their weight over that of the water plus friction), O D represents their travel.

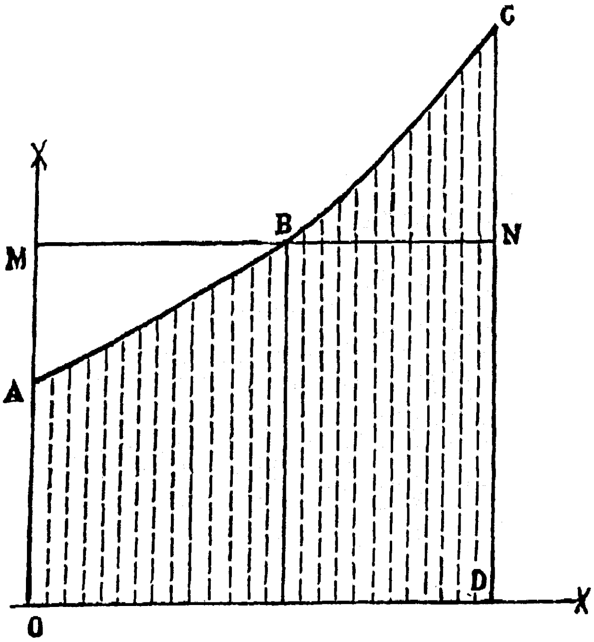


FIG. 31.—Diagram. Work of the balance on the down-stroke.

A B C D O is the work of resistance of the balance. O M N D is the work of the free weight of the pump rods. B is the point of equilibrium.

The surface A M B is the excess of the work of the free weight of the rods over the resisting work of the balance during the first part of the down-stroke.

The surface B C N = A M B is the excess of the resisting work of the balance over that of the rods during the latter part of the down-stroke.

B, the point of equilibrium—when the resistance of the balance, plus water, plus friction, equals the weight of the pump rods—is reached after the middle of the stroke; *i e.*, the velocity of the rods is accelerated during more than half the stroke.

The circumstances which led to the adoption of this balance at the Ondaine shaft of the Montrambert Company were as follows: It was necessary to lower the pump 328 feet (100 metres). The pumping engine was of the single-acting Cornish type, with a balance; it was in good condition, and to replace it with a double-acting engine with a fly wheel and much expansion, at a cost of $100,000, was deemed inexpedient. The leading dimensions were:

Steam cylinder, diameter, 72.4 inches (1.84 metres).
Steam cylinder, stroke, maximum, 9 feet 10 inches (3 metres).
Steam cylinder, stroke, usual, 9 feet 6 inches (2.9 metres).
Plungers, diameter, 15.6 inches (0.395 metres).
Plungers, stroke, 8 feet 6 inches (2.6 metres).
Discharge pipes, diameter, 15.7 inches (0.4 metres).

The new Rossigneux's balance, Figs. 29, 30, is made of iron 0.59 inch (0.015 metre) thick, and is suspended by two cast-iron supports weighing about 13 tons together. These receive the rockers or shoes, which are steel castings weighing about 11 tons. The whole rests on forged steel plates, supported by cast iron, resting in turn on masonry.

Though the normal motion of the balance would only cause it to rock without sliding, the shocks which often arise at the ends of the stroke might displace it. Its rockers are therefore provided with two large teeth, which gear into corresponding depressions in the

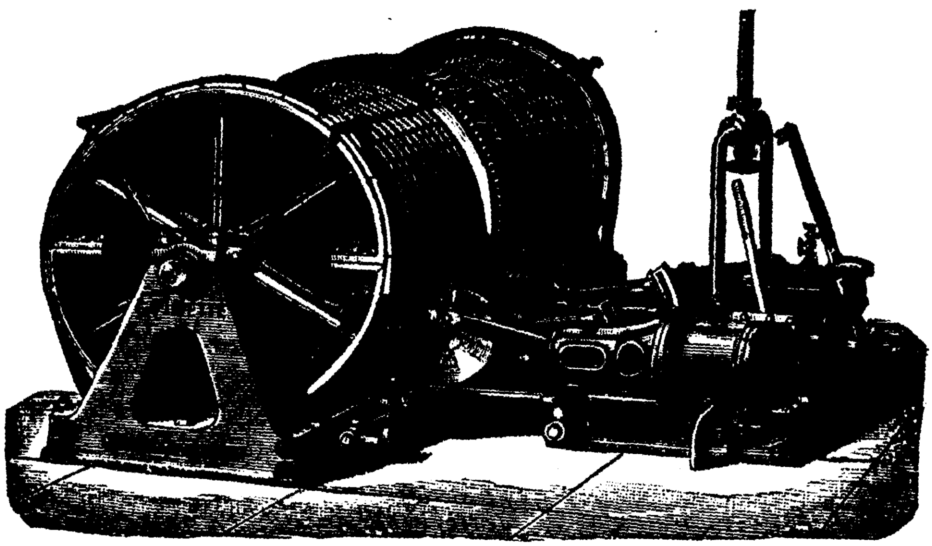


FIG. 32.—G. Pinette's hoisting engine.

plates on which they rock, so that if the balance be shifted slightly by these shocks as it rocks, these teeth bring it back to its normal position.

The chief dimensions, etc., of the new balance are as follows:

Total length, 44.62 feet (13.6 metres).
Lever arm of balance bearing on pump rods when balance is horizontal, 19.84 feet (6.048 metres).
Distance from center of counterweight axis of balance, 21.06 feet (6.42 metres).
Distance from center of gravity of balance to axis, 12.22 feet (3.724 metres).
Travel of balance on its supports, 7.05 feet (2.15 metres).
Radius of circle of rockers, 15.84 feet (4.83 metres).
Total weight of balance and counterweight, 144,182 pounds (65,400 kilograms).

Maximum velocity on up-stroke, 5.18 feet (1.58 metres).
Maximum velocity on down-stroke, 3.61 feet (1.10 metres).

	Seconds.
Length of up-stroke	2.39
Stoppage after up-stroke	1.54
Length of down-stroke	3.77
Stoppage after down-stroke	3.10
	10.80

In practice the engine and pump make 5.5 strokes per minute.

(12) *Brake attachment for hoisting engines.*—In the hoisting engine shown in Fig. 32 the brake band is held away from the drum by a simple and convenient device, a pair of nearly radial telescopic arms containing spiral springs, which allows the arms to telescope when the brake band is drawn to the drum.

The engine here shown is intended for depths of 1,000 feet and under. It can be used under ground, but is designed rather for the surface.

The table which follows may be useful in giving an idea of current French practice.

Nominal horse-power.	Vertical load.	Velocity of rope.	Diameter of drum.	Length of each drum.	Approximate weight.
	Pounds.	*Feet.*	*Inches.*	*Inches.*	*Pounds.*
45	4,400	328	63	24	19,800
60	6,000	328	67	31	24,000
80	7,700	328	71	39	28,600
100	8,800	328	79	47	33,000

(13) *Champigny's patent V-grooved pulley,* for wire ropes* (Fig. 33).—The V-groove offers a manifest advantage over the U-groove: the cable wedges itself into the groove, and so tends less to slide; or, to put it otherwise, given adhesion can be obtained with a shorter arc of contact between rope and pulley.

But as a common V-groove wears, it soon becomes a U-groove, the round rope wearing the groove to its own section. Champigny ingeniously overcomes this tendency by making his pulley of two disks, held slightly apart by distance pieces, against which they are of course firmly bolted. Clearly, as the pulley wears the groove will ever remain nearly V-shaped; at least it never can become even approximately U-shaped.

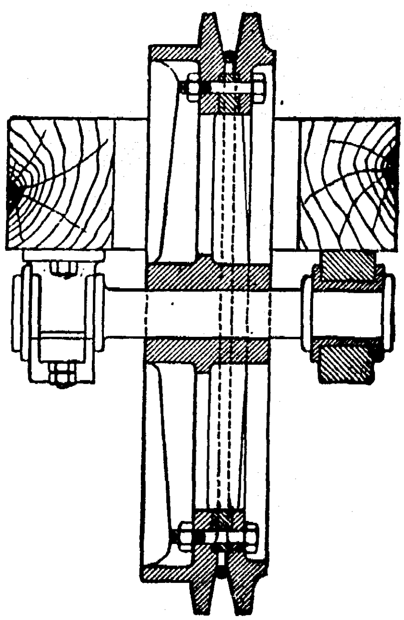


FIG. 33.—Section of Champigny's grooved pulley.

* Compt. Rend. Soc. Indust. Minérale, May, 1887, p. 82.

When the pulley has worn so far that its effective diameter is inconveniently reduced, he restores it to its original pitch by substituting thinner distance pieces for those used at first. This of course can be done repeatedly.

D.—Mining tools and appliances.

(14) *Safety lamps.**—A good safety lamp must fulfill several conditions, some of which are all but mutually exclusive:

1. It must give a good light.

2. It must not go out when inclined or swung, either in still air or in a current, mild, strong, or even violent.

3. Both when in a current and when, owing to the presence of an explosive mixture of fire-damp and air within the lamp itself, an internal explosion occurs, it must hold the flame in and not allow it to pass out so as to ignite a surrounding explosive atmosphere.

4. When surrounded by a combustible mixture of fire-damp and air which may burn within the lamp, the lamp must not grow so hot as to redden the exposed ironwork, or to crack the glass, or to set the oil boiling, lest the surrounding gas, in case its proportions become explosive, be ignited.

5. It must be either beyond the power or against the *immediate* interest of the miner to open it, or at least to open it under conditions which can cause an explosion.

Without attempting a discussion of this complex problem, I will simply point out how some of the lamps brought forward in connection with the Exhibition fulfill, or are designed to fulfill, certain of these conditions, premising that the draft of the lamp is one of the most delicate and important points. It must be so strong as to supply the wick with oxygen enough to give a clear flame, even when the lamp is inclined or swung, or in a current of air, even if this be moderately impure. But if a considerable excess of air over that needed for this end be admitted, either when the lamp is in repose, in a draft, or inclined, then, in case the surrounding atmosphere be itself combustible, it burns within the lamp; the heat thus generated, added to that given out by the wick, heats the lamp so hot that its walls redden, its glass cracks, or its oil boils. The lamp needs, then, enough draft to burn the oil under all conditions (as to position, motion through or of surrounding atmosphere, etc.) when the surrounding atmosphere is not highly combustible; but should not

*For the information and, indeed, reasoning on which these remarks are based, I am indebted to a considerable extent to the papers presented by Messrs. Marsaut, Le Chatelier, and Fumat in connection with the Exhibition, or with the International Congress on Mining and Metallurgy: "Les Lampes de Sûreté," J. B. Marsaut, Besseges, France; "Lampes de Sûreté," H. Le Chatelier, extrait du Bulletin de la Soc. de l'Industrie Minérale, 2d ser., III, 1889; "Lampe Fumat," 1889, Alais.

under any condition (as to position, etc.) have enough draft to burn the oil plus any large quantity of combustible mixture should the atmosphere become strongly combustible.

Hence the draft of the lamp—the rate at which the air passes through it—should be nearly constant. Special precautions, then, must be taken to prevent strong currents of air from altering it. Such currents are of course likely to be met, for instance, when the miner walks through a drift against an exceptionally strong ventilation current, swinging his lamp back and forth unconsciously as he walks; here, when the lamp is swinging forward, the effective velocity of the current is equal to its velocity through the drift, plus the velocity of the miner's walk, plus the velocity with which he swings the lamp forward. Again, the centrifugal force due to his swinging the lamp tends to change its draft.

The lamps which we will now consider may be divided into those in which the current of air rises, and those in which it descends toward the wick. The former class includes the Davy, the Gray, the Fumat, Figs. 34, 35, 36, and 37; the latter includes the Marsaut and the Mueseler, Figs. 38 and 39. The advantage of the descending current is that the air becomes more or less mixed with the products of combustion before reaching the wick, and a very small quantity of these inert gases, nitrogen, carbonic acid, and vapor of water suffices to render an explosive mixture wholly inexplosive.

Moreover, these products of combustion dilute the entering air; hence, if the surrounding atmosphere of the mine consist for the moment of a combustible mixture of air and fire-damp, the proportion of oxygen in the atmosphere immediately around the wick readily falls so low that not enough combustion can occur to keep this atmosphere, plus the gases distilled from the oil, up to the point of ignition, and the lamp goes out.

The descending current, then, has a double advantage, of rendering an explosive mixture locally inexplosive, and of putting the lamp out when the surrounding atmosphere is highly combustible. With descending-current lamps a far smaller degree of constancy of draft is needed than in case of ascending-current lamps, since the latter lack this double advantage, and must rely on the constancy of their draft to keep them alight in currents of air and to put them out in explosive mixtures.

But these advantages are necessarily coupled with the disadvantage that the flame is much less bright than when, as in case of the ascending air current, the air arrives at the wick unmixed with the products of combustion. Hence repeated efforts to obtain a safe lamp with ascending current.

A great defect of the old Davy lamp was that but little of the light could pass the wire meshing. Were this remedied by placing a glass chimney opposite the flame, and inclosing only the parts above and below in wire meshing, a lamp with ascending air current resulted, which, however, went out on the least provocation. The centrifugal force due to swinging the lamp in walking sufficed to overcome the draft of the lamp, the products of combustion were forced back on the flame, and the lamp went out.

In Gray's lamp, Fig. 35, the centrifugal force is balanced by making the air current first descend through vertical tubes, so that its downward travel is nearly as long as the upward travel of the prod-

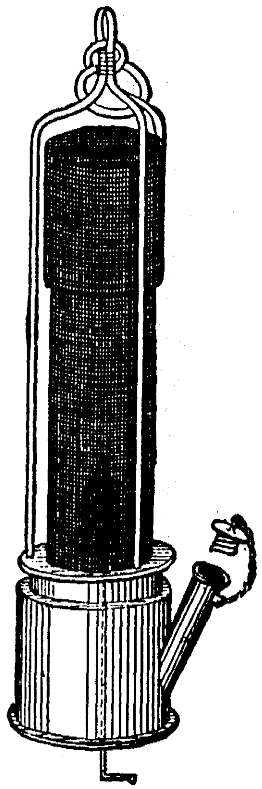


FIG. 34.—Davy's safety lamp.

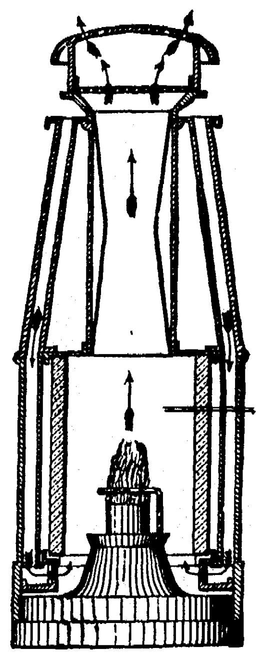


FIG. 35.—Gray's safety lamp.

ucts of combustion. The position of the entrances for air, too, should greatly lessen the influence of currents of air on the draft of the lamp. Still the draft is not constant enough. For, on the one hand, the lamp does not readily go out when placed in an explosive mixture, but enough air enters to burn both this and the oil, and the lamp grows dangerously hot. And if, on the other hand, we throttle the passages so much that this can not occur, then moderate agitation checks the draft so much that the lamp goes out even when surrounded by pure air.

Fumat's new lamp, Figs. 36 and 37, seems to have overcome these difficulties, for on the one hand currents of air, swinging, etc., seem to produce little effect on it, and on the other Le Chatelier states that it goes out immediately when placed in an explosive mixture, adding that it is the only lamp within his knowledge with ascending current which does.*

In the lower part of the lamp we have an annular passage, A A, which distributes the air so that it passes to the interior from all sides.

The middle section of the lamp has, on one side only, a metallic down-take, B, through which the air descends to the distributing passage A. The right-hand face of the right-hand wall of this down-take, *i. e.*, the face next the flame, is highly polished, and thus serves as a cylindrical concave reflector.

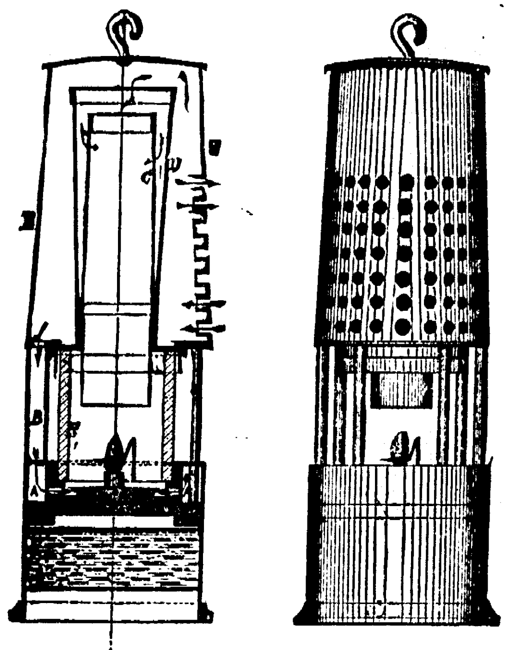


FIG. 36.—Section through reflector down-take. FIG. 37.—Elevation of side opposite reflector down-take
Fumat's lamp.

The upper section has in the first place a wire-gauze chimney, C, protected against currents by the sheet-iron chimney D, outside of which is the jacket E, which has 77 holes 0.2 inch in diameter (5 millimetres), each carrying a little ferrule or tube 0.2 inch long. These holes lie in the face of the jacket opposite to the down-take B. The air enters through the lower of these holes, passes down through the down-take B and through the distribution passage to the flame: the products of combustion pass up through and across the wire-gauze chimney C and escape through the upper holes in the jacket E, as indicated by the arrows.

We have here two columns of gas, separated by the sheet-iron chimney D and the glass chimney F. All but the lower part of the inner column is hot, all but the upper part of the outer column is cold. The centrifugal force developed in swinging the lamp affects

* Remarks at the International Congress on Mining and Metallurgy, based on his experiments of September 5, 1889.

these two columns so nearly alike that the draft of the lamp is not seriously changed. Again, currents of air pressing in through the holes in the jacket E strike into the cold outer column, which transmits the pressure to both ends of the hot column alike, and the draft of the lamp is not affected.

Placed in an atmosphere containing fire-damp this burns to a certain extent within the lamp, the cold column becomes heated, expands, loses its density and so diminishes the draft; at the same time less of it by weight can pass the wire-gauze of the distributing passage A A, less oxygen reaches the flame, which after a certain limit ceases to grow. Placed in an explosive mixture, not enough oxygen can reach the flame to keep it up to the point of ignition, and the lamp goes out.

Comparing this lamp with Gray's, we note, first, that the two columns are probably decidedly better balanced against the centrifugal force; I, because the cold column is heated to a considerable extent through the chimney D; and, II, because the upper part of the cold column is itself, if not hot, at least very warm, while in Gray's lamp the difference in temperature and hence in density between the two columns must be decidedly greater. Second, the additional heating of the cold column automatically checks combustion when Fumat's lamp is in a combustible atmosphere. To these I think should be added a third point, that the air, after entering the lower holes in the jacket E, becomes somewhat diluted with the overlying products of combustion which are passing out of the upper holes, since the entering and escaping bodies of gas are here in direct contact with each other and must inevitably become more or less mixed. To what extent this dilution occurs, with its advantage of giving safety and disadvantage of dimming the flame, direct trial alone can show, but it should be to a much smaller extent than the common descending current lamps. Finally, it would seem as if currents of air should affect the draft of Fumat's somewhat less than that of Gray's lamp; but on this one hardly likes to speak confidently.

Let us now return to the lamps with descending air current. The oldest of these, according to ʾhatelier, is the Clanny, a Davy lamp in which the lower part of the gauze cylinder is replaced by glass. The air enters through the lower part of the gauze and immediately above the glass, descends along the walls of the glass and passes to the flame much as in the Marsaut lamp, Fig. 38, the products of combustion passing up through the axis of the lamp. In addition to its much greater illuminating power, this lamp had the advantage that it went out when placed in a still explosive atmosphere. Unfortunately, if the atmosphere were in motion, the quantity of it which entered the lamp became so great as to supply enough oxygen to keep the flame alight; the fire damp as well as the oil burnt, the gauze became red hot, and hence allowed the flame to pass.

It was found that a metallic shield around the gauze tended to prevent currents of air from increasing the quantity of air which entered the lamp, even if they passed at the rate of 36 feet (11 metres) per second.

Marsaut's lamp, Fig. 38, is based on this principle. It is a Clanny lamp with the wire-gauze chimney G doubled or tripled, and protected by a sheet-iron jacket, H. The air enters horizontally and vertically through holes in H, and is baffled so as to diminish the effect of passing currents by the inner metallic ring opposite these holes. The products of combustion escape through holes in the upper part of the jacket after passing the gauze chimney G. The lamp goes out when in a still explosive mixture, as the exit passages are so slight that much of the products of combustion is baffled back, mixes with the entering explosive mixture and makes it incombustible. But this result is attained only by careful adjustment of the dimensions of the lamp, the permeability of the gauze, the size of the orifices, etc.

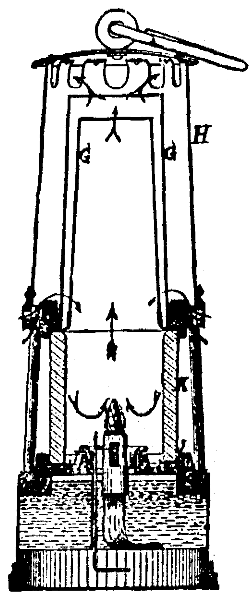


FIG. 38.—French form of Marsaut's lamp.

J is a bushing which may be screwed up or down to suit variations in the length of the glass chimney K, so that this joint is readily secured. The use of gaskets may be more convenient, but it is less safe than this arrangement. This joint is clearly made good wholly independently of the joint between lamp and oil cup.

In spite of the apparent safety of this lamp, it is reported that the sheet-iron covers of certain Marsaut lamps were found reddened with iron oxide as if they had been red-hot, after the fatal explosion in the St. Etienne coal mines, where they were in use. It is thought that the flames lengthened so much as to heat these covers red-hot, and that the explosion was thus precipitated. The explanation that the covers were heated to redness by the explosion does not seem reasonable. Quite an appreciable time would be required to heat these thick covers so hot that their surface would turn red. Could the flame of the explosion last so long? And if it lasted so long and were so hot as to heat these covers red-hot, would it not leave clear evidences of this condition of things on the other parts of the lamp, which, if the covers were heated to redness directly by the flame of the lamp itself, would still be relatively cool? Many competent judges in France, however, hold this lamp wholly blameless, and prefer it to all others.

Mueseler's lamp, Fig. 39, is, according to Le Chatelier, more extensively used than any other with descending current. Mueseler intentionally baffles back the products of combustion, so that they may dilute the entering air, by making them pass through a long narrow chimney, M, whose section is too small to allow them to pass readily, and which at the same time prevents the flame, in case of its lengthening when the surrounding atmosphere is combustible, from coming in contact with the gauze chimney N. This chimney is the essential feature of the lamp.

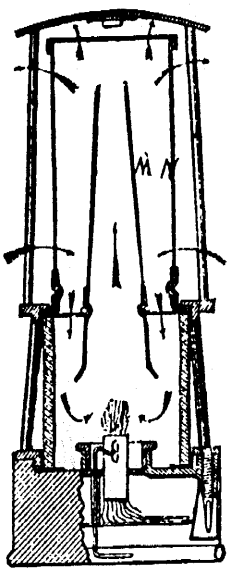


FIG. 39.—Mueseler's lamp.

This lamp always goes out when placed in an explosive atmosphere, either still or moving horizontally, and it is not put out by currents of air.

Since its invention in 1840 many modifications of it have been proposed, some of which wholly destroy its safety Much confusion arises from calling all these modified lamps Muesceler, and Le Chatelier would reserve this name for those of the dimensions of the Belgian royal decree of 1876, which follow:

Dimensions of Mueseler's safety lamp.

	The inventors.		Laws of 1851 and 1876.	
	Inches.	Millimetres.	Inches.	Millimetres.
Wire-guage—				
Meshes to the square inch	1264		929	
Diameter of wire	0.013	0.33	0.013	0.33
Glass chimney—				
Height	2.76	70	2.44	62
Outer diameter	2.01	51	2.36 to 2.40	60 to 61
Inner diameter	1.73	44	2.13 to 2.20	54 to 56
Sheet-iron chimney—				
Diameter of top	0.39 to 0.47	10 to 12	0.39	10
Diameter of base	0.98	25	0.98	25
Diam ter of bell	1.18 to 1.38	30 to 35	1.18	30
Height above diaphragm	3.74	95	3.50 to 3.58	89 to 91
Height below diaphragm	0.98	25	1.02 to 1.10	26 to 28

(15) *Fastenings for safety lamps.*—It has been found that miners so readily pick any common lock for fastening their safety lamps—the carelessness of a single miner who seeks to trim his lamp, thus exposing the lives of thousands to great danger—that fastenings other than keys and wholly beyond the control both of miners and foreman seem very desirable. I will describe three shown at Paris: Cuvelier's Hydraulic Method, Raffard's Magnetic Fastening, and the lead-rivet fastening.

Cuvelier's hydraulic fastening.--The lamp is opened by unscrewing the joint U U, so that the lower part containing the oil vessel, wick, etc., is separted from the ring V, to which the chimney, etc., forming the upper part of the lamp are attached. In the conditions shown in Fig. 40 the bolt *a* prevents our unscrewing this joint; the lamp is locked.

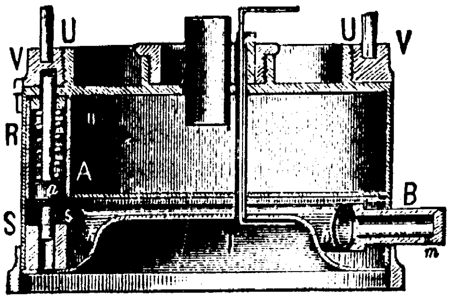


FIG. 40.

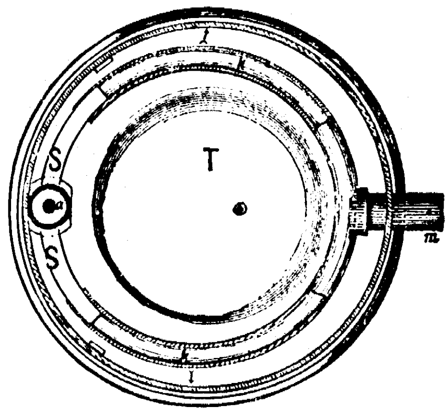


FIG. 41.

Cuvelier's hydraulic fastening for safety lamps.

The bolt *a* is held up firmly by the claws *ss* of the stout spring *k*, and can be lowered so as to permit us to unscrew this joint U only by withdrawing *ss* from beneath the shoulder of *a*.

Now just here is the gist of the matter. This spring is a flexible tube like that of a pressure gauge, bent around nearly to a circle. It is so stout that it can not be opened by pushing a wire into it; indeed, there is no entrance through which a stiff wire could be pushed. But it is readily opened, its two sides moving apart, as in the direction of the arrows in Fig. 41, on introducing into it through the little hole *m*, water or other fluid under enormous pressure. The hollow tubes *k*, opening centrifugally when under hydraulic pressure, withdraw the claws *ss* from beneath the collar on *a*, the spring R forces *a* down, and we can now unscrew our joint U, and thus open the lamp. The pressure is readily supplied in the lamp-filling room from any convenient source, but underground the miner, of course, has no means of generating or applying it.

A convenient form of press for supplying water under pressure is shown in Fig. 42.

We have in the first place a cast-iron reservoir, G, in the middle of which is fixed a strong bronze hydraulic cylinder, about 1¼ inches in diameter. In this cylinder plays a plunger, A, its lower end carrying a leather U packing. This plunger is held down by the weights B, and raised and lowered by the hand-wheel C. From the bottom of this cylinder runs a narrow tube, conveying water under pressure to

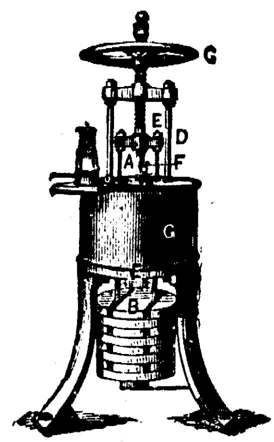


FIG. 42.—Press for opening Chevalier's fastenings.

the lamps, and controlled by a cock, F. From a little hole or induction port near the top of the cylinder runs another little tube to the bottom of the outer reservoir. When the piston is lifted by the hand-wheel C, a partial vacuum arises in the cylinder; as soon as the packing of the plunger has risen past the induction port, water rushes in from this outer reservoir and the cylinder is thus filled automatically. The rods E pass through pipes fastened to the bottom of the reservoir.

The apparatus certainly seems simple. There is only one valve, the cock F in the little pressure-pipe, and this cock and the packing on the plunger seem to be the only parts to which attention must be given.

This form of fastening has been adopted by eight important French and Belgian collieries. For information we are directed to apply to M. Catrice, Péruvelz, Belgium.

Magnetic fastenings.—The bolt which locks the lamp may be held in place by a powerful spring, to which is attached a bar of iron so shaped that it may be withdrawn, drawing with itself the bolt of the lamp, by means of a powerful magnet. The lamp, thus unbolted, is now opened by unscrewing its base from its upper part.

In Villier's arrangement the bolt of the lamp carries a horseshoe-shaped armature of soft iron, which is drawn down, unbolting the lamp, by means of a powerful electro-magnet, magnetized by a magneto-electric machine driven, through a pedal, by the lamp man's foot. But the power required to drive the magneto-electric machine is so great that a single lamp man, using all his strength, can open only six lamps per minute, and only three per minute during continuous work.

Raffard has substituted for Villier's electro-magnet a simple permanent horseshoe magnet, capable of lifting about 44 pounds. This magnet is fixed horizontally and immovably immediately beneath the top of the table shown in Fig. 43, its poles being prolonged up through the table-top by little iron cylinders 0.67 inch in diameter and 0.78 inch long, so placed as to fit against the ends of the armature attached to the lamp bolt.

In a hole in the table-top plays a copper disk, driven by the pedal B and the lever A. It fits the base of the lamp, and has two holes through which our little cylinders pass.

To open the lamp, place it on this copper disk, bringing the ends of its armature against those of our little cylinders, and raise the lamp by pressing on the pedal. As the armature, and through it the bolt, are held down firmly by the magnet, we thus unbolt the lamp, and can now unscrew and open it. Nothing remains but to free the base of the lamp from the magnet. This is done by pressing the pedal down a little farther, thus raising the copper disk a little higher, and with it separating the armature from the magnet.

As the distance through which the lamp man has to lift the lamp itself, and later the armature, in order to free it from the magnet, is small, the amount of work done is said to be inconsiderable, only one four-hundredth of that required in Villier's arrangement. It is reported that one lamp man can open more than 30 lamps per minute without fatigue.*

The lead rivet fastening is shown in Fig. 44. After the lamp has been screwed together, bringing two ears, *a*, on the body of the lamp, and, *b*, on its base, opposite each other, a lead rivet, *c*, is slipped through them, and a letter or other device is stamped on it.

Of course the workman can open this fastening by cutting the rivet with his knife; but he thus leaves a record which he can not efface, and which should lead to his discharge.

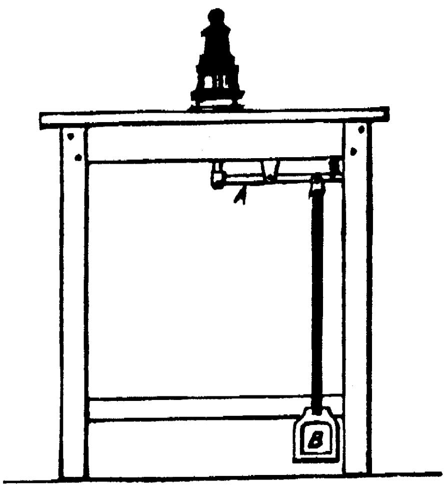


FIG. 43.—Apparatus for opening Raffard's magnetic fastening.

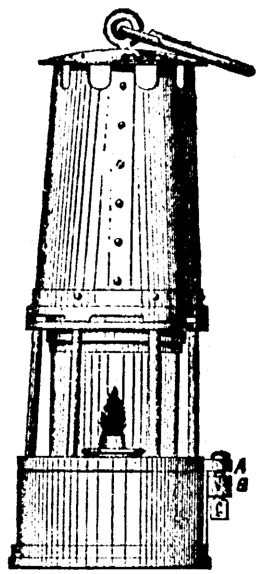


FIG. 44.—French form of Marsaut's safety lamp with lead rivet fastening.

Similar to this is the plan of soldering the two parts of the lamp together.

(16) *Steel mine cars.*—The rapidity with which steel cars have driven wooden ones out of use in the last few years is striking.

Romain Sartiaux, said to be the most important maker of mining cars in France, reports that, up to 1884, in the coal mines of the basins of the North and of the Pas-de-Calais in France, wooden mine cars alone were used, except at Anzin, Escarpelle, and Meurchin, where iron cars had already been introduced. The first trials with steel cars were made in 1884, 2,650 cars being used as an experiment. Last year Sartiaux supplied 5,250 steel cars, 11,552 steel axles with steel wheels, 23,377 steel wheels without axles, 31,369 steel axle boxes.

These cars are made wholly of steel (apparently mild Bessemer

* For further information, see a pamphlet by N. J. Raffard, May 1889, "Fermeture des Lampes de Sûreté des Mines," to be had from Maison Bréguet, the makers of the apparatus, 19 Rue Didiot, Paris.

or open-hearth steel). Their cost is said to be about the same as that of wooden cars of equal capacity, while their life is much longer (8 to 10 years if galvanized, 6 to 8 if black, against 3 years for wood) and their repairs much less expensive, to wit: Ten cents per car for the first year, 20 cents for the second, and 40 cents per annum for the subsequent years, while the cost of repairs to wooden cars is from $2 to $2.60 per annum per car in this district. It is only fair to add that the ratio of the cost of wood to that of steel is very much greater than in the United States. One may travel hundreds of miles through thickly settled parts of France without seeing a wooden house or a shingled roof.

(17) *Hardy's patent picks.*—Two of these are shown in Figs. 45 to 47. That in Fig. 45 needs little explanation. The sleeve at the end of the handle presses outward strongly, and so tends to keep the pick from slipping, while it of course protects the handle greatly.

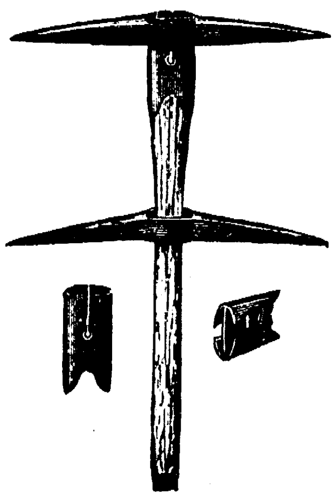
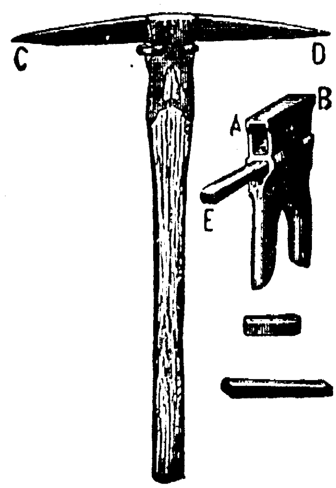


FIG. 45.—Hardy's pick.



FIGS. 46. and 47.

In the "Acme" pick, shown in Figs. 46 and 47, the pick proper, C D, fits into a socket on the handle, instead of having the handle fit into an eye in the pick. The pick proper has a groove on its upper side, just fitting the top part, A B, of the socket. In order to insert the pick into the socket the wedge E of the latter must be withdrawn, as shown in Fig. 47. The pick is then slipped in, and E is then driven home, forcing the top A B of the socket into the corresponding depression in the upper side of the pick. This pick is designed especially for coal mining.

(18) *Hardy's patent multiple wedge for bringing coal down* (Fig. 48).—Instead of a single wedge, a pair of wedges are used, shaped so that a third may be driven between them.

In using it a pair of feathers, as usual, is first inserted in the hole; within these is driven the first wedge, or rather pair of wedges, wedging the coal down somewhat, and within this pair of wedges is then driven the third wedge.

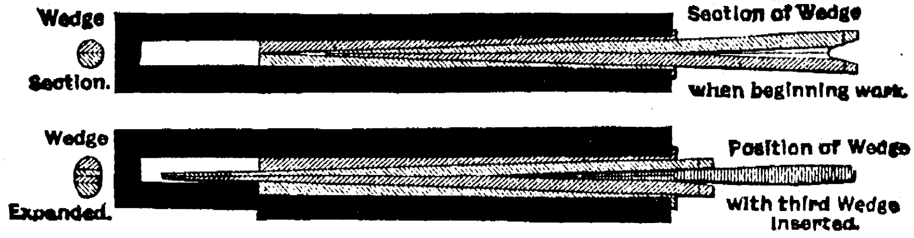


FIG. 48.—Hardy's multiple wedge.

E.—MINING TRANSPORTATION, ETC.

(19) *Transportation by hanging chains at Aïn-Sedma, Algeria.*—The problem which was presented at Aïn-Sedma was to transport an enormous quantity of rich iron ore to the Mediterranean from a point 2,300 feet above sea level and 3.75 miles distant in a straight line, a dozen deep ravines lying between.

Five plans were considered:

1. A common railway, with a maximum grade of 2.5 per cent., and more than 18 miles long.
2. A 39-inch railway running through the principal valley and fed by gravity inclines.
3. A railway with rack and pinion arrangement.
4. A suspended wire-rope railway.
5. A railway governed by hanging chains.

The latter was decided to be much the cheaper method under the existing conditions, and was adopted.

The line has a total length of 4.45 miles (projected horizontally), and a total fall of 2,292 feet, so that the average fall is 9.75 per cent. But as there are level places, and even up grades, the actual average fall is 15.5 per cent. The maximum grade is limited to 30 per cent. To keep within this limit it was necessary to span streams at a great height by means of trestles and very light bridges, and to pierce the summits by tunnels, sometimes of considerable length. Moreover, in order to avoid grades of 40 and even 50 per cent., it was found necessary to have several curves.

The hanging chain arrangement.—Conceive a common double-track narrow-gauge railway (Fig. 49), with a very steep grade, so

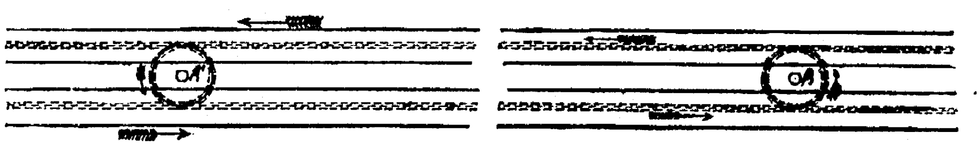


FIG. 49.—Transportation by hanging chains at Aïn-Sedma. Plan of railway.

steep that the ore cars, if left to themselves, would run down it at tremendous speed—in short, a gravity road. Imagine that about 5 feet above this road, and at considerable intervals, lies a series of transmission or toothed pulleys, A A', with vertical axes which stand midway between the tracks. Conceive a series of long endless chains, each slightly overlapping the next, each running around a pair of these pulleys, and each thus forming a long straight-sided loop, its straight sides parallel with the tracks, one side thus hanging above the middle of the down track and running down hill, the other side hanging above the middle of the up track and running up hill. Conceive further two series of ore cars running on these tracks at considerable intervals (Fig. 50), a series of full cars running on the down

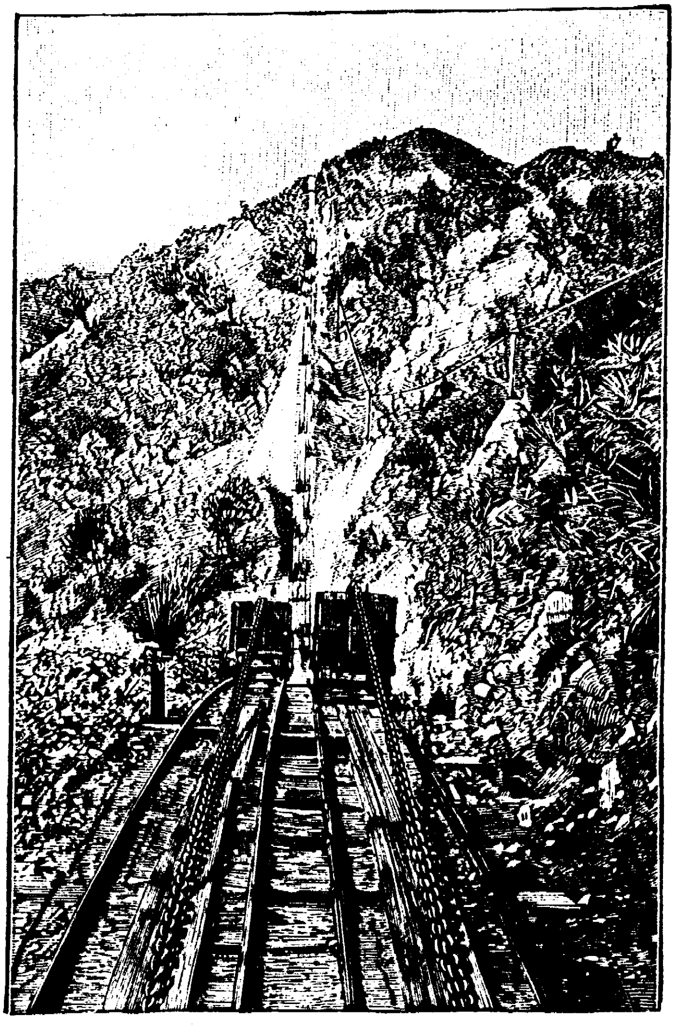


FIG. 50.—Transportation by hanging chains at Aïn-Sedma. General view.

track, a series of empty cars running on the up track. Conceive that each car has at one end, on its upper edge, an open U notch or crotch, so placed that the chain which hangs above the track hangs into and rests in it, thus laying hold of the car. This grasped, it is evident that the full cars on the down track, as they tend to run down hill, will drag this chain down hill with them, and that as this side of the chain travels down hill and approaches the pulley A′ (Fig. 49) at its lower end, the other part of the chain which lies above the up track will be dragged up hill towards pulley A, and with it the empty cars upon which it hangs and to which it attaches itself by means of the notches or crotches already referred to. Finally, conceive that these transmission pulleys are just a little higher than the tops of the ore cars, so that as a car approaches a pulley, say A', the chain is gradually lifted out of the notch on its upper edge, the car thus released running on by its own momentum to join the chain on the further side of the pulley, which, of course runs around a pulley similar to A and immediately beneath it, and is therefore not shown in Fig. 49.

Thus one side of each of these endless chains is pulling empty cars onwards and up hill, the other side is holding back a series of full cars which are running down hill.

FIG. 51.—Transportation by hanging chains at Aïn-Sedma. Station at head of section.

The whole line is divided up into six sections, and each section contains several endless chains, each chain tandem to and barely overlapping the next.

All the chains of each section are in communication and under mutual control; those of the different sections are independent.

In each section are many transmission stations, one at the end of each chain. A transmission station consists simply of two driving pulleys, *i. e.*, toothed pulleys, fixed on the same shaft. The links of the chains lay hold of or "mesh" into the teeth of these pulleys, and thus it is that successive adjoining chains are under mutual control.

The station at the head of each section has in the first place a loose pulley, which simply forms the lower end of the next upper section, and returns the descending chain. In the second place, it contains the main driving, or rather brake pulley of the lower section. This pulley is of the Lancashire type, and has stout vertical steel bars for teeth, which lay hold of the upper chain of the lower section and prevent its slipping. The chain makes one and a half and sometimes two and a half turns around the pulley.

The speed of this main brake pulley is controlled, first, by a fan brake (Fig. 51); secondly, by a common band brake, by means of which the upper chain of the section may be checked or even arrested, when through it, and thence through the pulleys of the transmission stations, we at the same time check or arrest successively the several lower chains of the same section.

The track and the travel of the ore cars are continuous from the top of the line to the sea. At the stations, both those of transmission and those at the section heads, the cars leave the chains momentarily, or rather the chains are lifted by the pulleys so high that they lose hold of the cars, which by their momentum pass from chain to chain. The inclination of the up track must be reversed from an up to a down grade for a short distance on each side of each station, so that the cars running on it may pass readily from chain to chain.

The gauge is 21.65 inches; the distance between the up and down tracks, 11.8 inches. The rails are of Bessemer steel, and weigh about 13 pounds per running yard. As the chains of the different sections support different stresses, owing to differences in grade, so their weight varies from about 17 to 26 pounds per running yard, their total weight being about 150 tons. They are of charcoal iron. Seven hundred ore cars are used.

The plant was built after the plans of M. Brüll, director of the mines, and under his direction, much of the material being supplied by the Taza-Villain establishment, to which we are indebted for a description of it.

(20) *Fan brake and gravity road at Bilboa.**—The distinctive feature of the Cadégal gravity road at Bilboa is the use on a large scale of the fan brake (Fig. 52).

The rich iron mines of Somorrostro lie at the summits of precipitous mountains, midway between Bilboa and the sea, at a height of from 650 to 1,000 feet. The problem of transporting the ore from the mountain tops to the plane at their feet is well solved by the use of the gravity road.

The Cadégal gravity road is about 2,000 feet long, with a total fall of about 525 feet Its inclination is 35 per cent. in its upper, 30

*Communication sur les Divers Moyens de Transport Mechanique Employés dans les Exploitations de Minerai de fer de Bilbao, par M. Malissard-Taza. 1881, per cent. in its middle, and 25 per cent. in its lower part. It is a straight double-track road, of 39.4-inch gauge.

The machinery (Fig. 52) consists of a great double drum, slightly conical, nearly 20 feet in diameter, covered with three-quarter inch

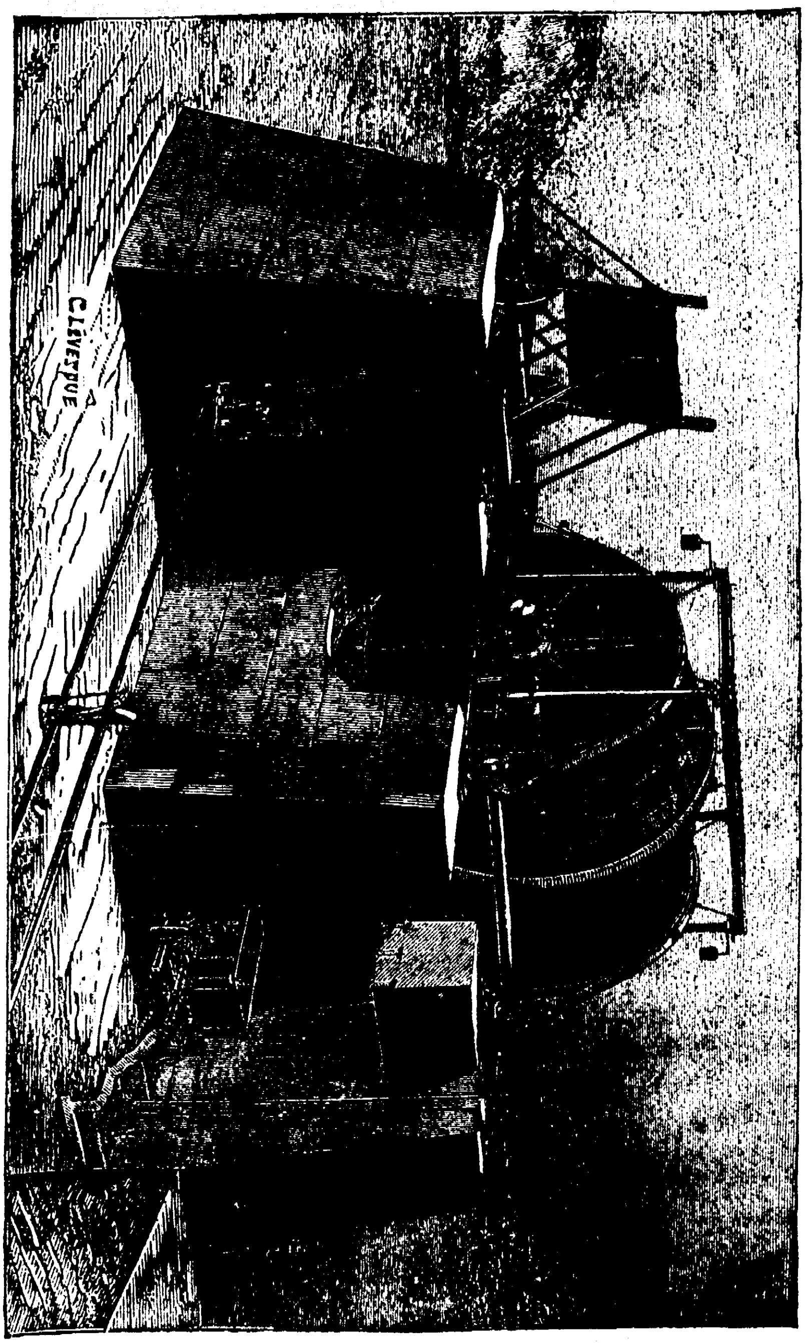


FIG. 52.—Drum and fan brake for the Cadégal gravity road, Bilboa.

iron plates, and supported by three strong spiders, the middle of which is toothed, and gears into a pinion on the shaft of the fan brake.

The fan brake is made up of four straight blades at right angles to each other. They are 6 feet 7 inches wide, while the outside diameter of the fan is 16 feet 5 inches. This brake acts solely by the frictional resistance which the air offers to the swift turning of its blades.

The peripheries of the end spiders of the drum have rims arranged so that they can be grasped by the band brakes, which can be worked by the engineer who stands at the head of the incline, at a distance of about 200 feet. The band brakes are held away from the drum by counterweights, as shown.

The cables are of steel, and 1.57 inches in diameter. The drum itself stands high enough to let the trains which form on the level at the head of the incline, and which have eight 2-ton cars each, pass beneath it. The upper and lower ends of the gravity road are so arranged that all the maneuvers of the cars, both on arrival and departure, are effected by gravity.

When the train is released at the head of the incline its descent at first increases rapidly, as the fan brake, now moving slowly, offers but little resistance. As the speed of train and fan brake increase, the latter offers more and more resistance, so that the velocity of descent very soon becomes constant. The fan brake is designed to give the train a maximum speed of about 600 feet per minute, which corresponds to a velocity of 90 revolutions per minute for the fan itself. Actually the train runs down the 2,000 feet of incline in about 3.5 minutes, while from 6 to 7 minutes are occupied by the maneuvers at the ends of the incline, so that we have a trip about every 10 minutes, or a traffic of about 1,000 tons per 10 hours. This, we are informed, could be raised easily to 1,500 tons, by having more cars per train.

This descent of the full cars and the ascent of the empty ones, be it understood, is accomplished without the use of the band brakes, the fan brake regulating the speed of the trains quite automatically, and without the intervention of the engineer, the band brakes being merely held in reserve in case of need. They are strong enough to arrest the train at any point in its descent.

The advantages claimed for the fan brake are:

1. That we avoid the friction and consequent heating and wear of the lagging of the band brake;

2. Perfect regularity of descent;

3. That it can be easily regulated in place, by changing the surface of its blades to suit variations in the conditions of descent. To these may be added another:

4. That the arrangement requires much less careful and constant supervision than the band and other common forms of brake; and that, as the resistance is necessarily applied extremely gradually, we avoid wholly the shock and consequent deterioration of the machinery due to sudden and violent application of the brake by careless hands.

(21) *Malissard-Taza's automatic "Basculeur," or dumping plant*, Figs. 53 and 54.—This is an arrangement for discharging coal from cars into boats, without power, and with but little labor. The car itself, with a short movable section of track, tips far enough to let the whole charge of coal slide out into a pocket, from which a chute leads to the boat. In order to accomplish this the movable section of track is laid on a strong platform of iron beams, which is movable, and pivoted at the point O, as shown in Fig. 53. As shown, this pivot, instead of being in the center of the track, is much to the land side, so that the weight of the loaded car tends to tip the platform down towards the chute and boat.

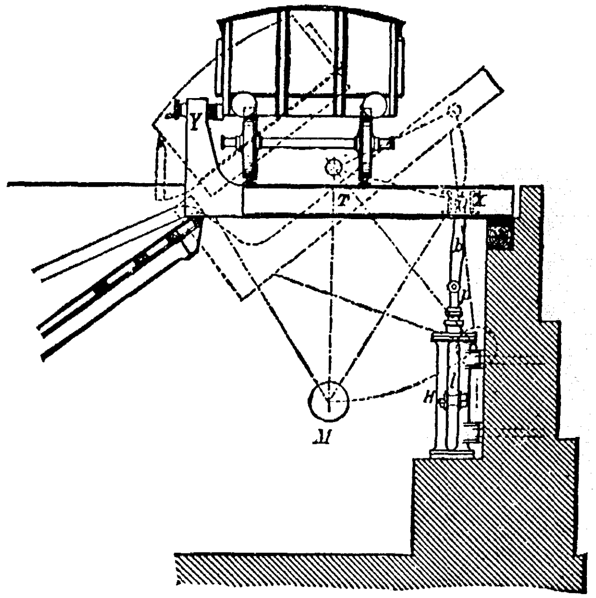


FIG. 53.—Malissard-Taza's "Basculeur," or coal-transferring plant.

A heavy bob, counterweight, or pendulum, M. (Fig. 53) is fastened beneath this tipping platform, so that it has to swing and rise as the platform and car tip. This pendulum is of such a weight that, while it is readily swung, and lifted by the weight of the full car, it suffices to bring the platform and car back to a horizontal position when the car is empty.

Clearly, without some special precaution the weight of the full car would tip the platform down violently, and after the car was emptied the pendulum would bring it and the platform back to their original position with a shock. To obviate this a hydraulic moderator or brake is attached to the platform. It consists of a hydraulic cylinder, H, with piston and piston rod, *p*, connected with the beams T of the tipping platform, at *x*, by the connecting rod *b*. The upper and lower ends of this cylinder are connected by a pipe, *l*, in the middle of which is a cock, which controls the passage of water from one end of the cylinder to the other, and thus the motion of the piston, and through this the motion of the tipping platform and car.

This hydraulic cylinder is merely a moderator or brake, and not a motor; we may call the cock which controls the motion of the water from one end of the cylinder to the other the brake cock.

The lower end of the chute may be moved by a wire rope running over a windlass at the level of the tipping platform, so that the stream of coal may be directed to the far or near side of the boat at will; while the boat itself is towed lengthwise by an endless iron rope, passing over sheaves about level with the boat and fastened to the vertical face of the masonry wall at such a distance on either side of the chute that we can bring all points in the length of the boat beneath it. This towing table is driven by a second windlass at the level of the tipping platform, and with it one man can readily shift the boat lengthwise.

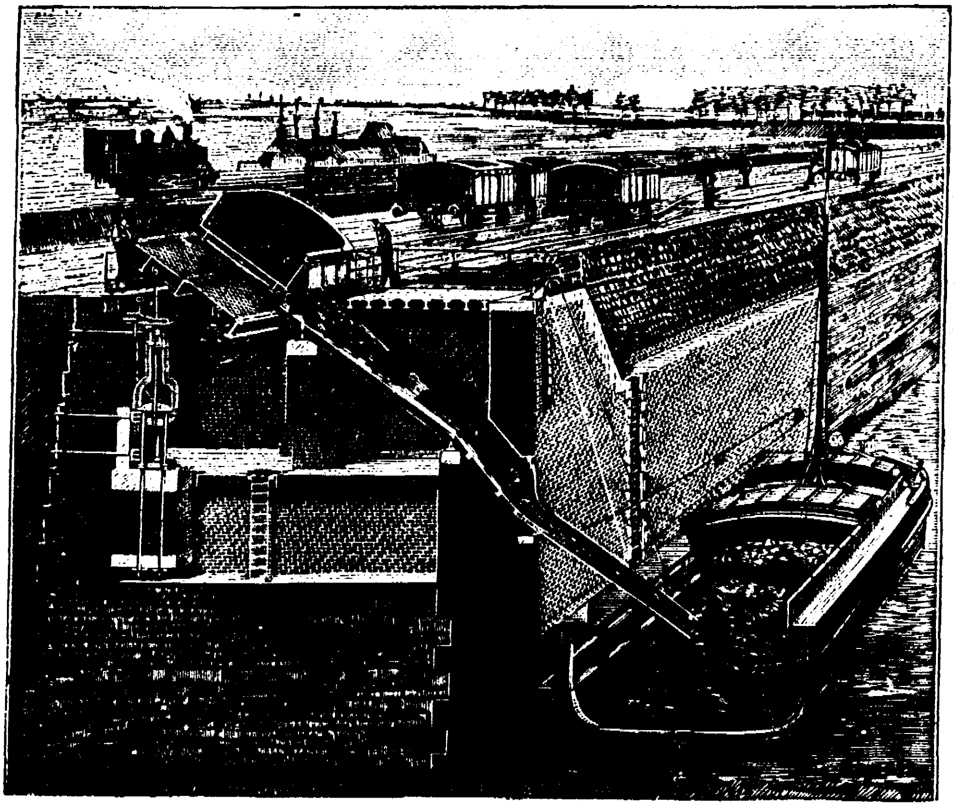


FIG. 54.—Malissard-Taza's "Basculeur."

The manner of operating the basculeur is as follows: The tipping platform is fastened in a horizontal position by means of a safety bolt. A full car is run upon it, and the stops Y are screwed by the hand-wheels shown against the water side of the car, to prevent the latter both from moving lengthwise, and from tumbling over into the chute when the platform and car tip. The safety bolt is now drawn, and the brake-cock connecting the two ends of the hydraulic cylinder is opened, allowing the water to pass from the upper to the lower end of the cylinder, thus permitting the piston to rise, and the platform and car to tip. Before the platform has tipped as far as is shown in broken lines in Fig. 53, the brake-cock is gradually closed, so as to check the motion of the car and prevent shock. As the car and platform reach the position shown in dotted lines, the fastenings of the car doors strike against fixed stops which unlatch them, allowing the car doors to fall open. The platform is immediately bolted in its inclined position, and held there till all the coal has run out, when the safety bolt is again drawn and the brake-cock again opened, the weight of the pendulum now righting car and platform, and forcing the water from the lower to the upper end of the cylinder.

The application of the pendulum is a particularly happy one. When the car and platform begin to tip, the pendulum offers the minimum of resistance to their motion, its resistance increasing rapidly toward the end of the stroke, and thus tending to lessen the shock. On the return stroke, however, when the weight of the pendulum rights the car and platform, it acts most powerfully at first, when the most powerful action is needed in order to overcome the inertia of the car and platform. Toward the end of the stroke, however, when its accelerating action would only tend to cause shock, it becomes weaker and weaker, and finally nil.

The basculeur shown in Figs. 53 and 54 is in use at the coal mines of Marles for 10-ton cars.

The advantage of this arrangement over Fougerat's and that adopted at Éleu is that no power is required for transferring the coal, while in these latter arrangements power is needed for lifting the body of the car in dumping. On the other hand, a little extra time is needed in Taza's arrangement for fastening the cars by the stops Y, though it is not clear why this may not be made automatic.

(22) *Fougerat's basculeur*, Fig. 55, used by the Bruay Coal Mining Company (Pas-de-Calais, France), raises and tips the coal car and a movable section of track, as shown in Fig. 55. The platform and movable track are pivoted at B, and are lifted by the hydraulic cylinder E, the link F compensating for the horizontal travel of the apparatus. A screw near D prevents the car from overturning.

The winch K enables us to raise the chute G completely out of the boat, so that the latter may pass on, or to simply change the inclination of the chute, to suit changes in the angle of repose of the coal. The worm beneath the chute controls the end of the chute, and thus enables us to discharge the coal to right or left, or even to arrest it.

In loading by hand the cost was formerly 2.4 cents per ton, and they could only load from fifteen to twenty 10-ton carloads daily. With a single basculeur the cost is only 0.6 cent per ton, and with the same number of men and cars as formerly they now load seventy 10-ton carloads daily. Much more could be loaded could it be brought to the basculeur, which can load 100 to 120 tons per hour, all maneuvers included, and has loaded 50 tons in 11 minutes.

Compared with Taza's basculeur the one before us has, as just pointed out, the disadvantage of needing considerable power for

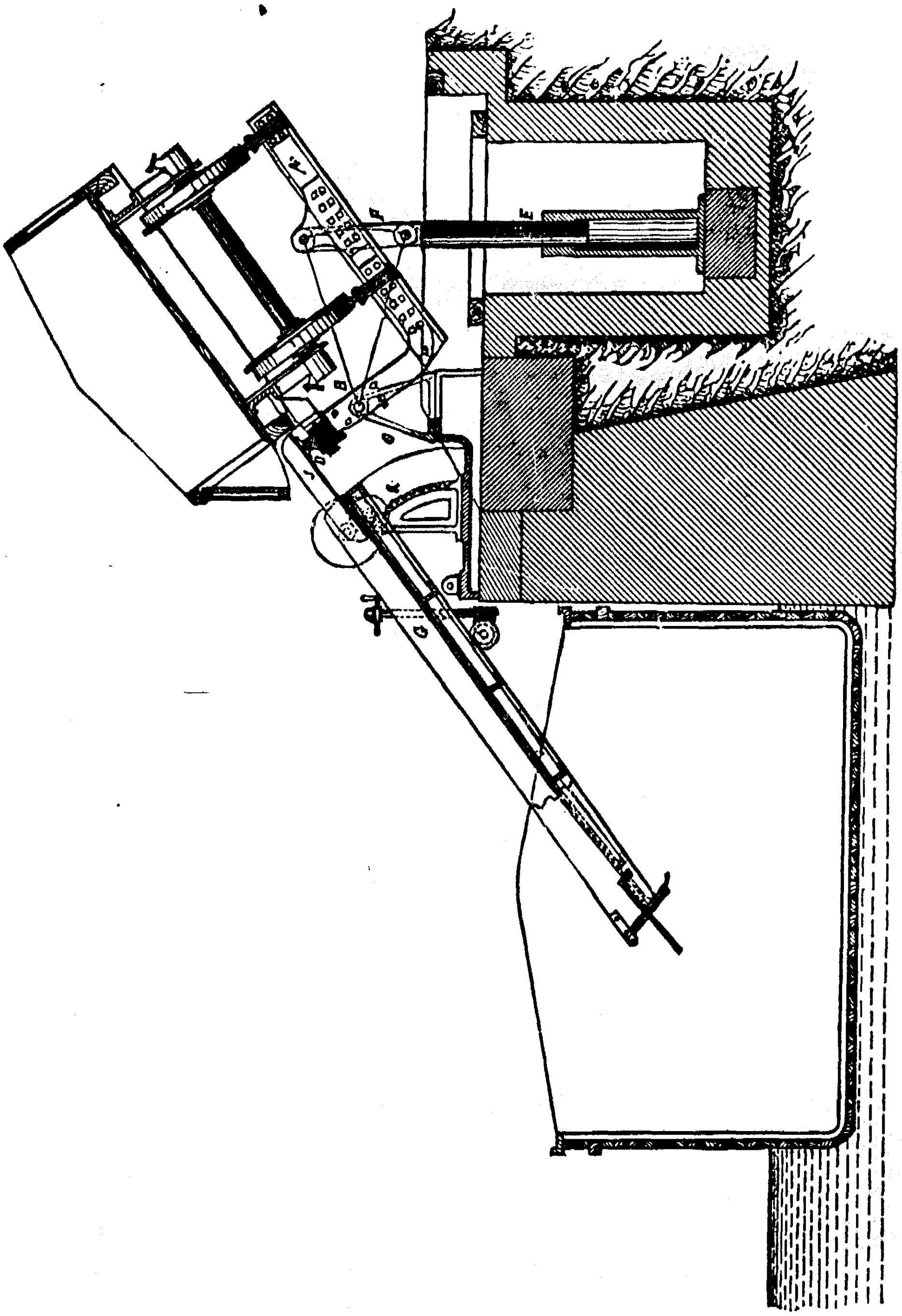


Fig. 55.—Fougerat's patent basculeur.

raising the car and platform, but the advantage that the coal probably slides out more gently, the door swinging open little by little as the car tips, and letting the coal out little by little; whereas in Taza's arrangement it is clearly necessary that the car doors should be kept closed till the car has tipped through its full travel, since it is the weight of the coal that tips the car. The doors being thus suddenly opened, the coal all gushes out at once, and more violently.

The cost of the apparatus is given as about \$200 to \$240.

These basculeurs are clearly applicable to materials other than coal, and with equal advantage.

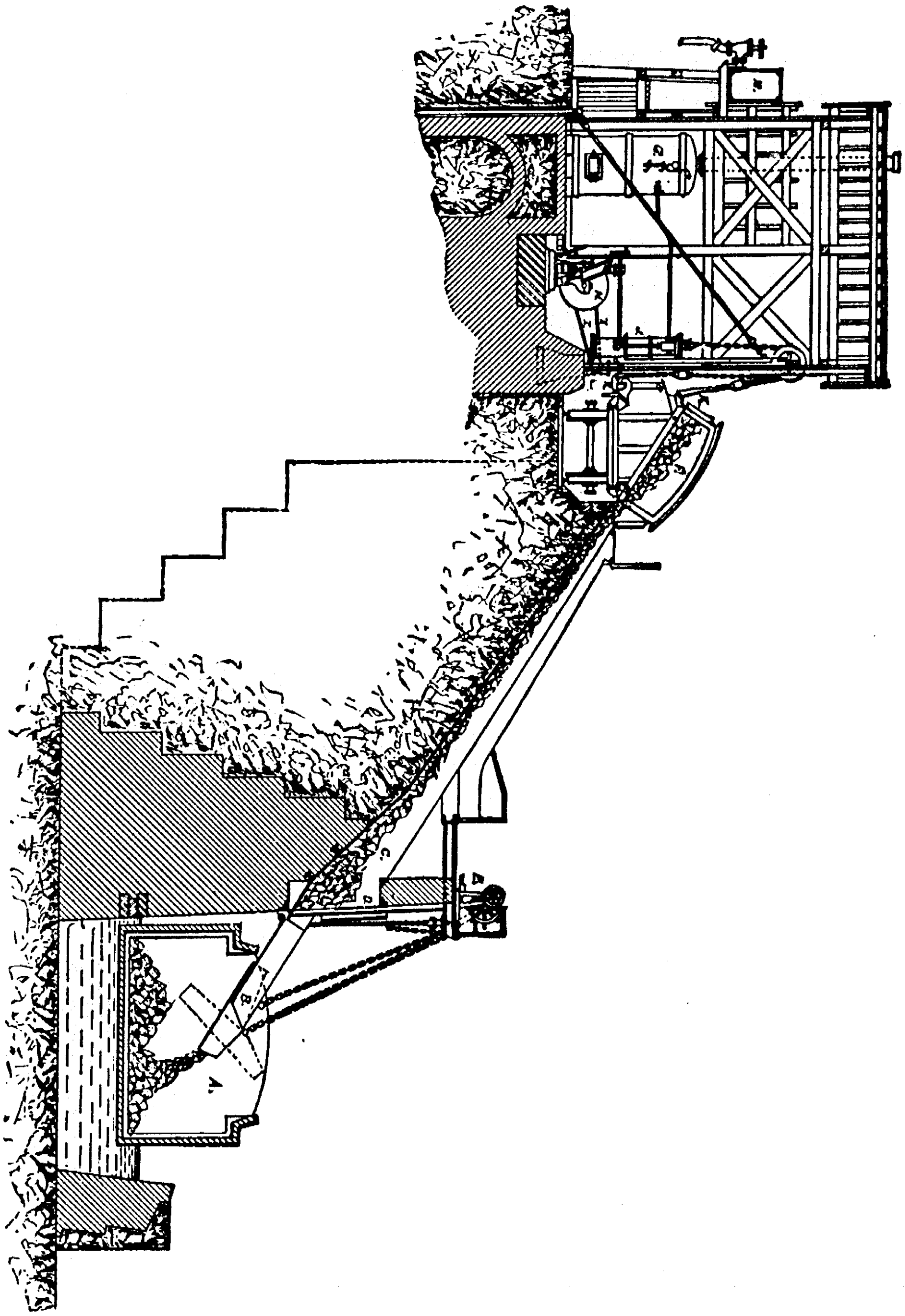


FIG. 56.—Coal-transferring plant at Éleu. A, canal boats loading; B, movable chute; C, fixed chute; D, door of coal pocket; E, windlass for moving B and D; F, movable body of 10-ton car; G, boiler—150 square feet heating surface; H, steam winch for moving cars along; I, wire rope for same; J, steam cylinder for tipping cars; K, hooks for tipping the car; L, sheaves for the wire rope; M, feed tank.

(23) *Coal-transferring plant at Éleu* (Figs. 56 to 59).—This is an arrangement for transferring coal from cars to boats, differing from Malissard-Taza's in that the body of the car, which is pivoted on the

truck, is tipped by power, instead of the whole car and a section of track being tipped.

A sheet-iron chute, C, leads the coal to the boat A. In it a pocket is formed by the gate D. The section of the chute beyond D is movable, so that by varying its inclination the velocity of the coal may be controlled. At the very end of the chute is a second movable section which, as shown in broken lines, may be swung so as to deliver the coal towards either side of the boat at will. The gate D and these two movable sections of the chute are moved by the windlass E. These movable sections of the chute are counterweighted, first by a heavy counterweight, secondly by a differential one which comes more or less into play to suit the varying positions of the end section of the chute.

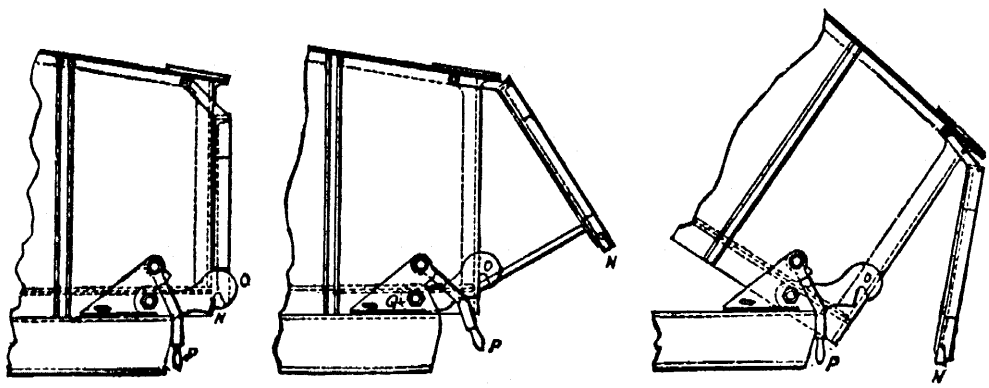


FIG. 57.—Door latched. FIG. 58.—Door unlatched by hand. FIG. 59.—Door unlatched automatically by the tipping of the car body.

Viala's patent automatic latch for coal cars used in the coal-transferring plant at Éleu.

The cars used are wholly metallic, weigh when empty 15,600 pounds, and consist of two boxes, F, each holding 5 tons, and pivoted on the car truck. An ingenious catch, shown in Figs. 57 to 59, allows the car door to swing open when the body of the car has been tipped so much that the coal will slide out. This catch can also be opened by hand when the car is level, so that these cars may be used for common filling purposes, etc., as well as for dumping into the chute.

This catch works as follows: The latch O is pivoted at Q, so that, when the door is to be opened by hand, it can be raised by the hand-lever P, releasing the lug N on the door, as shown in Fig. 58, but a stop on the truck prevents O from turning farther down than as shown in Figs. 57 and 59; hence, when the body of the car is tipped, the lug N descending, slides down and out of the jaw in O, and the door then swings out as shown in Fig. 59.

Each of the two boxes F of which the car body consists is raised and tipped 35 degrees by a hook K, which in turn is moved by one of the two single-acting steam cylinders J, by means of the chains shown in Fig. 56. The hook K is attached automatically to the car body.

Cars are brought by a locomotive in trains of twenty to the track which passes through the dumping plant, and are successively brought opposite the chute by means of a wire rope I, Fig. 58, running over the sheaves L L, and driven by the steam winch H, which readily moves the whole train bodily in either direction. This steam winch and the tipping cylinders are operated by levers which are placed so as to be simultaneously controlled by the engineer, who, with one other man, can, it is said, load six boats, or say 1,500 tons in twelve hours. A 250-ton boat has been thus loaded in 47 minutes.

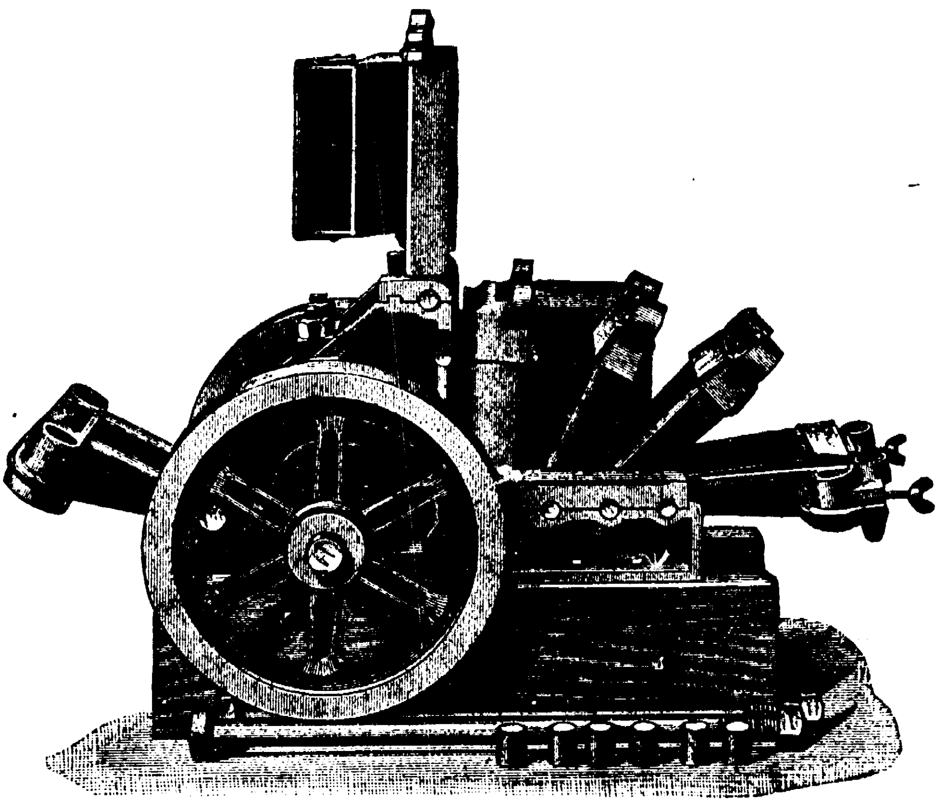


FIG. 60.—The Blake crusher: opened to show its construction.

F.—CRUSHING MACHINERY

(24) *The Blake multiple-jaw crusher* or granulator, Figs. 60 and 61, is a modification of the famous Blake crusher, with a number of jaws instead of a single pair, and designed for granulating, but hardly for pulverizing, already crushed ore, etc. Fig. 64 shows the machine opened to exhibit its interior; Fig. 65 shows it assembled for use. We note in the former three movable jaws, which rock around shafts at their bases. The chute shown feeds the already

crushed material between all these jaws simultaneously. The left-hand or fourth jaw is fixed.

The fly-wheel shaft carries an eccentric, which at each revolution forces a pitman upward against a pair of toggles which force the breech piece to the left, and thus, through the tension rods on either side of the machine, pull the right-hand movable jaw to the left. When, as in working, the spaces between the jaws are filled with mineral, this transmits the pressure to the left from jaw to jaw, and thus the mineral in all the spaces is squeezed and crushed at each turn of the fly wheel and stroke of the pitman.

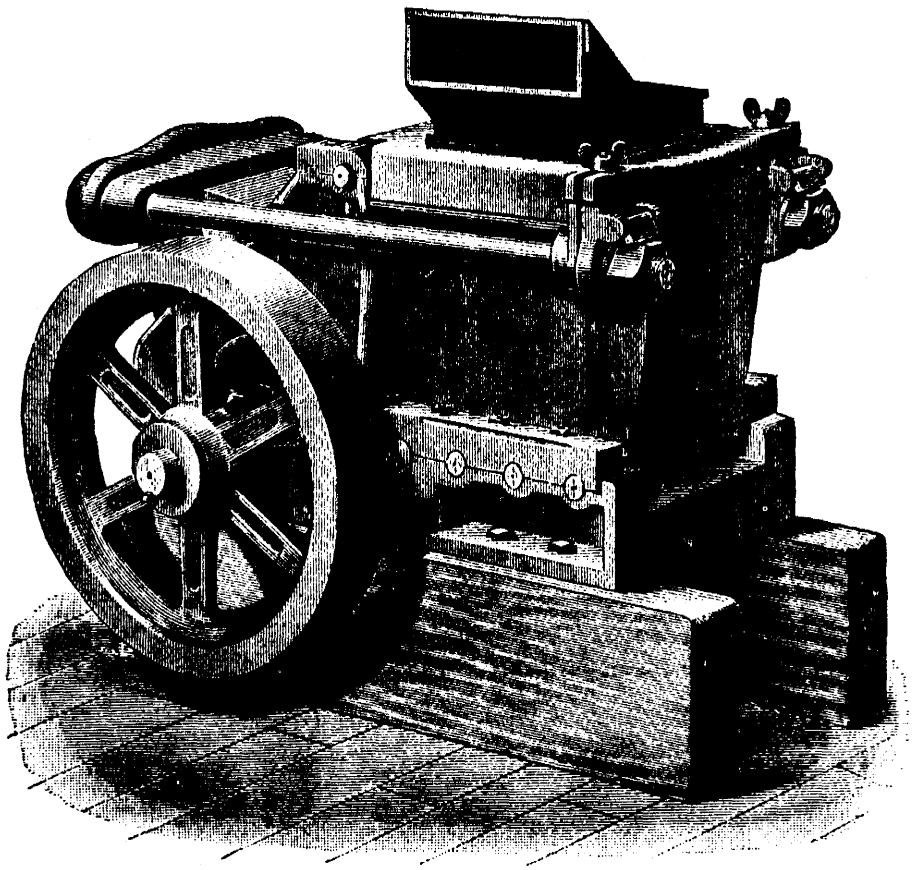


FIG. 61.—The crusher ready for work.

During the return stroke the jaws are all opened to the right, following up the motion of the tension rods by rubber buffers at their their upper corners, shown at the bottom of Fig. 60.

"The tensile strains are wholly upon wrought iron or steel, while those of compression are resisted by cast iron. The machine is closed, and the dust made by it wholly confined. The pivoting of the rear toggle-block is an important feature, and makes it easy to adjust the opening and take up the wear on the toggles and jaw plates by means of tension-rods. The construction of the pitman is somewhat similar to that in the Blake challenge breaker, with the difference that there is no tensile strain upon the pitman rods; they, in combination with the breeches, permit an easy adjustment of the length of the stroke of the main toggle jaw. This is effected by lengthening or shortening the pitman by means of washers on the rods beneath the breeches."

With the earlier machines there was a troublesome tendency to clog; the later ones seem to be doing much better. Some which were set up at the Lyon Mountain mills of the Chateaugay Ore and Iron Company have, according to Mr. Blake, been in continuous use night and day ever since. There are now fourteen of these machines in these mills, while in all twenty-seven machines had been sold up to July 8, 1889.

Mr. Blake informs us that, "A multiple-jaw crusher with three jaws, each 20 inches by 2 inches, receiving pieces 1½ inches and smaller, will readily crush 100 to 150 tons of hard quartz or lean magnetic iron ores, consisting of disseminated grains of magnetite in a tough feldspathic gangue, to corn-grain size and dust in 24 hours. If it be supplemented with another crusher with five jaws, each 15 by one-half inch receiving capacity, all the material can be crushed to one-tenth of an inch and smaller, that which is already reduced to one-tenth in the first machine being taken out by screening before sending the coarse to the second or supplemental crusher."

We have no direct information as to the consumption of power in granulating with this multiple-jaw crusher, but for crushing lumps of lean Chateaugay magnetite, 15 inches in diameter and less, in Blake crushers and subsequently granulating them in this machine, not more than half a horse-power is needed per ton of ore. For crushing, granulating, and concentrating 122,814 tons (of 2,240 pounds) of this ore the total cost was $0.34 per 2,240 pounds ($0.307 per 2,000 pounds). The item of "Mill-supplies, renewal and repairs" was from $0.075 to $0.08 per ton, including all repairs to jigs as well as to crushers and other machinery, and to the building itself.

Certain data as to cost, etc., follow:

Capacity per hour to corn-grain size.	Number of machine.	Number of jaws.	Receiving capacity of jaws.	Weight.	Price.
Tons.			*Inches.*	*Pounds.*	
....	1	3	5 by 0.5	225	$100
2 to 4	2	3	15 by 1.75	4,000	650
4 to 6	3	3	20 by 2.00	12,500	1,200

As already pointed out, the machine aims to granulate rather than to pulverize, in short to replace Cornish rolls, especially as preparatory to concentration. Mr. Blake thinks it inexpedient to use it for crushing finer than between 10 and 20 mesh, but recommends it especially on account of its low cost for labor, for power, and for repairs, its large output, and its small proportion of fines.

The following table gives the proportion of product of each of several degrees of fineness, as determined by T. A. Edison in crushing Chateaugay magnetite:

	Per cent.		Per cent.
Through 4 on No. 8	14.10	Through 60 on No. 70	1.12
Through 8 on No. 16	23.56	Through 70 on No. 80	3.37
Through 16 on No. 20	10.74	Through 80 on No. 90	.97
Through 20 on No. 30	15.38	Through 90 on No. 100	.97
Through 30 on No. 40	9.30	Through 100 on No. 120	2.21
Through 40 on No. 50	8.82	Through 120	6.09
Through 50 on No. 60	3.37		

G.—Blowing machinery for metallurgical works.

(25) *The Cockerill blowing engine for blast furnaces.*—The popularity of this admirable engine is shown by the fact that the one at the Exhibition is the one hundred and fifty-second of this type built by the Société Cockerill.

It is a vertical compound engine with one air and two steam cylinders. At the general level are the cam shaft, and the main shaft which carries two fly wheels, one at either end. Immediately above the main shaft are the two steam cylinders; next comes the crosshead, to which their piston rods and the connecting rods are attached below, and to which the piston rod of the air cylinder is attached above; while above all comes the single air cylinder. The connecting rods are attached directly to wrist pins on the fly wheels.

The principal dimensions are as follows:

	Feet.	Inches.
Diameter of air cylinder	9	10
Diameter of high-pressure cylinder	2	9⅝
Diameter of low-pressure cylinder	3	11¼
Stroke	8	0
Diameter of air pump	2	6
Stroke of air pump	4	0
Diameter of feed pump		5½
Stroke of feed pump	2	3½
Diameter of fly wheels	23	9
Weight of fly wheels ... net tons	19.8	
Normal speed ... revolutions	15	
Volume of air delivered at 15 revolutions, at 4¾ pounds pressure, cubic feet	13,703	

While adhering to this general type of engine, the Cockerill Company has made some important modifications, the most noticeable of which is in the manner of driving the cam shaft. It was formerly driven from the crank shaft by a train of gearing; this has been replaced by a single eccentric attached to the crank shaft, which drives the cam shaft by a small pitman. This is not only a more silent way of driving the cam shaft, but one which consumes less power, avoiding the friction of the gearing. The steam passages are larger than of old, the crosshead is strengthened, the cylinders are fastened more firmly to the bed plate, and this last is heavier than formerly. While 15 revolutions is called the normal speed, the engine may run advantageously at 18 revolutions.

The cut-off of the high-pressure cylinder is variable, but not automatic, and occurs at about one-third stroke. The piston packing in each of the four cylinders consists of a single steel ring, set out by springs. The air cylinder is neither lubricated nor cooled.

H.—Rolling mills and iron working appliances, etc.

(26) *Universal reversing plate mill of Chatillon et Commentry.*—This mill, which is at Montluzon, France, has two interesting features: arrangements for inclining the upper roll, so as to give the plates a pentagonal section, and for changing the distance between the rolls while always keeping their spindles parallel with each other and with the driving shafts. The first not only gives a considerable saving of metal but, what is much more important, permits us to reduce the great expense to which makers of armor plates have hitherto been put, of machining their plates to forms like that sketched in Fig. 62. The second aims to effect a considerable saving in friction, and hence in power.

Leading dimensions, etc.—The rolls are 39 inches (1 metre) in diameter, and 19 feet (5.8 metres) long, and weigh 29.5 gross tons (30,000 kilogrammes) each. They can now roll piles or ingots 3 feet 11 inches (1.20 metre) thick, and changes are now making which will enable them to receive pieces 6 feet 6¾ inches (2 metres) thick. Their housings are 15 feet 5 inches (4.7 metres) high, and 14 feet 1 inch (4.30 metres) apart.

The rolls are reversed by a five-gear arrangement, the clutch of which is driven by a special hydraulic cylinder.

The vertical rolls are 20 inches (0.5 metre) in diameter and 4 feet 3 inches (1.3 metre) long.

Arrangement for tipping the upper roll.—The journals of the upper roll rest in spheres within its carriages, so that it is free to tip. The arrangement for tipping it is sketched in Figs. 62 and 63 and shown on a large scale in Fig. 64. The rolls themselves are counterweighted, so that they always press up against the vertical screws shown in Figs. 62 and 63. These, as usual, are driven by worms on an overhead shaft, T T′ (Fig. 64), which in turn is driven only when the upper roll is to be raised or lowered, at other times remaining motionless. This shaft is not continuous; its right-hand end, T′, is driven, and from this motion may or may not be communicated to the left-hand end, T, at will, by a five-gear reversing arrangement.

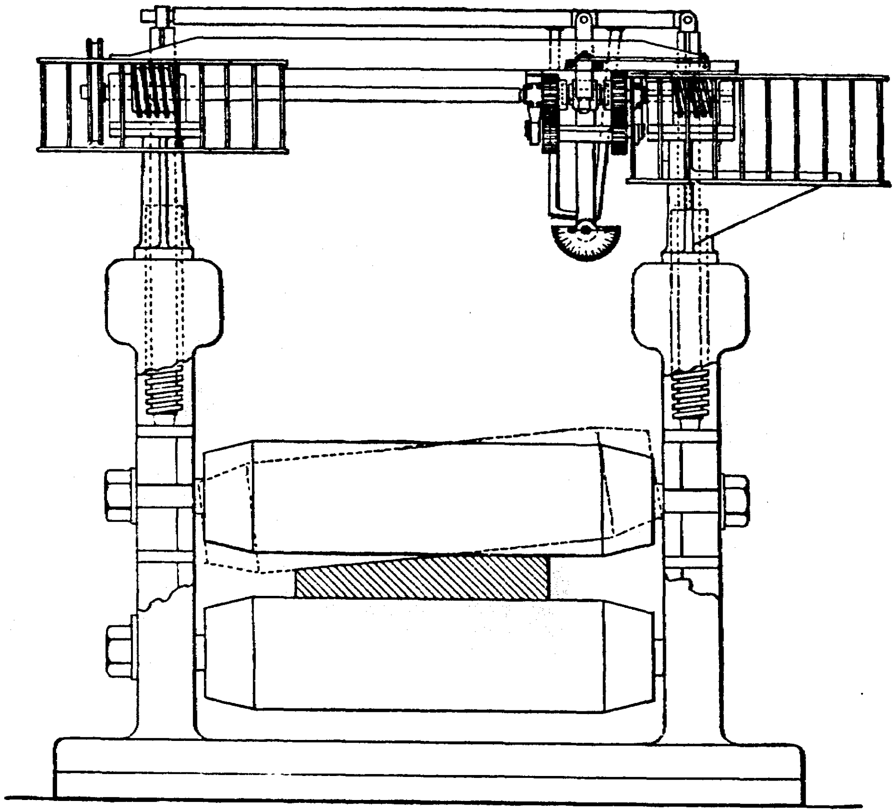


FIG. 62.—Front elevation.

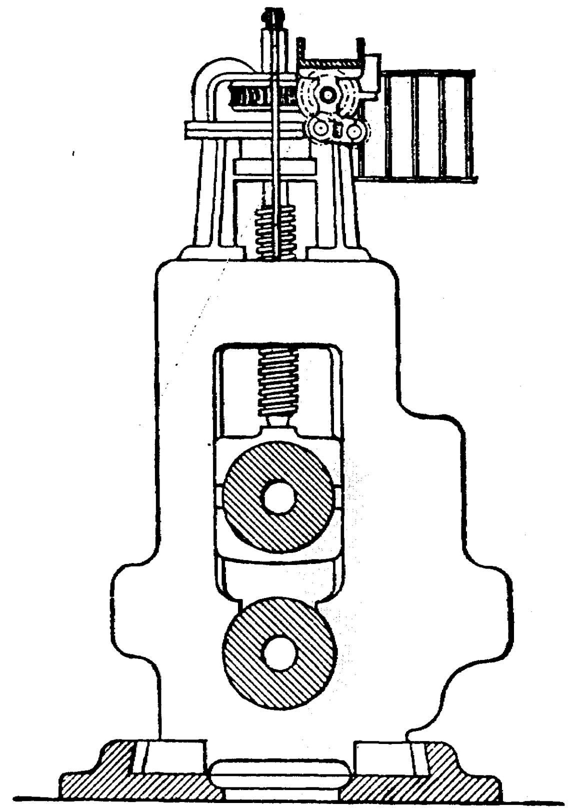


FIG. 63.—End elevation.

ARRANGEMENT FOR TIPPING THE UPPER ROLL IN CHATILLON & COMMENTRY'S REVERSING PLATE MILL.

Only four of these gears can be seen in the cut. Fig. 64 shows some details of this arrangement. Between T and T′ lies the crab Z, driven by T′, and thrown into gear with either of two clutches, one at the

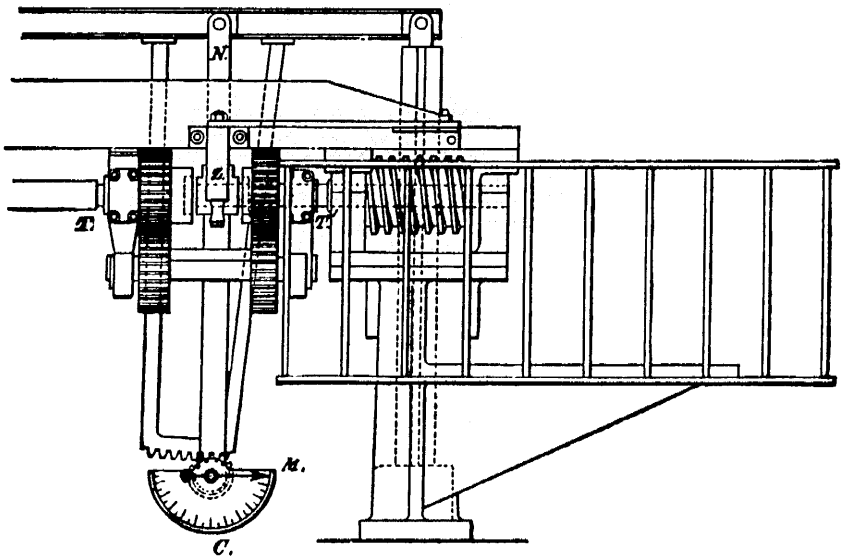


FIG. 64.—Detail of the tipping gear of Chatillon & Commentry's plate mill.

right, the other at the left, or held free between them, at will. The pinion at the left is keyed to the shaft T, while the pinion at the right is loose on the shaft T′.

If now the right-hand end, T′, of the shaft is to be driven while the left, T, is stationary, so that only the right-hand end of the upper roll is to be raised or lowered, Z is held free between the clutches If, on the other hand, both T and T′ are to be moved in the same direction, so that the upper roll may rise or fall without changing the inclination, Z is pressed against the clutch at the right, turning it, and through it T, in the direction in which T′ is turning. If, finally, T and T′ are to be moved simultaneously but in opposite directions, as happens when the inclination of the upper roll is to be changed rapidly, Z is pressed against the clutch at the left, which it forces to turn in the same direction as T′, and which transmits its motion, through the train of gearing shown, to T, which is thus forced to move in the opposite direction.

Arrangement for keeping the spindles parallel, Figs. 65 to 70.—The pinion P of the lower roll C is driven by the engine, in turn driving the pinion P′ of the upper roll C′ by means of the idlers S and S′. The bearings of S are fixed; those of S′ are free to slide in the groove shown in Figs. 67 and 70.

This groove is the arc of a circle concentric with S, so that S′ plays as a satellite around S. The shaft of the upper pinion P′ is fastened to the shaft of S′ by means of a link, so that S′ always remains in gear with P′, its own weight keeping it ever in gear with S. Thus when the upper roll C′ and its pinion P′ are lowered from the position shown in Figs. 65 to 67, S′ and its bearings slide to the left of the position shown in Fig. 67 till C′ and P′ reach the level of S′; as they descend farther, S′ slides to the right till, when C′ reaches its

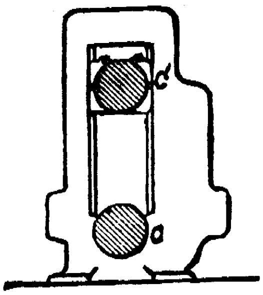


FIG. 65.

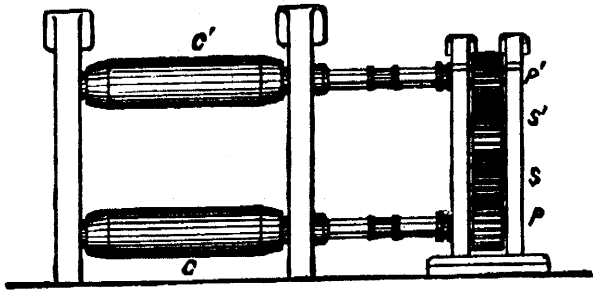


FIG. 66.

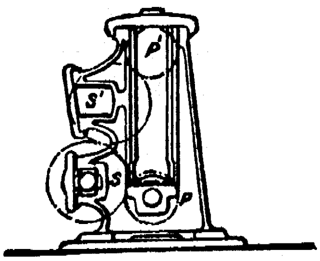


FIG. 67.

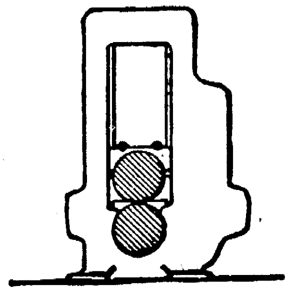


FIG. 68.

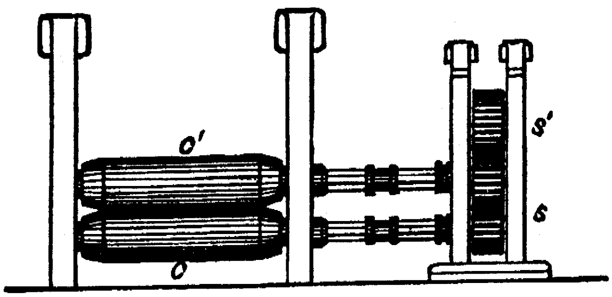


FIG. 69.

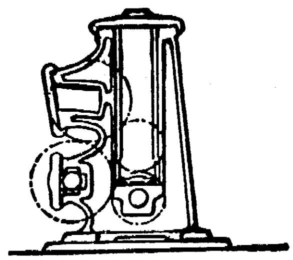


FIG. 70.

Chatillon & Commentry's plate mill.

lowest position, S′ stands as shown in Fig. 70. The pinion housings are of steel, and weigh about 83.7 gross tons (85,000 kilograms).

(27) *Five thousand horse-power reversing 26-inch blooming and rail train at Valenciennes.*—The distinctive feature of this train is that the blooming, roughing, and finishing stands are driven simultaneously and directly by one and the same horizontal reversing engine, without gearing; an arrangement which will hardly commend itself to American mill men, though it would be rash to say that it is not suited to the particular conditions existing at Valenciennes.

Next to the engine stands the two-high blooming stand, next comes the roughing stand, and beyond this the finishing stand. There is no gearing, save to transmit the motion from the lower to the upper rolls. Driven rollers on either side of each stand feed the piece into and out from the rolls; a manipulator traverses it lengthwise of the train; while an inclined track with loose rollers in front of the finishing stand helps to feed the piece into the rolls by gravity.

We will now take up the different parts in more detail.

The building has an area of 24,220 square feet, and is wholly devoted to this train and its appurtenances.

The engine, which has two cylinders, was especially designed for great power and great speed combined. Its leading dimensions, etc., are as follows:

Diameter of cylinders (1.250 metres), 4 feet 1¼ inches.

Stroke (1.400 metres), 4 feet 7 inches.

Steam pressure (3 to 5 kilograms per square centimetre), 43 to 71 pounds per square inch.

Cut-off, three-fourths stroke.

Maximum revolutions per minute, 150.

Indicated horse-power at 150 revolutions, 4,932.

Piston speed at 150 revolutions, 1,378 feet per minute.

Bearings of cross-head (1 by 0.30 metre), 39 inches by 12 inches.

Journals of shaft (.425 metre diameter by .7 metre long), 16.6 inches diameter by 27.5 inches long.

Bearings of connecting rods (.425 metre diameter by .52 metre long), 16.6 inches diameter by 20.5 inches long.

Weight of bed plates, 63 long tons.

Weight of foundation block, about 1,000 tons.

Weight of crank shaft, 62,800 pounds.

Weight of reciprocating parts of each cylinder, 23,000 pounds.

Total weight of engine, 434,000 pounds.

The bearing surfaces are all made large. The valves, which are cylindrical, are governed by two common eccentrics, with an Allen link, which can be fixed at any point, so as to vary the cut-off. The shaft is of steel and is hollow. The two cranks are at right angles. The admission ports have an area one-sixth that of the piston. A single engineer on an elevated platform commands the whole, controlling with levers the admission of steam, the reversing gear, the cut-off, and the manipulating mechanism for manipulating the ingot.

The engine is built to work either with or without condensation; actually it does not condense. The management believes that condensation is disadvantageous for engines of this class. First, it points out that, despite the area of the ports, one-sixth that of the piston, in order to reach a vacuum of 12 pounds per square inch, or four-fifths of an atmosphere, the steam must escape at a speed of 138 feet per second, a greater velocity, it is maintained, than the remaining one-fifth atmosphere can generate. It further points out that the communication with the condenser tends to cool the cylinders, thus diminishing the efficiency of the engine, and that the engine reverses much less quickly if condensing than if noncondensing, the steam actually present on the exhaust side of the piston in the latter case acting as a cushion to arrest and even reverse the motion of the engine. Finally, the management reports that the actual consumption of steam in rolling at Valenciennes with this noncondensing engine compares favorably with that of other engines doing like work.

The roll train.—The diameter of the blooming rolls is 26.37 inches; that of the finishing rolls, 26 inches. There are eight blooming passes in four grooves, seven roughing and five finishing passes, or altogether twenty passes from 13.3-inch ingots to rails or billets.

The feed rollers are driven by reversing steam engines.

The traversing piece is driven by hydraulic power, and passes in front of all three stands, passing the piece from stand to stand and from groove to groove.

There are sixteen soaking-pits with auxilliary gas firing, fed by two hydraulic cranes, which also serve a gas-reheating furnace, with a hearth 13 feet long, and with seven doors on each side.

The piece is turned by hand, the turning in front of the blooming rolls being effected by a suspended hook, which one man manages. There are three men before and three behind the train. Altogether there are twenty-eight men and four boys employed between ingots and rails, including the engineers for the engine, the feed-roll engines, the locomotive, and the pumps, and also the shear-men and saw-men, but not the rail-finishers. With this number of men 130 tons of 2-inch billets can be turned out in twelve hours, with a consumption of 55 pounds of coal in the soaking-pits and of 419 pounds of coal for steam raising per ton of billets, running single turn.

The rolls can be changed in an hour.

Sections weighing from 33 to 220 pounds per yard and pieces up to 200 feet long can be made in this mill.

The output seems trifling enough to American rail-mill engineers, accustomed to outputs of 1,000 tons a day; turning the piece by hand instead of by machinery seems crude enough; finally, the idea of driving the blooming and finishing rolls at the same speed and by the same reversing engine seems a step backwards, and a long one. If we only roll one piece at a time, *i. e.*, if we do not begin blooming one ingot till the preceding piece has left the finishing pass, our output is small and the friction is excessive, three sets of rolls running continuously while only one is working. If we would roll two or three pieces at a time the short bloom has to wait and cool between passes while the 200-foot billet or rail is passing through the finishing rolls, before we can reverse and enter the bloom for a new pass. Indeed, the two-high reversing mill seems especially unfitted for blooming, for here the piece is so short that we have to reverse at very short intervals. The power used in stopping and starting the engine is heavy in proportion to that used in the useful work of rolling.

It is claimed for the mill that it is especially suited for the existing conditions. It is called on to turn out very many small orders, and a large proportion of the time is therefore spent in changing rolls. The gross amount of the orders is not sufficient to fully employ a separate blooming mill with a separate engine and engineer. The answer would seem to be, combine with other concerns till your gross orders enable you to keep powerful machinery fully occupied. Have two finishing trains, so that one may run while you are changing rolls in the other.

(28) *Fox's machine-flanged plates.*—By means of powerful hydraulic presses, the Leeds Forge Company, limited, flanges large marine and other boiler fronts, and locomotive engine and tender frame plates, at a single operation between gigantic dies. Fig. 71 shows an engine frame plate thus flanged. A marine boiler front 13 feet 7½ inches (4.25 metres) in diameter, of steel about seven-eighths inch thick, with a flange turned around it about 7¼ inches deep, and with three flue-openings flanged about 4 inches deep, is shown at the Exhibition. It is claimed that when the piece leaves the press its flanges are accurately at right angles to its face, and that the piece itself needs no subsequent straightening.

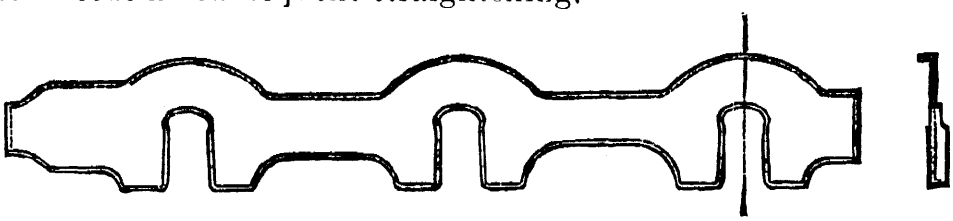


FIG. 71.—Engine-frame plate, flanged by Fox's process

For pressing long pieces two or more hydraulic plungers may press at the same time on different parts of the die.

(29) *Fox's patent corrugated boiler flues and furnaces.*—In making these the flue is first welded as a cylinder, and then corrugated while hot, between corrugated rolls. To do this the upper roll of the two rolls which corrugate the flue is withdrawn endwise through the window of one of its housings, the already welded and now red-hot flue is placed immediately above and resting on the lower roll, and the upper roll is rapidly slipped back into place through the flue, pressed down towards the lower roll, and both rolls are rotated; pinching, rotating, and corrugating the flue between them.

The chief advantages claimed for these corrugated flues and furnaces over plain ones are as follows:

1. Higher efficiency in evaporation, because they may be made much thinner than plain flues without danger of collapsing.

2. More rapid evaporation for given volume, thanks to their larger heating surface. It is also claimed that the increase of heating surface in the furnace itself leads to more thorough transfer of heat from the products of combustion to the water, *i. e.*, better efficiency.

3. The flues and furnaces are compressible lengthwise; hence, the

boiler as a whole is less strained and distorted by the excess of expansion of the furnace and flues over that of the less highly heated parts (*e. g.*, the shell in marine boilers).

4. It is not necessary to have stiffening rings, flanges, etc. These not only tend to burn out, but, heating and hence expanding at a different rate from the undoubled parts, induce internal stress.

It is claimed that direct comparative tests show that these corrugated furnaces offer 4.5 times as great resistance to collapsing pressure as plane-surface flues of like dimensions.

(30) *Lafitte's patent flux plates*, Fig. 72.—Believing that it is not easy to spread the borax or other flux used in welding uniformly over the surfaces to be welded, Lafitte uses his flux not in powder but in a thin sheet or wafer, C, Fig. 77. This wafer is given consistency by incorporating within it a very thin wire gauze netting with large meshes. In other words, he prepares his welding plates by covering both sides of a thin sheet of wire gauze with molten flux, which fill the meshes as well. The wire, whose volume is trifling, of course unites in welding with the pieces of iron welded.

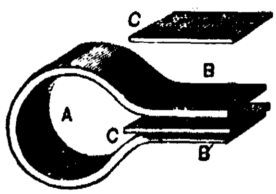


FIG. 72.—Lafitte's flux plates.

Many very important establishments are said to use these sheets, which certainly seem simple and convenient. A trial made with one of them for a member of the jury gave excellent results.

(31) *Self-skimming foundry ladle.*—Fig. 73 shows a foundry ladle with a partition designed to keep the slag back, so that it may not run into the molds with the metal and injure the castings. The names of thirty-nine establishments which use it, some of them, such as Vickers, Hadfield, and the Steel Company of Scotland, really eminent, are given. It is a clever adaptation of the so-called syphon tap used in copper and lead smelting to the needs of the iron foundry.

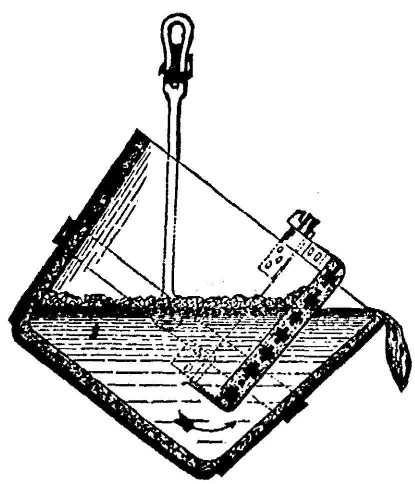


FIG. 73.—Self-skimming foundry ladle.

SPECIAL REPORT

ON

MACHINE TOOLS.

CLASS 53.

BY

PROF. JOHN H. BARR.

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SPECIAL REPORT ON MACHINE TOOLS.

By Prof. JOHN H. BARR.

(1) The United States exhibits of machine tools at the Paris Exposition of 1889 were not numerous, but were generally conceded to be excellent in workmanship, convenience of manipulation, and general design. All of them would bear comparison with similar displays from other countries, and some of the tools shown by our makers were quite universally acknowledged to excel those of all competitors. The only regret that an American need feel is that many other builders, capable of equally good work, were not represented.

Tributes to American mechanical skill were frequently expressed by both British and Continental engineers, and far more eloquent than words of commendation was the imitation noticeable throughout Machinery Hall.

But more is to be learned from a consideration of the features in which others surpass us than in contemplation of our own excellence, and it has, therefore, been the policy in writing this report to pay more attention to the leading European designs than to the well-known products of our own manufacturers.

Owing to the cheapness of labor it is not surprising that, in many fields, labor-saving machinery has been less generally applied on the continent of Europe than is common in the United States; yet, in some lines, the European manufacturers have carried the development of such machines very far, and particularly in the application of milling processes to bolt and nut machinery, and the process of sawing to the working of metals.

The American milling machine has made an ineffaceable impression on European practice; but in the use of milling machines for very heavy work, and for the reproduction of peculiar shapes, we can doubtless learn much from the study of the designs brought out in Europe. Several of these designs are treated more fully in the following notices, and it is unnecessary to give specific examples here.

The employment of band saws for metal working is now a well-established feature in manufacture abroad, and several establishments in Great Britain and the Continent now meet the demand for sawing machines designed for this kind of work.

Taken as a whole, the exhibits of this class did not present a great deal in the way of novelty.

(2) Bariquand & Sons, 127 Rue Oberkampf, Paris, made one of the finest and most attractive exhibits in this class. It included drilling machines, milling machines, lathes of various kinds, and several special tools, all of the highest order of workmanship and finish. The sensitive drills and other drill presses embrace no features of special interest except the nicety of construction. The latter have automatic feeds, and all have hardened and ground bearings. A combined drilling and tapping machine has automatic stop and return mechanism for the arbor.

A vertical milling machine, Fig. 1, has the spindle held rigidly in its vertical position, securing greater accuracy than could be expected in the adjustable spindles of the combination type so common in Europe. The table has automatic movements in two directions and the feed mechanism may be instantly disengaged at any point of its travel. In addition to the ordinary vise and dividing head, this machine is fitted with an attachment for dressing circular work (the hubs of cranks, etc.), a special head for holding bolts in facing the heads, and a small table with two motions controlled by a templet for copying work. In this machine the spindle is driven directly by a belt running over guide pulleys; but two larger sizes are made in which a cone and back gears are supplied, a pair of bevel gears communicating motion to the vertical spindle. The back gears are of the twisted form, which is much used in European practice in place of spur gearing.

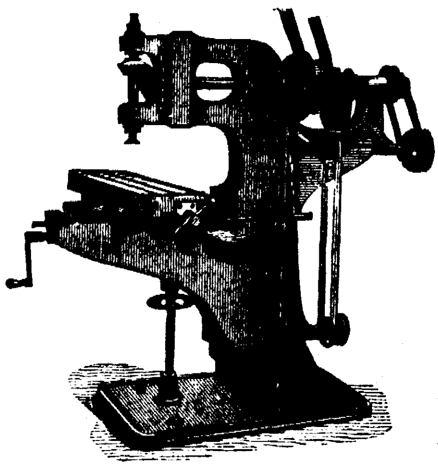

FIG. 1.—Upright milling machine, by Bariquand & Sons, France.

The horizontal universal milling machine built by these makers is very similar to the Brown & Sharpe machine.

A small precision lathe for tool work, instrument making, or other light work requiring great accuracy has two lead screws, one of which is reserved for making other lead screws, measuring-screws, or standards, only. This screw is made with great care after the standard metric scale of the Conservatoire des Arts et Métiers. Automatic disengaging mechanism is provided for the feed motion.

A hollow spindle turret-head screw lathe, admitting bars up to

1 9-16 inches through its spindle, has six tools. The turret mounting has five motions—a transverse motion of the whole, a circular motion, a longitudinal motion, a smaller transverse motion with micrometer stops, and the rotation of the turret on its center. In addition to the turret there are a screw-cutting slide and a cutting off tool. The back gears are engaged or disengaged by means of a cup friction on the cone, controlled by a hand lever, so that the speed of the spindle can be instantly changed in the ratio of one to six without shifting the belt or stopping the lathe.

(3) One of the most interesting special machine tools seen at the Exposition was the machine for fluting bayonets, etc., by which four converging flutes are cut at once on a taper shank. Four milling cutters placed opposite each other in pairs, and rotating in vertical planes, are connected by splined rods and bevel gearing so that they all approach or recede from the centers together. The blank form, with its axis vertical, is placed in the intersection of the planes of the cutters; and as the cut proceeds, the piece to be cut is given a vertical feed while the cutters are fed toward the center in a ratio corresponding to the taper. The four cuts oppose each other and thus do not tend to spring the piece.

(4) E. & Ph. Bouhey fils, 43 Avenue Daumesnil, Paris, made one of the largest exhibits of machine tools in the Exposition. It consisted almost entirely of heavy tools; milling machines (both horizontal and vertical), slotters, pulley and gun lathes, shearing machines, planers, drill presses, etc.

A massive radial drill press, built especially for Schneider & Co., of Creusot, has the following dimensions:

	Meters.	Inches.
Vertical travel of radial arm	1.200	=47.23
Vertical travel of drill spindle	0.500	=19.68
Maximum height of spindle above base	2.380	=93.68
Minimum height of spindle above base	0.680	=26.76
Horizontal travel of head on arm	1.700	=66.91
Diameter of spindle	0.100	= 3.96

At the base of the column there is a driving cone with five speeds, which transmits the power to a vertical spindle in the interior of the column, whence, by spur and bevel gearing, it is carried to the drill spindle. The column swivels on the base plate; the arm rotates about its own axis on the column through an angle of 60 degrees, and the spindle head swivels on the arm through an angle of 150 degrees. The latter movement is by hand but the others are automatic. The variety and range of movements avoid much trouble in moving and resetting the work.

(5) Machine for planing and chamfering the edges of plates. Length of travel 7 meters (23 feet). Vertical travel of head 0.5 meters (19.7 inches). The plate to be chamfered is held on a flat

bed, but is not clamped down along the edge to be dressed, as is ordinarily done. By any method of clamping the sheet down, the irregularities almost inevitably occurring are only partially taken out; and as the planer tool travels in a straight line, the result is that the edge is unevenly chamfered. In the machine under consideration, the tool is carried by a counterbalanced arm, and two jaws (one above the sheet and the other below it) travel with the tool along the ways. These two jaws follow the irregularities of the plate, and cause the tool on the counterbalance arm to take the same course; consequently, the chamfer is uniform throughout the length of the plate, regardless of irregularities. For planing a vertical face, the arm is clamped firmly to the traveling carriage, and vertical motion takes place only by the regular feed. The machine is then similar in its action to any side planer, the suppression of a long plate clamp permitting work of different kinds to be held on the table.

One other tool of a special nature is worthy of mention, namely, a lathe for turning cannon. Height of centers 605 millimeters (23¾ inches), distance between centers 7 meters (23 feet), length of bed 10.13 meters (23 feet 2¾ inches). There are two carriages, and a heavy taper attachment at the back, for giving the taper to the barrel, similar in principle to the Slate, and other familiar attachments, used on our tool lathes.

(6) Dandoy-Mailliard, Lucq & Co., Maubeuge, northern France, made one of the largest and most varied exhibits of machine tools to be seen in the Exposition, including lathes, planers, shapers, slotters, milling machines, drill presses, punches, shears, and other tools for the machine shop, blacksmith shop, and boiler works. The machines shown were generally strong, heavy, and convenient; but the finish was not of the highest class, the patronage of this firm being mainly from that class of small manufacturers, so numerous on the Continent, who demand a serviceable tool and do not exact the greatest precision and finish. Of the tools shown, few exhibit any great innovation in design or construction. One of the most noticeable was a large vertical-spindle milling machine with the planer type of bed and table. This seems to be a very serviceable tool for the heaviest of plain work, and represents very well a class of the machines extensively used in Europe for doing large work by the milling process. In this class of machines, more than any other perhaps, have our friends across the water surpassed us.

(7) A novelty in the way of a combined table and vise for a drill press is shown by this firm. A round flat table, with slots, as in the ordinary drill-press table, is split along a diameter, and the two semicircular plates so formed act as jaws of the vise. The inner edges have hardened steel plates, and these jaws swivel; when closed the two jaws can be rotated as a common drill-press table.

(8) Frey & Co., 23 rue de l'Atlas, Paris, exhibited a large combined milling, boring, and drilling machine. It is built for work on large and heavy pieces which are, from their nature, very difficult to mount on a moving table. The design, therefore, differs materially from the common construction. This tool resembles in a very general way the large boring machine brought out by Sellers & Co. some years ago, in which the work is secured to a slotted bed plate, and the working head is moved to a suitable position on the plate for operation. In the machine under consideration the work is secured to a solid stationary bed, and the spindle housings are carried on a saddle by two vertical columns. The head may be given rectilinear feeds in any of three directions at right angles to each other, vertical, transverse, or longitudinal. The former is given to the saddle on the column, the latter two are motions of the column itself on the bed. The spindle carries two tools or "fly cutters" on an arm, or it will take the ordinary forms of milling cutters, a boring bar, or a drill.

In addition to the stationary bed for holding the work, already referred to, there is a circular table, provided with a rotary feed by means of a worm and wheel, thus extending the range of the machine.

Four sizes of this machine are built, as shown by the annexed table:

No.	Longitudinal.		Vertical.		Transverse.		Prices.	
	Meters.	Feet and inches.	Meters.	Feet and inches.	Meters.	Feet and inches.	Francs.	Dollars.
1	2.000	6 6.74	0.750	2 5.5	0.450	1 5.7	7,000	1,400
2	2.500	8 2.42	1.000	3 3.4	0.900	2 11.4	10,000	2,000
3	3.000	9 10.11	1.150	3 9.5	1.000	3 3.4	15,000	3,000
4	4.000	13 1.48	1.800	5 10.9	1.300	4 3.2	22,000	4,400

The above prices given in dollars are only approximate. This machine, as will be readily seen, has a good range. The details are very conveniently arranged and it would be a useful tool for many shops. The workmanship, though fair, would perhaps not meet the most exacting demands.

(9) *P. Huré, 8 rue Fontaine au Roi, Paris.*—European builders make many forms of milling machines in which the spindle can be used in either a vertical or a horizontal position, and also many milling machines for reproducing from a template, or for making milling cutters in which the teeth follow the contour of the cutter. While no machines of these types can be as rigid as the standard form of milling machines commonly used in the United States, they are well adapted for certain kinds of light work. One of each class exhibited by Huré (see Fig. 2) will be described, though the variety of

such machines is so great that no one style can be considered as representative.

The combined vertical and horizontal machine has a longitudinal travel of 250 millimeters (9.84 inches), a transverse travel of 1 meter (39.36 inches), a vertical travel of 250 millimeters (9.84 inches); the distance from the vertical arbor to bed is 260 millimeters, allowing it to work to the center of a circle 520 millimeters (20.56 inches); weight, 1,300 kilogrammes (2,866 pounds); price, 3,400 francs ($680). A strong vertical column terminates in a flat circular disk or plate at about the height of the table. Upon this the head stock, the bottom of which corresponds in shape with the top of the post, stands. A strong bolt passes up through the center of the column and forms a pivot around which the head stock may swivel, and by means of which it can be clamped firmly at any position in a horizontal plane. This head stock carries two cutter spindles, one horizontal and the other vertical, the latter running in bearings in overhanging brackets. There is a horizontal countershaft at the base of the machine, and a belt runs from a cone on this shaft to one on a second countershaft, which is at the end of a swinging frame which in turn swings about the first shaft as an axis, while the spindle-driving belt passes from this secondary shaft over guide pulleys to the pulley on the end of the vertical cutter spindle when the vertical spindle is in use. To convert into a horizontal machine, the head is turned through a horizontal angle of 90° after loosening the clamping nut, the belt is run directly to the pulley on the end of the horizontal cutter spindle from the secondary shaft, and the swinging arm is dropped until the slack in the belt is taken up, in which position the arm is clamped fast to an arc provided for the purpose. The change is readily made and the design probably secures as stiff a tool as any of these convertible machines.

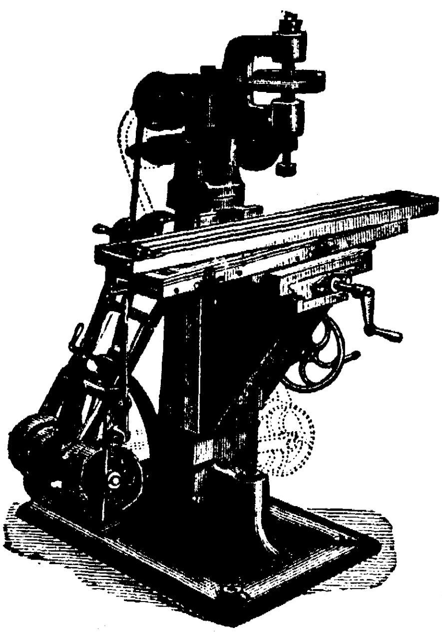

FIG. 2. Milling machine with vertical and horizontal spindles; P. Huré, France.

(10) The machine for reproducing or forming cutter teeth to template has a head with a horizontal arbor for carrying the blank. The cutting arbor is horizontal and is on a block which slides freely on the vertical arm of an angle iron. The other arm of this angle iron slides through a horizontal dovetail guide, clamped to the bed of the machine, the two giving the spindle any position, in a plane at right-angles to its axis, within its range. To the back of the arbor block, a long hand lever is attached by a universal joint. The

rear end of this lever is pivoted to the frame, also by a universal joint, and it has a handle at the front. This hand lever is provided with a conical guide roller which can be brought to bear upon the fixed template, serving as a guide. The driving belt runs directly to the countershaft, the latter having a radial balance compensating lever to take up the slack in the belt as the arbor is moved, thus keeping a constant tension on the belt. In operation the workman takes hold of the handle, after having started the machine, and by bearing against the template as he follows its contour with the conical roller its form is copied and reduced. If the cut is too heavy to be taken the first time, a second uniformly deeper cut can be taken by simply sliding the conical roller in the direction of its axis, making a part nearer the apex run on the template. This machine is sold for 1,100 francs ($220).

(11) Hurtu & Hautin, 54 Rue de Saint-Maur, make an exhibit of small tools of a high order. Many other houses had more and much larger tools in their spaces, but few equaled these in refinement of construction.

The small precision lathe, small milling machines, and drill presses are excellent tools for light work of the finest class, and the machine made for straightening taps, drills, reamers, arbors, etc., after hardening, is a simple contrivance that it would seem could be introduced with good results in many shops.

The precision lathe mentioned above is made with a bed to be mounted on a bench. It has a height of centers of 120 millimeters (4.72 inches), or a swing of 9.44 inches, and admits 400 millimeters (15.75 inches) between centers, the bed being 1.1 meters (43 inches) long. This machine is intended for plain work, but great care is taken in every detail to eliminate or reduce to the minimum all sources of error.

The carriage is weighted instead of being gibbed, and the rest has two motions, transverse and longitudinal. The carriage is attached to the lead screw by a solid nut, the screw lying between the two flat ways of the bed.

The screw is driven from the spindle by a short shaft and gearing, and the automatic feed is stopped by throwing out a clutch. A hand wheel on the screw (at the tail-stock end) serves as a hand feed in place of the ordinary rack feed.

Two types of milling machines, vertical and horizontal spindles, were represented by two sizes each. The smaller size machines have a longitudinal motion of 400 millimeters (15.75 inches), and a transverse motion of 105 millimeters (4.1 inches), while the larger machines have corresponding travels of 700 millimeters (27.55 inches), and 210 millimeters (8.2 inches), respectively. The small machines are mounted on strong iron benches, either singly or in pairs, the large machine being of the ordinary pillar form. Movable stops with micrometer adjusting screws are provided to determine the limits of feed in all directions, and the automatic feed motion is provided with disengaging mechanism. The spindles are of hardened steel, afterward ground.

(12) The machine for straightening taps, reamers, arbors, etc., shown by Fig. 3, consists essentially of a short, strong bed, carrying two movable heads with centers, and a bracket or arm overhanging the ways at the middle of the bed.

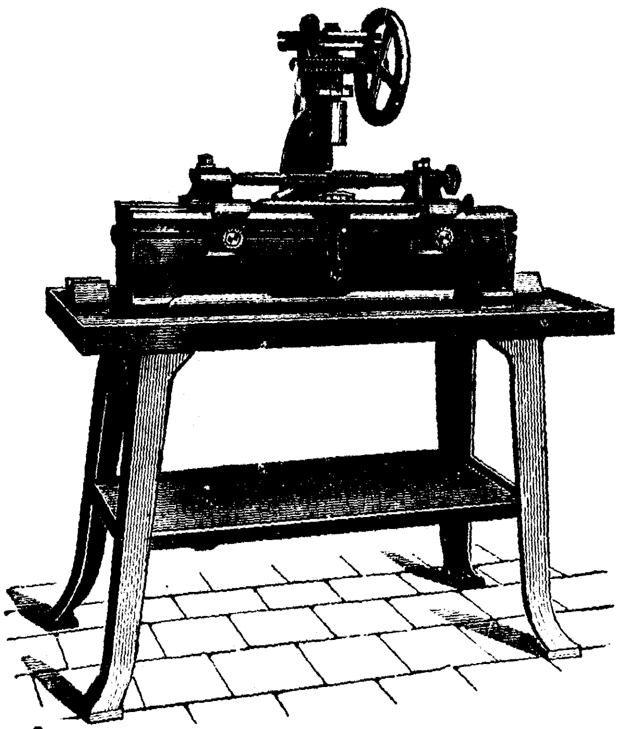

FIG. 3.—Machine for straightening taps, etc., by Hurtu & Hautin, France.

This arm has a vertical, differential screw which can be brought down upon the piece to be straightened. The screw has at its upper end a hand wheel with holes or notches at equal intervals, over which a click plays. The nut has a screw thread of a different pitch on its outer surface, with a worm wheel attached to the top, into which an endless screw gears. The piece to be straightened is placed between the centers (the amount of the distortion having been previously determined); the screw is then lowered until the piece is sprung a little more than enough to straighten it, and a gas jet is applied below it to heat it up. When cool the work is removed and examined, and if not rectified the operation is repeated until the result is satisfactory. For light work the hand wheel and simple screw alone are used, each one-tenth of a millimeter (0.004 inch) motion of the screw (or flexure of the piece) being indicated by the passage of the space between two adjacent notches under the click.

In heavier work, where sufficient force could not easily be applied by the simple screw, the tangent screw is brought into play, an index on the rim of the nut indicating flexure to one-twentieth of a millimeter (0.002 inch). The endless screw and its hand wheel move up and down with the nut, so that it is in gear and available for use at any position. A small block of brass, to fit the flutes of the reamer, tap, or drill being operated upon, may be placed under the end of the screw to avoid any injury to the parts exposed to pressure. Arbors up to 50 millimeters (2 inches) in diameter may be straightened with this machine. An accessory to the machine indicates the amount of distortion in the piece, and can also be used to determine the eccentricity of a piece which is out of round. Two flat guides or ways on the front face of the bed support two movable centers, between which the piece is placed. A small spindle, sliding in a vertical guide, has a foot at its upper end which is held against the work by a light spring, and the lower end of this spindle presses against the horizontal short arm of a bell crank, the longitudinal arm of which is a needle playing in front of a graduated arc. The brackets supporting this spindle, with its attachments, is traversed along the length of the piece; the spring holding the foot against the work, so that the foot moves up and down with the irregularities in the piece under inspection, and the needle indicates these irregularities, its movements being twenty times the actual deformation. For detecting and determining the eccentricity, or the amount of spring, the piece is revolved on its centers by hand, the readings of the needle being noted and the highest points marked, to aid in the straightening process.

In addition to the machines described above, a very complete line of milling-machine cutters, drills, etc., were shown in a great variety of forms, and of fine workmanship.

(13) A machine for fluting small twist drills, in which both flutes are cut at once, is a very well-arranged tool.

Two dovetailed guides on a vertical column carry sliding heads and cutter arbors, one of the cutters of the latter being parallel to each of the two flutes to be cut. One of these cutters works below and the other above the drill, and they are driven by small round belts. By this means the slender drill is relieved of the pressure due to the cut and the two flutes are made, in the line required, at one cut. The sliding heads allow the arbors to be adjusted for different sizes of drills or diameters of cutters. These machines are all intended for a high class of small work, and seem to be admirably adapted for the purpose.

(14) A. Janssens, 10 Rue Alibert, Paris, exhibited several machines, as the agent of George Richards & Co., of Manchester. Two of these may be mentioned: a side planing machine, the design of which is so well known in this country as to require no description; and a forcing machine for mandrels. This latter machine consists

of two upright columns having an adjustable table carried by clamp sleeves sliding on them, by which the table can be secured at any height. A cross-head connecting the columns at their upper ends has bearings for a horizontal shaft, and a guide for a vertical ram, extending downward from the underside of the shaft. The horizontal shaft has tight and loose pulleys at one end for driving it, a balance wheel at the other end, and over the ram an eccentric of short throw which gives to this ram a rapid reciprocating motion of one-eighth inch or less. The pulley, or other piece, in the bore of which the arbor is to be forced, is mounted on the table below the ram. The arbor is entered and the ram, by its gentle taps, forces it down. The ram is terminated by a long screw at its lower end, with a hand-wheel attached, and by running this screw down the arbor can be followed up as it enters the bore. The force of the blow is easily regulated by the amount of feed thus given. The machine will receive a piece 24 inches in diameter. The ram makes from 350 to 400 vibrations per minute. Larger sizes are made also. This machine may be employed for drifting out square holes, forcing pieces made for a driving fit, etc., as well as for the purpose for which it is especially designed.

(15) Jules LeBlanc & Co., 52 Rue du Rendezvous, Paris, displayed a large machine, on the Vincent system, for forging bolt blanks, rivets, etc., which was quite notable. The die is held in an anvil at the base of the machine, between the two uprights which constitute the frame. Above this die is a multiple thread screw of steep pitch, surmounted at its upper end by a horizontal conical friction wheel. A horizontal shaft above this carries two other friction cones, and a small end motion of this shaft causes one or the other of these cones to engage with the cone on the screw ram, by means of which the screw is alternately raised and lowered with considerable rapidity. The lower end of the screw carries the die for forming the head, and the momentum acquired in running the screw down is expended in upsetting the head. The action is automatic, the operator only inserting the stock and removing the finished piece, the machine itself starting it from the dies after the blow. The travel of the screw is easily adjusted, thus controlling the force of the blow. The capacity is from twenty to thirty pieces per minute. Five sizes are made for bolts from 6 to 40 millimeters in diameter ($\frac{1}{4}$ of an inch to $1\frac{9}{16}$ inches) and from 100 to 250 millimeters (4 to 10 inches) long. The prices range from 1,000 to 3,500 francs ($200 to $700). Similar machines for nuts are also made.

(16) A machine shown in this exhibit, for chamfering nuts, is very simple, and seems to be effective. A cone drives a spindle through single gears, and a revolving cutter head on this spindle carries a plug center just large enough to easily enter the hole in the nut. Two cutters inserted in this head from its back face, passing through

its flange and directed toward the axis, terminate in cutting edges at opposite sides of the plug center, the angle of the cutting edges being that of the desired chamfer on the nut. The tail block has a socket for receiving the nuts, and a hand crank feeds this tail block toward the head stock by means of a rack and pinion. The workman puts the nut in the socket with one hand, and brings the tail block up by a turn of the crank; the center enters the nut, holding it central, and the two revolving cutters chamfer it almost instantly. This machine takes nuts up to 35 millimeters (1⅜ inches), and will turn out, it is claimed, thirty per minute. Price, 700 francs.

A large circular shearing machine, or more properly scissors, as the action does not partake of the nature of shearing, involves a principle not in ordinary use. A strong frame, not unlike that of an ordinary punching or shearing machine, carries two horizontal shafts, geared together at the back ends and bearing two disks, with edges beveled both ways, at the front ends. The two conical frusta forming the edges of these disks make an angle of about 60 degrees with each other at their junction. The upper shaft has a vertical adjustment. The cutting edges of the two disks are exactly opposite (in the same plane), and the action on the sheet passing through is to groove it on both sides. The sheet can easily be so guided as to follow any desired path, straight or curved; and if grooved deeply enough can be readily broken along the grooves formed.

This machine will cut metal up to 20 millimeters (0.78 inch) in thickness. The disks are 510 millimeters (20 inches) in diameter. It will cut to the center of a sheet 1,200 millimeters (47 inches) wide. Its weight is 7,200 kilograms (15,800 pounds). Price, 9,500 francs ($1,900). These makers build many other forms of shearing and punching machines, bolt machines, etc.

(17) C. Lomont, of Albert, Somme, displayed several good tools, few of which, however, are of special interest. A planer was shown with proposed attachments for milling and grinding; the former is attached to the planer cross-head, the vertical milling spindle being driven by bevel gearing through a horizontal shaft with a cone at the end. The grinding head carries on a vertical spindle an annular grinder, similar to that described in the notice of the display of Ant. Fetu-Defize & Co. The grinder is driven at a high speed through friction cones. The planer itself differs in no important particular from the ordinary form.

A slotting machine, in which the head can be set at any angle in a vertical plane by clamping bolts, is a convenient tool, and well made, but aside from this feature, by which an inclined stroke as well as a vertical one may be obtained, it is of the ordinary type.

(18) E. Nury, Tarnos, has a process for punching plates, rails, or various forms of profile irons, when it is required to have many pieces, with several holes similarly spaced. A box is made to

fit the general contour of the metal to be operated upon and open at the ends. The covering plate to this box is a jig, with holes for spacing and guiding the punches. Below these holes in the jig there are corresponding holes in the box to allow the punches and plugs to pass through. The punches are simply short, slightly hardened. tapered rods, of a cross section agreeing with the holes to be punched (which need not be circular), and in operating, the bar, plate, or rail is put in place, the punches inserted in the jig holes (one punch in each); the whole is then put under a press and the punches are forced through. In addition to the boxes for these special profiles, a "universal" box is supplied for use in certain kinds of more general work.

(19) Panhard & Levassor, 19 Avenue d' Ivry, Paris, exhibit several machines for sawing cold metals. These are of three classes: (*a*) Ribbon or band saws, (*b*) Circular saws, (*c*) Jig saws, or reciprocating saws.

The most interesting and important of the machines in this display are those of the first class; consequently these will be considered in fullest detail. It is in this class that Panhard & Levassor have introduced most largely their special constructions, which are of a type that is probably not familiarly known in the United States.

Band saws were used as early as 1866 for sawing metals, and this house had a machine specially designed for such work, at the Maritime and Universal Exposition at Havre in 1868; but it was not until six or seven years later that they became adopted as a part of shop equipment, the first large establishment into which the new feature was introduced being the shops of the "*Chemin de fer du Midi.*"

In 1878 many improvements had been made, and these makers exhibited, at the Exposition of that year, a band saw for cutting iron, capable of sawing metal in various forms of large dimensions. This saw was purchased by the "*Compagnie des Chemins de fer de l'Ouest,*" and soon after that another was ordered by the same company.

Since 1878 improvements have been repeatedly made, and new types have been produced to meet special requirements from time to time.

The machine in itself is quite simple, consisting essentially of a strong frame, carrying two pulleys, on which are stretched the blade of the saw, the general appearance very much resembling an ordinary band saw for wood work. The speed of the pulleys varies with the nature of the metal. A table is supplied for supporting the work, the latter being fed by hand by a carriage driven through a screw and hand wheel or automatically, according to the nature of the work and size of the piece operated on.

The saw blades, in order to be used most efficiently, require special properties both in quality of material and in the manufacture.

Their great hardness prevents giving them much set, and it is therefore necessary to make them thicker at the teeth than at the back. The thickness of the blade is a matter of no little importance, and it varies with the diameter of the carrying pulleys. If the blade is too thin, it can not resist sufficiently the strain brought to bear by feeding the work against it; if, on the other hand, the blade is too thick, the constant bending soon fatigues the metal and it breaks.

A thickness of 1.3 to 1.6 millimeters (0.05 to 0.06 of an inch, or one-twentieth to one-sixteenth of an inch) is advised for blades running on pulleys of 1 meter diameter (39.5 inches, about); and for pulleys of 1.25 meters (49.25 inches, nearly) a thickness of 1.8 to 2.2 millimeters (0.07 to 0.08 of an inch) is recommended; the ordinary thicknesses are 1.4 millimeters (0.055 inch) for the first of the above size of wheels, and 2.0 millimeters (.078 inch) for the second size.

The pitch of the saw teeth is also a matter of importance. The spacing should, so far as possible, vary with the thickness of the work being cut.

For ordinary work the pitch runs from 3 to 6 millimeters (0.12 to 0.24 inch); but if the cut is 40, 50, or 60 centimeters in thickness (15.6 to 23.6 inches), the pitch may be 8, 10, or even 15 millimeters (0.31, 0.39, or 0.59 inches).

Less depends on the breadth of the blade; it should not be too great. If a saw cuts well it will penetrate the metal without the application of excessive force, making it unnecessary that it should possess great transverse rigidity; on the other hand, an increase of breadth involves, almost necessarily, an increase of thickness, which implies additional cost in manufacture and diminished durability. For straight cuts, 30 to 35 millimeters (1.18 to 1.38 inches) for the smaller machines, and 40 to 50 millimeters (1.56 to 2 inches) for the larger ones, are convenient widths. For cutting out curved outlines the width of the blade allowable depends on the radius of the curve.

The speed of the saw should vary with the nature of the material, being reduced as the metal is harder and increased for softer metals. These changes of speed, within reasonable limits, should be provided for in designing the tool.

For hard steel a linear speed of 40 to 45 meters (130 to 146 feet) per minute may be used. For soft steel, iron, or hard bronze this speed may be 55 to 60 meters (180 to 197 feet); for ordinary brass or bronze, 70 to 75 meters (229 to 246 feet) per minute; and for copper or zinc the speed may be much greater. For working these last-mentioned metals, however, machines different from those used with the harder materials would usually be employed.

The sharpening of the saws is of the greatest importance, and little can be expected from a saw poorly sharpened or improperly kept up. Up to 1883 the saws were filed by hand, an operation which, owing to the hardness and great number of teeth, was very laborious and expensive. It is now done by a special automatic machine, requiring little attention and costing a trifle only for the emery wheels used.

Besides the saw-sharpening machine exhibited by Panhard & Levassor, there were a great many others at the Exposition.

DESCRIPTION OF MACHINES.

Band saws.

Model A. N. (shown by Fig. 4).—This model has a frame in one piece, supporting two carrier sheaves each of 1 meter (39.37 inches) diameter, and a table on which the work to be operated upon is placed.

The lower sheave is driven with a slow rotation speed, by means

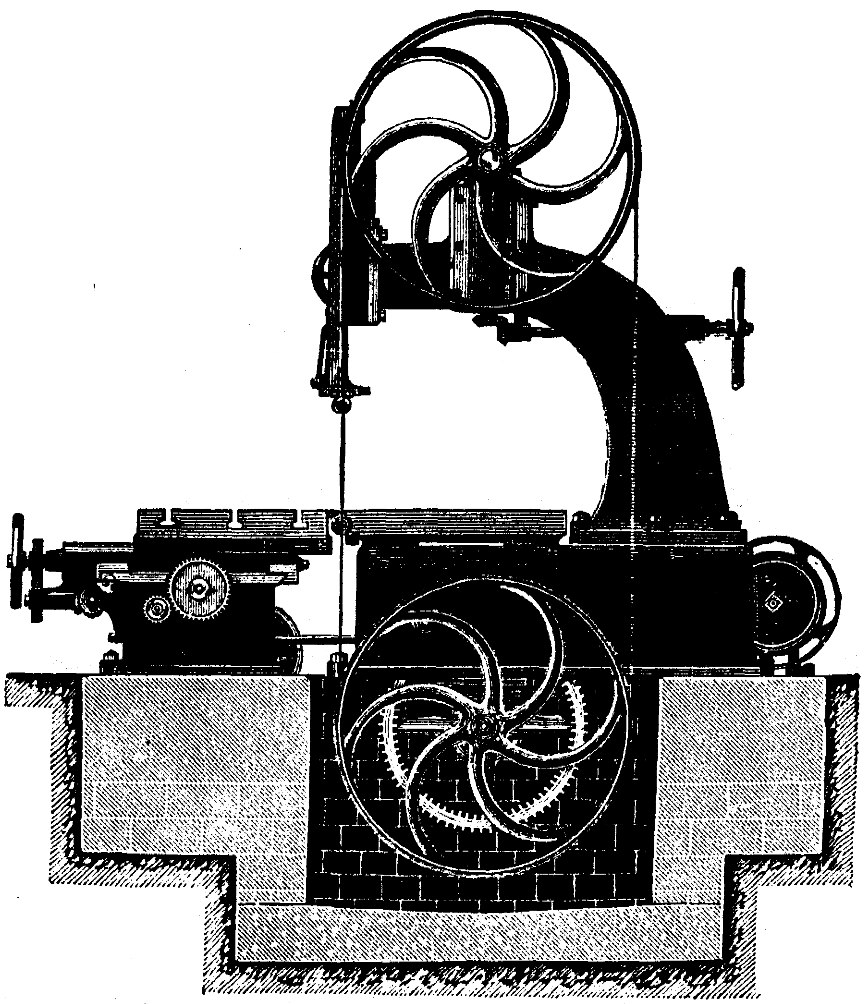

FIG. 4.—Panhard & Levassor's large band saw for metal; model A. N.

of a gear and pinion. The upper sheave is carried on a tightening block, by means of which the tension of the blade is adjusted, precisely as in an ordinary band saw for wood-working.

The blade when stretched on the sheaves is supported against the thrust of the cut and kept in line by two special guides, one below the table's surface and the other above, carried by an adjustable foot, thus allowing the blade to be backed up close to the cut, where the strain is applied to it.

The part of the table toward the frame (inside) is plane and stationary, while the outer portion has a carriage, movable in two directions at right angles with each other. The longitudinal movement is automatic, and has several variations of speed to suit work of different thicknesses and hardness.

A countershaft is provided, and by means of cones on it and on the driving spindle, the saw may be given a speed to correspond to the nature of the metal.

This machine will saw up to a thickness of 25 centimeters (9.8 inches), and is intended for railroad shops and general machine shops.

Model A N F.—This model has the same dimensions as the preceding, but has the plane stationary table only, the work being fed up and directed by hand. It is especially designed for sawing soft metals, as zinc, copper, etc. For this class of work a higher speed of saw is advisable, and the sheaves are driven directly from the line shaft; but it is also adapted for cutting harder materials, and to this end an intermediate arbor is provided for securing reduced speeds.

Model A U.—This model is similar to the first mentioned, but is much stronger and larger. The carrier sheaves are 1.25 meters (49.1 inches) in diameter, permitting the use of thicker and stronger saws, and consequently adapted for larger work, or capable of doing the same kind of work with increased speed.

In this machine the carriage is placed on an independent bed, making it possible to give it any desired size and range of movement. Ordinarily the longitudinal movement, which is automatic, is 1.0 meter, and the transvere movement is 50 centimeters.

The speed of the saw and the feed of the table may each be changed, by means of cones, to suit the work.

This machine will cut through 60 centimeters (23.4 inches) in thickness. It is built for shops manufacturing large work, as railroad shops, arsenals, etc.

Model A T.—This model has sheaves 1 meter in diameter. It is provided with a large solid table on which the work is placed.

The work may be fed to the cut by hand freely, or be forced up by a hand wheel. This machine is designed mainly to cut shapes, such as angle irons, T and I beams, channel irons, etc. In work of this class the hand feed is very advantageous, the workman being able to proportion the feed to the varying thickness of the work.

For bridge work, naval construction, etc., this model is particularly well adapted.

Model A P.—This is a type differing quite radically from the foregoing in some respects. In this model the large double bed is stationary, carrying between the two parts two horizontal ways, on which the saw frame proper slides. The work is held on the stationary beds, and the *saw is fed* into the cut.

For cutting up stock to a standard length (as cross-beams or other such material) both ends may be cut at once, the ascending edge of the saw cutting as well as the descending.

In trimming the ends of long, heavy beams or shafts the difficulty of supporting the outer end on a traveling carriage is obviated by this construction.

For advancing the saw into the cut a double series of speeds is provided. One series is used for thick parts of the work, and the faster feed is employed for the thinner parts. The advantage of this in sawing **I** beams and other profile irons will be apparent.

(20) *Automatic machine for sharpening saws.*

Model V S.—As before stated, the sharpening of the saws for cutting metal is a most important element in the efficient working of the machine.

Owing to the great number of teeth in a band saw an automatic sharpening machine has become necessary wherever band saws are extensively used, and many such machines, all of the general type well known in this country, were exhibited at the Paris Exposition. The hardness of the blades used for sawing metal makes the employment of such an auxiliary even more important than in the case of wood-working saws.

The machine built by Panhard & Levassor uses an emery wheel driven by a belt above, and is composed essentially of a frame, a balance lever carrying the emery wheel, a feed pawl which moves the saw ahead at each stroke of the lever, a clamp for holding the blade, and two sheaves on which the saw is carried. The movement of the emery wheel is controlled by an adjustable angular guide, which determines the form of tooth. For coarse-pitch saws the upper and under sides of the tooth are ground separately, while for fine-tooth saws but one face is ground.

A device is also attached for giving the "set" to the teeth, which attachment may be operated at the same time the grinding is progressing. A clamp closes at each stroke of the lever, and two small alternating hammers, placed on opposite sides of the blade, set the teeth.

It is claimed that one of these machines will keep the blades of five or six machines in order, and that a workman can give it the necessary attention and not interfere with his sawing.

The cost of emery wheels (special make) is small.

(21) *Circular saws and jig saws for cold metal.*

Circular saws.

Model F S.—For certain classes of work the circular saw is well adapted, but its range is very limited as compared with the band saw. It is best fitted for such work as "I" beams, channels, etc. The circular saw is less efficient than the band saw in two respects: First, because it will turn out less work in a given time, and second, because the saw is necessarily thicker, requiring greater power to drive it.

This type of machine, as made by Panhard & Levassor, takes a saw of 50 centimeters (19.68 inches) diameter, and will cut stock up to a thickness of 15 centimeters (5.9 inches). It has a table with two motions. The feed is automatic, and the other motion is given by a hand crank. The latter is very convenient in setting work, and permits, within certain range, taking successive cuts without resetting the stock.

Alternating or jig saw for cold metals.

Model E T. Shown in Fig. 5.—This machine is intended for light work, such as cutting out gauges, or ornamental sheet-metal work.

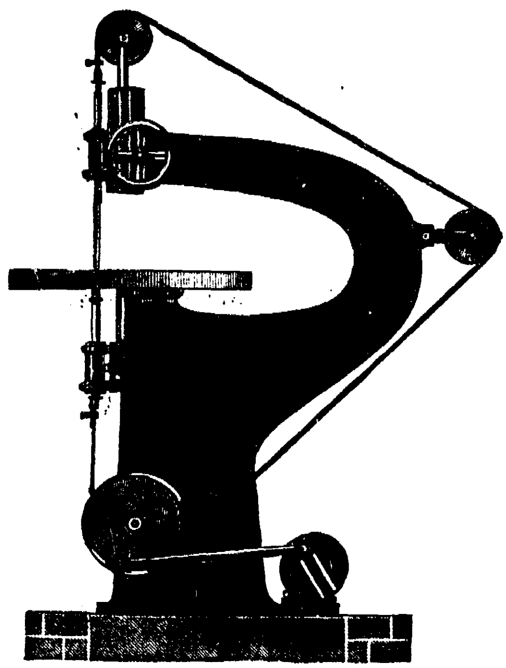

Fig. 5.—Jig saw for metal; Panhard & Levassor.

The blade is stretched by a band running over three pulleys, one at the top of the frame, one at the bottom, and a third at the back. The first two give the saw its vertical position and motion, while the third holds the tightening belt back, thus increasing the swing, or space for the work.

The reciprocating movement is obtained in a manner plainly shown in the cut.

A drill may be attached to the arm of the frame which overhangs the table.

In point of speed this machine does not compare with the band saws, but for cutting in the interior of a plate it is, of course, the only method possible.

(22) E. Prétot, 11 and 13 Rue des Immeubles Industriels, Paris, displayed a very rigid gang milling machine for finishing the sides of nuts. It is well designed for this work, and it is asserted that one man can attend two of these machines, turning out 1,000 three-fourth inch nuts in 10 hours. It has two horizontal spindles (one directly above the other), each carrying three milling cutters. A

low horizontal bed has attached to it two knees, either of them supporting one end of each spindle by adjustable saddles, the driving gear being at one end of the bed. A slotted table has a motion across the bed, and this table supports on arbors between centers the three strings of nuts to be finished. All of these nut arbors have, at the front end, worm wheels gearing in a long screw, by means of which they may be rotated to give the proper angle between the faces of the nut. The cutter spindles are adjusted so that the distance between cutters equals the diameter of the nuts, which in being passed through have two opposite faces cut at once; nuts for bolts from 8 to 30 millimeters ($\frac{5}{16}$ to $1\frac{3}{16}$ inches) can be cut on the No. 1 machine, and from 10 to 50 millimeters ($\frac{7}{16}$ to 2 inches) on the No. 2 machine. Each of the three arbors will hold ten three-fourths inch nuts. Nuts or bolts of two, four, six, eight, or twelve faces can be cut on this machine.

A convertible, horizontal, vertical or inclined spindle milling machine is built by this maker. The column of this machine is surmounted by a quadrant overhanging the table, the arc being on the upper and back side. The spindle case is pivoted at the center of the quadrant (its lower forward point), and can be clamped at any position to the quadrant by means of a slot in the latter. The driving belt passes over guide and tightening pulleys which take up the belt, adapting it to different positions of the spindle. The other features of the machine present no peculiarities except that two attachments are provided, one for making teeth on milling cutters by a template, or for doing other similar work, and the other for slotting or mortising. Neither of the attachments are especially well suited to the main machine, however.

(23) Sainte, Kahn & Co., 104–106 Rue Oberkampf, Paris, showed a large variety of emery wheels and grinders in machinery hall. Among the former may be mentioned wheels with iron bands set in the flat face or on projecting hubs for giving additional strength, some of the wheels being made in segments.

One of the most notable of the grinding machines was of the pantograph type, familiar in sand-papering machines, made by Sainte, Kahn & Co. A long, swinging, jointed, horizontal arm carries at its outer extremity an annular emery wheel, rotating in a horizontal plane. A balanced hand lever at the top of the grinding spindle affords means of varying the pressure of the grinder on the work. Motion is transmitted to the wheel by a series of belts, the first of which runs from a horizontal shaft at the bottom of the frame over two guide pulleys to a horizontal pulley, the shaft of which, with the frame and first section of the arm, form a hinge. A short belt runs from this hinge to the next joint, and a second short belt from this to the grinder spindle. In one form of the machine the bed is continued under the grinder, and this projecting base has at its extremity a column with a slotted table, adjustable in height.

(24) Sculfort-Malliar & Meurice, Maubeuge, exhibit a large collection of hand and power tools for punching, shearing, and drilling; and also special machines for the manufacture of wagons, etc.

A large hydraulic, combined punching and shearing machine is made with an automatic valve, for relieving the pressure from above the plunger instantly when the working stroke is completed, giving a quick return. A lever attached to the plunger rod oscillates about a fixed fulcrum. Two set screws are so adjusted that the lever opens the valve at the proper position of the plunger, making communication between the cylinder and the reservoir. A counterweight, acting through a lever at the back of the machine, raises the head rapidly. When the head reaches the prearranged limit of its upward travel, the valve is closed and another stroke is made.

(25) Société Alsacienne de Construction Méchaniques, Belfort. The display of large tools by this establishment was very creditable indeed. The workmanship and the designs generally were of a high order. A large gap lathe "Tour en l'air," for facing pulleys, and boring and facing gears, having the following dimensions, was among the many good tools in this collection:

Height of centers 260 millimeters (10.23 inches) or 20.5 inches swing above the bed. Height of centers in gap 800 millimeters (31.5 inches) =63 inches swing. Distance between centers, 1 meter=33.4 inches. Distance between bed and face plate (width of gap) 600 millimeters (23.61 inches). Diameter of face plate 1 meter (39.37 inches). Weight of lathe 2,850 kilogrammes (6,250 pounds).

The facing rest is carried by a vertical column, which can be set at the proper distance from the center and bolted down to the solid base plate. The short bed carries a tool also for turning the shaft, boring and facing the hub, etc.

A large slotting machine, especially well built, is worthy of some notice. The principal dimensions are: Stroke, 600 millimeters (23.6 inches). Longitudinal travel of table, 950 millimeters (37.4 inches). Transverse travel of table, 800 millimeters (31.5 inches). Distance from tool to the vertical column of the frame, 1,200 millimeters (47.25 inches). Weight, 14,500 kilogrammes (32,100 pounds).

The table of this machine has transverse, longitudinal, and circular feed motions, all of which are automatic and instantly reversible. A special feature is a releasing arrangement by which the tool is held firmly in place during the working stroke, but is allowed to fall back on the upward stroke; thus avoiding rubbing of the cutting edge. This is accomplished by pivoting the tool holder at the upper end and forcing it out against a stop by a wedge from behind. This wedge is attached to a lever which plays up and down with the ram between two adjustable stop pins; these pins throw the lever, thus withdrawing and inserting the wedge at the end of the lower and upper ends of the strokes, respectively. A four-stepped cone, with back gears, gives the usual range of cutting speed.

A large vertical spindle milling machine is a fine example of a type of machine extensively used on the continent, and it would seem that we might with advantage carry this principle into more general practice on large work in the United States.

It is shown in Fig. 6.

Distance from center of spindle to upright frame, 600 millimeters (23.6 inches); vertical movement of spindle, 520 millimeters (20.5 inches); longitudinal motion of tables, 900 millimeters (35.4 inches); transverse motion of tables, 1,400 millimeters (55.1 inches); diameter of spindle 110 millimeters (4.33 inches); weight, 7,150 kilogrammes (15,760 pounds).

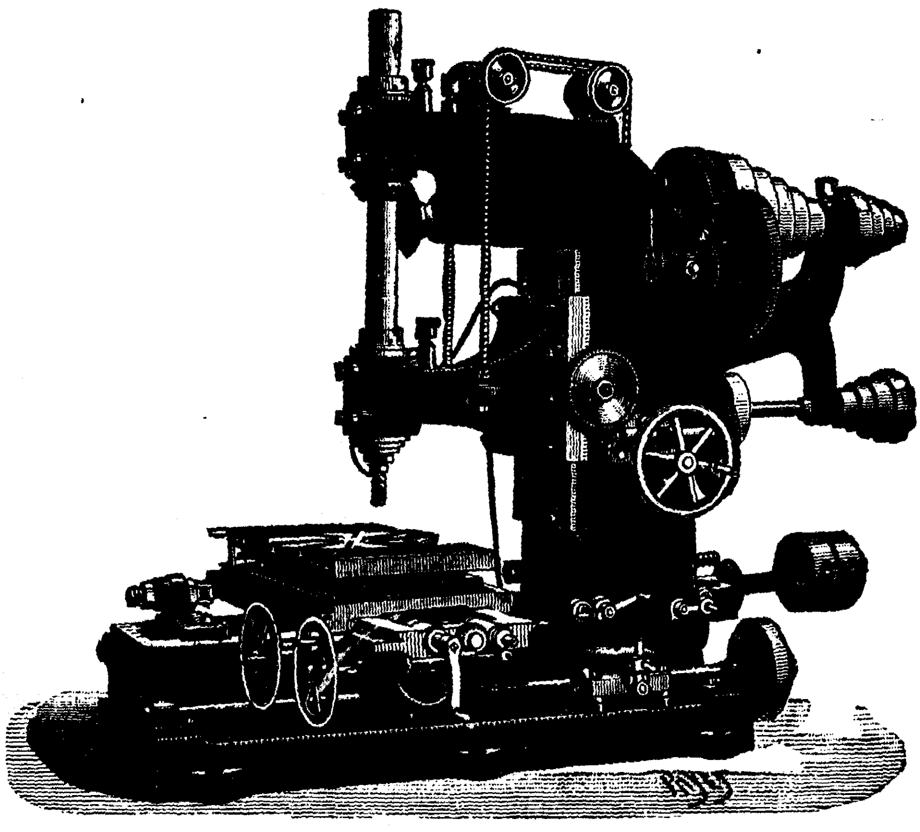

FIG. 6.—Vertical spindle milling machine by the Société Alsacienne.

The head supporting the spindle is gibbed solidly to the frame, and is balanced by counterweights.

A circular table is carried in the center of the main tables, and this has a rotary feed motion. This motion, as well as the other motions of the table and those of the rising and falling head, are so arranged that automatic or hand feeds may be used in any or all at will. The transverse feed can also be released, and a guide substituted, for profile work. This is a principle much employed in European milling machines. The attachment by which it is used on this tool is supplied as an extra, only upon order.

(26) A gear-cutter for cutting spur and twisted gearing up to 1 meter (39.37 inches) in diameter, shown by Fig. 7, was a prominent feature in the exhibit of this company.

It will cut spur gearing with 420 millimeters (16.5 inches) face, or twisted gearing with 200 millimeters (7.87 inches) face. This machine is made with a strong horizontal bed, the large hollow spindle being supported by two bearings, and the cutting head carried by a frame secured to the back side of the main bed. The milling cutter is driven by a shaft placed vertically for spur gearing, or at an angle with the vertical equal to the angle of the teeth, in cutting twisted gearing. In the former class of work the cutter is traversed parallel

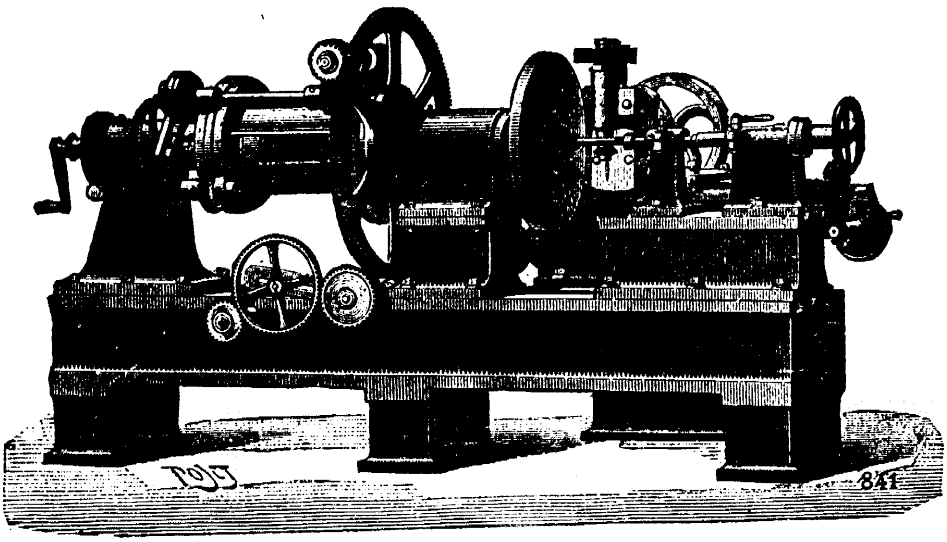

FIG. 7.—Large gear-cutter; by the Société Alsacienne.

to the bed of the machine, the wheel operated upon being held stationary during the cutting of the tooth, and only turned by the amount of the circular pitch in changing the cut from one tooth to the next. This movement of the wheel from tooth to tooth is not effected by an index plate, but is accomplished by means of a large worm wheel and worm, a train of change gears, and a crank which can be accurately turned by a quarter turn. The large dividing worm wheel is 917 millimeters in diameter (36 inches) and has 180 teeth. By a suitable train of gearing between the hand crank and the worm almost any desired division can be accurately made.

In cutting twisted gearing the milling head is not traversed, but the spindle is set at the proper angle and simply revolved in this position. The large dividing wheel is still held stationary during the cutting of the tooth, but a smaller worm wheel of 510 millimeters (20 inches) diameter is attached to a spindle, which passes through the center of the larger wheel and carries the gear to be cut. This smaller worm wheel is connected by a train of gearing to a screw, which gives an axial motion to this spindle. The relation between this circular motion and the axial motion can be arranged to give the proper resultant helical motion to the work, the large worm wheel, as before, fulfilling the function of the dividing head. This machine has a good range, and it is a strong, well-built machine, suited to a class of work common in European construction of machine tools, namely, twisted gearing. The weight of the machine is 3,930 kilogrammes (8,660 pounds).

(27) Société de Construction de Machines-outils. E. Le Brun, director, 28 Boulevard Richard-Lenoir, Paris, placed on exhibition a tool of quite original design; a vertical-spindle lateral-milling machine. The long horizontal bed resembles that of a large shaping machine, or more nearly the side planer. This bed carries two tables at its front side for supporting the work, and these have both horizontal and vertical slotted faces. On the top face of the bed are two flat ways, upon which slides an arm overhanging the tables. This arm is itself fitted with a horizontal guide, perpendicular to the bed, on which the spindle head is carried. The vertical spindle receives its motion from a shaft running lengthwise of the bed through suitable gearing and splined rods. The tables may be set at any height on the bed, or at any position along its length. The cutter has a vertical motion, by hand, to adjust it to the cut, while the head has an automatic movement along the arm (transverse to the bed), and the arm itself has an automatic longitudinal motion along the bed. The transverse movement of the spindle is 800 millimeters (31.5 inches), while the longitudinal movement is 1,800 meters (5 feet 10.8 inches).

It will be seen that this construction permits a range in plain milling far beyond machines of the ordinary type having much greater weight and bulk. While the overhanging arm may lack something of the rigidity to be found in the best American milling machines, the bearings on the flat ways are very broad and the arm is strongly gibbed to the bed; the tranverse feed may be disengaged by lifting out a half-nut, and a template clamped to the tables for giving the work a desired contour, or for reproducing peculiar forms.

(28) Another machine which embraces some new features in its construction is a pulley lathe, or "tour en l'air," as the French term it. The boring-bar for boring the hubs is supported, fed, and *driven* from the tail stock. By means of this arrangement the face of the pulley can be turned, and at the same time the hub may be bored, each tool having a suitable cutting speed. The two tool blocks for turning the face are placed one at the front and the other at the back of the lathe. For "crowning" the face the two blocks are connected with suitably formed curved guides or gauges which control the position of the tools in their travel. The cutters are placed at the outer edges of the pulley (one at either edge) in commencing the operation, and as the cut proceeds they approach the center of the

face along the fixed paths, where the two cuts run into each other. The same screw, one-half of which is right-handed and the other half left-handed, controls the feed of the tools.

(29) Of the other tools shown by this establishment but one can be mentioned, namely, a slotting machine with a head capable of being set at an angle to its ordinary vertical position. This displacement is effected through a tangent screw, and the amount of inclination is indicated by a graduated circle. The table has the three usual motions, transverse, longitudinal, and circular, all of which are automatic. When required, means of reproducing forms by a template, in a manner similar to that used in vertical milling machines, will also be supplied. The sizes range from a stroke of 150 to 700 millimeters (6 to 27.5 inches).

(30) Steinlen & Co., Mulhouse, Alsace, Germany. At the rear of the Palace of Machines there stood one of the largest of the private buildings, which was devoted entirely to the display of machinery built by the Alsatian house of Steinlen & Co. Besides machine tools, they exhibited dynamos, roller engraving machinery, and steam engines, among the latter being two large "straight-line" engines, built under license of the inventor. Some of their machines are of American origin, a fact that is freely admitted by them. Their grinding machines are after Brown & Sharpe's models, and they build gear cutters under Eberhardt's patent. Aside from these tools, however, there are many others of highly creditable design and construction, covering nearly all classes of standard machine tools as well as some machines of a special nature. Among these is a large planing machine in which the regular saddles can be replaced by milling heads, converting the machine readily into a strong milling machine, with great range for plain work. Milling is carried out extensively by this house in their own practice, and is applied to a much larger class of work than is usual in this country, by many of the European manufacturers.

A smaller milling machine for producing certain irregular forms, all of the same shape, in large quantities, involves a principle of construction differing from that employed by others. The work for which it is best suited is such as small cams, parts of guns, etc., or other work having a general outline approaching a circle. The spindle is horizontal and has a rising and falling movement. The blank to be cut is mounted on another arbor parallel to the cutter spindle and below it. This work arbor has at one end a template, similar in form to the desired shape; the cutter spindle has a roller, bearing upon the edge of this template; as the work arbor is slowly revolved under the cutter the latter is raised and lowered according to the form of the template and the piece is thus given a corresponding form. Several other applications of the milling machine to gunmaking and similar work are made by these builders, but they are, of course, largely special tools.

Many lathes are shown in this building, several being designed especially for boring, with a boring bar operated from the tail stock.

A few tools from the same house were shown in the main machinery building also. The special building not being occupied until late, this display did not show at its best; but, considering workmanship, design, variety, and number of machines exhibited, it was no doubt one of the finest sent to Paris this year.

(31) S. & M. Demoor, 35 Rue Zérézo, Brussels, Belgium, made an exhibit of special nut and bolt machinery, which, on account of the originality and capacity of the tools, was one of the most interesting of any to be seen in Machinery Hall, embracing, as it did, a complete outfit for making bolts, finished all over with great rapidity from the rough blank. The principle involved in the machine for cutting threads on bolts is the same as that used and exhibited by J. H. Sternbergh & Son, in the United States section. The dies are made with the threads cut on their flat sides, instead of on the ends, as usual. The sharpening of the disks after wear is then reduced to the simple process of grinding the end, the form of the thread not being altered. In the system under consideration but three cutters are used in the head, while the Sternbergh machines employ four cutters. A simple movement of a key or lever opens the jaws when the thread is cut, releasing the piece and allowing it to be withdrawn instantly. The system embraces hand die stocks, portable hand machines, and stationary power screw machines, or bolt cutters. The larger machines are made with two parallel heads of two faces each, one face of each being for cutting bolts and the other for tapping nuts. In these machines the release of the bolt at the completion of the threading is automatic, and the dies are also automatically closed for cutting the next bolt, to the exact size, it is claimed. Adjustment of the dies for changes in the diameter of the bolts, either for passage from one size to another for which the same die is used, or for compensating for wear of the tap, is easily and quickly made. Two sizes of machines are made: No. 1, for bolts of 20 millimeters (0.79 inch) and under; price 3,000 francs ($600). No. 2, for bolts of 35 millimeters (1.38 inches) and under; price 4,000 francs ($800). It is stated that this machine has a capacity of 1,000 pieces per hour.

A machine for turning the body of bolts to size, which also faces the under side of the head and dresses the end at the same operation, is made in two sizes, corresponding to those of the bolt cutters described above. They turn bolts of lengths up to 110 millimeters ($4\frac{1}{2}$ inches) and 200 millimeters (8 inches), respectively; prices 1,000 francs ($200) and 1,800 francs ($360).

The frame resembles that of a drill press, and a revolving vertical spindle (the lower end of which has a socket for receiving the bolt head), which receives a downward feed by hand or automatically, is placed over a table. This table has a hole through its center, in line with the axis of the spindle, with three radial cutter blades projecting inward. The cutting edges of these blades are made parallel, for the straight shank of a bolt, with similar cutting edges at the top for facing the under side of the head, and at the lower end for trimming the end of the bolt if desired. The vertical cutting edges may be made up of two or more separate cutting edges, to give different parts of the bolt different diameters. The operation is as follows: The spindle being in rotation, the operator picks up a blank, inserts the head in the socket in the end of the spindle, enters its lower end between the stationary cutters, and with the other hand applies the feed, which forces the piece down, the operation being complete at a single stroke of the lever or turn of the wheel.

The smaller machine has a capacity of 100 pieces per hour, the larger of 80 pieces per hour.

The departure from ordinary practice in the machine for shaping the heads of bolts is quite radical. It is a double machine and consists of two vertical rams forced downward through two boxes, compressing long coil springs. These boxes each carry two parallel hardened steel jaws with cutting teeth traversing their faces diagonally, and are so spaced that the distance between the opposite cutting edges equals the distance across the finished bolt head. A guide block which slides in grooves in the box, parallel to the cutters, has a slot across its upper face at an angle of 60° just wide enough to admit a bolt head, and holding two of its faces parallel with the cutters. The ram in descending presses down on the top of the bolt, forcing it and the guide block down through the box, and the cutters shave the two faces exposed to their action to form. At the end of the stroke the bolt is dropped into a tray, and the plunger, which is automatically released, is shot up to its original position by the coil springs. The bolts, of course, have to pass through three times to be finished. For the first passage through the machine a guide block is used with the slot on top large enough to admit a rough head, while for the other two passages, another guide block, with a slot just wide enough to take in the two faces already finished, is employed. Otherwise the bolt would not be held firmly and the form of the head would not be exactly hexagonal. Other work than shaping bolt heads and nuts may be done on this machine by using suitable guide blocks and properly spacing the cutters. The machine is double, one ram remaining up while the other is descending, thus making the action more continuous. It will take between the jaws 45 millimeters (1¾ inches), and will turn out about 150 pieces per hour. It is stated that the cutters need sharpening only once in ten days, with continuous work, and that the sharpening is done without drawing the temper. Price 3,000 francs ($600). In all of these machines soap water is used in place of oil on the cutters.

The set of bolt machinery is completed by two sizes of machines for facing and chamfering bolt heads and nuts. The sizes correspond to the machine for turning bolts. Prices 800 and 1,200 francs ($160 and $240). These machines are double, one end being for nuts and the other for bolt heads. No particularly new principle is involved in their design.

FIG. 8.—Drill grinder; J. M. Demoor, Belgium.

(32) A drill grinder exhibited by this firm is shown in Fig. 8.

(33) Fetu-Defize & Co., Liége, Belgium, exhibited a strong mortising or key-seating machine, which is very creditable in design. (See Fig. 9.)

A circular slotted table, about 33 inches in diameter, with a rotary feed motion through a tangent screw, is mounted on a square table having two horizontal motions at right angles with each other. Through the center of the circular table a strong tool bar travels vertically.

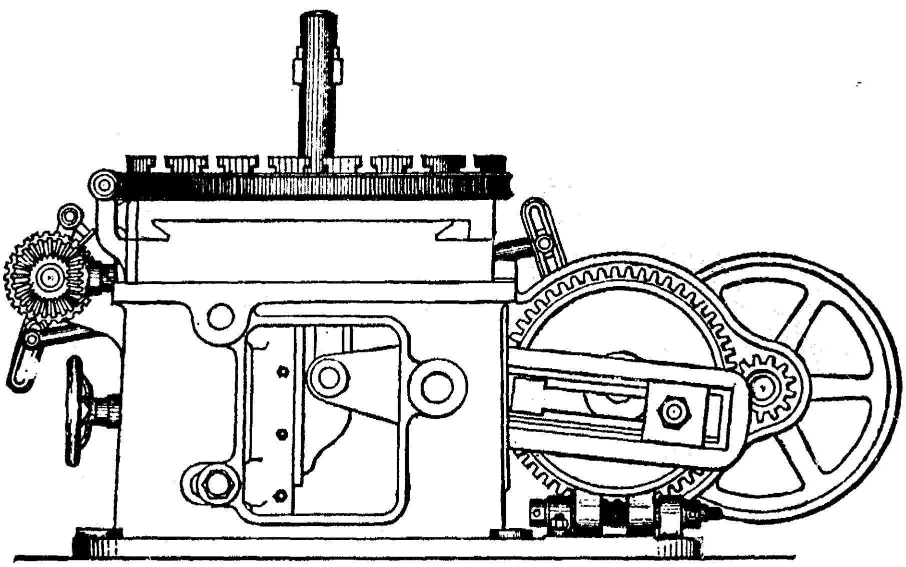

FIG. 9.—Key-seat slotting machine; Fétu-Defize & Co., Belgium.

This is actuated by a lever, the fulcrum of which is within the bed of the machine, and the outer end is slotted to receive a crank-pin block. The crank pin is attached to a disk driven through a gear and pinion from the cone; and the throw of the crank is varied by clamping the pin nearer to or farther from the center of the disk.

The arrangement is the ordinary quick return motion so often used in shapers. The machine is especially suited for key-seating. The pulley or gear to be operated upon being clamped to the table, the cutting takes place on the downward stroke, and the various motions of the table allow the work to be adjusted and fed up to the cutter as desired. This tool may, however, be used for other work than key-seating, such as dressing the inner faces of connecting-rod straps, etc. It is an exceptionally compact and solid machine, and one which will commend itself for the class of work within its range.

(34) A series of rectifying or special grinding machines, for finishing work after leaving the planer or other machine tool, especially adapted to locomotive construction, is built by the same company, and is worthy of attention. Three models were exhibited. Model B L 3 is for finishing the bearing surfaces of a link; it is shown by Fig. 10. Two suspension rods of variable length are carried by an adjustable pin above the machine's spindle, and the link is held by the lower ends of these rods.

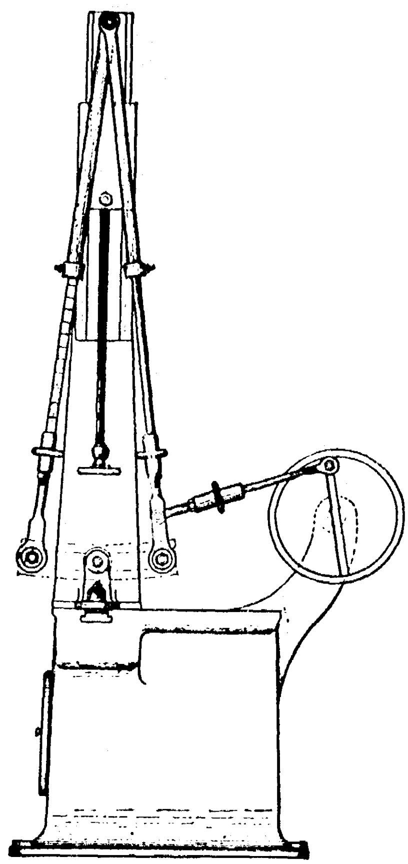

FIG. 10.—Machine for grinding the slots of locomotive links; Fetu-Defize & Co.

An adjustable crank causes the rods and the link to oscillate through an arc equal in length to a little more than the actual bearing surface of the link. An iron arbor, carried at the end of a rapidly revolving spindle, turns in the slot, its axis being parallel to the rectilinear elements of the link. The fine emery applied to this arbor grinds the surface accurately. To insure uniform grinding the arbor spindle is given a positive reciprocating end motion, so that the face of the grinder traverses the surface operated upon in a direction perpendicular to its rotation.

Model B L 4 has a similar rotating arbor with reciprocating axial motion; but as this machine is intended for small flat surfaces, the work is fastened to a horizontal traversing table. It is similar in appearance to a plane milling machine, except that the table motion is by a crank and slotted lever, giving more rapid motion and a quick return.

Model B L 5 is for larger flat surfaces and the frame is of the planer type. The platen travels to and fro as in a planer, the reversal being effected in the ordinary manner by stops on the side operating a belt-shifter. The cross-head carries a vertical spindle, driven by a belt from the countershaft and passing over guide pulleys. The lower end of this spindle is furnished with the grinder, which is annular in shape, the flat edge of the ring being the grinding surface.

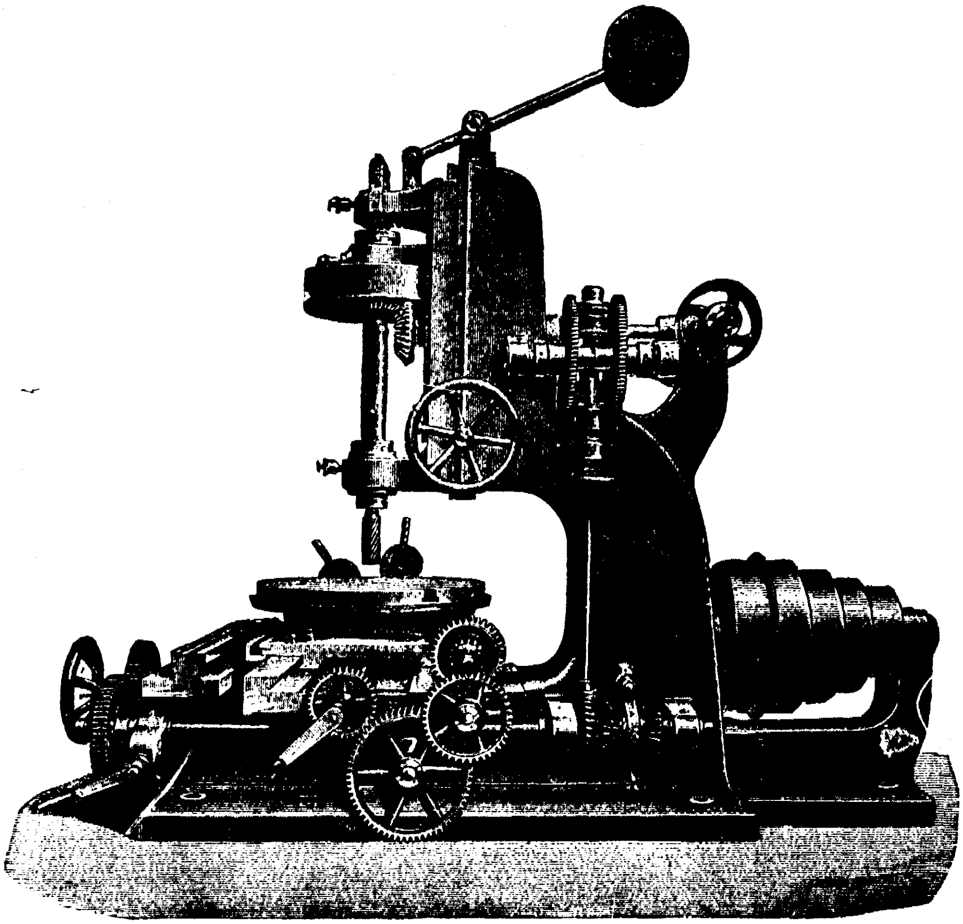

FIG. 11.—Large vertical milling machine. Fetu, Defize & Co.

These three machines give a high finish to work. All of them seem to be very carefully designed and constructed with accuracy.

In addition to those described above there was in this exhibit a very good line of general tools; one large turret lathe, a locomotive-wheel lathe, a radial drill press, and a large vertical milling machine. All were fine tools, but none, except the last mentioned, differ in any important features from those well known in the United States.

(35) The large milling machine referred to (see Fig. 11) is similar in type to that built by Société Alsacienne and Smith & Coventry, described as among their exhibits. Provision is made for reproducing by placing a guide template at the front of the machine, the ordinary screw motion being then disengaged. The diameter of the spindle is 90 millimeters (3.54 inches); diameter of the slotted

circular table, 850 millimeters (33.5 inches); clear height above platten, 370 millimeters (14.55 inches); transverse travel of table, 1.150 meters (45.25 inches); vertical travel of tool, 250 millimeters (9.84 inches); weight, 5,500 kilograms (12,000 pounds). Price, 5,000 francs ($1,000).

(36) The American Screw Company, Providence, Rhode Island, exhibited machines for making wood screws by the cold-rolling and swaging process. The principal requirement in metals to be treated by this process is homogeneousness in quality. A publication of the company's states: "All previous attempts to make a screw of the requisite stiffness, and having threads adapted for engaging in wood, failed of success until the American Screw Company developed a principle of forcing laterally the metal displaced by the dies instead of allowing it to move longitudinally, as it always did under dies constructed prior to their invention, as such longitudinal movement is directly opposed to the production of a sound deep thread, and hence could only be applied to shallow threads and short lengths in soft metal. Supplementing their process for enlarging the diameter of the thread some four to six sizes larger than the body of the blank, *and without which the enlarged diameter of the thread would have no practical value, is their process for producing a corresponding enlargement of the head having a swaged slot and finished surface*, thus producing, by the combined processes of swaging and rolling, a symmetrically proportioned finished wood screw, one vastly stronger than can be made by the cutting process, and costing much less to manufacture than a cut screw of the diameter of the wire from which the swaged and rolled screw is made.

The following claims are made for this process: (1) Decreased cost and increased selling price; (2) Stronger head; (3) superior point, enabling it to enter the wood straight; (4) deep, thin thread, having greater hold and not distorting the fibers of the wood; (5) small shank, which avoids splitting the wood; (6) extremely tough material; (7) no weak place in the screw.*

(37) Brown & Sharpe Manufacturing Company, Providence, Rhode Island, made one of the best displays of machine tools at the Exposition. It included several of their milling machines (universal and plain and of different sizes and types), a No. 2 vertical chucking machine, a No. 3 universal grinding machine, a No. 2 surface grinding machine, a No. 3 universal cutter and reamer grinder, an automatic gear cutter, two screw machines, a universal hand lathe, a tapping machine, a screw-slotting machine, high-speed and vertical spindle milling attachments, gearing models, milling cutters, sewing-machine parts, samples of castings, specimens of work done

*For a further description of this process see, under Class 53, the general review of the sixth group, in this volume.

on their screw machines, milling machines, grinding machines, etc.; also photographs and lithographs of the shops and a few of the smaller specialties of their manufactures.

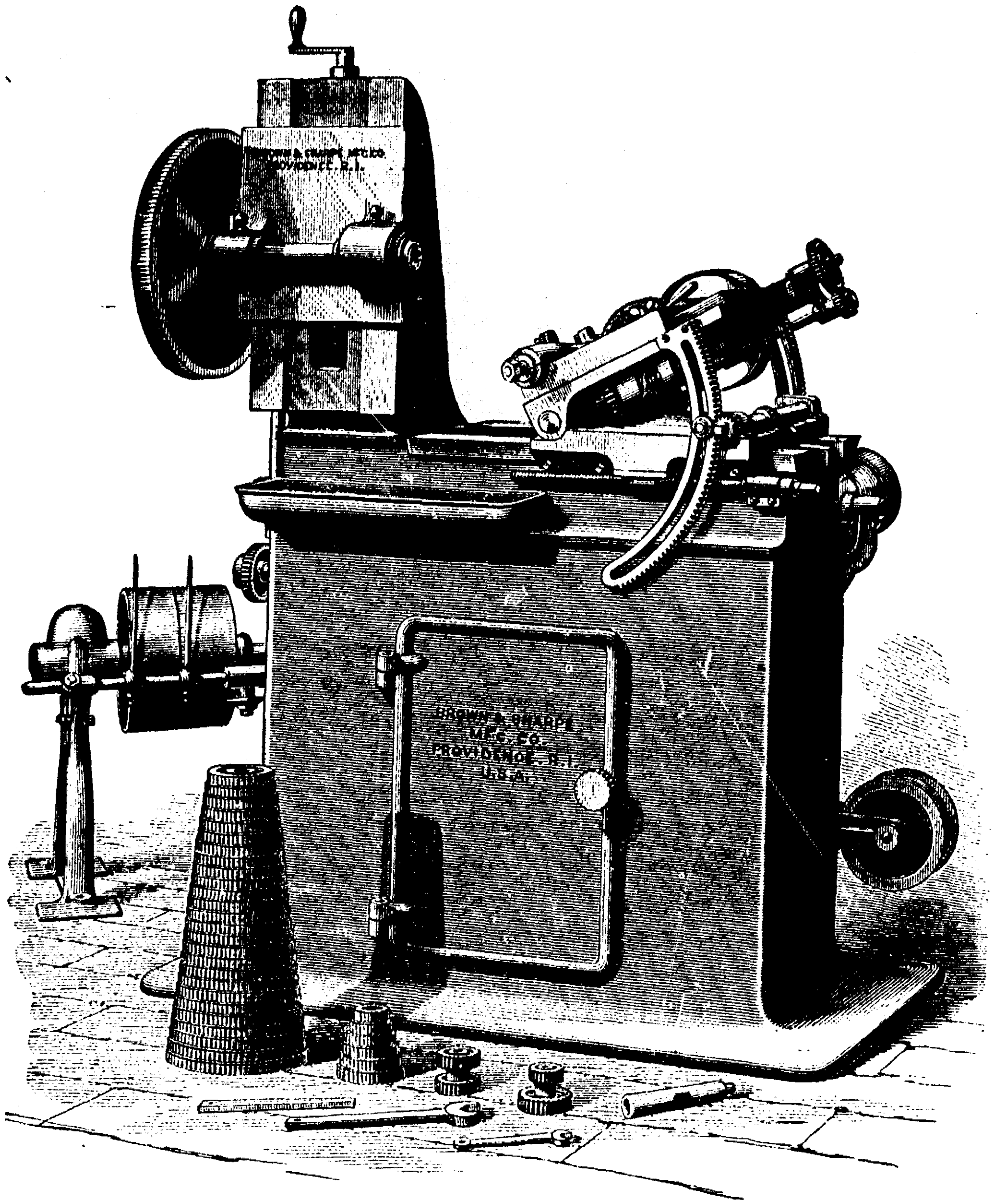

FIG. 12.—Brown & Sharpe's automatic gear cutter.

These tools were all of the standard design and finish, exactly the regular line of work put on the market by the Brown & Sharp Company, the character of which is too well known to Americans to need much description beyond mere mention, though a brief notice of one or two of the tools more recently brought out may be in order.

Their automatic gear-cutting machine is shown by Fig. 12. It is arranged for cutting both spur and bevel gears up to 18 inches in diameter, 4 inches face, and No. 6 diametal pitch. The indexing is done by worm wheel and worm through change gears. After the cutter is attached to the arbor the wheel blank is mounted on the head, which is lowered, to give the proper depth of cut, by means of a screw graduated to read to one one-thousandth of an inch. The cutter passes through the blank, returns with a rapid motion, then the wheel is revolved for the next cut, all of these operations being automatic. The cutter head is adjustable at any angle for cutting bevel wheels, being properly graduated for setting, and the cutter may also be moved laterally from the central position for this class of work.

In cutting spur gears the operator, having placed a blank in position and started the machine, need pay no further attention to it until all the teeth have been cut.

Another machine deserving notice is the chucking machine. The chuck, being horizontal, facilitates the setting of work in many cases. It will take pulleys up to 36 inches in diameter, 14½ inches face, and hub 12 inches long. Holes as large as 4 inches can be bored, and the turned head allows several different operations to be performed rapidly without displacing the work. The chuck table is driven by a five-stepped cone, geared 6 to 1.

The turret slide has a motion of 21 inches, and an automatic adjustable feed motion, with quick return. It is counterbalanced by a weight inside the column.

The exhibit was generally admitted by those familiar with machine tools to be of the very highest order. The principles and often the actual designs of the machines which the Brown & Sharpe Company have so successfully introduced, have been very widely adopted by European builders.

The undeniable traces of their work could be seen throughout Machinery Hall.

(38) William Sellers & Co., 1600 Hamilton street, Philadelphia, Pennsylvania. Two planing machines of an entirely new design, a vertical drill press, a tool grinder, and a drill grinding machine were sent to the Exposition by Sellers & Co., and much interest and many favorable opinions were expressed regarding them. The work of the tool grinder was greatly admired, and mechanics quite generally considered the planer a decided advance in the construction of that class of tools.

The following explanation of the new planer was kindly furnished for this report by the makers. The machine being so new, and of general interest, it is given in full:

36 BY 36 INCH PATENT SPIRAL-GEARED PLANING MACHINE.

The return stroke made in one-eighth of the time required for the cutting stroke. Driven by spiral gearing throughout, thus avoiding the intervention of spur or bevel wheels and insuring the engagement of not less than four teeth of the rack, simultaneously, with the pinion on the diagonal shaft, thereby imparting to the table a smoothness of motion not obtainable in any other form, and producing work that is smooth and entirely free from the chatter marks observable in that of all other planing machines. This construction also permits the strengthening of the bed in its most vital part, between the uprights, by two large box girders and one diagonal girder, in the space usually taken up by the spur gearing in other machines. The cutting stroke is at the rate of 18 feet per minute, the return stroke at the rate of 144 feet per minute—the quickest ever obtained on such a planer without overrunning the required distance—and the machine will plane to a shoulder with certainty; but either rate can be changed without affecting the other, as, for example, in planing unusually hard material the cutting speed may be reduced by changing the size of the driving pulley, without affecting the rate of the return stroke. The table is of unusual stiffness, with one plane and one very flat way, the latter having four bearing surfaces, two to carry the weight and two more to take any extra heavy side thrust. There are improved oiling devices in the ways, all thoroughly free from dirt. The driving belts are wide, on high-face pulleys, and are not shifted to change the direction of the table movement, the engagement with the driving shaft being effected through friction clutches which are small in diameter but certain in acting, reversing the motion without jar. The clutches are disengaged from the driving pulley positively by the stops on the planer table, thus making the length of the stroke definite, and avoiding the variations in length inseparable from the method hitherto employed, of shifting the driving belts from fast to loose pulleys. The release of the clutches starts a train of gearing driven from the slow-running pulley which engages the clutch with the opposite pulley and at the same time operates the feed and tool-lifting devices, which operations thus take place while the table is at rest or changing its direction of motion; hence the total stroke of the tool need not in any case exceed the length of the piece to be planed by more than 3 to 4 inches. The feed may always take place at the end of the back stroke, no matter in which direction the feed is working. The machine can be operated from either side by hand levers which control the table movement and at the same time disengage and arrest the feed at will, so that the table can be run past the stops as often as required for examination or adjustment of work, and when the planing is resumed the cut will show no mark of the feed arrest. The cross-head is unusually massive, inclosing the saddles; the slides being broad and flat, not angular, and fitted with bronze taper shoes to take up the wear. The cross-head is fitted with two saddles. The feed screws and rods to each are separate, so that each can be operated in all respects independently, except in the amount of feed, which will be the same for both saddles; but by extending the crank shaft across the machine and providing an additional crank, rod, and segment, the two saddles can have feeds entirely independent of each other. The feed is adjustable from one whole revolution of the feed screws down to nothing by an infinite gradation, as there are no teeth in the feed ratchet to limit the changes. The tool holders on the cross-head are fitted with tool lifters, raising both tools on the back stroke, no matter in what direction or in what angle the planing tool may be feeding. There is a vertical slide rest on each upright, operated by separate feeds, and the tools of these slide rests stand in the same plane with the tools on the cross-head. The vertical slide rests can be lowered below the top of the table when not in use. The cross-head is raised and lowered by power by means of friction wheels that can be held to their work with slight effort, but which stop as soon as the workman releases his hold on the lever, thereby avoiding the accidents arising from hoisting machinery set in motion and then left to work during the absence of the operator. For power of cut, smoothness of work, quickness of back stroke, length of stroke as compared with the length of work, facility of handling the table and the feeds from both sides of the machine, ability to stop the feed and restart it without marking the work, great strength and convenience, this machine is preëminent. It is placed parallel with the line shaft to economize room in the shop, but can be placed at any angle to this shaft with facility.

20 BY 20 INCH PATENT SPIRAL-GEARED PLANING MACHINE.

This machine is the same in general principle as the 36 by 36 inch machine exhibited. The cross-head is of a somewhat different form. The table is not operated from either side, and the tool is not provided with a lifting attachment, nor is the cross-head raised and lowered by power, such features not being required on a machine of this size.

(39) *Drill-grinding machine.*—This machine will grind accurately either flat or twist drills from one-quarter of an inch up to 2 inches, all drills being held in the same chuck without the use of bushings. It will grind drills to any included angle of point from 90° to 130°. The clearance varies, being slightly greater toward the center. The flat face of the stone is the grinding surface, and this stone is fixed on a cast-iron ring which is bolted to a flange on the arbor, diminishing danger of breaking the stone in screwing up. A drill-pointing device is also attached, by means of which the point is thinned down, reducing the rubbing action of the end and the force required to feed the drill. This feature is especially valuable as the drill becomes worn down toward the shank and the thickness of the point becomes greater. The nature of the work done by this grinder was shown by the equality of the two shavings turned out from opposite tips of the drill; both shavings being several inches in length and almost exactly alike in size and curvature.

The tool-grinding machine, while of quite recent origin, has received such notice as to render a lengthy description unnecessary. The following is from the makers:

All ordinary tools used in lathes, planers, and all other machine tools, the cutting edges of which are bounded by planes, or planes and convex curved surfaces, are ground to shape from the rough forging with ease and dispatch, irrespective of the position the cutting edges have in relation to the body of the tools.

The grinding wheel, of coarse structure, but which, from its direction of cut, grinds quickly and grinds fine, is mounted on a box frame, part of which serves as a tank to hold the water used in flooding the tool to keep it cool. This tool can be reversed, face about, on its spindle to equalize the wear, while it is protected or inclosed in a massive cast-iron cover. A rotary pump forces water to the tool being ground through a system of jointed pipes, the nozzle of discharge being made to hold the same relation to the tool in motion as at rest. Slide rests, adjustable in angle by means of graduated arcs and verniers, have vertical, horizontal, and rotary motion, moving the tool in all directions in front of the grinding wheel so as to grind several faces at one setting to any angle of clearance or top rake.

The machine is furnished with former plates for grinding all the forms of roughing tools we have found most useful in our practice, and also means to enable new former plates to be originated from a sample tool made by hand or otherwise.

It is also provided with—

(1) A chuck for circular or round-nose tools, which is also used in connection with former plates furnished to grind curved-face roughing tools, right or left hand, and at any angle.

(2) A holder to be used in grinding the side or base of the shank of tool.

(3) A chuck by means of which any bent tool can be ground on all its faces without changing its position in its chuck, with as much ease as the grinding of straight tools.

(4) A chuck to hold splining or key-seating tools in the same manner.

(5) A crane for lifting the heavy wheel cover, changing the wheel on its spindle, or lifting the chuck, etc.

Tables or diagrams showing all the angles and positions of chuck for fifty-six different plain-faced tools; nine different shapes (seven sizes each) of right and left tools, with former plate to be used with each; and a table for circular tools from one-fourth of an inch to 2¼ inches diameter of circle are also sent with each machine.

(40) Warner & Swasey, Cleveland, Ohio, exhibited a number of their specialties, including screw machines, monitor lathes, special tools for valve making, and brass-finishing machinery; and many of these were superior to any similar exhibit.

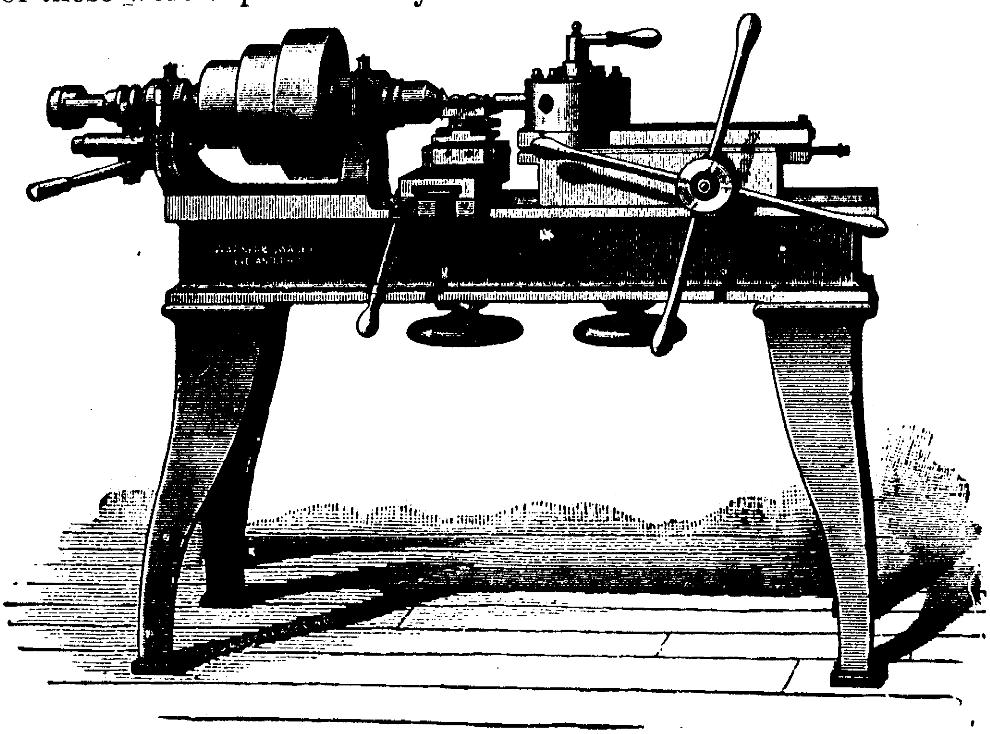

FIG. 13.—Turret lathe with forming tools; Warner & Swasey, United States.

The screw machine has a wire feed and the turret can be supplied with a great variety of tools, as a drill, adjustable box tool, hollow mill, die and die holder, reamer, and stop gauge. A great variety of pieces having different shoulders and sizes can be made with rapidity and accuracy by means of the ajustable box tool. In addition to the turret there is a slide for cutting-off tools, etc., provided with two tool posts. Four sizes of the machine are made, with 10, 12, 16, and 20 inch swings, having holes through the spindle of ¾, 1, 1¼, and 1⅝ inches, respectively.

The forming monitor (see Fig. 13) is of especial interest. The following is quoted from the publication of the makers :

These machines embody a departure from the old system of turning irregular shapes. Their operation is extremely simple and the quality of the work turned out is such that they are rapidly taking the place of all other methods.

The tool slide with its under-cutting forming tool is the most characteristic feature. The tool carriage is drawn forward by hand by means of a lever rack, causing the forming tool to pass under the piece at the proper distance below it to turn it off to the right diameter and shape. At the beginning of the return movement of the carriage the tool is depressed slightly by the automatic action of a double eccentric, and its edge is thus prevented from dragging across the finished work as the tool passes back to place. An automatic chuck is provided with these machines, which is worked by a lever shown at the left of the figure. By means of this the pieces to be operated upon can be placed in position, rigidly gripped in the spindle, finished and removed, without stopping the machine. In working the machine those operations on the piece requiring the use of the tools in the turret are first done, after which the forming tool is drawn under the part to be formed, and the piece thus completed.

The under-cutting tool is a bar, the upper face of which is milled lengthwise so as to give it a cross section, the outline of which exactly corresponds to that of the piece it is desired to produce. In grinding, therefore, it is only necessary to grind off the front end, and the center of the cutting edge remains unchanged.

(41) *Four spindle valve milling machine* (see Fig. 14).—The four heads carrying the spindles are supported by two knees, one on each side of the upright spindle which holds the valves to be milled. The knees are adjusted right and left on the bed by means of hand wheels. The upper heads are adjustable vertically to give the required distance between the upper and lower spindles, while the lower heads are adjustable right and left on the knees to insure milling both ends of the valve the same size. Thus each of the four spindles is adjustable separately, so that valves from one-half to 2 inches can be milled. The piece to be milled is screwed to its proper position on a rod sliding within the upright spindle and projecting a short distance above it, and is then drawn firmly against the spindle by a large hand wheel below. After milling two sides, a partial revolution of the valve through 60 or 90 degrees is obtained by giving a lever (just above the hand wheel) a forward movement, which unlocks the spindle, turns it the proper distance, and locks it ready for milling the next two sides.

By this machine the four parallel faces of the two hexagonal or square parts of the valves can be milled at once. A two-spindle machine is also made, which is similar except that but two opposite faces are milled at one operation.

Double-head key lathe.—This machine is designed for turning keys for cocks from one-eighth to 1 inch, inclusive. It is also especially adapted for making gas fittings. An automatic feed, adjustable to any desired taper, is provided, which, when once set, will feed across the work, or, if desired, will feed across the work, reverse and feed back, and then stop, taking on its return a chip due to any spring there may have been in the tool during the first cut. Two complete machines are placed on one bed, as one operator can easily attend both.

These makers also exhibited a case containing many of the finished parts of valves, etc., and some accessories used in this class of work.

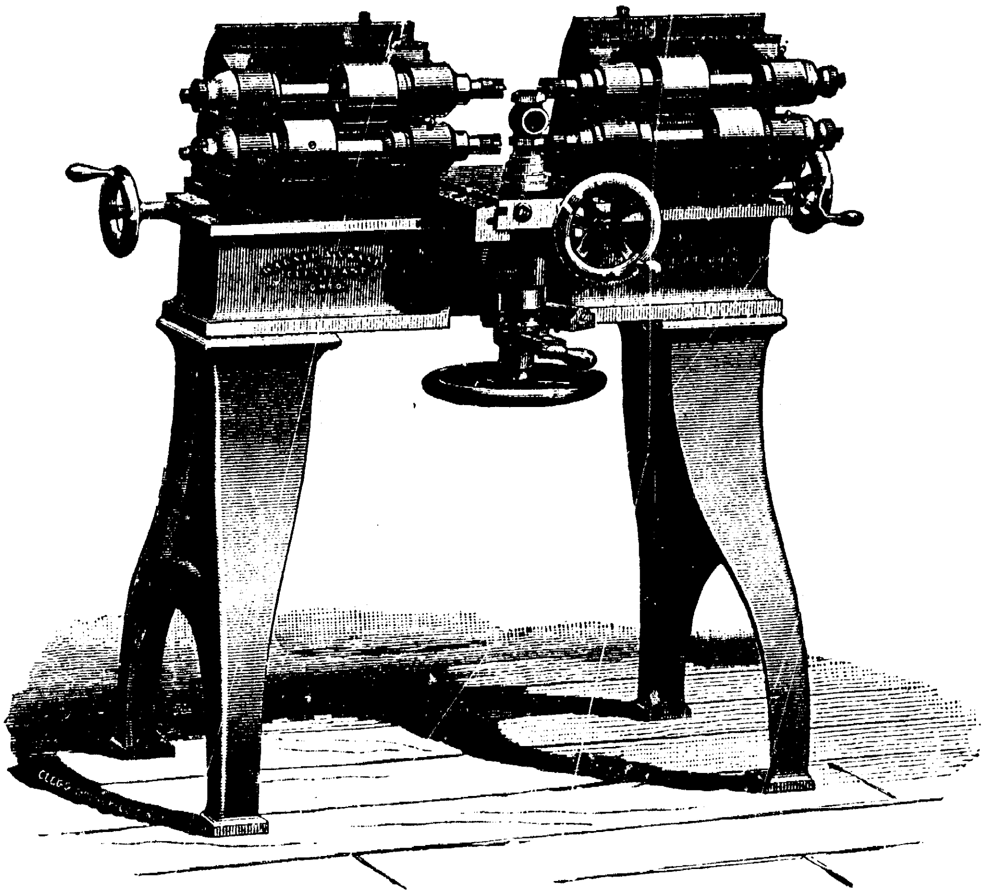

FIG. 14.—Four spindle valve milling machine; Warner & Swasey.

Their methods and designs are now so familiar in the United States that further mention, though merited, is not necessary.

J. H. Sternbergh & Son, Reading, Pa., exhibited an excellent bolt-milling and screw-threading machine which has been referred to above.

(42) Greenwood & Batley, Albion Works, Leeds, England. These builders have made many large tools for the arsenals and other Government institutions. They do not confine themselves exclusively to machine tools, but this line of work is the most important of their productions. The grandest single machine in this class at the Exposition was, without doubt, the large lathe just built for Schneider &

Co., of Creusot, by Greenwood & Batley. It is intended for boring and turning large ingots of steel weighing up to 100,000 kilograms (100 tons) or more. It is claimed that this lathe can easily (with the eight tools provided) cut off over a ton of chips per hour.

It is more than 75 feet long over all, and occupies almost 1,600 square feet of floor space. A few of the most prominent features of this wonderful tool are summed up in the following brief description, kindly furnished by the builders for this report:

The lathe we are now exhibiting at the Paris Exposition has a height of centers of 60 inches, or will admit between the centers 55 feet. The main spindle is of mild forged steel, oil tempered, and revolves in hard brass bearings. The driving cone has five speeds with single, double, treble, and quadruple purchase machine-cut gearing. All the pinions are of mild forged steel and the wheels of tough cast iron. There are four saddles, each arranged to carry two tools on the swivel slide. One of the special features is the self-acting traverse motion of the saddles along the beds. This is arranged so that one saddle can be moved quickly to the right hand while the other is going toward the left hand, or one saddle may be facing towards or from the center of the lathe whilst the others are sliding, or one saddle may be sliding a taper of 1 in 100 inches whilst the others are surfacing or sliding. The lever head is also new, and consists of a revolving spindle fitted with a four-jawed chuck to carry the end of the ingot whilst turning the center portion of the ingot or preparing spots for the supports. In the revolving spindle is fitted a sliding spindle with screw adjustment for ordinary work. The bed is in five pieces, each weighing about 24 tons. These are firmly bolted and keyed together, and fitted with two mild steel screws for the self-acting sliding motion, also racks for the quick traverse motion of the saddles and loose head stocks. The saddles are each fitted with a rest for crank-turning. These fit on the surfacing or transverse slide when the swivel slide is removed.

The boring bed is fitted with a boring saddle having a self-acting traverse of 21 feet, driven by suitable gearing from the main spindle. It has also a quick traverse motion in either direction, driven by open and cross belts from the main shafting in the factory. Some idea may be formed of the size of this lathe when we say the driving head stock and gearing weighs 31 tons, the driving spindle about 6 tons; each of the saddles weighs about 23 tons, and the total weighs of the lathe with countershaft about 330 tons net.

Each carriage is furnished with hand wheels for reversing or stopping both feeds. The feed mechanism consists of rods and bevel gearing, with positive clutches. The bevel gears are in pairs, with a double clutch between the two, so that by shifting the clutch sleeve the feed is first stopped and then (if continued) reversed. A ratchet lever is provided for moving up or feeding by hand. The screw and rod feeds of the front carriage are duplicated at rear of the bed for driving the back carriages. All feeds are positive, but a cup friction clutch (driven directly from the counter shaft by an independent belt), is used for the quick return motions.

A shaft runs down the center of the bed to give feed motion to the boring attachment. To avoid removing the pedestal and caps as the boring proceeds, a beveled pinion is placed between each pair of the bearings of this feed shaft.

Not the least remarkable thing in connection with this tool is the shortness of the time taken in its design and construction. A consideration of the following statement conveys some idea of the facilities possessed by this house for turning out large work.

The lathe was ordered by Messrs. Schneider & Co. July 31, 1888. The design occupied nearly four months, and the actual construction was not begun until the last days of November. At the end of April, 1889, it was shipped to Paris, the whole construction having taken less than six months.

This lathe is to be used at the Creusot Works in turning and boring large ingots for heavy guns and similar purposes.

Greenwood & Batley have built during the past five or six years many large lathes, ranging in weight from 50 to over 300 tons, supplying such establishments as, the Woolwich Arsenal; W. G. Armstrong, Mitchell & Co., Newcastle-on-Tyne; John Brown & Co., Sheffield; Thomas Firth & Sons, Sheffield; Taylor Bros. & Co., Leeds; Schneider & Co., Creusot, France; Société de Forges et Chantiers de la Mediteranée; F. Krupp, Essen; Arsenal of Alexandrowsky, near St. Petersburg; Arsenal of Caeraca, near Cadiz; Arsenal of Keaiuaeg, China, and also many others.

(43) Hulse & Co., Manchester, make one of the leading exhibits in the English section. The following description of four of the most noticeable of their tools was kindly furnished by the makers:

Improved double horizontal slot-drilling machine for cutting cotter holes in connecting rods, keyways in shafts, etc. The machine has two drilling head stocks, and these operate at both sides of the work simultaneously and are provided with self-acting feed and self-disengaging motions. The sliding carriage carrying the drilling head stocks is adjustable to any required position on the slide bed by rack and pinion, and is then connected with crank disks, which latter is actuated by elliptical gear for giving uniformity of traverse. For holding connecting rods, shafts, and other round objects a concentric vise is provided, together with a movable head stock, the latter acting as a "steady" for the overhanging ends nearest the drills. Work of other descriptions may be bolted to a grooved table placed along the bed, the vise and movable head stock being at the time removed.

Patent vertical milling and drilling machine for milling and drilling great varieties of straight and curvilinear work, such as levers, cranks, connecting-rod ends, brasses, etc., and also for milling the ends, flanges, and parts of cylinders, and drilling the stud-holes. It has a rising and falling spindle carried by and rotating within a hollow square vertical slide which rises and falls along with the spindle, so that the main bearing of the spindle is close to the cutter in all positions. The spindle has a self-acting feed action similar to that in vertical drilling machines. The shape and size of the spindle slide are such that the cutter can operate on surfaces of work which could not be got at by a cutter if an ordinary slide were employed. The table for carrying the work consists of longitudinal and transverse slides, surmounted by a rotary slide which can be removed so as to allow the work to be fixed to the uppermost of the other two slides when desirable. Each slide has an independent, variable, self-acting feed action which can be readily applied, reversed, or suspended, as required. The lubricant is contained in a cistern on the standard of the machine, and a centrifugal pump is provided for delivering a constant supply of it to the cutter, the surplus lubricant flowing back into the cistern. The machine admits work up to 36 inches in diameter and 16 inches in height when the rotary slide is in position: when this slide is removed, however, objects up to 24 inches in height can be operated on.

Universal cutter grinding machine: specially constructed for grinding to a keen cutting edge the teeth of face and edge milling cutters, parallel or taper reamers with straight or spiral flutes, and other similar cutters after they are hardened and tempered. The grinding is effected by a high-speed emery wheel, the work being acted on by one of the sides of the wheel, instead of by its edge as is usually done. This system has several advantages over edge-grinding, as, for example, that the grinding of the work into wavy forms is avoided, and that, in grinding cutters having finely pitched teeth, emery wheels of comparatively large diameter may be employed. At the outer end of the spindle of the machine is a second emery wheel for general grinding purposes, an adjustable T rest being provided for supporting the work.

A 5-foot radial drilling and boring machine stands on a base plate, tee-grooved throughout its upper surface. The radial arm is carried by a vertical slide which is raised and lowered on the upright frame automatically by screw, 5 feet being admitted under the spindle when in its highest position.

The spindle arm is traversed along the arm in either direction by a quick-threaded screw and hand wheels, one upon the slide itself and the other at the end of the arm, for convenience in working. The spindle is rotated by a long revolving tube with hard gun-metal adjustable bearings above and below, and has a variable self-acting feed motion by screw with adjustable nut for taking up end play. Single gearing is provided for drilling, and treble for boring; and these, in conjunction with a four-speeded cone pulley, give eight changes of speed.

In addition to the above machines, Hulse & Co. showed several other good tools, with independent screw and rod feeds, driven by separate trains of change gears. The sliding rest has a special mechanism for drawing the tool back from the work and advancing it again to its former place without moving the cross-feed screw. This is accomplished by a short, rapid-pitch screw and a short thumb lever at the front of the rest.

A hollow spindle lathe for turning screws and finishing up studs out of a long bar, taking stock up to 1½ inches in diameter. The bar is passed through the spindle and gripped by an eccentric chuck while being worked. Immediately the article is finished and cut off, the bar is fed along for the next piece. There is no tail stock, as the work is not placed between centers. The sliding rest has both screw and rack feeds, and carries a capstan head with 6 tools and a threading apparatus. The bed is formed with a trough for catching the lubricant, and sleeves for extra tools.

A vertical drilling and boring machine takes work up to 36 inches in diameter and 4 feet high above the base plate. It has a variable self-acting screw-feed motion, with an adjustable nut for taking up the wear. The work may be fastened either to a radial table having a vertical movement and provided with both vertical and horizontal slotted surfaces, or it may be attached directly to the bed plate.

(44) Selig, Sonnenthal & Co., 86 Queen Victoria street, and Lambeth Hill, London, E. C., exhibited both as makers and agents. One

of the most novel machines was the "wheel-tooth cleaner." The following explanation is taken from the trade catalogue of the exhibitors:

For cleaning the teeth of cast spur wheels by means of an emery wheel: making wheels equal in appearance to cut wheels, and taking off all irregularities of castings, thus enabling the wheels to run smoothly and in full gear to the bottom of the teeth. This is a very economical and useful tool for all machinists who use any quantity of cast-tooth wheels. The machine, as shown, is all self-acting in the pick, and may be regulated in the stroke and the picking motions for pitches from one-eighth of an inch to 1½ inches, and will admit wheels up to 42 inches in diameter.

The frame of the machine is a square vertical column with a flaring base and an overhanging arm at the top, which carries the emery wheel in a vertical plane. One side of the frame is provided with a broad vertical guide upon which a sliding carriage may be clamped at any desired height. This carriage has horizontal dovetail guides in which a ram travels back and forth, the gear to be cut being fixed to a shaft on this ram, with its teeth elements parallel to the travel. A countershaft at the base of the machine drives the emery wheel by a belt at a high speed; and through bevel gearing, a vertical splined shaft, and a crank of variable length the ram is given a stroke of a little more than the face of the gear. The shaft to which the gear is attached is turned automatically through an angle equal to the pitch angle. The operation is, first, to set the wheel to be cut on the supporting shaft, then to adjust the sliding carriage so that the emery wheel will grind to the proper depth, the splined shaft driving the crank at any height within the range of the machine. Now, upon bringing the center of a tooth space in the plane of the center of the emery wheel, the machine is ready to start. A set of emery wheels, having the edges formed to correspond to the spaces of different pitched wheels as nearly as possible, are used with this machine. It is not to be expected that this machine will take the place of a gear cutter for the higher classes of work, or even that it will make wheels "equal in appearance to cut wheels," but it no doubt may be a very useful tool in fitting up the rougher class of work, where cast gearing is commonly used, removing lumps or irregularities that would interfere with smooth running. The tool weighs about 1,350 pounds, and the list price is £50 ($250). A rack-cutting attachment is furnished as an extra at an additional cost of about $48.

(45) Smith & Coventry, Ordsal Lane, Manchester, England. The display made by this company was prominent among the English machine-tool exhibits. The firm build first-class heavy machine tools, and also make small tools, such as twist drills, reamers, etc. A heavy vertical-spindle milling machine is built in five sizes, the largest of which weighs about 15,700 pounds, will work to the center

of a 72-inch circle, and admits work up to 40½ inches under the mill. It has a longitudinal motion of 30 inches, a transverse motion of 40 inches, and a circular feed, all of which are automatic. The spindle has a conical lower bearing and is 5 inches in diameter. The lower bearing can be raised or lowered to bring it close to the work. In the larger machines the handles and levers for feed motions, disengage gear, etc., are all brought to one side for convenience. The feed motion is through friction disks, permitting considerable range. For copying or reproducing, a template is fixed under the work, and a weighted lever at the back of the machine keeps the guide roller up to the template.

Self-acting, open-spindle, capstan-rest chasing lathe.—The smaller sizes are made without back gears, but the larger lathes have them. The capstan rest has a self-acting feed, the feed nut, requiring a pressure to hold it in gear, springing out instantly when this pressure is relieved. The spindle is case-hardened wrought iron, and is provided with a coned chuck for gripping the stock. The chasing apparatus is attached to the back of the carriage and can be readily swung into position for cutting, by a lever.

A considerable variety of lathe-tool holders is made by Smith & Coventry, to be used in place of the ordinary solid forged tool. They also manufacture twist drills extensively.

(46) An accessory to the drilling and tapping machines shown by this house is Pearn's "Lightning Tapper." The cut, Fig. 15, shows clearly the construction of this device.

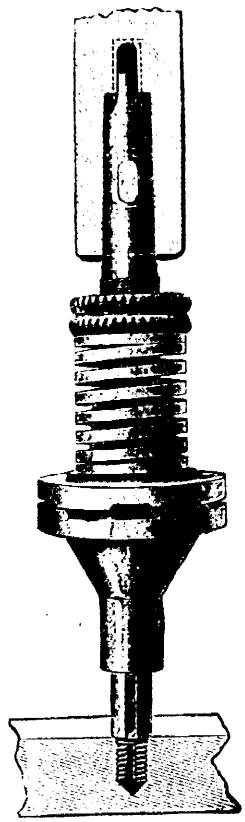

FIG. 15.—Pearn's tapping fixture: exhibited by Smith & Coventry, England.

The top is driven through the flange clutch while working regularly; but, in case of the bottoming of the tap or of its binding from any cause, the coil springs yield and the spindle turns without driving the tap.

(47) Maschinenfabrik, Oerlikon, Zurich, sent to the Exposition two gear cutters, embracing some original and interesting features.

A machine for planing bevel gears up to 360 millimeters in diameter (14.2 inches), shown in Fig. 16, has a pillar frame which carries the cutting tool. This much of the machine very strongly resembles an ordinary shaper. The tool block has right and left horizontal and vertical motions, but these are only used for adjustment, and in operation the tool moves back and forth in the same line; two strong brackets project from the front of the bed (one on either side), and bearings on their extremities (at the level with the point of the cutter) support the trunnions of the cradle on which the wheel is fixed. This cradle consists of two toothed segments (connected horizontally), at the centers of which the trunnions are fixed, swinging in vertical planes just within the two supporting brackets. The teeth on the rims of these segments engage with two pinions which, by the rotation, swing the sectors on their centers. The plate or web connecting the two segments, below the level of the cutting tool, is furnished with a strong arbor, the axis of which intersects that of the

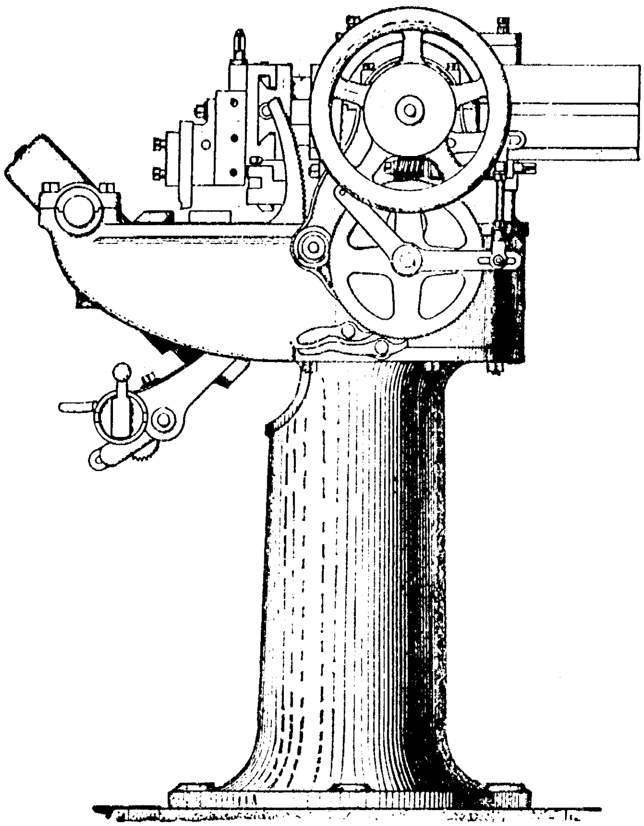

FIG. 16.—Machine for planing the teeth of bevel gears; by the Oerlikon Machine Works.

trunnions half way between the latter. On this arbor the wheel to be cut is placed, so that its converging conical elements pass through this common point in the two axes. It is evident that if the cradle is now moved upward till the outer and upper elements of the wheel are horizontal it will coincide with the path of the tool; then if, as the cradle is fed up farther, the arbor is turned properly in its bearings in the web, carrying the wheel with it, the cutter will shape out the tooth. To attain such a result a tooth model, which is an enlargement of the desired tooth form, is attached to the arbor below or back of the wheel. A blade or rule, secured to the frame, bears against this template, and a spiral spring stretched from the arbor to the cradle insures the contact of this blade and template. Now, as the planing proceeds the feed motion turns slightly at each stroke the pinions engaging the toothed sectors; the cradle thus swings upward, feeding the wheel toward the tool and at the same time the contact between the template and blade gives the wheel the proper circular movement on its axis; spacing mechanism is attached to the cradle, by means of which the wheel is turned through the pitch angle when a new cut is to be begun. In cutting gears from solid blanks, a straight cut is first made through the center of the space, and the sides of the tooth are dressed to the template afterwards. In this first operation the template is, of course, not used; and in the subsequent cuts (or in dressing a cast gear) the guiding blade is always placed on the opposite side of the template from the cutting tool. It will be seen from the foregoing that teeth of any desired form can be cut with this machine, and it will be further noted that with wheels of a given angle of pitch cone and the same number of teeth one template only is required. The spacing mechanism does not work automatically, but the other operations are automatic.

A large gear-cutting machine for spur or bevel gears in iron or wood, from 400 to 4,000 milimeters in diameter (15.75 to 157.5 inches), was placed near the one described above. It consists of a strong head for supporting the arbor on which the gear is fixed, provided, of course, with spacing mechanism. This mechanism is a large wheel and worm, connected with the actuating crank through change gears. The general principle of the machine, as arranged for cutting spur gears, is similar to that of the Gleason, or other familiar forms of such machines, the cutter in this class of work being a milling tool. The head carrying the milling spindle moves parallel to the axis of the wheel on a firm base plate. Another base plate is a quadrant, and the head may be clamped at the proper angle on it. The teeth in this class of work are planed out by a tool directed toward the center of the pitch cone. The departure from ordinary practice is in having two radial arms (which can approach and separate like shears) pivoted to the center; each carries a sliding tool block and is guided by a suitable template, so that two cuts are taken simultaneously, one on each of the opposite faces of the tooth. These two tools cut toward each other, one being at the smaller end of the tooth when the other is at the larger end. A long rod runs parallel to these radial guides, to which stops are fixed, and the feed to the tools is given by striking these stops at each stroke. While the design and construction of this entire machine is noteworthy, it does not differ essentially from the forms well known in the United States except in the feature of the double cut.

Other good tools were shown in this exhibit, among which may be named a universal milling machine. It is, however, of the type most common in America, and needs no further description.

SPECIAL REPORT

ON

MACHINERY FOR KNITTING AND EMBROIDERING,

CLASS 55.

BY

J. M. MERROW.

CONTENTS.

MACHINERY FOR KNITTING AND EMBROIDERING.

By J. M. MERROW.

I. KNITTING MACHINES EXHIBITED.

Knitting machines and accessories, including looping machines, yarn winders, and supplies, in Class 55, were located in Machinery Hall, and conviently displayed for public inspection, but the different exhibits were in many instances widely separated.

Such of the machines as were designed to be run by power were provided with suitable belt connections, and were usually found in operation.

Excellent displays of the products of the machines were made in some cases, while in other instances the exhibits of the articles or fabrics produced were not all that could be desired, especially when the products were such that further operations would be required to form useful articles from them.

Following, is a list with a general description of the principal exhibits, commencing with the French; no attempt being made to arrange them in the order of either their excellence or importance.

E.-M.-A. Argellier, 31 Boulevard des Batignolles, Paris, a manufacturer of knitted specialties to measure, exhibited one hand machine, illustrating the operation of producing various articles of admirable perfection.

A. Bonamy, of St. Just-en-Chaussée (Oise), exhibited several machines in operation, among which were automatic machines for knitting fashioned socks or stockings, and automatic circular rib machines with latch needles.

Emanuel Buxtorf, of Troyes, made an attractive exhibit of large circular machines with spring needles, some of which produced plush fabric, by which is meant a fabric with one face covered with projecting loops of a supplemental thread, which are subsequently brushed or napped, thus forming knitted plush.

A circular knitting machine adapted to produce a fabric in two colors, automatically knitting intricate designs of patterns, was an attractive object in this display. Two movable thread guides were actuated by electromagnets, controlled by a slowly revolving cylinder upon which was delineated in miniature the desired pattern. An endless chain provided with pointers moved so as to carry the pointers in contact with the pattern cylinder in a direction parallel with its axis of rotation. The pointers, which acted as electric conductors, were so disposed along the moving chain that at all times one pointer was in contact with the pattern cylinder. The pattern or design was drawn or painted upon the metallic pattern cylinder with a liquid which, when dried, formed an insulator, and as the pointers traversed the surface of the pattern cylinder the electric circuit was closed or open according to the pattern, and the thread guides correspondingly actuated to carry the threads.

The design or pattern in the fabric depends upon the relative positions of two threads, of contrasting shades or color, at the moment the loops or stitches are formed.

The patterns upon the fabric included elaborate designs, such as words, sentences, portraits, and outline views of the Eiffel tower.

The operation of the machine appeared to be perfect within its very low limit of speed.

H. Dégageux, 12 Rue St. Aventin, Troyes (Aube), displayed large circular knitting machines with spring needles, for knitting stripes and plush fabrics.

F.-L. Lemaire, 21 Rue des Coutures, Puteaux (Seine), exhibited a variety of straight knitting machines in operation. The most remarkable machine in this collection was an automatic fashioning machine of fine gauge and containing about thirty needles to the inch. This machine was designed to produce fine fashioned silk goods, and was claimed by the maker to have been of the finest gauge of any machine of that class ever built.

The operation of machines of such fine gauge is said to be feasible when skilled operatives are employed and when silk of suitable quality and size is used.

One straight knitting machine in this exhibit was provided with a so-called embroidery attachment, which consisted of a set of several extra thread carriers disposed at desired distances apart and operated in such a manner that each carried into a single needle a thread of a material or color different from body of the fabric.

Another knitting machine for producing fashioned socks in stripes was provided with a system of thread carriers and devices automatically controlled for actuating the guide carrying the desired color at the proper time, so as to produce stripes of one or more courses of each color, and at the same time allow the machine to produce fabric at every reciprocation.

An automatic fashioning machine of Cotton's type with some minor improvements was also exhibited.

C. Terrot, of Dijon (Côte-d'Or), France, and Cannstadt, Germany, displayed a line of interesting machines in operation. In this exhibit was to be seen a spring needle circular knitting machine of extremely fine gauge, about thirty-four needles to the inch, which was claimed by the makers to have been the finest gauge machine of its class up to that time constructed.

A large circular Jersey striping machine in this collection contained ingenious features.

In operating this machine to produce striped fabric, six threads of different colors or shades were employed, and by means of pattern mechanism the desired thread was introduced into the needles after a suitable number of courses of the next previous color had been finished. When a new thread or yarn was to be introduced it was tied to the thread which was running to the needles and the latter thread severed directly back of the knot.

The knot which united the threads was formed by a mechanical knot-tying apparatus which operated while the machine continued to knit, and the knots were tied with such precision that they all appeared upon the back of the fabric very nearly in a vertical line, as the fabric passed downward from the needles.

If the fabric should be cut longitudinally along this line of knots, no single knot need appear further than about one-fourth of an inch from the edge.

A circular rib knitting machine of fine gauge, about 18 inches in diameter, with two sets of spring needles, was a noticeable object in this exhibit. In this machine was employed a set of horizontal needles arranged radially much after the manner of spring needles in a circular machine for knitting plain fabric; and also an additional set of vertically disposed spring needles cast in "leads" and reciprocated vertically and laterally in the operation of knitting.

M. Grammot and H. Sirodot, of Troyes, France, made an exhibit of plain circular knitting machines provided with spring needles.

Hantz-Nass, of Réchésy (Territory of Belfort), France, had on exhibition and in operation several straight hand-knitting machines adapted to knit plain or rib fabric.

Edouard Dubied & Co., of Couvet (Neuchâtel), Switzerland, had on exhibition several straight knitting machines, some of which were in operation by power while others were designed to be operated by hand.

One of the power rib machines was provided with an electric apparatus for stopping the machine if the thread should break or if it should fail to unwind from the spool or cop with sufficient ease. A provision was also made in the electric apparatus for stopping the operation of the machine when a sufficient number of courses have been finished.

Another rib machine was provided with a Jacquard mechanism designed to produce fancy patterns.

D. Haenens-Gathier, of Gand, Belgium, exhibited an assortment of straight hand machines.

The Harrison Patent Knitting Machine Company, of Manchester, England, had in operation several hand and power knitting machines. For the most part their exhibit consisted in flat machines particularly adapted for producing rib goods. Some of the flat machines were, however, adapted to knit tubular work as well as flat plain and flat rib work.

One machine was provided with a series of extra thread carriers so arranged that each carrier should wind a supplemental thread of a contrasting color or shade around a single needle, at each course, to form longitudinal stripes upon the face of the fabric.

This exhibit contained a small circular machine for knitting plain seamless socks and stockings. The machine was provided with a set of inside needles with cams for operating them for producing rib tops for socks.

The Paget Company, of Loughborough, England, had in operation a straight warp knitting machine, an automatic fashioning knitting machine for knitting stockings, and a looping or "turning-off" machine.

The warp knitting machine (called also a warp weaver by the builders) contained several features not common to machines of this class. The machine exhibited was a straight machine of 18 gauge, *e. g.*, twelve needles to the inch, and contained 1,008 spring needles. The warp threads were carried to the needles by means of a series of troughs formed from pieces of thin sheet steel of suitable form folded together, instead of the usual form of "guides." This style of thread guide facilitates the process of introducing a new warp, as the threads composing the new warp are clamped into a holder adapted to the purpose before the new beam of warp is placed in position in the machine, after which the warp threads can be introduced simultaneously into their proper guides with great facility by properly manipulating the holder containing them.

By this means the labor of "drawing in" a warp as well as a considerable stoppage of the machine is saved.

The machine was also provided with means for adjusting the length of the stitch to a greater degree than is common in this class of machines, either by hand or automatically.

The greatest length of stitches for which the machine exhibited could be adjusted was seven thirty-seconds of an inch.

A series of hooks attached to an operative bar was employed to assist in forming and controlling the stitches or loops. The machine was provided with an apparatus for forming a fringe at either or both ends of an article while being knitted.

Garments or portions of garments can, in a degree, be "shaped" upon this machine by means of an automatic mechanism to govern the length of the loops or stitches, gradually increasing or diminishing their length. By increasing the length of the loops the fabric is increased in width as well as in length, which, within narrow limits, can be accomplished without materially changing the character of the fabric, and is feasible to a greater degree in warp knitting than in the ordinary knitting.

Various accessories to knitting and other analogous machinery were exhibited by Émile Brochon, of Troyes (Aube); Caron & Co., of Puteaux (Seine); Louis Godard, of Troyes (Aube); Philéas Vallée, of Romilly on Seine (Aube), France; and Tatham & Ellis, of Ilkston, Derbyshire, England.

The various displays included needles of a variety of forms, sinkers, jacks, mailleur teeth, narrowing points, loop wheels, and innumerable minute tempered and polished pieces in common use in this class of machinery.

It is to be regretted that the builders of knitting machinery in the United States did not see fit to make a display, though it seems probable that they could have gained little direct benefit had they done so, as the various European builders appeared to be prepared to supply the demand for the varieties of knitting machinery at the present time in use or required in their respective countries.

II. ART OF KNITTING BY MACHINERY.

In making comparisons of the varied types and forms of knitting machines displayed, with each other and with machines of the same

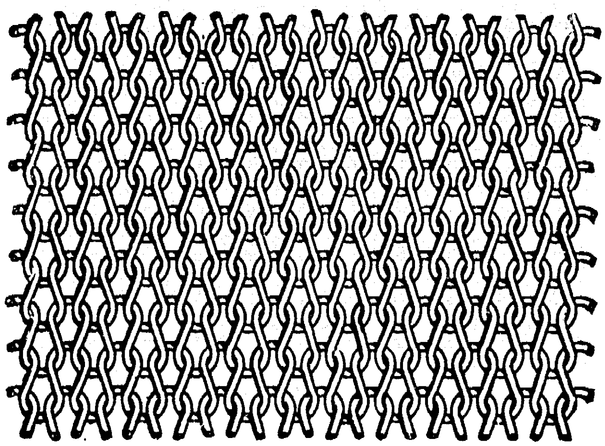

FIG. 1.—Section of plain knit fabric.

class made in the United States, and also comparing them with similar machinery in common use at the time of the World's Fair at Paris (1878), an outline of the art of knitting will first be given.

A knitted fabric in its simplest form consists of only one thread repeatedly looped, each loop extending through another loop previously formed.

Fig. 1 represents a section of such fabric composed of loops of considerable length for the size of the thread, to illustrate the course of the thread and the relations of the loops to each other.

Fabric of this kind is not alike on both sides and is said to have a "right" and "wrong" side which are but little alike in appearance.

In producing such fabric, either by hand knitting or by automatic machinery, each loop is held or supported upon a needle or analogous device until the thread, doubled upon itself, is drawn through said loop, thus forming a new loop which in turn is retained by the needle for future operations, while the old loop, which is "cast off" from the needle, becomes a portion of the fabric.

The art of crocheting is closely allied to that of knitting and the fabrics produced by both processes are in many particulars almost identical.

In simple crocheting, however, the end of the fabric is finished or "bound off" as the operation of crocheting progresses, and when each loop or set of loops has been completed only one loop is retained upon the single needle or hook employed, whereas in knitting all of the loops along the entire end of fabric in process are retained upon one or many needles or equivalent devices.

The art of crocheting, as the name implies, consists in forming fabrics by the use of a hook or hooked needle.

In crocheting by hand much skill is required to properly manipulate the needle to draw and form the loops, as the hook of the needle is liable to engage a loop while passing through it, and, moreover, it is necessary to retain at least a single loop upon the needle at all times.

In ordinary simple crocheting by hand nothing is needed to retain the last series of loops while the operation of crocheting progresses, for the reason that each loop or set of loops is at once finished and bound to the fabric and becomes a completed portion thereof.

Knitted or interlooped fabrics in their normal condition inherently possess much elasticity, longitudinally and laterally, as well as diagonally, and in this respect there is a marked difference between knitted and woven fabrics.

Simple woven fabrics are essentially composed of a series of threads, called the "warp," extending lengthwise of the web of cloth, substantially parallel to each other, together with a "weft" or "filling" thread repeatedly crossing the warp threads at right angles—passing over one warp thread, under a second, over a third, and in like manner across the whole number of warp threads in one direction, and alternating in a similar manner in the opposite direction; as illustrated in Fig. 2.

Woven fabrics possess little elasticity either longitudinally or laterally excepting that which is due to the construction of the threads or to the material of which they are composed, though diagonally, or bias, a loosely woven fabric can be considerably elongated, and possesses to some extent the property of renewing its original form.

Knitted fabric composed of interlooped thread together with a weft thread incorporated into the body of the fabric, but not interlooped, is a kind of combination of a knitted and woven fabric pos-

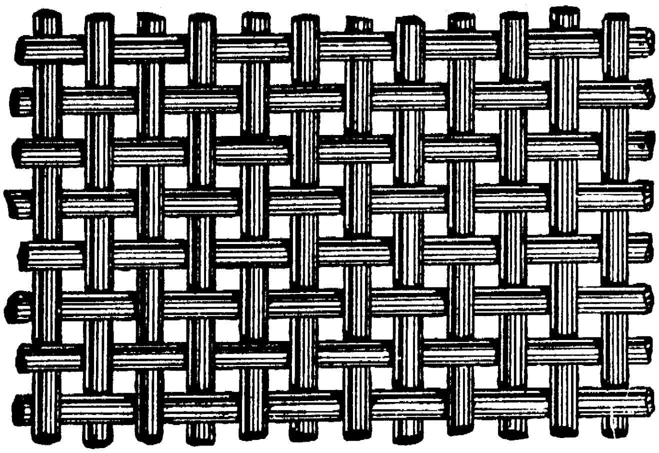

FIG. 2.—Section of plain woven fabric.

sessing little of the elasticity of the former though much resembling it in general appearance. One variety of such fabric is illustrated by Fig. 3.

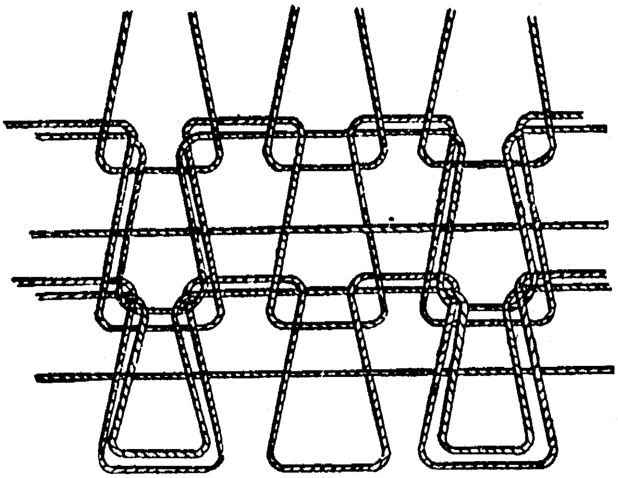

FIG. 3.—Section of weft-thread knit fabric.

Fig. 4 illustrates a fabric in which the weft threads are occasionally interlooped with the loops forming the body of the fabric. Such fabric, like plain knitted fabric, is not alike on both sides.

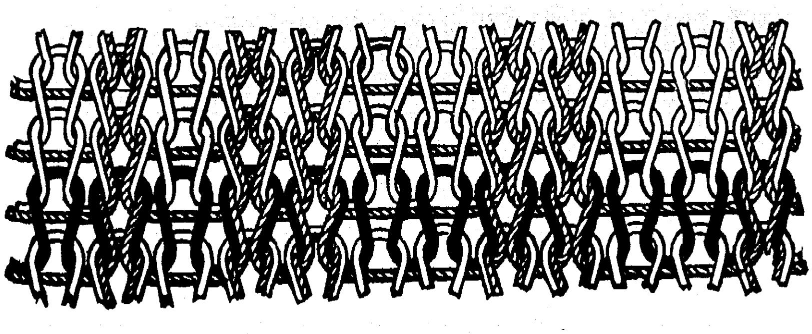

FIG. 4.—Section of knit fabric with weft thread interlooped (face side).

Fig. 5 represents the back or wrong side of the fabric illustrated in Fig. 4.

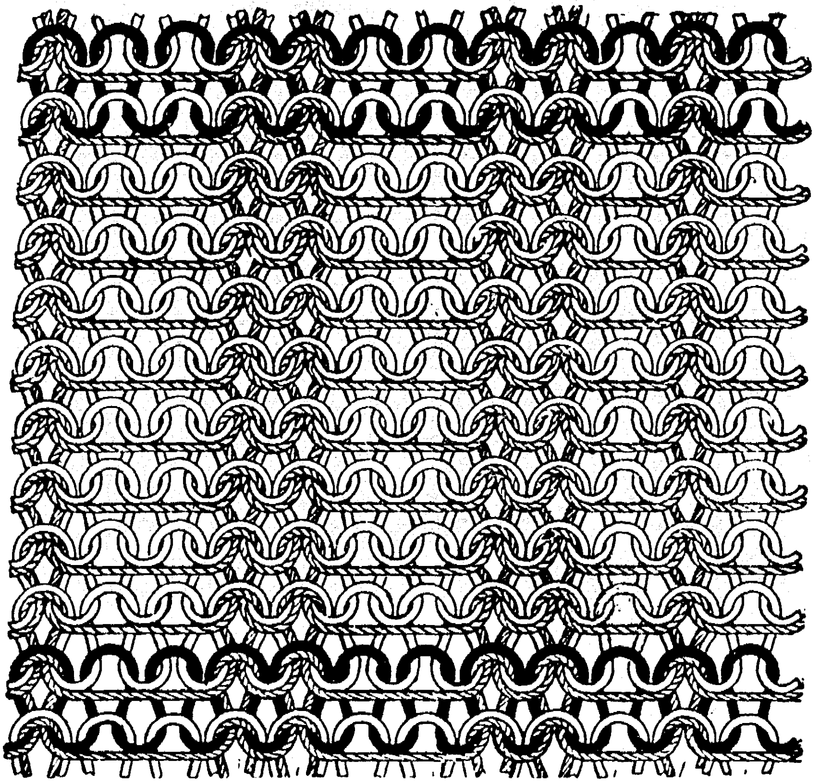

FIG. 5.—Section of knit fabric with weft thread interlooped (wrong side).

Fig. 6 represents a section of loosely knitted warp fabric which is composed of only warp threads, each being interlooped with its neighbor. The process of producing such fabric will be briefly explained in the description of warp knitting-machines.

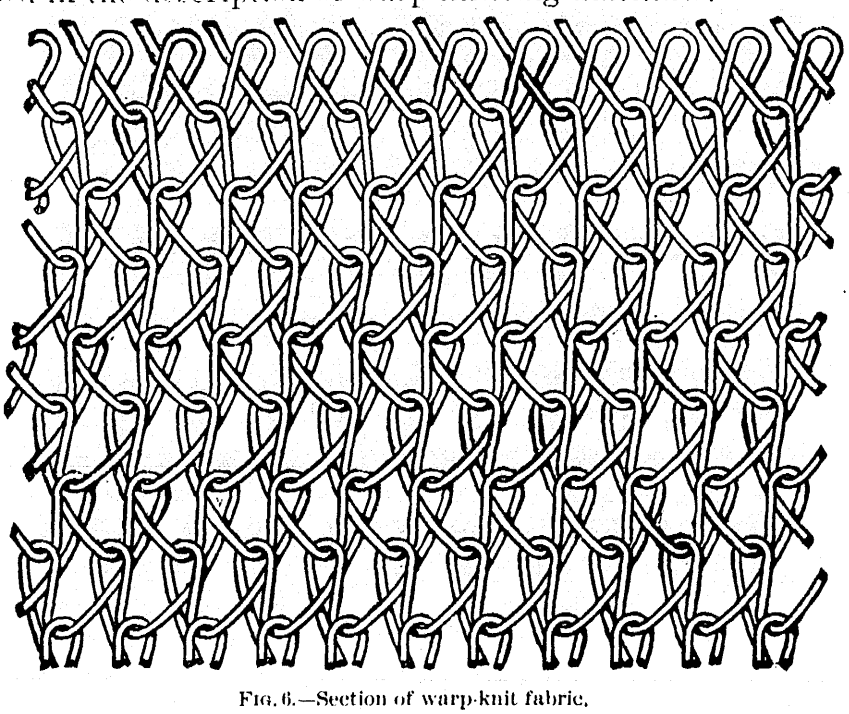

FIG. 6.—Section of warp-knit fabric.

Ribbed fabric known as "one and one rib," called also "Derby rib" after the locality in England where it first became popular, is composed of loops formed alternately on either side of the fabric, and, unlike plain knitted fabric, has substantially the same appearance on either side. "Cardigan rib" fabric is much thicker and wider than "Derby rib" when formed from thread or yarn of the same size, though much resembling it in general appearance, and is also alike on both sides.

Fig. 7 illustrates the disposition of the threads in a section of this fabric represented as loose or open to better illustrate it.

Half Cardigan rib fabric, a kind of combination of Derby rib and Cardigan rib, is somewhat thicker and wider than the former while it is less so than Cardigan rib. Advantage is taken of the various properties of knitted fabrics to form shaped garments, various ma-

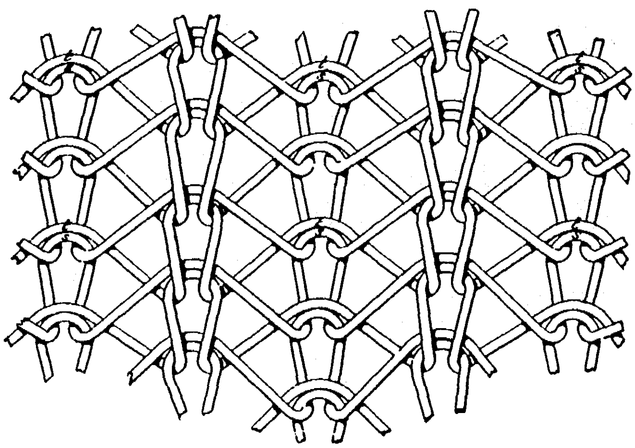

FIG. 7.—Section of Cardigan rib.

chines having been devised to form different portions of a garment with the required stitches or fabrics to effect the desired changes in width and thickness.

Various other effects are produced by numerous modifications and complications of knitting, but the fundamental principle of interlooping is always present.

The most common departures from the simple process will be again briefly mentioned in connection with the descriptions of various machines designed for producing such results automatically.

In the well-known process of ordinary hand knitting straight needles are employed, and these are usually formed from straight plain pieces of round steel wire, tempered and polished and of suitable size, the character of the fabric depending largely upon size of the needles relatively to the size of thread or yarn employed, as the loops or stitches of each course are retained upon these straight needles until they are cast off in forming a subsequent course.

The operations of hand knitting and crocheting have been imitated to a considerable degree in knitting machinery, and even in the modern improved machines much similarity still exists.

The needles usually employed for looping the thread, in knitting machines, bear a marked resemblance to the crochet hook as used by hand, and the operation of forming the loops or stitches is practically the same as in crocheting and in hand knitting, though knitting machines possess a separate needle for each loop or stitch of the entire series, but each needle also performs the function of retaining the loops in a manner not far removed from the corresponding function of the straight needles used in hand knitting.

In one variety of knitting-machine needles the hook is extended to a considerable distance and is sufficiently delicate to permit of being sprung or closed against the body or "shank" of the needle to prevent it from engaging the loop as it passes, thus allowing the loop upon the needle to be shed off as a new loop is drawn through it. Needles of this class are termed "spring" needles, but are also known as "barbed," or as "bearded" needles, and are illustrated in Fig. 8.

FIG. 8.—Spring needle.

Such needles were employed by William Lee, near Nottingham, England, in the year 1589, in the first knitting machine ever constructed, and the needles of this type in common use at the present time are in all essential respects substantially identical.

Another variety of needles much used in machines is provided with a hinged or swinging latch which protects the hook and permits the loop upon the needle to be shed off as a new loop is being formed. Needles of this variety are known as "automatic-latch" needles, or simply "latch" needles, and are illustrated in Fig. 9.

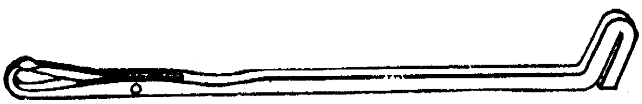

FIG. 9.—Latch needle.

The "latch" needle is believed to have been invented in the United States, and has proved to be an important factor in the knitting industry.

Fig. 10 is a copy of the drawings forming a portion of the specification of a United States patent to J. Hilbert, of Providence, Rhode Island, dated January 9, 1849, and well illustrates the action of this variety of needles.

The development of knitting machinery in which latch needles are employed has been accomplished almost entirely in the United States, though such machinery has to a considerable degree been imitated in other countries.

Other needles have occasionally been employed in knitting machines with some success, but are now seldom seen.

Fig. 11 illustrates a variety of knitting machine in which the operation closely resembles the process of hand knitting.

Knitting needles are not employed in this machine, the loops being individually retained upon the separate points or pins. The loops are formed by a special looping device, and when a new loop is formed it is placed upon one of the points in lieu of the old or previous loop, which is cast off.

Knitting machinery may naturally be divided into two principal classes, viz, straight and circular; these two principal classes, how-

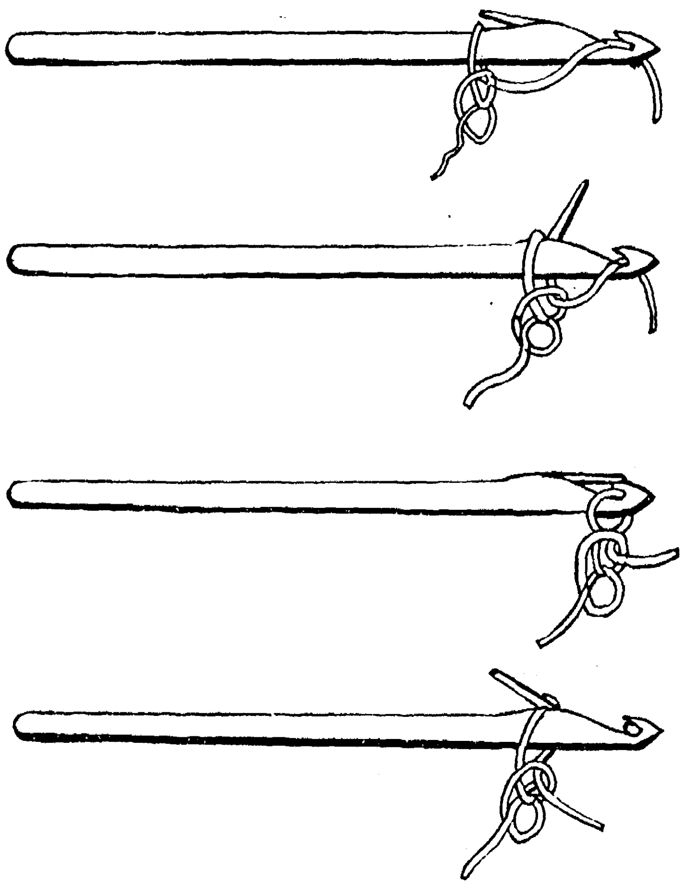

FIG. 10.—Showing the action of the latch needle.

ever, have so many elements in common that they can not be entirely separated in considering them.

The function of all such machines is to produce knitted fabric which, as has been stated, is essentially a looped fabric formed by repeatedly interlooping one or more threads together.

The two principal classes of needles, viz, automatic latch needles and spring needles, are employed in either the straight or circular machines, and in some instances the two kinds of needles are used jointly in the same machine.

For many years knitting machines were operated exclusively by hand, and the art of operating hand machines became a trade.

Straight machines were used exclusively up to a comparatively recent date, and the art of hand-machine knitting was carried to such a degree of perfection that, notwithstanding the marvelous improvements in machinery and its adaptation to be operated by power, hand-machine knitting is yet in vogue as an auxiliary in many large manufactories, while thousands of hand machines are in use among the smaller manufacturers and in families.

It is worthy of note that the hand machines in common use at the present time are as a rule of modern design and construction, and little resemble the machines in general use two decades ago.

In designing machines to operate by power the hand machine operations were first imitated quite closely, commencing with the simpler

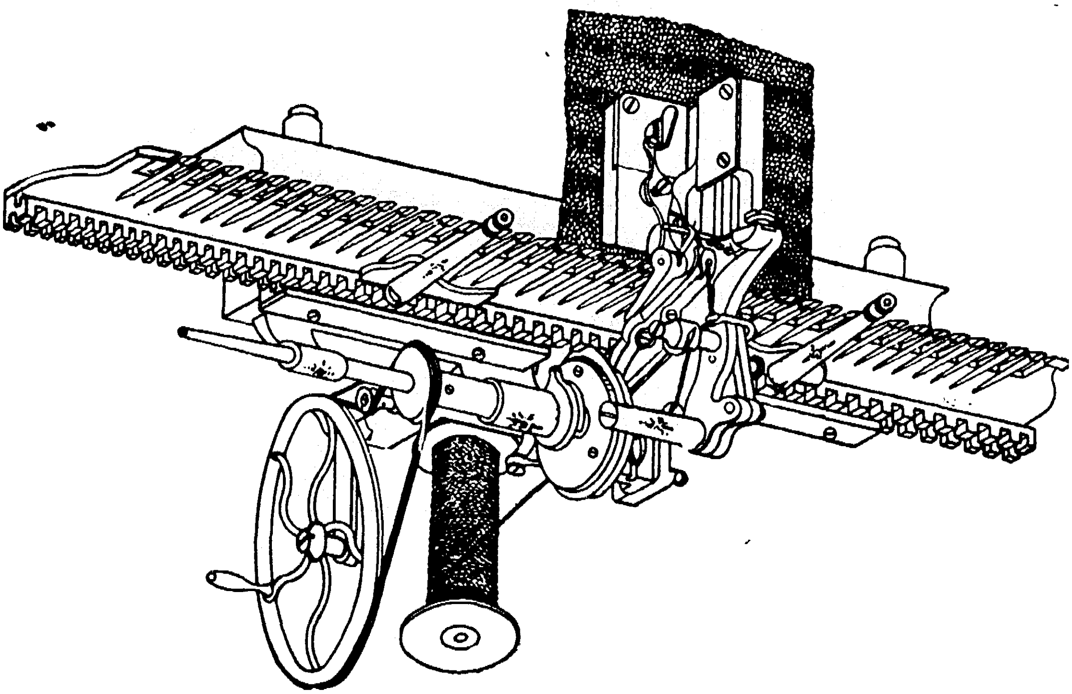

FIG. 11.—Straight knitting machine with loop retaining points.

and easier movements. One by one the more complicated operations were automatically produced, when the machines began to assume improved forms, departing widely from the earlier knitting machines, which were constructed with heavy wooden frames, from which fact probably originated the term "knitting frames" so often applied to this day to knitting machinery, even though the similarity is in many cases difficult to detect.

Spring needles were for a long time employed almost or quite exclusively in knitting machines, and perhaps still predominate, being adapted to produce fabric from finer yarn or thread, at the same time being less expensive and possessing other advantages, particularly in machines of fine gauge.

In the earlier hand machines the thread was carried over the needle by hand, but, later, mechanical thread carriers came into use, and at a comparatively recent date machines have been constructed with several thread-carriers, bearing threads of varying shades or colors, and acted upon by automatic mechanism to carry the desired threads at the proper time to produce stripes in colors laterally across the fabric.

In straight machines in which spring needles are employed the needles are usually secured to a bar, which in some varieties of machines remains stationary in the machine, while in other forms of machines the needle bar is reciprocated and correspondingly carries the needles to perform a part of the required operations of knitting.

In machines employing latch needles the latter are, with rare exceptions, operatively supported in grooves and reciprocated successively by means of cams to form the loops constituting the fabric. This plan has offered almost unlimited opportunites to inventors, and numberless contrivances have been originated to facilitate the operation of knitting well known fabrics and so produce varieties and effects before unknown.

Rib knitting machines contain two separate sets of needles, operating to draw loops or stitches in opposite directions; producing a fabric of greater thickness and elasticity which was used for many years principally for elastic cuffs upon garments; but in recent years ribbed fabrics have been employed in a wide range.

One variety of straight latch-needle knitting machines is provided with two separate sets of needles supported in separate needle beds at an angle with each other in one plane and with their edges adjacent and parallel, with cams for actuating the needles of both sets together to form ribbed fabric; with slight changes or adjustments these are adapted for knitting flat plain fabric by operating one set of needles and knitting alternately in opposite directions; or the same machine may with equally simple changes be adjusted to form plain tubular fabric by alternately knitting, in a given direction, with one set of needles supported in one of the needle beds, and in the opposite direction with the needles in the adjacent or companion needle bed.

Fig. 12 is an illustration of a hand machine of this variety.

Almost any knitted article, plain or rib, flat or tubular, straight or fashioned, and of any size within the limits of the particular machine used, may be made upon machines of this kind.

An immense number of machines of this type are in use, and probably a larger number of improvements have been applied to this species of machines than to any other, and an almost infinite variety of effects can now be obtained by the employment of the multifarious modifications and attachments now in common use.

While the machine illustrated in Fig. 12 is designed to be operated by hand, other forms of machines of this class adapted to be operated by power have come into general use.

Fig. 13 represents a power machine of this class.

Jacquard or analogous mechanism has been applied to knitting machines of this class to control the action of the needles whereby certain needles may be thrown into or out of action at premeditated times. Upon some of this class of machines complete stockings of the "seamless" variety may be made. In some of those machines the two opposite sets of needles act jointly once for the first course, and then the action of the needles included in one set is discontinued; the needles of the companion set are then operated, but in gradually decreasing numbers for a time, and afterward in gradually increasing numbers until all are again in use. This operation forms the toe, and then the needles of both sets are alternately brought into action to knit tubular fabric which forms the foot of the stocking.

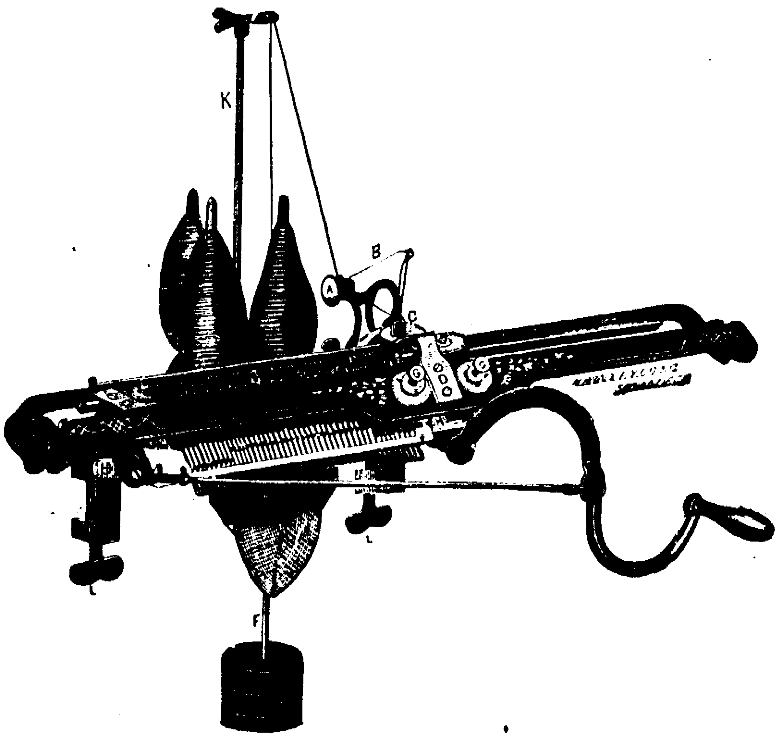

Fig. 12.—The Lamb knitting machine.

At the proper time the operation of one set of needles is again discontinued, while the companion set at the opposite side of the machine continues to operate to knit the heel of the stocking in the same manner as the toe was formed.

When the heel is finished the machine again proceeds to knit tubular work, as before, for the leg of the stocking.

In some machines a supplemental thread is introduced at the proper time to increase the thickness and firmness of the heel, and the stitches are sometimes gradually lengthed while knitting the leg of the stocking to somewhat enlarge or "shape" it.

These operations are entirely automatic, and the stocking is dropped from the machine complete with the exception of the top, which in the better grades requires some sort of finish.

Fig. 14 represents a machine of this type provided with a species of Jacquard or pattern mechanism for partially controlling the action of the needles.

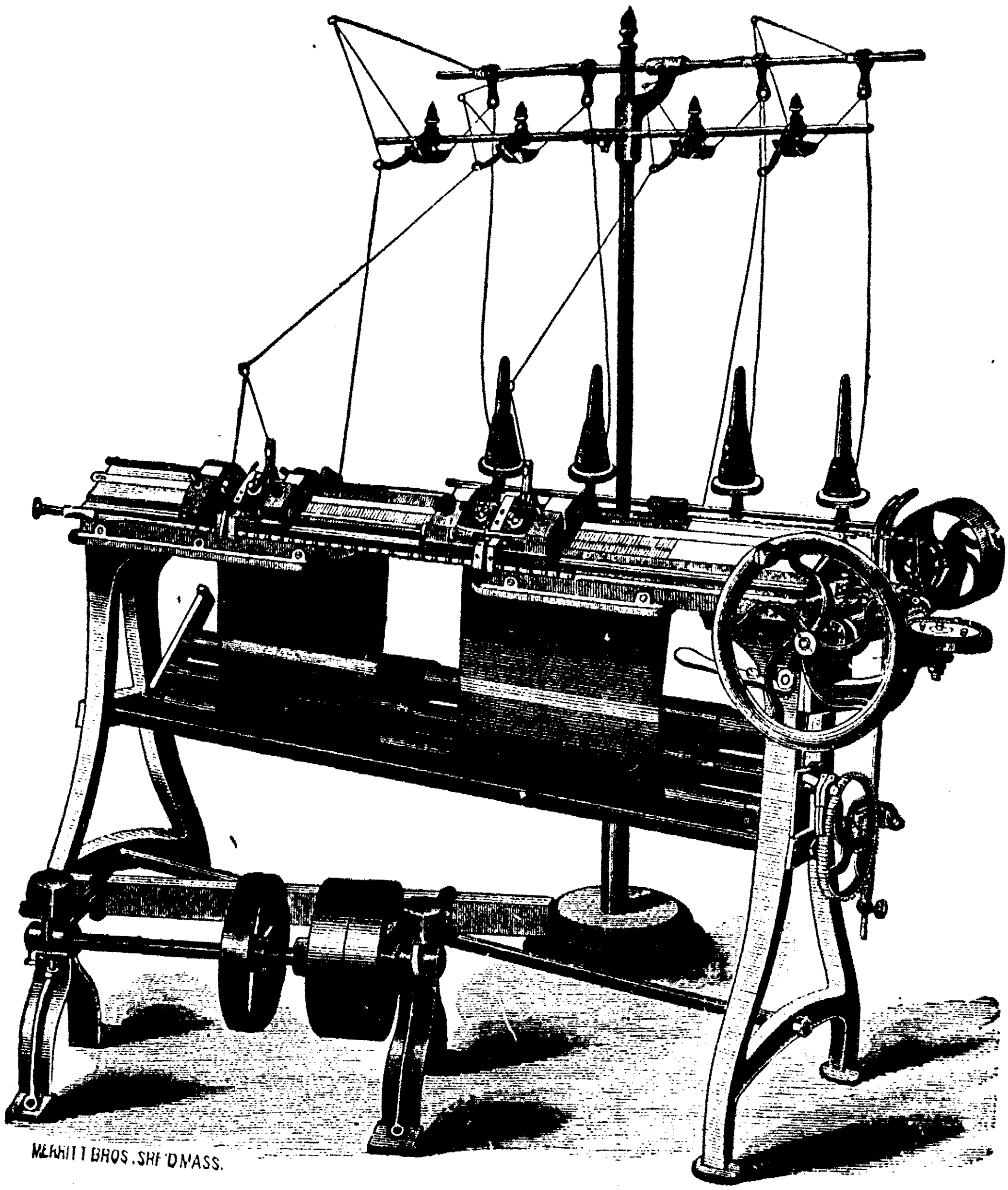

FIG. 13.—Lamb power Cardigan jacket knitting machine.

The operation of knitting "seamless" stockings will again be mentioned in connection with circular-knitting machines.

In operating knitting machinery it is common to form wide fabric, to be afterwards cut, and formed into garments by sewing the various pieces together; but the most expensive articles are "fashioned" in the operation of knitting, by transferring loops from needles at the edge of the fabric to other needles beyond and outside of the fabric to "widen," and to other needles nearer the middle of the fabric to

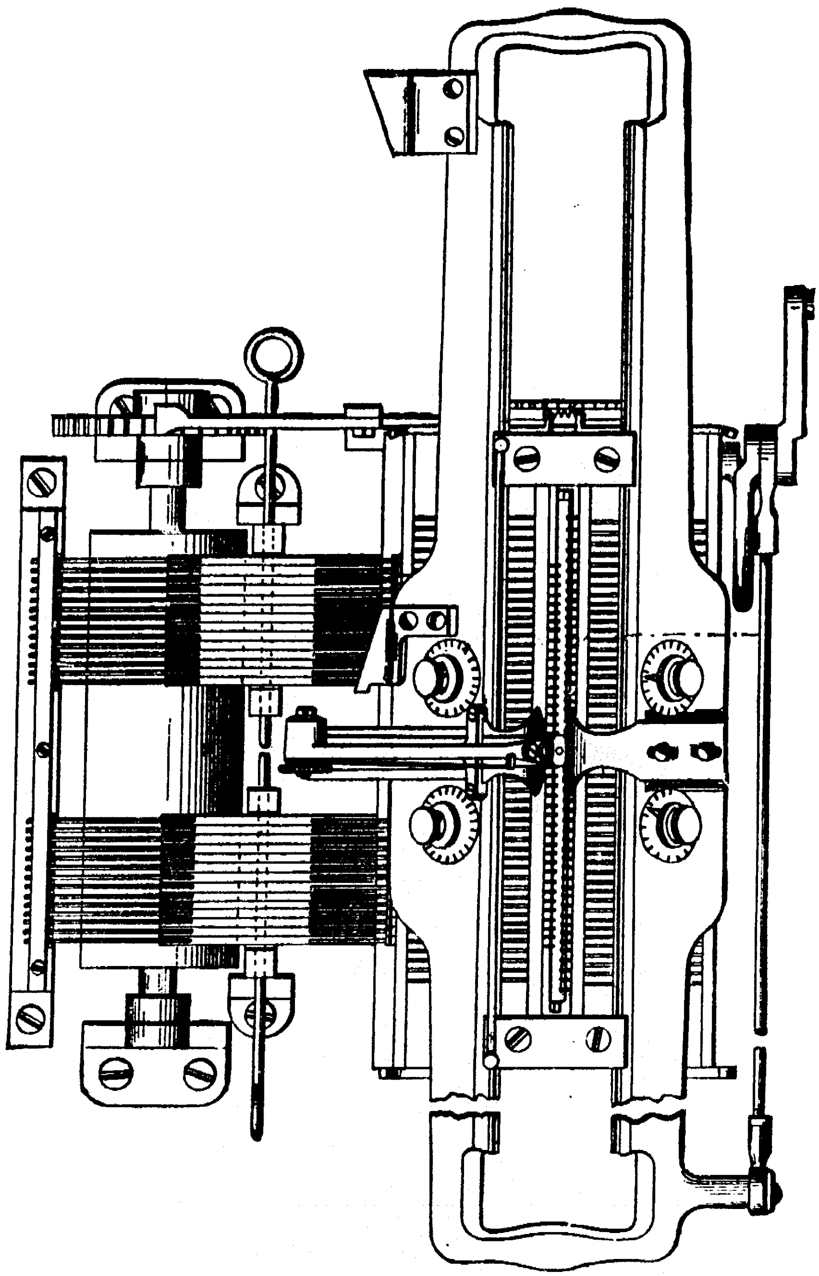

FIG. 14.—Straight knitting machine with pattern mechanism.

"narrow," in which cases the number of needles actually employed in knitting varies according to the width of the fabric.

Fabric knitted in this manner though varying in width retains its characteristic thickness and elasticity.

Fig. 15 represents a piece of narrowed or fashioned knitted fabric showing wales or rows of stitches merged together along the lines of "narrowing" or "fashioning."

The successive operations of narrowing are illustrated in Figs. 16, 17, 18, 19, and 20.

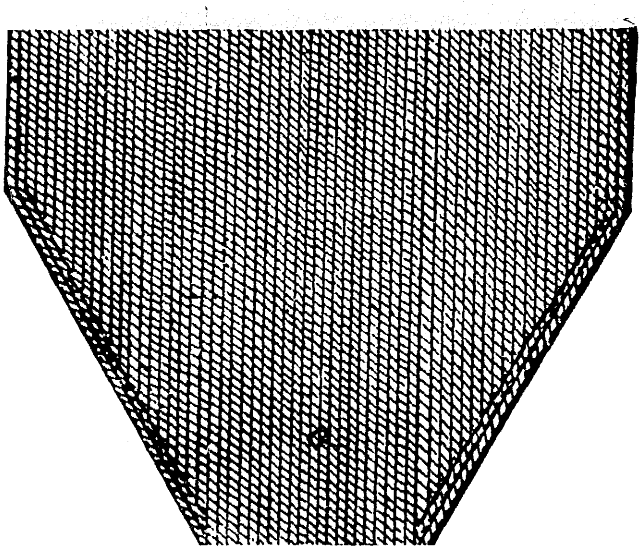

FIG. 15.

Fig. 21 shows two needle beds or supports of a knitting machine, showing a portion of one set of needles in positions to take the thread or yarn, and other needles in position to receive the transferring points.

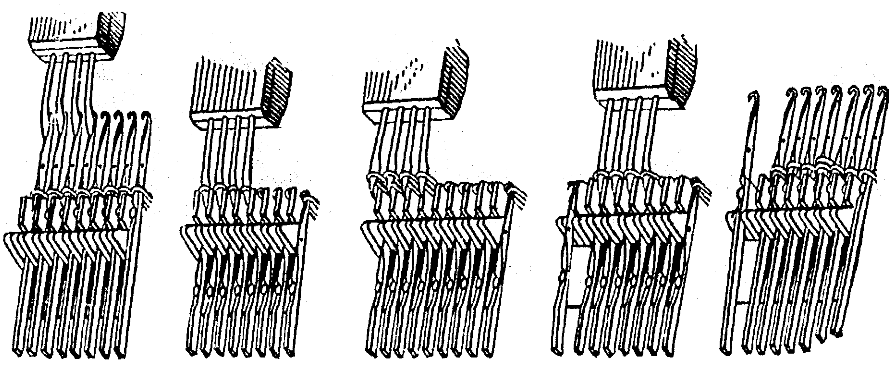

FIG. 16. FIG. 17. FIG. 18. FIG. 19. FIG. 20.

In Fig 16, the latch needles are represented as each retaining a loop and each extending outward from its support to the same distance. The transferring points, supported in a holder, are placed upon the needles and extend into small recesses in the needles near their hooks. The needles, together with the narrowing points, are caused to recede collectively from the positions shown in Fig. 16, to those shown in Fig. 17, when the loops before retained by the needles are now held upon the narrowing points, which are then raised to the positions shown in Fig. 18, afterward being moved laterally one space to positions directly over the needles as shown in Fig. 19. The needles are then collectively caused to move forward or outward in their supports, when their hooks pass through the loops held over and in front of them by the narrowing points, which are afterwards carried away from the needles, when the stitches are retained by the needles—as shown in Fig. 20, one stitch being upon each needle excepting the outside one, from which the loop was removed and was not returned to it; but it will be observed that there are two loops upon one of the needles which, when a subsequent course is knit, will cause a double loop at that point in the fabric which has been narrowed one "needle" as it is technically called.

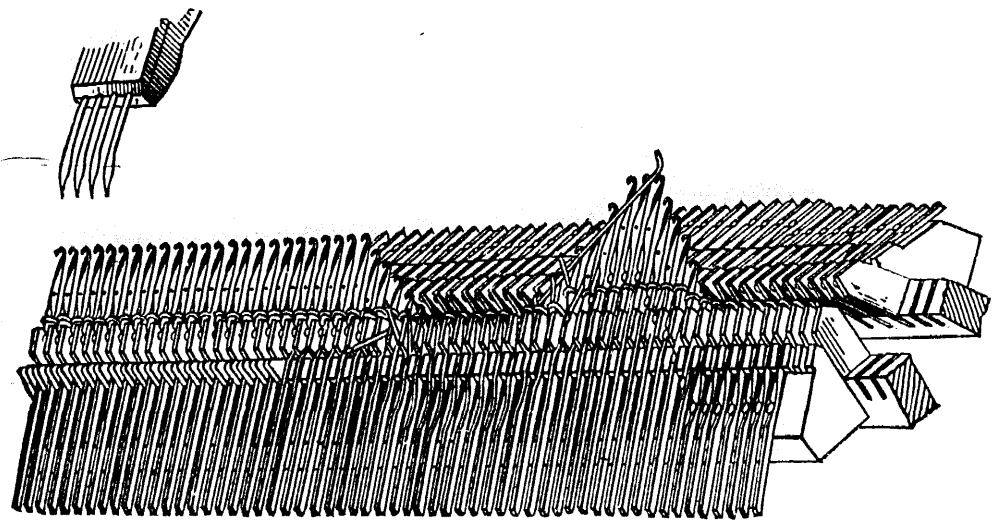

FIG. 21.

Several courses are afterwards knit without employing the outside needle and the operation of narrowing is again performed, and in like manner the fabric is "fashioned" to the desired width.

The operation of widening is analogous to narrowing, the transferred loops being carried in the opposite direction and instead of leaving two loops upon one of the needles a needle is left without a loop and a hole would appear in the fabric at that point if a loop previously made were not "picked up" and put on to the needle.

These operations of narrowing and widening may be performed by hand and are so done to a considerable extent, but they are all performed with ease and precision, even to picking up a loop and placing it upon the unoccupied needle, by means of automatic devices contained in modern fashioning machines.

The operation of transferring the loops in fashioning is substantially the same upon spring needles as upon latch needles.

Figs. 22, 23, and 24 illustrate machines provided with automatic fashioning mechanism.

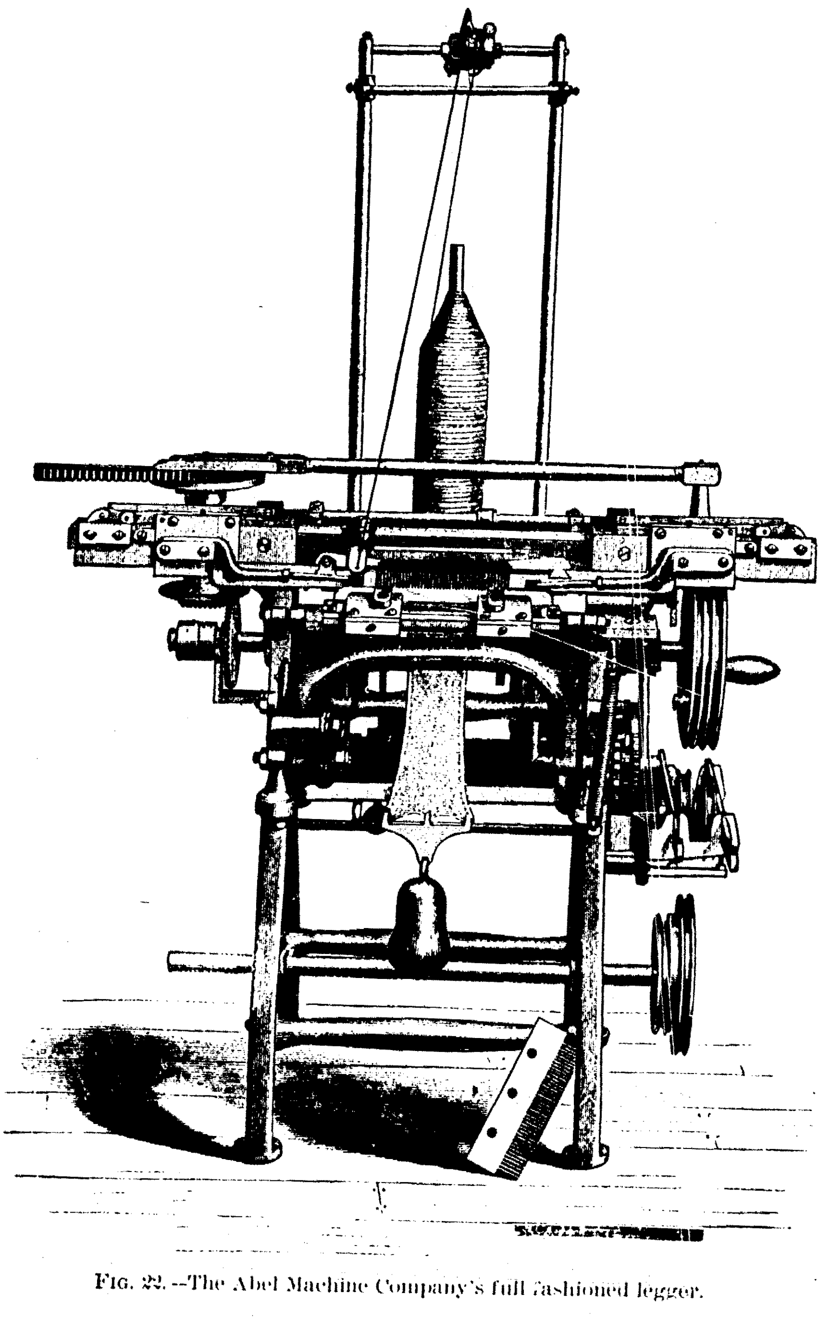

FIG. 22.--The Abel Machine Company's full fashioned legger.

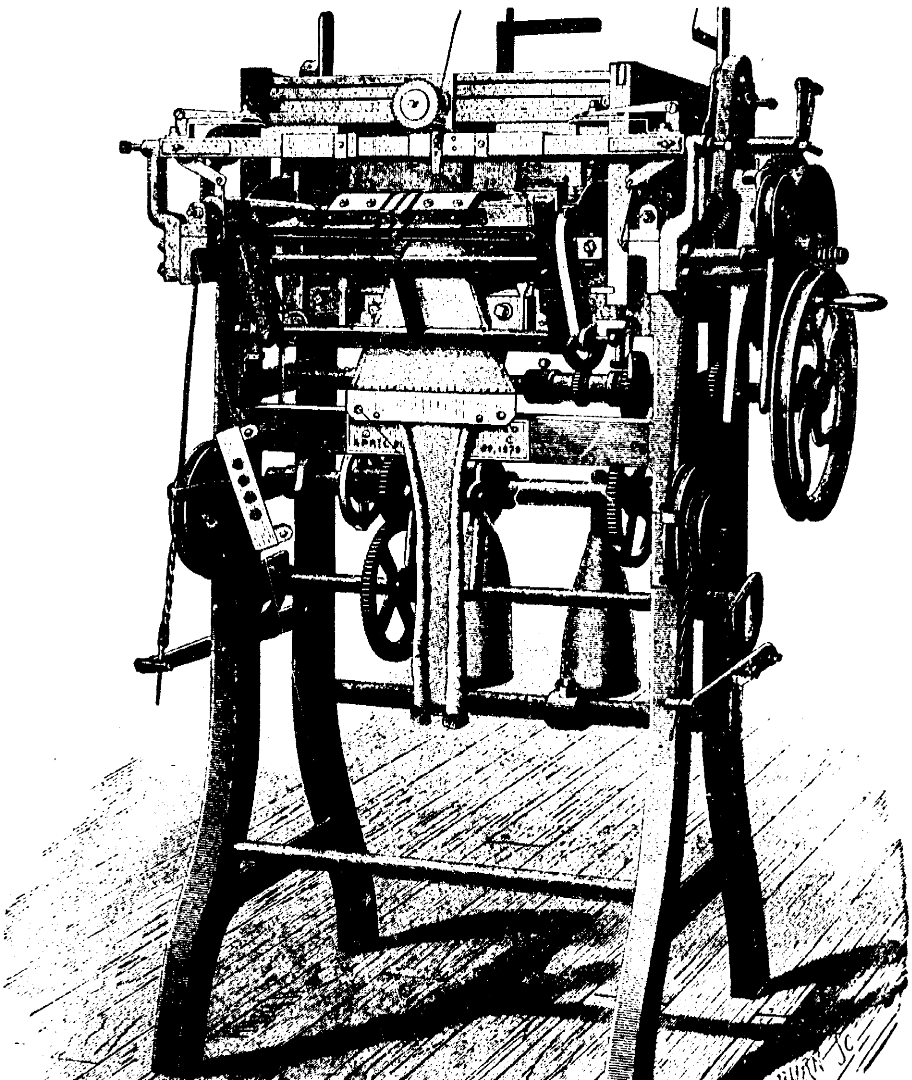

FIG. 23.—The Aiken full-fashioned footer; The Abel Machine Company.

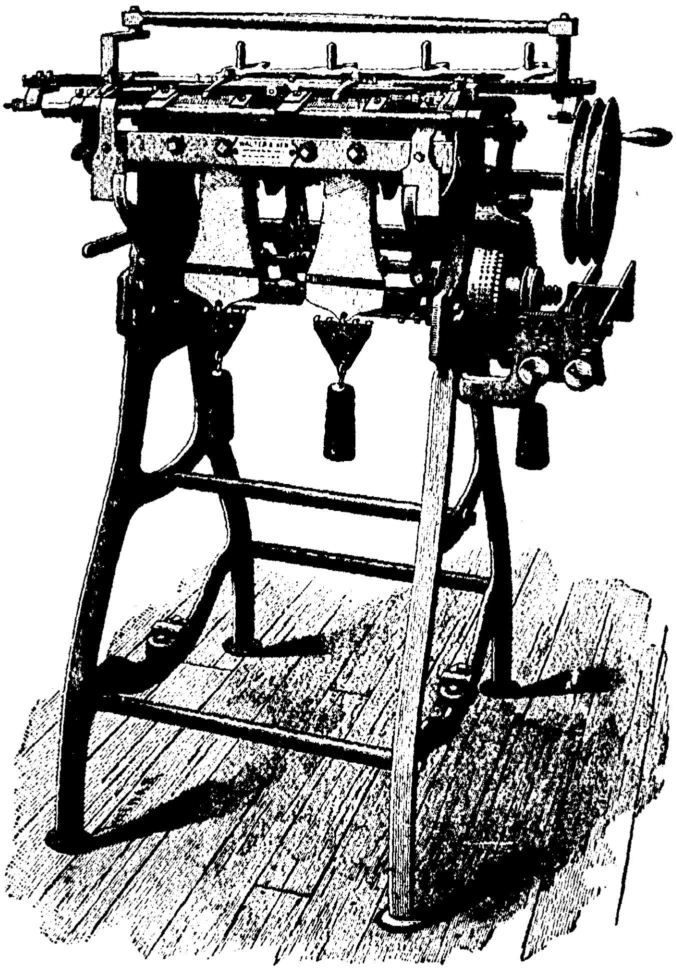

FIG. 24.—"Saxony Machine." (Full fashioning.) (The Abel Machine Company.)

Fig. 25 is an illustration of a knitting machine with two banks of latch needles and provided with automatic fashioning apparatus.

A high degree of excellence has been attained in the design and construction of knitting machinery for producing fashioned articles.

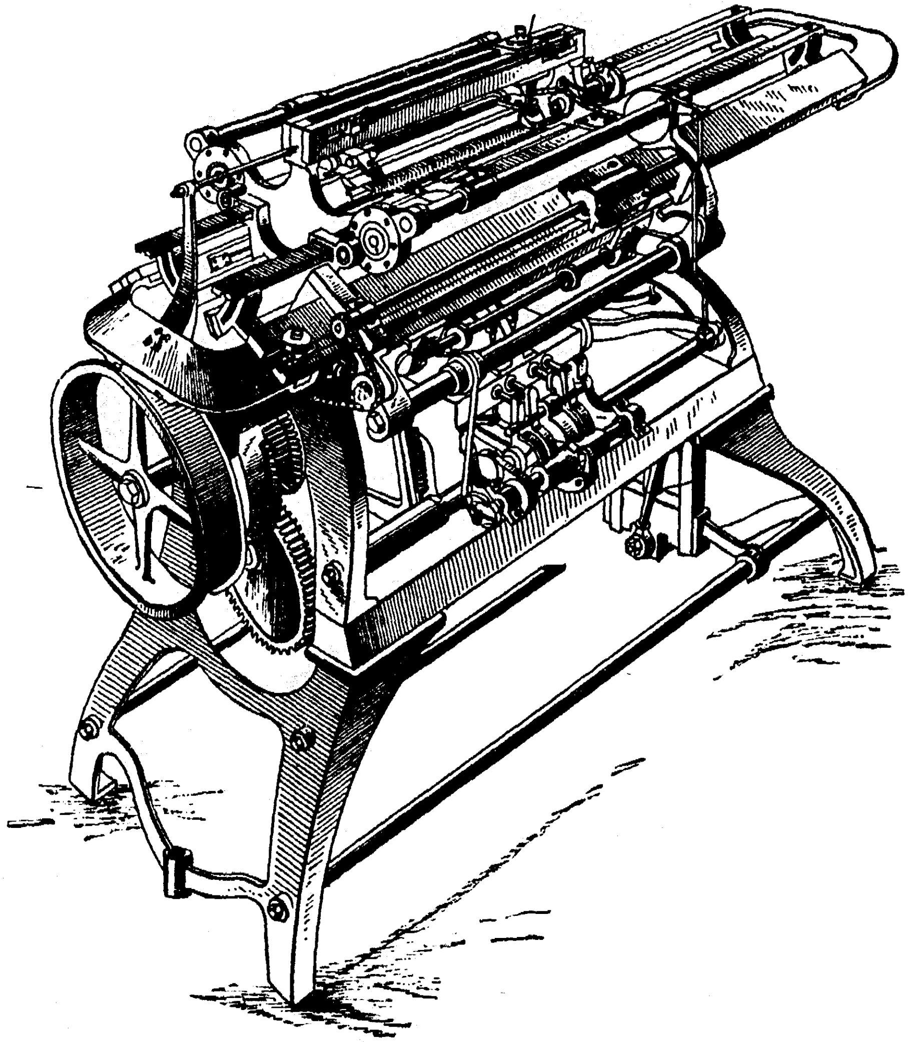

FIG. 25.—Straight rib-knitting machine with fashioning mechanism.

Some of the fashioning machines are of magnificent proportions and in many instances are adapted for producing automatically a large number of like articles at one and the same time. Fig. 26 is an illustration of such a machine.

In machines of this variety many threads are employed, and the fashioning as well as the knitting progresses simultaneously at many points along the machine. To the casual observer such machinery appears intricate and complicated, but it is worthy of note that operations apparently so delicate, and results so difficult to acquire, yet so desirable, are now attained with facility and economy upon modern machines of this class.

Warp knitting is, with rare exceptions, done upon straight machines, which are commonly called warp frames, and in the majority of such machines spring needles are employed.

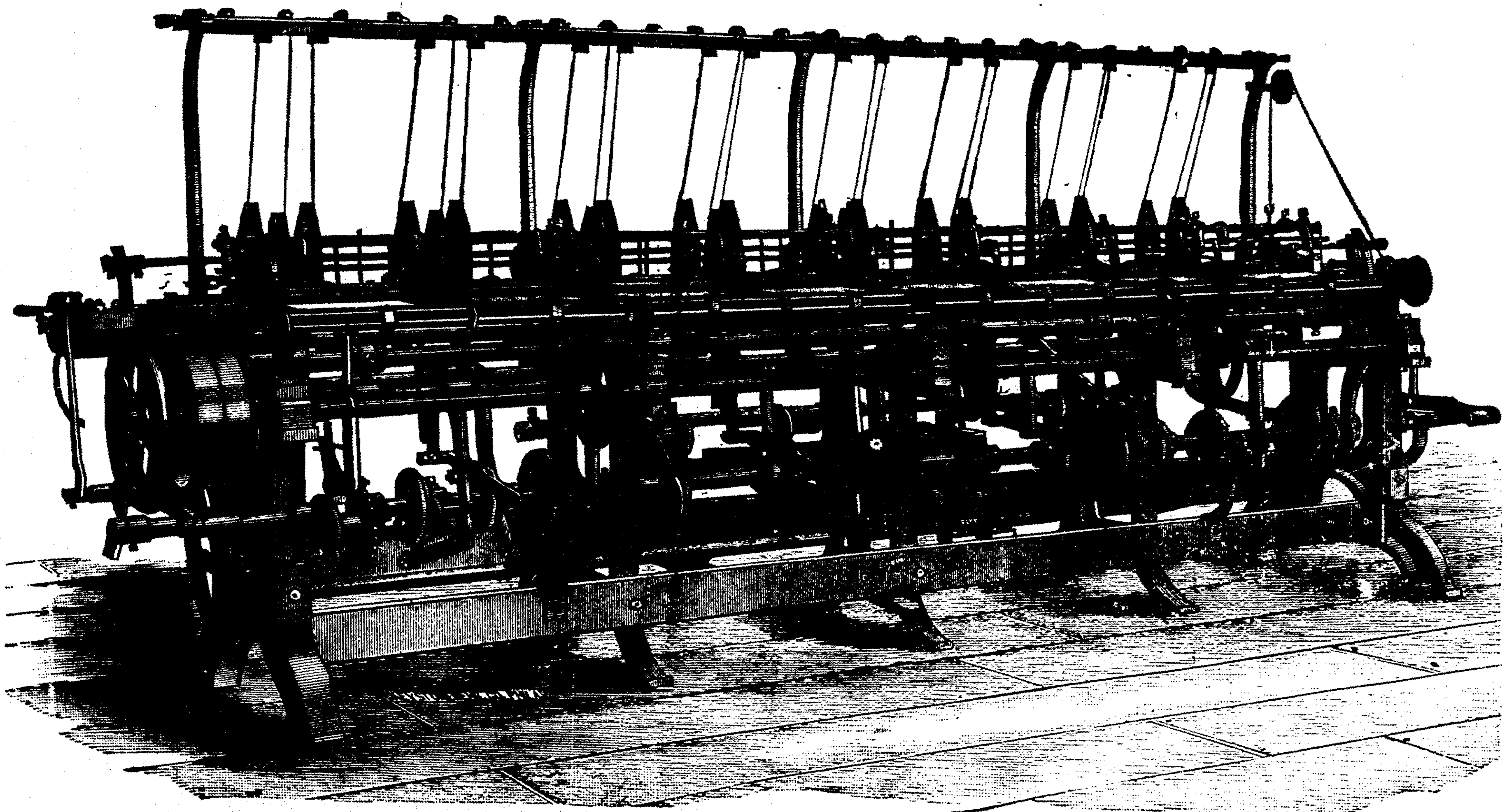

FIG. 26.—The Joseph Heginbothom Machine Company knitting machine.

In warp-knitting machines the fabric is formed from a number of parallel threads, each of which is interlooped with an adjacent thread by means of a needle for each thread and an extra needle for the whole number of threads.

Ordinarily, each thread of the warp is interlooped or enchained with the adjacent thread alternately at each side, forming a series of chains, each loop of which is interlooped with its immediate

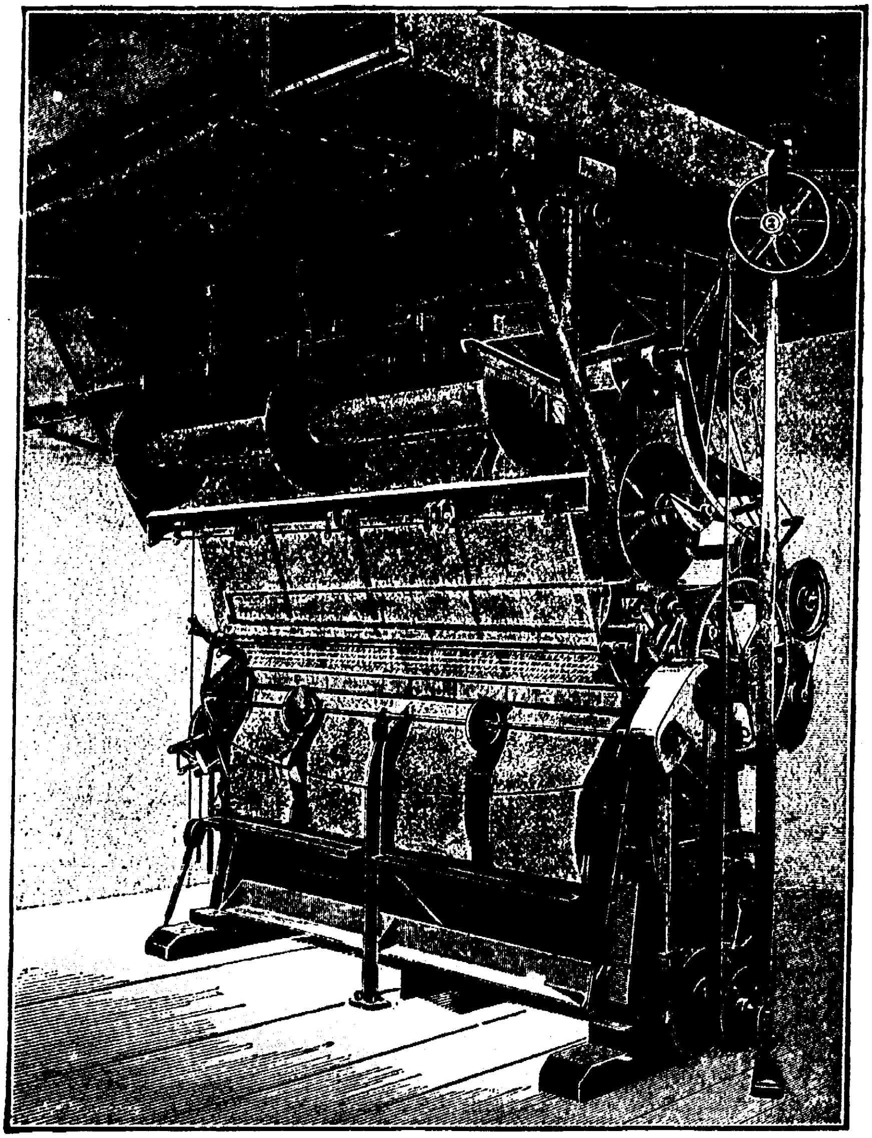

FIG. 27.—The Paget warp-knitting machine. (Front view.)

neighbor at either side, excepting at the edge or selvage, where the outside thread is only enchained and interlooped with the contiguous thread on one side.

In fabric made upon warp-knitting machines the enchained threads extend longitudinally with the fabric in a zigzag manner, instead of laterally, as in fabric knit in the ordinary manner.

Figs. 27 and 28 illustrate the Paget warp-knitting machine, which was exhibited in operation at the Universal Exposition at Paris in 1889 and has been described briefly herein above.

Machines of this class are usually massive, and are sometimes 18 or 20 feet in length, containing in some instances over 4,000 needles.

Two separate sets of warp threads are often employed in such machines, which are then provided with two independent thread-guide bars to carry the threads to the needles.

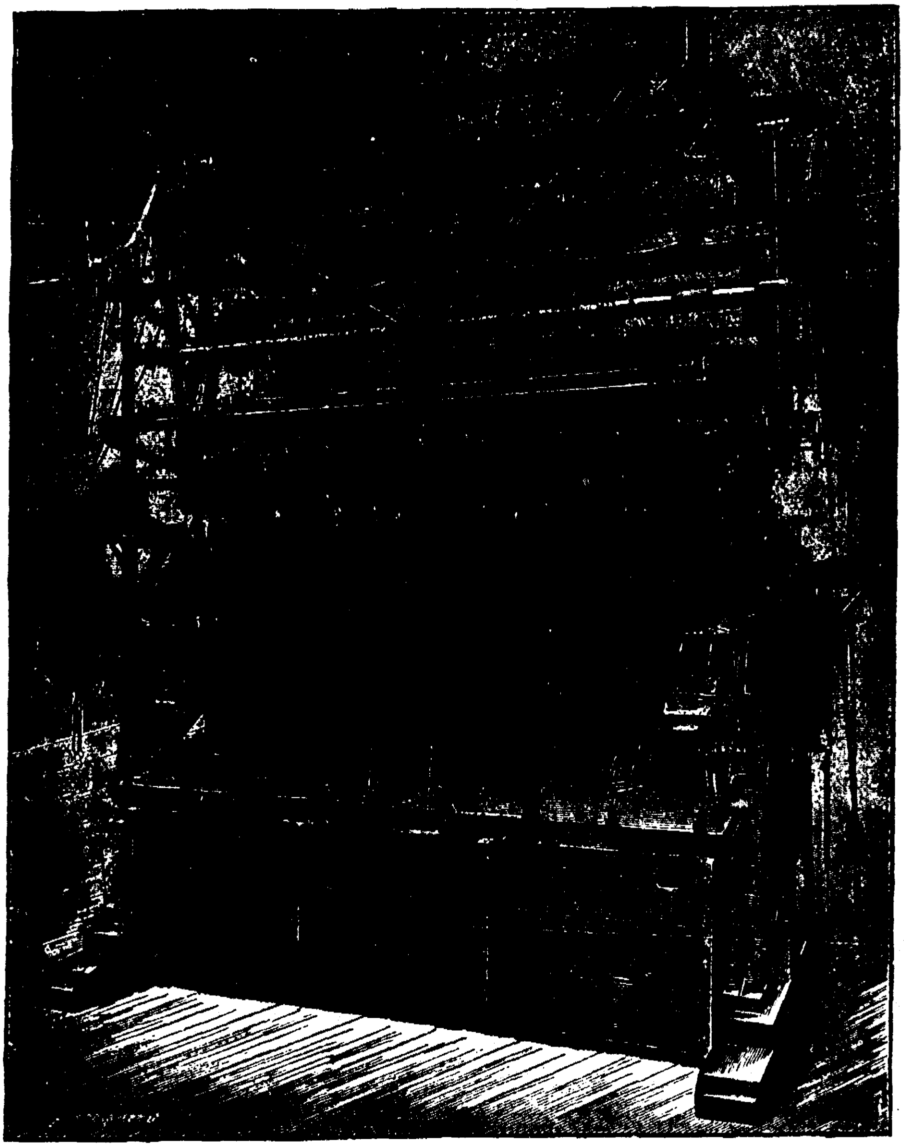

FIG. 28.—The Paget warp-knitting machine. (Rear view.)

A great variety of effects may be produced by numerous modifications of the simple warp frame, and many machines are now in use, particularly in England.

In the ordinary method of plain knitting a thread is carried to each needle of a series, and when more than one thread is employed each thread is carried to all the needles of the series, and as a consequence the loops forming the fabric are arranged in straight lines, instead of zigzag lines, lengthwise of the fabric.

In lengthening the loops, when arranged in a zigzag manner, the width of the fabric will be increased to a greater proportionate degree than when loops arranged in straight lines are correspondingly lengthened. For this reason the method of "shaping," by gradually increasing or diminishing the length of the loops or stitches, appears to be open to less objection in warp knitting than in ordinary plain knitting.

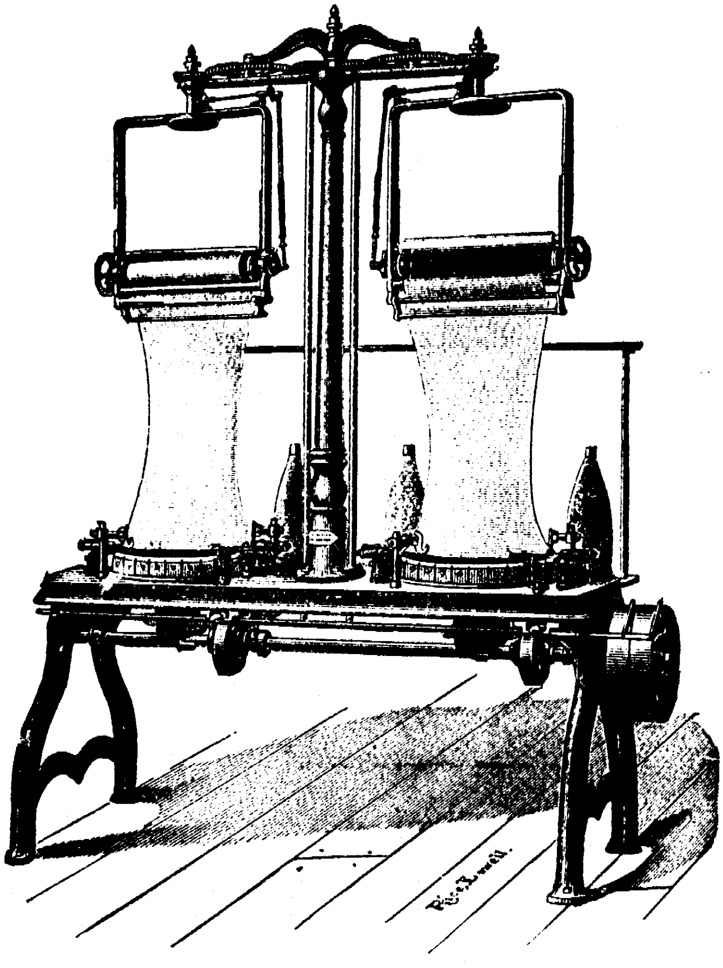

FIG. 29.—Spring-needle circular knitting machine. (J. S. Crane & Co.)

Warp knitting is sometimes called warp weaving, but it is not clear upon what basis the appellation is founded.

Circular knitting machines, although of later origin than straight machines, are yet of no less importance.

In circular knitting machines the operation of knitting is generally continuous in one direction, though there are important exceptions, which will be noted. The more simple forms are adapted to produce plain fabric, and contain a single set of needles arranged in a circle vertically or radially, supported by a ring or cylinder.

When spring needles are employed, as the needles are not generally reciprocated, but remain stationary, or revolve collectively, various devices are employed to carry the threads into the hooks of the needles, to change the positions of the loops upon the needles in the process of forming loops, and to shed off the loops when new ones are formed.

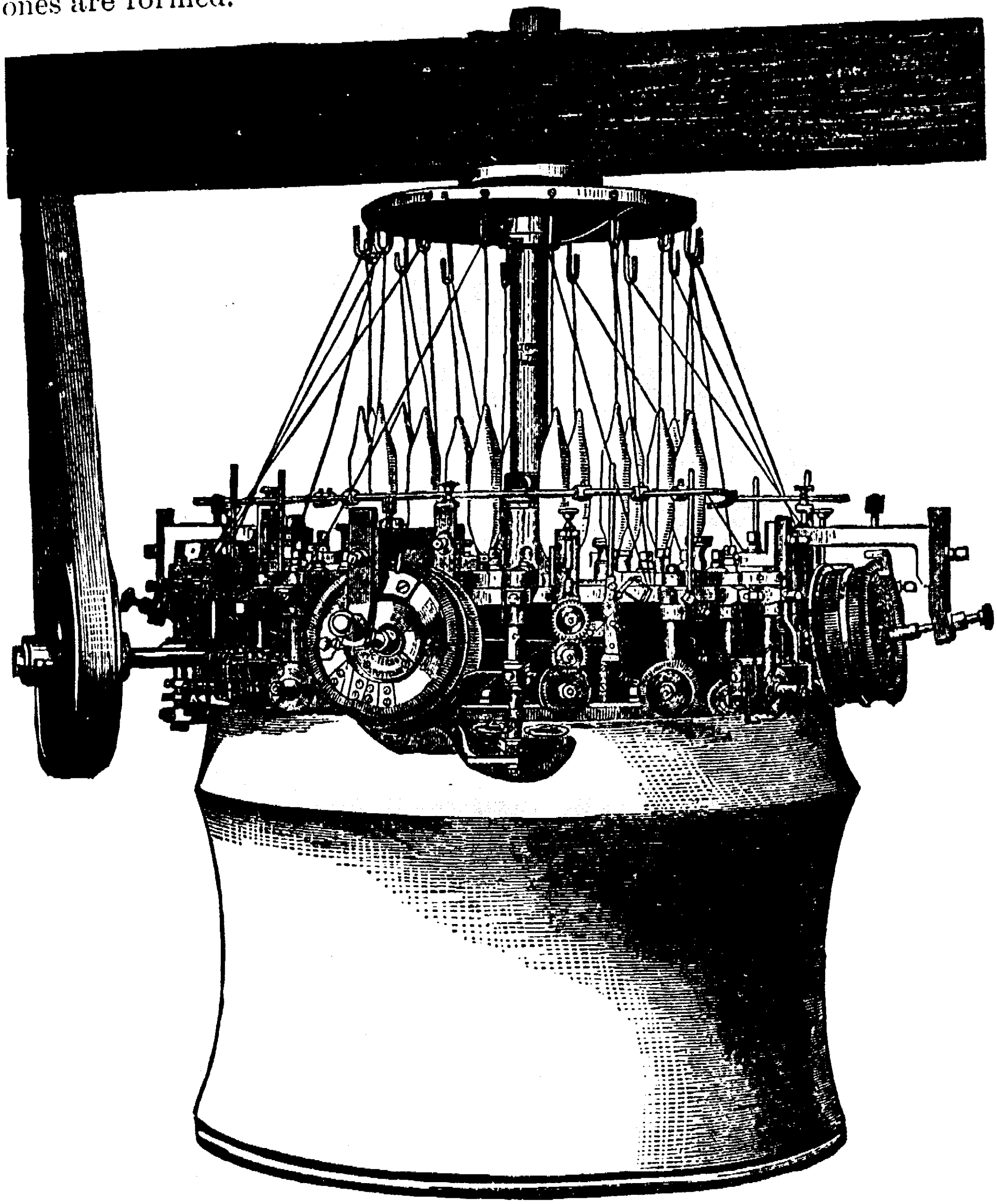

FIG. 30.—Circular knitting machine. (C. Terrot's.)

Fig. 29 is an illustration of a spring-needle circular machine for knitting plain fabric. It will be observed that this is a double machine and, in fact, is composed of two separate sets of knitting devices upon a single table.

This machine represents a type quite common in the United States and in England, but seldom seen upon the continent. Machines of this class are used in the manufacture of plain underwear, one of the most important branches of the knitting industry.

Fig. 30 represents a type of machines largely used on the Continent for knitting plain fabric.

Knitted plush fabric is largely made upon machines of the type represented in Figs. 29 and 30.

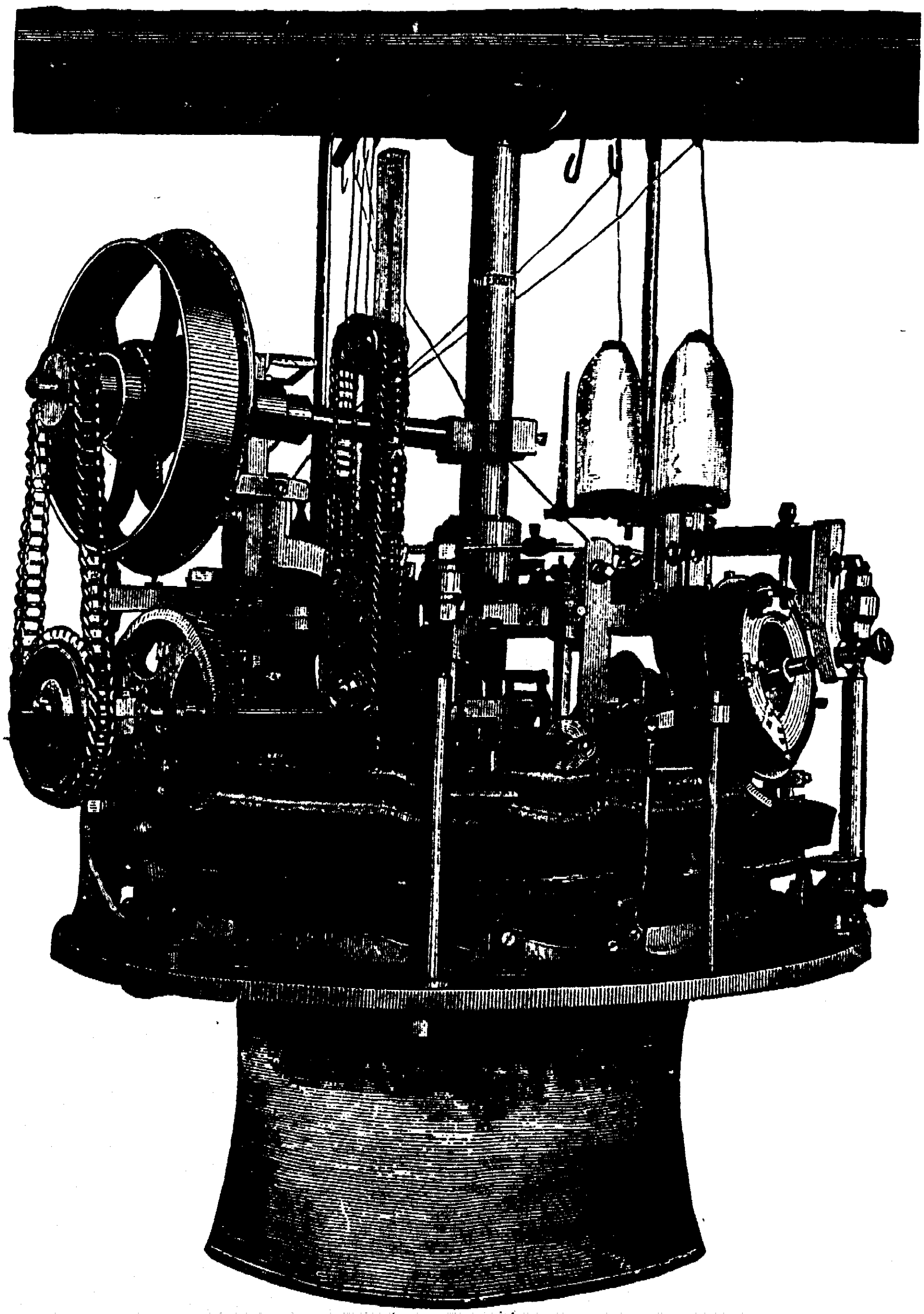

FIG. 31.—Circular rib machine with spring needles. (C. Terrot's.)

For producing such fabric an extra thread, usually of larger size and different material from that used in knitting the body of the fabric, is introduced in such a manner as to be knitted into the body of the fabric at occasional points suitably distant, thus forming myriads of loops from this supplemental thread upon the back of the fabric.

These loops are afterwards napped or brushed until they are destroyed, and the fiber of the material from which the loops were made then forms a "pile," much resembling woven plush.

Machines for knitting rib fabric are provided with an additional set of needles supported by a separate ring or cylinder arranged at an angle with the needles of the principal set.

Latch needles are almost universally employed in circular rib knitting machines, though spring needles have been used successfully. Fig. 31 illustrates a rib machine provided with two sets of spring needles and is designed for the production of fabric of the finer gauges.

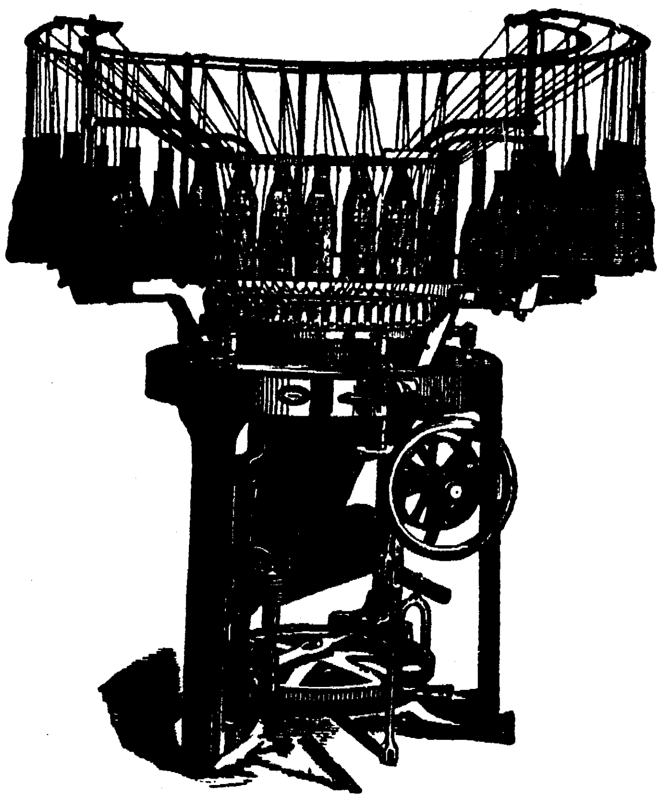

FIG. 32.—The Hepworth knitting machine.

When latch needles are used in circular machines they are usually supported in grooves and adapted to reciprocate, practically as in straight machines, and in one type of machines the grooved support in which the needles are held remains stationary, while the needles are reciprocated by cams carried by a revolving ring or cylinder; but in another type the needle supports, together with the needles, revolve, and at the same time the needles also have a reciprocating motion imparted to them as they are carried past stationary cams supported upon a suitable ring or cylinder.

While some of the smaller varieties of machines are designed to knit with one thread only, the majority of circular machines are adapted to employ several threads, and in some instances the number employed is great, reaching as high as sixty or above. Advantage is taken of such conditions to produce fabric in stripes, by employing threads of varying colors and shades to form the desirable combinations within the limits of the number of threads used.

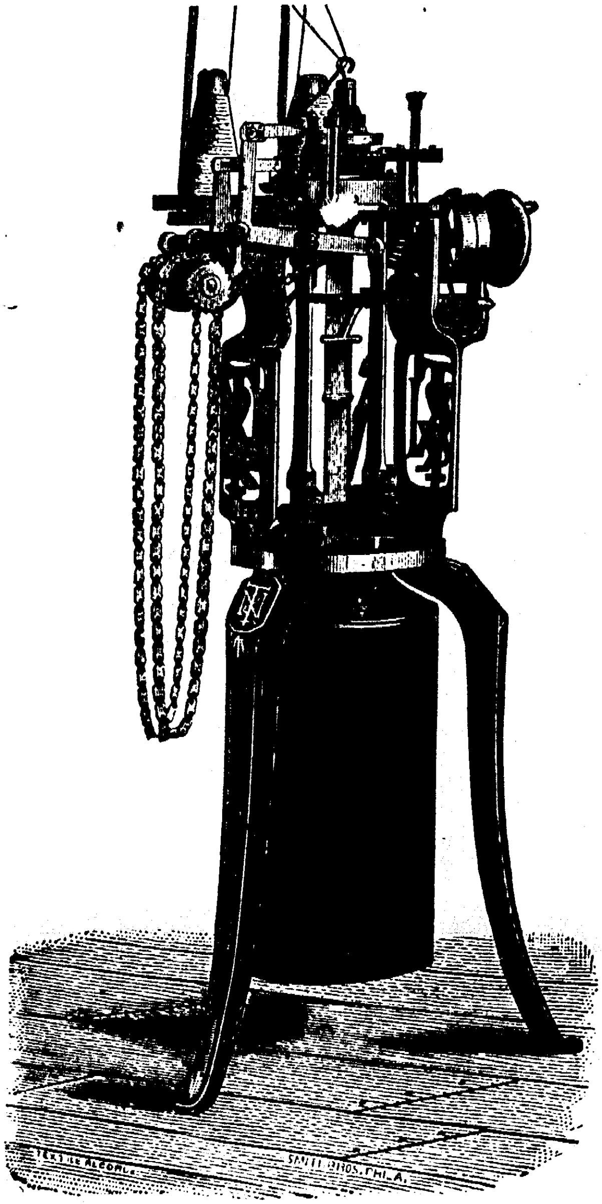

FIG. 33.—The Nye & Tredick circular rib-cuff machine.

Fig. 32 represents a circular knitting machine employing a large number of threads in the production of knit fabric in stripes of many colors.

Small circular machines with two sets of needles, adapted to knit rib fabric, are extensively employed in making elastic cuffs and rib tops for socks. These machines are provided with automatic devices to form a welt or "binding off," which is brought about by throwing one set of needles out of operation while retaining their loops and knitting a small number of courses with the other set of needles as though to produce plain fabric, afterwards continuing the rib knitting as before. Various modifications of this operation are in use in the different machines.

Similar machines with either one or more sets of needles are extensively employed to produce respectively plain and ribbed tubular fabric for use in making the less expensive grades of hose, stockings, and socks.

Fig. 33 is a representation of one type of machine of this class.

Modified forms of machines of this class are used in the manufacture of leggins and similar articles. Such machines are provided with automatic devices for changing the character of the knitting, producing Cardigan rib, half Cardigan rib, or Derby rib at the proper time to form or shape the knitted article as desired.

Fig. 34 represents a type of automatic circular rib-knitting machinery in which the needle supports of both sets of needles, together with the cloth-winding apparatus, revolve, while the spools and the needle-reciprocating cams remain stationary.

Fig. 35 represents a type of automatic circular rib knitting machinery in which the supports for the spools and needle-operating cams revolve, while the needles and fabric-winding apparatus do not.

Machines of the types represented by the two preceding figures are constructed to perform the operations of knitting simultaneously with many threads at several points around the circle of needles, and automatic devices are introduced to automatically modify the action of the needles, or certain of them, to produce various kinds of fabric and to control the length of the loops.

In this way such machines will produce Derby rib, half Cardigan rib, or Cardigan rib, and automatically change from one variety to another while in operation. By a suitable arrangement of the needles many styles of rib fabric, such as "two and one," "two and two," etc., may be made. By "two and one" rib is meant that two loops are formed in one direction or upon one side of the fabric and one loop upon the other side, and in like manner successively as the knitting progresses.

The combinations thus attainable are practically unlimited, and the useful effects are still further multiplied when threads of various hues or materials are employed. By the several means alluded to the character of the fabric is greatly altered in appearance as well as in width, and in this manner by the selection of suitable combinations the fabric is shaped to a very desirable degree to form entire garments, or portions thereof, as desired. Machinery of this class, though of recent development, has instituted a new and important branch of the knitting industry in the United States.

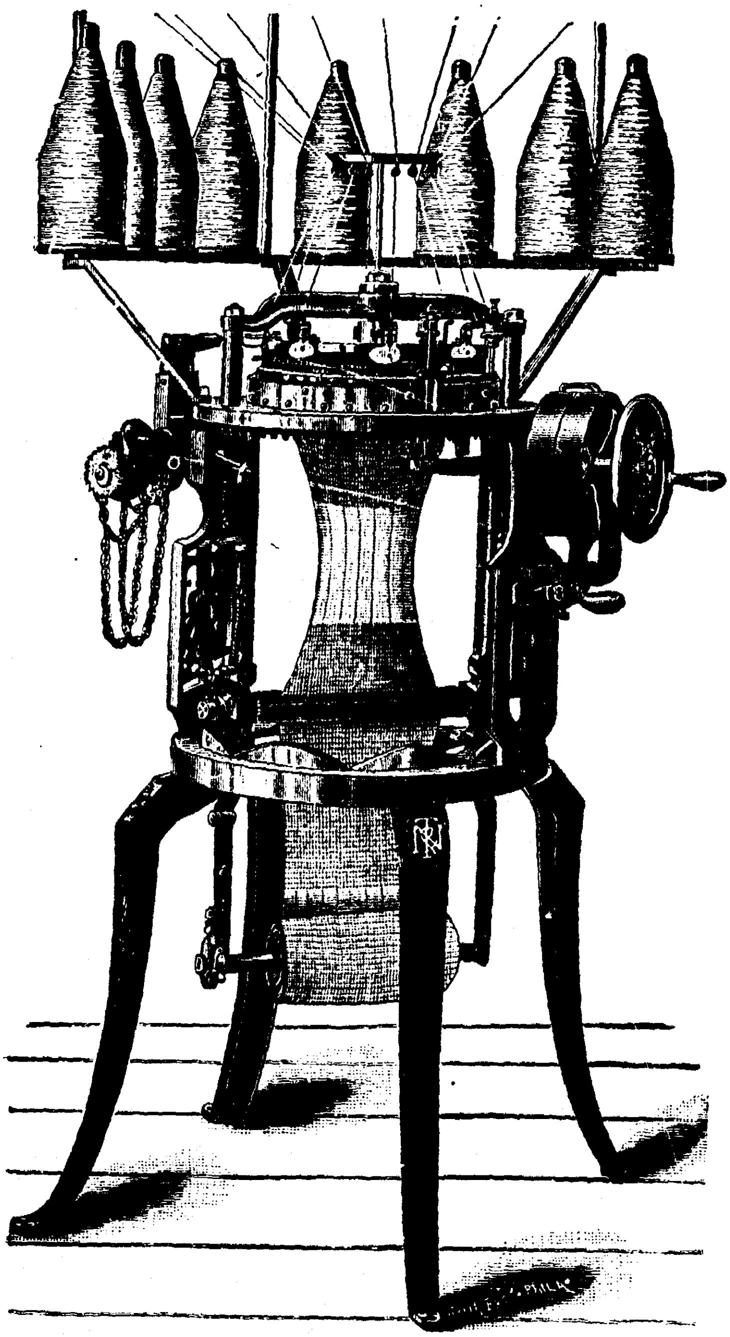

FIG. 34.—Nye & Tredick automatic circular rib-knitting machine.

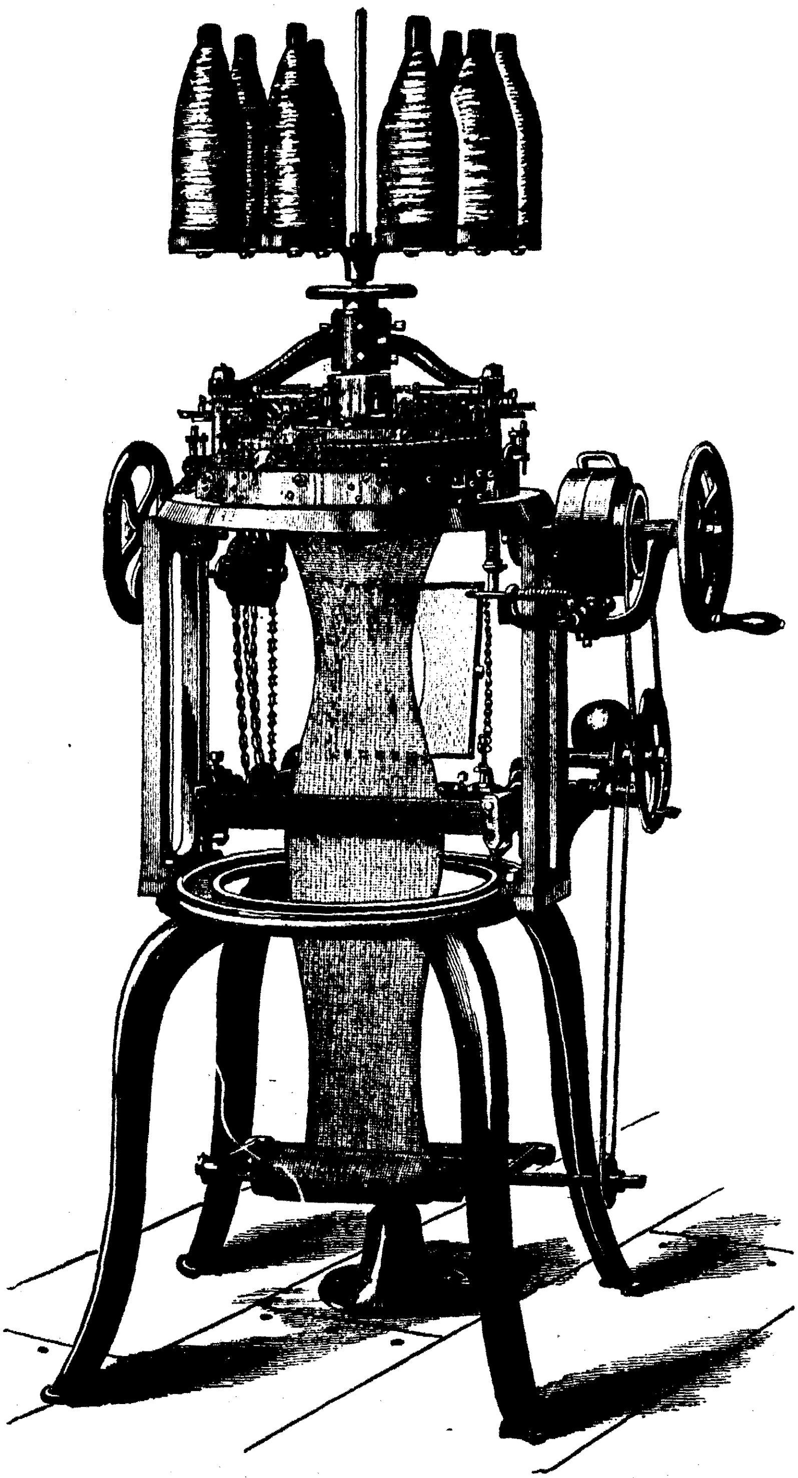

FIG. 35.—The Heginbothom automatic circular rib-knitting machine.

A great number of small circular machines have formerly been used in families for knitting "seamless" socks, but in later years such machines have also been used extensively by manufacturers, many hundreds being sometimes operated by a single management. Fig. 36 is an illustration of this type of machines.

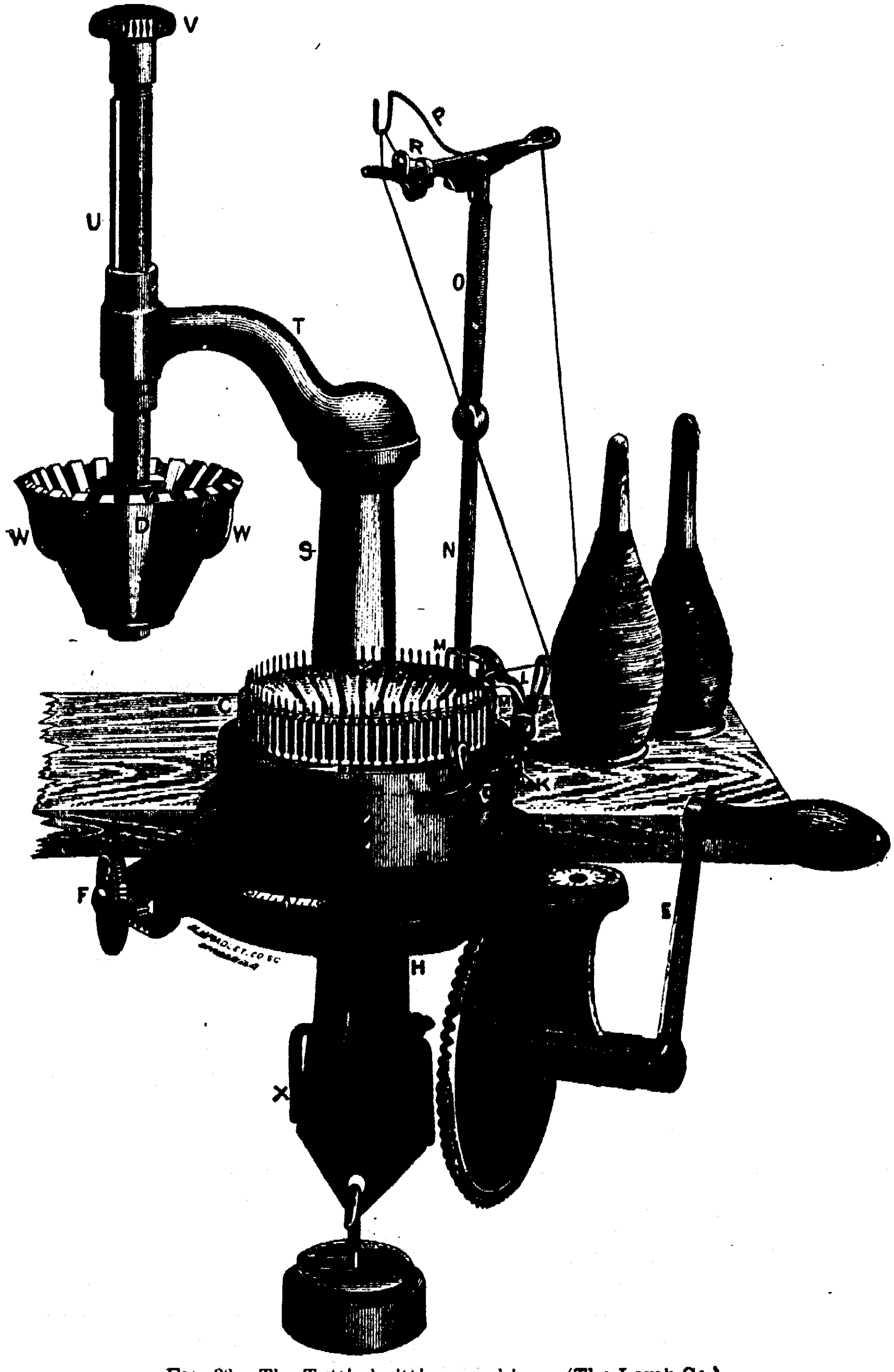

FIG. 36.—The Tuttle knitting machine. (The Lamb Co.)

The machine illustrated in Fig. 36 is provided with an extra needle cylinder, which is used when knitting rib fabric but can be moved out of operative position (as shown in the engraving) when knitting plain fabric.

Seamless socks with rib tops are made upon machines of this type, and great numbers of similar machines are now in use in factories as well as in families upon such work.

In factories, however, it is more common to first knit the rib tops upon a machine designed for the purpose, and afterwards "run" them onto the needles of a machine of the same type as shown in Fig. 32, but one not provided with the extra set of needles for knitting rib work, as they would not then be needed.

In "running" on the rib tops or cuffs the loops at one end are individually placed upon the needles in the machine, which then proceeds to knit plain work, and no blemish appears at the juncture of the rib and plain fabric.

The "seamless" sock or stocking was invented in the United States; and though for many years this invention made comparatively slow progress in gaining a market, this variety has now become a standard article both in the United States and in Europe, and the volume of its production and trade has reached important proportions.

The operation of knitting this variety of stocking upon circular machines is in general terms the same as that described in connection with straight machines, although it is customary to commence the knitting at the top instead of at the toe, and to leave an opening across one side of the toe to be afterwards closed by hand or by means of suitable machinery adapted for the purpose.

In knitting seamless socks or stockings upon circular machines, the required portions of the machines are caused to rotate continuously while knitting the tubular portions forming the leg and foot of the stocking. When forming the heel, the action of a portion of the needles (approximating one-half of the whole number) is discontinued, and the knitting is continued alternately in opposite directions while the number of needles in operation is gradually decreased until the narrowest part is reached; then the number of needles acting is gradually increased until the heel is finished, after which the whole number of needles in the machine is brought into action again and rotary knitting is continued until the tubular portion of the foot is finished, when the toe is formed in the same general manner as the heel was made. While the heel or toe is being knit, the loops upon the inactive needles are retained by them until they are again brought into operation.

This method is a species of fashioning by first "narrowing," not by transferring loops, but by employing a diminishing series of needles, followed by "widening" by employing an increasing series of needles.

The sock can be made complete by commencing at the toe instead of the top, but the operation is more laborious when accomplished upon circular machines if the opening at the toe is closed or knit together upon the machine.

Fig. 37 is an illustration of a portion of a seamless sock, showing the form of the heel and toe.

Fig. 38 illustrates an automatic circular machine for knitting seamless hosiery.

Machines of this type are provided with suitable mechanism for knitting continuously in one direction, or alternately in either direction, and devices for throwing certain of the needles out of and into action at the proper times.

As it is desirable to make the heel of a sock heavier than other portions, an extra thread is introduced, which sometimes necessitates a lengthening of the loops, which changes have a tendency to increase the size of the heel, which otherwise would naturally be somewhat smaller than desirable.

FIG. 37.—Seamless stocking.

All of these apparently intricate operations are accomplished automatically; and the stocking, if a plain one, is thus entirely made in one machine, with the exception of an opening at the toe, which is afterwards seamed together loop by loop.

When it is desired to produce socks with cuffs or rib tops upon such machines the ribbed pieces are first knit upon a separate machine, and the stitches at one end of these ribbed pieces are placed upon the needles in the machines before commencing to knit the socks.

Fig. 39 is a representation of one form of seaming or looping machine.

Machines of this class are provided with points upon which are placed the loops at the ends of two separate pieces or at both ends of a single piece to be sewed together loop by loop by means of looping or sewing devices, in the machine, which operate to carry a thread through each pair of loops, which are held or carried into proper posi-

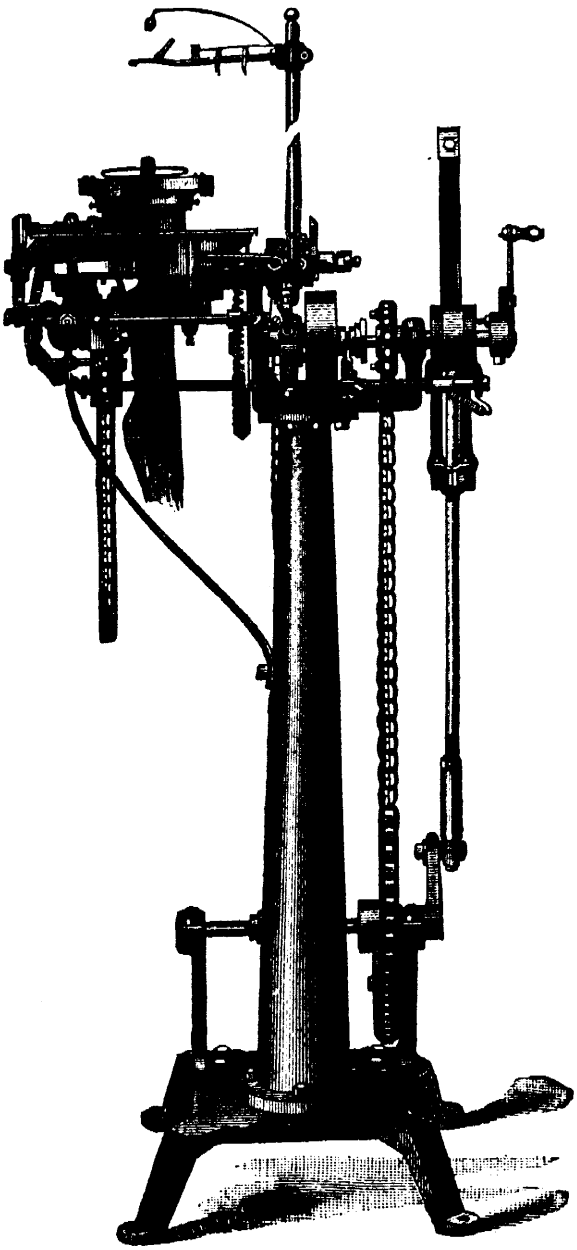

FIG. 38.—The National Automatic Knitter for seamless hosiery. (Walter P. McClure.)

tion by the loop-supporting points. The seam thus produced is almost invisible, and this class of machinery is in general use.

Weft thread knitting machines contain devices for introducing a supplemental thread into the fabric between the loops alternately upon either side, without being interlooped either upon itself or with the loops forming the main body of the fabric, or interlooped only at occasional points. By this means the fabric is reënforced or strengthened and its elasticity greatly reduced.

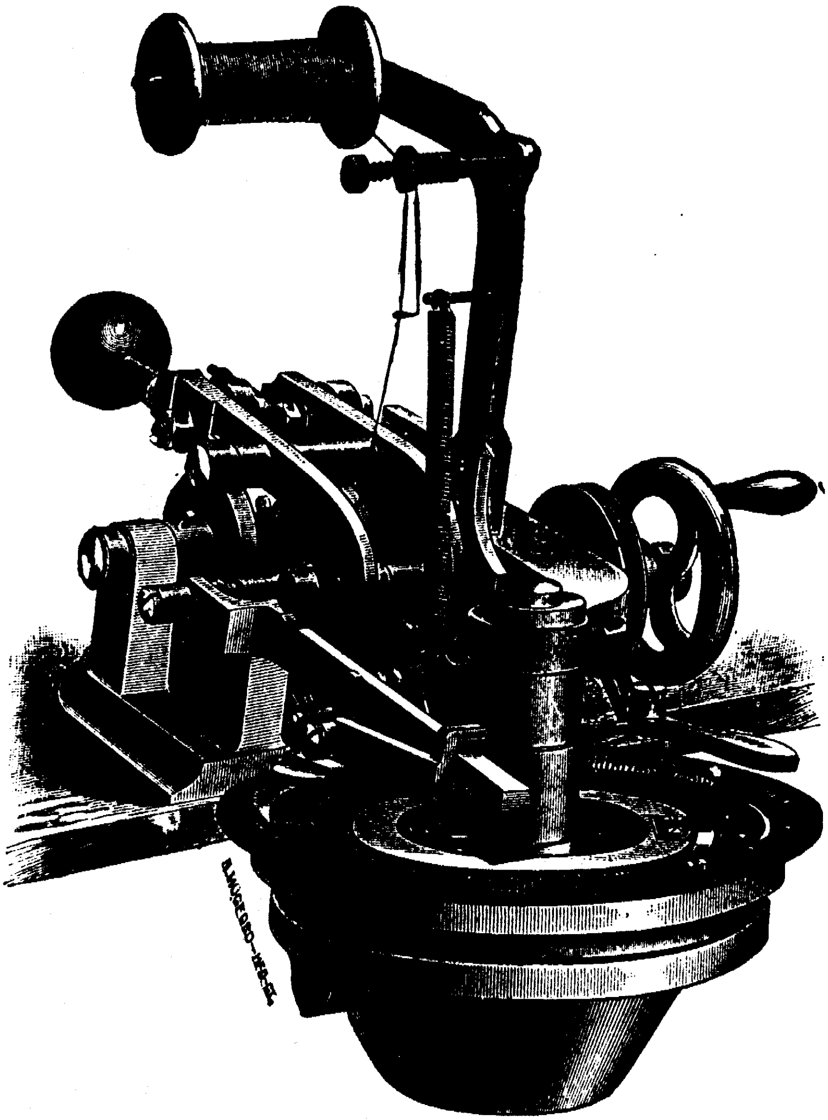

FIG. 39.—The Lamb Machine Company's looper.

In knitting machines a certain tension is required upon the fabric or upon the loops on the needles. In small hand machines the required tension is commonly produced by means of weights, though in many cases the fabric is grasped by the hand of the operator and the required tension given by muscular effort. Mechanical devices are, however, generally employed in power machines to accomplish this important function, and the plan in most common use is to pass the fabric between rolls which are driven either intermittently or continuously at the proper speed to exert the necessary strain upon the fabric. In some machines, however, each stitch is individually acted upon by a holder or tension device, in which cases no stress is needed upon the fabric.

During the last ten years much progress has been made in the improvement of nearly all kinds of knitting machinery in common use, and along some lines the improvement has been very marked. Types of machines which had already reached a high degree of perfection at that time have since been improved in details and construction.

Great advances have been made in rib machinery, both straight and circular, for making "shaped" fabric and other tasteful and useful products. "Seamless" socks and stockings have increased in favor as they have been improved in style and decreased in cost, and the machinery for producing such goods has met with notable changes and improvements.

The knitting industry has been enabled to reach its present high state of excellence, not entirely through improvements in the art itself, but, in no small degree, through the progress made in the other arts upon which knitting is to some extent dependent.

Improvements in the construction of knitting machinery, in carding, in spinning, in dyeing, in the manufacture of worsted, cotton, and silk adapted to knitting purposes, in the various accessory machines, such as sewing machines and machines for finishing and ornamenting knit goods—in all of these and in many other lines, the improvements which have followed in rapid succession have lent their aid to accelerate the advancement of this, one of the youngest of the arts.

The use of improved machinery has greatly facilitated the production of knit goods, and in consequence of the attractive appearance, the increased utility, and the decreased cost of such goods, the volume of production and trade have reached stupendous proportions, raising this branch to an important position among the foremost industries of the world.

III. EMBROIDERING MACHINES.

Class 55 contained embroidery machines, a number of which were exhibited in operation.

This class of machinery may naturally be divided into two principal varieties or systems; viz, the short thread, and the continuous thread.

The short-thread machines usually contain a large number of needles bluntly pointed at either end, with an eye in the middle, to which a short thread is secured, the threads for each needle being of the same length. Each needle is held by a pair of automatically acting fingers supported upon a straight bar forming a portion of a carriage mounted upon small wheels and adapted to travel to and fro laterally upon level tracks. A second carriage of the same sort, provided with the same kind of mechanical fingers, travels upon similar tracks upon the same level in the machine, upon the opposite side.

A frame adapted to support a piece of fabric under tension in a vertical position is suspended in the machine between the two traveling carriages. The frame supporting the fabric is nicely balanced and under the control of a pantograph in any direction edgewise, but is prevented from moving laterally, in a direction at right angles with the surface of the fabric, by suitable means.

The needles project somewhat more than half their length towards the fabric as they are held by the mechanical fingers.

In operating such machines one of the carriages is brought near to the frame, when the needles pierce the fabric and project upon the opposite side. The mechanical fingers mounted upon the other carriage are at this time open, or somewhat separated, and in such a position that the point of each needle passes between two of the fingers, which then close and grasp the needles; the carriage bearing the fingers is now caused to travel the requisite distance away from the fabric, but not, however, until the fingers at the opposite side of the fabric have opened to allow the needles to be drawn through the fabric, each carrying its thread. The fabric is then moved a short distance in the proper direction and the carriage bearing the needles is again brought near the fabric at another point, when the needles pierce the fabric and are grasped by the mechanical fingers waiting at the opposite side. This carriage, bearing the needles, then retires to a distance equal to the length of the thread, drawing each thread with sufficient tension to lay the thread evenly upon the fabric. The threads are in this manner passed through the fabric alternately in either direction. Each needle works a separate figure, and all the figures are the same in design but sometimes vary in color.

The pantograph is provided with a pointer which is held by the hand of the operator at the proper point upon a diagram each time the needles are passed through the fabric.

The diagram is usually made six times the width and length of the figure to be worked upon the fabric, in order that small errors in the location of the pointer of the pantograph will not be noticeable in the figure upon the fabric.

The operator holds the pointer of the pantograph against the diagram with one hand and operates the carriages with the other hand by means of a crank. It will be observed that the carriages travel a shorter distance at each successive operation, as some of the thread is taken up to form the design upon the fabric.

Short-thread multiple-needle embroidery machines were exhibited by the following Swiss houses, viz: Beninger Brothers, of Uwgl (St. Gall); Otto Tritscheller, of Arbon (Thurgovie); Wiesendanger & Co., of Bruggen, near St. Gall.

All of the machines were well constructed and contained recent improvements, but the machine exhibited by Wiesendanger & Co. was particularly notable.

This machine was provided with an automatic apparatus for operating the carriages, and contained devices for governing the length of travel of the carriage and the tension upon the threads. It was claimed that by means of such automatic mechanism much larger machines could be employed and the speed somewhat increased, while the labor of the operator is considerably decreased.

Continuous-thread embroidery machines are more closely allied to ordinary sewing machines, and some varieties are but little removed, while other varieties, employing many needles, more closely resemble the short-thread machines in form and mode of operation. Continuous-thread embroidery machines usually operate to form stitches with two threads, one of which is carried by an eye-pointed needle while the other is carried in a shuttle. In some varieties of continuous-thread machines the fabric is automatically carried to and fro laterally and longitudinally, while in other machines the sewing apparatus is automatically carried in either direction laterally in relation to the fabric, while the latter is slowly advanced, either continuously or intermittently.

The embroidery machines more closely related to ordinary sewing machines were classified with the latter in the official catalogue of the Exposition.

F. Saurer & Son, of Arbon, Switzerland, exhibited several machines in operation. These machines were modeled after the style of the short-thread machines, but operated with two continuous threads.

Some of the machines in this collection were provided with pattern cams for automatically controlling the position of the fabric while the needles and shuttles operated to work the designs.

This house also exhibited an automatic needle-threading machine, designed expressly to thread the needles used in short-thread embroidery machines.

The thread, which was wound upon a spool, was grasped by a hook which passed through the eye of the needle and drew the thread back through the eye, when a knot was formed automatically and the thread severed at a suitable distance from the needle. Another needle was then automatically brought into position and held while the hook again passed through its eye, to draw the thread through as before. It was claimed that this machine would thread 30,000 needles per day of ten hours.

Embroidery machines of the short-thread type, although now used quite extensively in the United States, are for the most part, if not entirely, imported from Switzerland.

SPECIAL REPORT

ON

BRICK AND TILES,

AND

MACHINERY FOR THEIR MANUFACTURE.

CLASS 57.

BY

H. D. WOODS, C. E.

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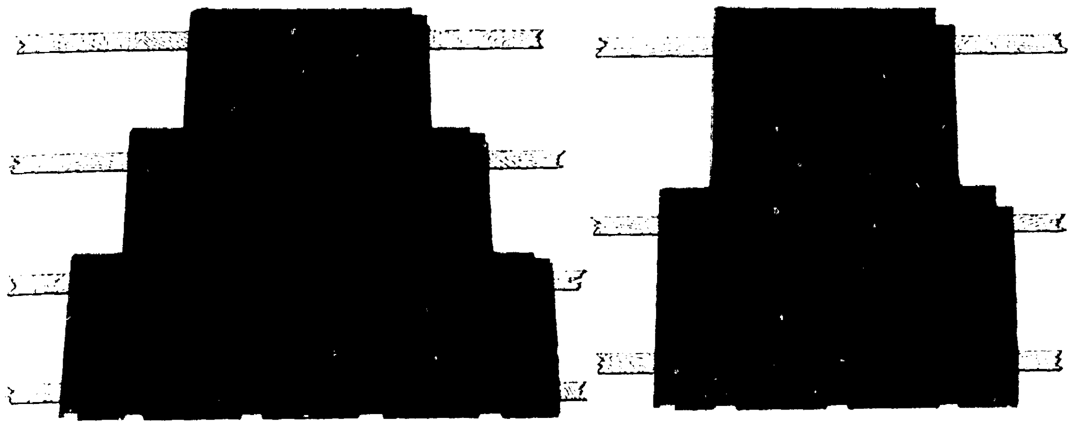
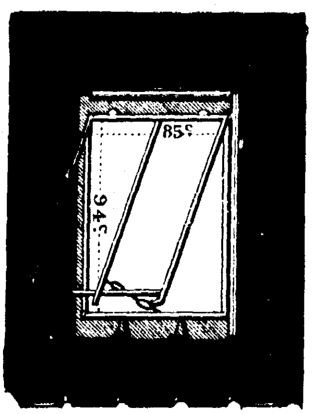
Various forms and arrangements of tiles.

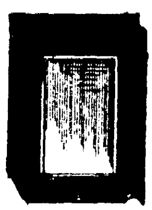


Tiles laid on battens.

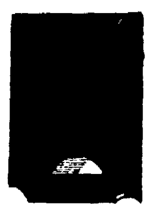
Ridge tiles.



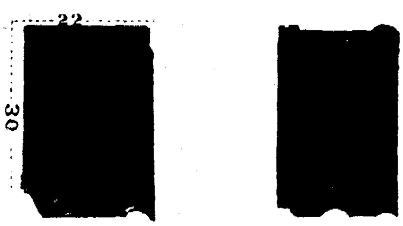
Glazed iron sash frame inserted in tiling.



Glazed tile.



Hooded tile.



Ribbed tiles.

SPECIAL REPORT ON BRICK AND TILES MACHINERY.

By H. D. WOODS, C. E.

(1) There are a large number of exhibits of both bricks and tiles of all kinds, especially in the French sections; there are, however, but few exhibitors of machinery for the manufacture of these articles or the preparation of the clay used in their manufacture.

The tile and brick-making machinery is for the most part located in Machinery Hall, and in the French section. Most of the machines are of the ordinary type, and have been in use for some years. Improvements have been made in some of the working parts, to diminish the amount of power necessary to run the machines, and in the presses new combinations have been introduced for giving the pressure by repeated action instead of by one only, so as to allow the air to escape and to obtain a more homogeneous product.

The use of hollow brick for masonry work has been much extended, especially in France. The same may be said of tiles for roof covering. In fact, all over the Continent the use of tile roofs is very prevalent, and as a rule they give good satisfaction, both in warm and cold regions. But where there are sudden changes of temperature a better class of tile must be used than in warm, dry climates. The improvements in the mode of preparing the clay and pressing the tiles have had perhaps as much to do with their increased use as have the improvements in the shape of the tiles themselves. In many regions, usually in rural districts where the manufacture is carried on, ordinary clay, only slightly moistened, is worked up and pressed into tiles. The product thus obtained contains many air spaces, and in cold weather the water that the tile absorbs causes an exfoliation of the surfaces which soon destroys them completely.

For first-class tiles good materials must be selected and well mixed. It is seldom that suitable clay can be found, clay that does not need dosing with sand or other ingredients in order to form a good material for tiles. The mixtures, besides being carefully measured out, should be thoroughly ground together with plenty of water. Of course this addition of water causes the clay tile or brick to air dry more slowly, and more heat is required for baking, as there is more steam produced; but the product obtained is much more compact and homogeneous, and being less porous, is less affected by atmospheric changes. If well made the tiles will last for years on a roof of sufficient pitch. They form a good protection against heat, require less weight of framing than slate, and have a picturesque appearance. For sheds, storehouses, and similar structures, all that is needed to sustain them is a light frame with slats to which the tiles are hung, and if exposed to high winds they can be made fast by nailing from beneath. To obtain tighter roofs a plain boarding is laid under the tiles. If all dampness is to be kept out, tar paper or roofing felt may be laid on the boarding before the cleats for holding the tiles are nailed on. For the better class of dwellings there may be a coat of plastering put on the under side of the boarding, or if the tiles are laid on an iron frame roof the spaces between the rafters may be filled with concrete or plaster and the tiles put outside. Special forms of tiles are used for the ridge and for the gable ends and eaves of the roof, so as to keep the wind from starting up the first courses.

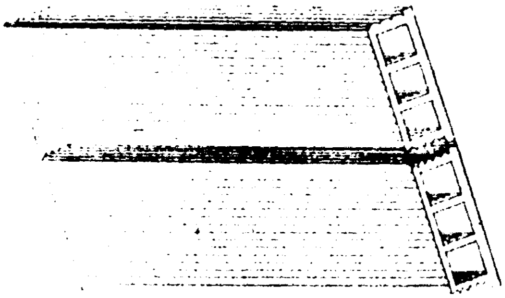
The simplest, and perhaps oldest form of tiles was that of slates or shingles, simply plain slabs of clay burnt in kilns or furnaces. They were held to the roof frame or boarding either by nails passing through perforations prepared for them, as with slates, or else by means of a projection on the under side, which caught on cleats set at regular intervals corresponding to each row of tiles. The projections frequently have a hole by which the tile is made fast, either by a nail driven into the cleat or a wire twisted around it.

Later the Dutch form of tile, still used somewhat in that country, had an extended use. These are ∽-shape in section, the sides lapping over each other and sometimes plastered together, the different rows lapping on like slates, and the tiles thus forming a series of gutters down the slope of the roof for rain water.

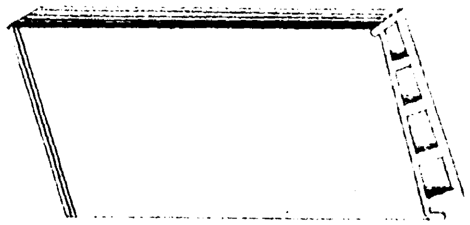
But as the manufacture of tiles improved, apparatus was designed for *stamping out* the clay so that a series of grooves of different forms might be made, according to the judgment and taste of the designer, and the tiles were then made with joints which interlocked both laterally and on the rake of the roof. This form of tile is the one most used at the present time. Some tiles have a more or less perfect lock joint; having one or more ribs fitting into corresponding grooves near the lateral edges of the adjacent tiles, while the top and bottom joints are made in a similar way, and the rows set so as to make the lateral joints alternate. It is in order to cover the joint at the intersection of the lateral and the top and bottom joints that the variously shaped ridges are made, while these also add an ornamental feature.

Where it is desired to have light let in through the roof, either pressed-glass tiles are used, or clay tiles so formed that a pane of

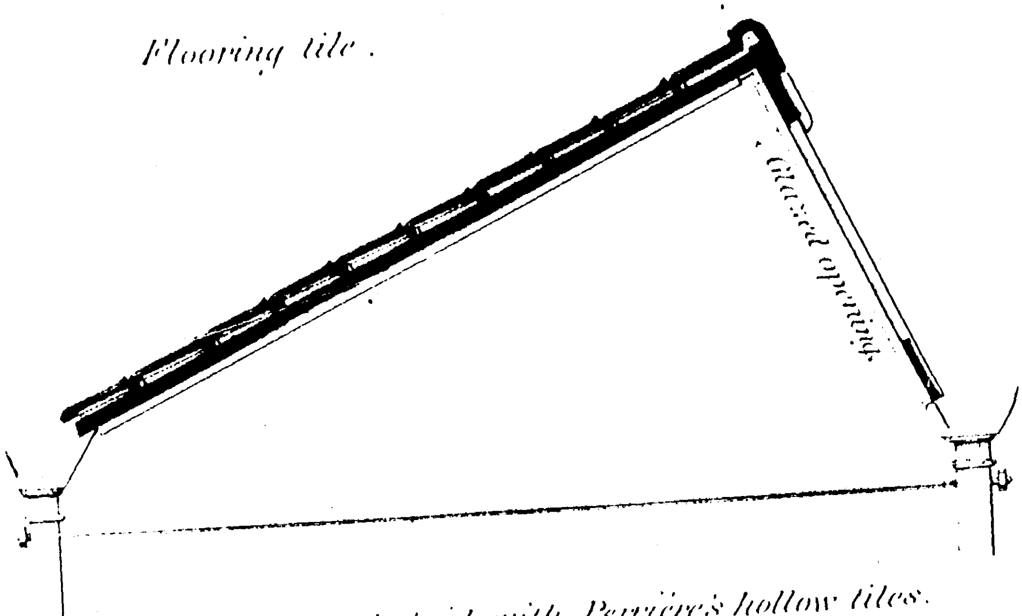
Various forms and arrangements of Perrière's hollow tiles.



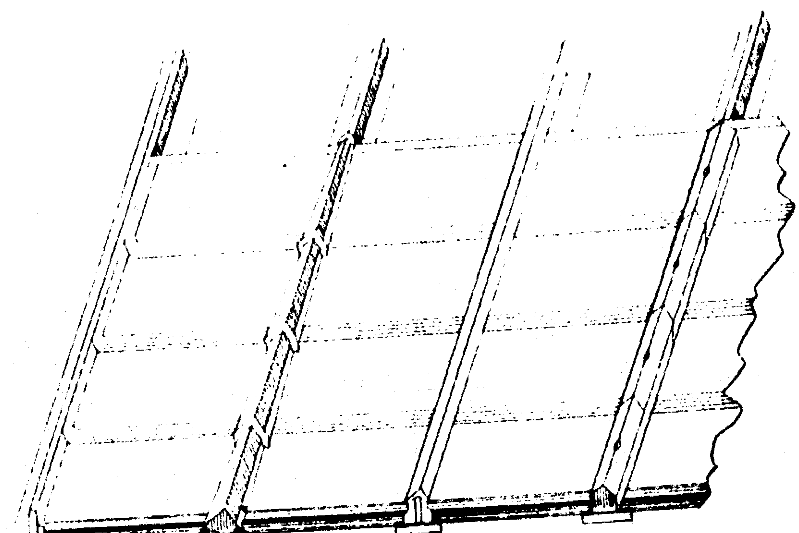
Flooring tile.



Roofing tile.



Roofing tiles underlaid with Perrière's hollow tiles.



Roofing tiles on iron rafters.

glass can be inserted, or in some cases a certain number of tiles are omitted and a special metal frame for containing a sash is provided, the edge of the frame being shaped so as to form a lock joint with the tiles. When simply vent holes are required, a special form of tile, having a semicircular, hood-shaped opening, is introduced in places, and these can be screened if need be.

All these tiles are held by projections on the bottom, which hook onto cleats, and may be nailed or wired to them.

(See Pl. I, showing different forms of pressed tiles.)

Where it is important to make a roof which will keep out heat and cold as much as possible, a filling of hollow brick beneath the covering of tiles is frequently used. Mr. Perrière Ainé exhibits a new form of hollow tile, which gives an air space below the surface. These may be set on a frame of ⊥ irons, and thus form an even, finished surface on the inside when this is desirable, and a special saddle-shaped covering piece, either of metal or tiling, is used to cover the lateral joints. These hollow tiles are also used beneath the covering tile, in the place of hollow brick; see Pl. II. They are made in the ordinary continuously acting brick machines.

(2) Another product, made of the same material as the hollow bricks and tiles, is much used in France, called chimney wagons; that is, sectional chimney flues. These are usually made in a vertical forcing press, in sections about a foot long. The inside is smooth with rounded corners, and the outside is fluted or corrugated to receive plaster. The joints are very short bell and spigot joints, obtained simply by trimming the end, while green from the machine, to a depth of one-half or three-fourths of an inch. They are made of different widths to suit brick walls, are inserted when the wall is going up, and form the complete thickness of the wall, or sometimes even project as breasts. The plastering is applied directly to the outside of these tiles the same as to the brick or stone wall (very little furring or lathing is used in brick buildings in France).

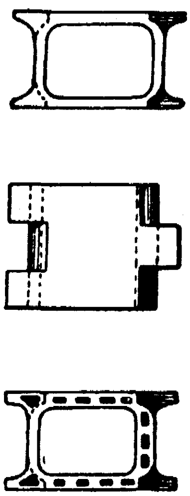
These "wagons" are also made slanting for use in drawing in the chimney breasts.

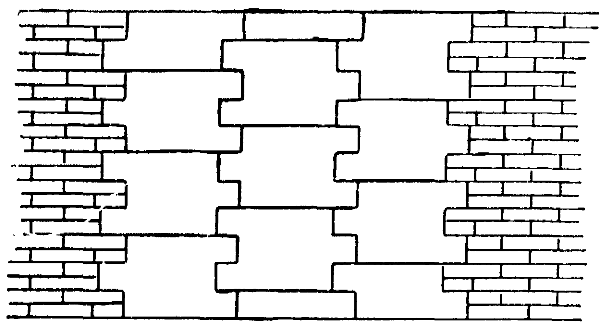
The ordinary kinds are usually made with solid walls having a thickness of about one or one and a half inches; but with improved machines they are also made with hollow walls having air cells about one-half or three-fourths inch wide running lengthwise. These give much more safety where open fires are used, when the flues get very hot and are thus liable to set fire to or injure hangings, mirrors, pictures, etc., hung on the walls. Such fires are, however, rare except where wood fires are much resorted to, as the inner surfaces of these flues are much smoother than those of brickwork, and soot is less liable to accumulate if there is no creosote to run down the surface and cause it to adhere.

A new form of these "wagons" is shown in the Exposition by Mr.

Victor Duprat; these have lateral wings, so to speak, that form lock joints between the several flues and toothing with the brickwork, thus giving a much better bond between the different flues and the main wall.

These are made on the vertical press, and alternate sections of the edges are afterward cut out while the clay is in the green state. This form is also made with hollow channels on one, two, three, or four sides for air spaces, giving more security from fire; it is usual, where there are several flues together, to omit the air spaces, or cells, on the sides which separate the adjacent flues.





Three flues side by side in a brick wall.

FIG. 1.—Duprat's interlocking chimney-flue tiles.

MACHINES.

(3) The preliminary work of grinding the clay is done either by horse power, in a Chillian mill with large grinding wheels revolving in a tub, or by steam power between cylindrical rollers. See Fig. 2. This grinding to be well done should be done several times over with less space each time between the cylinders.

When the clay has been well worked so as to be plastic and homogeneous it is ready for the molding process.

The vertical mixing machine generally in use is similar to that used for mixing concrete and mortar, only it is possibly a little heavier, and has rotating cutting arms to cut up the clay as it is thrown in in lumps (Fig. 3).

(4) For tiles that are made on presses, that is, for molded or machine tiles, the clay is placed on the mold in the form of flat slabs about the size of the tile and a little thicker. These are prepared either on a regular brick drawing machine, cut off to the proper length, or else, with an expert workman, the slat may be taken directly from one of the vertical mixing machines. In this case the lower sliding door is lifted far enough to let out a quantity of mate-

rial of the proper thickness, and the workman cuts off the slab to the proper length by eye. The prepared slab is then placed on the bottom mold, ready to receive the pressure from the top mold.

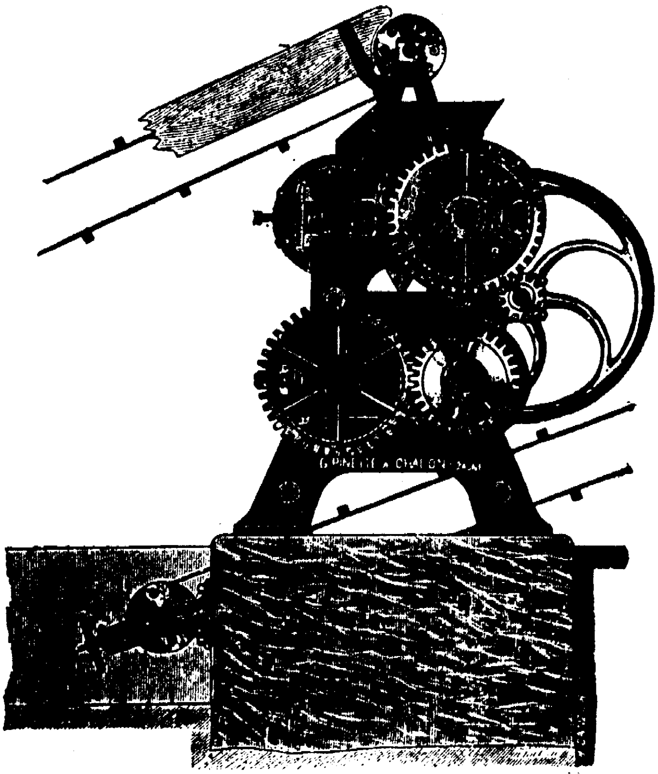


FIG. 2.—Pinette's cylinder mill for grinding clay.

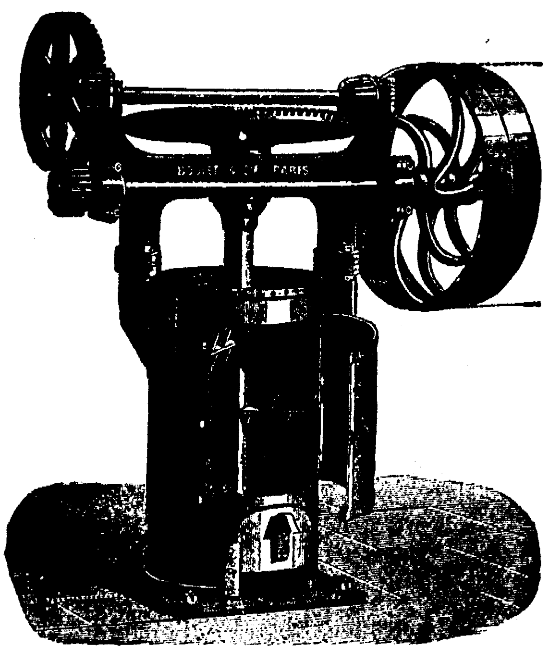


FIG. 3.—Boulet's mixing mill.

In small works various forms of hand presses are used, the simplest being a striking press, consisting of a vertical screw with a large fly-wheel, which is revolved by hand and brings the matrix down on the clay, which is spread on a mold having the imprint of the bottom of the tile, or on one which is of the size of the brick to be made. This general form of press is used also for light power machines, in which case there are usually two sets of molds and an operative on each side of the machine; one is filling his mold while the other is pressing; then, as the first operative withdraws his mold from the press and removes the brick or tile from the mold, the second operative pushes his mold under the press (see Figs. 4 and 5).

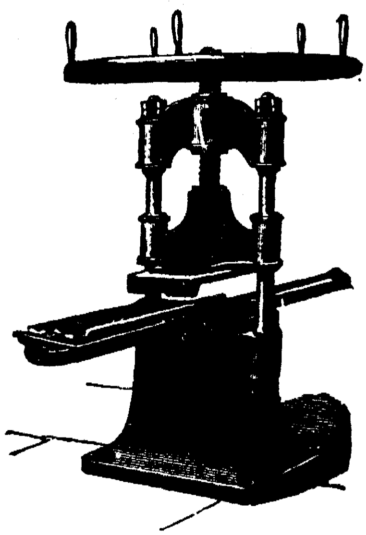


FIG. 4.—Boulet & Co.'s hand screw press.

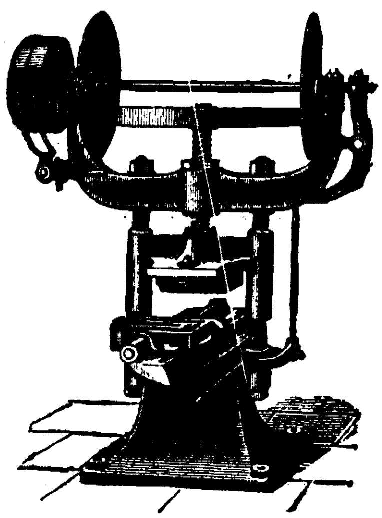


FIG 5.—Power screw press driven by friction disks.

Another form of hand press is worked by a lever. This form is usually set on truck wheels so as to be moved about as required, and has a platform attached on which the operator stands, and which forms a means of holding the press steady while the lever is being worked. The machine is small and comparatively light, and the tendency of the blow given on pushing down the lever would be to upset the machine if it were not for the projecting platform. These are made to work with one or two molds, as the other style is. The different makes of these machines differ in the method of applying the pressure; some use a cam motion, others employ levers and eccentrics.

This style of machine is exhibited by E. Delahaye, and also by Joly & Foucart. In the latter (Fig. 6) the pressure is obtained by a cam; with this form four to five hundred pieces may be made per hour.

In operating this machine, the mold being in place, the operator gives a sudden downward motion to the lever; this gives the pressure and the lever returns by recoil. With all these hand machines several successive blows may be given if desired.

J. Ollagnier also exhibits this style of presses (Fig. 7), with lever motion which draws down the upper cap.

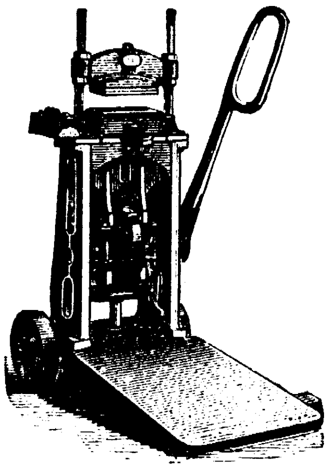


FIG. 6.—Joly & Foucart's lever press.

This form of press is made of large size for tile work, with the lower mold on a sliding frame so that it may be withdrawn and then inverted in order to dump the pressed tile out of the mold.

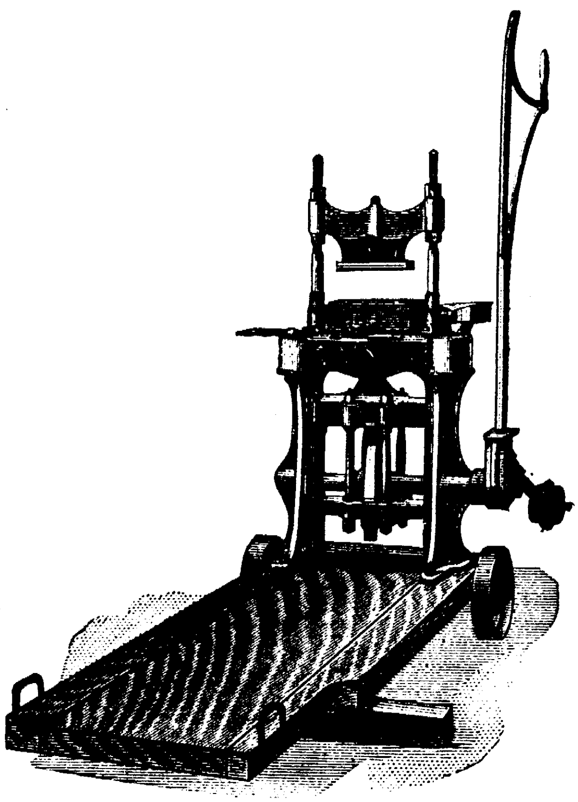


FIG. 7.—Ollagnier's lever press.

For all tile presses there need to be two molds, one for the upper and one for the lower surface of the tile. These are made of cast iron, with some sort of lining giving a smooth finish and allowing the pressed clay to drop out easily. The best lining has been found to be plaster of Paris. The molds are made in such a way that when closed they leave a little more space than the thickness of the finished tile, to allow for shrinkage in baking. The surplus clay is, of course, pressed out over the edges, and that is one of the advantages of a

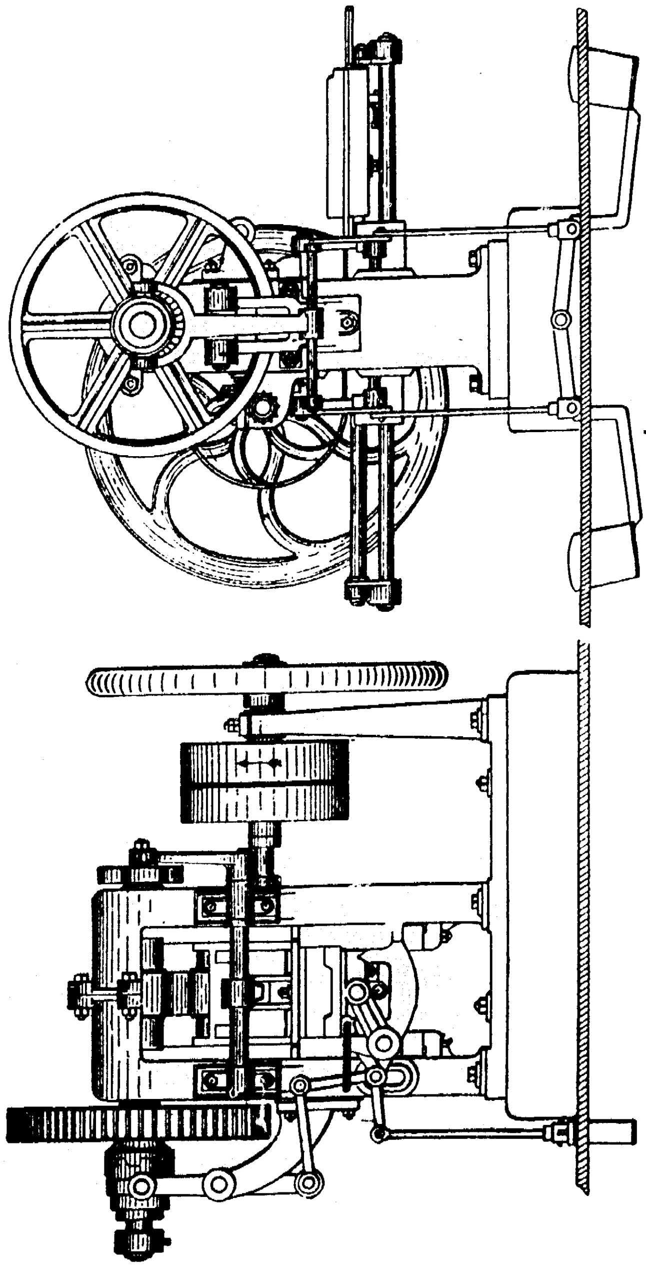


FIG. 8.—Power press for pressed tiles, by Schmerber Bros., Tagolsheim, Alsace.

double or triple pressure; it allows the surplus clay to find its way out better, and consequently the molds come together more accurately.

(5) The same principle is used sometimes with power attachment for tile presses. Such a machine, manufactured by Schmerber Brothers, Tagolsheim, is shown in Fig. 8.

Such presses are usually made so as to be worked either by hand or power, but to run this kind of machine by hand requires two men, one to turn the machine and another to tend the press, whereas in the small lever machine the same man can work the lever and attend to the molds.

Joly & Foucart exhibit a small power machine on this principle, in which the pressure is applied by cams, made in such form that the pressure is applied three distinct times at each revolution of the driving shaft (see Fig. 9).

The slide carrying the under mold may be single, as shown in the figure, or may be double, having a mold at each end, so that two operatives can use the same press; this is usually the arrangement when the press is run by power. When the bottom mold is withdrawn and is turned over by means of the handle *h*, being pivoted

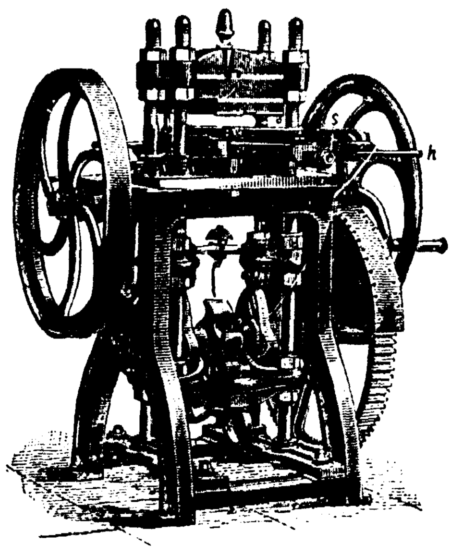


FIG. 9.—Joly & Foucart's power press, giving three successive pressures.

on the spindle *s*, the tile drops out upon a board on which the operative receives it, and on which it is taken, on a wheelbarrow, to the air-drying sheds.

With one man at the press this machine will make from two to three hundred tiles per hour. The power used is about one-half of a horse-power, and the pressure obtained is 30 tons, applied three times with progressive force and sudden release.

These machines are neat and strongly built, giving very good results.

(6) Massive power presses are not used much for making pressed brick, but are very generally used for machine-made tiles.

These consist of a frame formed of two heavy uprights united top and bottom and supporting the bearings of the different shafts.

The principal feature of the machine is a rotary pentagonal drum on which five molds for the bottom side of the tile are made fast.

This drum is revolved either by means of a pawl and ratchet, or by the friction of a belt acting on a pulley on the drum axle. It turns one-fifth of a revolution at a time, so as to bring one of the molds to the top in a horizontal position at every motion, in which position the drum is held for a time by means of a bolt or locking device.

Above this portion of the machine is the slide or gate carrying the mold for the top of the tile; this slides up and down between the side posts of the machine and gives the pressure on the cylinder below. The main difference in the different machines exhibited is in the method of giving this sliding motion and pressure to the top mold.

Mr. G. Pinette exhibits a fine specimen of this kind of press, shown in Fig. 10.

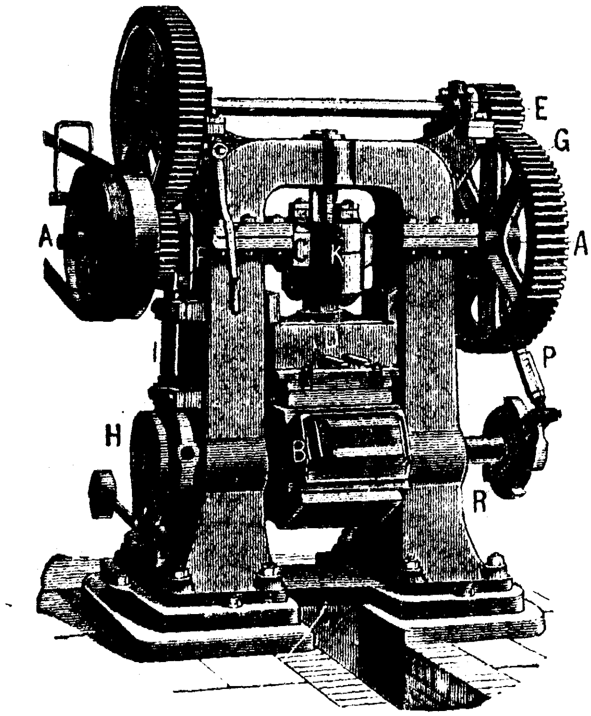


FIG. 10.—Pinette's automatic tile press.

The drum B, on which are placed the five bottom molds, is turned by means of the ratchet wheel R, having five teeth, and the spring pawl and arm P, connected to a crank-pin on the main gear G. On the opposite end of the drum shaft is a disk, H, having five cylindrical holes into which the bolt I drops, under impulse of a spiral spring, at the moment when a mold reaches its upper horizontal position, and keeps the drum fixed while the pressure is applied. This bolt is raised by a cam on the main crank shaft, A, the bearings of which are in the frame F. The gate D, which carries the upper mold, slides vertically, steadied by guides on the standards. It receives its motion from the crank C' on shaft A, the crank-pin turning in a block which works in the slotted cross-head K, to which the gate D is attached.

After the pressure has been applied to the tile the bolt I is raised, the pawl P turns the drum B one-fifth of a revolution to bring the next mold in position, and the bolt I drops and holds it. These machines will produce about five hundred tiles per hour.

(7) Messrs. Boulet & Co., of Paris, exhibit quite a number of machines for working clay. Besides the ordinary mixers and brick machines they have different forms of hand machines for pressing tiles or bricks, similar to those described.

Their molded-tile machine is shown in Fig. 11.

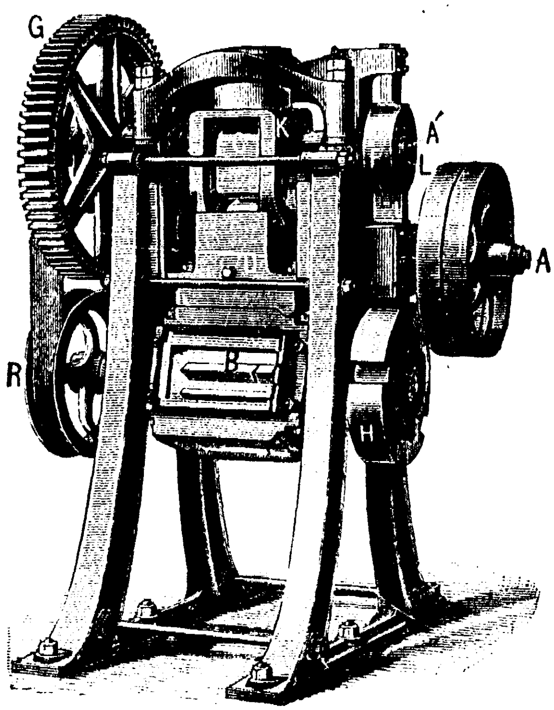


FIG. 11.—Boulet & Co.'s automatic press.

The letters correspond to the same parts as in Fig. 10. In this machine there are three successive pressures brought to bear on the clay. The pressure is given by the cam C, which revolves with the shaft A′, and presses against a roller set in top of the gate D, which carries the upper mold. The driving shaft A is at the back of the machine and drives the cam shaft A′ through the gear G. The bolt I is worked by a cam L and drops in slots in disk H. The motion is communicated to the drum B by a belt instead of by a ratchet and pawl, the belt slipping on the pulley R when the drum stands still. In the machine exhibited, however, the movement is by ratchet and pawl on the end of the drum shaft, similar to that in Pinette's machine.

J. Chambrette-Bellon exhibits a "Universal Molding Press," which gives two separate and consecutive pressures, with a slight release after each to allow the clay to expand and let out the excess of imprisoned air. It is shown in Fig. 12.

This press differs from the others exhibited in the fact that the part to which the top mold for the tile is attached is fixed in position, and it is the pentagonal drum carrying the five bottom molds that travels up and down to produce the pressure.

The pentagonal drum B has sliding bearings, and is raised by means of two cams, C C, on the main shaft A. Two weighted levers, L L, placed on top of the cap D help to balance the weight of the drum B. The cams C C have two slight projections close together for producing the pressure, so that there is a slight lowering of the drum between the two pressures. Then the drum comes down to

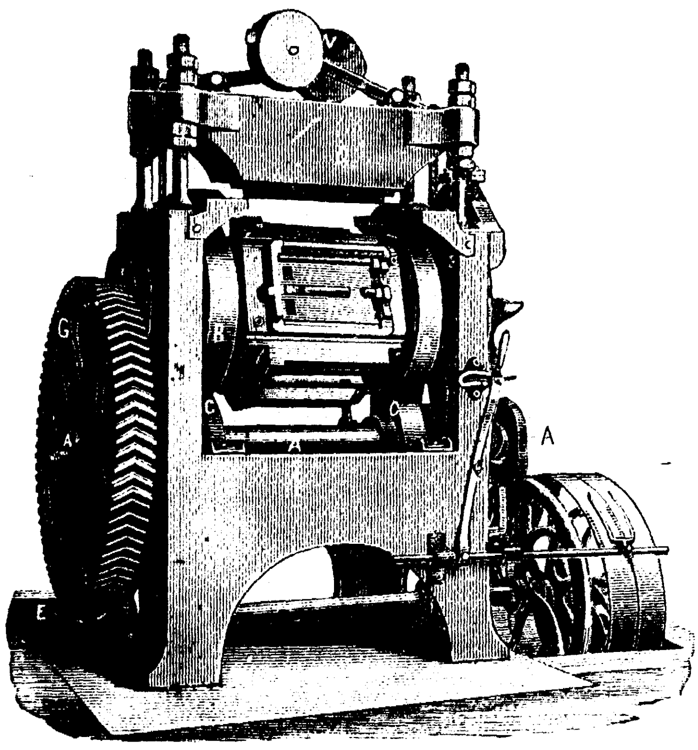


FIG. 12.—Automatic tile press by J. Chambrette-Bellon, Bèze, France.

its lowest position, and a wheel with one cog engages a corresponding cavity in a disk on the arbor of cylinder B and revolves it one-fifth of a revolution, when the drum is again raised by the cams C C, while at the same time one operative removes the pressed tile from one side and the other operative applies a fresh slab of clay to the other side. The whole machine is robust and not liable to be deranged. The working parts, arbor A, gears G, E, etc., are all closed in by sheet-metal guards.

The regular power brick machines are either presses for compressing the clay in molds, or else so-called drawing machines, properly forcing machines, which thrust forth a continuous prismatic mass of the clay, which is cut into lengths to form brick.

(8) Messrs. Boulet & Co. exhibit one of the presses (Fig. 13); it has a revolving table, T, provided with sets of openings or molds for the brick. This is revolved by means of a ratchet and pawl. When the mold comes under the press P this is driven down by means of a cam and gives the pressure. Then the table turns through one-quarter of a revolution and comes over a vertical piston, Q, which rises, pushes up the bottom of the mold, and lifts the brick out on the surface of the table, from which it is pushed off upon another table by an automatic arm, N, and the mold is ready for another load of clay.

This machine will make about eight hundred or one thousand brick per hour, and takes two or three horse power to drive it, depending on the stiffness of the clay. The machine is served by

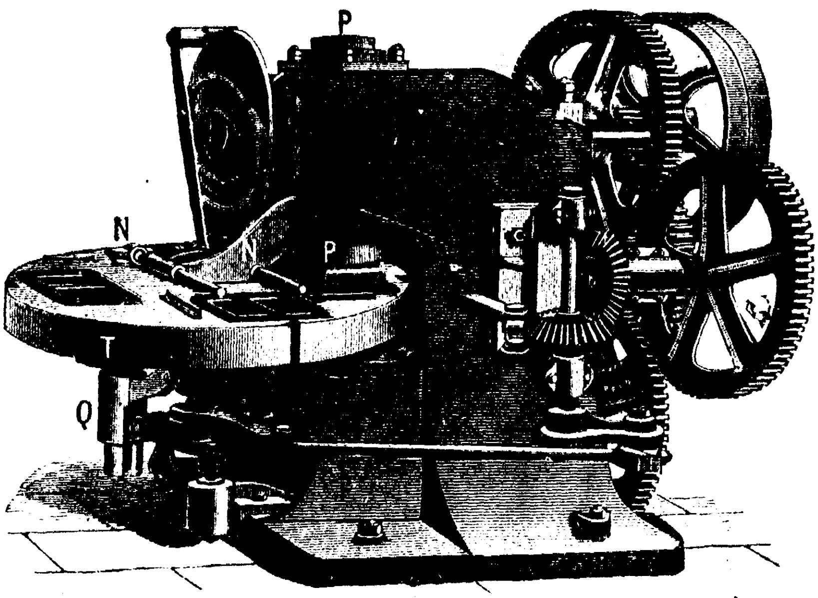


FIG. 13.—Boulet & Co.'s automatic brick press.

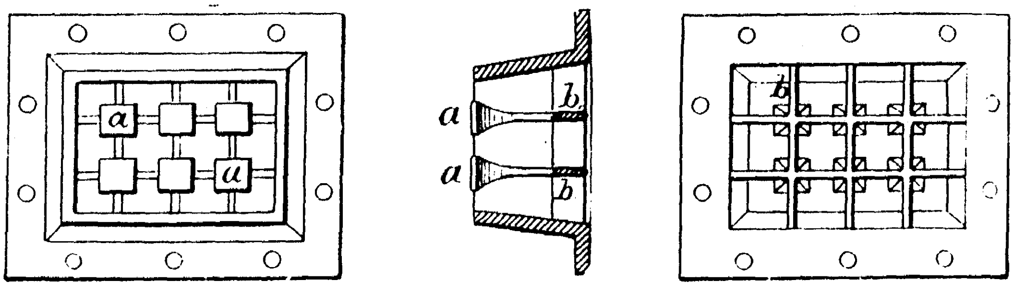
three men, two to charge the molds with clay and one to take off the brick as they are delivered. The machine weighs some 6 tons. The cams, etc., are of hardened steel.

A similar style is also made for making tiles.

(9) The forcing machines for bricks consist essentially of a framework having at the top a hopper set over a pair of large revolving steel rolls that grind up the clay and also act as feed rolls. Below these is a chamber with an opening at one end, to which different forming plates are attached for forming solid or hollow bricks, tiles, drain tiles, etc. These plates are steel boxes some 3 or 4 inches deep, open at both ends, but with converging sides so that the section at the outlet is reduced. For hollow work there are core pieces *a* (see Fig. 14), which are short rods held at one end by thin ribs *b* which cross the wider inner end of the box. These ribs cut through the clay, but, as the box becomes smaller beyond them, the clay joins together

again beyond the ribs. The boxes are bolted on by means of a flange to the front end of the chamber below the cylinders.

There are various methods by which the clay is forced through the plate, and this is where the principal difference occurs in the different machines. This operation is performed either by means of a piston moving horizontally, or by a set of screws turning in the chamber, or by the compression produced by the feed rolls them-



Outer face. Section. Inner face.

FIG. 14. Forming plate for hollow or perforated brick.

selves which obliges the clay to be crowded out by the only outlet presented, which is through the draw plate.

In conjunction with this style of machine a receiving table has to be used, on which the clay is received as it leaves the draw plate. This consists of a frame carrying a set of small rollers covered with cloth or leather on which the body of clay slides along. To this frame is attached a lever with wires set the right distance apart, by means of which the body of clay is cut up into the required lengths for the different articles being produced. These tables also vary in form with different makers. The frame of the table is either stationary, or else set on castors so as to move ahead in case the clay gets to the end before the attendant cuts it off. With some the

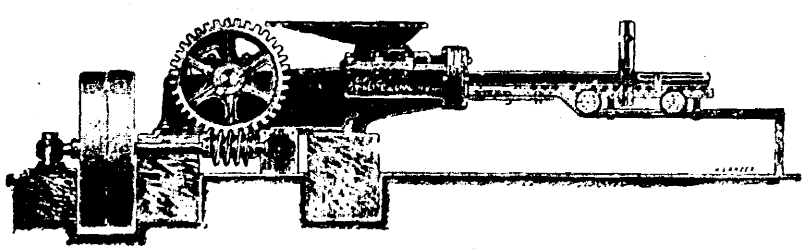


FIG. 15.—Pinette's forcing press with single piston.

frame carrying the rollers runs on castors on rails set on top of a fixed frame.

G. Pinette makes both piston, and cylinder or roll machines. In the piston machine of this make (Fig. 15) there are no feed rolls below the hopper.

When the chamber has been filled the piston is moved forward by means of a cog wheel, and the power is applied by a worm gear. This will give three or four hundred pieces per hour. The same style is also made double (Fig. 16): that is, there are two hoppers and the piston acts in both directions, the power being applied in the middle: the production is from four to six hundred per hour.

This style of machine is especially used for pretty dry clay for making the slabs used on tile machines, also for hollow brick, drain tiles, etc.

The cylinder machine of this maker will deliver one thousand hollow bricks per hour, having six holes; or eight hundred tile slabs, or sixteen hundred floor tiles, which are smaller and thinner

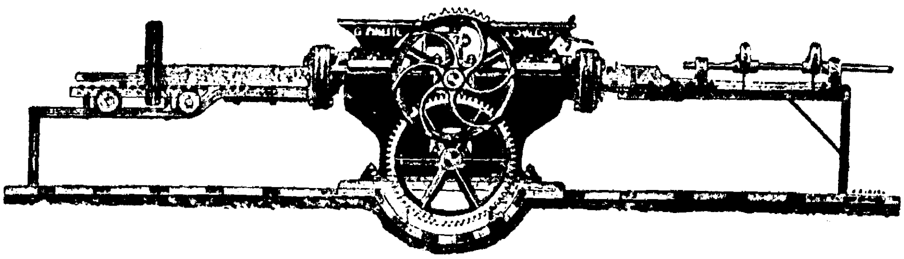


FIG. 16.—Pinette's double-piston press.

than roofing tiles. The forcing cylinders F F are at the rear of the machine and the hopper is at the back instead of on top, as in some machines; See Fig. 17, which shows the machine making four rows of hollow brick with 3 cells in each.

The receiving table has a fixed portion, A, with a set of rolls, B, near the draw plate, and a movable portion, C, carrying the cutter D on a frame that slides with it. At the end is a foot board, E. When the machine is started the movable part C of the table is set up

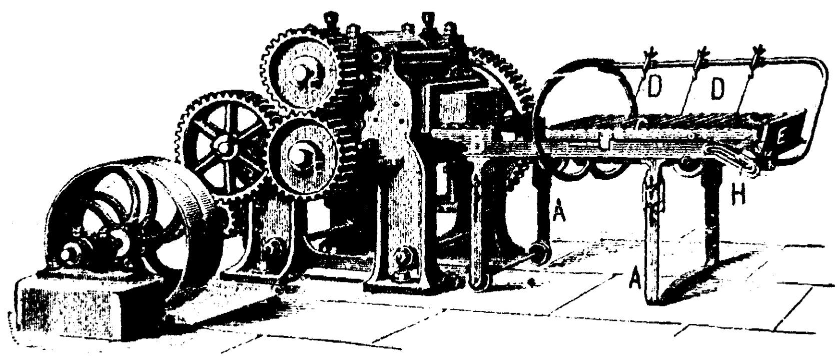


FIG. 17.—Pinette's forcing press with forcing cylinders or rollers.

against the fixed part B: the pressed clay glides along over the rollers till it reaches the foot board E, when it pushes the portion C ahead; as this goes forward the operator throws the cutters D D over, thus cutting off three lengths of brick which he then removes; while he does this the clay is still advancing. As soon as the operator has unloaded the bricks, he pushes back the part C and the foot board comes back into place automatically by the guide grooves H, ready for another cut.

This is a strong, simple machine, easily taken apart for cleaning, and will deliver slabs down to 1 inch in thickness perfectly well, or hollow slabs 1¼ inches, for partitions.

Boulet & Co. exhibit a machine, shown in Fig. 18, with two propelling screws: these turning towards each other below the feed rollers force the clay out through the draw plate.

The propelling screws are driven by gears on either side of the main shaft. The table of this machine is similar to that of Pinette's. The machine will make seven hundred to one thousand bricks per hour with 6 horse-power. The cut, Fig. 18, shows the whole rigging set up for brick making. The vertical mixer A is supplied by the endless belt B on which is thrown clay already wetted, or else dry clay

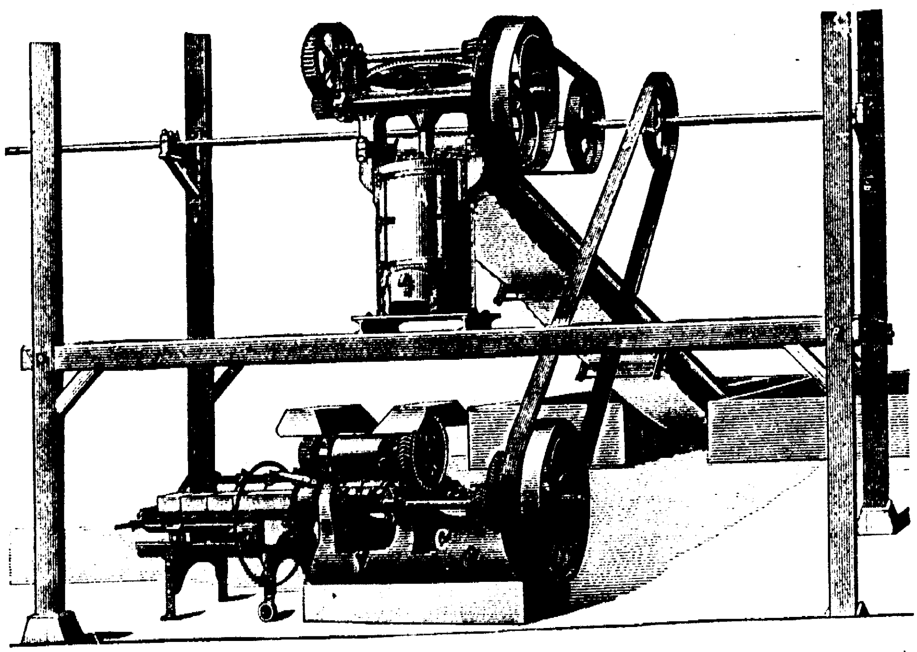


FIG. 18.—Boulet & Co.'s press with two forcing screws, arranged in connection with the mixer, conveyor, etc.

to which the water is added in the mixer. The brick machine C is set just below the mixer and fed from it. The larger size of this machine will make fifteen hundred bricks per hour, with 6 to 8 horse-power.

They also exhibit a single screw machine of the form shown in Fig. 19.

Messrs. Joly & Foucart exhibit a machine of similar type, but more compact: Fig. 20. This machine makes four hundred to one thousand bricks per hour with 6 horse-power. They also make the larger size.

The same firm also exhibits a special delivery table (Fig. 21) for making plain flat roof tiles. As the clay comes from the draw plate it passes between two large rollers, E F, covered with kid, whose circumference is just the length of one tile. The upper cylinder E carries a recess into which a projection of the lower cylinder F fits:

as it comes around it forces the clay into the recess and thus forms the projection or hook on the tile. Just beyond the recess in cylin-

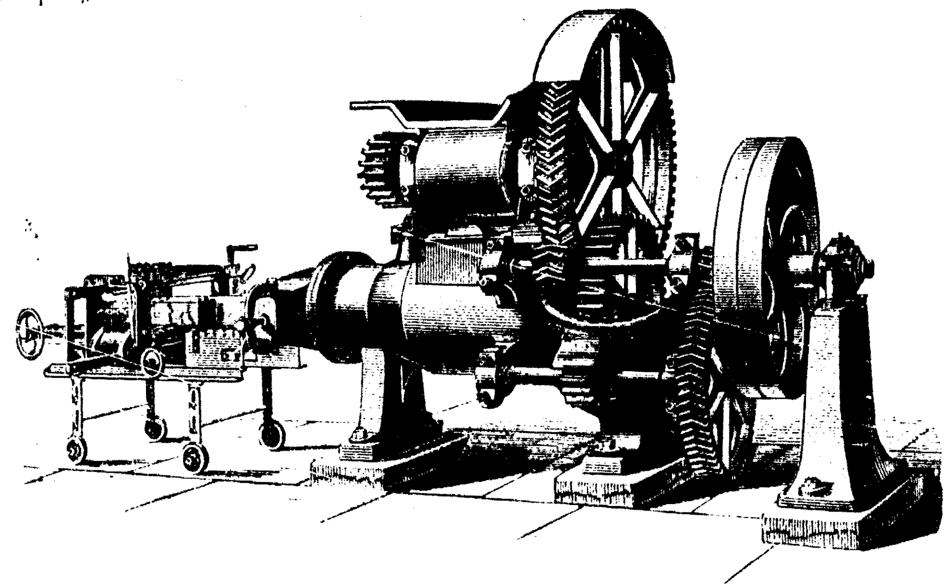


FIG. 19. Boulet & Co.'s press with single forcing screw.

der E a wire is stretched across two of the gear teeth, and this cuts the tiles off the proper length.

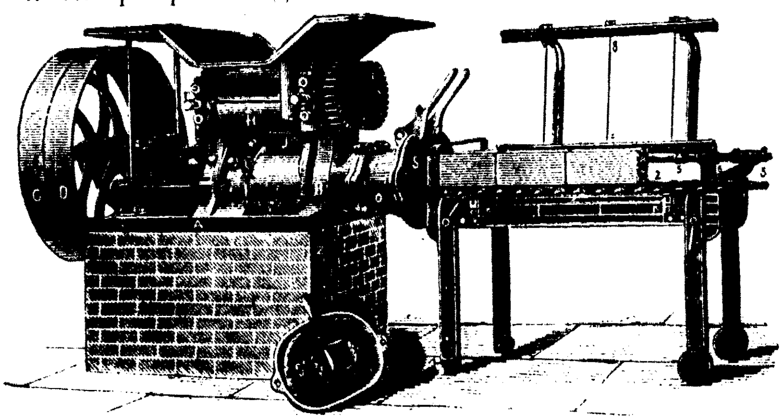


FIG. 20. Joly & Foucart's forcing press.

One Swiss house, C. Borner & Co., of Rorschach, show a fine line of brick and tile machinery, including clay washers, grinders, mix-

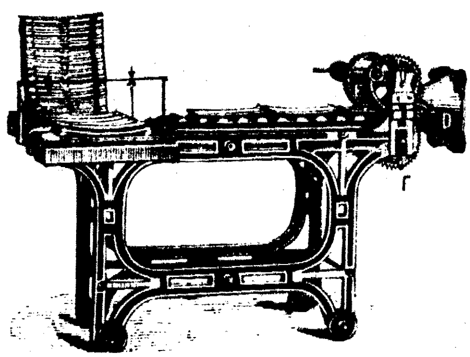


FIG. 21. Joly & Foucart's delivery table.

ers, and cutters, besides the regular brick machines. Their brick machine (Fig. 22) has a fine finish and is supplied with steel shafting and cast-steel screw. They make two sizes. The smallest will make from seven to eight thousand brick per day, and takes 4

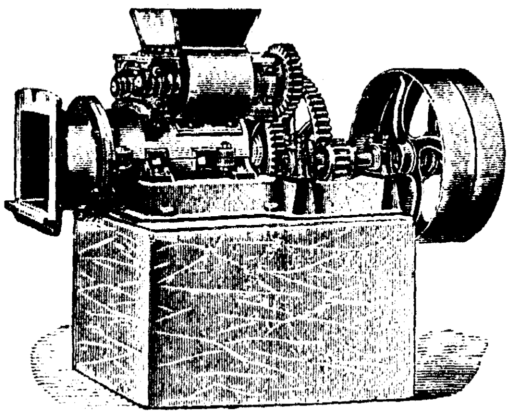


FIG. 22—Brick machine, by Borner & Co., Switzerland.

to 5 horse-power. The larger size makes eight to ten thousand brick, and takes 7 to 8 horse-power to run it. They are fitted with different forms of draw plates for hollow brick, tiles, fancy brick, etc. There is one for making a corrugated lap-joint tile having a lug at one end for securing it in place. In order to obtain the projecting lug,

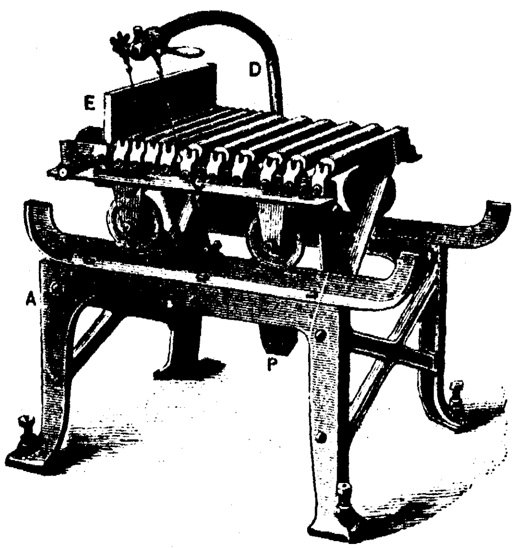


FIG. 23.—Cutting table, by Borner & Co.

which is on the upper end of the under side, the tile as it comes from the machine has a rib on its whole length, the greater part of which is removed by hand with a special tool, leaving only the upper end for the hook. They also make a very neat form of cutting table, shown in Fig. 23. The receiving table of this firm is built in a little different form: the roller carriage C' is set on grooved casters running on rails, set on top of the fixed table A. The lever D, carrying the wire cutters, is balanced by a counterweight, P, below the table, that brings it back into place after use.

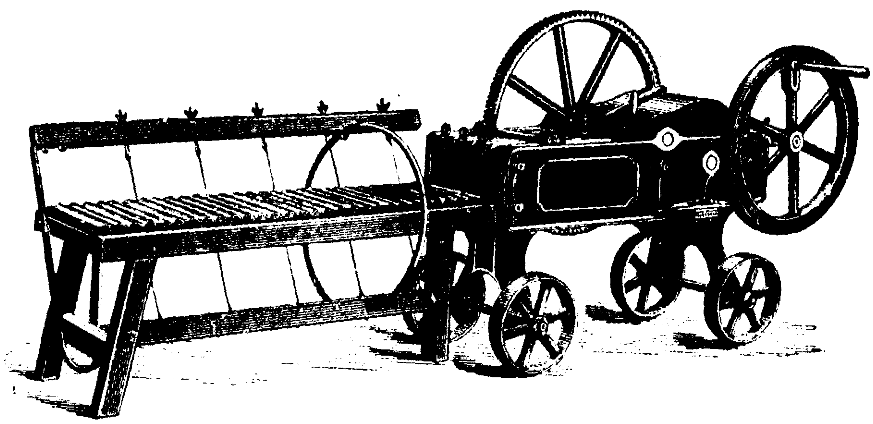


FIG. 24.—Hand-power brick machine, by J. Ollagnier.

Mr. J. Ollagnier exhibits a small hand-power brick machine (Fig. 24). With a man to run it and a boy to attend the bricks and clay, three to five hundred brick may be made per hour. It is a piston

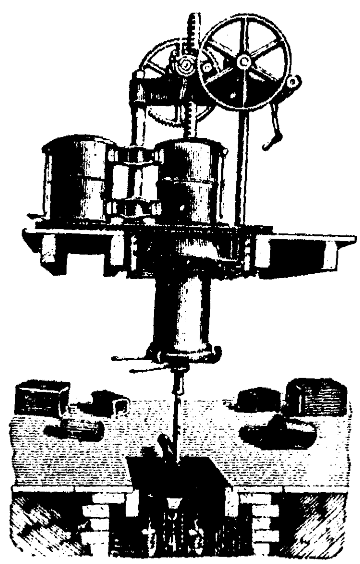


FIG. 25.—Boulet & Co.'s "revolver" forcing machine.

machine, with rapid return of the piston in order not to delay the work. It is a stout, simple machine, and quite low priced, costing about $110.

This style is also made to work both ways, with two draw plates operated alternately. It can also be run by power as other machines.

(10) The machines for manufacturing chimney-flue tiles or "wagons" so much used here, and drain pipes with heel joints, are similar in their working to the brick machines, only they are set up vertical. They are really vertical forcing machines, and are either continuously fed, by rollers, or else operated by means of a piston, in which case there must be pauses in the work in order to reload the chamber. Several exhibits of these machines are made.

Boulet & Co. make both piston and cylinder machines. In both cases the operator is on the floor below that on which the machine is set.

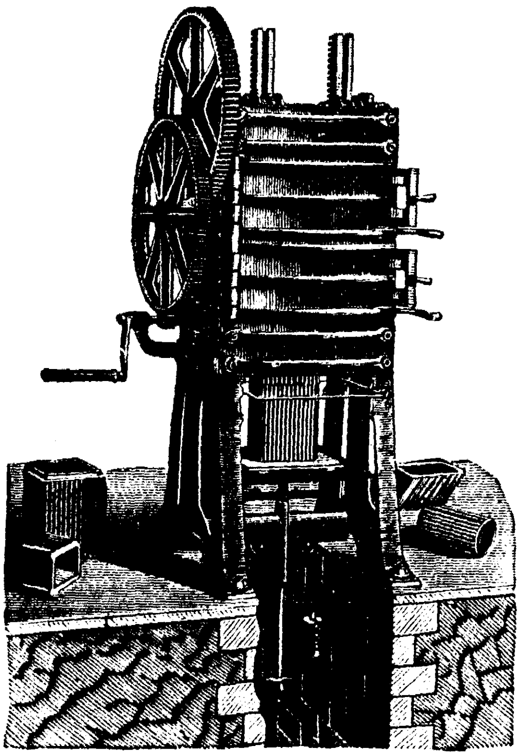


FIG. 26.—Boulet & Co.'s vertical flue-tile machine with charging doors

One of their piston machines has two cylinders used alternately with the same piston; one is being filled while the other is under pressure; it is called a "revolver" machine on this account. See Fig. 25.

The material as it passes through the forcing plate is received on a table which is so supported by chains and counterweights below the floor, that it is pushed down as the clay descends. A sliding cutter cuts off the material to the proper length. This will make eighty pieces per hour. The draw plate is made in a similar way to that on the horizontal machines.

Another of their piston machines shown in Fig. 26, has a square cylinder which is charged at the side through doors.

This firm also makes machines where the pressure is produced by the action of the feed cylinders, thus making a continuous machine; (Fig. 27). It takes 3 to 4 horse-power to run it.

Messrs. Joly & Foucart exhibit a continuous machine (Fig. 28), where the whole machine is on one frame, set on the floor, where the operator stands so that he can see and attend to all the parts.

The feed is from the side, through the hopper H, which is fitted with a frame, F, to receive an endless belt bringing the clay up from

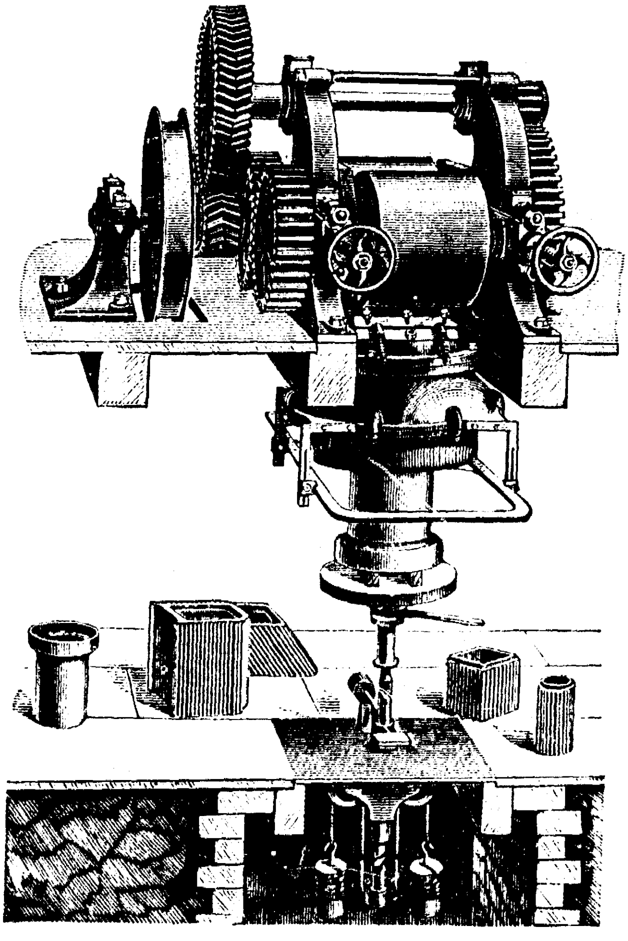


FIG. 27.—Boulet's vertical tile machine with forcing rollers.

the floor. The brick are cut off by means of the slide frame S, carrying a wire. An automatic stop-lever T is set at the right height so that when the material should be cut off the belt is thrown off and the feed and pressure motion stopped immediately. This machine has a powerful screw that forces the clay through the draw plate.

For pieces with slanting ends the cutting frame S is lowered on one side the proper amount to give the slant.

(11) The firm of J. Chambrette-Bellon, exhibits a piston machine, worked by hand, for making small hub pipes up to 8 inches; see

Fig. 29. The piston forces the material upward instead of downward. The draw plate portion D is hinged so as to be removed for filling in the clay. It will make fifteen to twenty pieces of pipe per hour up to 40 inches long.

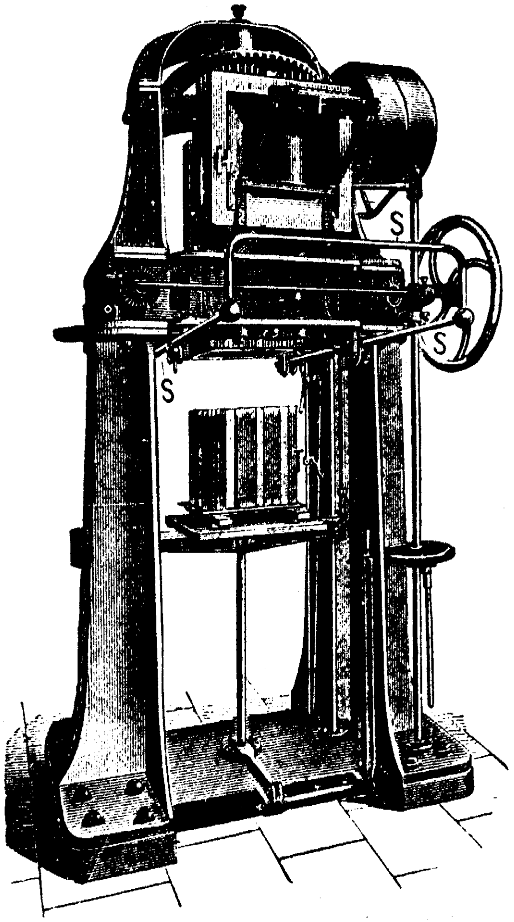


FIG. 28.—Joly & Foucart's self-contained continuously acting tile machine.

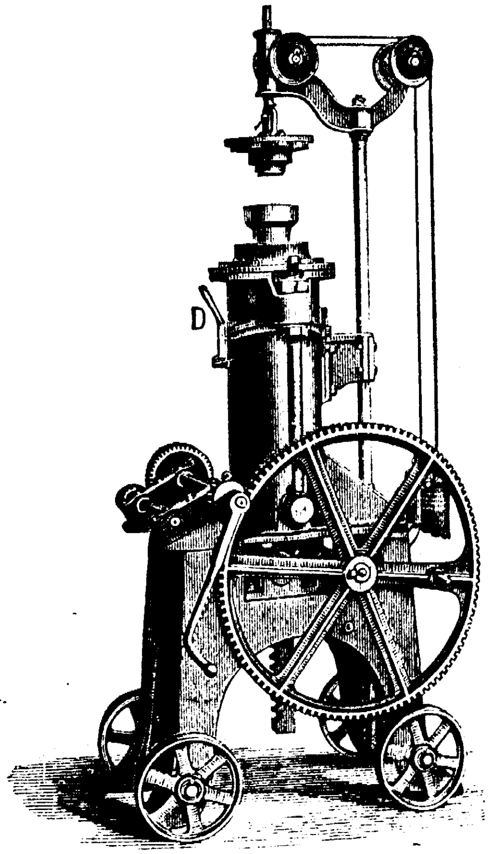


FIG. 29.—Small drain-pipe machine, by J. Chambrette-Bellon.

SPECIAL REPORT

ON

RAILWAY PLANT,

CLASS 61.

BY

PROF. LEWIS M. HAUPT.

CONTENTS.

REPORT ON THE RAILWAY PLANT.

By Prof. LEWIS M. HAUPT.

I.—The Installation.

Under Class 61, in the sixth group, are included the various appliances for the construction, equipment, management, and operation of railways from distant quarters of the globe.

They are conspicuously displayed in the western angle of the "palace" or machinery hall, where they cover more than 3 acres of space, and include such articles as—

Springs, buffers, brakes, etc.

Permanent way: Rails, chairs, fish plates, crossings, switches, turntables buffers, water cranes and water tanks, optical and acoustic signals.

Various kinds of safety apparatus and block systems.

Fixed appliances for tramways.

Rolling stock: Passenger cars, construction cars, freight cars, cattle cars, locomotives, tenders.

Self-moving carriages and road engines.

Special machines and tools for shops of maintenance, repair, and construction.

Appliances and machines for inclined planes and self-acting planes; models of engines, systems of traction, and apparatus relating to railways.

Rolling stock for tramways of various kinds.

Models, plans, and drawings for depots, stations, car houses, and other buildings necessary for the working of railroads.

The exhibits are not arranged in groups according to subjects, but appear to be assigned indiscriminately according to territorial divisions, some miscellaneous models of this class being in detached buildings or in other portions of the Exhibition. The plant represents not only the present forms of construction, but is to some extent historical, illustrating the development of railroads and their appliances from the days of Trevethick, Watt, and Stephenson to those of modern constructors innumerable.

It is not our intention, however, to devote any space to the history, which is an oft-told tale, but rather to direct attention to some of the more prominent features of this truly excellent display as they have been presented to meet the requirements of transportation in the civilized countries of the world.

The principal nations represented are: France, with her 158 exhibits; the Colonies, Algeria, with 4 exhibits; Austria-Hungary, 2; Belgium, 37; Spain, 2; the United States, 20; Bolivia, 2; Chile, 1; Great Britain, 19; Italy, 4; Norway, 1; Brazil, 3; Roumania, 1; Russia, 2; Switzerland, 8; and Holland, 1; giving a total of 265.

II.—Description of Typical Exhibits.

FRENCH EXHIBITS OF ROLLING STOCK.

Amongst the most important of the French exhibits may be mentioned those of the Administration des Chemins de fer de l'État; Société des Anciens Établissements Cail; Compagnie de Fives-Lille; Compagnie des Chemins de fer de Bône à Guelma; de l'Est; du Midi et du Canal Latéral à la Garonne; du Nord; de l'Ouest; de Paris à Lyon et à la Méditerranée; de Paris à Orléans; with numerous manufacturers and special exhibitors, including the railway statistics by the minister of public works, in the Trocadero.

The Western Railway Company (Compagnie des Chemins de fer de l'Ouest), M. F. Clérault, chief engineer, make a representative display of modern rolling stock as used in France, which they have fully presented in a special monograph entitled "Notice sur les Objets présentés à l'Exposition Universelle de 1889."

This exhibit embraces locomotives, carriages, special vans and apparatus, models, and designs as follows: Express locomotive No. 623, with three axles, two being coupled; another, No. 951, with two coupled drivers and bogie truck; a tank engine with two axles, sleeping cars, mixed carriages for light trains, experimental van with dynamometer, etc.

In addition to the above there are sixty-three special exhibits of brakes, couplings, apparatus for heating and lighting, and various mechanisms, forming a very instructive display.

This company was the first in France to construct locomotives with coupled drivers. The type introduced in 1855, with wheels of 6.26 feet diameter, was in use without material change until 1874.

Since then greater power has been obtained by extending the fire box over the rear axle, increasing the diameter of the drivers to 6.7 feet, and enlarging the cylinders and smokestack. Seventy-one of these machines are now in service.

The general construction of the engine is shown in Figs. 1 and 2, from which it appears that the cylinders are inside with valves above. The forward drivers have crank axles, but the connecting rods are outside. The total wheel base is 16.5 feet.

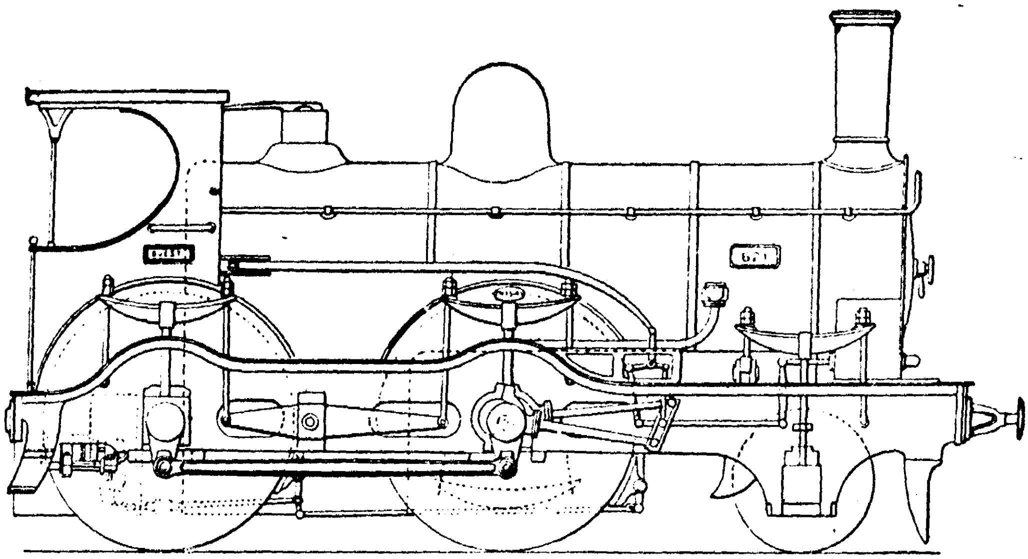


FIG. 1.—Elevation.

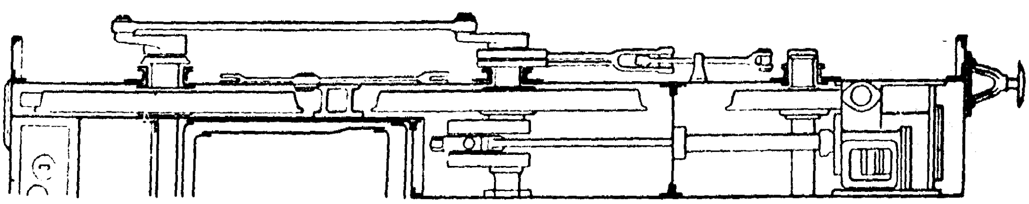


FIG. 2.—Plan.

Express passenger engine No. 623.

The principal dimensions and weights are given in the accompanying table.

The total length of engine, without tender, between buffers, is 26.9 feet.

General data relative to engines.

	Passenger No. 623.	Bogie No. 951.	Tank No. 3533
Gauge .... feet..	4.477	4.477	4.47
Length of grate .... do...	5.18	5.58	4.13
Breadth of grate........ do...	3.43	3.45	3.36
Surface of grate .... square feet..	17.76	19.25	13.77
Mean height of fire box........ feet..	5.64	5.51	4.92
Number of tubes........	223	183 12	203
Exterior diameter of tubes........ inches..	1.75	• 1.92 1.76	1.75
Length between boiler heads........ feet..	10.5	13.71	10.5
Heating surface of fire box .... square feet..	103.3	107.6	81.77
Heating surface of tubes (exterior) .... do...	1,086	1,341	990.6
Heating surface, total........ do...	1,189	1,448.6	1,072.4
Outside length of fire box .... feet..	5.9	6.17	4.72
Outside breadth of fire box (top)........ do...	4.32	4.37	4.36
Outside breadth of fire box (bottom)........ do...	4.13	4.03	3.93
Mean diameter of boiler .... do...	4.03	4.07	4
Length of boiler........ do...	9.97	13.38	10.17
Thickness of boiler plate........ inch..	0.55	0.6	0.55
Height of axis above rail........ feet..	7.21	7.21	7.15
Volume of water when 4 inches below crown .... cubic feet..	107.63	127.08	94.15
Volume of steam when below crown .... do...	51.1	56.48	50.48
Boiler pressure (square inch)........ pounds..	142	156.2	142
Distance between longitudinal frames .... feet..	5.73	4.16	4.13
Total length between buffers .... do...	26.9	33.39	27.97
Diameter of wheels:			
Forward .... do...	3.74	3.08	5.05
Drivers........ do...	6.70	6.70	5.05.
Interval between axles:			
Front to second........ do...	7.7	6.56	7.05
Second to third .... do...	8.86	8.89	7.54
Third to rear .... do...	....	8.85	....
Total wheel base .... do...	16.56	24.30	14.59
Diameter of cylinders........ do...	1.41	1.51	1.41
Stroke of pistons........ do...	1.968	2.16	1.968
Length of driving rod .... do...	5.90	7.21	5.74
Distance between cylinders .... do...	2.70	2.33	2.13
Weight of engine (empty)........ pounds..	78,100	96,800	73,480
For service:			
Leading axle .... do...	26,290	19,800	29,700
Second axle........ do...	29,480	20,900	30,360
Third axle........ do...	29,480	32,560	31,240
Trailing axle........ do...	....	31,900	....
Total .... do...	85,250	105,160	91,300
Adhesion (calculated at one-sixth)........ do...	9,834	10,740	15,216
Height of stack .... feet..	13.94	13.94	13.94
Weight of water in tank .... pounds..	....	....	8,800
Weight of fuel .... do...	....	....	2,640
Maximum load on single wheel .... do...	14,740	16,280	15,620

Express locomotive No. 951 with coupled drivers and bogie.

Another style of engine shown by this company was specially designed for the heavy traffic on certain parts of their lines.

Its characteristic features are well illustrated in Figs. 3 and 4. The use of the bogie truck has been found in practice to increase the stability of the machine as well as to preserve the track. The

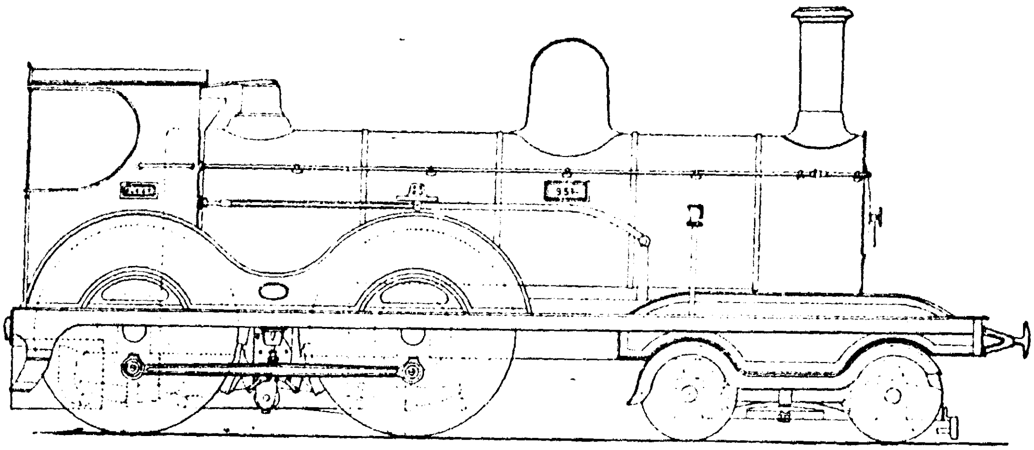


FIG. 3.—Bogie engine No. 951, Western Railroad, France.

mechanism is modified accordingly. The cylinders, valves, and connections are well inside the frame, excepting the connecting-rod for the drivers.

The lateral play of the bogie is about 2 inches. It is controlled by a spring of which the initial tension is 3,080 pounds, and the elasticity 1 inch per ton. The axis of the pintle is supported 2 inches to the rear of the center so that the tracking of the bogie is facilitated on curves.

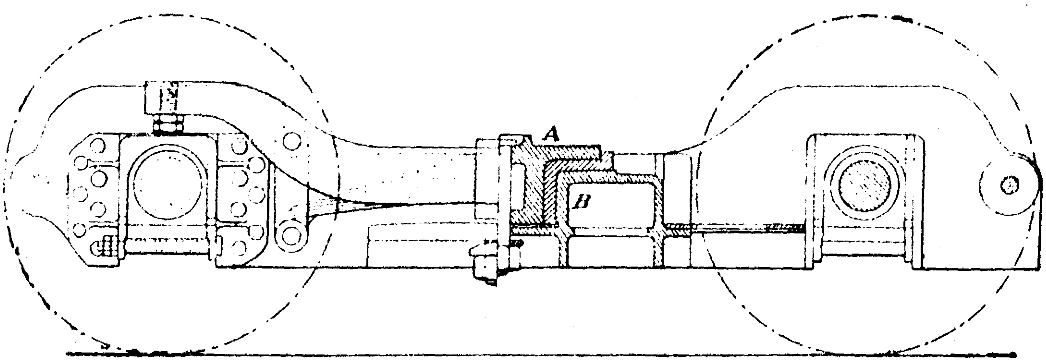


FIG. 4.—Bogie truck of No. 951, Western Railroad, France.

The total weight of the engine is 105,160 pounds, and the length between buffers for engine only is 33.39 feet. (The remaining data are given in the preceding table.)

The load is distributed equally over the drivers by means of two longitudinal balance beams connected with the springs.

The draw bar between the engine and tender has no springs but adjusts itself by means of the oblique buffers, known as the system of E. Roy and introduced by this company in 1884. The buffers are of cast iron; those on the engine have a spherical surface, the center of which is at the coupling pin; those of the tender are plane and inclined at an angle of about 50 degrees. This arrangement eliminates the oscillations on tangents and adapts itself to curves with good results.

The feed water is supplied by two of Friedman's injectors.

The brake consists of four cast shoes placed between the drivers and actuated by two vertical, pneumatic cylinders operating upon the cams.

Tender with two axles.—The capacity of the tank is 370 cubic feet. This quantity enables the engine to draw trains of fifteen carriages, without stopping, from Paris to Rouen (84 miles). It has been designed with the view of securing the maximum load compatible with only two axles.

The air brake has eight cast shoes operated through triangular connections as on the carriages. A footboard extending the length of the tender permits communication to be made with the engine driver.

The weight of empty tender is	pounds	26,620
The weight of tools	do	1,320
The weight of water	do	23,100
The weight of fuel	do	6,600
Total weight ready for service	do	57,640
Weight on each wheel	do	14,410
Wheel base	feet	9.68
Diameter of wheels (tires 2.6 inches thick)	do	3.74
Total length of engine and tender	do	49.95
Total weight of engine and tender (in use)	pounds	162,800

Carriage with a sleeping compartment.

(Figs. 5 and 6.)

The car shown in these figures contains three compartments for first-class passengers, two for day travel, with space for eight persons each, and one for night travel, with beds for four adults. The middle compartment, which is 8.85 by 10 feet, contains, beside the three movable couches, a toilet closet. The dimensions are adapted to the wheel base (14.43 feet), which in turn is limited by the turntables of the main line. Whilst there are seats for five there are but four full length beds; three of these are placed parallel to the axis of the train and are folded down by a bascule movement. The fourth bed is made by a leaf prolonged under the lavatory table so as to permit

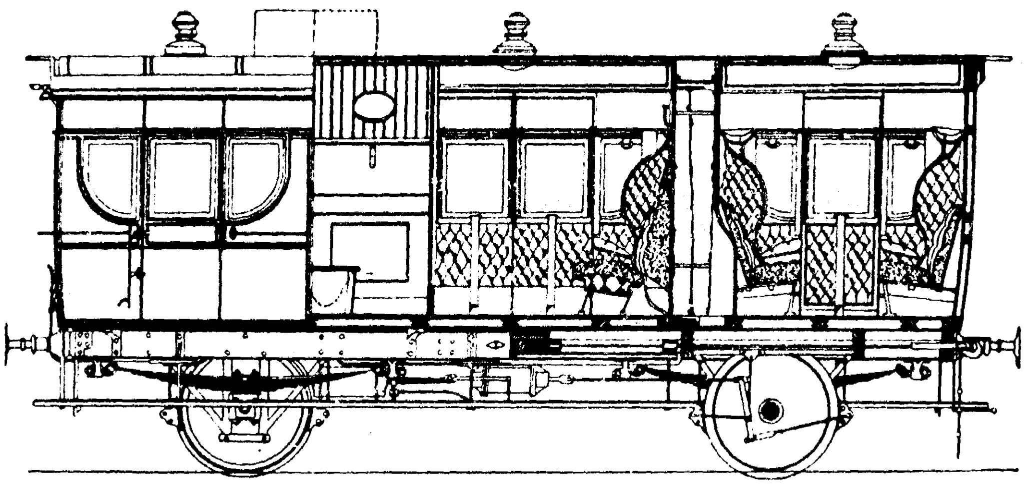


FIG. 5. Saloon sleeper. Western Railroad, France.

the traveler to extend his full length across the car. This couch is sufficiently large for two children. There are also pillows, folding chairs, ottomans, an articulated table, and other appointments. For the use of invalids the doors are made double, so that when necessary both may be opened to admit a bed, litter, or rolling chair. In

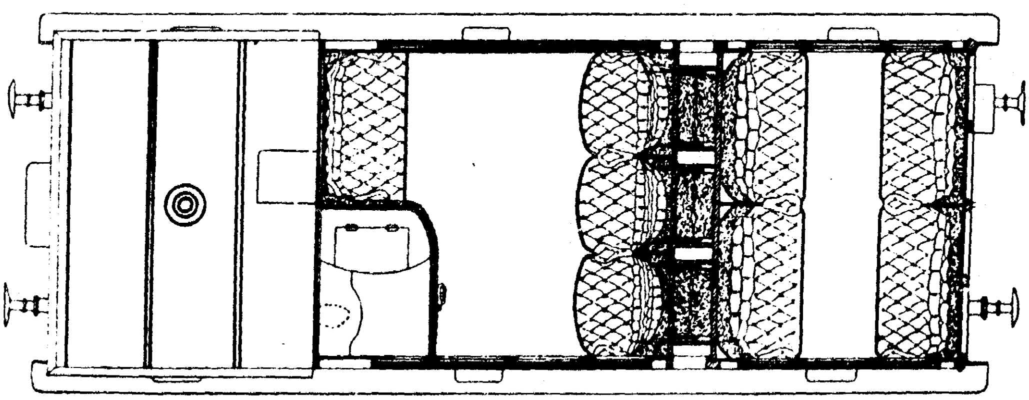


FIG. 6.—Plan.

all the compartments the floor is covered with a thick felt packing to deaden the vibrations. Communication between the carriages is effected by means of the outer footboard and handrail.

The journal boxes have a transverse and longitudinal play of about one-third of an inch.

There are eight cast-iron brake shoes operated by compressed air. The general dimensions are given in the following table:

Dimensions and weights.

	Saloon sleeper.	Mixed car.
Maximum length of car body ... feet.	24.99	23.42
Maximum breadth of car body ... do	8.85	8.85
Maximum height (floor to ceiling at center) ... do .	6.80	6.50
Total number of passengers ...	21	28
Length from out to out of buffers ... feet.	27.94	27.2
Length of springs between points of support ... do	7.21	5.05
Flexibility per ton (2,240 pounds) ...	0.42	0.16
Axle journal, diameter ... inches .	3.96	3.12
Axle journal, length ... do	7.08	6.24
Axle body, diameter at center ... do	5.0	4.44
Wheels, outer diameter ... feet	3.38	3.38
Mean weight of an axle, mounted ... pounds.	2,200	1,980
Number of axles ...	2	2
Distance between axles ... feet	14.43	12.32
Weight empty (including brake) ... pounds	23,100	22,440
Dead load per passenger ... do	1,100	802
Unit of length per passenger ... feet	1.33	0.97

Mixed carriage for light trains.

This carriage is designed to transport first and second class passengers and to provide a large baggage compartment, so that by the addition of a single third-class carriage it may constitute a train of sufficient capacity for secondary or branch lines.

The principal dimensions are stated in the foregoing table.

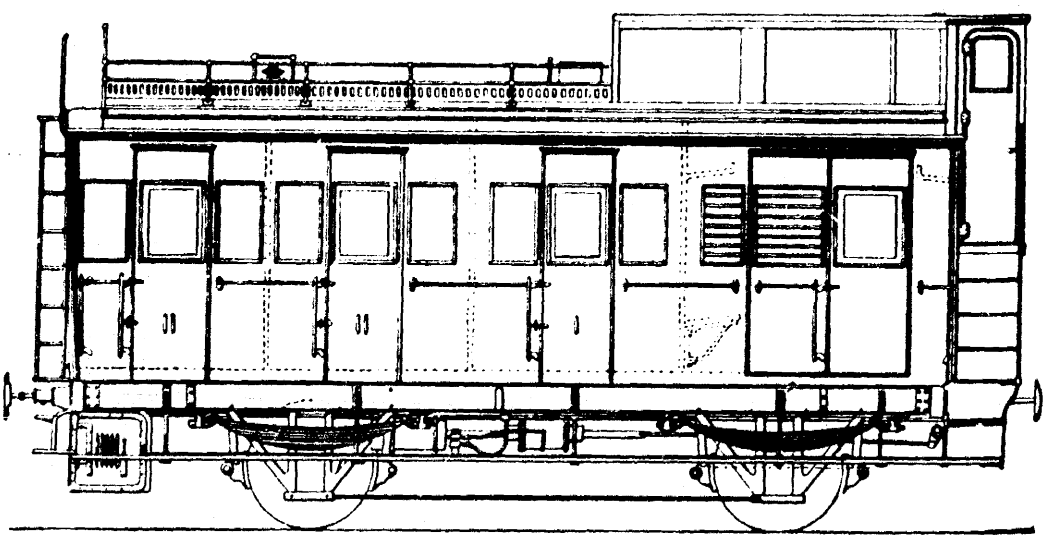


FIG. 7.—Mixed carriage, Western Railroad, France.

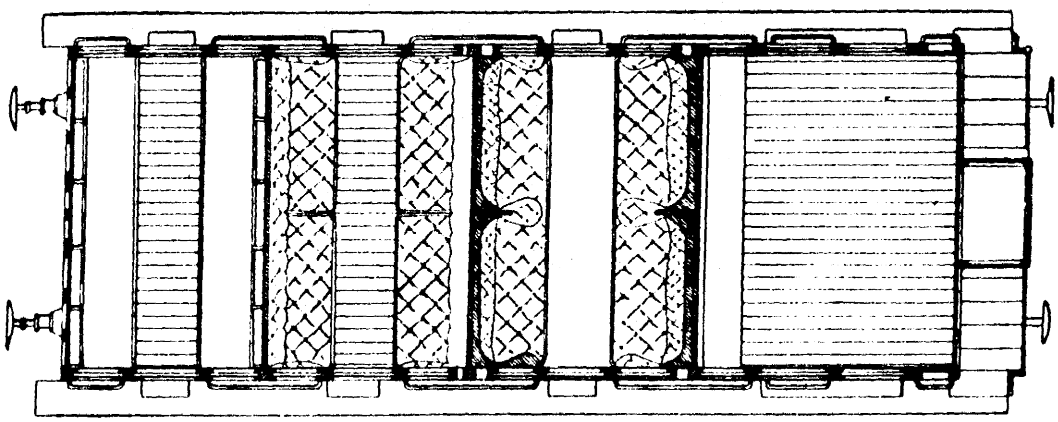


FIG. 8.—Plan.

SPECIAL DEVICES AND APPARATUS.

The most direct method of determining the resistances of trains is by means of the dynamometer, and with this end in view this company has fitted up a car with instruments designed—

(1) To measure and record the power.

(2) To measure and record total work.

(3) To register the speed by means of a special trochometer.

(4) The determination of the number of revolutions of the wheels.

(5) The registration of time every ten seconds by means of an electric clock.

(6) The marking of the kilometers or any other important distances on the route.

These three last elements are indispensable for verifying the results furnished by the other instruments.

(7) The analyses of the gas used in combustion.*

The Western Railway Company of France also use the Westinghouse compressed-air brake, and have placed in each compartment a button or ring by which the train may be stopped by any passenger, but the unnecessary use of it is accompanied by a severe penalty. In the course of its experiments as to the best mode of coupling the air brakes the company have tried no less than nine different systems since 1883, and are still trying new methods. These are described in a pamphlet issued by the company.

Since 1876 an improved method of oiling pistons, eccentrics, and axles has been in use and has been extended rapidly. It consists of capillary tubes in which the oil drawn in by the movement of the piece is projected into a sort of basin, from whence it is fed to the part to be lubricated through a small opening.

A new automatic greaser is also used for the valves. It was introduced in 1884.

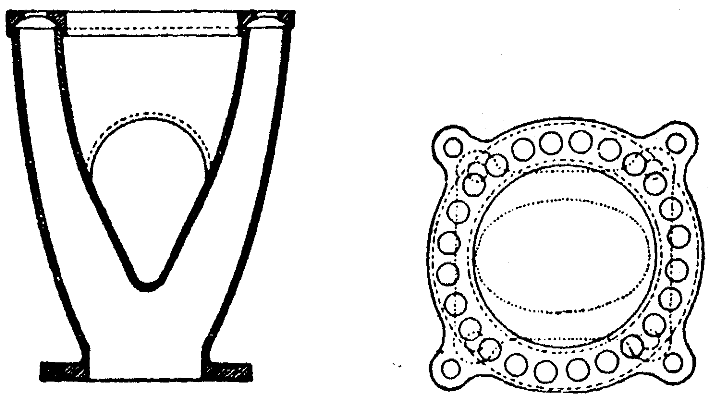
Since January, 1878, mineral oils obtained from Russian and American petroleum have been in successful use for lubrication with good results. Samples are on exhibition.

* The description of these instruments is omitted for want of space.

Escape nozzles have been designed by this company, which are so successful as to have led to their general application. These are so fixed as to increase the useful effect of the apparatus. (See Figs. 9 and 10.) An annular tuyere containing a large number of holes induces a suction through the ring. A central opening distributes the draft more uniformly amongst the different layers of the tubes and facilitates their cleaning.

To prevent waste of fuel from the energetic draft a brick arched deflector is placed in the fire box immediately below the tube plate, whereby a more perfect combustion is effected. It has been in use since 1884 with very good results. The mean life of the arch is seven months.

Acetate of soda heaters.—By this mode of heating (Ancelin system) the crystallized acetate of soda, freed from tarry matter and containing four equivalents of water, is substituted for the warm water. This salt by reason of the latent heat necessary for fusion contains



Figs. 9 and 10.—Escape nozzle.

for an equal volume, and between the same limits of temperature, four times more useful heat than does water. These heaters, tried by the company in November 1879, on an express train from Paris to Rennes, have since been introduced in all the express and omnibus lines of Havre and Dieppe, and also in the trains of the line to Versailles; 2,100 of the acetate heaters were in use during the winter of 1888-'89.

Heaters with interior flues.—These heaters were intended to dispense with the maintenance of the hot-water boxes in the carriages by placing below the floor a fixed heater fed by water warmed from a flame of fire at the end of the box (Fig. 11). In each heater there is a horizontal flue in the form of an ⊃ which carries off the products of combustion (Fig. 13). The firebox consists of a cage of perforated sheet metal in which the ignited fuel is placed. The liquid employed is a mixture of glycerin and water which freezes only at 2° F. The temperature may be maintained at 50° for eight to nine hours without adding fuel, which may be done by trainmen without disturbing the occupants of the carriage.

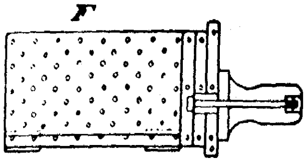


FIG. 11.—Fire box.

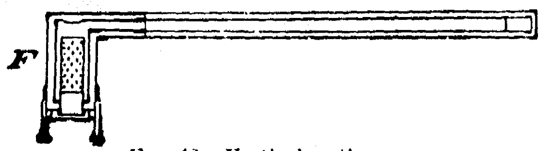


FIG. 12.—Vertical section.

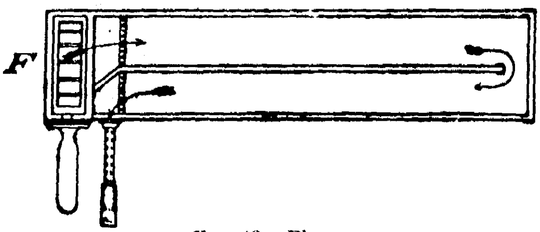


FIG. 13.—Plan.

Heater with interior flues.

Thermosyphon heaters.—Another form of heater consists of a fire-box, H (Fig. 14), in the form of a cylinder of sheet-iron pierced with holes and placed under one of the outer traverses of the carriage. A

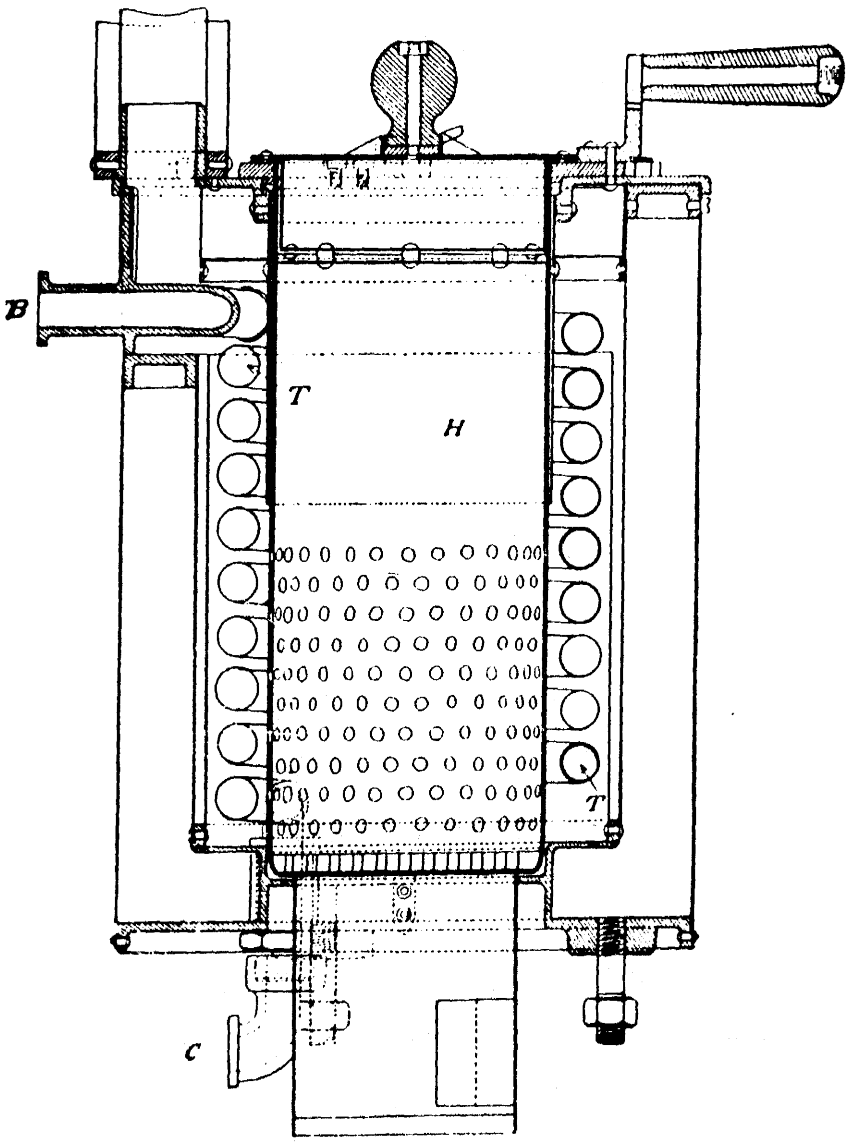


FIG. 14.—Thermosyphon heater

helical tube containing the water to be warmed surrounds the cylinder and extends by branches along the sill of the carriage, establishing a circulation with the several compartments. It will warm two compartments for about five hours without replenishing the fuel, which is charcoal.

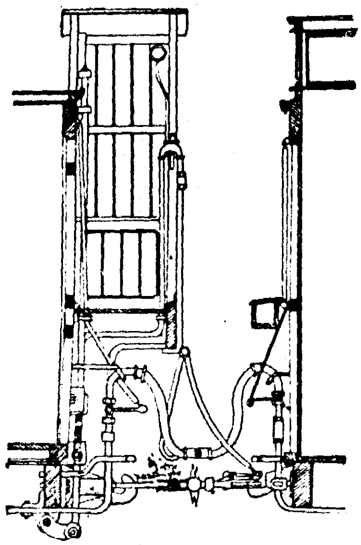


FIG. 15.—Uncoupling device. Elevation.

Tendeur à déclenchement (*uncoupling device*).—When it is desired to drop passengers at a station without stopping the express trains a special carriage is placed in front of the cars to be detached, which are at the rear of the train. At the preceding station a "guard" uncouples the safety chains and just before reaching the proper point a train hand closes the valves of the air brakes of both carriages

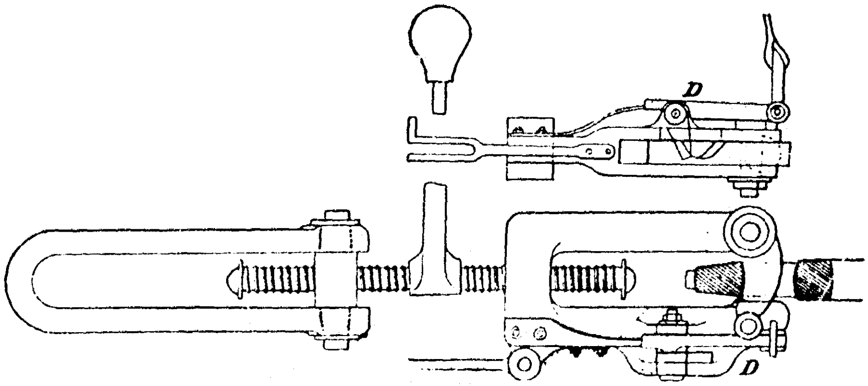


FIG. 16.—Uncoupling device. Details.

and separates the hose couplings, and finally at the right moment he opens, by means of a pawl, the outer cheek and allows the hook of the preceding carriage to escape. A special reservoir furnishes power for the brakes of the detached portion of the train. (For details, see Fig. 16.)

Molding by machinery.—For a long time machine-molding has been substituted for hand work with better results and less cost.

The tool consists of a pair of machines, one of which makes the top, the other the bottom of the mold. The two flasks containing the pieces to be cast are assembled on a centering machine ready for use. By this means a great variety of forms are turned out at the foundry in a very short time, and in excellent condition.

The exhibit also embraces an axle which has made a mileage of 491,338 miles without signs of fracture, and a cast-steel driving-wheel tire of 273,737 miles. The latter was in use eight years, from 1881 to January, 1889, in which time its original thickness of 70 millimeters (2.73 inches) was reduced 50 per cent. The proof test for tires in 1885 consisted of a breaking stress of 102,564 pounds per square inch, with an elongation of 15 per cent at the point of rupture and four blows from a ram of 1 ton falling from a height of 32.8 feet. The result of these severe tests has been to increase the life of the tire about 40 per cent.

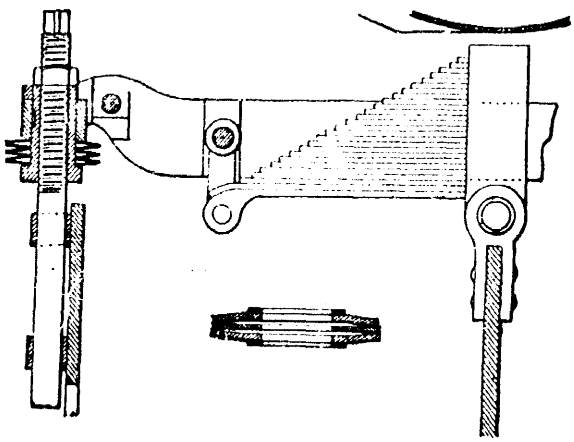


FIG. 17.—Balance beam.

A chronographic register is also used to show the irregularities of the train movement and various other important elements. From the register submitted it would seem that at high speeds the oscillations are considerable.

On engine No. 621 there is also shown a tranverse balance beam for equalizing the load on the journals of the forward driver. It consists of an articulated beam resting on disks, as seen in Fig. 17. Another form of transverse balance is also shown on engine No. 623. The remainder of the exhibit consists of charts, designs, and photographs illustrating the developments made by the company from 1837, when the engines weighed only 9.5 tons, to the present time.

As the water used on this route contains lime and other ingredients producing incrustations, the company have recourse to a disincrustant made by boiling together 100 parts by weight of a wash of caustic soda at 45° Baumé, 200 parts of powdered quebracho wood, and 500 parts of water, which is allowed to settle, and after decanting the clear liquid the residue is again mixed with water, boiled, and decanted. The operation is repeated until the material is exhausted. This should give about 2 tons of liquid, showing 11° by Baumé's hydrometer. It has been in use for ten years. This company operated 2,694 miles of railroad (January, 1889). The annual train mileage was 20,454,200 miles at the same date.

It has in actual service—

Locomotives	1,369
Passenger carriages	3,709
Special wagons	1,773
Freight wagons	20,203
Dumping cars	486

Valued at $39,258,600, with nearly $2,000,000 worth of tools and machinery at the various shops and depots.

THE PARIS, LYONS AND MEDITERRANEAN COMPANY.

This company made an extensive display, embracing two locomotives, C-1 and No. 4301, one sleeping car, three day coaches, and

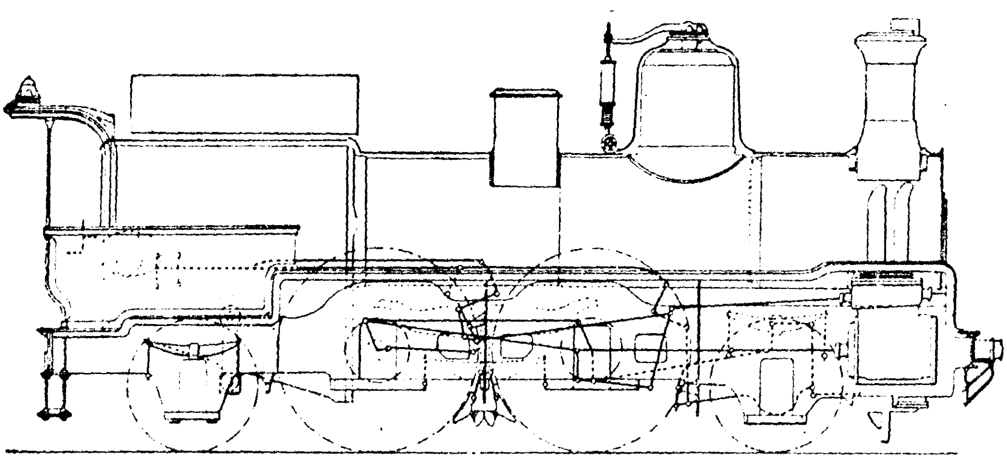


FIG. 18.—Paris, Lyons and Mediterranean Company's engine C-1.

various special features of which only a few pieces can be described in detail.

The locomotive C-1 (Fig. 18), designed for high speed, has only been in service since the beginning of the year 1889.

It is a compound engine with four cylinders, two interior operating the forward drivers and two exterior on the rear drivers. In addition to the drivers it has one leading and one trailing axle.

The general design of this engine is shown by the diagram.

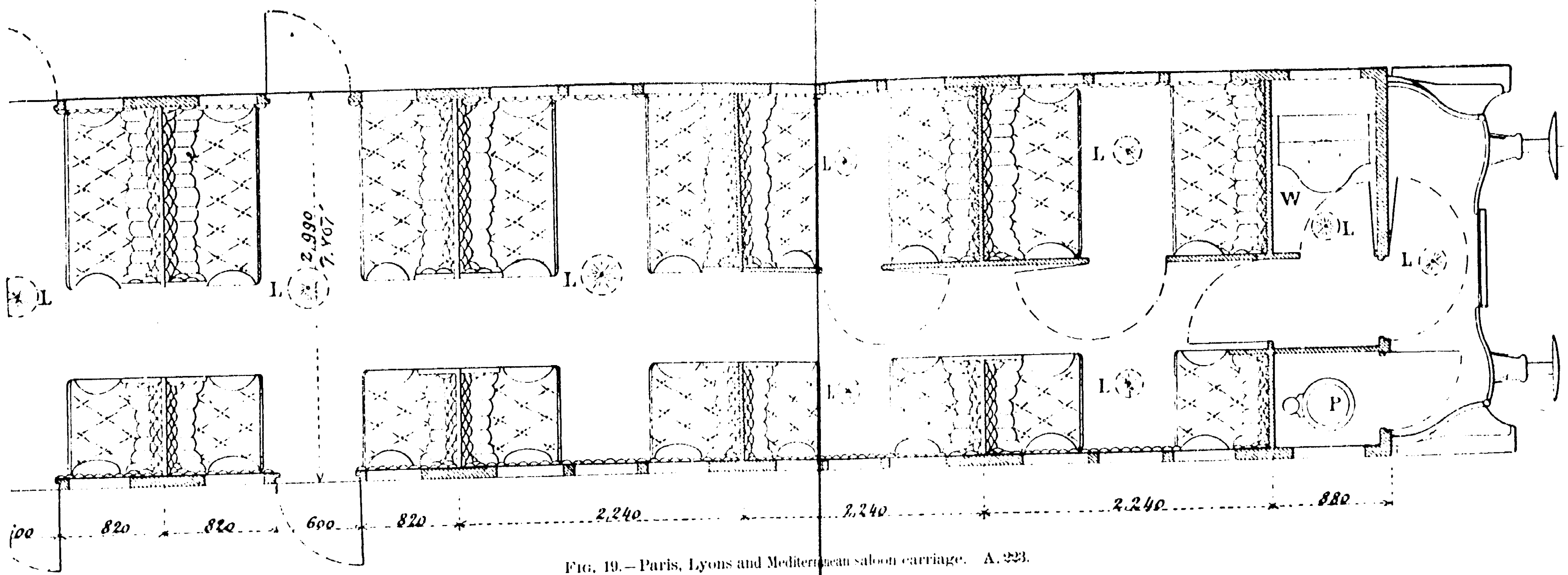


Fig. 19.—Paris, Lyons and Mediterranean saloon carriage. A. 223.

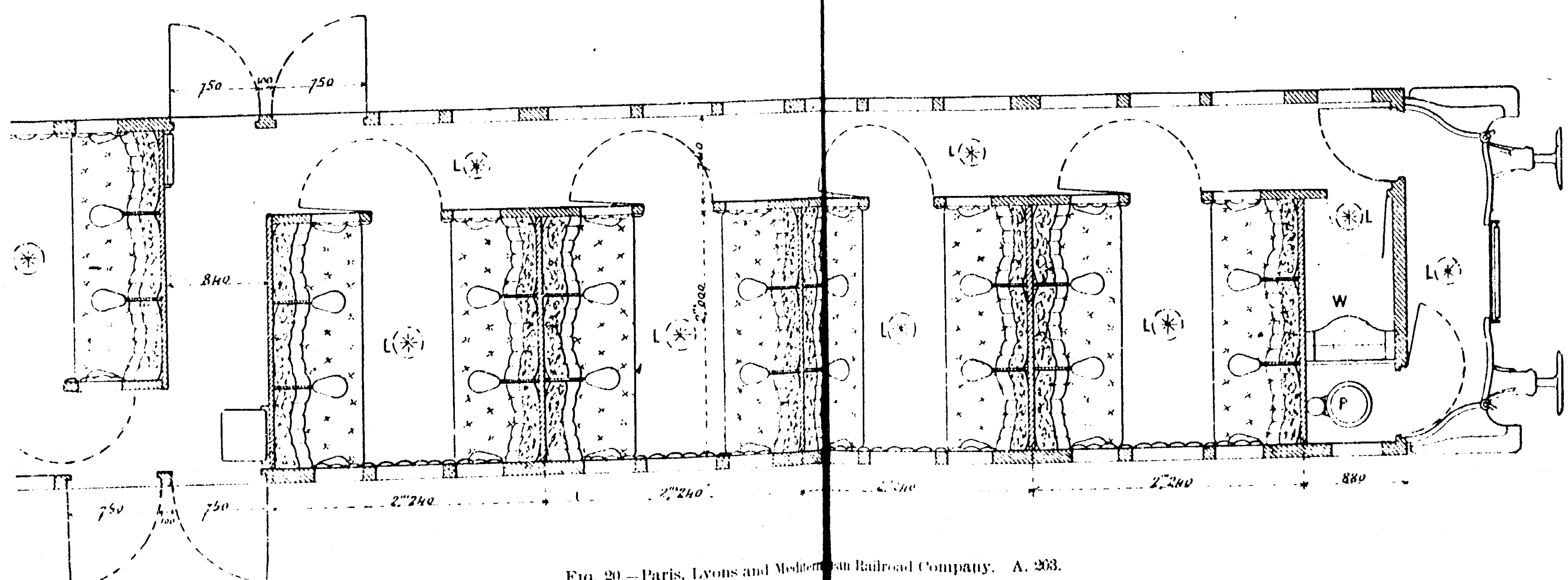


Fig. 20.—Paris, Lyons and Mediterranean Railroad Company. A. 263.

The principal dimensions and weights are:

	No. C-1.	No. 4301.
Length of grate ... feet	7.59	7.08
Breadth of grate ... do	3.31	3.29
Surface grate ... square feet	25.15	23.46
Number of tubes	185.	247.
Length of tubes ... feet	13.22	13.61
Interior diameter of tubes ... inches	1.75	1.75
Interior surface tubes ... square feet	1,159.05	1,577.
Surface of fire box ... do	124.9	117.8
Total heating surface ... do	1,284.01	1,694.8
Interior diameter of boiler ... feet	4.13	4.92
Thickness of boiler (steel) ... inches	0.55	0.57
Boiler pressure ... pounds per sq. in	213.3	213.03
Water capacity (with level 4 inches below crown) ... cubic feet	130.6	183.09
Diameter of admission cylinder ... feet	1.01	1.18
Diameter of expansion cylinder ... do	1.64	1.77
Stroke of pistons	2.02	2.13
Number of axles	4	4
Number coupled	2	4
Distance between extremes ... feet	19.22	13.28
Diameter of drivers ... do	6.56	4.13
Diameter of bearing wheels ... do	4.26	....
Weight on rails per axle (in service)—		
First ... pounds	29,480	28,798
Second ... do	32,560	29,590
Third ... do	32,560	35,178
Fourth ... do	23,100	32,054
Total weight ... do	117,700	125,620
Total weight empty ... do	108,900	113,498
Tractive power ... do	9,552.	22,660
Adhesion at 14 per cent of weight on drivers ... do	9,116.08	17,597.08
Tenders—		
Capacity of tank ... cubic feet	568.03	2-2.04
Weight of fuel ... pounds	6,600.	11,000
Wheel base ... feet	11.15	8.02
Diameter wheels ... do	3.93	3.93
Weight on rail per axle, loaded		
First ... pounds	26,224	28,182
Second ... do	27,118	29,700
Third ... do	27,118	......
Total ... do	80,020	57,872
Empty with fixtures ... do	38,500	29,282

First-class coach with interior central aisle (*No. A-223*).—This elegant carriage contains eight first-class compartments and approximates to the saloon cars in use in the United States. As will be seen from the drawing (Fig. 19), the capacity is limited in consequence of the inability to increase the width, and hence 25 per cent of the seats are surrendered for the interior passageway. The compartment feature is retained in the end sections, whilst the centre is made into a saloon. The water closets at the ends are accessible to all passengers. The heaters are reached by the train hands from the platform.

These cars are unusually large, being 73.37 feet in length from out to out of buffers, 9.8 feet in width, and 8.29 in height of body. As these dimensions give a scant clearance, the windows are guarded by iron bars. The car will seat forty-seven passengers and one porter, or forty-eight persons.

On either side of the coach there are two doors, placed near the middle, with steps which are operated automatically. These, with the end platforms, give four entrances and exits. By thus dispensing with the former exterior footboards more space is gained for air and circulation inside.

The car body is supported upon two bogie trucks, each having but two axles (four wheels), and is furnished with Chevalier and Rey spring draw-bar; a compressed-air brake; a system of heating from two stoves with heat siphons, each supplying one-half the carriage with a circulation of hot water; electric bells, to call the conductor; double sash, and an interior doorknob to open the doors without having to lower the sash and reach out, as at present.

The frame is iron, covered with wood.

Principal dimensions and weights.

Diameter of wheels	feet		3.28
Weight of an axle mounted	pounds		2,618
Length, out to out (over all)	feet		73.37
Length of body, end to end (outside)	do		65.00
Length of body, end to end (inside)	do		64.55
Interior width	do		9.28
Exterior width	do		9.80
Floor space	square feet		599.8
Height at center of ends	feet		8.29
Cubic contents	cubic feet		4,150
Number of first-class seats		47	
Number of porters		1	48
Weight empty	pounds		78,672
Weight equipped with water, coal, etc	do		81,213
Weight with forty-seven passengers and luggage (these together being estimated at 154 pounds)	pounds		7,238
Total	do		88,451
Dead load per passenger	do		1,727
Dead load per passenger without coal and water	do		1,672
Ratio of live to dead load			1:12
Floor space per person	square feet		12.5
Volume per person	cubic feet		86.4
Car length per person	feet		1.53

Another first-class carriage, No. A. 203 (Fig. 20), is shown in which the passenger way is placed next to the car body for each half length and is connected by a transverse aisle. The three seats are thus made adjacent, giving six to each of the eight sections, or forty-

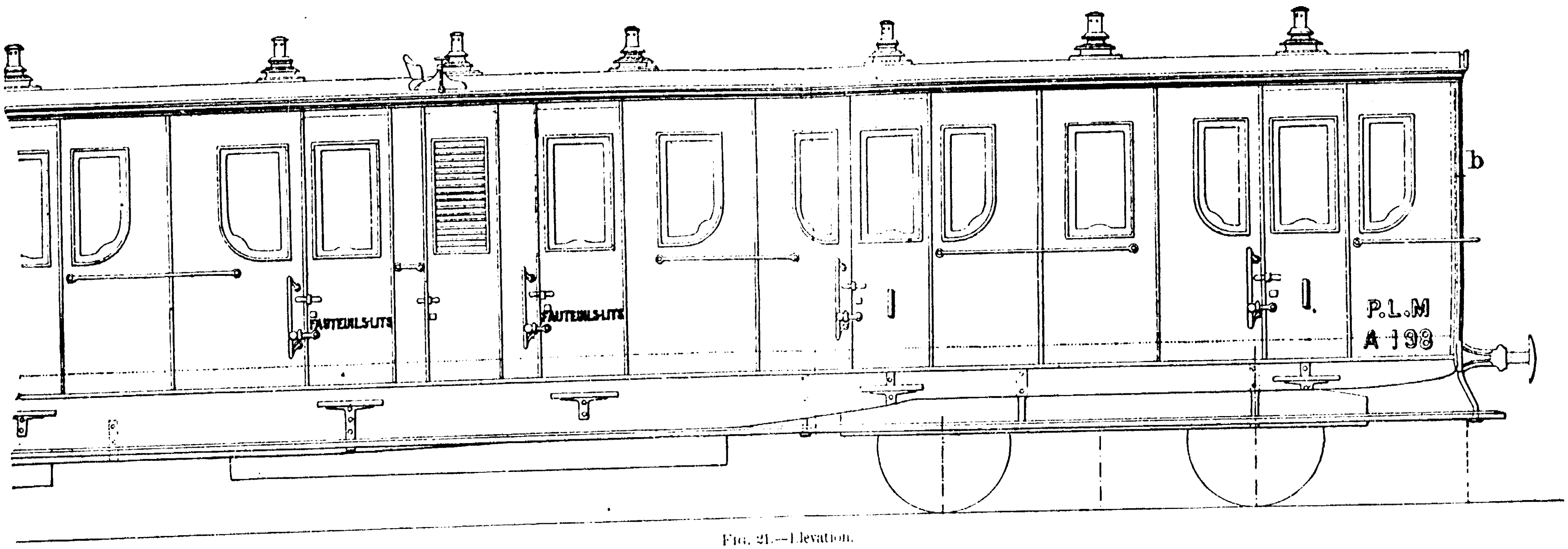


FIG. 21.—Elevation.

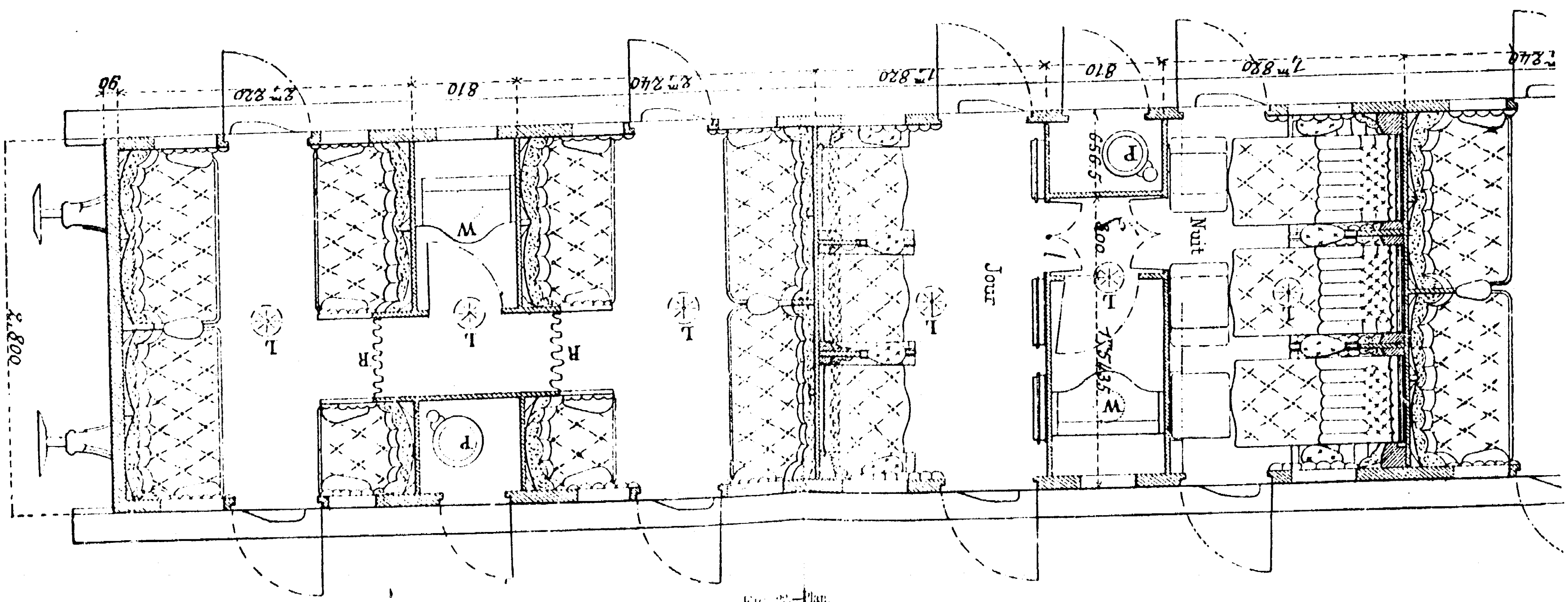


FIG. 22.—Plan.

Paris, Lyons and Mediterranean Railroad Company's car A. 198.

eight in all. Each compartment is closed by an inside door. The general appointments remain as in car No. A. 223, but the dimensions are a few inches longer. There are sixteen lamps in each car. The weight of No. 203 filled with passengers is 90,893 pounds.

The dead load, with fuel and water per passenger, is 1,738 pounds. Ratio of live to dead load, 1:11.2.

Still a third form is shown in Figs. 21 and 22, in which the through aisle is omitted, and the compartments are connected, two and two, by a short passage-way containing toilet rooms and stoves. One pair of the eight sections is fitted up with movable couches which can be lowered for the night and converted into beds, three in each compartment. The remaining six compartments will seat seven persons each, making the full number forty-eight. This car has, consequently, eight doors on each side and the continuous foot board for external passage of "guards."

The outside width of car body is 9 feet 2 inches, and the length, over all, is 74 feet. It is mounted, like the others, on two bogie trucks of four wheels each, spaced 49.3 feet apart.

A few of the more important data are given in the general table relating to cars.

A car devoted exclusively to sleeping saloons (Fig. 23) is also on exhibition. It contains but three compartments, with toilets and three beds in each, giving a total of only nine passengers. It is much shorter than the others, being only 31.3 feet long, and is supported on three axles, with a wheel base of 19.35 feet. Its frame is of iron **I**-beams and channel bars. The wheels are a little smaller, being only 3.05 feet diameter.

These cars are the most capacious, but at the same time the most expensive, both on account of the long wheel-base and great ratio of dead to live load.

Another typical coach for first-class day passengers, well finished, is mounted on an iron frame resting upon three axles. It is furnished with an automatic air-brake, which operates on the four end wheels; four lamps, electric call bell, small windows looking into neighboring compartments, and contains seats for thirty-two persons, with their hand luggage.

The seventh and last carriage embraced in this representative train is one for third-class passengers exclusively. There is no provision made for second-class, and the heavier baggage is carried in separate vans.

This car has a maximum capacity of fifty persons, and is the lightest and smallest of any. Its ratio of live to dead load is, therefore, brought very low, being but 1 to 3, and if the only object were economy at any cost, it would be a model; but were this car full in stormy weather, when the single window in each door must be closed, existence would soon become a burden, since it gives but 31.5 cubic feet of air per passenger. The remaining data of importance are given in the general table.

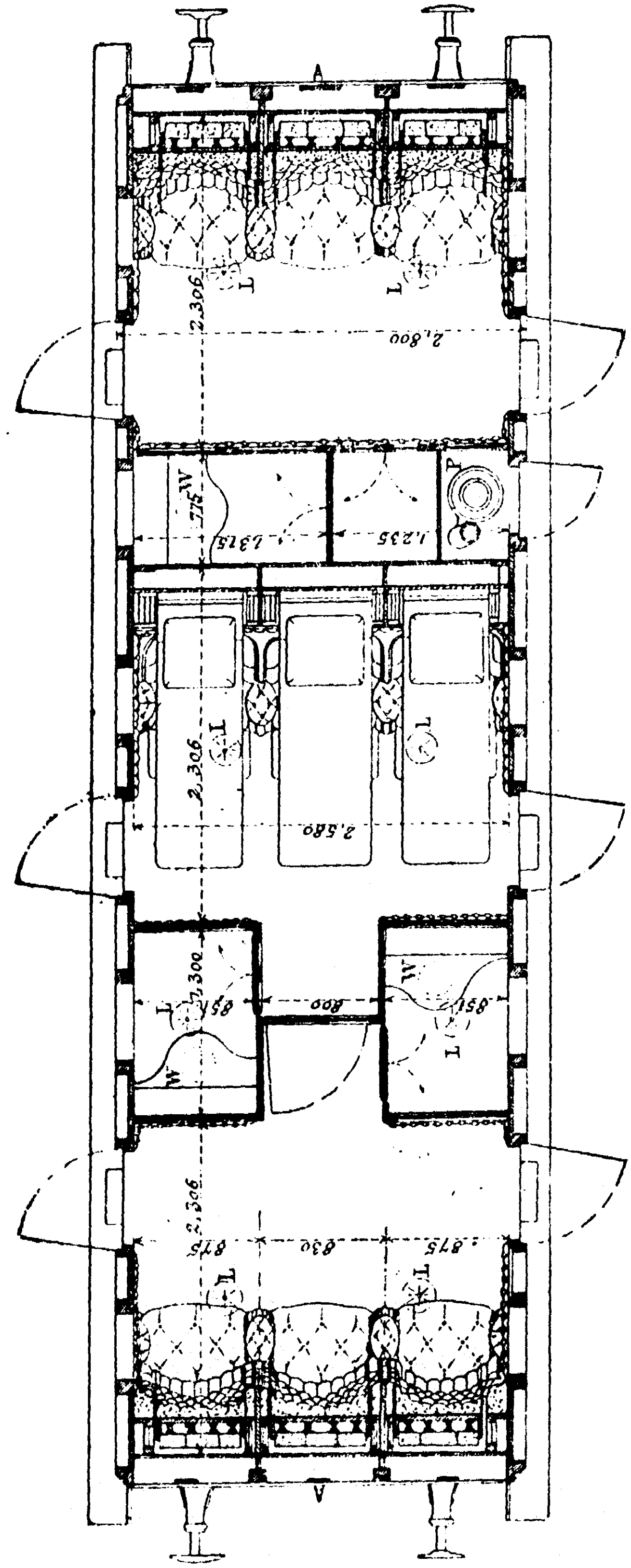


FIG. 23.—Saloon sleeper. Paris, Lyons and Mediterranean Company. No. 11.

The Paris, Lyons and Mediterranean Railway Company have also an extensive display illustrative of the material employed on the way and for construction. It includes pieces of boiler-plate riveted by hydraulic press, eccentrics, gas-lamps, air-brakes, valves, tubes, journal boxes, and tools of various kinds.

Of special machines there is one for making briquettes, one for regulating the speed of mining buckets or skips, a drop testing machine, another for testing axles and tires by flexure and by compression, an hydraulic dynamometer registering up 85 tons, a chronotrochometer and various others.

THE WOOLF ENGINE.

Amongst locomotives the Woolf engine exhibited by the Compagnie des Chemin de Fer du Nord is one of the most novel and interesting as representing the latest developments in motors in France. It is of the quadruple cylinder, double-expansion type, having the cylinders placed tandem, two on either side. It has four axles with coupled drivers each 4.27 feet in diameter. The general elevation of the engine is shown in Fig. 24 and the section of the right-hand cylinders in Fig. 25.*

The operation of steam admission and exhaust in this locomotive is as follows: When the train is being started high-pressure steam is admitted to the passage A, shown in Fig. 25, at the top of the steam-chest cover, whence it passes down through the main valve, as indicated by the arrow, and into the low-pressure cylinder. Therefore in starting all cylinders can be used with high-pressure steam if desired.

When operating with double expansion the steam is admitted into the steam chest at B, as shown by the exterior pipes on the side elevation; thence it passes through the port C into the passage D and into the high-pressure cylinder. When the steam has been expanded in the high-pressure cylinder it is exhausted, as shown by the arrow at E, through the passage F and through the large port into valve G, and also through the auxiliary port in the valve, as shown by the arrows, into the passage H, and thence into the low-pressure cylinder. After being expanded in the low-pressure cylinder it is exhausted, as shown by the arrow at I, in the usual manner through the exhaust nozzles. The exhaust pipes are independent of each other until near the top, where they discharge into one common nozzle. This is stated to be an improvement over a former construction, which consisted in making one common pipe answer the purposes of both exhausts.

It was necessary to use the double port valve in connection with

*These cuts, figures, and abstract are from the Railroad Gazette of March 8, 1889, which contains also an account of trials.

the large cylinder in order to admit the larger volume of low-pressure steam into the low-pressure cylinder without wire-drawing, it being found almost impossible to sufficiently increase the ports of the low-

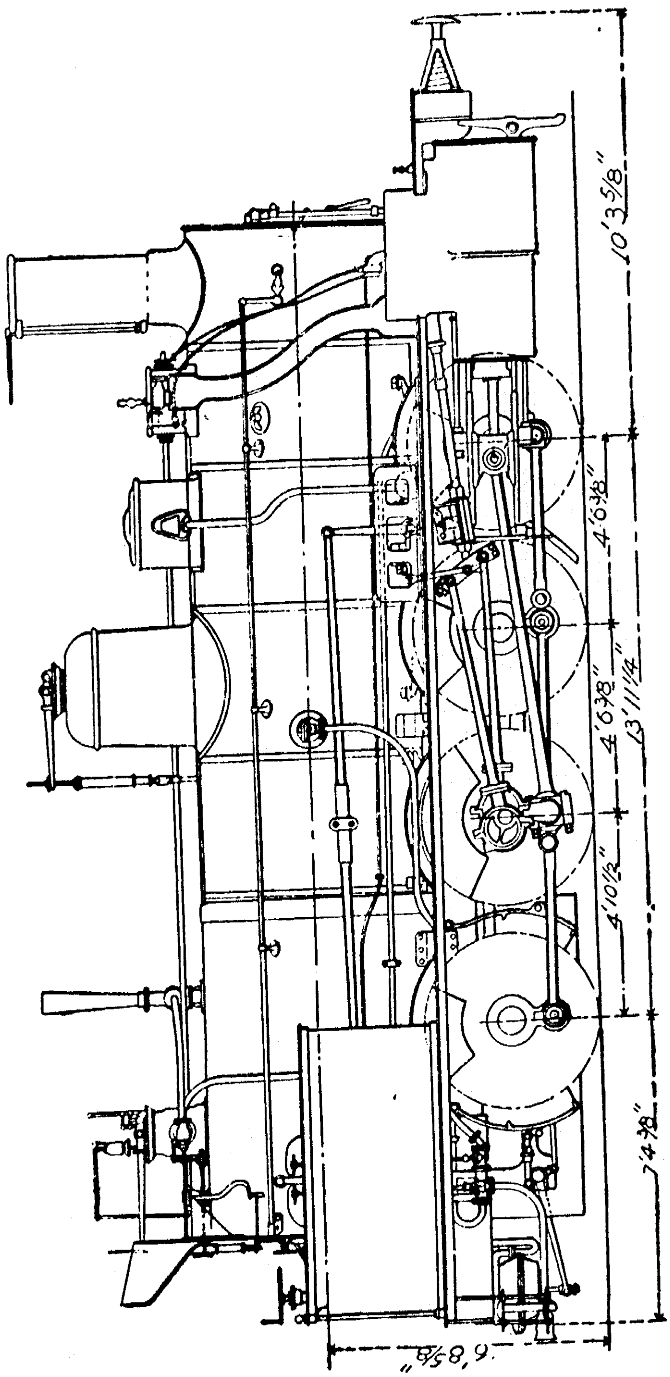


FIG. 34.—The Woolf engine, elevation.

pressure cylinder and thus omit the auxiliary port without increasing, beyond a reasonable limit, the ports of the high-pressure cylinder. It will be noticed that the ports as now made are remarkably large. In a design of valve intended to admit and govern steam admissions into both low and high pressure cylinders the ports must necessarily be large. This valve is made of gun-metal bronze and balanced by an annular packing ring, as shown in Fig. 25. Any leakage of high-pressure steam past the packing rings is admitted into the low-pressure cylinder. It is stated that this valve, in spite of its complication, has been running a long time with very little wear.

The details of the construction of the pistons are worthy of note, owing to their extreme lightness. The high-pressure piston is forged to the rod and made of steel. The low-pressure piston head, also of forged steel, is riveted and keyed to the rods; great attention has been paid to the reduction of the weight of the reciprocating parts to a minimum.

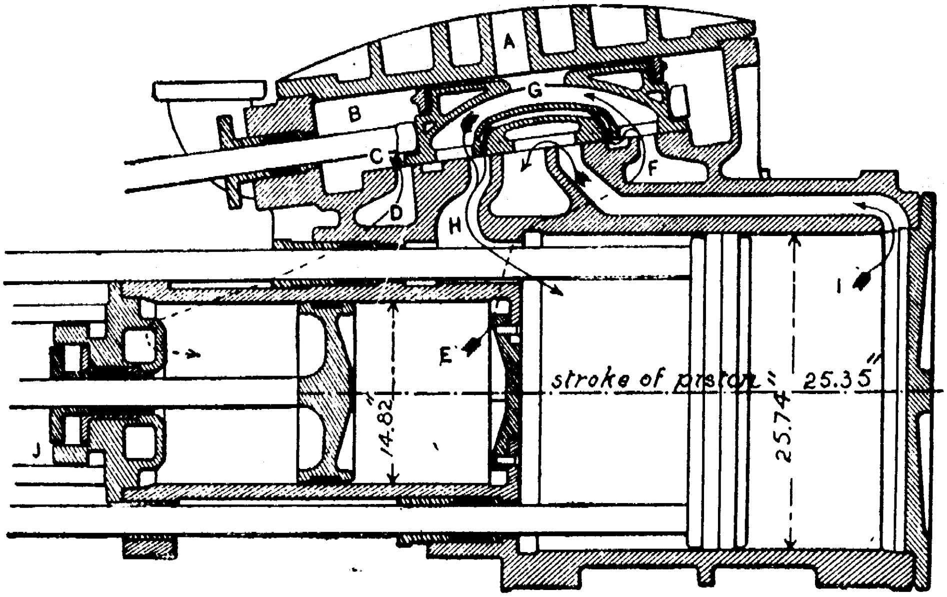


FIG. 25.—The Woolf engine, section of cylinders.

In order to prevent serious disaster to this expensive machinery in cases of the breaking of the connecting rod the length of the high-pressure piston rod has been arranged so that the cross head will strike the back cylinder head at J before the piston reaches the front end of the cylinder, and for the same reason the spaces between the high-pressure piston and the front cylinder head, when the piston is at the end of the stroke, is less than the distance between the low-pressure piston and the front cylinder head of the low-pressure cylinder when in the same position.

A very ingenious cylinder cock is used with this locomotive, which operates with steam pressure from the cab by opening the valve in the cab. The pressure of steam admitted to the pipe leading to the cylinder cocks opens the cylinder cock and drains the cylinder. The device is very simple and does away with an immense amount of rods and levers so commonly seen. These cylinder cocks are, in this design, bolted to the barrel of the cylinder.

This company have also displayed an express locomotive with bogie truck; a compound locomotive for mixed trains; various carriages for day, night, passenger, and freight service; cross-ties, rails, switches, semaphores, and signals; electrical apparatus for regulating switches, and many other elements incidental to the operation of an extensive railway system.

The Compagnie du Midi have two engines; one first-class sleeper; one first-class compartment carriage with communicating toilets; one second and one third class coach; one mail car; one platform car; also the usual elements of the roadbed, bridges, and station designs, making an excellent display.

The Paris and Orleans Company show a passenger express locomotive with tender; also an engine and tender designed for heavy grades; various forms of carriages, vans, and freight cars; turntables; signal tools, etc.

The express engine has some special features. Its boiler is of a peculiar form, being provided with two domes, one over the fire box and the other over the forward end of the cylinder. These domes are connected by a horizontal external pipe which passes through the sand box. The fire box crown is made up of U-shaped plates, the flanges of which form ribs. They were designed by M. Polonceau. Instead of the ordinary firebrick arch it has the Tenbrink water box which is in general use on this line. Beside the ordinary fire door there is a smaller one at a higher level. The injectors feed into a pair of clack boxes grouped under the boiler, and under them is placed a casting whence pipes lead to the mud collectors placed under the front and rear ends of the barrel.

The locomotives exhibited by the Chemins de Fer de l'État comprise two engines, Nos. 3510 and 2601, for "goods" and passenger service. The first is a compound engine of the Mallet system with outside cylinders and inside valve gear, and is operated by a boiler pressure of only 128 pounds per square inch.

The passenger engine (2601) has four axles, the wheels of the central pairs being coupled; of these, the leading pair is fitted with a steam sand jet to increase the adhesion.

The special feature of this engine is the valve gear which is known as the Bonnefond system. The motion of opening the steam valves is obtained from a cam carried upon a return crank on the driving axle, this gear being fitted with reversing link; the valves are closed by a trip gear which detaches the valve spindles from the opening gear.

As the trip gear is actuated from the cross, head it gives perfectly even cut-offs for both ends of the stroke, but it is not a commendable feature for locomotive engines.*

*Several of the above descriptions are abstracts from the full reports on the Paris Exhibition published in Engineering (London), 1889, to which the reader is referred for drawings and more minute details.

The Compagnie des Chemins de Fer du Nord operate about 2,225 miles of lines, covering nine departments and including a tributary population of about 5,000,000 people. Their exhibit includes the apparatus used in the services of operation, of material, and traction, and of the way.

Of the material used for traction there are fifty-one locomotives for express trains having two axles coupled and a forward bogie very similar to the American type, which have been doing excellent service since 1878. They are so satisfactory that a new but more powerful engine (No. 2101) has just been built and is on exhibition. The most important changes are an increase of the boiler pressure to 156.2 pounds per square inch, and an enlargement of fire box, boiler, and cylinders giving a maximum tractive effort 5,280 pounds greater than formerly.

The three-cylinder compound engine (No. 3101) has been in service since August, 1887. It has three coupled axles and one leading "pony" truck. Its peculiar features are the high boiler pressure, which is placed at 199 pounds, and the system of distribution of the high-pressure cylinder which is placed on the same line and between the two outside cylinders, which are low pressure.

In consequence of its high tractive power and great adhesion, this engine is equivalent to one with four coupled axles.

In 1878 a trial was made of small locomotives with capstans for handling trains in stations, which proved so satisfactory that since then thirty-four machines have been built for regular service and the use of horses superseded. The maneuvers are effected by means of a steel wire cable attached to the car and wound up on the capstan, and the expense is said to be but 15 to 20 per cent of that by horses.

The Crampton locomotive is extensively used by this company. Its characteristics are three axles, two of which have outside bearings, while the motor axle has inside journal bearings and wheels of a diameter of 6 feet 10 inches. The cylinders are placed on the flanks of the boiler and the center of gravity is very much lower than usual. Sixty of these engines have been delivered to the company by MM. J. F. Cail et Cie, Ancien Établissement, but only twenty-six are now in service.

There is also a compound four-cylinder engine, No. 701, built by the Société Alsacienne, having four wheels coupled, with a leading bogie truck. Two cylinders are inside and two out. It represents a class of which the company have one hundred and three machines.

The principal data are as follows:

Grate surface	square feet	24.42
Heating surface (total)	do	1,108.28
Boiler pressure	pounds	156.42
Maximum pressure on intermediate reservoir	do	81.76
Diameter of leading wheels	feet	4.26

Diameter of middle and rear wheels	feet	6.89
Diameter of high-pressure cylinder	inches	13
Diameter of low-pressure cylinder	do	18
Stroke of both pistons	feet	2
Weight of engine empty	tons	34.8
Weight of engine in service	do	37.8
Useful weight for adhesion	do	27.6

In 1885 the Compagnie du Nord introduced a special form of carriage with interior aisle, known as the tramway coach, for the purpose of relieving the suburban traffic of the regular trains. During the year 1888 there were running each day 332 tramway trains, properly so called, composed of a single carriage and serving nineteen geographical sections, representing a total length of 168 miles, and 177 light trains composed of from two to six carriages, serving twenty-one sections and representing a length of 257.8 miles.

The tram coach exhibited in the gallery of Machinery Hall is one of the new type designed for the light-train service. It is intended to fulfill the conditions of (1) the least weight per passenger carried; (2) ready ingress and egress and easy access for the conductor of the car; (3) to permit the conductor to circulate readily amongst the passengers to examine tickets, to announce the names of stations before reaching them, and for the passenger to prepare for exit, to approach the doors, and to descend rapidly; (4) to have a carriage of large capacity in which the number of places offered for each class corresponds sensibly to the number actually occupied, in about the proportions of 10 to 12 per cent of first class, 20 to 25 per cent of second class, and the rest of third class; (5) to give to each class a different access, so arranged that all passengers can enter or leave the car at any point of the line without assistance from the conductor; (6) to arrange the car so that when required it is possible to reserve a compartment for postal service or baggage; (7) to give to it, notwithstanding its large dimensions, a flexibility which will enable it to turn curves of 292 to 328 feet radius.

These requirements are met by the car designed by M. Bricogne and adopted by the Compagnie du Nord. It is mounted on six axles, which are composed of three articulated trucks. The car contains places for one hundred and two passengers, a baggage and postal compartment, and weighs when empty only 27 tons. The body is 78.7 feet long and is divided by a central passage, reached by three platforms, one at either end and one at the middle.

It is divided into three parts for travelers. At one end is a second-class compartment containing twenty places; following it, one for twelve places of the first class, and again one of the third class for seventy. The compartments are separated by glass doors. There are thirteen lanterns, ten inside and three on the platforms. The body and frame are also articulated. There are many other interesting exhibits by this company, but we can only note the sleeper for sixteen persons, weighing empty 27,676 pounds, (length but 32 feet over all); and the platform car No. 31,523, which presents some novel features. The latter is designed to carry long sheet-metal or commercial irons, and consists of a platform 49.2 feet, resting upon two trucks of four wheels each. The trucks are connected by a coupling bolster and move around the center pintles. They are built of U irons and rest upon four springs of 1 meter in length (3.28 feet.) The dead load when empty is 37,180 pounds, the live load 55,000 pounds, and the total load on rails 92,180, giving a load per wheel of 11,523 pounds. Ratio of dead to live load, 1 to 1.5.

The Compagnie des Chemin de Fer du Sud exhibited a locomotive and car. The engine is adapted to lines of light traffic in the south of France, in the departments of Var and on the Maritime Alps. It approaches a type already used in the United States for similar traffic. The distance between the coupled axles is only 4 feet 3 inches, and the total wheel base is but 16.1 feet. To give the locomotive sufficient steadiness on tangents without diminishing its flexibility on curves the Roy radial axle boxes of the leading wheel are fitted up with properly graduated abutment blocks.

The greatest speed is 24 miles an hour and the average 15 to 17. The cylinders are 14.8 inches in diameter, with a stroke of 22 inches, giving a theoretical tractive power $\left(\frac{Pd^2 L}{D}\right)$ of 14,828 pounds. Empty the weight is 56,100 pounds. Ready for service, with tools and personnel, it weighs 73,810 pounds, distributed as follows: On leader, 16,060; on motor axle, 21,780; on coupled axle, 21,010, and on trailing axle, 14,960. Although the weight on the drivers appears small, it is claimed that in this latitude and climate, instead of the usual limit of one-seventh for adhesion, the results obtained here are about one-fourth, giving in consequence greater tractive power.

The engine is furnished with a steam sand ejector and draws without difficulty its usual load of 75 tons over every part of the system. The train consists of a light van, mixed carriage, and four loaded wagons capable of carrying 10 tons each.

These machines are constructed by the Société Alsacienne de Constructions Méchanique, at Belfort.

The carriage on exhibition is fitted with first and second class compartments, supported on two bogie trucks. It contains in all forty-six places, fifteen of the first and thirty-one of the second class. The length of the frame is 37 feet. A platform is placed at either end for the seperate use of each compartment. The body is supported upon two four-wheeled trucks placed 19.68 feet apart from center to center of pintles. The total weight is 20,724 pounds, giving 450 pounds of dead load per place. The weight when loaded is computed at 27,720. The average weight of a passenger is therefore 152 pounds.

The same type of carriage applied only to second-class passengers contains seats for fifty-six persons, giving a dead load of 352 pounds per passenger, which is thought by the management to be a result not attained by any other class of material. The carriage was built in the shops of the Société de la Buire, at Lyons.

Other pieces of rolling stock comprise a dumping-wagon and a platform car.

These wagons are built on a metal frame, designed to turn sharp curves. They have given entire satisfaction. The floor spaces are 14.76 by 6.56 feet, The tare of the first wagon is 8,932 pounds; that of the second is 8,074 pounds. The ratio of dead to live loads is as 1 to 2.46 and 2.72, respectively.

The Société Anonyme Internationale have on exhibition one first and one third class carriage built for the State Railroad of Belgium, and one second-class carriage for the National Society of Railroads.

The first two are designed to carry forty and eighty passengers, respectively, and are 38 and 40 feet long. Each car is mounted on three axles, the middle one of which has a lateral play to permit free movement on curves. The wheel base is 11.5 feet from center to end axles. They are furnished with Westinghouse brakes and are designed to fulfill all the requirements of a convenient and safe car. The remaining car is for a narrow gauge of 1 meter (3.28 feet) and is designed to carry twenty-four passengers. The interior is finished in teak and pitch pine, with veneers, while the body is in teak and oak.

The Compagnie Internationale des Wagons Lits exhibits a highly finished vestibule train modeled largely after the American parlor cars. It consists of four coaches with end platforms and vestibules, having a total length of 220 feet. The types shown in this train are: (1) A dining car, 56.17 feet long, for thirty-six persons; (2) a chair-saloon car, 60.11 feet long, for twenty-six persons; (3) a sleeping-car, 57 feet long, for eighteen persons, and last, a smoker and baggage van, 46.7 feet long, for ten persons; making a total capacity of ninety passengers, or 2.44 linear feet per capitum.

These cars are finished in the highest style of art, beautifully carved, and handsomely upholstered with elaborate decorations. They are designed not only to remove the discomforts of traveling, but to make it a luxury. The dining car contains a kitchen, with all accessories, an office, a large and a small saloon: the first for twenty-four persons, who may smoke; the second for twelve who do not; also water closets and toilets, accessible from the platform.

The chair coach is divided into two saloons, the one containing eight places, with four arm-chairs fixed in the corners, and the other of eighteen places, with fourteen revolving and four fixed chairs. A closet at the end is provided for small baggage or "luggage," and two cabinets with lavatories for ladies and gentlemen, placed at one end, complete the appointments.

The sleeper is divided up into seven compartments, with a passageway along one side of the car, and is provided with a toilet and water closet at either end. The beds are placed traversely, some of the sections containing only two, others four.

All the carriages have fixed and movable windows; those of the restaurant open at the top, those of the saloon at the bottom, while those of the sleeper alternate top and bottom.

These coaches are remarkable for their steadiness and the ease with which they run over curves even at a speed of from 50 to 62 miles an hour. They are supported on bogie trucks placed at about 26 to 40 feet apart. The cars are lit by electricity fed by accumulators.

The Société Générale des Chemins de Fer Économiques presents a large display embracing designs for various railway lines of general and local interest, stations, installations, and plant. Of the latter there are one locomotive, three passenger and one freight car.

The locomotive is mounted on three-coupled axles and an independent trailing axle furnished with Roy's radial boxes. In consequence of its short, rigid wheel base (7.34 feet) it is able to turn easily curves having a radius of only 328 feet. Its tractive force is about 400 tons, and on a straight line the speed is 21.7 miles per hour (35 kilometers) on a grade of 2½ per cent. It is able to draw a train of 70 tons at a speed of 12.4 miles per hour. The cylinders are 13.6 by 18 inches, boiler is 3.28 feet diameter, pressure 142 pounds, surface of grate 10.76 feet, total heating surface 640.2 feet, and the total weight in service, with fuel and water, 28 tons. The guage is 1 meter (3.28 feet).

The train of cars consists of one third-class carriage, one for first and second class, and one for all three classes, with a compartment for baggage, and arranged for the free circulation of the train master when in motion. The bodies rest on bogie trucks with center pintles. The drawbars and buffers are placed centrally one over the other. These cars are about 31 feet long and weigh 22,120 pounds, or 400 pounds per person. The third class accomodates fifty-six passengers.

The Compagnie Bône-Guelma (Algérie-Tunisie) exhibit some rolling stock, cross-ties in wood and iron, a general chart of their lines, photographs, technical reports, and an album of general statistics.

The rolling stock embraces a mixed carriage mounted on bogies, with internal Z passage ways; for standard gauge. The body, having a length of 37.7 feet, rests on a frame 42 feet long over all. The outside width is 10.17 feet. It contains one first-class compartment with six seats, one half compartment (coupé) for three, four second class with ten seats each, and one cabinet and toilet, giving a capacity of forty-nine persons.

Communication is obtained by means of two galleries extending half the length of the carriage but on opposite sides, connected by a transverse passage in the middle. At each end is an inclosed platform which permits of passing from one car to the next. It weighs, with brakes ready for service, 31,154 pounds, giving a dead load of 635 pounds per passenger. This form of carriage has been in use for three years, and is highly appreciated by the traveling public.

The lateral gallery permits passengers to circulate freely from end to end of the train, while it at the same time preserves the isolation and privacy of the compartment and admits of a complete and ready inspection of the train by the company's employés. It was introduced for the first time in France by M. H. Desgrange in 1872, on the line from Treport to Gamaches, and since, in 1876, on the line to Royan. In these cases the passage was on one side only. By the present arrangement the load is more evenly distributed.

The material for narrow-guage (1 meter) road exhibited by this same company consists of a tank locomotive with three coupled drivers, of which the following are the dimensions:

Length of grate	feet..	4.92
Breadth of grate	do...	2.00
Area	square feet..	9.84
Height of roof of fire box	do...	3.48
Heating surface, fire box	do...	64.64
Heating surface of tubes	do...	643.56
Total	do...	718.20
Mean diameter of boiler	feet..	3.34
Effective boiler pressure	pounds per sq. in..	128
Diameter of cylinder	feet..	1.45
Stroke of cylinder	do...	1.7
Diameter of wheels	do...	3.6
Wheel base	do...	8.85
Weight, empty	pounds..	55,000
Weight of water	do...	7,920
Weight of fuel	do...	1,760
Weight, total	do...	64,680

This company has sixty-seven locomotives of different types.

There is also shown a baggage van 20.33 feet long by 8.2 wide, containing a mail compartment, water-closet for passengers, and a mixed bogie carriage 36.4 feet long and capable of seating twenty-four first-class and eight second-class passengers. It contains a saloon with chairs for twelve and has a central passage for the free circulation of travelers. Its weight when empty is 17,820 pounds, giving a dead load of 594 pounds per passenger.

SPECIAL MOTORS.

Amongst the special forms of motors found in the French department may be mentioned the engine of Messrs. Francq & Lamm. (See Fig. 26.)

The Continental Company for operating locomotives without fire, and of which M. Leon E. Francq is the director, exhibit one of their locomotives. It differs from the ordinary type in having no fire box, but in place thereof a simple cylindrical reservoir surmounted by a dome subjected to a pressure of 213 pounds per square inch and filled to three-quarters of its capacity with water. It is in this body of water, reheated by means of the steam furnished from a stationary generator under a pressure of 227.6 pounds, that the energy is stored for operating the machine.

The charge of heat to the magazine is complete when there is an equilibrium of pressure between the generator and the reservoir. Thus charged the machine can furnish an amount of power for traction which depends upon the quantity of water heated to 392° F. This

FIG. 26.—Fireless locomotive.

water supplies the steam for the cylinders at a pressure varying from 28 to 71 pounds per square inch, according to circumstances, by means of a particular form of pressure regulator.

These machines of Francq & Lamm have been in successful operation for eight years in the Indies, Netherlands, France, England, Austria, and the United States.

They operate with great regularity and to great advantage. It is claimed that they have saved $1,400 a month in the operation of the tramways between Lille and Roubaix, France, 6.6 miles. Their cost is about one-half that of the locomotives with fire boxes, which they have supplanted, and they possess numerous advantages over the smoke and steam generating machines, which have gained for the inventor the cross of the legion of honor. The address of the company is No. 15 avenue Kleber, Paris.

Another of these hot-water engines is exhibited by the *Compagnie des Omnibus et Tramways de Lyons*. It is a neatly finished motor weighing 16 tons, and is attached to a carriage of 4.2 tons, having a seating capacity of forty-eight passengers. The engine is capable of hauling four such cars up a grade of 3 per cent. The second-class cars carry fifty persons, and the total load of engine and four cars is computed at 46 tons, or 187½ pounds per passenger.

The following statistics of the tramway between Batavia and Meester-Cornelis will give an idea of the conditions under which this motor can be successfully operated:

The total length is 41,377 feet, or nearly 8 miles, and the difference of level between the termini is 50 feet, with undulating grades. There are curves having a minimum radius of only 82 feet, while the maximum gradient is about 3 per cent. The gauge is 3 feet 10½ inches. The mean load drawn is about 25 tons at a speed of 9 miles per hour for 15 hours of each day and the number of machines in service on this line is twenty-three. The total number in use is stated to be one hundred and thirty-three. The cylinders have a diameter of 9 inches and a stroke of 12 inches. The diameter of the wheels is 2 feet 7½ inches. The capacity of the reservoir is 2,000 quarts of water and 550 of steam, and the weight is about 10 tons. There are four generators in each station, but only three are in constant use, the other being in reserve.

This company also exhibit photographs illustrating the application of the motors to canal towage, to driving machinery, and to other purposes.

An exhibit which can not fail to attract attention is that consisting of an engine with tender and one car, evidently designed as a special solution of the high-speed problem.

All the wheels are of the same magnificent proportions, namely, 8 feet in diameter and have a wheel base of 18 feet. The engine has three axles, the tender and car two each.

The latter is about 42 feet long and consists of a pair of heavy, longitudinal, arched beams supporting a double-decked body which is divided into compartments. The lower ones are suspended before, between, and behind the axles and contain seats for ten persons in each. In the second story there is room for forty, in all making a total of seventy passengers. This uncouth model has been finished several years, but its utility would appear to be very doubtful on account of its size, weight, and inconvenience.

As to velocity, it is reported to have run at the rate of 66½ miles per hour, which is no more than has been reached by existing forms of plant.

Among the various interesting exhibits made by the *Société des Anciens Établissements Cail* we can only notice specially the small tank locomotive illustrating the De Bange system. It has four axles with coupled wheels, but they run loose and the axles can radiate on curves. The cylinders, which are inside, drive a crank shaft resting in bearings attached to the engine frame above the level of the wheels. The ends of this shaft are coupled to cranks at the ends of two auxiliary shafts placed between the two leading and the two trailing axles, respectively, these latter shafts also resting in bearings on the frame.

The wheels are driven by connecting them with the triangular coupling joining the crank shafts, by ball and socket joints, so that the engine can turn curves of very short radius, the one on which it stands being only 32.8 feet. The mechanism is ingenious but complicated.*

The remaining exhibits include one Crampton locomotive made in 1849 for the Northern Railway Company, which has made 720,000 miles to date: one Bange truck, one tank engine with six drivers, system Achiét á Bapaume, and one 4-ton tank engine for farm purposes; also locomotives without fire boxes (Francq system) and various designs, photographs, etc.

These constitute but a small part of the magnificent display of rolling stock shown by the numerous French exhibitors in this class, but in this condensed account it has not been possible to refer specifically to all. Additional notice will be made of some of them under their appropriate headings. We now pass to a consideration of the exhibits of foreign countries, beginning with Belgium.

THE BELGIAN RAILWAY PLANT.

Next to France Belgium makes the most extensive display of railroad plant. There are twelve engines, embracing a variety of types, and designed for heavy work, with slack coal for fuel; hence special attention has been given to the enlargement of the grate areas and to securing greater boiler capacity.

The compensating levers work on knife edges, which is a common practice in this country; and in the later patterns the stacks are being made square in horizontal section, as tending to simplicity.

The radial axle boxes, Walschaert valve gear, central frames, coupling rods, with solid bushed ends, Belpaire fire box and springs, and Westinghouse brakes constitute the predominating features of the Belgian models, which are more particularly described in the following account of a few of the exhibits:

THE GRAND CENTRAL RAILWAY.

The imposing display made by this company is well worth a careful inspection, not only on account of the general excellence of the workmanship but also because it represents an advanced stage of railway construction, especially in rolling stock.

* Engineering, August 2, 1889.

1. They show an eight-wheel coupled tank locomotive (No. 170) for steep grades, the diagram of which is appended with the principal dimensions. It has the Walschaert valve gear with open link.

Similar engines have been in use since 1865, but the one on exhibition contains all the latest improvements. (See Fig. 27).

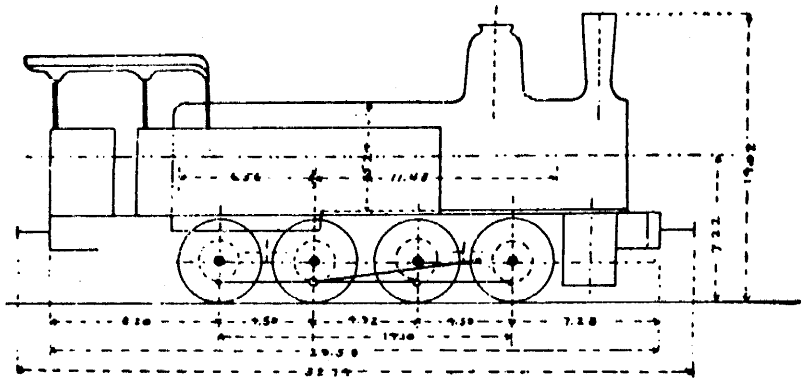


FIG. 27.—Tank locomotive. Belgian Grand Central Railway.

The principal dimensions are—

Mean interior diameter of boiler	feet			4.92
Area of grate	square feet			24.86
Tubes	number			270
Length	feet			11.48
Exterior diameter	inches			2
Heating surface:				
Fire box	square feet	94.6		
Boiler tubes	do	1,510.70		
Total	do			1,605.10
Working pressure	p.	pounds per sq. in.		147
Diameter of cylinder	d	inches		18.84
Length of stroke of piston	l	do		22.6
Diameter of wheels	D	feet		4
Contents of coal bin	cubic feet			88.2
Contents of water tank	do			158.8
Weight, empty	pounds			90,200
Weight, in service:				
Leading and second axle	pounds	52,800		
Third and trailing axle	do	62,480		
				115,280
Tractive force:				
Theoretical	pounds			23,846
Actual, 55 per cent	do			13,112

A mixed carriage for first and second class passengers (Fig. 28).—This carriage is designed to secure greater capacity and comfort, yet still keeping within the limits of clearance of the permanent way. The body constructed of fat pine contains 1,301.5 cubic feet, and is divided into two compartments of the first class, with seats for eight persons, and two of the second, with seats for ten; total thirty-six passengers.

The net weight of the carriage is about 23,320 pounds. The heat apparatus weighs 990 and the brake 1,650 pounds.

Dead weight in service	pounds	25,960
Dimension of axle journals	inches	8.2
Wheel base	feet	14.43
Length of sill	do	25.58
Length of body	do	25.90
Width of body	do	7.67
Length of springs	do	6.88
Length from out to out of buffers	do	29.12
Area of floor space	square feet	196.2
Units of floor space per passenger	feet	5.45
Units of volume per passsenger	cubic feet	37.25
Units of length of car per passenger	feet	0.81
Units of weight of car per passenger	pounds	721
Weight of passenger (average)	do	154
Ratio of dead to live load		4.71

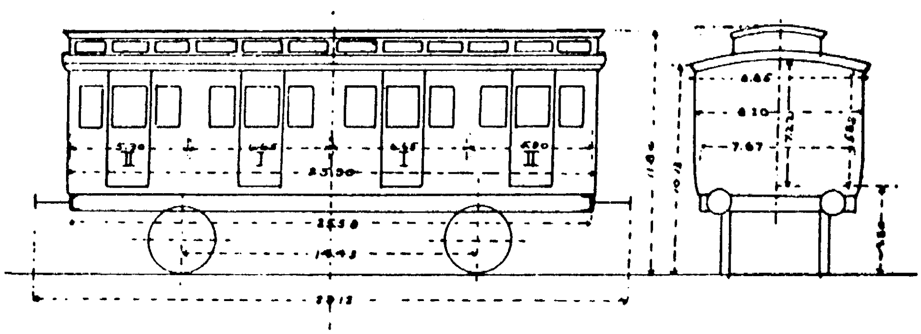


FIG. 28.—Mixed passenger car. Belgian Grand Central Railway.

The supporting links of the springs are inclined towards the "interior" (Feraud's system*). The springs are fixed to the boxes. The car is lit by the Schallis and Thomas lamps burning petroleum.

The heating is by the Belleroche † system; the brakes are of the automatic vacuum system.

The heaters are let into the floor under the feet of the passengers and are kept warm by a current of hot water, which is easily regulated both as to quantity and temperature. The water starts from the engine or from a heater van, and returns to this point after having circulated through the train on both sides. It has been in practical use for sixteen years.

The couplings are of the Deitz system.

3. *A 20-ton gondola with movable sides* (Fig. 29).—For freight purposes, a well-built gondola is shown, having an iron frame 33.13 feet in length, supported upon two bogie trucks.

This style has been in use by this company since 1869.

Out of 7,024 goods wagons 180 are of this kind.

* See special exhibits, page 528.

† *Vide* Revue Universelle des Mines, January, 1884.

The general dimensions are:

Extreme length between buffers	feet	36.4
Extreme length of frame	do	33.13
Extreme width of frame	do	8.53
Distance between pintles of trucks	do	21
Wheel base of trucks	do	4.26
Live load	pounds	44,000
Dead load (tare)	do	26,950
Capacity	cubic feet	380
Ratio of dead to live load		1:1.62

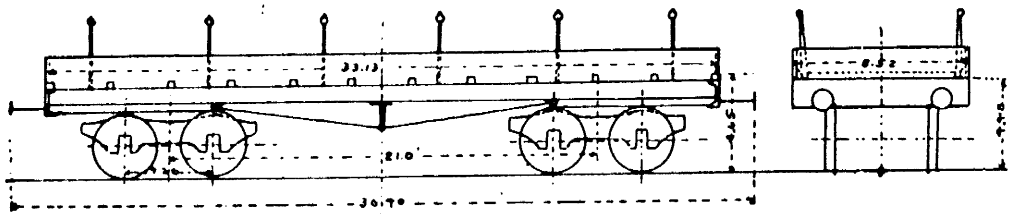


Fig. 29.—Twenty-ton gondola. Belgian Grand Central Railway.

Special machines are on exhibition for cutting and trimming crank pins.

THE BELGIAN STATE RAILWAYS.

An engine of attractive design and excellent finish is that numbered 192,* built by the Société Cockerill, of Seraing. Its most novel feature is the rectangular form of its stack, which is spread out at its base to make a simple and firm joint with the barrel. There are four axles: the two central ones holding the drivers are 6 feet $10\frac{1}{2}$ inches and the others 3 feet $11\frac{1}{6}$ inches in diameter. These engines pass freely around curves of 984 feet radius and draw trains of 150 tons net, or 230 gross, up gradients of one-half per cent at a speed of 59 miles per hour, and keep up steam on such a grade $7\frac{1}{2}$ miles long. They make a run of 5 hours with one stop of 4 minutes, and three others of 2 minutes each. The general data will be found in the table at the end of this report.

Another engine (Fig. 30) was constructed by MM. Carels Frères, of Gand, from plans of M. Leon Bika, engineer-in-chief of the Belgian state railroads.† It is adapted to heavy grades, and hence is made heavier and stronger than its predecessors, from which it differs but slightly in other particulars. In addition to the two outside frames it has also a strong central frame, composed of two plates separated by distance pieces and carrying a central bearing for the crank axle, so as to relieve the latter from the bending strains due to the thrust of the pistons.

In this engine the ordinary reversing lever is replaced by the Stirling apparatus, consisting of two horizontal cylinders, the pistons of which are mounted on the same spindle. One of these cylinders

* Abstract from Engineering of August 9, 1889.

† Abstract from Engineering, July 5.

is filled with oil or glycerin and connected by a pipe which allows the fluid to circulate from one end to the other. In the middle of

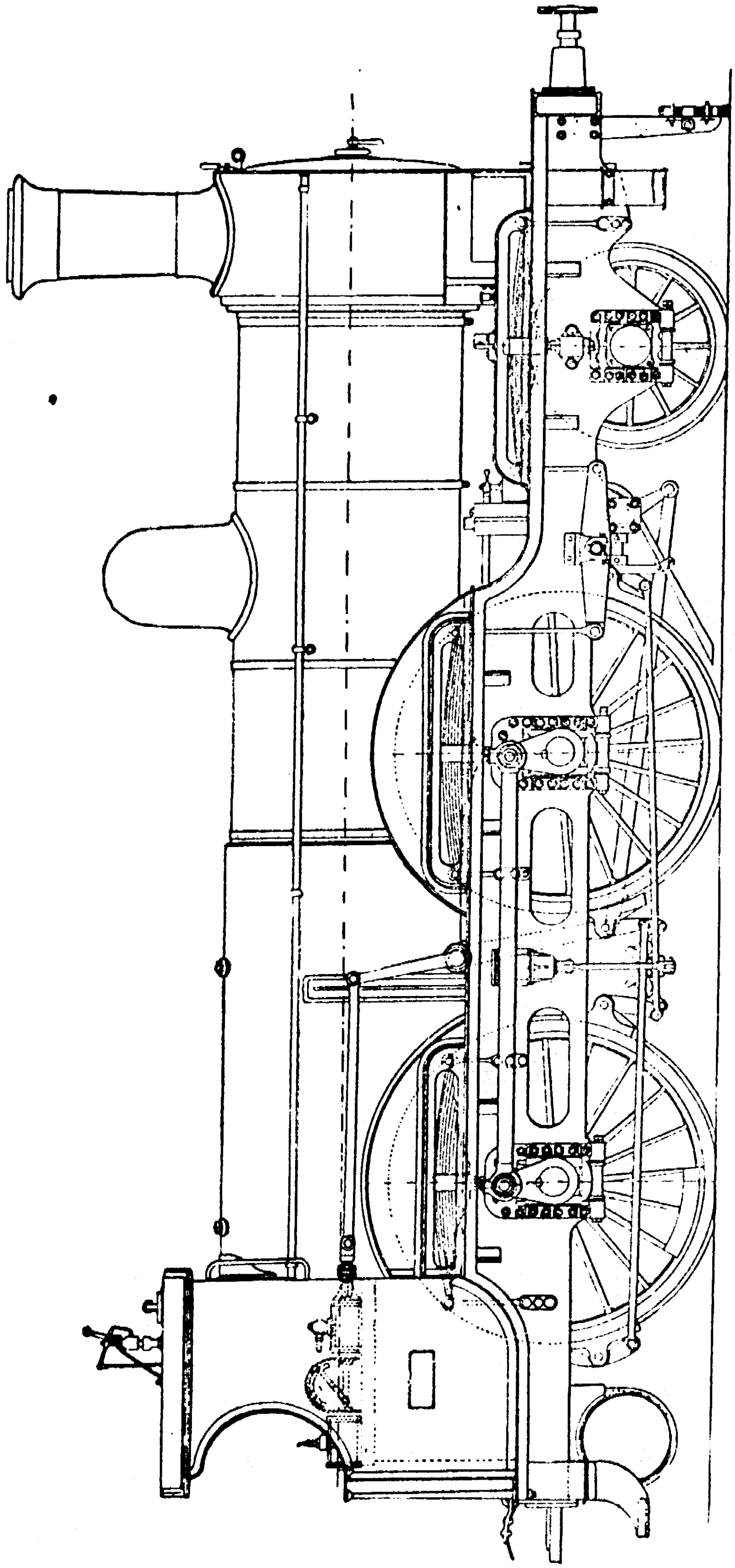


FIG. 30.—Belgian state railways. Locomotive for heavy grades.

the pipe there is a valve which cuts off communication between the piston heads and keeps the piston fixed in any position. The piston in the other cylinder receives the pressure of steam from the boiler and can be moved to and fro by means of a controlling valve. The reversing lever is connected to the rod carrying the two pistons.

The axle boxes of the leading wheels are fitted so they have a lateral play in their guides when passing around curves; the pressure on the leading springs is transmitted to the axle boxes through inclined planes, which bring the boxes back to their normal position as soon as the engine passes on to a tangent.

The springs, of the inverted Belpaire, type are connected by compensating levers. For dimensions see the general table of rolling stock.

Another locomotive deserving mention is that made for this company by the Société Anonyme des Forges et Fonderies de Haine St. Pièrre.

It has been employed for working mail trains of 110 tons net at a speed of 37½ miles per hour over grades of 1.6 per cent. At several points these gradients extend for 9.3 and 19.9 miles, requiring heavy work.

There are three pairs of coupled drivers, 5 feet 6.9 inches in diameter, and one pair of leading wheels of 3 feet 5.7 inches in diameter. Inside cylinders, 19.69 inches diameter by 23.62 inches stroke, are placed under the boiler in rear of the leading axle. The grate area is unusually large, being 62¾ square feet, while the total heating surface is 1,588 square feet, of which 151.8 are in the fire box. The boiler pressure is 142 pounds per square inch, and the engine weighs 48 long tons empty, or 52 tons in service. The load on drivers is 42 tons.

There are also several small tank engines and locomotives for tramways and narrow-gauge railways which go to complete the excellent display of this enterprising nation, but which we are compelled to omit.

The tank locomotive "Le Cinquantenaire," made by *La Société Anonyme, "La Metallugique,"* of Brussels, resembles so closely in its weight and running gear the latest American heavy freight engine of the consolidation type* as to merit a brief notice.

It was designed from an engine running on the inclined plane at Liége, by M. Belpaire, and intended to operate on steep gradients of 1 to 40 or 2½ per cent. The weight in service is 166,000 pounds (75,000 kilogrammes). That available for adhesion is 132,000 pounds, distributed over four pairs of driving wheels coupled together. There is moreover a trailing axle furnished with radial boxes, permitting the engine to turn curves of 492 feet radius.

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*See No. 10 of the Baldwin exhibit.

The stack is rectangular and forms the prolongation of a large smoke box-giving ample draft. The tanks are placed like panniers on either side of the boiler, and the coal box surrounds a capacious cab. This is claimed to be one of the best examples ever produced of an engine designed for heavy work. In the four trial trips made on the Liége plane this engine drew the load ordinarily requiring two eight-wheeled freight locomotives up the grade of 3 to 100. In all the trials the pressure, thanks to the large heating surface, was never below ten atmospheres. This machine represents the most recent improvements in the art of engine-building.

The brochure of this company describes many of its structures, workshops, and various types of rolling-stock built at Tubize, Nivelles, and La Sambre, which are necessarily omitted.

La Société Anonyme des Ateliers de Construction de la Meuse, of Liége, Belgium, present—

First. A stationary engine for operating an electric-light plant in the workshops of the Belgian State Railway Company.

Second. A novel type of locomotive for the State Railway, for drawing light trains.

Its dimensions are as follows:

Weight in service	pounds..	66,400
Weight empty	do ...	54,340
Gauge of track	feet..	4.9
Diameter and stroke of cylinders	inches..	13.8–19.2
Diameter of coupled wheels	feet..	3.9
Total wheel base	do...	13.12
Heating surface of fire box	square feet..	68.2
Heating surface of tubes (interior)	do....	494.0
Surface of grate	do....	21.4
Number of tubes		147
Length of tubes	feet..	8.2
Volume of water tanks	cubic feet..	144
Volume of coal bunker	do....	71

The engine exhibited is taken, without special selection, from the usual run of the stock, and is representative of the workmanship of this company, which is of a superior grade.

There are shown also photographs of boats, hydraulic cranes, locomotives for portable railways, tramways, industrial ways, and other devices for railroads and mechanical operations.

Madame Aurelie Verhaeghen, proprietress of the Usine Ragheno, at Malines, Belgium, exhibits—

First. A mixed carriage of great capacity, divided into two compartments and a coupé of the first class (twenty places) and three compartments of the second class (thirty places). It is supported on three axles and furnished with a Westinghouse brake.

Second. A first-class carriage with two compartments, for suburban traffic.

These works are the oldest and most important in Belgium, and thoroughly equipped for the construction of all kinds of conveyances for railway service. They employ about 350 workmen and produce annually about 1,800,000 francs ($360,000) worth of product.

The following are the general dimensions of these cars:

	Mixed carriage.	Suburban carriage.
Total length from out to out.....feet..	39.75	23.8
Distance between axles.....do...	10.48	5.9
Breadth outside.....do...	8.51	7.54
Height.....do...	7.21	7.20
Length of body, outside.....do...	36.90	15.74
Weight, empty.....pounds..	33,400	9,460.01
Price.....	$3,400	$900

ENGLISH ROLLING STOCK.

The London, Brighton and South Coast Railway Company exhibit one of their express engines of the "Gladstone" type. It is peculiar in having large coupled leading wheels. There are three axles, the two forward ones, wheels 6 feet 6 inches diameter, being used for drivers; the rear ones, wheels 4 feet 6 inches, for the trailing wheels.

Compressed air is used for the reversing lever and locking gear, as designed by Mr. James Stirling. It is taken from the Westinghouse brake reservoir.

The tender is six-wheeled, with inside bearings. The following dimensions and weights will serve to give a better idea of the locomotive and its capacity:

Particulars and dimensions of B class engine and tender.

	Feet.	Inches.
Diameter of cylinder.....	1	6¼
Stroke.....	2	2
Lap of valve.....		0⅞
Lead in full gear.....		0 3/32
Distance of cylinders apart.....	2	1
Diameter of driving and leading wheels.....	6	6
Diameter of trailing wheels.....	4	6
Driving center to leading center.....	7	7
Driving center to trailing center.....	8	0
Total wheel base.....	15	7
Total wheel base of engine and tender.....	38	9½
Length of engine and tender over buffers.....	51	10
Length of boiler barrel.....	10	2
Mean diameter, outside.....	4	5
Firebox, outside length.....	6	8¼
Working pressure.....pounds..		150
Number of tubes.....		333
Outside diameter of tubes.....inches..		1½

Heating surface of tubes . . . square feet . .		1,386
Heating surface of firebox . . . do . . .		114
Total heating surface . . . do . . .		1,500
Grate area . . . do . . .		21
Average temperature of feed water . . . degrees . .		145
Quantity of water evaporated per pound of coal . . . pounds . .		12
	Tons.	Cwt.
Weight on leading wheels . . .	13	16
Weight on driving wheels . . .	14	10
Weight of engine . . .	38	14
Total weight of engine and tender . . .	66	
Capacity of tender . . . gallons . .		2,250
Maximum number of vehicles to train . . .		26
Maximum weight of train and engine . . . tons . .		378
Booked speed . . . miles per hour . .		46½
Average coal consumption of eighteen of these engines, pounds per mile . . .		28
Longest run without stop . . . miles . .		80

Constructed in the Brighton Works.

The locomotive and tender representing the *South Eastern Railway Company* is a fine specimen of workmanship. Its main feature is the pneumatic reversing gear as designed by Mr. James Stirling. It is mounted on a bogie truck, with two outside coupled drivers. The bearings and cylinders are inside and the forward driver has a crank axle. The tender is carried by three axles with wheels of 4 feet diameter, spaced 6 feet apart.

The following data are furnished by the company:

	Feet.	Inches.
Boiler:		
Firebox casing, length outside . . .	5	9
Width outside at bottom . . .	4	0
Height from rail to center . . .	7	5
Volume of water at 4 inches above crown of fire box . . cubic feet . .		54.32
Steam pipe perforated on top with 260 holes one-half inch diameter.		
Copper firebox:		
Length inside box (parallel) . . .	5	0⅝
Width at top . . .	3	6½
Width at bottom . . .	3	3¾
Height from top of firebox to crown at tube plate . . .	5	6½
Height from top of firebox to crown at back . . .	5	0½
Area of fire grate . . . square feet . .		16.78
Heating surface of firebox . . . do . . .		103.5
Tubes:		
Length between tube plates . . .	10	0$\frac{1}{16}$
Thickness (wire gauge) . . .		11 to 13
Outside diameter . . .		1⅝
Number . . .		202
Total heating surface . . . square feet . .		1,020.5
Cylinders:		
Diameter . . .	1	7
Stroke . . .	2	2
Center to center . . .	2	4½

	Feet	Inches.
Cylinders—Continued.		
Length of steam ports	1	4
Width of steam ports		1½
Width of exhaust ports		3½
Slide valves, phosphor-bronze:		
Travel, full gear		4 5/16
Lead, full gear		3/16
Outside lap		1
Wheels:		
Diameter of coupled wheels with tires 3 inches thick	7	
Center to center of coupled wheels	8	6
From center of bogie to driving wheel	10	¼
Weight in working order:	Tons.	Cwt.
Bogie	13	8
Driving wheels	15	5
Trailing wheels	12	17
Total	41	10
Tender:		
Capacity of tank ... gallons		2,650
Coal space, about ... tons		4
Wheels:	Feet.	Inches.
Diameter with tires 3 inches thick	4	
Distance center to center	6	
Weight in working order:	Tons.	Cwt.
Front wheel	10	6
Middle	10	1
Hind	10	3
Total	30	10

The North London Railway Company exhibit a complete working model of their standard bogie-tank passenger locomotive on a scale of one-eighth, or 1½ inches to a foot.

The engine represented has—

		Feet.	Inches.
Four coupled wheels (diameter)		5	5
Four bogie wheels (diameter)		2	10
Outside cylinders (diameter)			17
Length of stroke			24
Tractive force ... pounds			16,500
Working pressure ... do			160
Heating surface of tubes ... square feet	904		
Heating surface firebox ... do	91		
Total heating surface ... square feet		995	
Grate area ... do			16.62
Wheel base ... do			20.8
Contents of tanks ... gallons			850
Contents of coal bunker ... cwt			25
Total weight in working order ... tons			46

THE LONDON AND NORTHWESTERN RAILWAY.

As representing one of the most progressive companies of Great Britain this exhibit possesses peculiar interest both from an historical and practical point of view. The model of the Webb compound double-cylinder engines and the old types of George Stephenson, as exemplified in the Rocket, and of Richard Trevithick's No. 14, contrast strongly, and serve to impress upon the observer the great strides made in the art during the past fourscore years.

The full size model of the Rocket represents the original engine as it appeared when it competed for the prize of £500 ($2,500) offered by the directors of the Liverpool and Manchester Railway Company at Rainhill in 1829. The model has been prepared from various drawings and also from information given in the Mechanics' Magazine of 1829.

The engine weighed in working order 4 tons 3 cwt. It ran at the rate of 12½ miles per hour with a load equivalent to three times its own weight, and when taking a carriage and passengers it traveled at the rate of 24 miles per hour. The model stands on old fish-bellied wrought-iron rails and stone sleeper blocks taken up from the archway where the old engine used to stand, and which formed part of the original Liverpool (Crown street) Station.

A high-pressure engine designed by Richard Trevithick about 1803–'09 and made by Hazeltine & Co., of Bridgeworth. This engine was found at Hereford, in a dismantled state, by Mr. F. W. Webb, of Crewe, in 1883, and purchased as scrap iron. The parts were taken to Crewe and put together as now seen. Some of the parts were found to be broken; these were mended and a few missing pieces replaced and made to accord as nearly as possible with the illustration in "The Life of Trevithick."

The boiler is of cast-iron, with the cylinder, which is vertical, placed inside it. The cast-iron manway cover bears the following inscription: "Hazeldine, Bridgeworth, No. 14." This firm appears to have been the makers of many of Trevithick's engines.

There are also shown the following relics: An old fish-bellied cast-iron rail and stone sleeper blocks, which were taken up from the Cromford and High Peak Railway, and formed part of that line when it was first constructed; a Blenkinsop's rack rail and wheel, as laid down on the Middleton Colliery Railway near Leeds in 1812. An old steel rail 2 feet 6 inches long. This is a piece of one of the 21-foot steel rails first laid down at Crewe Station in 1863; it was turned in 1866 and taken up in 1875. It is estimated that 72,000,000 tons have passed over it. The greatest wear of tables is 0.85 inches. Loss of weight, 20 pounds per yard.

A model of compound engine (*Webb's system*).—The total miles run by the seventy-five compound engines now in use on the London and

Northwestern system since their introduction in 1882 amount to 11,644,222, and the average consumption of fuel of all types of these has been 32.9 pounds per mile. As illustrative of the kind of work these engines are called upon to perform it may be stated that the one named the "Marchioness of Stafford," between December 17, 1885, and May 31, 1889, ran (1) two hundred and forty-four trips from Crewe to Carlisle and back, with a maximum load of twenty-two coaches and an average load of thirteen coaches in both directions; (2) two hundred and forty-three trips from Crewe to London and back, with a maximum load of twenty-two and with an average load of thirteen coaches; (3) fourteen trips between various points, with a maximum load of sixteen and an average of nine coaches, covering in all a distance of 154,342 miles, with a coal consumption of 36.5 pounds per mile, including that burnt whilst standing in steam, and, in fact, issued for all purposes. She was turned out of the Crewe workshops on February 28, 1885, and on the 20th of April following was sent to the International Inventions Exhibition, and her designer and builder, Mr. F. W. Webb, was awarded the gold medal for railway plant by the executive council. On November 30 she arrived back at Crewe, and on December 17, 1885, commenced her working career, continuing in active service, with slight interruption for repairs, up to the present time.

The average consumption of fuel of forty of her class and dimensions has been 36.8 pounds per mile, whilst the loads mentioned above may be taken as fairly typical. The average cost of maintenance compares very favorably with that of other classes, and in all respects the commercial results obtained with compound engines on the London and Northwestern system up to the present time have been very satisfactory, and have shown to great advantage in the case of one of the ordinary type of metropolitan engines working on the district railway, which was converted into a compound some time ago.

This engine has run 178,337 miles since its conversion, the average consumption of coal being 23.2 pounds per mile, including the usual allowance for raising steam, whilst the average consumption of the same type of engine, noncompound, doing similar work was, during the past six months, 32.4 pounds per mile. A model of one of these engines is exhibited.

The sleeping saloon built by the London and Northwestern Railway Company at their works, Wolverton, England, to run between London and Scotland, is 42 feet long, 8 feet 6 inches wide, and 7 feet 10 inches high at center outside dimensions, and is divided into four sleeping compartments, each compartment being provided with a separate lavatory. The entrance to each compartment is from a transverse vestibule, of which there are two, connected by a corridor on the side of the two central compartments. The following outline sketch will further illustrate the arrangement of each compartment. (See Fig. 31).

The saloon is constructed to carry twelve passengers (four in each of the end compartments B and I and two in each center compartments D and G). The compartments B and I have pull-down upper berths over each of the longitudinal lower couches, marked 1 and 2, which are provided with hair mattresses, pillows, etc. The compartment is fitted up with American walnut framing, burr walnut panels, and bordered round with Hungarian ash bands, the whole being upholstered in moquette cloth of a velvet pile, with laces to match. The lavatory (A) belonging to this compartment is fitted up with a silver wash basin, in one piece, with all the requisites for toilet. There is also a water-closet, fitted with all the latest sanitary improvements and provided with folding flaps. The closets are supplied with water carried at the under side of roof in copper tanks, tinned on the outside, the water gravitating to the basin and water-closet through suitable flaps. These lavatory tanks are filled from the outside by a portable water tank and pump at the terminus. The fitting of the lavatory is in American walnut fascais and frame, with sycamore panels, with walnut molding between each, and the whole polished.

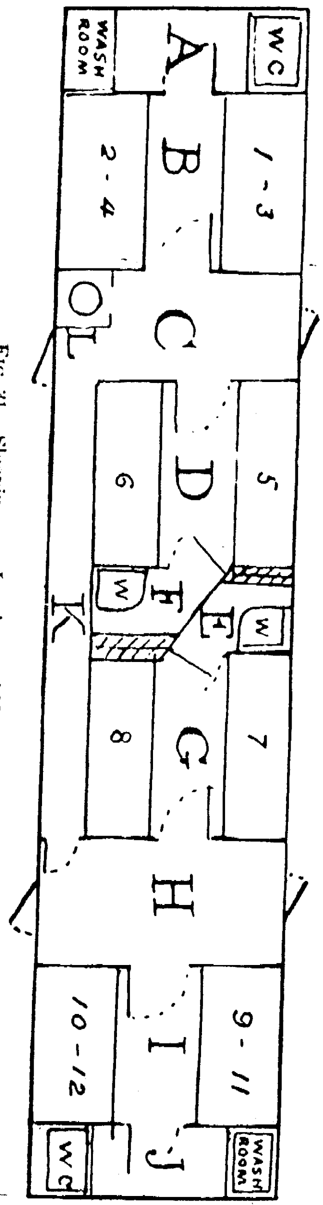

Fig. 31.—Sleeping car, London and Northwestern Railway.

The sleeping compartment I is also similar to B in arrangement, with pull-down upper sleeping berths, etc. The center compartments D and G are provided only with sleeping berths below. The dimensions are 6 feet 3 inches long by 6 feet wide.

From each of these central compartments D and G there is a diagonal lavatory fitted with folding wash basin, shutting up into a small compass when not in use, as well as a corner water-closet with folding flaps. The entrance to each of the sleeping compartments is from the vestibules C and H; these again are connected by a corridor, K. The vestibule H serves as a smoking compartment and is furnished with eleven revolving walnut cane-seated chairs; this compartment is fitted up with rosewood panels and satinwood band moldings, etc.

The small vestibule C is arranged to carry an attendant, who also prepares light refreshments, tea and coffee, there being apparatus fitted up in the stove chamber I. The stove is used also for heating the saloon by means of a small pipe, through which hot water circulates around each compartment, returning again to the stove. The saloon is also fitted with electrical communication from each compartment to vestibule C to call the attendant. It is also lighted by compressed oil gas, burnt in the same way as coal gas, toned down to burn at atmospheric pressure by suitable valves, the gas for this being carried in a cylinder attached to the under frames. The lamps in each compartment are regulated by the attendant, there being valves inside to do this when required. The weight of saloon in service is about 22 tons exclusive of passengers. The frame on which the saloon body is mounted is carried on four pairs of Mansell wheels. The two center pairs have a fixed wheel base of 16 feet, working between iron axle guards or hornplates fixed to the side of carriage frame, while the two end pairs are fitted with Mr. F. W. Webb's radial axle boxes at 8 feet outside each center pair, thus making a total wheel base of 32 feet. Each of the latter axles has the axleboxes guided by hornplates, forming part of an independent frame which is capable of moving laterally under the main frame of the carriage, the direction of its movement, however, being controlled by suitable curved guide blocks so that it can only move along an arc of a circle of 6 feet 9½ inches radius. The lateral play allowed is 2½ inches in each direction from a central position, the movement being controlled by a central spring which is compressed by the movement of the lower frame to either the right or left.

At each corner of the lower frames is a casting upon which rests the slipper block attached to the main frame. The weight is thus transmitted to the lower frame and all tendency to rolling on the lower frame is avoided.

The whole arrangement is simple and effective. The under frame is also constructed to carry two gas cylinders for supplying the sleeping saloon with compressed gas. These cylinders are 16 feet long by 13 inches outside diameter, are suspended by spectacle eyes partially encircling them, and attached to the center and outside of the frame.

Carrying brackets are also attached on the outside cast-iron body for bolting the body to the frame, and in them is inserted India-rubber cylinders to take off the jar and tremor from rolling of wheels. The bearing springs also are suspended by adjusting screws and India-rubber cylinders to further eliminate any jar to the body of carriage. It is also fitted up with the simple automatic vacuum and Westinghouse brakes complete.

The frame is made of steel throughout except the longitudinals

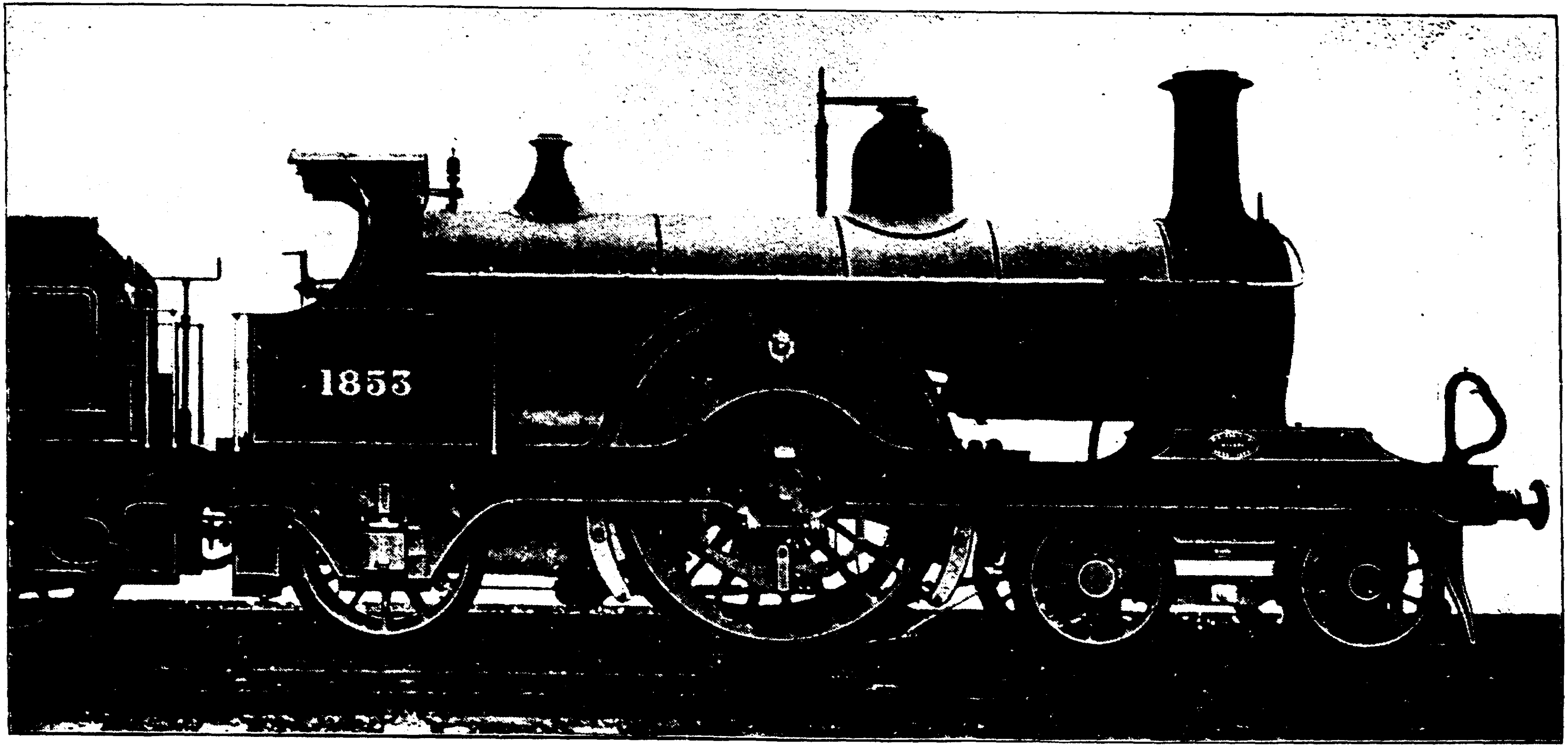

FIG. 32.—The Midland Railway, England. Passenger engine No. 1853.

and diagonals, which are of oak timber, the whole being riveted together and forming a very strong carriage frame.

The Midland Railway Company's engine No. 1853.—The latest improvements in rolling stock in England are revealed in the beautiful types of locomotives and carriage shown by this company, of which Mr. S. W. Johnson is the locomotive engineer. In its profile the engine is very neat and trim, all the working parts being well covered. The *tout ensemble* is as simple as it would seem possible to make it, judging from the exterior view as illustrated in the accompanying cut.

The workmanship is finished in the usual excellent style. The engine is mounted on four axles, two of which are under the bogie truck and have inside bearings. There is but one driver, 7 feet 6 inches diameter, connected by a crank axle with the inside cylinders. There is one pair of small trailing wheels under the cab and three axles under the tender. The boiler pressure is 160 pounds per square inch, and the engine is designed to run at the schedule rate of 53½ miles per hour with from nine to thirteen coaches. These engines have been doing this work for two years with an average consumption of from 20 to 23 pounds of coal per train mile, and have frequently taken from thirteen to sixteen coaches without loss of time.

The leading wheels are 3 feet 6 inches in diameter, placed 6 feet apart, and permit of a lateral play of three-fourths of an inch on each side. The truck is brought back to its central position by a combination of steel springs and rubber cushions. There are two hundred dred and forty-four copper tubes in the boiler, 11 feet long and 1⅝ inches external diameter, fastened to the fire box by ferrules and to the smoke-box end by expansion. All the motion work is of mild steel, case hardened.

Two automatic injectors supply the feed water to the boiler. These are fitted directly on the back of the fire box, and the clack boxes are included in the casting of the injectors. There are no pipes under pressure outside the boiler, and the injectors can be taken out and examined without lowering the steam pressure.

The engine is fitted with the automatic vacuum brakes for the train, in combination with a steam brake for the engine and tender; also with a steam sanding gear and an automatic sight-feed lubricator.

The water tank of the tender will hold 3,250 gallons and the bin about 3 tons of coal.

The draw and buffer springs are India rubber cylinders, but a large C spring, with about 1½ inches initial compression, is used as the draw spring between the engine and tender.

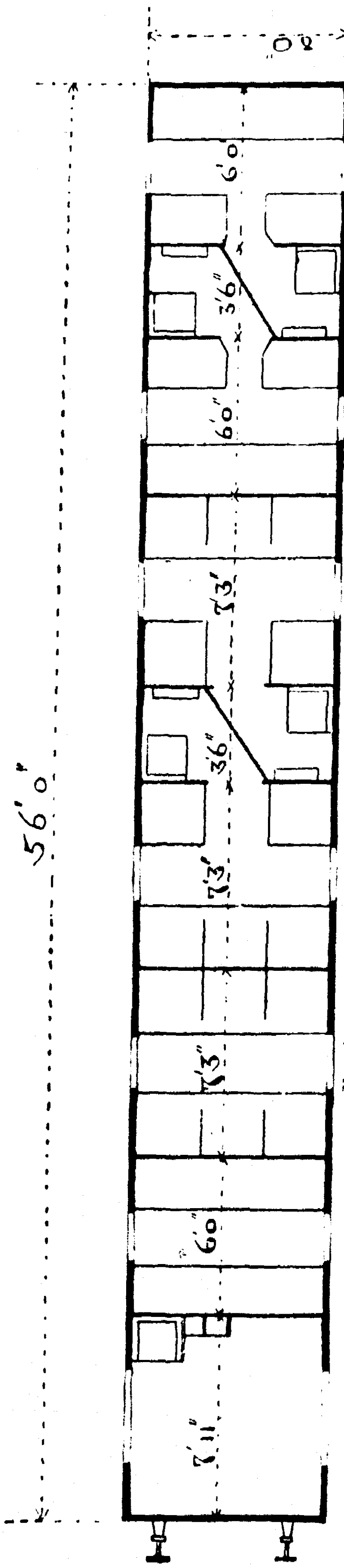

FIG. 33.—Plan of compartment carriage, Midland Railway, England.

Midland Railway carriage No. 916, on two six-wheeled Bogie trucks (Fig. 33).—This carriage contains three first-class and three third-class compartments, with lavatory accommodation to two compartments of each class; also a compartment for the guard and luggage. This is fitted with hand brake and provided with racks and shelves for letters and parcels; also with switch for controlling the electric light, cord communication, appliances for communicating with the engine driver; also automatic vacuum brake-indicator gauge and valve for applying the continuous brake.

This carriage is the ordinary type of six-wheeled Bogie carriages working on the Midland Railway, and the three first-class compartments are samples of the styles of upholstery and finishing adopted for the Midland Company's carriage stock.

The first-class compartment for ladies is upholstered in brown plush, and the inside casing of the compartment is of walnut wood, relieved by solid chasings and moldings.

The nonsmokers' compartment is upholstered in blue woolen carriage cloth, and the inside casing is of sycamore panel, with maple and walnut moldings.

The first-class compartment for smokers is upholstered in crimson morocco and the inside lined with Lincrusta-Walton, with mahogany facings.

The third-class compartments are of the ordinary description and style of the third-class compartments in the Midland Company's carriage stock, upholstered in crimson and black plush.

Both the first and third class lavatory compartments are of the ordinary description and fittings pertaining to each class.

The carriage is 56 feet long over the

body, 8 feet wide, and 7 feet high. It accommodates sixteen first-class and twenty-eight third-class passengers; total capacity, forty-four. It is fitted with the automatic vacuum continuous brake and lighted with electric light. The under frame of the carriage is made of white oak, as is also the body framing. The floor, partitions, roof, and the inside casing boards are of Swedish red deal. All the outside paneling and moldings are of Honduras mahogany.

The Bogie trucks are chiefly constructed of wrought iron.

The bearing ard buffer springs are all laminated, and, with the tires and axles, are made of Bessemer steel. The disks of the wheels are formed of teak-wood segments. The boss is of cast iron, arranged to give increased end-bearing surface to the wood block. The axle boxes are arranged so that the brass bearings may be taken out and replaced without lifting the carriage.

The compartments are lit by electricity. The total weight (tare) is 25 tons, of 2,240 pounds.

In addition to the several railroad companies' exhibits there were numerous others containing a goodly display of material used in construction and operation, including electric signals, compressed-air and vacuum brakes, nuts, bolts, switches, splices, rails, ties, lamps, buffers, boilers, etc., constituting an instructive display.

The characteristic features of the English engines are the absence of pilots and headlights, the inside connections and cylinders, the small size of the cab, which is wanting in some patterns, and the general simplicity of the design.

SWITZERLAND.

The Société Suisse, of Winterthur, have on exhibition a compound locomotive with three coupled axles and a pony truck, having outside cylinders and Stephenson valve gear, the latter being inside and operating by means of rocking levers. It is of the Mogul type and designed for a standard gauge. The locomotive is characterized by a pilot and headlight, as in the American pattern, and carries a large cab.

Another engine is shown for a 1-meter gauge. It has three axles coupled, and is designed for tramway service. A mountain locomotive of a mixed type, constructed to run by simple adhesion, or by rack and pinion, is also placed on exhibition by this company. It has four wheels coupled to the central shaft carrying the toothed wheel, which can be geared into the crank shaft driven by inside cylinders.

The Mount Pilatus engine is also a feature of this exhibit. It is mounted on two axles and propelled by double horizontal pinions gearing into the rack. The maximum gradient on this unique line is 48 per cent, and the difference of elevation between its termini is 5,343 feet. The total length is 15,147 feet and the gauge 31½ inches.

ITALY.

The Société des Chemins de Fer de la Méditerranée, of Milan, have on exhibition a locomotive and carriage of excellent design and finish. The engine, No. 1701, has four axles, two coupled, and a Bogie truck. It has outside cylinders, and valve gear of the Gooch stationary-link type, a boiler pressure of 142 pounds per square inch, and a long fire grate extending over the trailing axle.

The locomotive shown by the *Société Italienne des Chemins de Fer Méridionaux*, of Florence, is also an eight-wheeled machine. It is similar in many respects to the Swiss engine already described.

One of the most instructive of the Italian exhibits was that made by *Miani, Silvestri et Cie.* of Milan. It comprised an engine and train of seven special carriages. The engine rests on a Bogie truck and three coupled axles. The valve gears and cylinders are outside, and the workmanship is very good.*

The only other exhibit in this class was that made by *M. Cyriaque Helson*, of Turin, who shows an interesting collection of metallic cross-ties, in both iron and steel, for railroads.

* Condensed in part from Engineering, August 9, 1889. London.

UNITED STATES.

During the year 1888 the Baldwin Locomotive Works, at Philadelphia, Pennsylvania, turned out no less than 727 engines, classified as follows: Consolidation, octopod engines, 272; six wheels coupled, freight and passenger, 275; passenger engines, four wheels coupled, 188; special single-driver engines, 1; rack-rail engines, 1. The smallest number built in any one month was 54 and the largest 75.

As illustrating the great variety of locomotive construction now prevailing we have to submit from the Baldwin works the following illustrations of twelve different kinds of engines of their manufacture, together with a brief description of each.

Fig. 34 represents a ten-wheeled passenger locomotive, with radial stay wagon-top boiler, built for the Denver and Rio Grande Railroad Company. Cylinders, 18 by 24 inches; driving wheels, 54 inches diameter; rigid wheel base, 6 feet; driving wheel base 11 feet 9 inches; total wheel base, 22 feet 1 inch; weight in working order, total, about

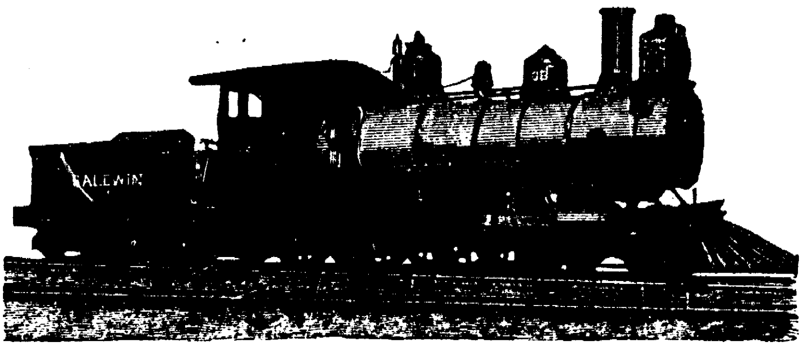

FIG. 34.—Ten-wheeled passenger.

101,000 pounds; weight on driving wheels about 77,000 pounds. Fitted with two Friedman Monitor No. 9 injectors, Nathan sight-feed lubricator, Westinghouse automatic brake for tender and train wheels, and the LeChatelier water brake acting by back pressure on the pistons.

Fig. 35 is a rack rail locomotive of the Riggenbach's system, designed for the Estrada de Ferro de Grao Para, of Brazil, to haul 22 tons (of 2,204 pounds) of cars and lading up a grade of 15 per cent, or 792 feet per mile, at a speed of 9 kilometers (or 5½ miles) per hour. Cylinders 12 by 20 inches, geared driving wheels 41.35 inches diameter on pitch line, carrying wheels 27 inches diameter. Weight in working order about 42,000 pounds. Fitted with hand screw brakes acting on geared wheels and the LeChatelier water brake operating by back pressure on pistons.

Fig. 36, decapod locomotive built for the Northern Pacific Railroad Company, the dimensions of which are as follows: Gauge of track, 4 feet 8½ inches; actual weight in working order exclusive of tender, 148,000 pounds; actual weight on driving wheels, 133,000 pounds; estimated weight of tender, including coal and water, 80,000 pounds; estimated weight of locomotive and tender, in working order, 228,000 pounds; cylinders, 22 by 26 inches; driving wheels, five pairs coupled, 45 inches diameter; total wheel base, 24 feet 4 inches; driving wheel base, 17 feet; rigid wheel base, 12 feet 8 inches; boiler, of steel,

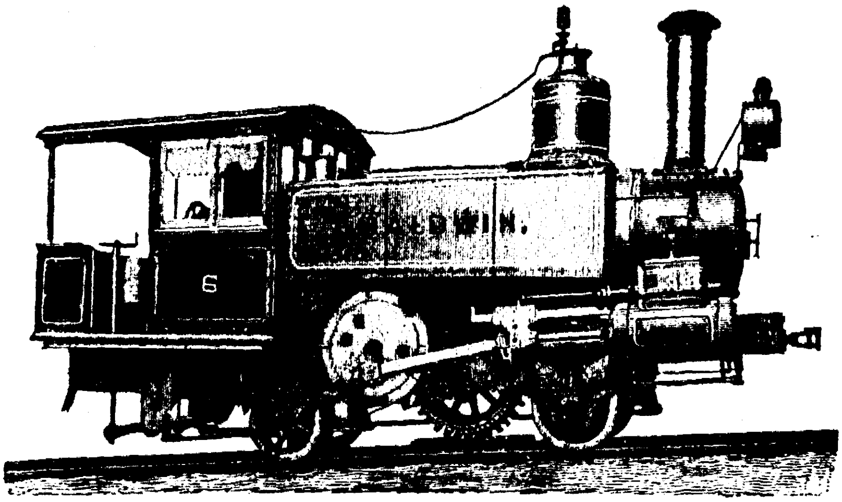

FIG. 35.—Rack rail—Riggenbach's system.

⅝ inch thick, 68 inches diameter; height of center line of boiler above rail, 7 feet 3½ inches; fire box, 10 feet 1 inch long by 3 feet 6½ inches wide; tubes, 270 in number, 2¼ inches diameter, 13 feet 6 inches long. Heating surface: fire box, 162 square feet; tubes, 2,148 square feet; total 2,310 square feet; tank capacity, 3,600 gallons. The first, fourth,

FIG. 36.—Decapod.

and fifth pairs of driving wheels of these engines have flanges, the second and third pairs are plain. To reduce the friction when traversing curves the rear or fifth pair of driving wheels has additional play. The rigid wheel base is therefore practically only the distance between centers of the first and fourth driving wheels, namely, 13 feet 8 inches, which is less than that of either a consolidation or Mogul locomotive of ordinary type.

Of the performance of the "decapod" Mr. G. W. Cushing, superintendent M. P. M. & R. S. of the Northern Pacific road, writes as follows:

With reference to the "decapod" engine: During the work of construction I am not likely to get experimental trips of which to send you reports, but am able to report the remarks of my assistant in regard to their present working, as follows: "The "decapod" engines are working well, and you would be surprised to see the track they can run over and remain on the rails. They go anywhere, either on bad track or curves, that an eight-wheeled engine can go, and surprise us all. The result certainly justifies your choice of these engines for the special work."

I may add in explanation, the track is unusually bad because of the peculiar conditions of climate and soil which render track-laying in the mountains possible in January. At a later date, when track becomes settled and in good surface, it will be fair to experiment with reference to capacity of these engines on a 300-foot grade, and I anticipate their work will then further surprise those in charge. I am entirely pleased with their performance.

FIG. 37.—Noiseless steam street car.

Fig. 37. Noiseless steam street car: Cylinders, 8 by 10 inches; driving wheels, 30 inches diameter: weight in working order, without passeners, about 16,000 pounds. Built with steel boiler and fire box, steel tires and wrist pins and charcoal iron flues. Fitted with steam brake applying to tread and flanges of the driving wheels, two injectors, two headlights and all necessary tools. A steam car of this type is used by the Grand Trunk Railway Company for ferry passenger service on the International Bridge at Buffalo, between Black Rock and Fort Erie.

Fig. 38. Six-wheels-connected switching locomotive, with separate eight-wheeled sloping back tender, of 2,400 gallons capacity, built for the Norfolk and Western Railroad Company. Cylinders, 18 by 24 inches; driving wheels, 50 inches diameter; wheel base, 10 feet 6 inches; weight in working order, about 83,000 pounds. Built with steel boiler and fire box, steel tires and wrist pins, and lap-welded charcoal iron flues. Fitted with two Friedman Monitor No. 8 injectors, steam brake, and Nathan sight-feed lubricator.

Fig. 39. "Forney" type locomotive, with two pairs of driving wheels connected and a four-wheeled swing bolster truck in rear,

FIG. 38.—Switching.

built for the Suburban Rapid Transit Company of New York. Cylinders, 14 by 18 inches; driving wheels, 48 inches diameter; weight, in working order, total, about 55,000 pounds, weight on driv-

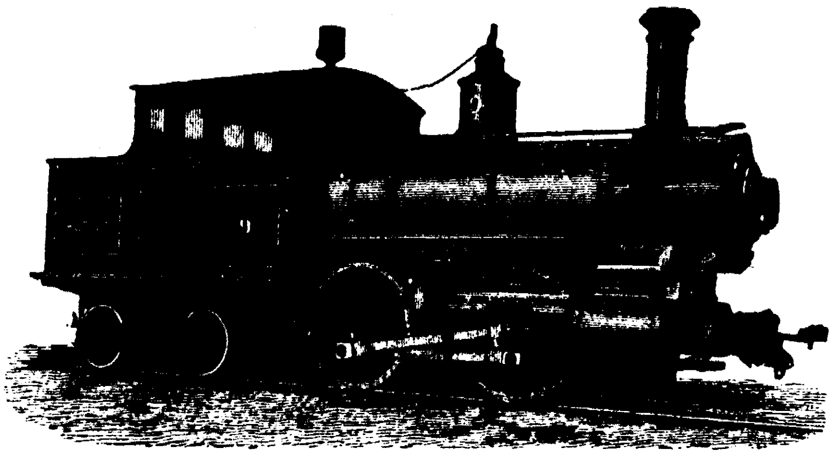

FIG. 39.—Forney.

ing wheels, about 42,000 pounds; tank of 600 gallons capacity carried on extension of engine frames. Built with steel boiler and fire box, steel tires and wrist pins and charcoal iron flues. Fitted with

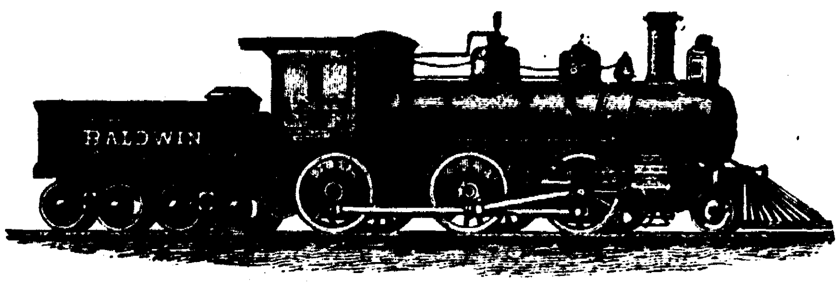

FIG. 40.—Mogul.

Eames vacuum brake, Shaw muffler for safety valves, two No. 6 Friedman Monitor injectors, and all necessary tools.

Fig. 40. Mogul locomotive, built for the Central Vermont Railroad Company. Cylinders, 19 by 26 inches; driving wheels, 57 inches di-

ameter; weight in working order, about 100,000 pounds; weight on driving wheels, about 82,000 pounds; separate eight-wheeled tender of 3,000 gallons capacity. Boiler of steel, lagged with asbestus; fire box, tires, and wrist pins of steel, flues of charcoal iron. Fitted with Eames vacuum brake, Seibert sight-feed lubricator, and two Friedman Monitor No. 9 injectors.

Fig. 41. Double-ender suburban passenger locomotive, with two pairs of driving wheels connected and a two-wheeled swing bolster

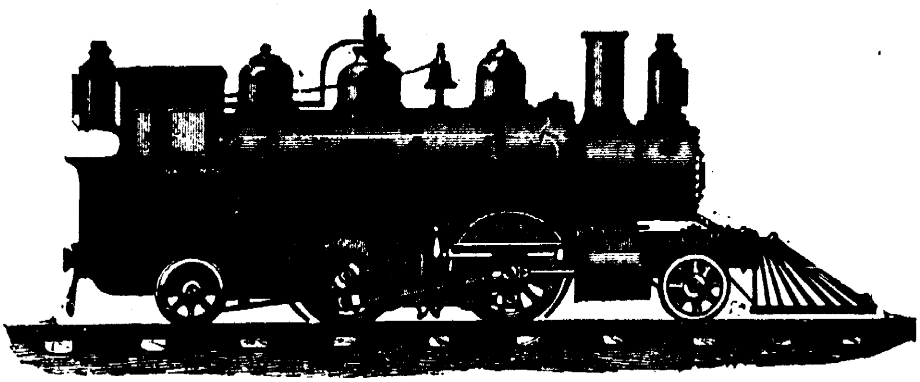

FIG. 41.—Double ender—Suburban.

truck with radius bar front and back, each truck equalized with adjacent pair of driving wheels, built for the Brooklyn, Bath and West End Railroad Company, to burn hard coal. Cylinders, 15 by 22 inches; driving wheels, 49 inches diameter; weight in working order, about 70,000 pounds; weight on driving wheels, about 53,000 pounds; tank of 900 gallons carried on boiler. Total wheel base 21

FIG. 42.—Tank switching.

feet 8 inches; driving wheel base, 7 feet 6 inches. Built with steel boiler and fire box, steel tires and wrist pins, and charcoal iron flues. Fitted with water tubes and drop bars for grates, hopper ash pan, Eames vacuum brake, two Friedman Monitor No. 7 injectors, Detroit sight-feed lubricator.

Fig. 42. Six-wheels-connected tank-switching locomotive built for the Cambria Iron Company. Cylinders, 15 by 22 inches; driving wheels, 43 inches diameter; weight in working order, about 70,000 pounds; wheel base, 10 feet; tank of 750 gallons capacity. Built

with steel boiler and fire box, steel tires and wrist pins, and charcoal iron flues. Fitted with two Sellers's 1876 injectors and Detroit sight-feed lubricator.

Fig. 43. Consolidation freight locomotive, built for the Buffalo, Rochester and Pittsburg Railway Company. Cylinders, 20 by 24

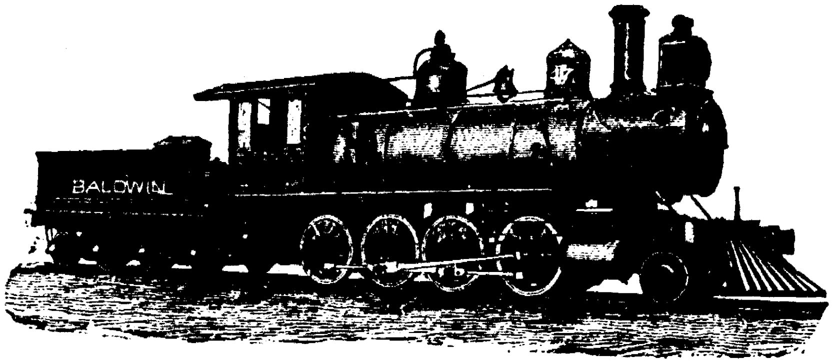

FIG. 43.—Consolidation freight.

inches; driving wheels, 50 inches diameter; weight in working order, total, about 116,000 pounds; weight on driving wheels, about 103,000 pounds; total wheel base, 21 feet 6 inches; driving wheel base, 14 feet; tender of 3,000 gallons capacity. Built with steel boiler and fire box, steel tires and wrist pins, and charcoal iron flues. Fitted with Westinghouse automatic brake for driving, tender, and train wheels, two Friedman injectors.

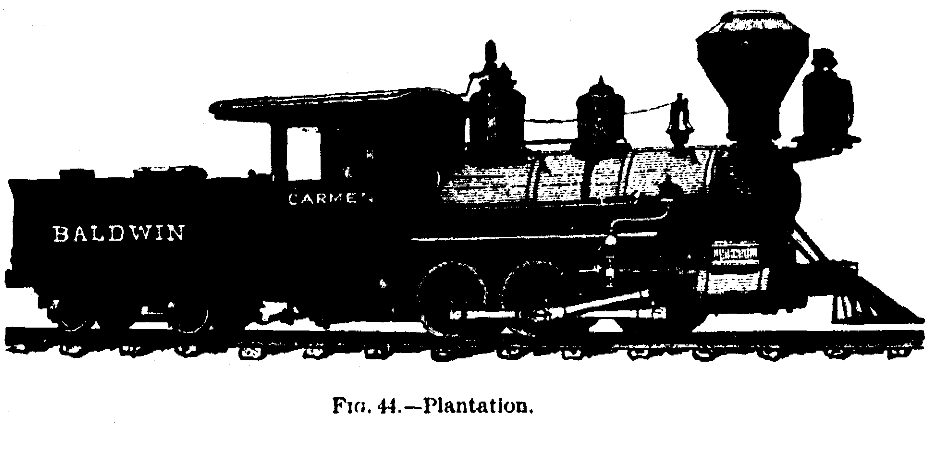

FIG. 44.—Plantation.

Fig. 44. Six-wheel-connected plantation locomotive, with separate four-wheeled tender of 900 gallons capacity, built for Messrs. Krajewski & Pesant, of New York, for service in Cuba. Cylinders, 13 by 16 inches; driving wheels, 33 inches diameter; wheel base, 7 feet 8 inches; weight in working order, about 34,000 pounds. Built with steel boiler and fire box, steel tires and wrist pins, and charcoal iron flues. Fitted with Radley & Hunter stack, one No. 5 eclipse injector, one brass pump, and all necessary tools.

Fig. 45. American type passenger locomotive, built for the Norfolk and Western Railroad Company. Cylinders, 18 by 24 inches; driving wheels, 62 inches diameter; total wheel base, 24 feet 6½ inches; driving wheel base, 9 feet; weight in working order, about 101,000 pounds; weight on driving wheels, about 67,000 pounds; tender of 3,000 gallons capacity. Built with steel boiler and fire box, steel tires and wrist pins, and charcoal iron flues. Fitted with two No. 9 Friedman Monitor injectors, Westinghouse automatic brake for driving, tender, and train wheels, and Nathan sight-feed lubricator.*

The more practical technical information regarding a few of the numerous types produced by this enterprising company will be found in the accompanying general table of data, and the sectional diagrams submitted herewith (Figs. 46, 47, and 48). The facilities of the establishment are such that recently an engine was designed, drawn, built, and delivered in eight days. The present output av-

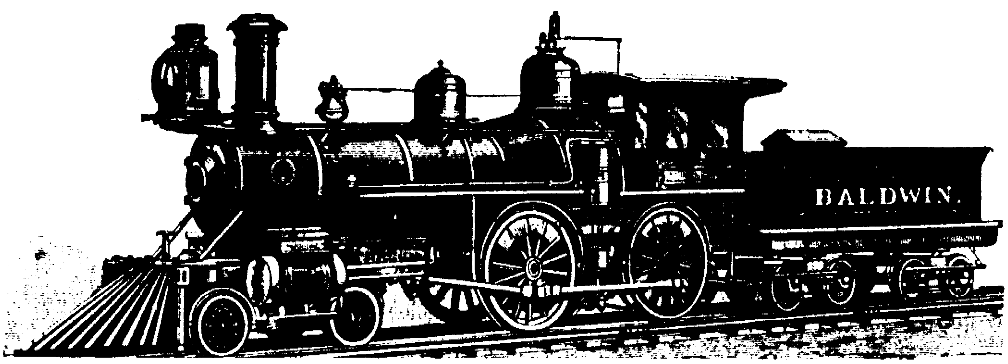

FIG. 45.—American type passenger.

erages two locomotives per diem, and arrangements are now perfected by the firm for turning out one thousand locomotives in a year, if it be found necessary.

For heavy work a few engines of the "Decapod" type, shown in Fig. 36, have been built, with its five pairs of drivers, but it is found that substantially the same results are obtained by an eight-wheeled driver and larger boiler capacity, so that the Decapod type is practically superseded by the "heavy consolidation freight" engine, similar to No. 43. A late engine of this type, built for the Northern Pacific Railroad Company, is now in use on the mountain division, where there are 10° curves (573 feet radius) and grades of 116 feet to the mile (2.2 per cent). Under these conditions the engine is reported to be able to draw "about eighteen loaded cars, and for winter about sixteen will be the average." The largest load yet hauled by it was twenty loaded cars, weighing in the aggregate about 600 net tons, or 535 tons gross.

The actual weight in working order, exclusive of tender, is 150,000 pounds, and the weight in drivers, 135,000 pounds. The cylinders

* Extract from the Railway Age, Chicago, March 8, 1889.

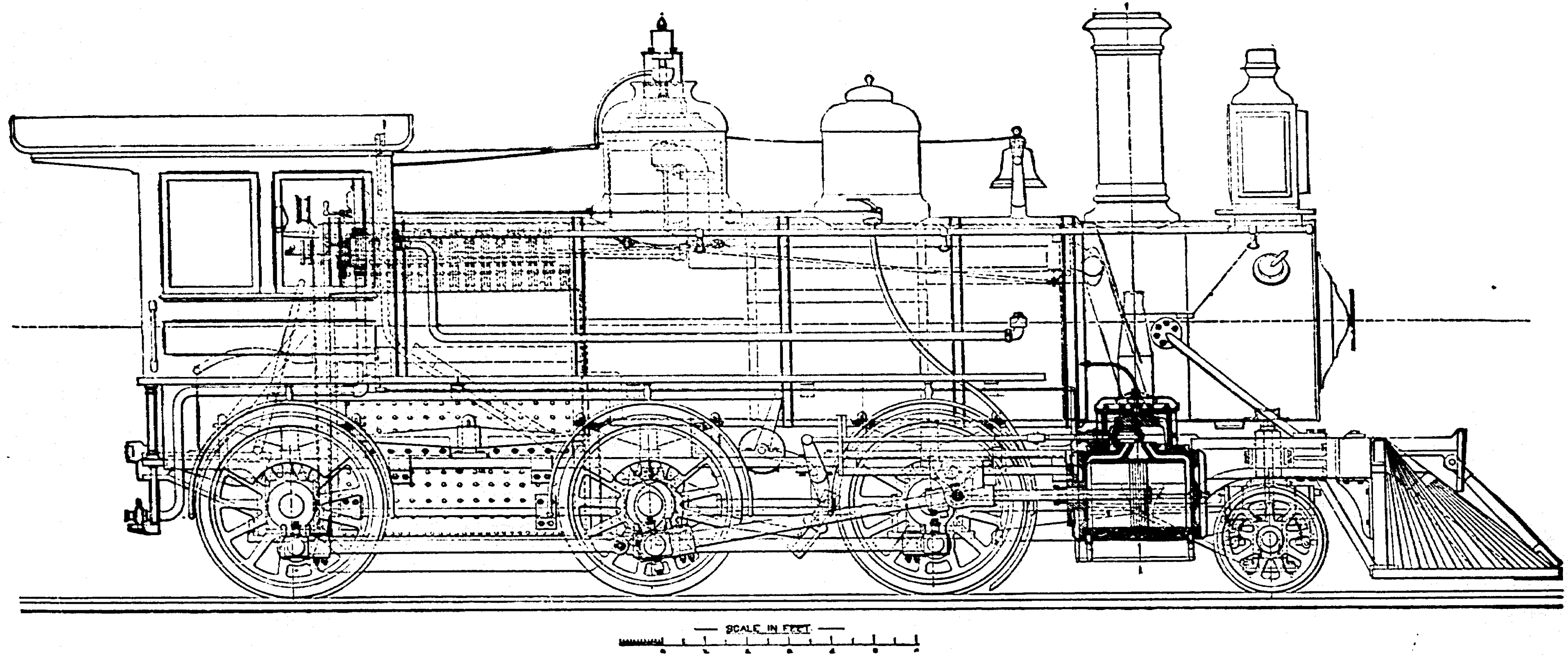

FIG. 46.—"Mogul" pattern, freight locomotive, longitudinal section.

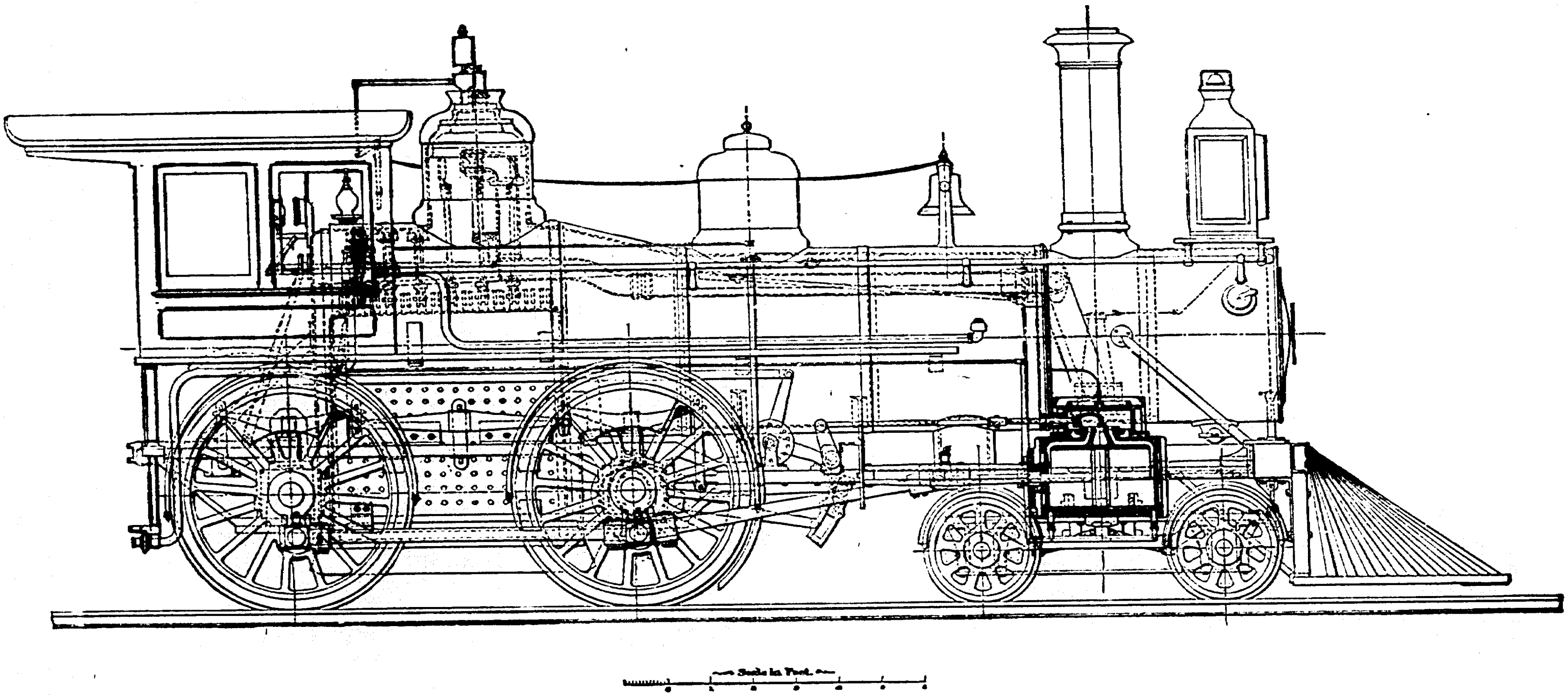

FIG. 47.—"American" pattern passenger and freight locomotive (longitudinal section).

are 22 inches diameter by 28 inches stroke. The driving-wheel base is 14 feet, but the central wheels have no tires and a broad tread.

It is therefore the heaviest American engine on the general list, and is exceeded by only one Belgian locomotive, of substantially the same design, but having its tank over the drivers. The weight on each pair of the driving wheels is 33,750 pounds, or on each wheel, 16,875 pounds. Additional data will be found in the table.

Consolidation locomotive with Wootten fire box Fig. 48 represents a special consolidation engine, built by the Baldwin Company for the Calumet and Hecla Mining Company, of Michigan. The engine is fitted with the Wootten system of fire box, and, though built for a narrow-gauge line, has slightly more tractive power than most consolidation engines and considerably greater weight, being the heaviest consolidation engine ever built for any gauge by the Baldwin Locomotive Works. The following are the leading particulars and dimensions of the engine:

Cylinders, diameter and stroke, 20 by 26 inches.

Tractive force per pound average pressure in cylinders, 208 pounds.

Gauge, 4 feet 1 inch.

Fuel, buckwheat or pea anthracite.

Weight in working order, about 130,000 pounds.

Weight on driving wheels, 116,000 pounds.

Total wheel base of engine, 21 feet 9 inches.

Driving-wheel base of engine, 13 feet 8 inches.

Total wheel base of engine and tender, 50 feet 6 inches.

Driving wheels, diameter on tread, 50 inches.

(Front and back driving wheels flanged, intermediate wheels plain.)

Driving-axle journals, diameter and length, 7½ by 8½ inches.

Engine-truck journals, diameter and length, 5 by 8 inches.

Tender journals, 3¾ by 7 inches.

Boiler, Wootten patent, straight top, of steel, ⅝ inch thick.

Diameter of waist of boiler at smoke-box end, 60 inches.

Fire box, inside, 114 inches long by 95¼ inches wide.

Tubes, 204 in number, 2 inches diameter, 10 feet 6½ inches long.

Boiler tested to 200 pounds per square inch; working pressure, 160 pounds per square inch.

Boiler lagged with asbestos.

Variable exhaust; diameter maximum opening, 6 inches.

Feed water supplied by two Rue injectors, one No. 9 and one No. 10.

The brake shoes of the Ross pattern, with bearing on flange of tire and tread inside of track line, but recessed over the part where the wear of the rail naturally comes, so as not to increase the wear of tire at the point where they are worn by the rails.

The cylinders tapped so that indicator cards may be taken when the engine is put into regular service.

A steam gauge attached to the steam-brake pipe, so that the engineer can see just what effective brake pressure he has available.

Le Chatelier pipe for braking by back pressure on pistons.

Hudson's patent automatic bell ringer.

Relief cocks on steam chests, operating automatically and by rod running back to cab.

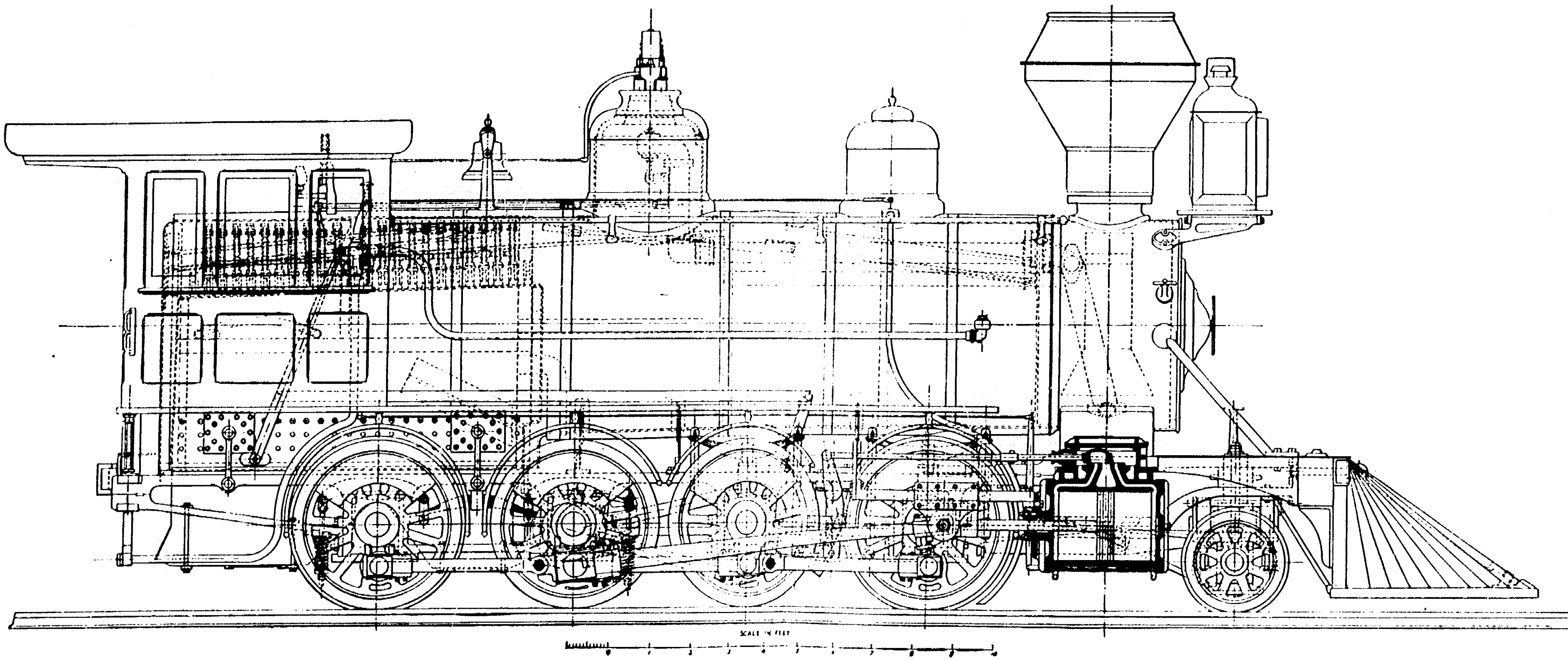

FIG. 48.—"Consolidated" freight locomotive (longitudinal section).

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Boyden's sight feed lubricator for cylinders.
De Lancey's patent balanced slide valves with Allen ports.
Reverse quadrant graduated to each inch of cut-off.
Steam brake acting on forward side of all driving wheels.
American steam brake on tender wheels.
Height from rail to center of boiler, 7 feet 5¼ inches.
Height from rail to top of boiler, 10 feet 1¼ inches.
Height from rail to top of stack, 15 feet 2¼ inches.
Engine-truck wheels with steel tires.
Driving boxes of cast steel.*

Description of miscellaneous articles exhibited by the Pennsylvania Railroad Company of Pennsylvania.

(1) One cast-iron wheel worn out in service under a passenger car. Length of service, 21½ months. Mileage, 126,915.

(2) One cast-iron wheel defective in casting. The defects in this wheel are chill cracks due to contraction of the wheel while cooling in the mold. These chill cracks are the most common defect in the manufacture of cast-iron wheels, and wheels having these defects are never placed in service.

(3) One new cast-iron wheel with piece broken out to show depth of chilled iron on tread, and also having holes broken in the plate to show strength of metal. This wheel was struck over 200 blows with a 25-pound sledge.

(4) One pair 33-inch wheels mounted on axle, showing the wheels and axle ready to be placed in a truck for service.

(5) One section of Pennsylvania Railroad standard 85-pound rail and rail joint, showing simply the shape of the rail and the style of rail joint used.

(6) Trestles and chocks for setting up the wheels.

(7) One 33-inch Pennsylvania Railroad standard wheel flask, filled with plaster of Paris to represent sand, and having a wooden pattern in position to represent a wheel in the mold. A piece is cut out through the flask, plaster of Paris, and pattern to show the position of the different materials in the mold as in casting the wheels.

(8) One Pennsylvania Railroad standard freight-car truck, showing the truck complete and ready to be placed under a car.

(9) One Pennsylvania Railroad standard passenger-car truck, showing the truck complete and ready to be placed under a car.

(10) One section of the Pennsylvania Railroad standard box freight car, showing the height, width, and general style of framing, weatherboarding, and roofing. This car complete is 34 feet long and has a door 4½ feet wide in center of car on each side. The car weighs about 29,000 pounds and has a carrying capacity of 65,000 pounds. It is used for carrying grain, merchandise, and all classes of perishable freight, except such as are required to be carried in refrigerator cars. This car is known as class "Xc" box car.

*The Railroad Gazette, 73 Broadway, New York.

(11) One section of the Pennsylvania Railroad standard coal car, showing width, height of sides, and general style of floor framing. This car complete is 26 feet long, and has a hopper and drop bottom in the center, from which about two-thirds of the load can be dropped on the coal wharves. The car weighs about 23,000 pounds and has a carrying capacity of 65,000 pounds. It is principally used for hauling coal, ore, and other materials of that character, but may also be used for lumber and other materials which do not require protection from the weather. This car is known as class "Gd" Gondola car.

(12) One section of the Pennsylvania Railroad standard passenger car, showing style of finish, seats, etc. This car complete is 46½ feet long, and seats fifty-six passengers. It is provided with a saloon for the accommodation of passengers, a tank containing drinking water, and is heated by two stoves, from which hot air is conducted through boxes on each side of the car beneath the seats. From these boxes the hot air is distributed throughout the car by means of openings under the seats. This car is known as class "Pf" passenger car.

Another exhibit is an album of specifications for materials, etc., used by the Pennsylvania Railroad Company. The materials which are referred to in these specifications are tested either chemically or physically, as the case may be, and any which do not meet the requirements of these specifications are condemned and returned to the manufacturers to be replaced with materials of the proper kind; and the last is an album of photographs of the Pennsylvania Railroad standard locomotives and cars, and also a few miscellaneous pictures of special equipment, scenery, etc.

From this brief description it appears that the capacity of the rolling stock is kept up to modern standards, and that it is much greater than formerly, when dead and live load were about equal. At present the ratio is about as 29 is to 65 for the box car "Xc," or as 1 to 2.24; for the standard coal car it is as 23 is to 65, or 1 to 2.82. The economy resulting from this change is manifest in the great reduction of rates.

The body of the standard passenger day coach is 46½ feet long, and the end platforms 3 feet each, making 52½ feet for a seating capacity of 56 persons, or 11 inches of train length per passenger.

The car seats, intended for two, are about 40 inches long, placed transversely and separated by a central aisle about 20 inches wide, giving an interior width of 100 inches or over, say 8½ feet. The cubic contents would then be 46½ by 8½ by 9=3,557 cubic feet, while the floor space is 395½ square feet. There result, 7.06 square feet of area and 63.5 cubic feet of volume per passenger.

Again, rating the weight of the passenger at 154 pounds, the paying load would amount to 8,624 pounds per car, while the dead load is about 39,300, giving a ratio of 1 to 4.6.

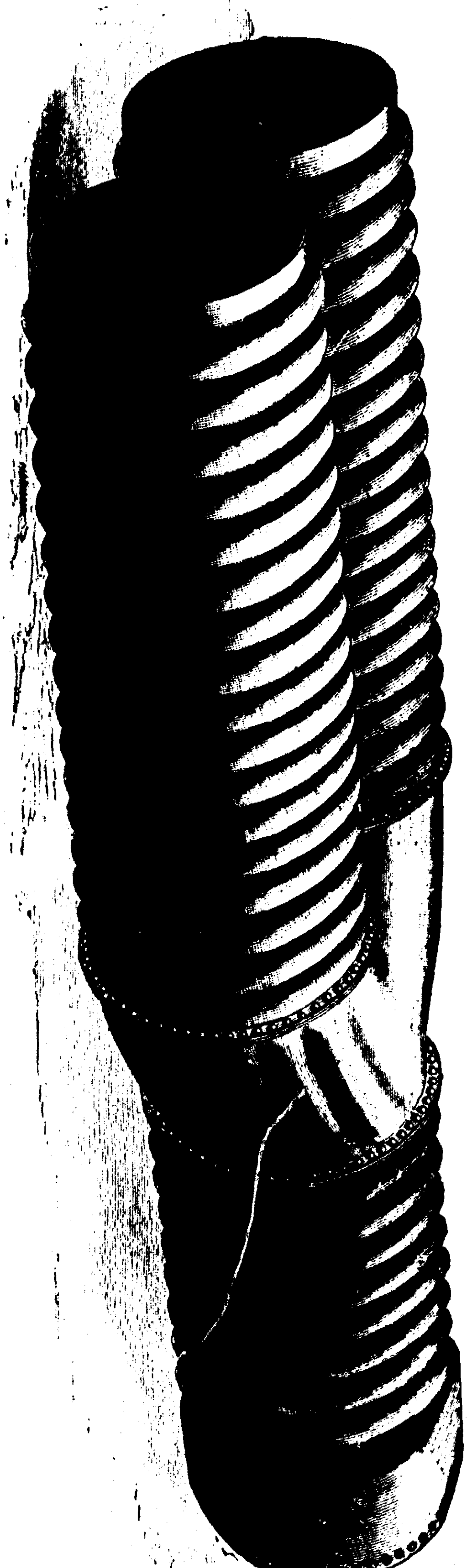


FIG. 49.—Strong locomotive; corrugated fire boxes, junction and combustion chamber.

The freight cars vary in length from 28 feet for the "gondola (Gd)," to 36.4 for the stock car, "K D," and are therefore all mounted on four-wheel bogie trucks.

The Strong locomotive No. 444.—This machine represents a new departure in American practice, and although not represented at the exhibition it is believed necessary to allude to it in this report as one of the types of engines which mark a radical change in this branch of the service in America.

Its designer, Mr. George S. Strong, has endeavored to improve upon what he regards as the weakest parts of an engine, viz, the boiler, the valve gears, and the valves themselves, and hence he has made important modifications in these parts with the view of obtaining greater efficiency.

In the boiler he has done away with all flat and square forms which resist pressure by their transverse strength alone, and has adopted the corrugated cylindrical form, thus dispensing with all stays and crown bars. There is also a duplex-fire box discharging the gaseous products over a hollow bridge, where they receive the supply of air necessary to cause complete combustion, and by alternate firing an incandescent fire is always maintained on one side to burn the gas from the opposite chamber. The combustion and fire chamber are welded, corrugated, steel cylinders, flanged out so as to be riveted externally, thus preventing exposure of any rivet heads to the direct action of the fire. The longitudinal joints are all welded. The boiler is designed to carry 175 pounds per square inch internal pressure.

The result of these modifications in the boiler has been to produce the long, peculiar form, resembling a tuning fork or >-, as shown in the annexed illustration.*

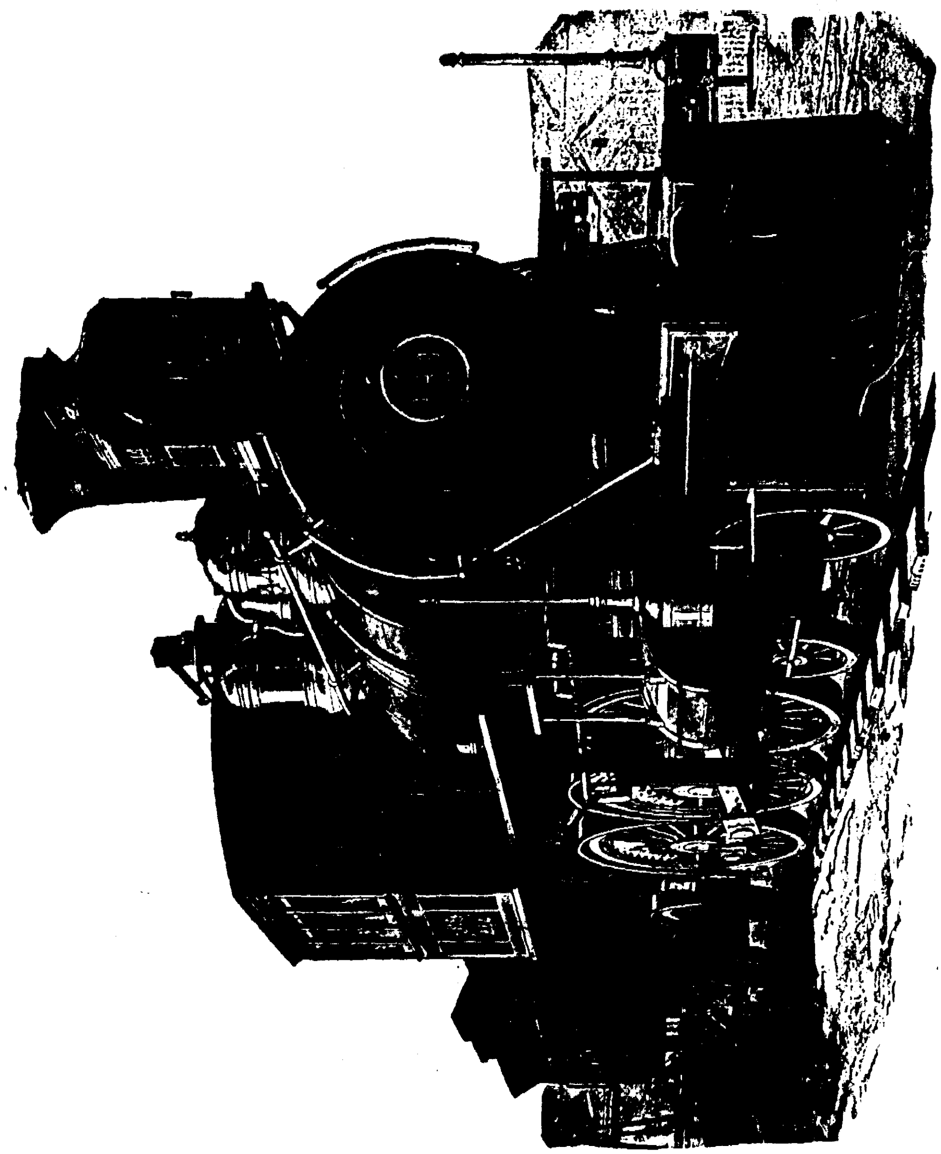


FIG. 50. The Strong locomotive.

The valves used are of the "gridiron" pattern, having ten ports per valve, each $4\frac{3}{4}$ by $\frac{3}{4}$ inches. The travel of the valve is $1\frac{1}{16}$, the lap $\frac{5}{16}$; the lead, for the steam, $\frac{1}{2}$ inch; for the exhaust, $\frac{5}{16}$, and the throw of the eccentrics, $2\frac{1}{2}$ inches. "With these quadruple valves all the advantages of balancing are secured without its complications.

* For fuller descriptions and tests see Franklin Institute Journal of February, 1888, vol. cxxv. Philadelphia, Pennsylvania.

for, by the peculiarity of the motion given to the rocker gear, it happens that when the load on the valves is greatest they are mostly at rest, and when they are moving, the compression coming beneath the steam valves, so relieves them of load that they are to a large extent balanced, whilst similarly when, in turn, the exhaust valves move they are exposed only to pressure from the expanded steam. The fact that in actual work the wear of the valves is found to be almost nothing, shows that the adaptation of this type of valve to locomotive practice has been well chosen, and that four separate valves are superior to one, and secure a better distribution of the steam."

This valve gear is based upon the Walschaert system, which has long been in use with good results.

"The valve seats are plugs, fitting into holes bored in the passages from the saddle to the cylinder, the ordinary steam chest being dispensed with. The valves are let into grooves milled or planed in the seats, so arranged that the valves are free to move up or down in the seats." All the objections to the link motion are removed by this valve-gear, which is of the radial type.

This machine, No. 444, when run on the Northern Pacific Railroad by an engineer who kept a fairly open throttle, developed, at high speed, over 1,800 horse power, or over 1 horse power from a square foot of heating surface, or 30 horse power per foot of grate and per 75 pounds weight, and it is claimed that this power can be maintained indefinitely. The engine gives a good distribution of steam, large cards, high power for an ordinary cylinder capacity, and great economy,* especially for high speeds. Its general appearance is indicative of power, and its evolution marks an epoch in steam motors. The more detailed data will be found in the general table.

The H. K. Porter & Co. locomotive.

The only American locomotive actually placed on exhibition in its full size was that manufactured by H. K. Porter & Co., of Pittsburgh, Pennsylvania. It is designed for a great variety of uses and not simply as a mining engine as has been frequently asserted. For foreign markets it is made at prices ranging from $2,000 to $3,500, delivered on board the steamers at New York.

The claims which the company make for the design shown in Fig. 51 are as follows:

The locomotive is intended for use in hot countries, and for this purpose a canopy is used to protect the engineer from the heat of the sun, the boiler is thoroughly jacketed, and the arrangements for carrying the fuel and water, and the general construction of the engine gives the greatest comfort and convenience to the engine-driver, as well as full control of all working parts. It is especially designed for

* Prof. Robert H. Thurston's discussion.

working on very sharp curves, and is constructed with a truck which is arranged for working on very rough track and for sharper curves than any other truck made. The engine is also well adapted to working very steep grades, and is therefore desirable for work on portable track or light track on plantations where the ground is apt to be soft, the grades steep, and the curves sharp. The center of weight is placed very low, so that the engine can not be derailed easily. The design is simple, without any complications, so that an ordinary engineer can keep the machine in good order and operate it. The journals are large size; the brasses are of the hardest composition of copper and tin; the valve motion throughout is case-hardened steel with hardened steel pins and thimbles, so that the locomotive will run a very long time without repairs, and their duplicate system of construction makes such repairs, when needed, very easy, not requiring any great skill.

While the company have aimed to secure the greatest convenience and adaptation to severe service they have not paid any special attention to ornamentation, so that there are no useless brass ornaments. The locomotive is built for work rather than for looks, but at the same time it has a neat finish. The locomotive was not constructed especially for exhibition, but the different parts for its construction were duplicate parts taken at random from the finished stock kept on hand.

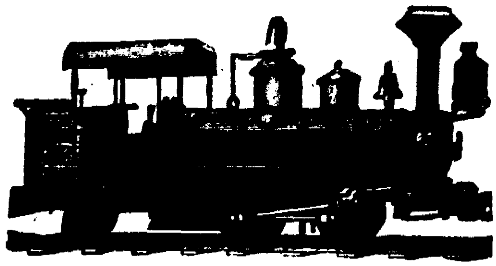


Fig. 51.

The general characteristics of this machine are as follows: Gauge 3 feet; fuel, coal or wood; service, plantation; weight, 15,000 pounds; boiler of homogeneous cast-steel plates with the shell $\frac{9}{32}$ inch, cylindrical sheets $\frac{7}{32}$, and the round head $\frac{11}{32}$; diameter 25 inches at front end, 25½ at rear. The dome is 18 inches in diameter, 20 inches high, with cast ring and caps lagged and cased. The boiler tested to 180 pounds pressure. The grate is cast iron. The stack contains a spark arrester and steel wire netting and an adjustable petticoat pipe. The valve motion consists of shifting links graduated to cut off equally at all parts of the stroke. The drivers are furnished with cast-iron centers with steel tires. For other data see the general table.

SPECIAL ENGINES AND APPLIANCES.

The Decauville railway and appliances.

The establishment of Decauville Aîné, à Petit-Bourg (Seine-et-Oise), France, makes a variety of engines for general purposes of transportation under peculiar conditions. One of these is the compound articulated locomotive on the Mallet system, weighing 12 tons in service. It burns wood or coal, and is capable of turning curves of only 65.6

feet radius and of mounting gradients of 8 per cent on ways of from 1.96 to 2.46 feet gauge. Its horse power is computed at 85. It has four axles with wheels 23.6 inches in diameter. Its peculiar feature is in the compounding of its cylinders, they being arranged tandem and so far apart that the forward one drives the four front wheels while the one in the rear operates the remaining drivers, the one being a duplication of the other, with the necessary valves, gear, etc., excepting as to diameter, that of the forward cylinder being 10 inches and of the rear 6.69 inches. The stroke of both is 10 inches. The tractive power is 3,190 pounds. The gross load on a level, including the motor, is 290 tons, and the price is 26,500 francs (about $5,300).

Another type is seen in the double-headed, duplex articulated engine, which is almost a duplication of "L'Avenir" just described, excepting that a single boiler drives both sets of pistons.

The lack of space precludes even a brief description of the remarkable development of these works of MM. Decauville at Petit-Bourg and their varied industries, with the excellent coöperative features of the establishment. Suffice it to say, that within a score of years it has expanded from nothing to a plant which covers about 20 acres and turns out daily 120 tons of railway material, including permanent way, and more than 100 types of rolling stock, yet all of comparatively diminutive sizes, making a great many pieces. The average weight of the permanent way is only 15 pounds per yard. About 5,000 miles of the Decauville railway have been laid in various parts of the world for shops, yards, agricultural and mining purposes. The railway connecting the various buildings of the exhibition, which rendered such excellent service during the preparatory stages of erection and in the subsequent transportation of visitors, is but a type of the many lines in existence of this very useful and portable system.

Engine for high speed.

M. Charles Saint Dizier has published a monograph descriptive of an engine designed by him for high speed, in which the drivers, either single or coupled, have a diameter of 3.2 meters (10½ feet), and the estimated velocity is placed at 74.4 miles per hour. To avoid the elevation of the center of gravity due to this increased diameter of drivers he proposes placing the boiler under the plane of the axles and the fire box between them, so that its size may be made to conform to the greater quantity of steam required for such service. There are but three axles in all; the leading wheels have a diameter of 3.28 feet. The axle passes through the smoke box, the plates of which are cut to permit of its passage. The journals are fitted with radial boxes for facility in turning curves.

The cylinders are placed about midway between the driving-wheel axles but outside of the frame. Each cylinder on the same side has two pistons. The boiler pressure is computed at 12 atmospheres, 176.4 pounds. The weight of the machine is given at 83,600 pounds.

It will require 13,200 pounds of coal and 3,750 gallons of water, carried by a tender supported on three pairs of wheels. The body of the cars will be designed on the American system.

Speed regulator.

A speed regulator for locomotives, patented by M. Hausshoelter and made by Dr. G. Hasler, at Berne, Switzerland, contains the following advantages: First, an apparatus for registering the speed on a band of paper every twelve seconds; second, by indicating on a dial every six seconds it enables the engine driver to keep a continuous record of the speed, and in case of any excessive velocity there is an annunciator which calls the attention of the engineer by ringing a bell. The entire mechanism, excepting the bell, is inclosed in a cast-iron case.

The Iron Car Company's exhibit.

As the object of every system of transportation, whether on land or water, is to overcome all resistances with the least possible cost, and as the greater portion of these resistances result from weight and friction, it is self-evident that the economical solution of the problem must lie largely in the direction of reduced ratio of dead to live load and diminished friction. Any improvement, therefore, which increases the capacity of a train without augmenting its gross load, or, in other words, which reduces the weight of the vehicle whilst retaining its strength, flexibility, and size, must be a change in the interest of economy. Since the introduction of steel on a large scale, and in any required structural form, it has become possible to make these very desirable modifications in the form and material of railway rolling stock, and the Iron Car Company, of 120 Broadway, New York, deserve the highest commendation for the enterprise displayed by them in supplying this long-felt want by their excellent system of tubular frames for freight cars of all types and descriptions. By the substitution of steel tubes there has been effected a reduction in the weight of the dead load and an increase in that of live load, until the ratio of the two is considerably more than doubled.

The several parts of these cars are made, as far as possible, on the same pattern, so as to be interchangeable. They are all light and can be readily shipped to any part of the world and are capable of being assembled by an ordinary mechanic.

The best result hitherto obtained with wooden cars has been, for dead weight, 20,000 to 23,000 pounds for a load of 40,000, or a ratio of 1 to 2. The tube-iron car weighs from 18,000 to 25,000 pounds, according to the size and weight of the body. Its regular load is

60,000 pounds, giving ratios of 1 to 3⅓ and 1 to 2.4. It is computed that on the coal tonnage of the Philadelphia and Reading Railroad for one year the saving effected by the use of the iron car would have been $1,729,076.

The oldest train of these cars has been in service over ten years and it has cost practically nothing for repairs excepting to paint them. Carefully collected statistics show that while wooden freight cars cost on an average $59 per year for repairs, and wooden coal cars $36.49, the outlay on the tube car has not averaged 50 cents per car.

The following data relative to the types of these cars will serve to confirm these claims as to capacity:

	Capacity.	Weight	Length inside.	Depth.	Width inside.	Cubic contents, including drops	Remarks.
	Pounds	*Pounds*	*Feet.*	*Feet.*	*Feet.*	*Cu. feet*	
Series A, drop-end freight	60,000	19,600	33	15	7	900	
Series B, drop-bottom freight	60,000	21,800	32½	15	7½	930	
American Midland Railroad, No. 4	60,000	21,400					Gondola.
New York, Susquehanna and Western Railroad.	60,000	25,500					Box, open.
Southern Iron Car Line, No. 608	60,000	18,800					Flat car.
Beech Creek Railroad, No. 6201	*30	25,500					Coal car.
Rome Railroad of Georgia, No. 751	60,000	21,800					Gondola.
Chesapeake and Ohio	60,000	25,500					Box, open.

*Tons.

Another test of strength of these cars is to be found in the use of them for the removal of the Brighton Beach Hotel a distance of 595 feet in the spring of this year, to protect it from the encroachments of the sea. This building was 460 feet long, with an average depth of 210 feet, three to four stories high, with five large towers. Its total weight of about 6,000 tons, was supported on 112 cars, resting on 24 railroad tracks, for more than 6 weeks. This would give an average load of over 53 tons, omitting any effects due to wind; but it is believed that the load on some of the cars exceeded 120 tons, yet there were no indications of excessive loading visible on the cars, nor any injury to the building, which would have resulted had the cars yielded to the pressure.

There are now about five thousand of these cars in use in the United States, where they are attracting great attention, and it is expected that during the current year ten thousand more of them will be supplied to fill orders.

By thus reducing the cost of movement the market range of all commodities is increased, while at the same time the revenues of the railroads using them are augmented. But it is manifestly impossible to do this subject of the economics of railway management justice in this limited report. The interested reader must be referred to the standard works of A. M. Wellington, Robert Gordon, Edward Bates Dorsey, and others.* Suffice it to say that these cars have come nearer to a correct solution of the great question of economic transportation than any other form of plant which has come under our observation.

It may be confidently asserted, therefore, that the tube-iron freight car will supersede the wooden car, for the following reasons:

(1) It is from 2,000 to 5,000 pounds lighter.

(2) It will carry from 10,000 to 40,000 pounds more than wooden cars now in use, its capacity being 60,000 pounds and upwards.

(3) Being built exclusively of double-refined iron and steel, it is durable.

(4) The cost of repair is reduced to a minimum; cars are now running after five years' service without other repairs than an occasional coat of paint.

(5) The saving due to lessening of dead weight is more than equal to the mileage on an ordinary car.

(6) The saving due to increased load is more than equal to first cost of car.

(7) The car rides as lightly as a carriage, thus greatly reducing the wear and tear upon rails and roadbed.

(8) The length of train being shortened one-third to one-half, the required engine power is reduced in proportion.

(9) A less number of cars being required, the saving in dead weight may be utilized by a corresponding increase in paying load.

(10) The draw frames are the strongest ever devised; they are invulnerable to an impact that would wreck the wooden car.

(11) In case of a wreck the salvage on the tube-iron car greatly exceeds that of the wooden car. All the parts being interchangeable, the injured portions may be readily removed and replaced with new parts.

(12) The car is very elastic. The movement around curves is noticeably easier upon the engine than in trains of wooden cars.

COMPRESSED-AIR MOTORS.

The Société Nouvelle des Moteurs à Air Comprimé show some of their machines designated as the system of L. Mekarski.

These motors are modifications of those which have been operating at Nantes for ten years, but they are built larger and heavier to increase their capacity and adhesion. They will carry fifty persons

*The Economic Theory of Railroad Location, by A. M. Wellington, civil engineer: Engineering News Publishing Company, New York. Gordon on Economical Construction of Railways: Proceedings Institute of Civil Engineers, Vol. LXXXV. London. English and American Railroads Compared, by E. B. Dorsey: Transactions American Society Civil Engineers, Vol. XX, New York, 1886.

on each car, viz. twenty inside, twenty-four on the top, and six on the rear platform, being very similar in construction to the cars of the Paris General Omnibus Company. The total weight with passengers is about 28,600 pounds, although the motor itself weighs but 16,500.

The consumption of air on an undulating line as actually measured amounts to 22 pounds for 0.62 of a mile (3,280 feet) for the motor running alone and 28.6 pounds when hauling an ordinary car. Comparing the results with the consumption of fuel for ordinary steam or even with hot-water engines under the same or less favor-

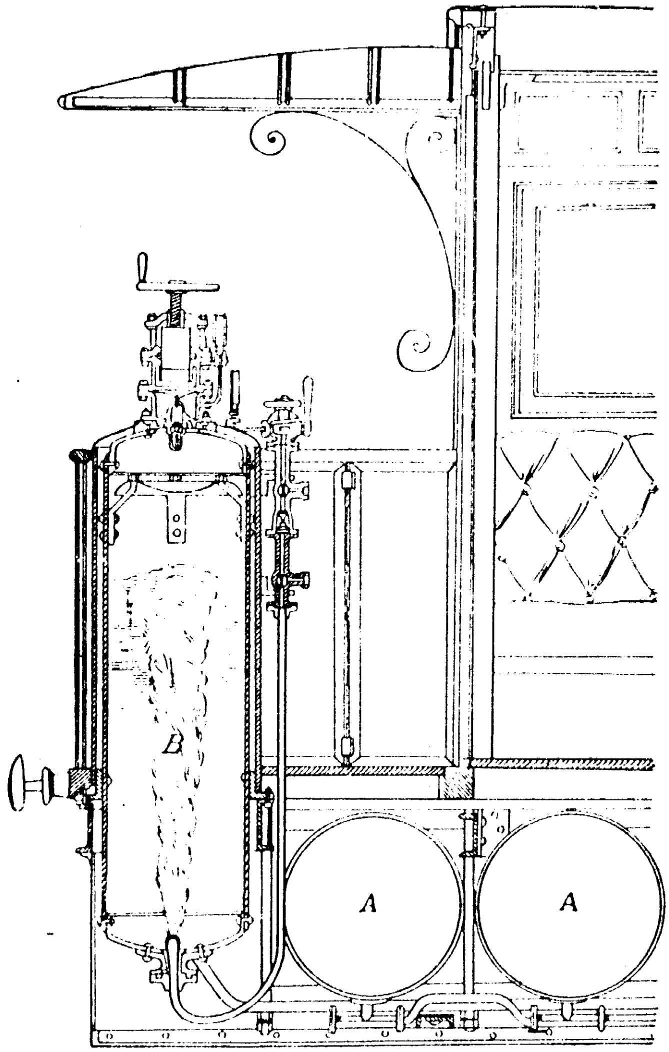


FIG. 52.—Mekarski compressed-air motor.

able conditions and deducing the weight of vapor expended by these machines per kilometer of run it is easily seen that one kilogram (2.2 pounds) of compressed air furnishes very much more useful work than one kilogram of steam. Similar conditions in favor of the compressed-air motor exists with reference to the other items of expense.

The general arrangement of the cylinders and hot-water boiler is shown in Fig. 52, where A A represents the cylinders for compressed air, in front of which is placed the heater B, through which the air circulates on its way to the pistons. It enters through a rose by which it is divided, passes up through the liquid columns and becomes heated and saturated with vapor at a temperature which is recorded during the trip at the same time with the pressure, hence the consumption of air and water can be readily determined. The use of compressed air is not so objectionable as has been supposed, and is justified as an intermediate step between the expense of a stationary and a small locomotive engine.

These compressed air motors are in use on the tramways of Nantes, in the mines of Graissessac, Chemins de fer Nogentais, and in Berne (Switzerland), and designs have been prepared for the proposed Metropolitan Railways of Paris.

The practicability of this system will be seen from the following brief account of the road at Nantes:

Here there are two lines in operation, the one, 20,054 feet long, has been working since February 13, 1879, the other, 7,380 feet long, since June 14, 1888. Both have proven entirely satisfactory. The plant consists of twenty-two automotors without upper deck, capable of carrying from thirty to forty passengers; four ordinary carriages with double deck for forty-six persons, to be attached to the motors when the traffic is heavy.

These motors weigh when empty about 14,300 pounds. Their axles are disconnected and they mount without difficulty the grades found on the line (one of which is as high as 4½ per cent), with a carriage attached, in ordinary weather.

During the last half of the year 1888 the following results were obtained:

Number of miles run	174,006
Number of passengers carried	1,547,430
Receipts from operation	$45,760.00
Receipts per mile run	$0.263
Receipts per passenger	$0.029
Expenses of operating	$32,617.17
Expense per mile run	$0.187
Expense per passenger	$0.021

The profit per passenger was therefore about 8 mills and the average length of ride per passenger was only 580 feet.

For traction and maintenance of rolling stock there was required $15,182.20, or 8.7 cents per mile.

The application of compressed air to tramways was thoroughly studied in the winter of 1878-'79 by Gen. H. Haupt for the Pneumatic Tramway Engine Company of New York. His exhaustive report may be found in the proceedings of the Engineers Club of Philadelphia, Pennsylvania, for 1879. In it he has demonstrated the great economy to be derived from this form of motor and especially when supplemented by the hot-water tank as used on the Mekarski motors, yet it is a field in which comparatively little progress has been made.

These motors are well adapted for subterranean lines for cities of the first class.

III.—The permanent way.

Probably no part of the railway structure exercises a greater influence upon the economical management of the road than does the permanent way. Its first cost is therefore a matter worthy of serious consideration, but this is a function of various local conditions such as the character and prices of the materials and labor available. Hence it is that so great diversity is found in the existing lines of roadbed in different parts of the world. Of the various elements which constitute the way, the most important in point of maintenance is the cross-tie or sleeper, since it is not only essential to aid in distributing the load over the roadbed, but to preserve the gauge of the track. It is therefore subjected to complicated cross and longitudinal stresses, which it should be designed to resist as well as to afford facilities for readily and securely fastening the rail and for removal of the tie in case of necessity.

In countries where timber is abundant these requirements are most economically satisfied by the use of the various species of oak, black locust, chestnut, beech, red elm, cherry, maple, butternut, tamarack, yellow pine, red and white cedar, and lignum-vitæ; occasionally hemlock and white pine are used, but they are only temporary expedients, not justified in good practice, and dangerous.

As the life of wooden ties is limited to from five to seven years, involving an enormous consumption of timber annually, many companies, especially in Europe, have erected creosoting plants for treating the ties on their lines, and at the same time they have to a large extent resorted to the use of metal ties to increase the durability of the roadbed. So extensively has this been done that there are now many hundreds of miles of such lines in use in France, Belgium, Germany, England, and other countries.

A few of these forms of ties and roadbed are to be seen under the rolling stock of the various companies at the exhibition. On most of the lines the ballast consists of gravel, which packs readily in and under the ties. The forms given to these latter are such as to prevent the shifting of either the tie or the ballast. They are of mild steel, wrought and cast iron not being found entirely satisfactory, and are made of a thickness and weight varying from 65 to over 100 pounds. Between 20 and 30 miles of steel ties have been laid on the London and Northwestern Railway of England for over seven years. There is some difficulty in adapting the steel tie and chair to the "bull-headed" rail, but this disappears with the use of the flange rail of the American pattern.

In France various systems of ties have been tried. In 1886 there were 17,000 of the Post ties ordered and 80,000 of the old "Berg-et-Marche" type in use. Last year there were reported to be in operation 2.10 miles of the Paulet-Lavallette; 16.25 miles of ties similar to the Post, with 30,000 more ordered; 4.4 miles of the Vautheren ties, of uniform thickness, and 4.5 of the same with varying thickness, and 0.56 of the Boyenval and Pousard types.

In Holland, where timber is scarce, continuous and successful experiments have been made, and after frequent modifications the tie which seems to give the best result is that invented by Mr. J. W. Post.*

The first trials were made in the Netherlands in 1865, of a combination tie (Cosýns) of iron **I** beams, with oak cushions, but while at first giving good results they are now superseded by those of the improved Post type. Nearly 500,000 of these ties are now in service on different continental lines. Their average weight is 116 pounds.

A modified form, known as the Durand tie, made of old rails and scrap, has recently been introduced. Its weight varies from 65 to 100 pounds, and it is claimed to cost only $1 for the lighter variety and $1.35 for the heavier. The cost of manufacture is put at 30 cents.

There are many forms in use for supporting the rails, but most of them have not been in service long enough to furnish definite data as to their peculiar merits. Several hundred patents have been issued in the United States alone during the past six years. Of these only a few are to be found on exhibition. A comprehensive digest of them may be found, however, in the report compiled by Mr. B. E. Fernow, chief of the Forestry Division, Department of Agriculture, Washington, with much valuable material relative to ties in general, contributed by Mr. E. E. R. Tratman, civil engineer.†

In Germany the use of metal ties has increased rapidly, having extended from 730,000 to 770,000 tons during the last year.

The average weight of the flanged rail is 70.5 pounds per yard, and nearly 50 per cent of those in use are of iron. There are 9,159 miles of track laid on metal ties, an increase of 659 miles during the year.

The average number of wooden sleepers is only 1,765 to the mile, and of these, 73 per cent are "preserved."‡

In England, also, it is the practice to space the ties about one yard apart (see Fig. 52 *a*) and to use creosoted timber, while in the United States there are from 16 to 17 ties to each 30 feet of track (one ordinary rail length) giving 2,816 ties per mile.

Taking it at only 2,600 as an average of all roads, there would result for the 160,000 miles of roadbed, 416,000,000 cross-ties.

* Engineer of Permanent Way, Netherlands State Railway Company.

† See Bulletin No. 3, Forestry Division, Department of Agriculture, U. S., 1889.

‡ Annual report on Railroads of Germany.

If the average life of a tie be but 5 years there would be required for annual renewals over 83,000,000, representing in round numbers for material alone about $50,000,000. Hence the importance of securing a good, cheap, and durable metal tie.

At the price of the Durand tie it ought not to be many years before the use of wood is largely superseded by mild steel.

The Webb tie.

Mr. F. W. Webb, the enterprising superintendent of the London and Northwestern Railway, has been using a steel tie with steel chair on that road for some years. In 1888 there were 83,204 such ties in use. The general form is an inverted trough either rolled or stamped. The chair is composed of two plates bent to fit the English rail on one side and on the other to grasp the oak key, there is also a base

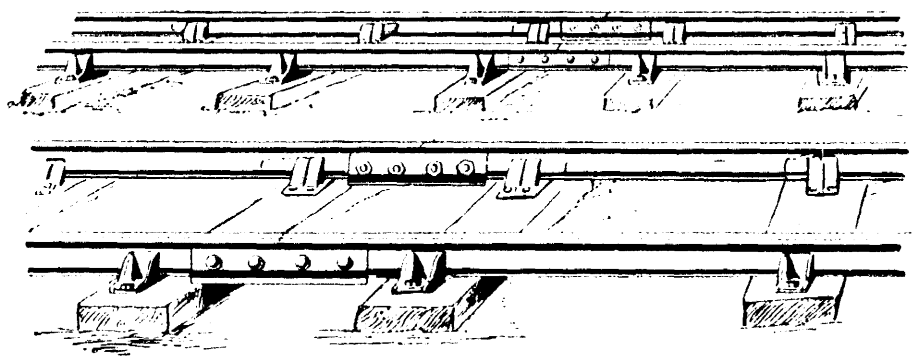


FIG. 52 *a*.—English track with wooden ties.

plate under the rail and chair. The parts are assembled by rivets, making a number of pieces, which can be united, however, before leaving the works.

The Belgian (Z) iron tie.

A form which is found to give good results in Belgium consists of two angle irons rolled in the form of Z's with the web vertical. The top flanges flare outwardly, the bottom inwardly but touching. They are braced apart by a cast-iron chair placed under the rail and riveted to the tie. This chair is grooved for the rail seat and is fastened to the rail flange by a steel key. These ties are in use on the Charleroi suburban lines, where the grades are as steep as 6 per cent and there are curves of 82 feet radius. Gauge 3.28 feet (1 meter). They work smoothly, are free from noise, and very secure. They weigh but 114.4 pounds for this gauge, but for standard gauge with heavy traffic the weight should be increased to 209 pounds.*

*See Engineering News, September 7, 1889, for illustration.

RAIL JOINTS AND FASTENINGS.

Very few special forms of joints were exhibited, but the standard types were shown as a part of the permanent way. These were generally suspension-spliced joints, consisting of two fish plates of various forms fastened by four bolts passing through slots in the rail. On some roads these plates were but 18 inches long, with the first bolt spaced 2 inches from the end, the second 4, leaving 6 inches pitch between those at the center. In several cases the fish plates overlap the bottom flange and project about two inches downward to increase their stiffness.

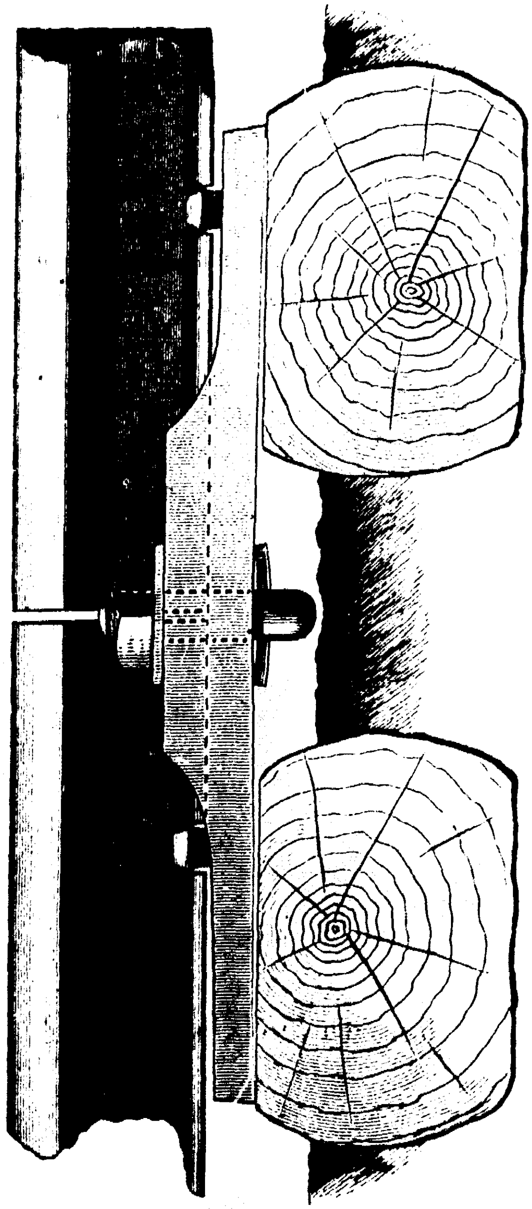


Fig. 54.—The Clark-Fisher Company's "bridge joint."

The latest American practice as exemplified on the Pennsylvania Railroad is to increase the length and bearing of the joint by using a longer scarf, covering 28 inches or more, and having in some cases as many as six bolts. When only four are used the spacing is 5, 11, 17, 23, 28, making the pitch 6 inches from center to center.

The end ties are also placed a little closer than the rest to give a bearing for the fish plates, and the rails are made to break joints, whereas in England the practice is to lay the joints opposite. The British and Continental method of keying the rails to each tie by means of chairs and wedges gives greater stiffness for a lighter rail and permits of great economy in ties. On some roads it is the practice to place the wooden key on the inside of the track, while on others it is on the outside.

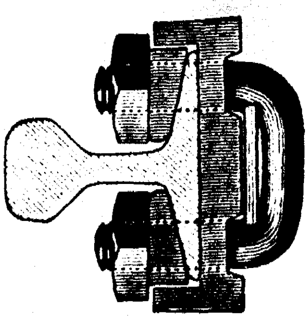


Fig. 53.

Of American manufacturers the *Clarke-Fisher Company*, of Trenton, New Jersey, exhibit their "bridge joint" (see Figs. 53, 54), for which they claim the combined support of two ties acting as one for each joint, and rail ends carried directly by the arched beam and

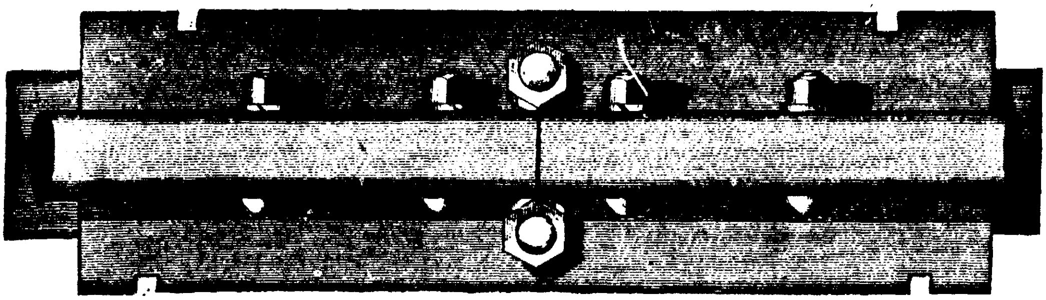


FIG. 55.—The Otis joint. Top view.

screwed down to it with a force of 15,000 pounds, making practically a continuous rail. No holes in web of rail, giving the whole surface of base for support and wear. No breakage of rails or joints. No "low joints." No "creeping." No loose nuts. Cost of keeping up track reduced to one-half of that with angle bars and giving smoother surface.

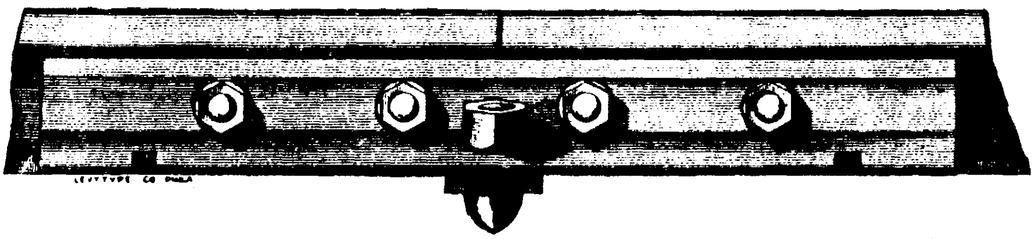


FIG. 56.—Side view.

The parts are assembled in the shops with the nuts screwed almost "home" so that, in track laying, it is only necessary to slip the ends of the rails under the "forelocks" or washers and tighten the nuts, care being taken to screw them down equally and simultaneously on the

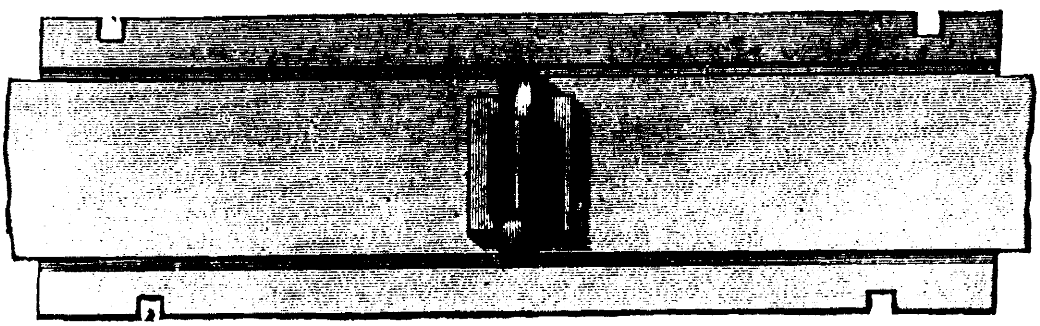


FIG. 57.—Bottom view.

opposite sides to prevent an oblique clamping of the bolt. So, in spiking, the spikes on the *same* side should be driven at the same time to preserve the alignment. With these precautions observed the abutting rail ends will be firmly held in the same horizontal plane and the joint be efficiently bridged without reducing the strength of the rail nearly 50 per cent by punching, as in the ordinary fish joint. This fastening readily adapts itself to any pattern of rail, and any wear is readily adjusted or taken up by tightening the nuts.

This is not a suspension but a supported joint with double the amount of support given by any other through the arched bearer.

To utilize still further angle-bar splices, which, without strengthening, would have to be rejected, this company has recently introduced a modified form known as the "Otis joint" (Figs. 55, 56, 57, 58), designed to be applied as a stiffening clamp and support to worn-out angle splices. It consists of a shackle placed under the joint and passing through two holes drilled in the lower flanges of the opposing angle irons, to which it is fastened by bolts, without "forelocks." The shank under the rail is made flat on top and is widened out to give a better bearing to the steel bridge plate, which is inserted between it and the base of rail. A better idea of this joint may be obtained from the illustrations.

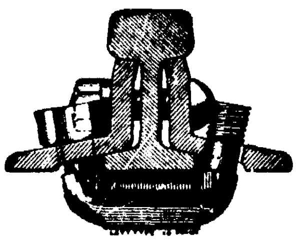


FIG. 58.—The Otis joint. Section.

By the use of this joint the ends of the rails are clamped together vertically as well as laterally and the injurious action incidental to the old form of spliced angle bar is entirely avoided. The result is a much longer life to the entire rail as well as to the rolling stock due to the stiffening of the joint, practically making the rail continuous. The Otis joint is not intended to supersede the Fisher, but merely to be used in strengthening the ordinary fish-plate.

The Hoffmeier system.

As the continuous longitudinal stringer or "balk" has some inherent defects and the cross-tie does not give a continuous support, Mr. A. K. Hoffmeier, of Lancaster, Pennsylvania, has conceived a form of tie which is designed to meet both objections.

In the language of the inventor, the improved tie consists of a central piece or beam about 8 inches wide, with arms, each of 8 inches length, projecting from both sides and directly opposite, near the ends thereof. These arms are made integral with the central beam, and with it form a continuous bearing or rail support when the ties are laid in a roadway. The contiguous arms are adapted to connect with each other by means of tongues and grooves, one of each pair of arms having a horizontal groove in one end, the other a corresponding tongue, but the tongues and grooves are located at the end of opposite arms of the pairs of each tie, so that any two ties will interlock when laid down, no matter which sides of the ties may be brought together. On the upper surface and along the center line of these projecting arms is placed a shallow groove or channel adapted to receive either the flat base of the ordinary T rail or elliptic base of the English rail.

The tie and its arms are made hollow on the under side by tapering downwards the upper surface toward the outer edge, along which is placed a thickened vertical flange or rib, giving to the tie sufficient depth and strengthening it, as is illustrated in Figs. 59 to 64, inclusive; or, the upper surface of the tie and its arms may remain flat, having attached underneath a strengthening rib of sufficient depth, placed vertically along their center lines, as is illustrated in Fig. 65.

Through the tie on each side of the rail bed or channel and close to its edges are cut perforations adapted to receive the bolts and other fastening devices used to hold the rails in place. These perforations are shown in the several plan views in Figs. 59, 62, 64, 65.

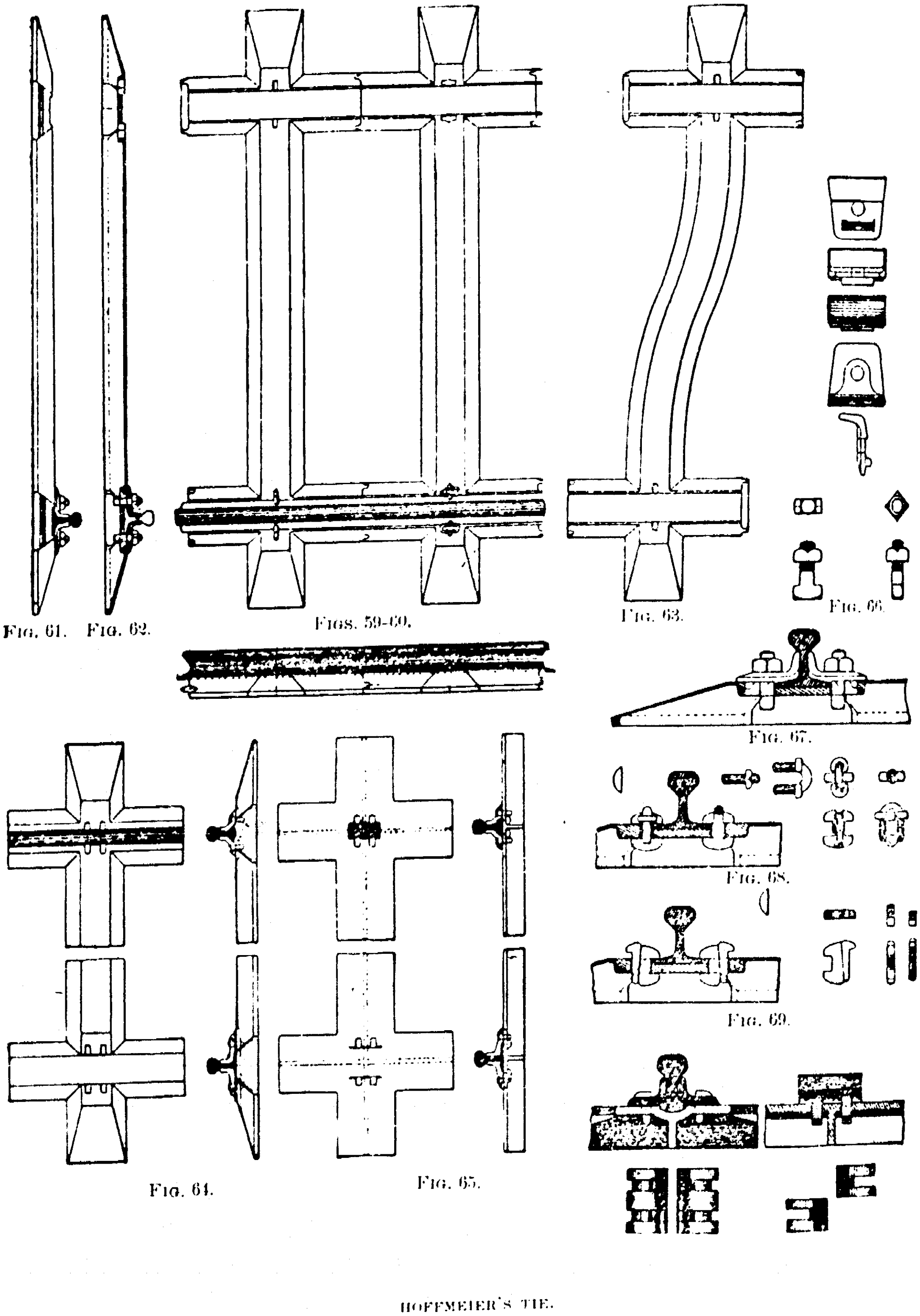
Two clamping-plates, bolts, and nuts, as shown in detail in Fig. 66, are used where two rails meet to hold the ends of said rails to the tie, as is shown in Fig 67. This joint should always be at the center line of a cross-tie. This clamping-plate consists of a vertical and horizontal portion, forming an angle iron; the vertical portion is adapted to engage and bear against the web of the rail, and the horizontal portion is adapted to engage and bear on the base of the rail, the rear end resting on the upper face of the tie; a shoulder on the bottom of this plate is adapted to bear against the edge or vertical face of the rail channel, and a log near the rear end is adapted to bear against the rear face of the orifice or perforation in the tie, the two preventing said plate from slipping away from the rail, while the T-bolt and nut hold it downward in place (see Fig. 67).

On each side of the rail channel, near the upper ends of the intermediate ties, and on the center lines, are shown perforations adapted to receive the double-jawed clamp-bolt and locking-staple shown in detail, Fig. 68; two of each are used to hold the rail in place, as shown in the sectional view, Fig. 68.

On each side of the rail channel, near the upper ends of the two end ties, and on the center lines, are placed perforations adapted to receive the single-jawed clamp bolt and locking wedge key shown in detail in Fig. 69. Two of each are used to hold the rail in place, as shown in the sectional view, Fig. 69.

When it is desired to have the joints of two contiguous ties not in the same line, a form of cross-tie shown in Fig. 63 may be used, the center lines of the opposite ends being about 8 inches perpendicularly apart.

It is claimed that this system of railway track laying furnishes a continuous bearing or rail support throughout the entire length of



HOFFMEIER'S TIE.

track, using a less number of ties than would be required to lay the same length of track with wooden ties under the present American system.

No up-and-down motion where two rails meet, as the load on them passes from the end of one rail on to the end of the other, as is the case in the old system.

The rail channel in the ends of the ties forms a continuous rail seat that effectively prevents throughout the spreading of the rails and the consequent derailing of trains, liable to occur at any point in the present system.

A solid, compact, and continuous roadway makes the entire track a unit, imparting a smooth, even, and easy motion to a passing train; no jarring, jolting, or excessive rattling, as is the case in the present roadway of the wooden tie.

A complete chair for the seating of the elliptic base of the English rail; in fact, of any base of any rail without the extra piece fitting and bolting required in the old wooden-tie system.

A continuous bearing or rail support, preventing the springing or bending down of the rails between the ties, caused by the heavy trains passing over them, straining them, and, with the abrasive force of the loaded iron wheels, causing the rails to scale and strip, as is the case in a roadway of wooden ties in the present American system.

No use for fish plates and no holes through the web at each end of the rails; doing away with the two fish plates, six bolts, and nuts required at each rail joint in the old system, under which in each mile of track, there being 352 rail joints, are used 704 fish plates, with 2,112 bolts and nuts, requiring the constant and careful attention of trackmen, while in the new system the clamping plates and T bolts take their place, requiring in the same distance only 704 of each, yet making in every respect a superior joint.

No spikes to be driven into intermediate ties to hold the rail base to them, the double or single-jawed clamping bolts taking their place.

No chairs to be spiked to the ties where the ends of two contiguous rails meet; the rail channel in the tie forms the base of the chair, while two clamping plates, one on each side of the rail, complete it, each clamping plate being held in place by a T bolt and nut.

No use for bridge joints of any kind; the ties forming a continuous bearing, leave no portion of the rail to drop or break.

No holes through the web at the ends of the rails (fish plates being discarded) to weaken them where, if anywhere, they should be strongest.

WOODEN CROSS-TIES.

The Cie Boñe-Guelma use cross-ties of oak 8.2 feet long by 9¾ inches wide and 5½ thick. There are two varieties: (*a*) the *chêne zéen* from the forests of Beni-Salah (Algeria), weighing 235.4 pounds; (*b*) the *chêne zéen* from the forests of Ouchtettas (Tunis), which weigh 209 pounds. These oaks are a peculiar variety found on the coasts of

Barbary, where they cover an extensive territory in the mountainous regions of the Kroremirie. They remain green all the year, and attain a height of from 80 to 100 feet and a circumference of 9.8 feet. They grow rapidly and with great density, having a specific gravity of about 1.26, and decay very slowly, making them unusually valuable for these purposes. The principal defects result from a tendency to warp and check, making it necessary to fell the trees when vegetation is least active, that is, in midwinter.

Other ties are obtained from the extensive forest of beech on the sand hills of Croatia, cut when the trees are about sixty to ninety years old. After treatment with chloride of zinc and exposure to the air they acquire a remarkable durability. The treatment consists of the three operations of sweating or drying, pumping a vacuum and injecting the antiseptic.

Ties of the eucalyptus tree have not yet been generally introduced by this company, but from the tests made up to date it is hoped that they will be found to answer the purpose. It should be noted that only the *Eucalyptus resinifera*, or red gum, should be employed, because of its straight grain, while the *Eucalyptus globulus* gum should be rejected because of its crookedness.

OTHER METALLIC TIES.

Sévérac's system in mild steel (4-feet 9-inch gauge).—This tie is formed by an I beam of mild steel resting at each end on a steel plate. Two chairs are riveted to the girder and the rail is supported on the chairs by a steel cotter held by friction between the flange of the rail and a lug on the chair. The weight of such a tie, with its fastenings, is about 114 pounds, and its length is 7.12 feet.

The Boyenval and Ponsard system is composed of double channel bars closed at their extremities by beating down the ends of the metal in the press. The bed plates are attached by four rivets, the outer edge having a lip extending throughout its length, which is fixed on the tie by two of the four rivets, giving a bearing of 3.78 inches on the outer rail flange. The interior edge is held by a nut. The weight of the tie, with fixtures, is about 125 pounds, and its length is 7.54 feet.

Two thousand five hundred of these ties of both systems have been under trial since they were inserted, from March, 1888, to April, 1889, and although the time has been too short for any conclusion as to economy of maintenance, yet it is said they have required no special attention, and that the movement of trains over these sections is very smooth; neither was there any difficulty in putting them in place.

The Paulet system (Fig. 70).—This metallic way comprises two systems resulting from the same idea, one simple, the other doubled or coupled.

They are equally applicable to roads of any gauge and to rails of any pattern.

The principles involved are: (1) The bearing surface of the tie on the ballast is made flat; (2) the attachment of the rail to the tie is made by the intervention of chairs with locking wedges of wood for the double-headed rail (English), and of iron or steel for the T rail (Vignoles pattern): (3) the keys are slightly conical. The fastening of the chair to the tie is simple and firm.

The Sandberg system.—The new Goliath rail section, as exhibited by Mr. Sandberg, has a wider head than the old pattern, being 3 inches instead of 2¾, and it is 1¾ inches in depth instead of 1½. The head, however, contains a little more metal, namely, 2.5 per cent. There is no change in the web, but the flange is correspondingly lighter. The top is somewhat more curved than formerly, the radius being 8 instead of 10 inches.

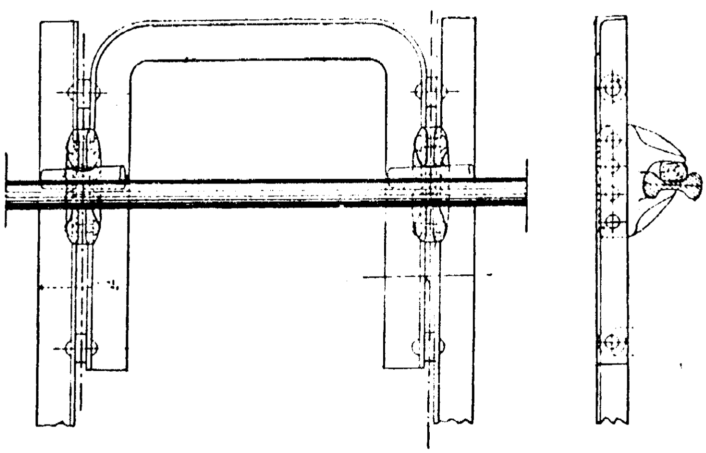


FIG. 70.—The Paulet iron tie.

A thin base plate is recommended to be placed under the rail on each tie, say 12 by 8 by ½ inches, and thus secure a good and safe permanent way at a cost somewhat less than that in the English bull-headed rail.* This new pattern of rail weighs 100 pounds, and has been in use in Belgium since 1885, when it was rolled by the Société Cockerill. It is claimed to possess many advantages over the lighter rails aside from its relative economy, and its use is being rapidly extended. The cross section of the rail and fish plate, as shown in the accompanying Fig. 71, represents that now in use by the Pennsylvania Railroad on its main line, and will give a good idea of the heavier Sandberg rail and fastening.

The Magnat system.—The system designed by M. Edmond Magnat is one permitting cars to turn curves with a radius no greater than the breadth of the vehicle. It consists of a pair of guide wheels placed under each end of the trucks to direct their motion. These

* Engineering, July 26, 1889, p. 117.

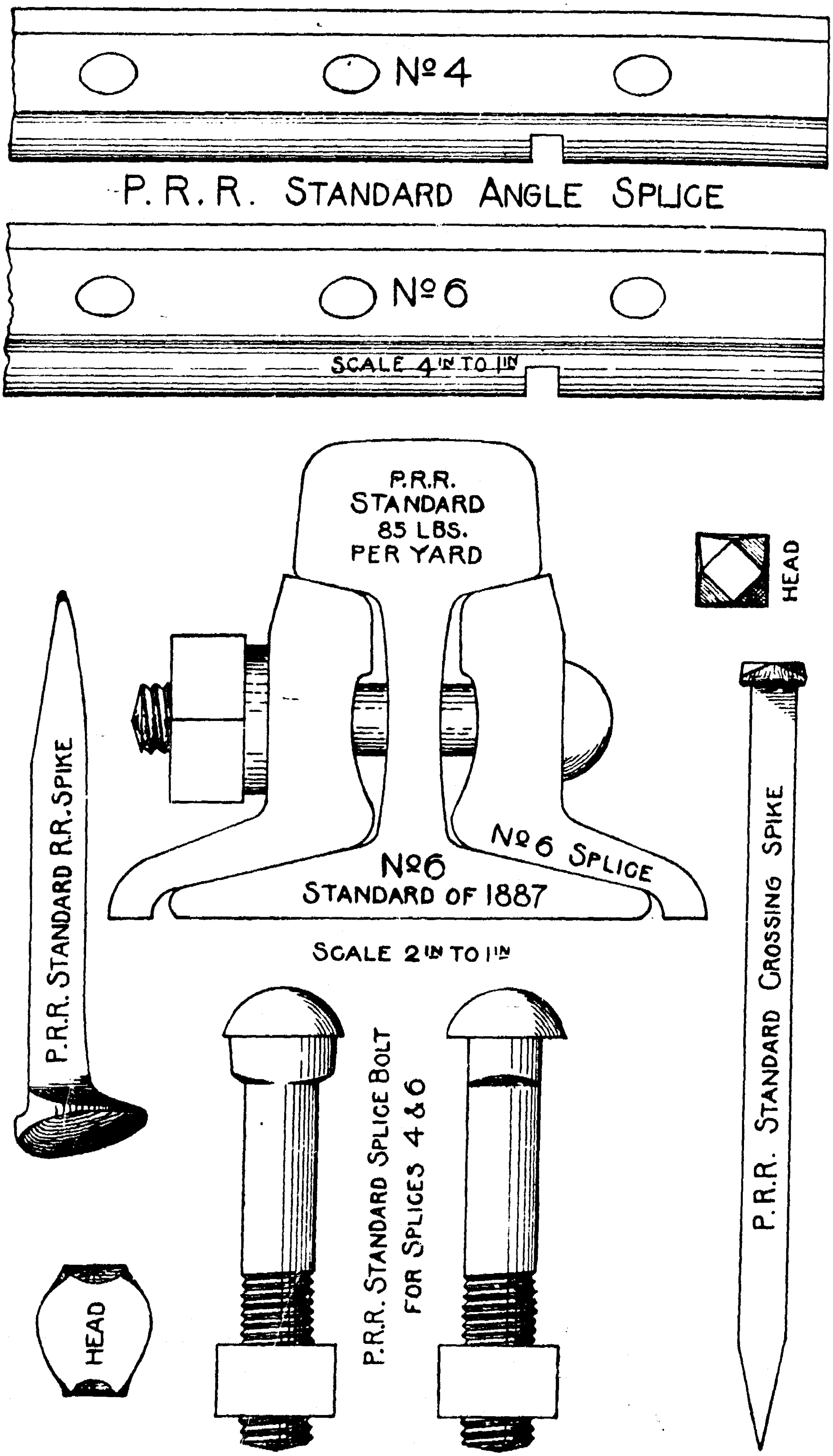


FIG. 71.—Heavy rail and fastenings used on the Pennsylvania Railroad.

wheels bear upon the cheeks of a central rail so placed as to follow the line described by the apex of a triangle, the base of which is the axle of the single pair of wheels supporting each half of the truck. This latter is articulated, the halves being supported by a hinge or draw bar which permits great freedom of motion in a horizontal plane, but prevents any deformation in a vertical direction. On the curve both the front and rear axles follow the same path, but at the tangent point the rear guides follow a different curve c_2 c_3 c, while the forward ones take the path c_2 k c (Fig. 72).

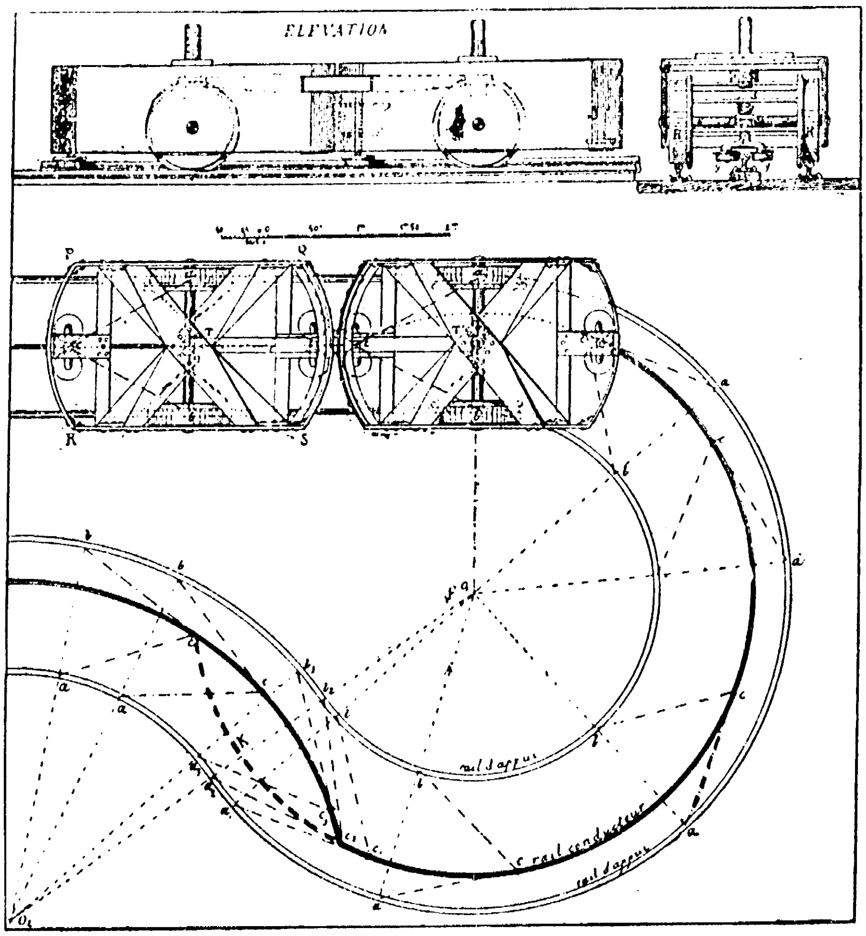


FIG. 72.—Magnat system.

The advantages claimed for this system are to diminish the chance of derailment; to reduce the friction on curves; to permit the passage of curves of 50 feet radius, with wheels keyed on their axles, but with loose wheels the radius may be no greater than the width of the car body (2.5 meters) 8.2 feet; to admit the rolling stock of this system on ordinary ways by locking the articulation by a rigid beam; and to reduce the cost of construction to a minimum by permitting a "surface" line to be adopted.

The central rail may be placed on the same ties as the others and may be of lighter weight. The form of switch required is shown in Fig. 73.

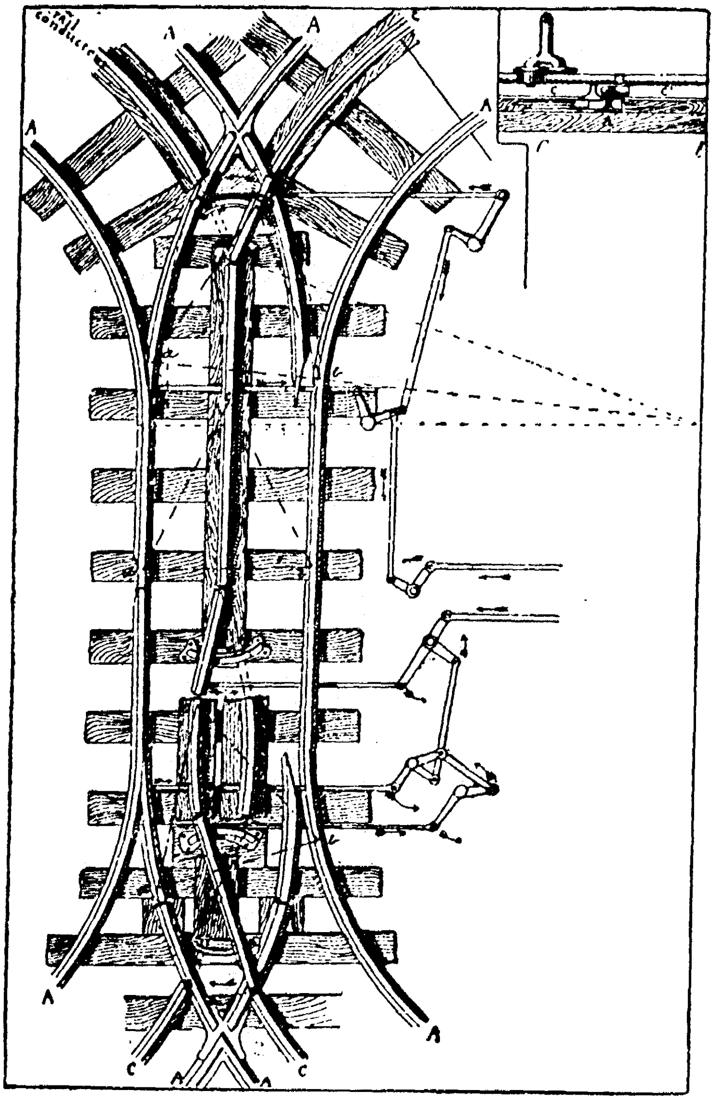


FIG. 73.—Magnat Switch.

PORTABLE RAILWAYS.

From the extensive works of *Achille Legrand*, at Mons, Belgium, there are shown material for narrow-gauge railroads, comprising a locomotive, a mixed carriage, two third-class carriages, an ambulance car, and cross-ties of iron.

The peculiar features of this portable way consists of the iron ties and their fastenings. The ties are inverted channel bars having a bent lug, serving as a clamp, bolted to the upper face. On one tie both of these clamps will be placed on the inside of the rails and on the adjacent tie upon the outside. By this alternate arrangement of outward and inward flaring lugs the track can be laid rapidly by merely slipping the tie under the rails obliquely and then revolving them into their true position at right angles to the rails, where they are held by tamping. They require no bolting or spiking in the field.

The catalogues of the company show great variety in the forms and weights of both ties and rails. The ties are adapted to the Continental and American patterns of rails. For the former they are flexed vertically, forming a recess or trough in which the rail is laid and keyed by the usual hard-wood wedge. The company manufacture all varieties of rolling stock from the simplest truck to the most complicated motor.

The Legrand journal box is simple, compact, and durable. It is a light cylinder, embracing the journal and closed at its inner face by a wooden packing block which surrounds the shoulder of the axle. The lower bearing is omitted. Fastened to the outer end of the journal there is a projecting feather, called a palet, which at each revolution dips into the pool of oil collected in the bottom of the box, thus raising a portion to the journal. Its speed is automatic. The oil is introduced through a small hole, closed by a bolt, on top of the box.

H. De Ville-Chatel et Cie, of Brussels, have displayed their "Voies de Soignies, portatives," and the different forms of rolling stock used on them. In this system the track is very light, the normal length of rail is 16.4 feet, and the weight of one section of track with its five ties attached is but 132 pounds. The extreme ties are placed near the ends of the rail to support the joints, which are opposite and made with light fish plates. The ties are light channel bars. The various patterns of iron rails range from 6.6 to 19.8 pounds per running meter.

Wagons, trucks, and dumping carts, crates, turn-tables, switches, crossings, frogs, cranes, and engines are all manufactured by this company according to the types shown in their illustrated catalogue, to which the reader is referred for dimensions, price, etc.

The monorail system of M. Charles Lartigue.—Another of the portable railways, which has already demonstrated its practicability by existing lines, was shown by its inventor at the exhibition. As the name indicates, it consists of a single rail supported at a variable height by batter posts which are bedded on a sill placed on the ground, forming a trestle or horse. The trestles are connected by a pair of horizontal braces which serve the double purpose of stiffening the way and steadying the trains, which have guiding wheels bearing upon them. The rolling stock straddles the track, overhanging it like panniers. The economy and advantages from this form of way are manifest and have been repeatedly stated.

Its extreme flexibility is an important characteristic, as by its use trains can turn curves of 82 feet radius or less without difficulty, and the stability of the train is greater than on the ordinary way. Switches are made by revolving a section of the way about a vertical axis, but grade crossings are readily avoided by elevating one or the other of the intersecting lines so as to pass overhead.

A line of this description 9.3 miles long was put in operation on the 29th of February, 1888, from Listowell to Ballybunion, in County Kerry, Ireland. The total weight of the track, including the trestles, does not reach 103 pounds per meter, about 31 pounds per foot, with horses one meter high and the same distance apart.

The rolling stock is adapted to all kinds of traffic, whether passengers, goods, animals, minerals, timber, etc. The boilers of the locomotive, placed on either side of the single rail, are united with each other and the steam cylinders. There are three drivers, coupled together.

The machines were designed by M. A. Mallet, with the most recent mprovements. They weigh 14,850 pounds, or, with tender 24,200 pounds. The tractive effort as given by the formula, $0.62 \frac{Pd^2 l}{D}$, is about 2,200 pounds. The 62 per cent is taken to cover losses by condensation and friction of machinery.

> P is the pressure of steam, 142.2 pounds.
> *d* is the diameter of the cylinders, 6½ inches.
> *l* is the stroke of the cylinders, 12 inches.
> D is the diameter of the drivers, 20.8 inches.

The speed obtained from the tractive effort is from 6.8 to 7.4 miles per hour.

Taking 12 pounds as the maximum tractive force per ton, there will result from these 2,200 pounds the ability to draw a train of about 183 tons, or, deducting the weight of the engine and tender, 11 tons, there remains for the load 172 tons. On a 2 per cent grade the net load would be about 28 tons, or 5 wagons of 5½ to 6 tons.

On the Listowell line trains have been run at a speed of 24.8 miles per hour, and the complete practicability and economy of this system is believed to be established.

The Abt system of railways for steep inclines.—Herr Roman Abt exhibits by drawing and descriptive matter his various improvements in mountain railways. These consist of a compound rack rail, composed of a number of bars having their teeth arranged in eschelon—that is to say, instead of the usual single rack or ladder between the bearing rails, this rack is divided longitudinally in two or more sections so placed that the teeth "break joints." By this means the pitch is divided into two, three, or more parts, which engage in as many different cog wheels or driving pinions mounted on the same axle on the engine, thus producing a more constant pressure and giving a much more uniform motion.

A second modification consists in the arrangement of the mechanism of the locomotive whereby two of its four cylinders are employed to drive the pinions on steep inclines and the remaining two the ordinary adhesion wheels on limited gradients.

The engine is adapted to operate on grades where practical limits have not yet been reached. On the Oertelsbruck railway the maximum gradient is 13.7 per cent, or about 1 in 7, and the curves have a radius of 120 meters. The weight of the engine is about 42 tons, having a tractive force of 6 tons, while on some roads it is as great as 54 tons.

The driving pinion is divided into two or more parallel disks whose teeth are so set as to engage in the corresponding portions of the split rack, as already described.

A third important improvement consists in an elastic entering section of roadbed which enables the train to pass from the ordinary way to the rack without stopping. This is accomplished by mounting the rack of this section upon involute springs which yield to the action of the pinions and take up the motion gradually as the rack engages with it, the pinion being meanwhile capable of turning independently of the supporting wheels so that the latter will not be compelled to slip or slide on the outer rails. This section of the rack rail is hinged to the main rail by means of links. The teeth of the entering section are also made of diminishing depth towards the entering end, so as to vanish at that end, and they are rounded off also to facilitate the admission of the train.

This very interesting and useful system has received universal recognition and the unqualified indorsement of the numerous scientific societies and is a very happy solution of a difficult engineering problem.

THE HYDRAULIC RAILWAY (CHEMIN DE FER GLISSANT).

This interesting and novel invention has only now reached that stage of development which enables its projectors to exhibit a model of sufficient magnitude to demonstrate the future possibilities which await its extensive application to the problem of rapid transit.

The line as constructed in the Esplanade is but 500 feet in length, yet the train makes the run in 30 seconds, including stops. This is only about 12 miles per hour; but it is claimed that this motor is capable of generating a speed of 200 kilometers (about 120 miles) per hour. It can be started and stopped in a very short distance, without shock. It glides along noiselessly upon a cushion of water, and is propelled by jets of water under pressure impinging upon a rack composed of horizontal buckets attached to the bottom of the train. There are no wheels, trucks, nor complicated mechanisms for reducing friction and giving stability, since the bearing points are "patins," skates or shoes, to which the carriage body is connected by a short spindle fitting into a socket. These skids are lubricated by a film of water fed to them from a reservoir carried on the train, and which is kept under pressure.

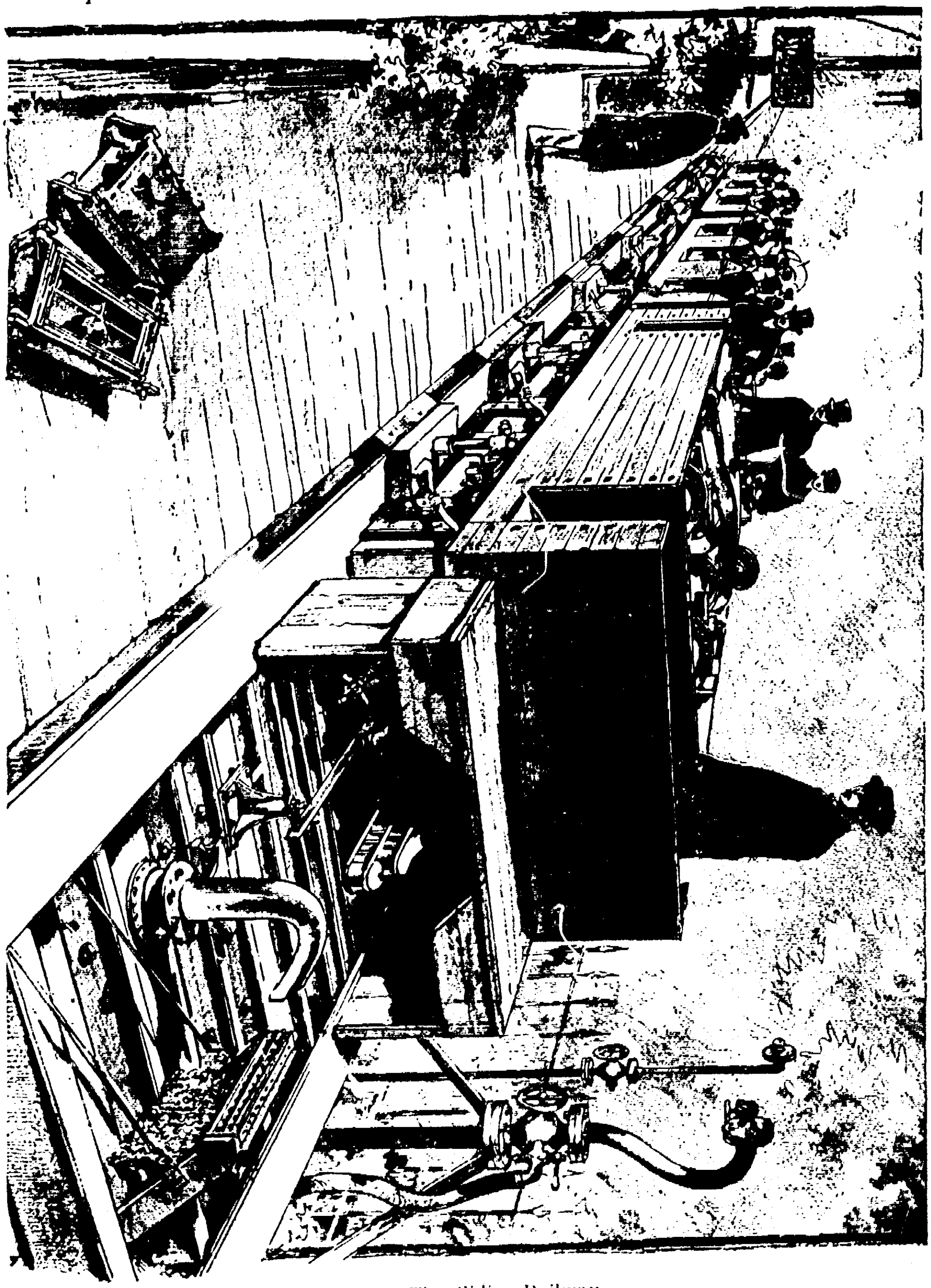


FIG. 74.—The Sliding Railway.

The waste water is conducted to a central trough under the way and utilized in part for propulsion. The water for this latter purpose is stored in a conduit laid under the track and having reservoirs at frequent intervals subjected to a pressure, in this case of about 10 atmospheres (147 pounds). The pressure is maintained in the mains by a stationary engine placed at any convenient point on the line.

The way itself consists of two continuous rails or plates, 8 inches in width, upon which the skates slide, and the necessary framework with the water mains and nozzles at short intervals for maintaining the constantly impinging jet of water. There are two series of buckets under the train, one flaring forward, the other backward, and two sets of jets on opposite sides, either of which may be thrown into play by the train guards, whereby the train may be started, stopped, or backed. After starting these valves are opened and closed by the moving train. The amount of water said to be required is 1 liter (quart) for each patin per second, and 21 liters per ton per kilometer, under a pressure of 10 atmospheres, for propulsion. In winter it is proposed to use 20 per cent of glycerine with the water to prevent freezing.

This remarkable departure from the use of steam motors for transportation was first conceived by M. L. D. Girard, a prominent hydraulic engineer of France, who in 1864 built a model of his project on his private grounds, and, under the patronage of the Emperor, Napoleon III, continued to experiment and improve his plans until his death from a bullet, in 1871, during the Franco-Prussian war. His collaborateur, M. A. Barre, has since continued the work and has organized a French company for the completion of the methods and introduction of the system embodied in this model,* which is one of the most interesting of the many novel attractions of the exhibition.

THE METROPOLITAN RAILWAY OF PARIS.

This grand enterprise, conceived and projected by M. Hagg and his associates, contemplates the opening of a wide avenue through the heart of Paris, upon which shall be constructed an elevated railway, forming an arcade in the middle of the street. It is intended to be built either in masonry or iron and to be finished so elaborately as to constitute an attractive architectural feature of the city.

The exhibit of the project consisted of large wall maps showing the plan of the route, with numerous sections, profiles, grades, tables of probable revenues and expenses, estimates of cost, and an interesting model of the city. The graphic manner in which the subject was presented left nothing to be desired. In plan the road forms an "inner belt," covering both banks of the Seine, with occasional loops and branches so disposed as to connect the stations of the various trunk-lines centering in Paris. These include the termini at St. Lazare (western), Du Nord (northern), De'l Est (eastern), De Vincennes, De Lyon-D'Orleans, Mont Parnasse, and Champ de Mars, giving a development of about 12½ miles.

As the design requires the purchase and removal of many valuable

*Sketches accompanied by a more complete description of this invention will be found in Engineering News of August 31 and October 26, 1889.

buildings and the reconstruction and opening of new streets parallel with the railroad, and many other conditions peculiar to this city which tend to increase greatly the cost, the estimate is made liberal to cover all conceivable contingencies.

The net cost of acquiring right of way is $55,000,000.

Of this amount the various railway companies would guaranty the interest at 4 per cent on fifty millions in tolls. The construction of the road and auxiliary works will cost about $20,000,000.

The annual receipts of the Metropolitan Railway are estimated at a minimum to be $3,280,000, from which is to be deducted $2,000,000 in annuities to the city, leaving $1,280,000 for distribution.

The general character of this project will be more fully realized by reference to the dimensions adopted for the estimate. Thus certain sections of the line are to embrace an elevated structure extending 28 feet above the streets and nearly 40 feet wide, with lateral avenues on either flank, each 65 feet wide, requiring the construction of two parallel streets, as well as the demolition of numerous obstructions. Yet, notwithstanding these unusual expenses, the company expects to clear sufficient revenue to make it a profitable investment. The question assumes importance as one of the solutions of the ever-present problem of rapid transit in cities, and it differs only from other elevated railways in the physical conditions which surround this particular project. The condition of the streets and sewers of Paris would constitute an almost insuperable obstacle to the construction of an underground road in this city, complicated as it would be by the necessity of crossing the Seine at not less than three different points.

MISCELLANEOUS.

Edward Noulet & Co. have on exhibition:

(1) A bridge of 30 tons weight supported on metallic foundations instead of the masonry foundations, which are always expensive and sometimes difficult. "The price of a bridge is 2,750 francs ($550)."

(2) A switch, left handed, with Goliath rails, designed especially for rapid trains and giving perfect security at the point of divergence. The price of the switch is 930 francs ($186). The annual output about 3,500.

(3) A metallic semaphore with three arms, with lamps and connections. Price, 1,200 francs ($240).

(4) A platform car having a capacity of 10 tons made very light and strong, at a cost of 1,200 francs ($240); 600 of these are turned out annually.

The exhibit of *W. H. Inloes*, of Asheville, North Carolina, consists of a model of a lock for a turntable.

Whilst this invention has not been as yet extensively introduced it is one deserving of consideration for its strength, simplicity, and cheapness. The experience with it in the railroad yards of the Richmond and Danville Company has demonstrated its practicability. There are two locks or bolts and two sockets required for each table, weighing together nearly 500 pounds. The socket is placed on the rim of the well in which the table revolves, while the bolt is attached to the table by means of a rectangular trough (open on top), in which it slides by a lever. The box or frame which guides the bolt is 18 inches long and 6 deep; the cheeks are 1 inch thick; the bolt is rectangular in section, 5 inches deep by 2½ inches thick. The socket is 12 inches long and 6 wide, made of cast iron 1 inch thick. The great merit claimed for this simple device is that it can not bind and is abundantly strong and safe. The price is $26.

The house of *Pierre Brouhon*, of Liege, Belgium, exhibit a dumping car with an automatic flap designed by the engineer, M. H. Brouhon, to save time and reduce the risk. This is accomplished by placing the body on a rocker so poised that it rolls over and dumps the load laterally by merely detaching a lever which releases the body from its normal position and opens the tip-car door automatically by means of a linkage connecting the door with the frame. By reversing the movement the door is again closed.

The Valère Mabile, of Mariemont, France, manufacture iron buffers of all descriptions, ironwork for wagons, grates, journal boxes, bascule bridges, crossings, switches, and the smaller parts of railways.

In consequence of the limited space assigned to this company only a small number of the one hundred and twenty-two kinds of buffers were exhibited. Particular attention is given to the manufacture of steel axles and elliptical and spiral springs, of which a very large number are produced annually. These extensive shops give employment to seven hundred workmen. It is here that the Dixon injector used by the Chemins de Fer de l'Etat, of Belgium, is made, also the Wilson valves, of which about two thousand five hundred have been manufactured in two years and sold to various companies. There is also a testing machine worth $1,000 for testing a great variety of forms.

The Merchants' Despatch Transportation Company, of No. 335 Broadway, New York, and of which Mr. John C. Noyes is the general manager, have placed one of their full-sized refrigerator cars on exhibition.

The body of this car is 33 feet long, 8 feet 2 inches wide, and 7 feet 6 inches high, inside dimensions, and it weighs when in service empty 36,000 pounds. It is a type of two thousand five hundred others owned and operated by this company on the railroads of the United States and Canada. These cars are used only for the transportation of fresh meats, vegetables, and dairy products. In consequence of the complete isolation due to the interior partitions the car is proof against the extreme cold of the winters in the Northwest and Manitoba, whilst during the summers the refrigeration renders perfect security on the longest journeys. The car is constructed to secure perfect purity of the air by the renewal of the water from the melted ice which circulates through small galvanized tubes.

The designs are those covered by the patents of Mr. J. H. Wickes, car superintendent for the above company. There are six thousand of these refrigerator cars in use by the twenty-two different transportation companies of the United States, and they are found to fulfill the requirements of the traffic entirely.

The Gruson coupler is a patented device for diminishing the risks of coupling by rendering it unnecessary for the guard to pass between the cars; it reduces the danger of derailment resulting from an irregular draft; it dispenses with the safety chains, reduces the time required to couple and uncouple trains, and has other advantages.

The device consists of a draw-bar with an articulated head. The latter is hinged eccentrically so as to fall back when uncoupled and to be raised to a vertical position by the action of the socket into which it slides when coupled. This socket is an open drawhead, the

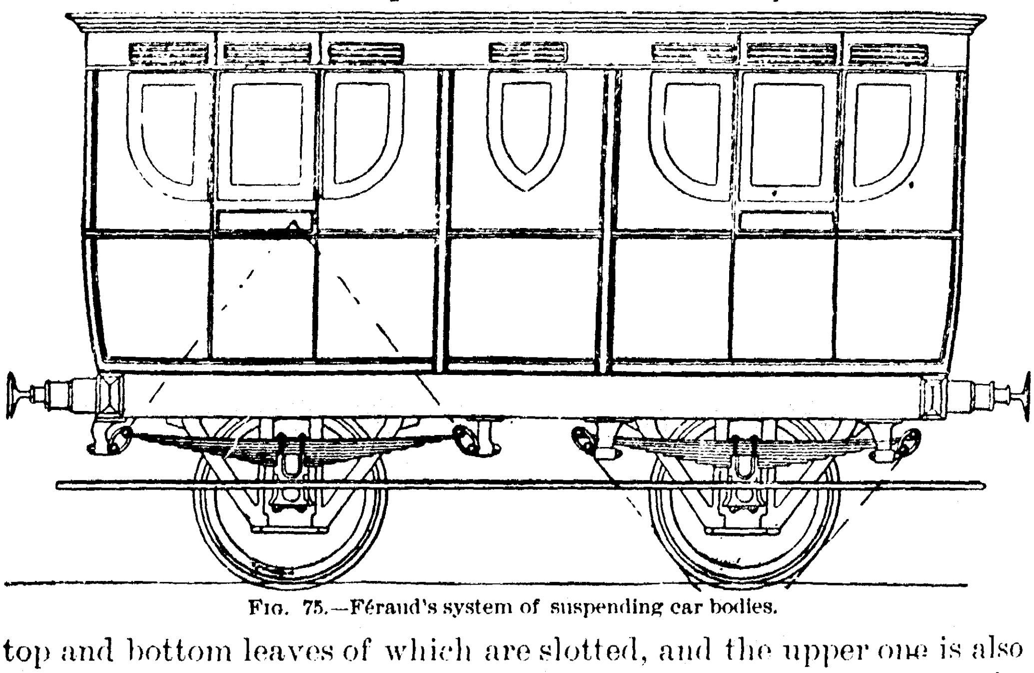


FIG. 75.—Féraud's system of suspending car bodies.

top and bottom leaves of which are slotted, and the upper one is also hinged so as to be raised by a pair of outside links which may be lifted by a cam, operating on a short piston. The shaft containing the cam is revolved by an external lever.

There are two couplers at each end of a car adjacent to the buffers.

Detailed information of this device may be obtained from M. D. Gruson, Calais, 22 Rue des Prairies, France.

The Féraud system of supporting car bodies as compared with the ordinary method.

In the former the suspending links are placed within the length of the spring and the inclination is reversed so that the axes of the links, if produced, would intersect below the base as in Fig. 75, while in the latter method this point is above.

Although this modification involves no increase of parts and is very simple, it is claimed to effect a material economy in the maintenance of the rolling stock and way by the improved action of the spring. It has been introduced on the carriages of the Grand Central Railway of Belguim.

The claims made by the inventor are:

(1) That the main blade of the spring is not extended more than the others and consequently does not tend to separate from them.

(2) At each oscillation the carriage decends less than the flexure of the spring.

(3) The loss of cambre due to the dead load is less than that which should result only from said load.

(4) The flexibility is increased from 20 to 40 per cent of the normal amount.

(5) For springs of greater length it permits the axles to be spread farther apart and thus increases the stability, a great advantage in carriages with three axles.

(6) The hangers, moreover, embracing the sp:ings, as they do, guaranty against all accidents from the breaking of the links or bolts.

The corresponding negations are properties of the ordinary springs.

The system is patented in France and foreign countries.

The Peckham Street Car Wheel and Axle Company, of Kingston, New York, exhibit, through the secretary, Mr. George L. Fowler, 239 Broadway, New York, some of their ordinary wheels—steel-tired paper wheels, steel-tired metal wheels and car axles. The hubs of the elastic motor wheels are lined with a rubber cushion which bears on the axle, thus increasing the life of both wheel and axle, and prevents crystallization, reducing the cost and increasing their efficiency. These cushions also reduce the noise and give an easier motion. The wheels of the motors are attached to the axles by an annular disk, with bolts passing through the hub, so as to be readily removed by an ordinary workman without detaching the motors from the axles. The axle is also enlarged at the bearings of the motor-driving gear; it is not weakened by cutting a slot in the body of the axle for the keyseat, and it has an adjustable screw-threaded collar to take up the lost motion of the motor bearings.

Messrs. Charles G. Eckstein & Co., as agents for the Arbel patent wrought-iron center, steel-tired wheel, show the method of fastening the tire to the wheel.

The Arbel wheels are made at a single operation, being stamped and welded by a few blows from a heavy hammer. They are not dependent upon bolts or screws for strength. The method used for fastening is what is known in England as the Gibson and in Germany as the Bute key. It consists of a ring of metal which overlaps the joint between the web and tire, and so clamps the tire to the wheel that, even in cases where the tire breaks, it is prevented from becoming detached. The form of the key can best be seen by reference to Fig. 76.

By this combination it is claimed that "the life of the center is practically unlimited," and that the Arbel solid-spoke wheels, as made by the Cockerill Company, are noted for their "strength, lightness, safety, durability, and economy." The weights vary from 440 pounds for the 24-inch wheel, to 925 pounds for that of 42 inches.

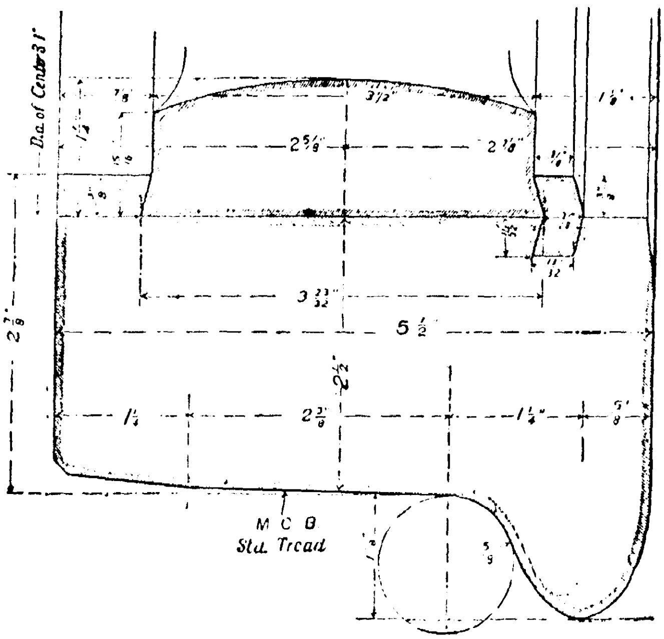


FIG 76.—Arbel's car wheel.

The centers can be re-tired at a nominal cost in any railroad machine shop.

IV.—BLOCK SIGNALS.

Many of the railway companies, in addition to their rolling stock, have placed on exhibition their systems of operating whereby greater safety is secured. Chief among these is the block system of signaling and of operating switches. Under this head we find *The Simplex Railway Patents Syndicate*, of Temple Chambers, London, claiming for their devices an increased economy with additional facility and safety in traffic movements over any other system.

This machine consists of a successful combination of (1) duplex plunger point locks; (2) double indication detectors; (3) "selectors" for lever saving purposes, all operated by one cabin-frame lever. Whilst the "simplex" is thus able to operate simultaneously both a "point lock" and a "point detector," by one lever, with the ordinary pull-and-return movements, yet the detecting indications and the locks are distinct for each road and double for each of the single blades in the wire connections at the detaching box.

This system is installed at the Waterloo station of the London and Southwestern Railway, which is one of the most complicated points in England. There are in all one hundred levers placed in the cabin. Of these thirty-one levers are employed to operate the thirty-two pairs of points; nineteen levers work the selector bars of the nineteen "simplex" machines, and thus perform the desired locking, detecting, and indicating features of this new machine; twenty-four levers work the semaphore-arm signals; five levers only work in connection with the advance and rear fouling bars, whilst of the remaining twenty-one levers, nine are spare ones and twelve work shutting signals. Another characteristic feature of this lever frame is the "special rotation" locking, which is too technically intricate to justify description without detail drawings. The same may be said of the general system, but more complete information can be obtained from the company.

The Compagnie du Midi have a device for maneuvering several fixed signals by a single lever so adjusted that one of them may be opened only while all the others are closed. It consists simply of a number of rods connecting the various signals with a yoke placed horizontally upon fixed chains. The ends of these rods may be fastened successively to a chain connected with the maneuvering lever whereby they may be opened. Their normal position is maintained closed by a counterpoise attached to the signals.

Another mechanism for operating a single point and disk simultaneously, consists of a small cast-iron box placed behind the lever for throwing the switch, in which there is placed an auxiliary lever connected by a wire with the signal so that one movement controls the position of both point and signal.

A third device is shown for operating a fixed signal and a movable stop by a combination of levers so adjusted that the disk is only able to be opened when the stop closes the lateral line, and conversely. The stop consists of a chock of wood which is thrown over the rail by a lever.

A fourth system for operating two or three disks by means of a single rod is composed simply of the transmitting articulated rod passing over pulleys and connected at the outer end with the several signals to be operated by means of levers.

By combinations of the above types, four, five, six or more movements may be obtained by a single lever of transmission.

Still a fifth device, consisting of a cabin containing twelve levers, is shown as one of the types adopted by this company at the station at Pau, and designed to effect in the simplest manner and with the fewest parts the maneuvering of signals and switches. In this case the table accompanying the levers is horizontal. Another in which the table is vertical contains twenty levers. These block stations do not differ materially from the customary forms except in their details. There is also a mechanism for operating and locking points, a turntable, platform scales, and other appliances which go to complete this instructive display of material.

The Lesbros system permits the automatic closing of the signals by the action of the car wheels. It is composed chiefly of two levers moving in a vertical plane and connected on the one side with the wires leading to the disks and on the other to the maneuvering levers in the cabin. On the first of these levers is fixed a spring clasp and on the other a movable catch with a counterpoise. These two parts operating together unite the levers, which are mounted on the same axle, so that the latch can not be unclamped by any external action, but is opened by a lever actuated by a pedal which is itself moved by the operation of the first wheel of the carriage.

The Compagnie de l'Ouest have introduced the electrical system for operating signals on adjoining blocks. This involves, for each cabin, (1) a stop signal with detonators, a caution, and an "all right" signal, disks by day and lamps at night. (2) These signals are duplicated by others at distances varying from 1,300 to 2,000 yards, operated from the same cabin.

Adjacent cabins are put in circuit by electrical conductors connected with Regnault indicators. These boxes carry two indices, one outside of the station and visible to the engineer, the other inside and in sight of the station agent. The arrival and departure of a train on a block section is indicated by the position of the index, any change in which is announced by a bell. The operator at any station can not unblock nor open the section until word has been received from his neighbor of the arrival of the train upon the forward block. To insure against inattention or sudden disability of the operators the system is designed (1) to prevent an agent from announcing an approaching train before he has first set the distant signal and then blocked the line by the home signal; (2) to prevent his withdrawing these signals before they are unlocked from the adjoining cabin; (3) that the next operator shall not be able to give the electric signal until he has first set his own block. These requirements are met by the locking gear, the electric lock and bolt, and the electric relay.

The London and Northwestern Railway Company show the train staff, working for single lines of railway, under the *Webb & Thompson system*, which is described as follows:

Railways in Great Britain constructed for a single line of rails upon which both the up and down traffic is conducted are as a rule worked on a system generally known as the staff and ticket system.

With a small traffic and trains running at stated times it is possible to work this system without delay; but where the traffic is heavy and variable, and where a time table can not be adhered to, serious delays result, due to the fact that if a train has been dispatched from station A to station B with the staff, a train running out of course, or a special train arriving at A, can not proceed until the staff has been returned from station B.

To get over this difficulty the London and Northwestern Railway Company have adopted a system whereby a number of staffs are provided at each staff station in suitable receptacles, and so controlled by electrical and mechanical devices that, although only one staff can be in use at a time, the moment the staff in use has been deposited in the receptacle, say at station B, a second staff can be obtained by A; and so the delay of waiting for the staff previously sent to B to be returned to A is avoided. By these means a single line of railway may be utilized to its fullest capacity, and the traffic conducted with perfect safety and regularity.

The apparatus adopted by the London and Northwestern Railway Company is the joint patent of Mr. F. W. Webb, Mem. Inst. C. E., the chief mechanical engineer of the company, and Mr. A. M. Thompson, Mem. Inst. C. E., the company's signalling engineer, and it has been in use on a busy section of the London and Northwestern Railway for about twelve months, during which time it has proved itself to be in every way reliable.

The apparatus is characterized by great simplicity of construction, and as it dispenses with the usual telegraph instruments for block working, it not only possesses the advantages previously referred to but is an economical substitute for the old system, which, it is reasonable to anticipate, will be rapidly replaced on all busy lines by this the latest contribution to our list of safety appliances for railways.

A valuable feature of the new system is the key-interlocking which is combined with it. Each staff is formed into a key at one end, which unlocks the points of any siding which may join the main line between the two staff stations. The staff is used to unlock the points, and immediately they are unlocked the staff itself becomes locked, and can not be withdrawn until the points are again closed and locked, and thus perfect security is afforded at a trifling cost, all signals being dispensed with.

Although Block signals are in general use on the continent, and many modifications were shown at the exhibition, their introduction into the United States has not been as rapid as the safety of the traveling public would seem to require. Quite recently an improved parabolic semaphore has been invented by Prof. Koyle, of Swarthmore College, Pennsylvania, which renders it more distinctly visible both by day and night. It is a great improvement over the old form of flat vane.

V.—Electric Motors.

The Sprague Electric Railway and Motor Company, of 16 and 18 Broad street, New York, made an exhibit of a complete street railway truck, equipped with its standard electric motors, as shown in the accompanying view (Fig. 77).

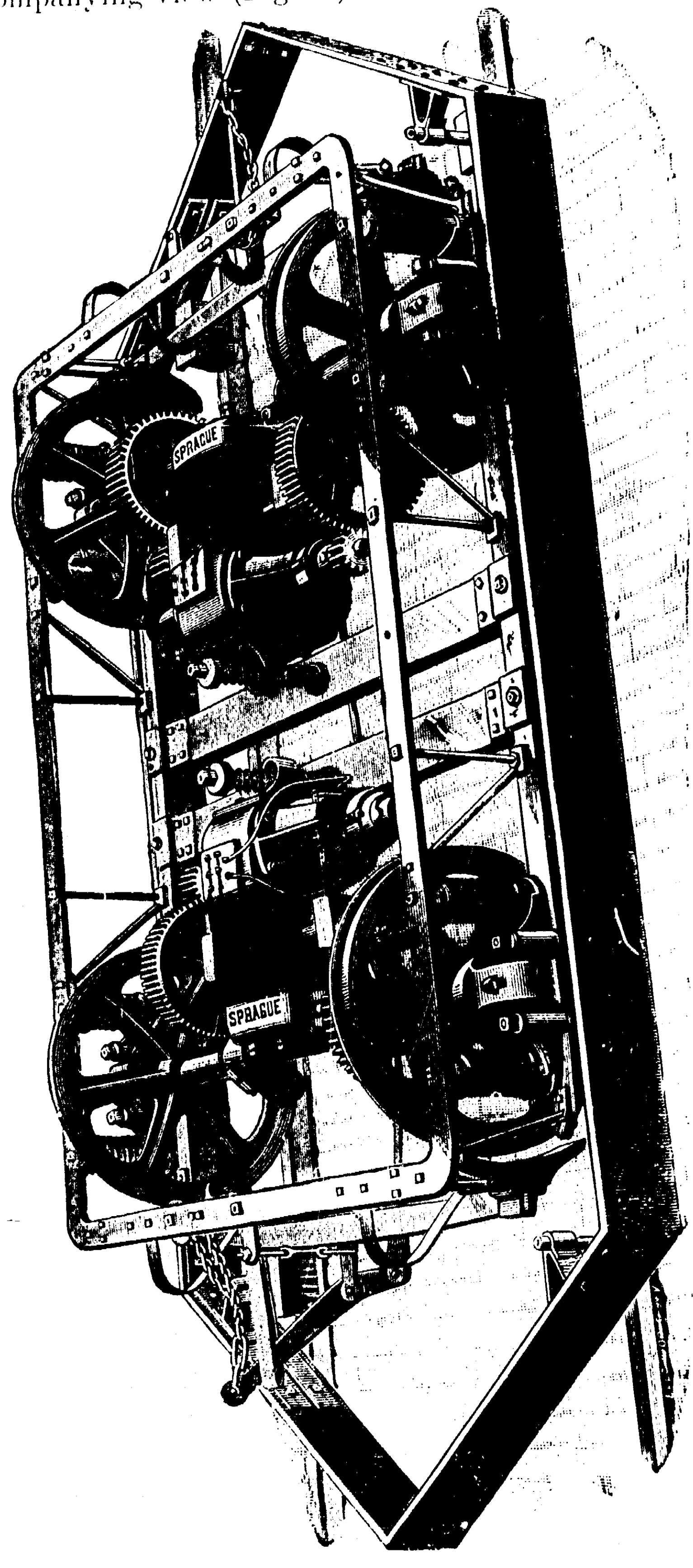


FIG. 77.—The Sprague Electric Motor.

In order to secure the necessary track adhesion by means of independent driving, and to permit the entire weight of the car and its contents to be available for traction, two motors are used on each car, one for each axle, with independent driving. At the same time both motors are capable of perfectly simultaneous control by a switch placed at either end of the car, this switch controlling both the speed and the direction of movement of the motors.

Each motor is of very compact form and simple construction, and occupies no valuable room in the car, since its position is underneath the flooring, where it is geared to the axle. At one end of the motor are projections which enable it to grip the axle of the car, and it is held in position by iron caps. Inside of these are split liners to take up the wear.

In order to permit of free movement of the motors under the car, and at the same time preserve perfect parallelism in the meshing of the gears, each motor is centered upon its axle, and at the other end is supported by double compression springs playing upon a loose bolt resting upon the cross bar of the truck.

By means of these springs the motion of the armatures is transmitted to the axles through a spring gearing of compact form and great strength, and whenever the axles are in motion there is a spring touch of the pinions upon the gears.

This method of flexible support of the motor is of vital importance, not only for relieving the motor from sudden jar, but also for taking up part of any sudden strain upon the gears by making the movement always a progressive one.

From this it will be seen that, barring friction, a single pound of pressure exerted in either direction will lift or depress the motor a slight amount. It follows that no matter how sudden or great the strain, whether because of a variation in load or speed, or reversal of direction of rotation, it is impossible to strip the gears unless the resultant strain is greater than that of the tensile strength of the iron, because the moment that the motor exerts a pressure upon the gears at the same instant do the spring supports allow the motor to yield. The result in practice has been that with a weight equivalent to two tons on each wheel they have actually been skidded in continuous rotation upon a clean dry track, and the strain necessary to do this amounts to from 1,000 to 1,500 pounds upon each gear.

Both motors are simultaneously governed by a single Sprague switch from either platform, which throws the winding of the motor field into different electrical combinations, thus altering the current, maintaining practically a constant field, and thereby varying the power and speed of the motor without the use of any wasteful resistance. By this method there is no loss of power, and the control over the car is perfect.

The brushes are on an entirely new principle and design, and are remarkable for ease and adjustment, and work with equal facility in running either forward or backward. By their means a perfect electrical contact is secured without excessive pressure on the commutator, and all wear is reduced to a minimum.

The cars can be run at widely different speeds, varying from the least movement to 12 or more miles per hour.

They can be started and stopped without the use of brakes in the space of 3 or 4 inches; and when making the normal running speed can in an emergency be stopped and reversed without brakes within less than a quarter of a car length by allowing the electric current to flow through the motors in the reverse direction. This ability to quickly start and stop is especially advantageous in crowded thoroughfares, and makes an electric car running at the rate of 12 miles an hour much safer to the general public than an ordinary horse car with only half that rate of speed.

The motor equipment as shown can be used with either storage batteries, overhead wires, or underground conduit. When the overhead wires are used, a special arm (also shown) for making contact with the overhead wire is required.

This consists of a light trolley pole supported upon stout horizontal and vertical springs, so that it can move in every direction, and having at its upper end a grooved wheel, making a running flexible contact on the under side of the working conductor. The flexibility of this arrangement is very great, it being able to follow with facility variations of the trolley wire 4 or 5 feet in either horizontal direction or more than 12 feet in a vertical direction. By this means a constant contact is made by the trolley wheel at different rates of speed or around curves and for different heights of the trolley wire.

It is impossible (working underneath) to pull the trolley wire down; and if off the line the trolley can be replaced quickly and easily, even in the darkest night.

By the use of this underneath contact not only are there no complicated switches on the overhead conductors, but all changing of contact is avoided when passing the turnouts.

The truck shown was manufactured by the J. G. Brill Company, of Philadelphia, Pennsylvania. The entire weight of truck and motors is about 6,000 pounds. Selling price of truck and equipment, $3,275.

The Thomson-Houston International Electric Company, of Boston, Massachusetts, have placed on exhibition a complete street-railway car truck with electric motors attached, to show the operation of their system. (See Fig. 78.)

This plant is designed to fulfill the following conditions:

(1) The motors must be placed under the car bodies, instead of upon the platforms, and must be so arranged as not to project above the floor, nor require any change in the body of the car.

(2) Direct gearing must be used instead of the sprocket chain employed when the motor is placed on the platform.

(3) In general, each car must be equipped with two motors, driving two independent axles; also that the trucks of ordinary cars should be changed for motor trucks provided for the purpose.

The system of conduction is that by overhead wires supported upon bracketed poles erected on the sidewalk, or in some cases along the center of the street or road. The current is generated by dynamos at a central station, from whence it passes, through the trolleys bearing against the under surface of the overhead conductor, to the motors on the axles of the cars; thence through said axles and wheels to the rails, which complete the circuit. The joints of the rails are bridged by copper wires riveted to each end, and finally the current is conveyed to the negative pole of the generator by an underground wire.

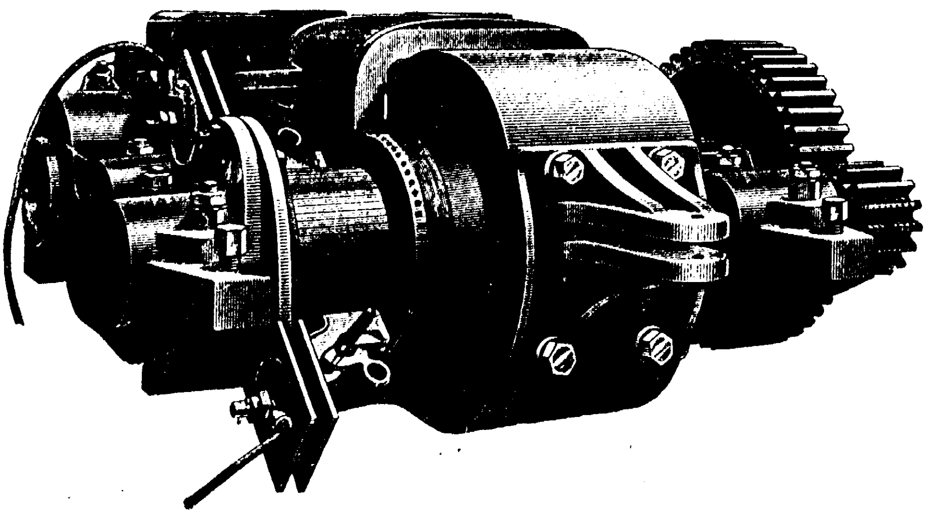


FIG. 78.—The Thomson-Houston electric street-car motor.

The current is developed by a "series-shunt" generator driven by any suitable mechanical motor, which is operated automatically according to the amount of electrical power required, giving great economy and efficiency of operation.

The motors also are "series-wound" and are proportioned to develop the additional power required to propel the car upon grades or around curves without too great loss of speed. The form of these motors is seen in the accompanying cut.

This company have introduced carbon instead of copper for their brushes, with improved results, in some instances obtaining a mileage of 2,900 miles before the brush wears out. There is a corresponding economy in the commutators from the use of this material. These and other improvements have resulted in reducing the cost of maintenance and operation and have rendered this system justly popular with its patrons.

VI.—AMERICAN ROAD MACHINES.

The American Road Machine Company, of Kennett Square, Pennsylvania, have on exhibition at Paris one of their machines, known as the "American Champion." Its weight is about 2,200 pounds. Four heavy or six ordinary horses haul it. The blade or mold board is 8 feet long, 16 inches wide, and is adjustable to either right or left angle to line of travel. The vertical pitch is also adjustable; either end of the blade can be raised or depressed independently, and all these adjustments can be instantly made by the operator without leaving his position on the machine. These machines move the earth to right or left in manner similar to a plow; they are mainly used for repairing earth roads or digging surface drains, ditches, or irrigating ditches, and for grading new roads which nearly correspond with the surface of the ground, at which work the capacity of the machine is very great, ten doing as much work as could be done by fifty men and fifty horses in the old way, or one hundred men with only pick and shovel. They are sold for $250 on cars at the shops. The demand for them has increased very rapidly during the past six years, and their use in the United States is general, although they were only introduced in 1882.

The Fleming Manufacturing Company, of Fort Wayne, Indiana, exhibit through their agents, the Brooklyn Railway Supply Company, of 90 Chambers street, New York City, one of their nonreversible "Leader" road machines, which they describe as comprising an all-steel cutter bar or scraper, 8 feet long, to which the knives are attached. They are concave in section, made of the best steel, highly polished, and can, if necessary, be easily detached and sharpened. The leader is a light and strong four-wheeled machine with the front draft. The draft bars of the scraper bar extending direct to the front truck make it a light-draft machine. The leader is coupled short and the front truck swings under the frame, enabling it to be turned in the shortest possible space. The device used for the fifth-wheel is a ball and socket arrangement which can not bind. The weight is about 1,200 pounds. To prevent any lateral motion those machines are provided with flanges on one wheel.

The price of the "Leader" road machine with all-steel cutter bar is $125. The following are amongst the claims made by this company:

These are the cheapest and best machines ever offered to the public. They will do as much or more and as good work as the higher priced machines, require much less power to operate, and therefore are the most economic tools for road work on the market.

The machines are made either right or left hand, to suit right or left hand plows; therefore a road district can have two machines, one right and one left hand, at less cost than one complicated reversible; can operate them easier and will find them much less liable to get out of repair.

The Vulcan Road Machine Company, of Media, Pennsylvania, exhibit one of the Lamborn road machines, for which they claim:

It is constructed almost exclusively of iron and steel, the only available materials that possess in themselves in the highest degree the important combination of strength and durability without undue weight, that objectionable characteristic of all road machines made of wood.

No other road machine is so simple in construction, so steady in action, so light in draft, or so great in capacity, with the same amount of team, as the Lamborn.

No other road machine is so generally useful or so easy to operate.

No other road machine will do the same amount of work in hilly countries in a given time. Indeed, it is the only machine that can be used with full satisfaction on an up grade.

The Lamborn has won the enviable position that it now holds as the standard road-making machine by the excellence of its work on the public highways from Maine to California, and by the fact that it lasts almost a lifetime without expensive repairs

These claims are based upon certain peculiarities in the construction whereby efficiency, lightness, strength, durability, and simplicity are secured. Most of these desiderata are obtained by the form of the cutter bar and the method of supporting it. Its bearings are braced to the frame at nine different points, thus distributing the strain over the whole machine. The bar is coniform in shape, resembling in action the coulter of a plow as it cuts under the earth at one end and rolls it back towards the other, which, being more nearly vertical, operates as a scraper. By means of levers and racks it has great vertical range and can be used for side ditching. This machine is sold at the low price of $150, on board cars.

MISCELLANEOUS UNITED STATES EXHIBITS.

The remaining American exhibits include a combination railroad joint submitted by *Major D. E. Bishop*, of 822 Broadway, New York.

A train showing *the Boyden power brake*, from the company at Baltimore, Maryland.

The B. F. Laird automatic car coupler, of Covington, Kentucky.

Equipments and supplies for building and operating railroads, by *The New York Commercial Company, Limited*, of 140 Pearl street, New York.

The Railway News Company, of New York, models of engines, bridges, railroads, and engineering works.

A railway crossing gate, car coupler, brake, antiderailing switch, frog, and crossing combined, all by *Edward O. Stevenson*, of Mingo, Ohio.

Tubular steel wheelbarrows and dumping tubes for coal or ores, by *The Tubular Barrow Machine Company*, of 169 Fourteenth street, Jersey City, New Jersey.

Lever lifting and lowering jacks for railroad work, by *Andrew Warren*, of St. Louis, Missouri.

The American manufacturers of railway appliances were distinguished by their absence, due doubtless to the difficulty of shipping full-sized models of rolling stock, the remoteness of the market, and the well-known conservatism, which renders it difficult to introduce any important changes in Continental practice.

The sections shown by the Pennsylvania Railroad Company were excellent types of their kind, taken from the regular stock, but were insufficient to give an idea of the appearance, capacity, comfort, safety, and efficiency of a fully equipped American train as contrasted with those of Europe. The few articles exhibited were instructive and succeeded in attracting considerable attention, but it is to be regretted that they were not more numerous and representative of the railways of the United States.

DEDUCTIONS.

The great discomforts of foreign cars as contrasted with American are so well known as to require no detailed description here. But it is claimed that this is offset to a large extent by the lightness of the rolling stock; yet it would seem that the long wheel base and rigidity of movement more than counterbalance the gain in weight and that the cost of transportation on European roads is much higher than on American. This is due largely to the necessity of providing for at least two and in some cases three distinct classes of patrons. These again must be subdivided to provide compartments for single ladies traveling alone and for nonsmokers. The same complications are introduced in the waiting rooms and ticket or booking offices of the stations, requiring a much larger personnel and staff for operation of the lines, and longer trains and stations for the passengers. On most roads the percentage of first-class travel does not reach 12, and that of second class from 20 to 25, yet these classes must be provided with separate rooms and compartments at stations and in cars which are seldom if ever all filled. Thus the cost of operation is increased. Some lines have discarded the second class to reduce expenses.

The statistics of standard American and foreign railroads when compared show that in the former country a locomotive does more than six times the work, makes annually nearly twice the mileage, with a charge of less than one-half for the traffic, and earns nearly double the revenue of its European competitors.

These results are in themselves sufficient to demonstrate the superior earning capacity of American railways; but it is not to be concluded from this that there is not room for improvement in many of our means of locomotion. For rapid transit in cities there is much to be learned with reference to motors as well as to the way.

The extent and variety of the exhibits comprehended in this class make it one of great interest to the railroad builder, contractor, manager, manufacturer of supplies, and capitalist interested in economic transportation. Indeed, every one desiring speed, comfort, safe y, and convenience in traveling could find much of interest and profit in this display. The principal innovations were noticeable in the increasing use of long bodied or saloon coaches on the continental routes, and even on the shorter lines of Great Britain there was a marked tendency to substitute the "American" passenger coach. The "goods waggons," however, have not made much progress in the direction of increased capacity and reduced resistance. They are still small and in general open, the contents being protected by canvas covers or tarpaulins.

The latest improvements in German railroads and rolling stock have not been touched upon in this report, since that country was conspicuous by her absence from this class, and it is not felt that, with the possible exception of the Pennsylvania Railroad Company's exhibit, the transportation methods of the United States were adequately represented at this notable Exposition at Paris. This was due largely to the expense and difficulty of moving the full-sized plant of American rolling stock across the ocean, and to the further fact that the European markets are already well supplied by domestic manufacturers, with whom American contractors do not in general compete.

The following general tables contain important data relative to a large percentage of the rolling stock at the exhibition, from which some interesting conclusions and comparisons may be deduced. For instance, the car giving the highest nonpaying or dead load per passenger is the sleeper (No. 41), where the ratio is 1 to 28. The greatest load per wheel is on the large first-class coach (A 203) of the same company, giving a pressure of 11,362 pounds: but this is much lighter than the load on drivers of many engines. Class P of the Pennsylvania Railroad gives 18,400 pounds per wheel. The least load is that shown by the mixed carriage of the Midland Railway, which, being mounted on bogies, gives a minimum of wear and is light-running. Its capacity, however, is not so great as some of the other cars. That having the greatest capacity for first or second-class traffic is the standard day coach of the Pennsylvania Railroad, which will seat fifty-six passengers in a length of 46.5 feet, and weighs 702 pounds per passenger, giving a ratio of live to dead load of 1 to 4.6. The apparent exception to this is the light car of the Chemin de Fer du Sud, but this is only for suburban travel. The other instance is that of a third-class car, where fifty persons may be crowded into a length of 25.6 feet in closed compartments, having but 34½ cubic feet of air to each passenger, and with no opportunity to move about or even to leave the seat except at stations, whereas in the cars of the

American pattern, although there is nominally but 0.8 of a foot of car length per passenger, the traveler may move freely from one end of the car or train to the other, and there is an abundance of ventilation from the numerous doors, windows, and ventilators found in the cars.

ACKNOWLEDGMENTS.

In concluding this report the writer desires to express his obligations to Gen. William B. Franklin, commissioner-general; Professor Charles B. Richards, expert commissioner for the sixth group; Mr. H. B. Plant, United States juror, class 61, and Mr. H. D. Woods, secretary, for much of the data and information embraced in this paper.

General Data Relating to Rolling Stock (Locomotives).

Exhibitor.	Designation.	Service.	Gauge.	Wheels. No. of axles.	Wheels. Coupled axles.	Wheels. Diameter of drivers.	Wheels. Total wheel base.	Wheels. Rigid wheel base.	Cylinders. Position, inside or out.	Cylinders. Diameter.	Cylinders. Stroke.	Tubes. Number of.	Tubes. Length.	Tubes. Exterior diameter.	Furnace. Grate area.	Furnace. Height.	Furnace. Length of grate.	Furnace. Breadth.	Heating surface. Fire box.	Heating surface. Tubes.	Heating surface. Total.	Weights. Forward or bogie.	Weights. On second axle.	Weights. On third axle.	Weights. Trailing axle.	Weights. Total in service.	Boiler pressure.	Adhesion.	Height of stack.	Maximum load on one wheel.	Total length.
			Feet.			Feet.	Feet.	Feet.		Feet.	Feet.		Feet.	Inches.	Sq. feet.	Feet.	Feet.	Feet.	Sq. feet.	Sq. feet.	Sq. feet.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Lbs. per sq. inch.	Pounds	Feet.	Pounds	Feet.
France.																															
Cie des Chemin de Fer de l'Ouest	Engine No. 621	Passenger	4.7	3	2	6.7	15.56	8.86	In	1.41	1.97	223	10.5	1¾	17.7	5.64	5.18	3.43	103	1,086	1,189	26,290	29,480		29,480	85,250	142	9,834	13.9	14,740	26.9
Do	Bogie No. 951	do	4.7	4	2	6.7	24.3	8.85	In	1.51	2.16	{183 / 12}	{13.7}	{1.92 / 1.76}	{19.2}	5.51	5.58	3.45	107	1,341	1,448	19,800	20,900	32,560	31,900	105,160	156	10,740	13.9	16,280	33.4
Do	Tank engine No. 3533	do	4.7	3	3	5	14.6	14.6	In	1.41	1.97	203	10.5	1¾	13.7	4.92	4.13	3.36	82	990	1,072	29,700	30,360		31,240	91,300	142	15,216	13.9	15,620	27.9
Do	Tender No. 951	do	4.7	2		3.7	9.68	9.68																		57,640				14,410	*50
Cie Paris, Lyons and Mediterranean	Express engine C 1	do	4.7	4	2	6.56	19.22		{2 in / 2 out}	1.01 / 1.64	{2.02}	185	13.2	Interior 1¾	{25.2}		7.59	3.31	125	Interior 1,159	{1,284}	29,480	32,560	32,560	23,100	117,700	213	9,116	13.9	16,280	
Do	Express engine No. 4301	do	4.7	4	4	4.13	13.28	13.28	2 out	1.18 / 1.77	{2.13}	247	13.6	1¾	23.5		7.08	3.29	117.8	1,577	1,694	24,798	29,590	35,178	32,054	125,620	213	17,598	13.9	17,589	30.9
Do	Tender C 1	do	4.7	3		3.9	11.15	11.15														26,224	27,148	27,148		†80,520					
Do	Tender No. 4301	do	4.7	2		3.9	8.2	8.2														28,182	29,700			‡57,882					
Cie des Chemin de Fer du Nord	Woolf 4-733	Freight	4.7	4	4	4.27	13.93	13.93	Out	2.175 / 1.25	{2.134}				22.4				98.7	1,256	1,355	29,674	31,394	30,820	22,090	113,978	142			15,697	31.6
Do	No. 2-035	Shunting	4.7	2	2	2			Out	0.59 / 0.59	0.82 / 0.82				5.6				29.9	98.1	128										
Do	No. 3-101	Mixed	4.7	4	3	5.4			{In / Out}	1.5 / 1.64	2.3 / 2.3				22.5				100	1,125	1,225					106,176	199				
Do	No. 2-101	Passenger	4.7	4	2	7									22				148	1,045	1,193					96,880	171				
Cie des Chemin de Fer Paris à Orléans	Express	do	4.7	4	2	6.9			In																	127,680	185				
Cie des Chemin de Fer du Midi	do	Freight	4.7	3	2	6.56	17.7	7.7	Out	1.44	1.64	194	11.48	1¾	18.3	4.92	5.57	3.28	104¼	1,097	1,201	28,160	33,000		33,000	94,760	142	11,000	13.9	16,500	27.2
Do	Freight	do	4.7	4	4	3.97	12.66	12.66	Out	1.77	1.66	217	16.07	2	20.4	5	6.23	3.28	116.7	1,904	2,020	29,480	29,480	30,360	29,480	118,800	128	19,800	13.9	15,160	30.9
Belgium.																															
Grand Central Belgé Railway	Tank engine No. 170	do	4.7	4	4	4	14.10	14.1	Out	1.57	1.80	270	11.5	Exterior 2	{24.8}				95	1,510	1,605	52,800		62,480		115,280	147				32.74
Belgian State Railways	Express No. 192	Passenger	4.7	4	2	6.9	21.5	21.5	In	1.64	1.80				53.8				129	1,238	1,367		58,400			109,760	142				
La Société —— la Métallurgique	"Le Cinquantenaire"	Freight		5	4	3.44						242		1¾	53.8				140	1,452	1,592		132,000		33,000	165,000	147			16 500	
England.																															
London, Brighton and South Coast Railway	"Edward Blount"	do		3	2	6.5	15 7	8	In	1.5	2.17	333	10.1	1¾	21				114	1,386	1,500	33,320				86,550	150				*51′ 10″
South Eastern Railway Company	Express	do	4.7	4	2	7	21.19	8.6	In	1.58	2.17	202	10	1¾	16.8				103	917	1,020	29,020		34 100	28,580	92,600			13.33	17,050	30
North London Railway Company	Tank No. 70	do		4	2	5.42	20′.7	8	Out	1.42	2				16.6				91	904	995					102,800	160		13		31.4
Midland Railway Company	Express No. 1853	do	4.7	4	1	7.5	21.75	.8	In	1.54	2.26	241	'1	1¾	19.7				117	1,123	1,240					97,700	160		13.18		
America (United States).										Ins.	Ins.																				
Baldwin Locomotive Works§	"American"	Passenger or freight	4.7	4	2	5.5	21.75	8	Out	16	24	161	10.8	2	15.5	5.3	5.3	3	100	831	930	27,000	49,000			76,000	30		13.4	12,250	*52′ 7″
Do	Wootten consolidation	Freight	4′ 1″	5	4	4.2	21′ 9″	13′ 8″	Out	20	26	204	10.5	2	75		9.5	7.9				14,000	116,000			130,000	160		15.2	14,500	
Do	do	10-34 E	4.7	5	4	4.1	21.4	14	Out	20	24	266	12.6	2	30	4.3	8.6	3.5	117	1,754	1,871	13,000	97,000			110,000	130		14.6	13,750	*57′ 7″
Do	"Mogul"	8-32 D	5	4	3	4.35	23.2	15.2	Out	19	24	220	11.5	2	23	5.9	6	2.9	102	1,063	1,165	16,400	77,420			93,820	130		13.85	12,903	*55′ 9″
Do	"Consolidation"	Freight	4.7	5	4	4.17	22.2	14	Out	22	28	271	13.5	2¼	35.35		10.1	3.5	172	2,121	2,293	15,000	135,000			150,000	150			16,875	
Pennsylvania Railroad Company, Altoona	Class A	Passenger or freight	4.7	4	2	5.66	22.7	7.75	Out	17	24	201	11.5	1¾	34.8		10	3.48					29,500	33,100	30,900	93,500			14.7	15,550	
Do	Class P	do	4.7	4	2	5.66	22.7	7.75	Out	18¼	24	210	11.5	2	33.3		10	3.33					33,150	36,500	36,800	106,500	160		15	18,400	
Do	Class R	Freight	4.7	5	4	4.17	21.75	13.9	Out	20	24	183	13.1		31.5		9	3.5				14,025	24,225	23,875	{26,750 & 25,750}	{114,625}			15	13,375	
Hinckley Locomotive Works‖	Strong "444"	General	4.7		3	5.2	30.2	5.6		20	24	306	11.4	1¾	62		9	3.33	{93 / 155}	{[illegible],600}	1,848	{Truck 27,000}	90,000		{Rear truck 21,000}	{138,000}	160		14.28	15,000	
Special engines.																															
H. K. Porter & Co., Pittsburg	Porter No. 1	do	3	3	2	2	9	4	Out	6	10	48	3.66	1¾	3.33		2	1.66				9,000			6,000	15,000				2,250	
Decauville Ainé à Petit Bourg	Mallet compound	do	2 to 2.5	4	{2 / 2}	1.8	9.18	9.18	{Out / Out}	10 / 6.69	10 / 10										240					26,400	170		9.2		28

* Engine and tender. † Weight empty 38,500 pounds. ‡ Weight empty 29,282 pounds. § Only the photographs of this exhibit were shown at Paris. ‖ Not exhibitors; inserted for comparison.

Data Relating to Railway Carriages

Exhibitor.	Designation.	Service.	Gauge.	Wheels.			Cars, carriages, and vans.												Average units of comparison per passenger per car.				Weight of passengers and luggage, at 154 pounds. Live load.	Total load in service.	Load per wheel.	Ratio of dead to live load.
				Number of axles.	Diameter.	Wheel base.	Number of compartments. First-class.	Second-class.	Third-class.	Baggage.	Length of body.	Breadth.	Height at center.	Area of floor.	Volume (cubic).	Number of seats.	Total length between buffers.	Weight in service (no passengers).	Dead weight per passenger.	Length per passenger.	Floor area per passenger.	Volume per passenger.				
			Feet.		Feet.	Feet.					Feet.	Feet.	Feet.	Sq. feet.	Cu. feet.		Feet.	Pounds.	Pounds.	Feet.	Sq. feet.	Cu. feet.	Pounds.	Pounds.	Pounds	
France.																										
Cie de Chemin de Fer de l'Ouest	Saloon car	Passenger	4.7	2	3.4	14.43	3				25.0	8.85	6.80	221.2	1,502	21	27.9	23,100	1,100	1.33	10.5	71.5	3,234	26,334	6,558	7.1
Do	Mixed car	do	4.7	2	3.4	12.32	1	2		1	23.4	8.85	6.50	207	1,345.5	28	27.2	22,440	802	0.97	7.4	48.0	4,312	26,752	6,688	5.2
Cie Paris, Lyons and Mediterranéan	First-class A 223	do	4.7	4	3.28	7.70	8				64.5	9.28	8.30	600	4,150	48	73.4	81,213	1,727	1.53	12.5	86.4	7,392	88,605	11,076	11.0
Do	First-class A 203	do	4.7	4	3.28	7.7	8				67.2	9.81	7.93	659	5,210	48	76.3	83,501	1,738	1.60	13.7	108.5	7,392	90,893	11,862	11.2
Do	First-class A 198	do	4 7	4	3.28	7.7	8				66.1	9.18	7.64	630	4,737	48	71.0	80,223	1,671	1.50	13.0	99.0	7,392	87,615	10,952	10.8
Do	First-class sleeper No. 41	do	4.7	3	3.05	19.35	3	Sleeping			31.3	9.18	8.03	287	2,298	9	35.2	38,858	4,317	4.0	32.0	255.0	1,386	40,224	6,704	28.0
Do	First-class sleeper No. AA, 11584	do	4.7	3	3.05	19.35	4				29.2	9.18	7.38	268	1,978	32	33.0	31,872	980	1.0	8.4	62.0	4,928	36,300	6,060	6.4
Do	Third-class sleeper No. CC, 13225	do	4.3	3	5.05	14.10			5		25.6	9.18	7.38	235	1,724	50	20.5	23,958	479	0.51	4.7	34.5	7,700	31,658	5,276	3.0
Do	Smoker	do	4.7	4	Bogie		1			1	43.2	9.2		397		8		44,000	5,500	5.4	50		1,232	45,232		*36.0
Compagnie des Wagons Lits	Chair car	do	4.7	4	do		2 saloons				57.4	9.2		568		26		58,300	2,240	2.2	21		4,004	62,304		14.5
Do	Dining car	do	4.7	4	do		do				53.8	9.2		495		36		59,400	1,650	1.5	14		5,544	64,944		10.7
Do	Sleeping car	do	4.7	4	do		7				54.4	9.2		500		18		59,400	3,300	3.0	28		2,772	62,172		21
Do		do	4.7	4	2 bogies						37.0	9.2		333		46		20,734	450	0.8	7.2		7,084	27,802		2.9
Compagnie des Chemin de Fer du Sud																										
Belgium.																										
Grand Central Belge Railway	Mixed first and second	do	4.7	2		14.43	2	2			25.6	7.67	7.4	196	1,301	36	29.12	25,963	721	0.81	5.45	37.2	5,544	31,564	7,876	4.7
Do	20-ton gondola	"Goods"	4.7	4		4.26	Freight				33.4	8.53			380		36.4	26,950					†44,000	70,950	8,870	0.6
England.																										
London and Northwestern	Sleeper	Passenger		4		32.0					42.0	8.5	7.83	357	2,794	12		49,280	4,107	3.5	30	250	1,848	51,128		27
Midland Railway Company	No. 916	do	4.7	6		11.5	3		3	1	56.0	8.0	7.0	448	3,136	44	59.0	56,000	1,273	1.3	10	72	6,776	62,776	5,231	8.2
United States.																										
Pennsylvania Railroad Company, Philadelphia		do	4.7	4	2 bogies						46.5	8.5	9.0	395.5	3,557	56	52.5	39,300	702	0.8	7.0	63.5	8,624	47,924	6,000	4.6
Iron Car Company, 120 Broadway, New York		Freight	4.7	4	do		Series A				33	7.0	1.25	231	300			19,600					†60,000	79,600	9,950	0.326

* And baggage.

† Load.

REPORT

ON

CIVIL ENGINEERING, PUBLIC WORKS, AND ARCHITECTURE.

BY

WILLIAM WATSON, Ph. D.,

Fellow of the American Academy of Arts and Sciences; member of the National Academy, Cherbourg; of the French Society of Civil Engineers; of the Prussian Society of Industrial Engineers; of the American Society of Mechanical Engineers; of the American Society of Civil Engineers; late U. S. Commissioner to the Vienna Exposition; member of the International Jury of the Paris Exposition of 1878, etc.

WEIGHTS AND MEASURES

CONVERSION OF FRENCH WEIGHTS AND MEASURES INTO THEIR ENGLISH EQUIVALENTS.

Measurements of length.

French.		British.
	Meters.	
Millimeter	0.001	0.03937 inch.
Centimeter	0.01	0.3937 inch.
Decimeter	0.1	3.937 inches.
Meter	1	3.2809 feet.
Kilometer	1,000	0.62138 mile.

Measurements of surface.

French.		British.
	Square meters.	
Square millimeter	0.000001	0.00155 square inch.
Square centimeter	0.0001	0.155006 square inch.
Square meter	1	10.7643 square feet.
Square hectare	10,000	107,643 square feet = 2.47114 acres.

Measures of volume.

French.		British.
	Cubic meter.	
Cubic millimeter	0.000000001	0.0000610271 cubic inch.
Cubic meter	1	35.3166 cubic feet.

Measures of capacity.

French.	British.	
1 liter	61.0266 cubic inches	0.220215 gallon.

Weight.

French.		British.
1 kilogram	1,000 grams	2.20462 pounds.

Measure of work.—1 kilogrammeter = 7.23314 foot-pounds.
Money.—1 franc = $0.194 gold.

TABLE OF CONTENTS.

PART II.—TIDAL, COAST, AND HARBOR WORKS.

PART III.—BRIDGES AND VIADUCTS.

PART IV.—CIVIL CONSTRUCTION AND ARCHITECTURE.

PART V.—LIGHT-HOUSES.

CIVIL ENGINEERING, PUBLIC WORKS, AND ARCHITECTURE.

By WILLIAM WATSON, Ph. D.

INTRODUCTION.

The information contained in this report is derived from official sources. Most of that relating to the public works of France has been obtained from the notices and documents collected by direction of the minister of public works, and exhibited in a special pavilion erected for the purpose.

For a large number of stereotyped illustrations of these works I am indebted to the administration of roads and bridges, through the courtesy of M. Collignon, inspector of the school of roads and bridges. I wish also to express my obligations to M. Schwebelé, the accomplished librarian of the school, and to M. Boulard, the superintendent of the pavilion of public works, for explanations and valuable suggestions.

For the information and drawings relating to the port of Genoa and the submarine work of the outer harbor of La Pallice, I am indebted to the contractor, M. Terrier, of the firm of Zschokke & P. Terrier.

To Mr. L. F. Vernon-Harcourt for his paper on the training of rivers through tidal estuaries.

To MM. Eiffel and Nougier for the descriptions, pamphlets, photographs, and prints relative to the Eiffel tower and the Garabit viaduct.

To M. Contemin and his assistant, M. Grosclaude, for information and drawings relative to machinery hall.

To M. Baudet for much information concerning the civil constructions described, including portions of the machinery hall, which were erected by him, as well as the lock gates and dock sheds at Havre.

A model of one important work, viz, the Forth bridge, was shown at the exhibition; this bridge has since been successfully completed and may justly be considered the greatest triumph of engineering skill. An elaborately illustrated account of this structure has been published in Engineering, and it has not been thought best, for this reason, to enter upon its description here, as the author had no information concerning it that was not accessible to the public.

PART I.—HYDRAULIC ENGINEERING—RIVERS AND CANALS.

CHAPTER I.

HYDRAULIC CANAL LIFTS AT LES FONTINETTES, FRANCE, AND AT LA LOUVIÈRE, BELGIUM.

The Neufossé Canal unites the Aire Canal with the rivers Lys and Aa. It connects Dunkirk, Gravelines, and Calais with the system of internal navigation, and has an annual traffic represented by 13,000 boats.

The Fontinettes locks, situated on this canal at Arques, near St. Omer, consist of a chain of five successive locks surmounting a difference of level of 13.13 meters.

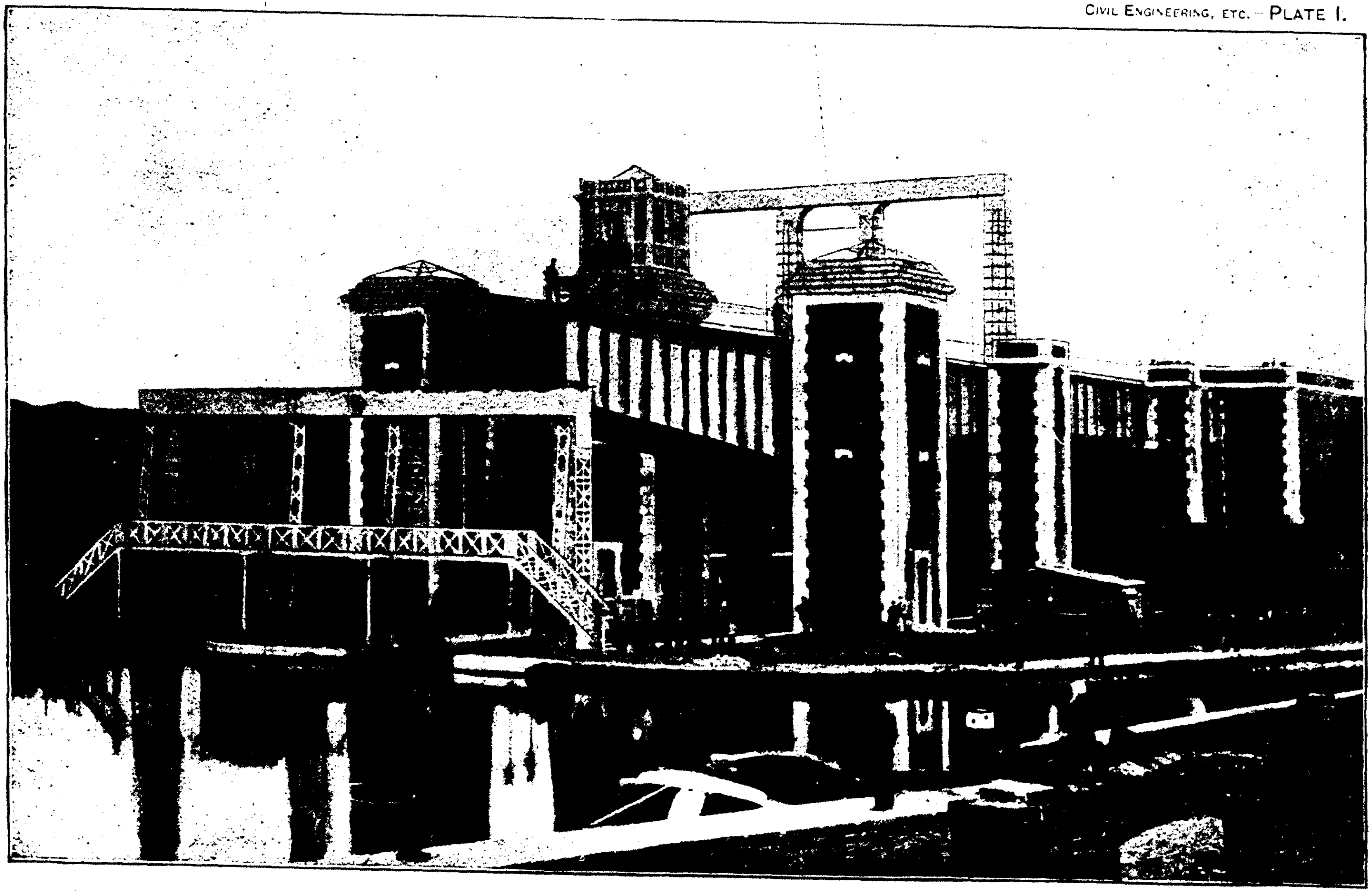
The time consumed in passing through these locks often exceeded two hours; the system of crossing was consequently abandoned, and one day the locks were used for ascending boats and the next for those descending. Much time was thus lost, involving constant crowding, and it was easy to see that the capacity of the locks would soon be reached. Again, as the Fontinettes locks did not admit boats of more than 34.80 meters in length, they could not accommodate those of 38.50 meters, carrying loads of 300 tons, which were in use on the northern canals.

(2) To remedy this deplorable situation the Government ordered the construction of an hydraulic lift by the side of the Fontinettes locks, and similar to that in use at Anderton in England, on the Trent and Mersey Canal, which accommodates small boats of from 80 to 100 tons.

The Government wished thus not only to improve the passage at Fontinettes, but also to try the experiment of raising boats of 300 tons burden by an hydraulic lift.

(3) *Principle of the lift.*—The lift, properly so called, consists of two iron troughs containing the water in which the boats float. Each trough is bolted at its center to the head of a piston, or ram, which works in an hydraulic press set up in a basin. The two presses communicate by a pipe containing a valve serving to cut off, at will, communication between the cylinders.

We thus have an hydraulic balance, and it is sufficient to give a certain surcharge of water to one of the troughs when the valve is opened, in order that one trough shall descend, and in doing so raise the other. Besides, the weight of the trough does not vary, whether it contains a boat or not, provided the water in it stands at the same level in both cases.



GENERAL VIEW OF THE HYDRAULIC CANAL LIFT AT LES FONTINETTES.

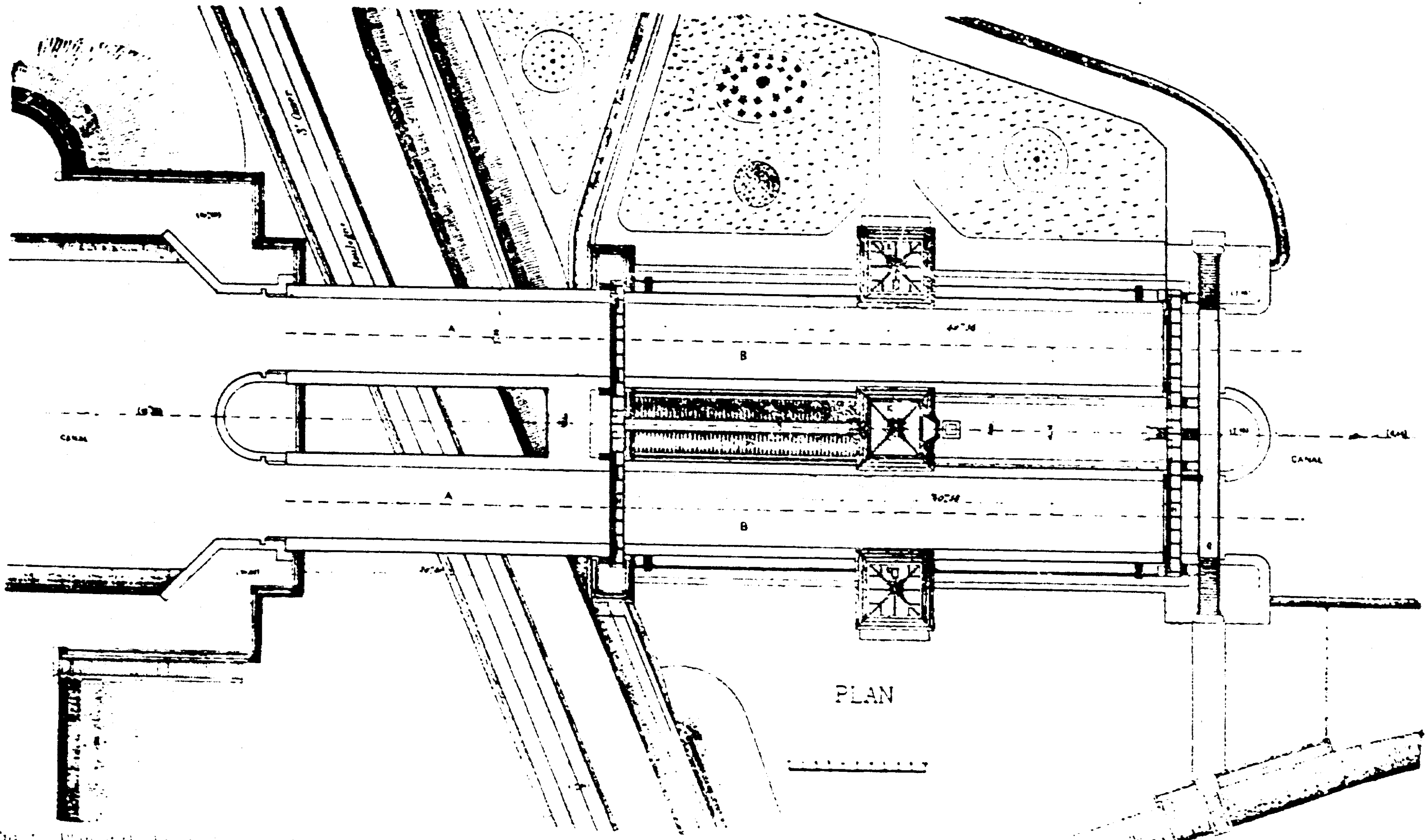


FIG. 1. Plan of the hydraulic lift at Les F[illegible] A A, [illegible] crossing the railroad from Boulogne to St. [illegible] B B, movable troughs. H H, frames supporting the gates. K K K, [illegible] L, [illegible] M, machine house. Q, service bridge. S, capstan.

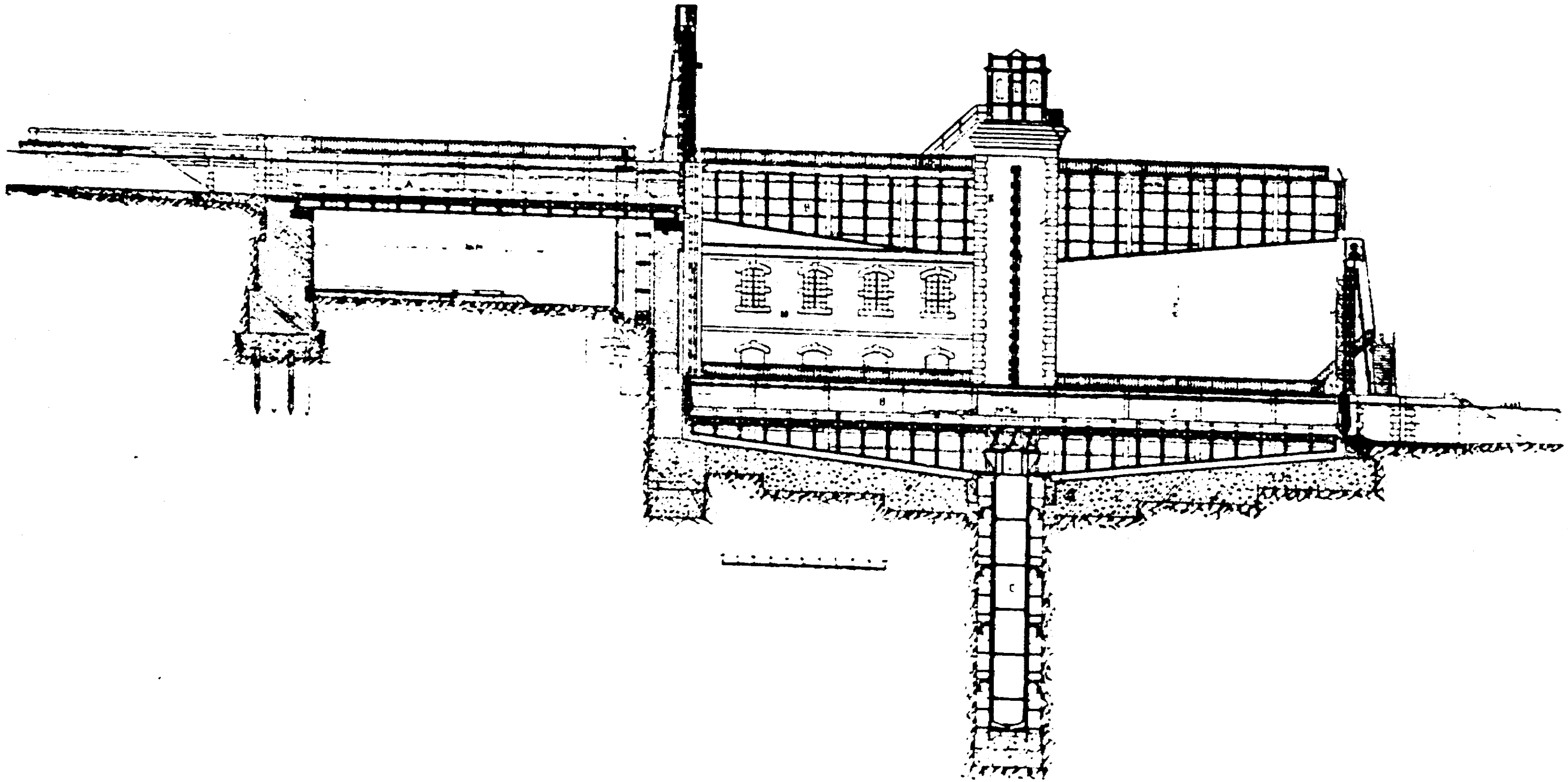


FIG. 2. Hydraulic lift at Les Fontinettes. Longitudinal section along the axis of the trough. A, canal bridge; B, movable trough; C, pistons; D, great presses; H, frames supporting the [illegible] gates; I, guides; K, towers; L, lookout cabin; M, machine house; Q, service bridge; S, capstan.

HYDRAULIC CANAL LIFT AT LES FONTINETTES. VIEW OF THE TROUGH BASIN

(4) *Description of the works.*—A cut-off was made in the right bank of the Neufossé Canal parallel to the Fontinettes locks, with a depth of water 2.20 meters and a width at the bottom of 17.95 meters. It is provided with a guard lock 6 meters wide at the junction of the excavation and embankment, and it crosses the Boulogne and St. Omer Railroad by an iron aqueduct divided into two independent lines, A A, each with a span of 20.80 meters. Immediately below this point the lift is placed. (Fig. 1.)

A general view of the lift is given in Plate I.

In the foreground is seen the iron lattice bridge over the two branches of the canal containing the lift. Immediately behind is the lower iron frame supporting the downstream gates; the trough on the right is raised; on the right and left are the towers with their iron guides to steady the trough in its ascent and descent. Behind the first tower, on the left, is the machine house containing the accumulator, the turbines, and the feed pumps; on the top is the lookout cabin containing the levers for opening and closing all the valves used in operating the lift. Still farther in the rear are the supports for the upstream gates, also containing the hydraulic moving apparatus. Below, in the rear, is the iron girder bridge carrying the canal over the Boulonge and St. Omer Railroad, resting on the massive abutment. At the extreme right is the original canal leading to a flight of five consecutive locks.

Plate II shows the trough basin, giving a view of the trough as seen from beneath when it is raised, and of the parts of the structure which are then below the trough. It exhibits the junction of the square head of the ram with the trough bottom and the details of the construction of the latter. On the side of the house is seen the guide; beyond is the gate with its lifting chain and guide pulley, surmounted by the iron lattice supports. On the left side is a little centrifugal pump for draining the trough basin.

(5) *The troughs.*—Each movable trough, B, is 40.35 meters long and has a working length of 39.50 meters. It is formed of two girders 5.60 meters apart, 5.50 meters in depth in the middle, and 3.50 meters at the extremities, not including the angle irons. These girders, carrying the corbels supporting the footbridge, are united by cross girders 0.525 meters high and 1.50 meters apart.

The four middle transverse girders are 1.50 meters high; to these the piston head, hollowed out for this purpose, is attached by strong brackets, thus forming a rectangle 3.50 by 3.10 meters with a border 0.010 meters thick.

The minimum depth of the water in the troughs is 2.10 meters; the ends are closed by lifting gates. The troughs are lodged at the bottom in a dry masonry basin below the level of the lower bay, which is divided into two compartments by a wall 5.20 meters wide; each compartment has its lower entrance closed by a gate at the extremity of each aqueduct.

(6) *The pistons.*—The pistons are cast-iron plungers 17.13 meters long, 2 meters in diameter, and 0.07 meter thick: they are formed in sections 2.80 meters long flanged on the inside, united by bolts and made water-tight by a ring of sheet copper inserted between each flange.

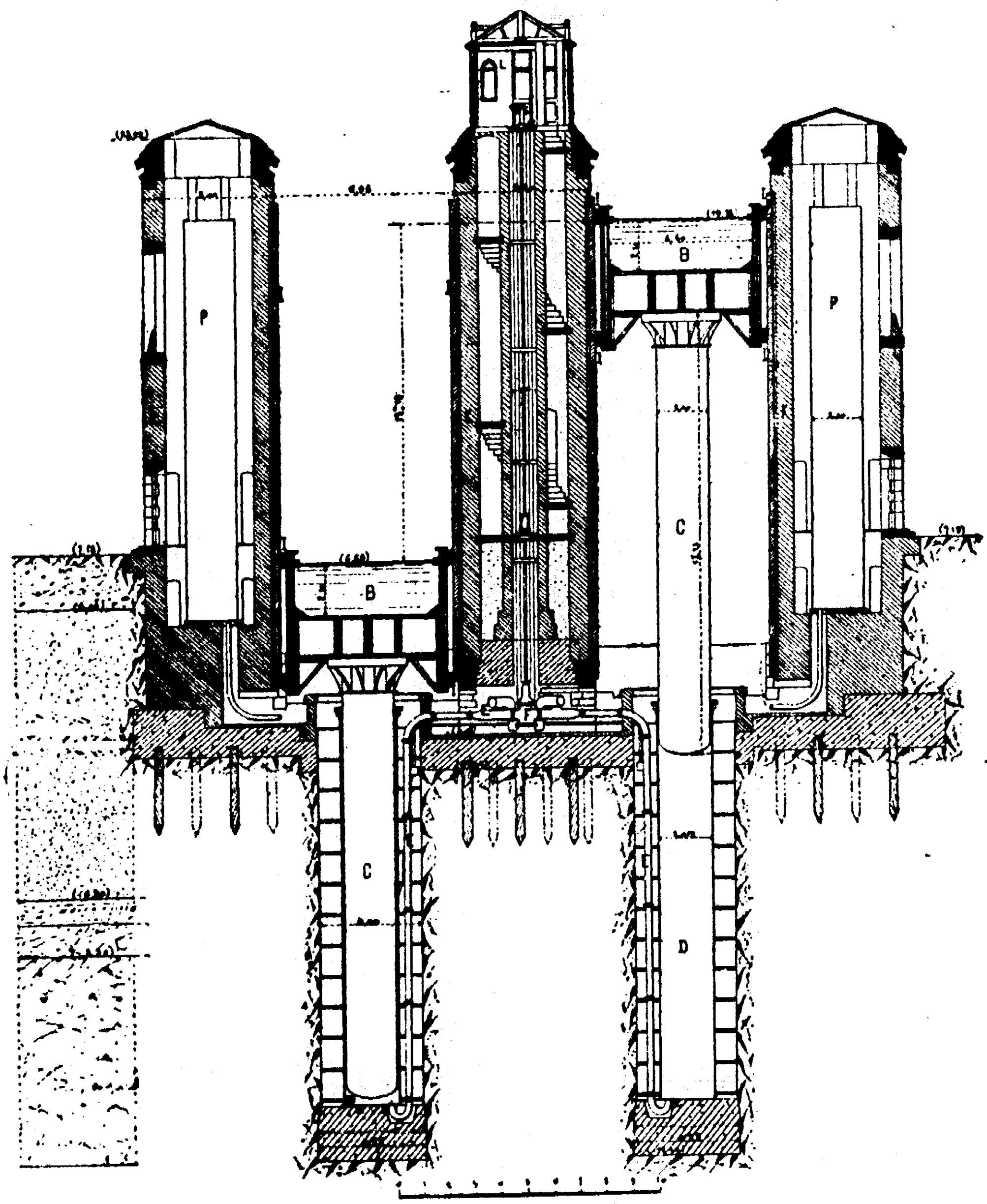


Fig. 3.—Cross section through the transverse axis of the Hydraulic lift at Les Fontinettes.—Geological section: Gravel with smooth stones; sand; fossil shells; broken tufa; compact tufa.—B B, movable troughs; C C, pistons; D D, great presses; E E, supply pipes; F, connecting valve; I I I I, guides; K K K, towers; L, lookout cabin; P P, compensating reservoirs.

(7) *The presses.*—The great presses are 15.682 meters high and 2.078 meters in diameter. They rest upon masses of cement béton at the bottom of the pits, which are 4 meters in diameter and tubbed

with cast iron. The presses themselves are made up of rolled weldless steel hoops 0.155 meter wide and 0.06 meter thick, stepped into each other at half thickness, with a joint 0.005 meter high, and made water-tight by a copper lining 0.003 meters thick.

Each cylinder is stiffened by vertical angle irons, fastened to a hexagonal framing below the press, and above to a collar surrounding the cylinder. Four crossbeams supporting the flooring, and resting upon the tubbing of the pits, complete the system. The bottom of each press is of armor plate 2.25 meters square.

The joint between the piston and the press is formed by an India-rubber band, lined with sheet copper and lodged in an annular recess made in the cylinder cover; this lining is kept in place by a bayonet attachment.

(8) The presses communicate by an iron pipe 0.25 meters in diameter inside, starting from the bottom of each cylinder and ascending the corresponding pit; the pipe has a horizontal branch at the bottom of the basin between the two pits and contains a valve in the middle. This branch has also tubes connecting with two distributors, by means of which water may be forced under pressure into either press, or allowed to escape therefrom.

(9) *Guides.*—The troughs are guided on the upstream end and in the middle. The upstream guides are fixed to the downstream pier of the aqueduct, which forms the lift wall. The center guides, D D, which are the most important, rest against three massive square towers. They consist of strong steel shoes attached to the troughs and clasping the cast-iron guide bars. The downstream ends are not guided.

(10) The engineer in the valve-house, L, at the top of the central tower directs the whole apparatus, opens and closes the connecting valve between the presses, and the valves of the distributors. Access to this house is afforded by the tower staircase or by a footbridge from the top of the lift wall.

(11) The side towers contain wrought-iron cylindrical reservoirs 2 meters in diameter—equal to the exterior diameter of the pistons. Each of these compensating reservoirs, as they are called, can be put into communication with the corresponding trough by a jointed pipe.

(12) When one trough is raised to the end of its course there is a play of about 0.045 meter between its upstream extremity and the downstream end of the aqueduct connecting with it. At the moment of raising the gates to allow a boat to enter or to pass out of a trough the joint is made, by an India-rubber hose running round the end of the aqueduct and protected by springs. This hose is inflated with air at a pressure of 1½ atmospheres. Little valves inserted in the gates permit this space (between the gates) to be filled with water before making the connection. The same arrangement is made for the lower bay joint.

(13) Porticos constructed on the lift wall, and also on the tail wall, have, on their tops, hydraulic apparatus for lifting the gates. The gates, which are balanced to a great extent by counterweights, allow, when raised, a free height of 3.70 meters above the level of the water. Below the lift, a footbridge, Q, connects the two banks with the central masonry wall.

(14) *The machinery* (Pl. III) placed in a building, M, between the two compartments of the dry basin on the upstream side of the central tower, consists of two turbines driven by the water of the upper bay, brought into a tank between the two lines of the aqueduct. One turbine of 50 horse power drives four double-acting force pumps coupled together two and two, and supplying an accumulator of 1,200 liters capacity. The other 15 horse-power turbine drives the air compressor for the inflation of the joining hose, and also a centrifugal pump which serves to keep the trough basins clear of water, whether from leakage or false maneuvering.

A little steam engine works the pump when the upper bay is not in use.

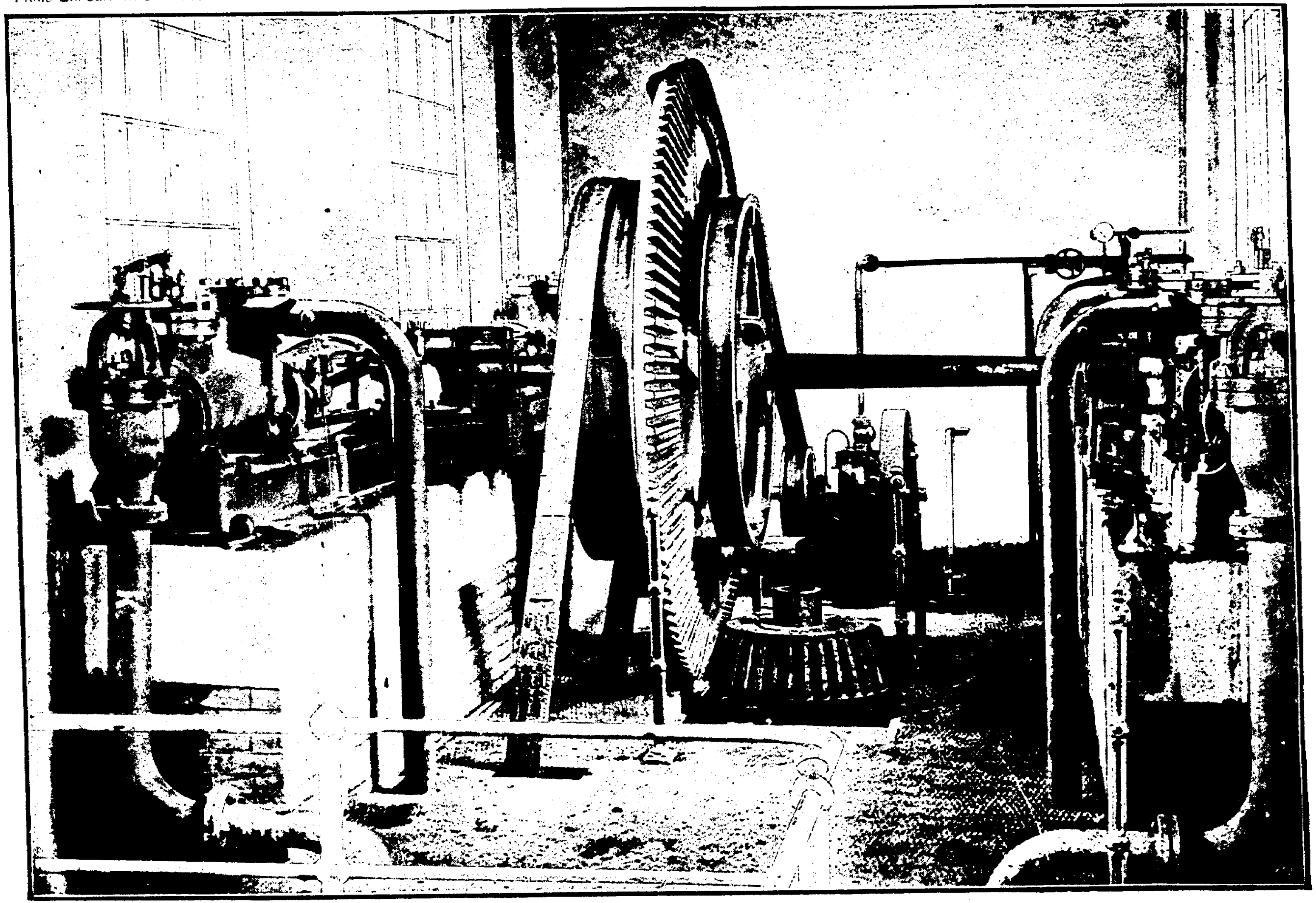
(15) The weight to be raised, including a piston, a trough, the water, and a boat floating in it, amounts to about 800 tons; the pressure in the presses is, therefore, about 25 atmospheres. But the accumulator has been loaded to 30 atmospheres to make sure of the efficient working of the presses for lifting the gates.

The compensating reservoirs were intended by the authors of the project to reduce the consumption of water, but it has not been thought best to use them.

(16) *Method of working the lift.*—The lift is worked as follows: One of the troughs being raised to the height of its course and containing a depth of water 2.40 meters, the joint is made by opening the cock admitting compressed air into the hose running around the face of the end of the aqueduct. Then the trough and aqueduct bridge are hooked together, and at the same time the space between the gates is filled by means of a little valve. The two gates are then raised together by means of a counterpoise and the hydraulic apparatus; a boat is hauled into the trough, then the gates are lowered and unhooked, the valve is closed, and the air in the rubber hose allowed to escape.

During this time similar operations have taken place below; the other trough being at the end of its course, resting on wooden blocks and containing water 2.10 meters deep. The upper trough has thus a surcharge of 0.30 of a meter in depth, corresponding to about 64.6 tons.

The connecting valve between the presses is then opened and one trough descends while the other rises. The motion is stopped by closing the connecting valve when the level in the ascending trough is 0.30 of a meter below that of the upper bay. The descending



HYDRAULIC CANAL LIFT AT LES FONTINETTES. VIEW OF THE PUMPING MACHINERY.

trough has also its level 0.30 of a meter above the level of the lower bay. The joints are formed, and the gates lifted, slightly at first, then completely. The upper trough takes its surcharge for the following operation while the lower one gives up its water ballast to the lower bay. The boats can then be hauled out and replaced by others.

The position of a trough may be corrected either before or after the opening of the lifting gates. It is sufficient for this purpose to move the distributor valves so as to allow water to escape from the press or to introduce water under pressure from the accumulator into it.

Also safety valves are introduced, opening automatically, and thus preventing the trough from rising too high, which might be dangerous.

(17) At the beginning of the operation, the press of the upper trough contains 41 tons of water more than that of the lower. The force producing the descent attains about 106 tons. This force progressively diminishes, since the water in the first press passes gradually into the second, and at the end of the operation the force is only 24 tons; this is necessary to overcome the friction and passive resistances. This force would be in reality only 12 tons if the connecting pipe was entirely free, but it was thought best to reduce the section by valves and thus regulate the apparatus, in order to avoid either an excessive velocity or a premature stoppage in case of error in taking the surcharge.

As we see, the initial force diminishes and the motion slackens continuously, so that each trough comes to the end of its course with nearly no velocity.

(18) The actual time of the up and down movement of a trough is on an average 26 minutes, made up as follows:

	Minutes.
Entrance of the boat and closing of the gates*	8
Ascent and descent of the troughs†	5
Correction of the position of the troughs	3
Opening the gates and hauling out the boats	10
Total	26

When the hydraulic capstans are set up to hasten the entrance and exit of boats, which is now done by men, this time will be reduced to 20 minutes, and six boats per hour will be passed.

The works were begun at the end of 1883. The first attempts to work the lift took place in November, 1887, and it was opened for traffic the 20th of April, 1888.

*This is a mean of 4,769 operations.

†This time would have been reduced to 3 minutes if the section of the conduit between the presses had not been reduced as a precautionary measure.

(19) *The towers.*—The slightest movement of the towers would affect the verticality of the guides; they were accordingly built on piles.

(20) *Erection of the presses.*—Ingenious devices were adopted to set up the presses and pistons.

The troughs were put together upon scaffoldings 7 meters above bottom of the basin, leaving the central portion above the pits open. In this position the girders of the troughs served to support a traveling crane which carried the pieces to be lowered into the pits.

Each press was erected as follows: The hexagonal framing having been placed, the bottom of the press with the first steel rings and the lower elbow of the connecting pipe were lowered, the whole having been lined with copper, the latter projecting beyond the rings. A copper collar 2.44 meters high, made in the workshop, was then riveted and soldered to the lining already placed so as to form on the exterior a regular cylindrical surface. The collar had a diameter very slightly less than the interior diameter of the rings. The latter were threaded on to the collar to a certain height, and then a new collar was placed, and so on.

The presses being set up, they were tested by a hand pump up to 54 atmospheres.

The presses were found perfectly tight, and the result of the test was to press the copper lining exactly against the steel rings.

(21) *The pistons.*—After this trial the pistons were set up as follows: Each press was filled with water and the connecting pipe closed by a plug having in it a three-way cock. The first section of the piston was placed so as to be supported by the water and project out of the press. The second section was then placed and the joint carefully made. By allowing a small quantity of water to escape from the cylinder the two sections were lowered so as to put on the third, and so on. If one of the joints was not tight it was discovered immediately by means of the hand pump, the piston was raised, and the defect corrected.

When the piston was in place the central portion of the trough was completed. Then the piston head was raised so as to bolt it on to the cross girders. The whole was then raised slowly by the hand pump and the trough lifted from its scaffolding, which was then removed.

(22) *Cost.*—The cost was nearly as follows:

	Francs.
Lands and buildings bought	165,017.32
Foundation (by compressed air) of the lift wall	97,000.00
Earthwork and masonry	583,492.71
Ironwork, including the sinking of the pits	831,102.00
Salary and patent royalty to Mr. Edwin Clark	47,670.00
Sundries	145,717.97
Total	1,870,000.00

The location of the Fontinettes lift was necessarily fixed; consequently the purchase of lands and buildings of great value, the expense of making a cut-off in a high filling, of crossing a railroad track, and of laying foundations under great difficulties, could not have been avoided; besides, the Government made its contract with Cail & Co. when the price of iron was very high. Considering the circumstances, it may be affirmed that if a similar lift were to be constructed on a new canal, the total expense would not exceed 1,300,000 or 1,400,000 francs.

(23) The plans for the earthwork and masonry were prepared by Messrs. Gruson, chief engineer, and Cètre, assistant engineer, who directed the works.

The contract for the metallic portion was awarded to Cail & Co., who intrusted it to M. Barbet, their chief engineer. Most of the work of erection was directed by M. Ballon.

SUMMARY.

Les Fontinettes lift—Neufossé Canal, France.

Trough—		
Length	meters	39.50
Breadth	do	5.60
Depth of water	do	2.10
Press—copper internal cylinder with exterior weldless steel hoops.		
Thickness of copper cylinder	meters	0.003
Thickness exterior steel hoops	do	0.060
Length of press	do	15.682
Length of stroke (height of lift)	do	13.13
Pressure in the press	atmospheres	25
Ram or piston—		
Thickness of cast iron	meters	0.070
External diameter	do	2.00
Total weight lifted, including water, trough, and ram, 800 tons.		
Equivalent to a pressure of 25 atmospheres.		
The contents of one stroke, in water	tons	41
Equivalent to a surcharge on the trough of	meter	0.20
Actual surcharge used	tons	64.6
Equivalent to a depth of water of	meter	0.30
Size of boats lifted	tons	300
Actual time of lift	minutes	5

Acknowledgment.—I wish in this connection to express my indebtedness to M. Gruson, chief engineer of roads and bridges, for the information concerning this interesting subject as well as for the three figures which accompany it.

THE LIFT AT LA LOUVIÈRE.

(24) This lift is situated in Belgium at La Louvière station on the railroad between Mons and Namur, on what is called the Center Canal, which, when finished, will unite the Mons and Conde Canal

with a branch (*i. e.*, the Houdeng-Goegnies) of that from Charleroi to Brussels. The canal itself is only 15 kilometers long, but the chief difficulty is in a section of it 7 kilometers long, from La Louvière to Thieu, with a fall of 66.196 meters, which it is proposed to surmount by the construction of four lifts.

(25) The first lift already completed is in the commune Houdeng-Goegnies, not far from La Louvière, so that it is sometimes called the Houdeng lift.

The masonry work of this lift was begun on the 15th of May, 1885, and the ironwork was finished in the beginning of 1888.

It is not proposed to consider here the motives which induced the Belgian Government to adopt the lift system, nor to repeat a detailed description of it. The two lifts of Fontinettes and La Louvière are similar in all their essential parts; they only differ in their dimensions, their weight, and in some details of construction, which we now propose to notice.

(26) *The presses.*—The only real difficulties met with were in the construction of the presses for raising the troughs. These are the most important and dangerous parts of the system. Upon them the stability and equilibrium depend; they must have unusual dimensions; it takes a certain amount of audacity to put a load of 2,096,000 kilogrammes upon two presses, requiring their interior diameters to be 2.06 meters each, with a permanent tension of 34 atmospheres.

(27) We have already seen how the problem was solved in France. In Belgium, after many experiments, it was decided to form the presses in cylindrical cast-iron sections 0.10 meter thick, 2.06 meters in diameter, and 2 meters high, around which weldless steel coils 0.05 meter thick and 0.152 high are shrunk on so tightly as to prevent the cast iron from having, at the interior concave surface, a stress of more than 1 kilogram per square millimeter with a tension of 34 atmospheres inside the press.

(28) *Tests of the iron and steel.*—One of the sections broke on trial at a pressure of 146.5 atmospheres. The steel has a tensile strength of 46.87 kilograms per square millimeter with an elongation of 25 per cent at the point of rupture.

The cast iron, run into little bars, had a tensile strength of 17.53 kilograms and a resistance to compression of 73.49 kilogrammes. Finally, and this is the most important test, a cast-iron section hooped with steel, after a series of trials going up to 200 atmospheres, broke at 265 atmospheres, the cast iron only having given way without producing a rupture or any alteration in the steel hoops.

We may therefore consider the resistance of the presses at least eight times superior to the permanent tension to which they are exposed.

The cast iron here plays the part of a tight lining only, and it seems more simple and rational, at least in theory, to replace it with copper a few millimeters thick, and depend wholly on the steel hoops for strength, as in the French lift.

(29) *The pistons*—Each cast-iron piston has three parts; the head, which supports the trough, and is 3.20 meters square, and 1.40 meters high; the shaft, composed of 8 sections, each 2.13 meters high and 0.075 meter thick, bolted together; and the foot, which is a spherical segment 1 meter in height.

(30) The communication between the presses takes place near the top through a flanged annulus bolted in between two segments, thus forming practically the strongest portion of the press, which is fed through a series of holes 0.05 meter in diameter made in the annulus; the two distributing annuli are connected by a special pipe.

It will be remembered that in the Fontinette lift the presses are connected at the bottom, thus requiring a pipe double the height of the pits.

The spaces between the troughs and the aqueducts, above and below, are closed by metallic wedges lined with India rubber. Sets of hydraulic apparatus driven by an accumulator containing water under a pressure of 40 atmospheres drive these wedges, lift the gates of the aqueducts and troughs, and turn the capstans for hauling the boats in and out of the lift.

Cost.—The cost of construction of La Louvière lift is as follows:

	Francs.
Purchase of lands	11,273.00
Earthwork and masonry, including the tubbed pits and machinery houses	402,165.36
House for the engineers	26,891.68
Metallic portion, including the machinery	899,062.71
Patent rights, and salaries of L. Clark Stanfield, and E. Clark	65,586.61
Total	1,404,979.36

If we add the cost of journeys, plans, committees of consultation, and oversight, the sum will amount to at least 1,500,000 francs.

(31) *Precautions against frost.*—During heavy frosts the troughs are both lowered, and the presses and pipes emptied. In the new lifts about to be erected by the Belgian Government all the pipes will be protected from frost by being inclosed in large masonry chambers in which fire can be kept; the same precautions are taken in reference to the valves, the pumps, and the hydraulic machinery.

(32) *Conclusion.*—The experience acquired and the observations made in the construction and working of this lift have suggested numerous and important improvements which will be introduced into the lifts now in process of construction. The whole apparatus will be considerably simplified. The compensating reservoirs have been definitely abandoned, and the footbridges around the troughs dispensed with.*

* Report of M. Duffourny.

The iron aqueducts uniting the upstream end of the canal with the troughs are replaced by masonry ones. The wedges are fixed with a possibility of adjusting the upper one by hand. The downstream guide is omitted, and every cause of accident due to the spontaneous action of water under pressure is carefully removed by taking care to move by hand the wedges and the hooking bolts of the gates. The operating levers worked by hand are interlocking, and absolute security results from the fact that an error in operating is mechanically impossible.

The bottoms of the basins have been raised considerably by giving a more natural form to the longitudinal trough girders, and the weight of all the movable parts of the system has been reduced by the substitution of steel for iron. A last improvement is the protection of the pipes and valves from the action of the frost.

SUMMARY.

La Louvière lift, Canal du centre, Belgium.

Trough:		
Length	meters..	43.000
Breadth	do...	5.800
Depth	do...	3.250
Weight	tons..	296
Draft of water	meters..	2.400
Ram or piston—cast iron:		
Diameter	meters..	2.000
Thickness	do...	0.075
Length	do...	19.440
Weight	tons..	80
Press—cast iron, hooped with continuous steel coils:		
Internal diameter	meters..	2.060
Thickness of cast-iron core	do...	0.100
Thickness of steel coils	do...	0.050
Length of press	do...	19.590
Length of stroke	do...	15.397
Weight of trough, water, and piston	tons..	1.048
Equivalent to a pressure of	atmospheres..	34
The contents of one stroke in water weighs	tons..	49.3
Working surcharge 0.25 meters	do...	63
Actual time of lift, from 2 to 3 minutes.		
Size of barges lifted	tons..	400
Total time, including entering and departure of a barge in each direction, 15 minutes.		

CHAPTER II.—THE MOVABLE DAM AT SURESNES ON THE SEINE.

(34) The needle dam constructed at Suresnes in 1866 assured a draft of water through Paris of 2.20 meters; to obtain one of 3.20 meters above Paris it was decided in 1880 to reconstruct the dam so as to have an additional fall of 0.97 meters.

The river Seine is divided at Suresnes into three branches by the Folies and Rothschild islands. The dam is built at the head of these islands and consists of three separate passes. Looking down the stream on the left is the navigable pass, 72.38 meters. To the right, between Rothschild and Folie islands, is the waste weir or intermediate pass, 62.38 meters; to the extreme right is the raised pass, 62.38 meters; the total length, 197.14 meters.

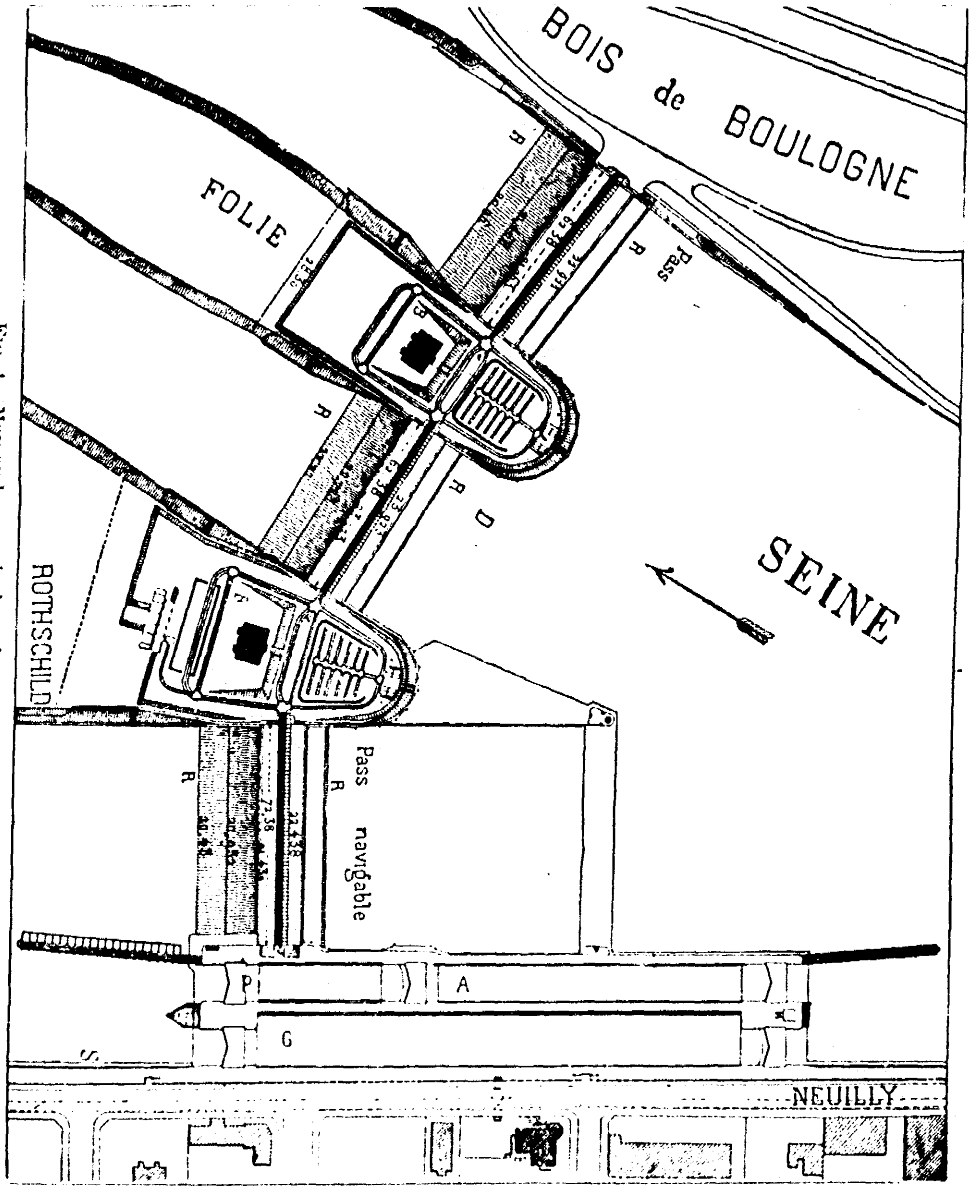


FIG. 4.—Map and general plan of movable dam at Suresnes.

Above and below each pass are the aprons marked R. Next to the navigable pass are the little lock, P, the old lock, A, and the great lock, G. On the left bank is the lockman's house, E, and on each of the two islands houses, B B, for the "barriagists" or dam keepers.

The rectangle in front of the navigable pass shows the location of the old dam, and the old weir extending from the end of Rothschild Island to the outer end of the rectangle.

The normal fall is 3.27 meters.

(35) The dam is closed by a method imitated from Poirée's system of needle dams; Poirée's frames (fermettes), Fig. 5, have been retained, but with such modifications as were requisite to withstand the increased pressure due to the unprecedented difference of level.

	Number of frames.	Height of frames.	Weight of a frame.	Cost.
		Meters.	*Kilos.*	*Francs.*
Navigable pass	58	6.	1,800	1,500
Raised pass................	50	5.49	1,350	1,135
Waste weir..................	50	4.14	800	660

(35) *Frames.*—Each frame (Fig. 5) consists of a downstream and upstream upright, united by horizontal and diagonal bracing. These uprights, instead of being merely plates, are made up of channel iron put together so as to form (Fig. 6) box girders. These girders have the advantage of resisting equally well in the direction of the water pressure and in that at right angles, produced by raising or lowering the frames. To vary the resistance in the first direction it is only necessary to increase the distance between the channel irons; to vary it in the direction at right angles it is sufficient to increase the number of irons.

The bracing consists only of channel irons having nearly the same dimensions as those of the uprights.

The frames, 1.25 meters apart, are united by three distinct rails which serve to carry the hoisting windlass and the planks of the service bridge crossing all three passes.

(36) *Operations.*—The difficulties in raising or lowering the frames are satisfactorily overcome by the use of Megy's patent windlass.

All the frames of the Seine pass are united by a continuous chain by means of link catches placed on their upper cross brace. The length of the chain between two successive frames is greater than the distance between the axes of rotation, so that six frames are lowered or raised like the sticks of a fan: the chain is hauled in by a windlass placed on the abutment of the pass.

By this system, having put the first frame in place, it is only necessary to haul in a short length of chain to bring the second into its upright position, and the operations of opening and closing the passes are almost reduced to the taking up or putting down of the rails and planks of the service bridge.

At Suresnes the opening of the navigable pass, 72.38 meters in length, is accomplished in 3 hours, and the closing in 5 hours; although each of the fifty-eight frames weighs 1,800 kilograms. The following table indicates the diameter of the chains and the cost of setting up of three dams.

MOVABLE DAM AT SURESNES.

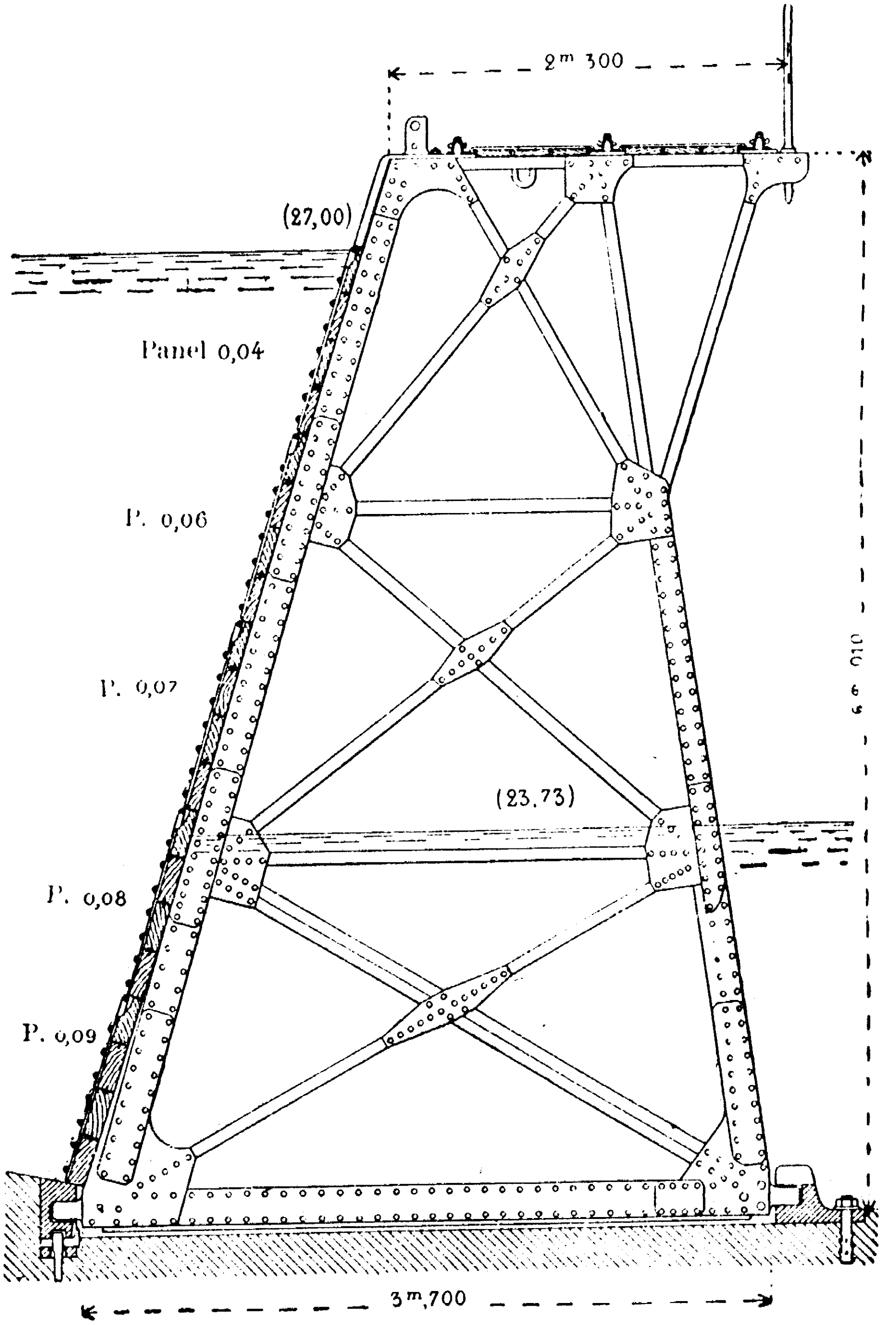


FIG. 5.—Movable frame (fermette) of the navigable pass.

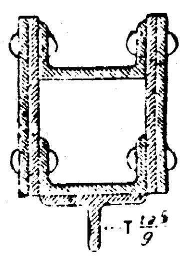


FIG. 6.—Transverse section of the upstream upright.

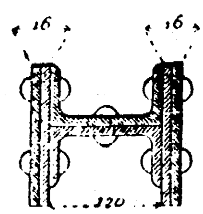


FIG. 7.—Transverse section of the downstream upright.

	Power of windlass.	Diameter of the chains.	Total cost.
	Tons.	*mm.*	*Francs.*
Navigable pass	10	26	9,400
Waste weir	4	17.5	5,400
Raised pass	6	21	6,600

(37) The flooring, fixed in the masonry, has the peculiarity of having no portion hollowed out to receive the frame. The sill is placed at such a height as to protect the frame when lowered, but at a certain distance from them it is united by an inclined plane to the row

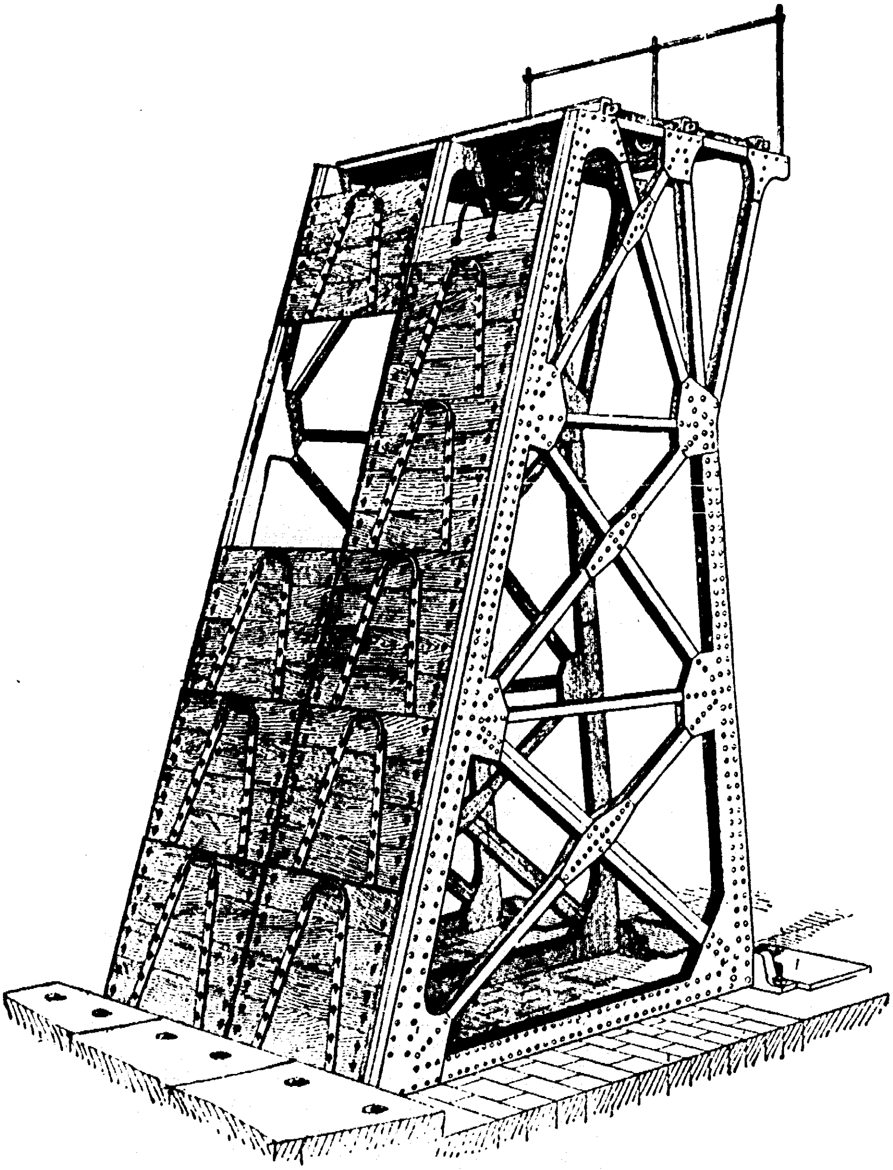


FIG. 8.—Dam at Suresnes. Movable frame with its panels.

of cut stones containing the upstream axle bearing. These stones project a distance of 0.30 meter, and beyond them the flooring is horizontal. Hence no deposit can be formed to obstruct the lowering of the frames. Iron sockets placed on each side of the frames allow the formation of a cofferdam in case of need, with the aid of a windlass, for the purpose of making repairs.

(36) *Panels.*—The dam is closed both by M. Boulé's panels and by M. Cameré's curtains. (The latter will be hereafter fully explained).

M. Boulé's panels are of wood, 1.22 meters wide by 1.10 meters high, varying from 0.04 to 0.09 meter in thickness.

A panel of 0.09 meter is placed between two frames of the navigable pass at the bottom, then one of 0.08 meter, followed by one of 0.07, 0.06, and finally one of 0.04 meter. (Fig. 8).

The water flows over the tops of the panels, and the opening takes place in horizontal layers; the upper panels across the dam are first removed, then the second, the third, and so on to the last; the flow always passing over the top.

This apparatus is strong, simple, and easily operated, for, as the panels are removed the head falls, and consequently the pressure diminishes, so that the effort to raise a panel under water is always slight, and about the same whatever height the dam may have.

(37) *Handling the panels.*—The panels are handled by means of of a windlass with a long straight rack terminated by a hook and guided by the frames themselves.

(38) *Cost.*—The works for the erection of the dam were begun in 1882, and finished in 1885, at a total cost of 2,799,958 francs, including those for the protection of the banks in the three passes, the earthwork on the islands, the storehouses and dwellings for the lockmen, etc.

The dam, properly speaking, including the abutments, piers, flooring, and movable parts cost, per running meter—

	Francs.
For the navigable pass (frames 6.01 meters)	12,262
For the raised pass (frames 5.49 meters)	10,817
For the waste weir (frames 4.14 meters)	7,727
Average cost for the dam per running meter	10,370

The following table indicates the weight and prices of the different panels:

Thickness of panels.	Weight.	Cost.
Meters.	*Kilos.*	*Francs.*
0.04	83	41.01
0.06	115	52.01
0.07	136	58.95
0.08	147	60.40
0.09	183	70.84
Total for one span	664	283.21

The project was prepared and the works executed under the direction of M. Boulé, chief engineer, and MM. Nicou and Luneau, assistant engineers.

CHAPTER III.—MARLY DAM ON THE SEINE.

(39) The old Marly dam which consisted of five piers and two abutments, supporting six spans of planks 5 meters long, with a cross section of 25 × 20 millimeters, very difficult to handle, and indeed often impossible in times of freshet, has just been replaced by a Poirée dam, that is, the piers have been replaced by iron frames like those of the movable dams; upon these frames panels, large and small, rest and slide, which are easily handled under all circumstances.

But as this dam is situated in a branch of the Seine which is not navigable, and behind the screens for protecting the water wheels which form the Marly machine, the frames are never lowered as in movable dams, for no boat ever passes through it; and as the screens protect it completely from ice, it is sufficient to vary the flow over the weir as the waters rise or fall. These frames being thus fixed, and incapable of being lowered, certain modifications in their construction have been made, economizing material used, and changing the system of attachment to the flooring, both of which have been here introduced for the first time.

The dam is 36.15 meters wide and has a fall of 3 meters. The flooring is placed 0.20 meter above the lower bay.. The frames are twenty-eight in number, 1.25 meters apart; the dam is closed by panels, large and small, sliding in guides formed by the upstream uprights of the frame, and handled by a windlass rolling on the service bridge.

(40) *Flooring.*—The flooring, 12 meters long, between two rows of piles and sheet piling, is 3.75 meters thick, consisting of: (1) A layer of beton 2 meters thick, laid under water, and covering the heads of 210 piles, driven to consolidate the foundations; (2) of a mass of rough masonry 1.30 meters thick; (3) a hewn stone revetment 0.45 meter thick.

The rear apron, 4.50 meters long, is formed of masonry blocks, 2.250 cubic meters, weighing about 5,000 kilograms each; and at the end of these blocks coarse riprap is placed.

This dam was constructed by means of a cofferdam built above, having a fall of 3.20 meters. Below, the work was sheltered from little freshets by simply raising the inclosing walls, which were sawn away when the frames had been set up.

(41) *The frames.*—The fixed frames are 3.80 meters high and 3 meters long at the base (Fig. 9). The upstream upright, inclined at an angle of 22° 30′, with the vertical, directs the resultant pressure towards a point exterior to the base but very near the downstream end; the overturning moment is nearly nothing, and the general action of the frame upon its fastenings is reduced nearly to a horizontal thrust. The pressure is transmitted directly to the apron by three inclined braces, which divide it between the different groups of fastenings, so that these fastenings only resist shearing.

Nevertheless, to guard against the vertical tension from below upward the first anchorage consists of a great cut stone, attached to the mass of the apron by channel-iron plate bands and anchor rods 2.50 meters deep, with washers 0.40 meter in diameter.

Each frame rests upon the horizontal surface of the apron, on its lower flange, forming a double T reversed, and strengthened by a plate, the whole having the form shown in Fig. 10. It is fastened by eight bolts divided into four groups, and a cast-iron shoe placed on the downstream side, fastened by three bolts 0.03 meter in diameter.

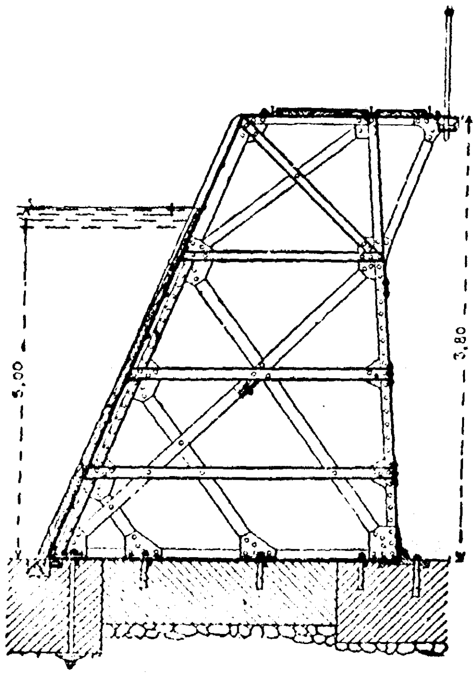


Fig. 9. Fixed frame used in the Marly Dam.

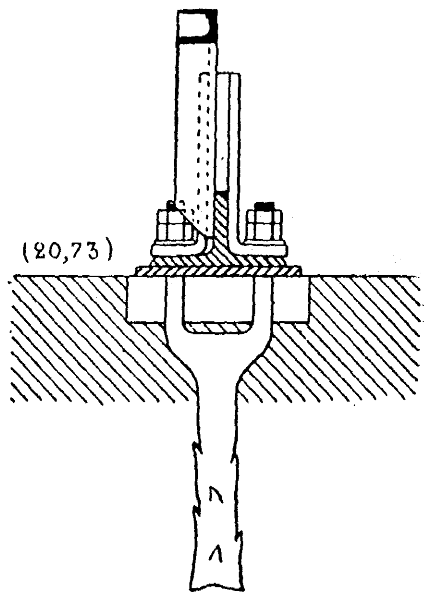


Fig. 10. Method of anchoring the frame.

The total maximum pressure of 9,579 kilograms gives a horizontal component of 8,850 kilograms, and if we admit that the lower flange of the frame divides this effort equally between all the fastenings—which is a rational supposition in view of the situation of the braces, and the rigidity of the lower flange—we find that each bolt has a load of 805 kilograms, that is, a maximum load of 2.05 kilograms per square millimeter of section.

The weight of each frame is 6.35 kilograms.

(42) *The panels* are 3 meters high vertically and 3.25 meters in the direction of the uprights of the frames. They are divided into four ranks, having the following heights, respectively, 0.89, 0.98, 1.09, and 0.32 meters. The last rank serves to regulate the fall. In each rank the thickness of the panel varies from the base to the summit, so as to avoid all useless weight.

These panels can be handled from the upper service bridge by means of a windlass of 1,800 kilograms power, which can raise a panel from the bottom or drive it back under a fall of 3.80 meters, a fall higher than would be possible under any circumstances.

The upper panels are moved by a little crane of 300 kilograms power, more easily handled than the windlass.

(43) *Cost.*—The cost amounts to 271,000 francs, as follows:

	Francs.
Upstream cofferdam, 60 meters long, built in a fall of from 1.50 to 2 meters	55,000
Dredging foundations in the location of those of the old Marly machine	30,000
Wood and masonry work for flooring and abutments	133,000
Storehouse and removal of the cofferdam	24,000
Iron frames, panels, windlass, etc	22,000
Total	271,000

Price per running meter, 7,496 francs.

The work were directed by M. Boulé, chief engineer, and M. Jozan, assistant engineer.

CHAPTER IV.—THE NEW LOCK AT BOUGIVAL AND ITS HYDRAULIC WORKING APPLIANCES.

Looking up the stream on the right is the famous Marly machine, a collection of water wheels for supplying the city of Versailles with water; at right angles to it is the new dam, N, at Marly (see Fig. 11). A is its waste weir; on the left is Loge Island, on which a roadway is built at a reference, 26.80 meters above sea level, connected by a foot-bridge with the right bank. Next on the left is a great lock, G, connecting the two pools, Bezons, 23.73 meters, and Andresy, 20.53 meters. To the left is the little lock, P. Two houses for the lock-men, E E, are situated, one on Loge and the other on Gauthier Island.

(44) The work of constructing new locks at Bougival for the purpose of obtaining a draft of 3.20 meters between Paris and Rouen was begun in 1879 and finished in 1883.

Two locks, side by side, have been built, one, 220 meters long and 17 meters broad, for trains, and the other, 41.60 meters long and 80.20 meters broad, for isolated boats. Both locks accommodate boats drawing 3 meters. The fall is 3.20 meters.

The length of the great lock was made 220 meters, instead of 140 meters the usual size on the lower Seine, in order that it might contain the largest trains which the towing company generally tows between St. Denis and Paris, that is to say, sixteen or seventeen barges and the towboat.

(45) *Motive power*—All the apparatus of the locks except the gate sluices are worked by water power, from an accumulator loaded so as to produce a pressure of 60 atmospheres and supplied by pumps driven by turbines obtaining their power from the Marly dam.

The motive for adopting this apparatus was the great traffic passing through these locks, which are the most frequented, not only of the lower Seine, but of the navigable water ways of France. There passed in 1888 through the Bougival locks 23,230 boats, carrying 3,056,829 tons of merchandise.

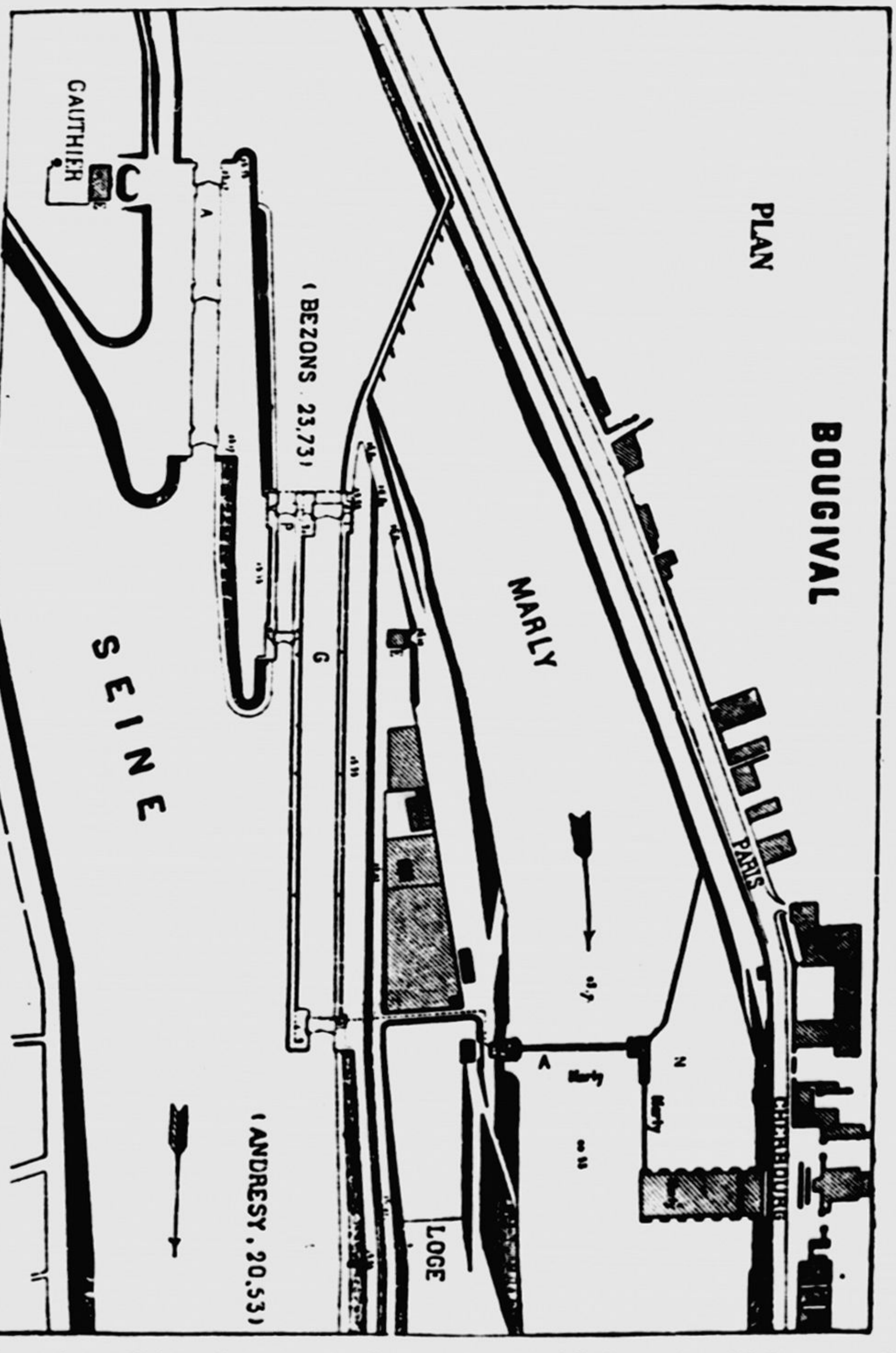


Fig. 11.—Map of the situation of the new river lock at Bougival.

Before describing the new locks we must add that the old Bougival lock constructed in 1838 by M. Poirée has just been restored, giving a chamber 113.50 meters of available length and 12 meters wide, capable of containing six barges drawing 2.36 meters.

(46) *New locks.*—The coping of the new locks is placed 1.61 meters above the normal height of the upper bay, which is the height corresponding to the highest water safely navigable with the towboat.

The gates, 12 meters wide for the large lock and 8.20 meters for the small, are of pitch pine with oak frames. Each pair of leaves has four gridiron valves having a total section of 3.43 square meters.

Besides these valves, culverts, placed in the walls on each side of the gate, fitted with gridiron sluices, have a total sectional area of 4.80 square meters for the large lock and 3.50 square meters for the small.

The volume of water requisite for each lockage is, respectively, 13,800 and 1,750 cubic meters.

(47) *Hydraulic machinery.*—The application of hydraulic power for working the new locks at Bougival according to the plans of M. Barret was decided on in 1879. The system includes: (1) The machinery and accumulator; (2) the piping; (3) the hydraulic presses for moving the gates, culverts, sluices, and capstans.

The machinery and accumulator are placed in a building on the right abutment of the Marly dam and comprise:

First. Two Fontaine-Baron turbines worked by the fall of the Marly dam which varies from 2.30 meters to 0.80 meter and gives under the least favorable condition 14 horse power.

Second. Two sets of three single-acting plunger pumps driven by the turbines by means of beveled gearing, capable of making from twenty-three to forty-five strokes per minute and forcing into the accumulator from 1.372 to 2.205 liters per second. A pump is attached to each turbine to raise water for the tank on the first story, which supplies the water for the accumulator.

Third. An Armstrong accumulator of 700 liters capacity loaded for a pressure of 60 kilograms per square centimeter. Its stroke is 5 meters, and it is filled in from 4 to 9 minutes.

The piping comprises the supply pipe from the accumulator to the hydraulic machinery on the lock walls, and the pipe which returns the water to the feeding tank; so that the same water constantly circulates, except some slight losses which are made good by the pumps. The pipes are cast iron or drawn wrought iron; those which have to sustain pressure are tested up to a hydrostatic pressure of 110 kilograms per square centimeter.

The head walls are reached by means of siphons submerged in the gate chambers.

The effective pressure in the pipes is transmitted to a distance of more than 600 meters from the accumulator without loss of head on account of the slight flow and the small diameter of the pipe, which is only from 0.06 to 0.07 meter in interior diameter.

NEW LOCK AT BOUGIVAL.

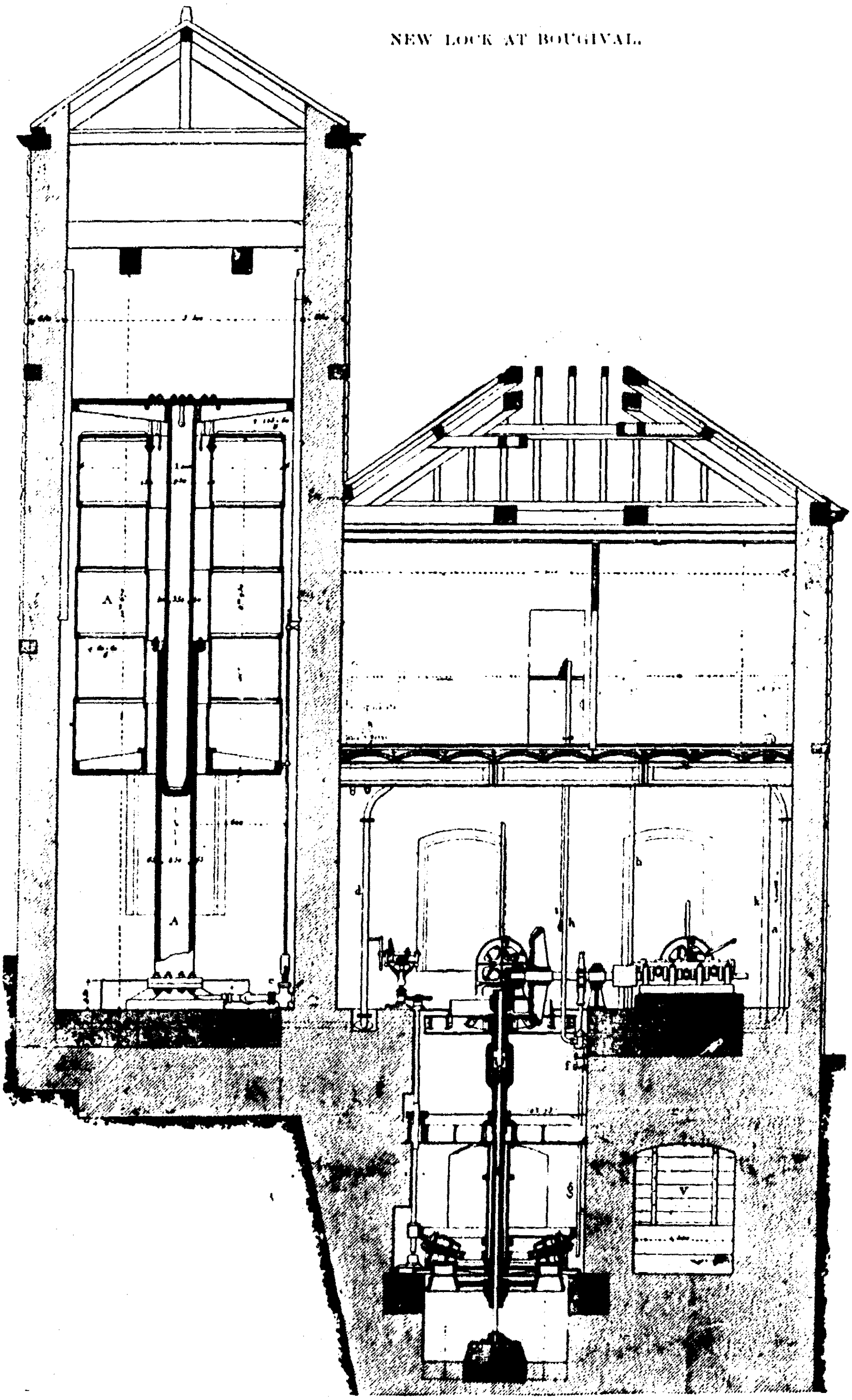


FIG. 12.—Machinery house and accumulator, longitudinal section along A B (Fig. 13).

NEW LOCK AT BOUGIVAL.

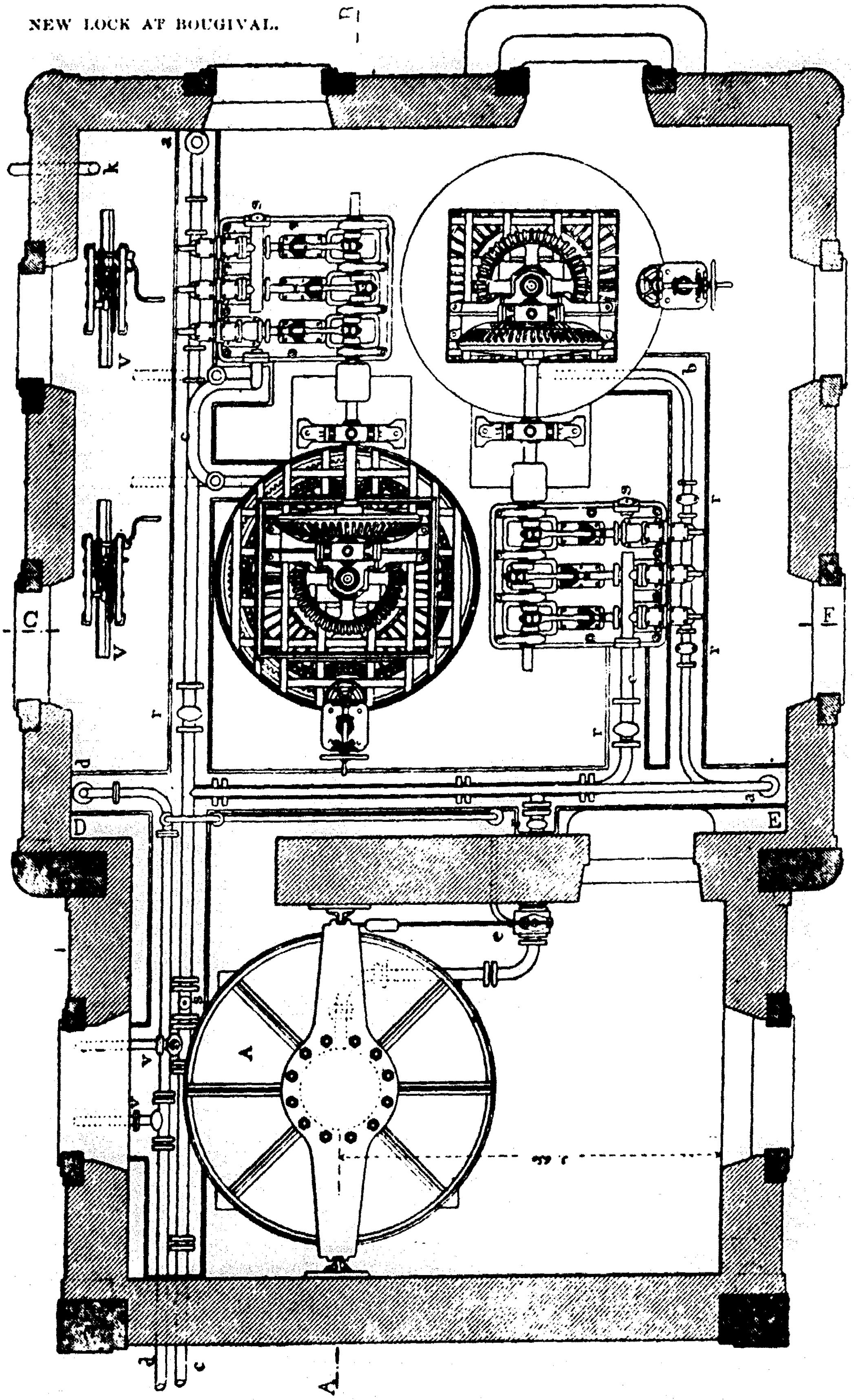


FIG. 13.—Machinery house and accumulator, horizontal section.

LOCK AT BOUGIVAL.

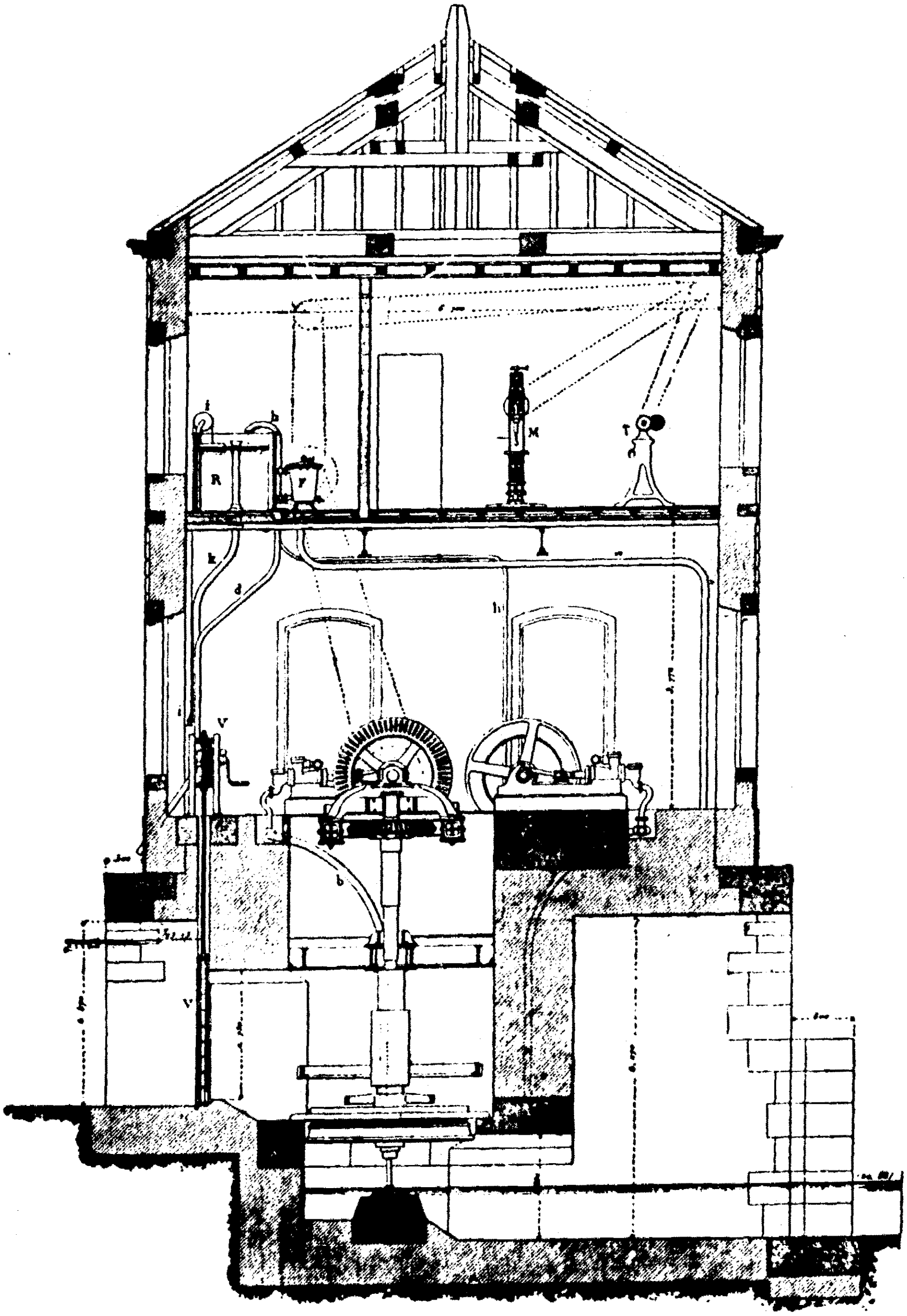


FIG. 14.—Machinery house, transverse section along C, D, E, F (Fig. 13).

LOCK AT BOUGIVAL.

APPARATUS FOR OPERATING THE LOCK SLUICES BY HYDRAULIC POWER ALONE.

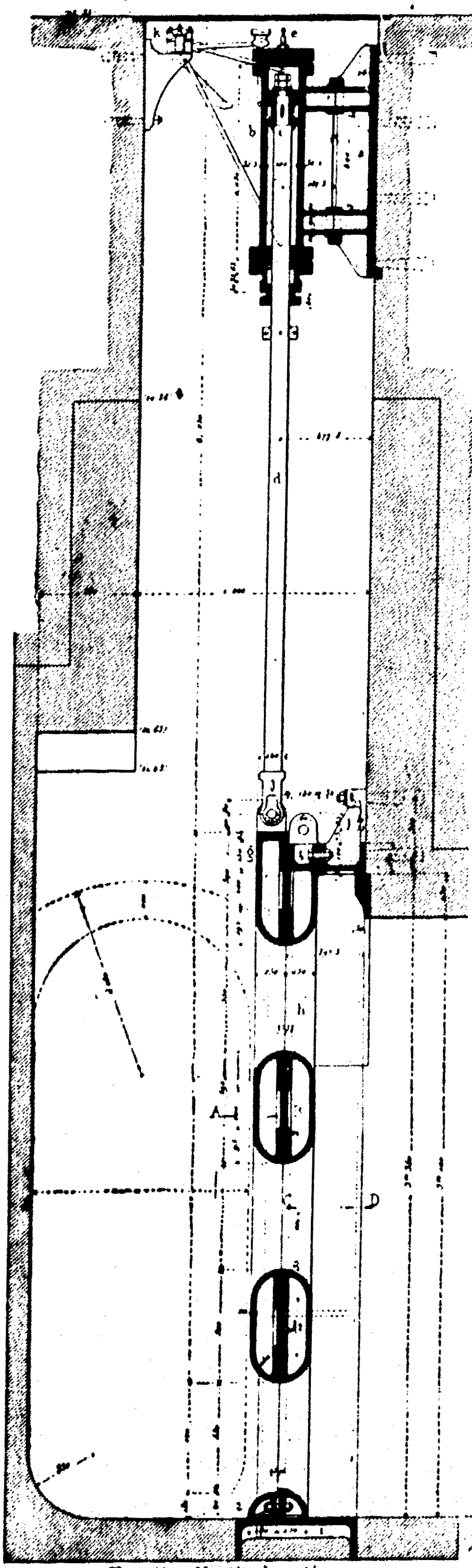


FIG. 15.—Vertical section.

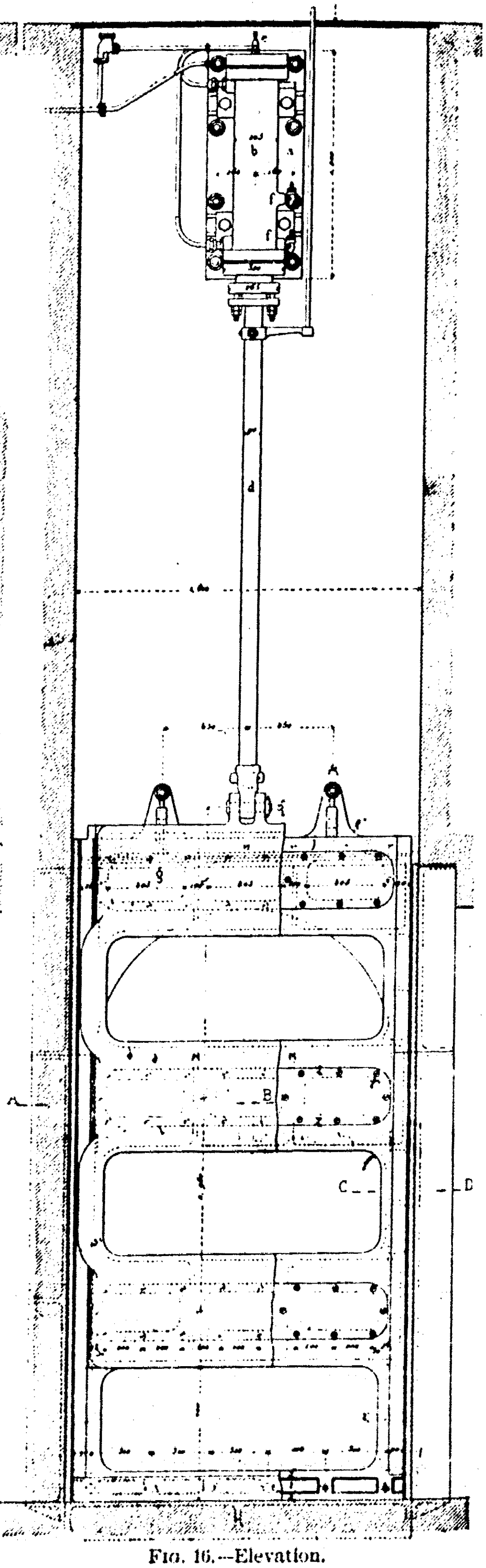


FIG. 16.—Elevation.

LOCK AT BOUGIVAL.

APPARATUS FOR OPERATING THE LOCK SLUICES BY HYDRAULIC POWER ALONE.

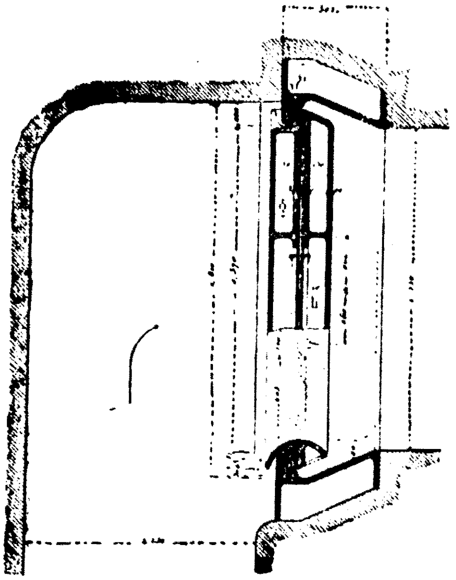


FIG. 17.—Horizontal section along A, B, C, D, (Fig. 15)

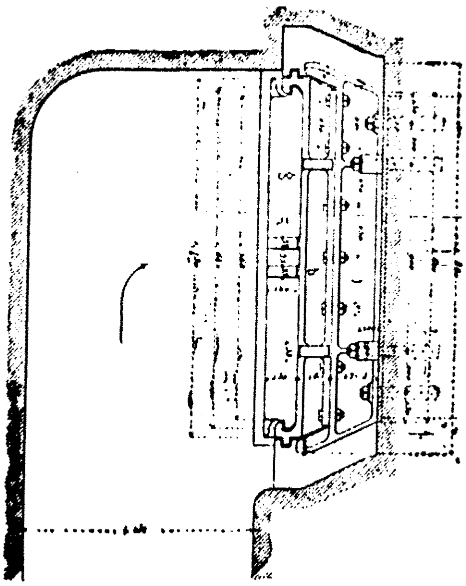


FIG. 18.—Plan of the sluice.

FIGS. 12, 13, 14.—*Machinery house and accumulator.*

a, Supply pipe from the tank to the pumps.
b, Direct supply pipe for the pumps.
c, Supply pipe from the accumulator to the presses.
d, Return pipe.
e, Waste valve regulated by the stroke of the accumulator.
f, Lifting pump; *g*, its suction pipe.
h, Pipe supplying the accumulator.
F, Filter; R, reservoir; *i*, float.
k, Waste pipe; *rr*, stopcocks; *s*, safety valve.
M, T, Punching machine and lathe.
V, Turbine sluices.
v, Emptying cock for the pipes.

FIGS. 15-18.—*Apparatus for operating the lock sluices.*

a, Frame of the cylinder for operating the sluices; *b*, Cylinder for operating the sluices; *c*, Differential piston; *d*, piston rod; *e*, air cock; *ff*, Water cocks; *g*, gridiron sluice; *h*, sluice seat; *j*, Upper bearer; *k*, valve chest.

LOCK AT BOUGIVAL.

COMBINED APPARATUS FOR OPERATING THE LOCK SLUICES EITHER BY HAND OR BY HYDRAULIC POWER.

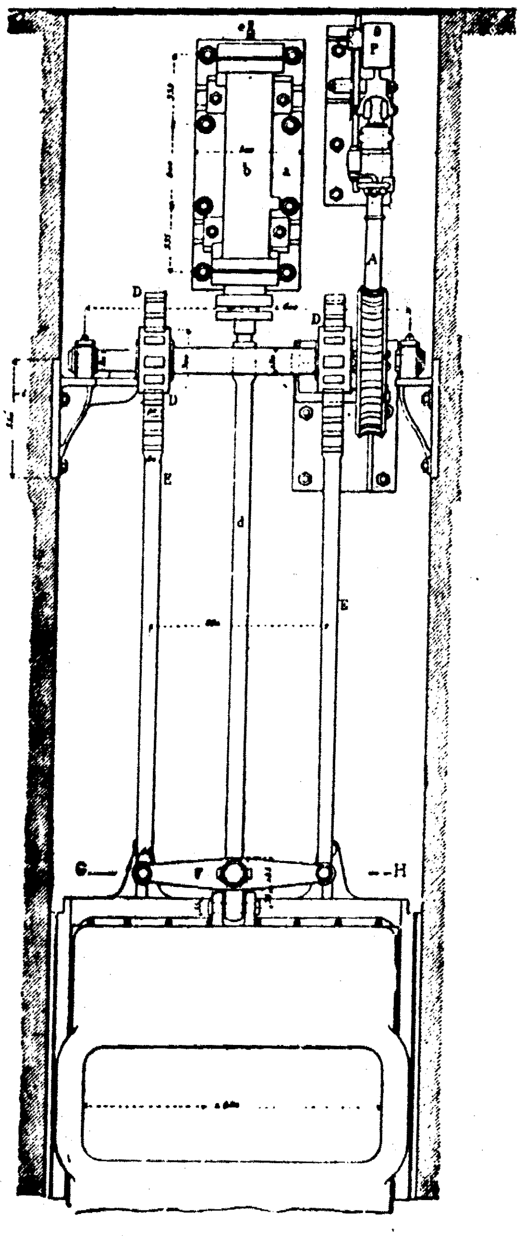


FIG. 19.—Elevation.

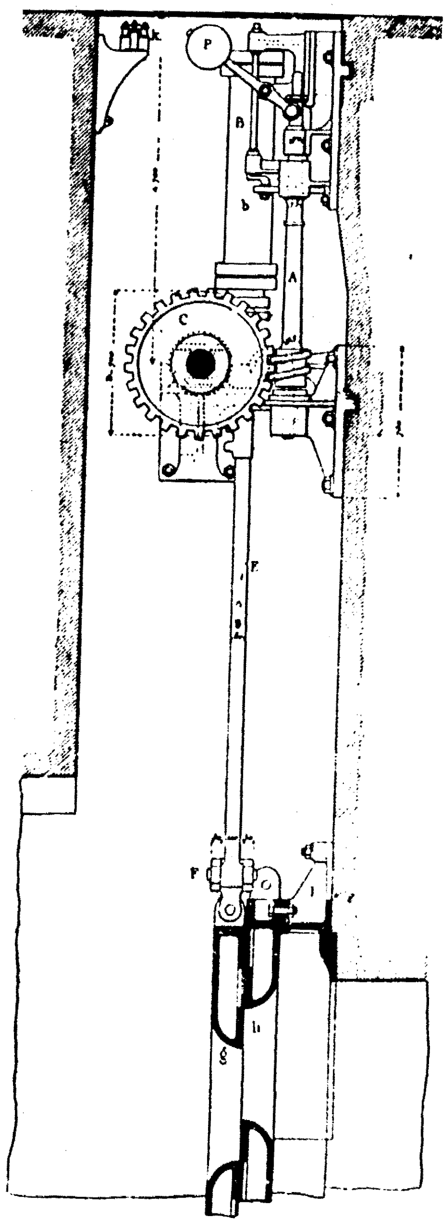


FIG. 20.—Vertical section.

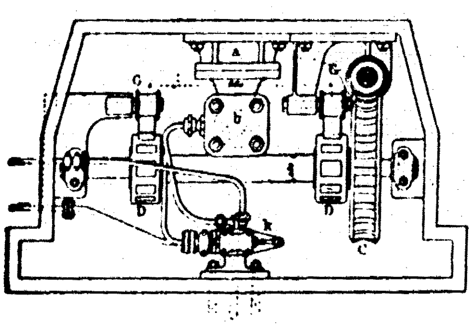


FIG. 21.—Plan.

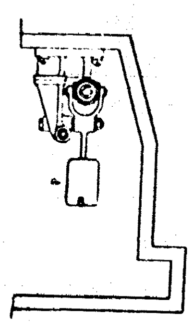


FIG. 22.—Engaging gear.

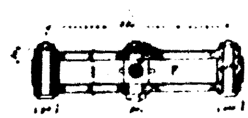


FIG. 23.—Section G H (Fig. 19).

LOCK AT BOUGIVAL.

FIGS. 19-23.—*Apparatus for operating by hand.*

A, Endless screw terminated above by a square head on which a strong key, provided with handspikes, fits.
B, Vertical cylinder for operating the abutment sluice.
C, Worm wheel driven by the endless screw and driving the rack and pinion; E E, racks.
F, Balance beam driven by the racks and united in the middle of the sluice.
G, Rollers guiding the racks; P, counterpoise counterbalancing the endless screw to facilitate the working of the engaging and disengaging gear.

HYDRAULIC APPARATUS FOR OPERATING THE LOCK GATES.

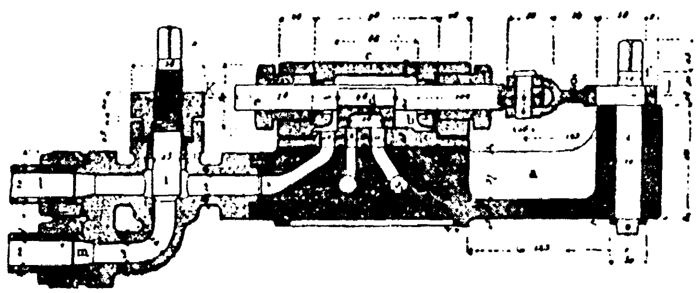


FIG. 24.—Valve chest, vertical section along I J (Fig. 25)

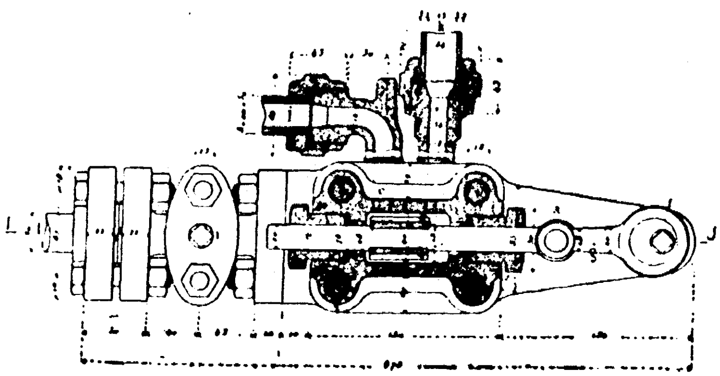
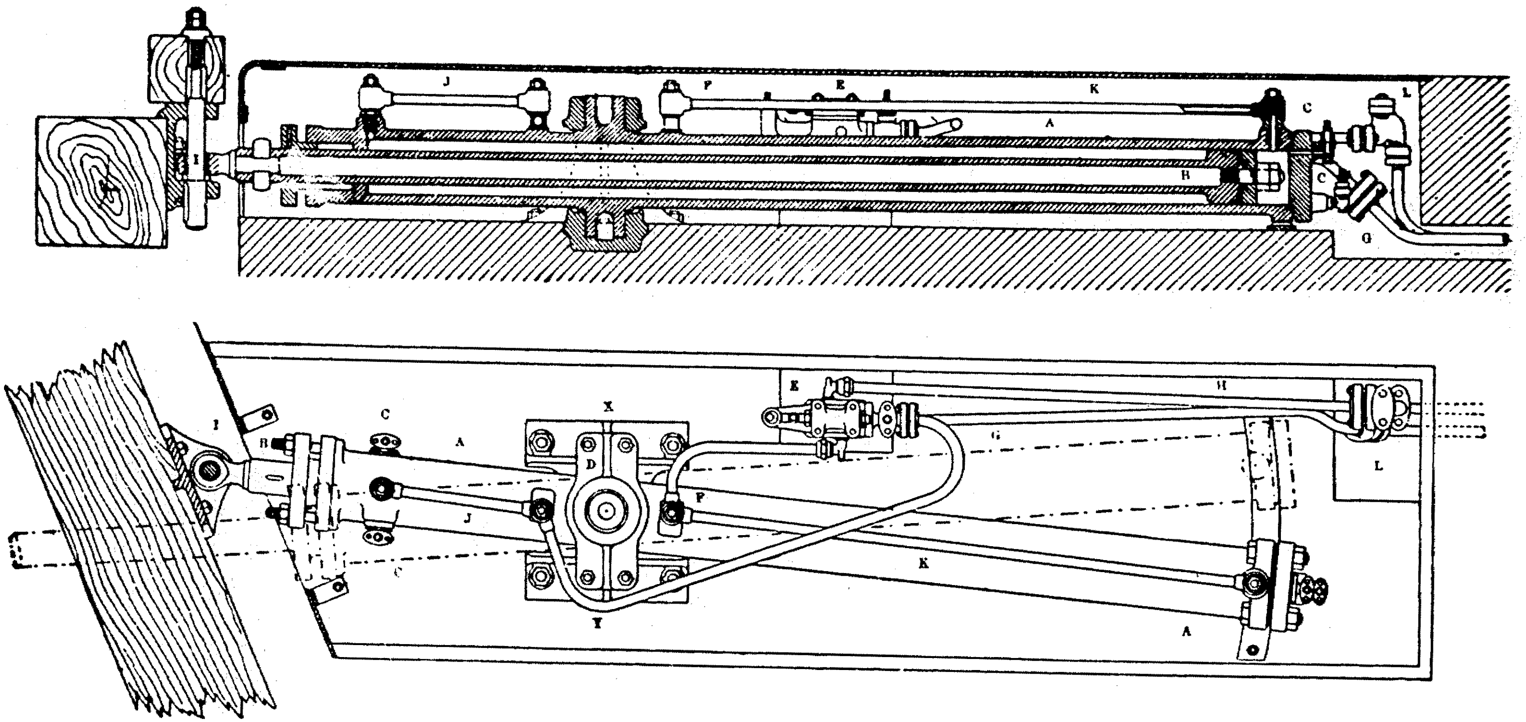


FIG. 25.—Horizontal section along K L (Fig. 24).

a, Cast-iron frame; *b*, bronze valve seat; *c*, valve chest; *d*, D valve; *e*, valve rod; *f*, eccentric; *g*, eccentric rod having its vertical axle with a square end to fit the operating key; *i*, the stem of the stop valve, forming the valve itself; *j*, duct leading the water under the piston; *k*, exhaust; *l*, duct leading the water above the piston; *m*, supply pipe for the water under pressure.

LOCK AT BOUGIVAL.



FIGS. 26 and 27.—Longitudinal section and plan of the hydraulic apparatus for opening and closing the lock gates.

A, Cylinder 15 centimeters in diameter and 25 millimeters thick; B, Piston, with hollow cast-iron piston rod, 10 centimeters in exterior diameter and 25 millimeters thick; C C, air cocks; D, cylinder support; E, valve chest for the water under pressure; F, joint of the supply pipes; G, supply pipe for the water under pressure; H, return pipe; I, spindle connecting the piston head with the transverse beams of the lock gate; J, jointed pipe connecting the valve chest with the posterior end of the cylinder; L, stop cock for closing the return pipe.

(48) *Protection against frost.*—In the winter, to avoid frost in the apparatus and in the pipes exposed to the air in short lengths, 6 or 8 kilogrammes of glycerine per cubic meter are added; this material has the advantage of lubricating the surface of the pistons, while chloride of magnesium, though cheaper, corrodes them and is hard to preserve on account of its deliquescent properties.

When the apparatus is well guarded by manure, glycerine is only used when the temperature descends 7 or 8 degrees below freezing.

(49) On the supply and return pipe four pieces of apparatus are placed for operating the gates of the large lock, each consisting of a horizontal cylinder (Figs. 26 and 27) oscillating around a vertical axis and having its piston attached to the upper transverse girder of the leaf, 2 meters from the heel post; this piston is called differential, because in one direction, the pressure being the same on the two faces of the piston, the motion is due only to the difference of the sections

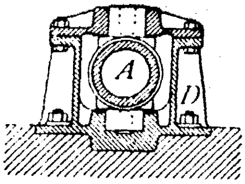


FIG. 28.—Transverse section through X Y (Fig. 27).

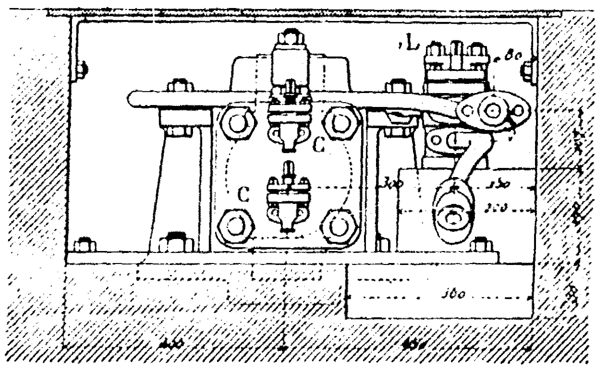


FIG. 29.—Section parallel to X Y through L (Fig. 27).

on which the pressure acts. This pressure acts constantly upon the face next the gate, that is, upon the annular face; the other face, which corresponds to the total section of the cylinder, is put alternately in communication with the accumulator and the return pipe.

The piston is attached to the gate by a double nut which can be raised while in use to prevent the former from bending, and its eye is oval shaped to allow for the transverse displacement of the leaves in their various positions.

The breech of the cylinder rests on an iron guiding sector. Finally the piston stroke exceeds by 2 centimeters its requisite geometric length, so as to take into account the possible deflections of the leaves.

This apparatus is lodged in a pit 3.50 meters long, 0.85 meter wide, and 0.46 meter deep, just below the coping. It is capable of exercising a tensile effort of 6,600 kilograms on the piston rod to open a leaf, and a compressive effort of 4,710 kilograms to close it. The dimensions are as follows:

	Meters.
Diameter of the piston	0.155
Diameter of the piston rod	0.100
Maximum stroke	2.520

Water expended in a double stroke, 47.5 liters.

Each apparatus has on its supply pipe a cock to cut off the water; at the bottom of the cylinder a waste air cock; also two cocks for emptying the cylinder in case of need.

(50) The apparatus for the small lock consists also of four pieces similar in every respect to those of the large one.

	Meters.
Diameter of the piston	0.128
Diameter of the piston rod	0.080
Maximum stroke	2.060

Water expended in a double stroke, 26.5 liters.

This apparatus is capable of exerting on the piston rod a tensile effort of 4,710 kilograms to open the gates, and a compressive effort of 3,016 to close them.

(51) *The apparatus for operating the culvert sluices for filling and emptying the lock chamber* are eight in number, consisting of cylinders with differential pistons having a stroke of 0.55 meter and acting directly on the gridiron sluices, capable of exerting a tensile effort of 8,244 kilograms for raising the sluices, and a compressive effort of 3,816 to close them.

HYDRAULIC CAPSTAN FOR NEW LOCK AT BOUGIVAL.

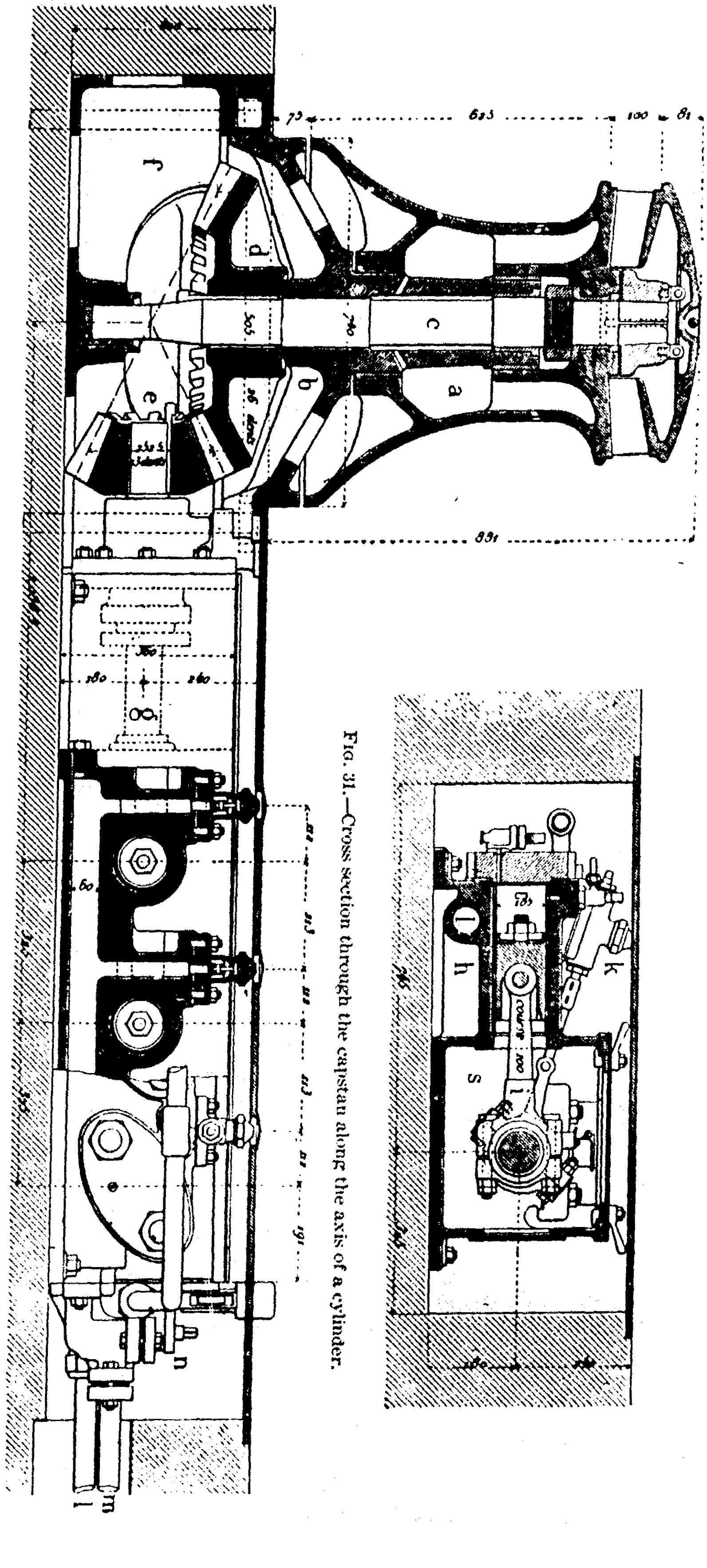


FIG. 31.—Cross section through the capstan along the axis of a cylinder.

FIG. 30.—Longitudinal section along E, F, G, H, Fig 32.

a, Capstan barrel; *b*, bearing frame for the barrel; *c*, central spindle; *d e*, bevel gear wheels driving the barrel; *f*, frame of the water motors, driving the capstan; *g*, steel motor shaft; *h*, cylinders; *i*, connecting rods of motors; *j*, slide valve eccentrics; *k*, valve chests with D valves balanced by springs; *l*, supply pipe; *m*, return pipe; *n*, return pipe valve; *o*, valve to admit, or shut off, the pressure from the accumulator; *p*, lever of the valve; *q*, counterpoise of the lever; *r*, pedal for operating the valve *o*; S, hermetically sealed cast-iron box to protect the pieces. See also Figs. 32-34.

HYDRAULIC CAPSTAN FOR NEW LOCK AT BOUGIVAL

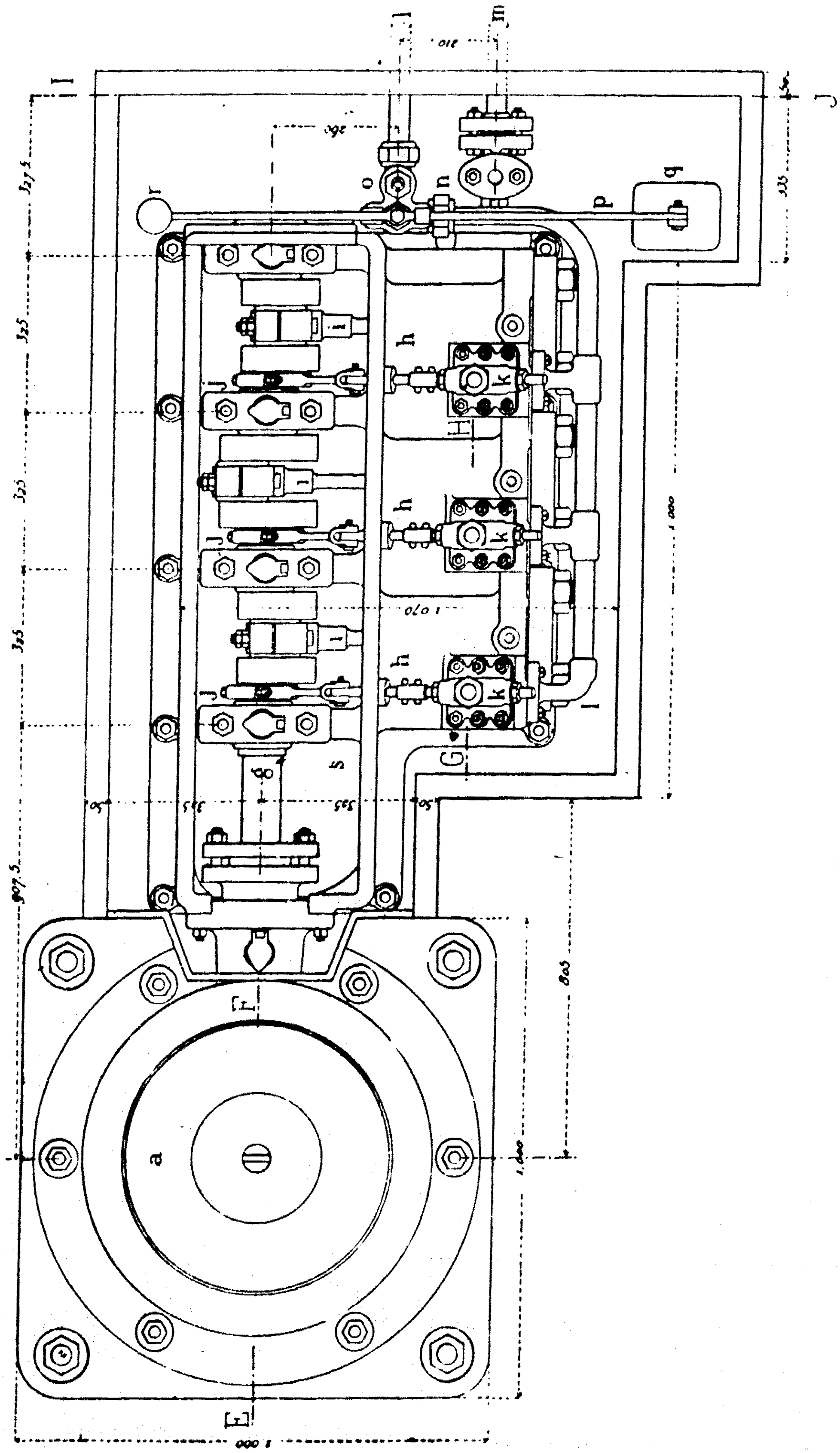


FIG. 32.—Plan (cover removed).

(52) *The ten hydraulic capstans* (Armstrong type modified by M. Barret) placed on the side walls of the great lock can exert a tractive effort of 12,000 kilograms on a cable, at a velocity of 0.43 meter per second (about 7 horse power).

All these pieces of apparatus are so arranged that they can be disconnected (in case of failure of the water supply, or for any other reason) and worked independently by hand (Figs. 19, 20).

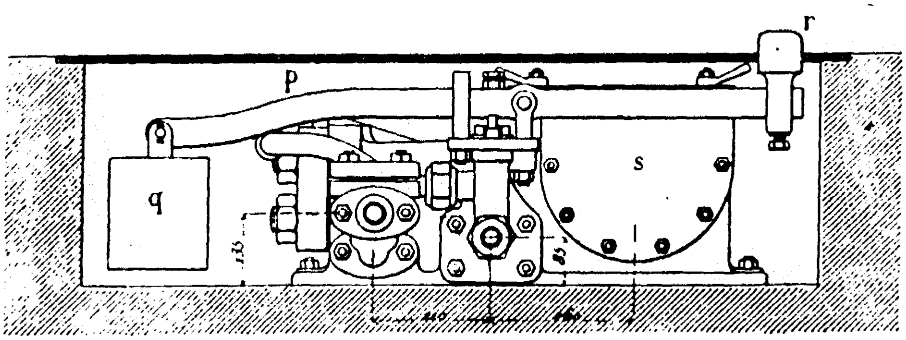


FIG. 33.—Lateral elevation along I J (Fig. 31).

Since these hydraulic appliances were set up in 1883, there have been only three insignificant interruptions in their regular working, and no hindrance has occurred in the navigation; and in virtue of the precautions taken to guard the pipes and presses, there has never been any interruption in the service on account of frost.

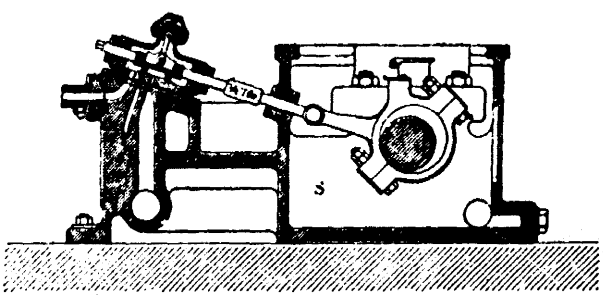


FIG. 34.—Cross section through the valve chest.

(53) *Advantages of the system.*—The lock chamber of the great lock at Bougival can contain sixteen or seventeen barges with their towboat, and the time of lockage is thus made up: Entrance, arrangements, and securing the boats, 20 to 25 minutes; closing the gates, 30 seconds; filling the lock chamber (13,800 cubic meters), 15 minutes; opening the gates, 30 seconds; unfastening and hauling out the boats, 15 minutes.

We see that for the largest train which the lock can contain, and which may carry 4,500 tons, the total duration of the process, from the time of entrance of the towboat to the exit of the last boat, is 56 minutes, and that of this time 40 minutes are taken up in the entrance and exit arrangements.

The small lock can pass eight boats per hour. The traffic in 1888 through the Bougival lock exceeded 3,000,000 tons, and the appliances would serve for twice that amount.

(54) *Cost.*—The total cost is as follows:

	Francs.
Cost of land damages	164,942.41
Earthwork and masonry for the cut-offs and locks	3,240,000.00
Four pairs of gates	72,318.64
Stockades above and below the locks	20,000.00
Hydraulic appliances	277,087.50
Total	3,774,330.55

The annual cost of working the hydraulic appliances is about 7,200 francs.

(55) *Conclusions.*—From a thorough examination of the working of these hydraulic appliances we may conclude:

First. That the introduction of hydraulic appliances in the great lock at Bougival constitutes, in respect to operating by hand or by horse power, a considerable improvement, without which this lock would be very inconvenient, and limited to a traffic of about 3,000,000 tons per annum, while this figure was exceeded in 1888.

Second. That the cost of establishment and maintenance is compensated by an economy nearly equal in amount made by the boatmen, so that in a general point of view these appliances are advantageous, since they allow without increase of cost the working of the locks with a traffic of 5,000,000 or 6,000,000 tons, while the ordinary appliances would not suffice for the transit of such a tonnage.

These works were directed by M. Boulé, chief engineer, and De Preaudeau, assistant engineer. The hydraulic appliances were constructed by the Fives-Lille Co.

Figs. 12–33, inclusive, are taken by permission from the Portefeuille des Ponts et Chaussées.

CHAPTER V.—NEW MOVABLE DAM AT POSES ON THE SEINE.

(56) The movable dam at Poses on the Seine, 202 kilometers below Paris, is the most important of those recently constructed between Paris and Rouen to realize at all times a minimum draught of 3.20 meters. In virtue of its exceptional height, it maintains this draught in a bay extending from Poses to Notre Dame-de-la-Garenne, a distance of 41 kilometers, while the average length of the other bays is only 23 kilometers in the canalized portions of the river between Paris and Rouen.

In the preliminary project for the works requisite to give a minimum draught of 3.20 meters to the lower Seine, it was proposed to erect at Poses a Poirée dam having a height of 4 meters above the sill; but even this would be insufficient to cover the shoals of la Mare and Tosny, without requiring excessive dredging, and a second

MOVABLE DAM AT POSES ON THE SEINE. UPRIGHTS AND CURTAINS FOR THE WEIRS.

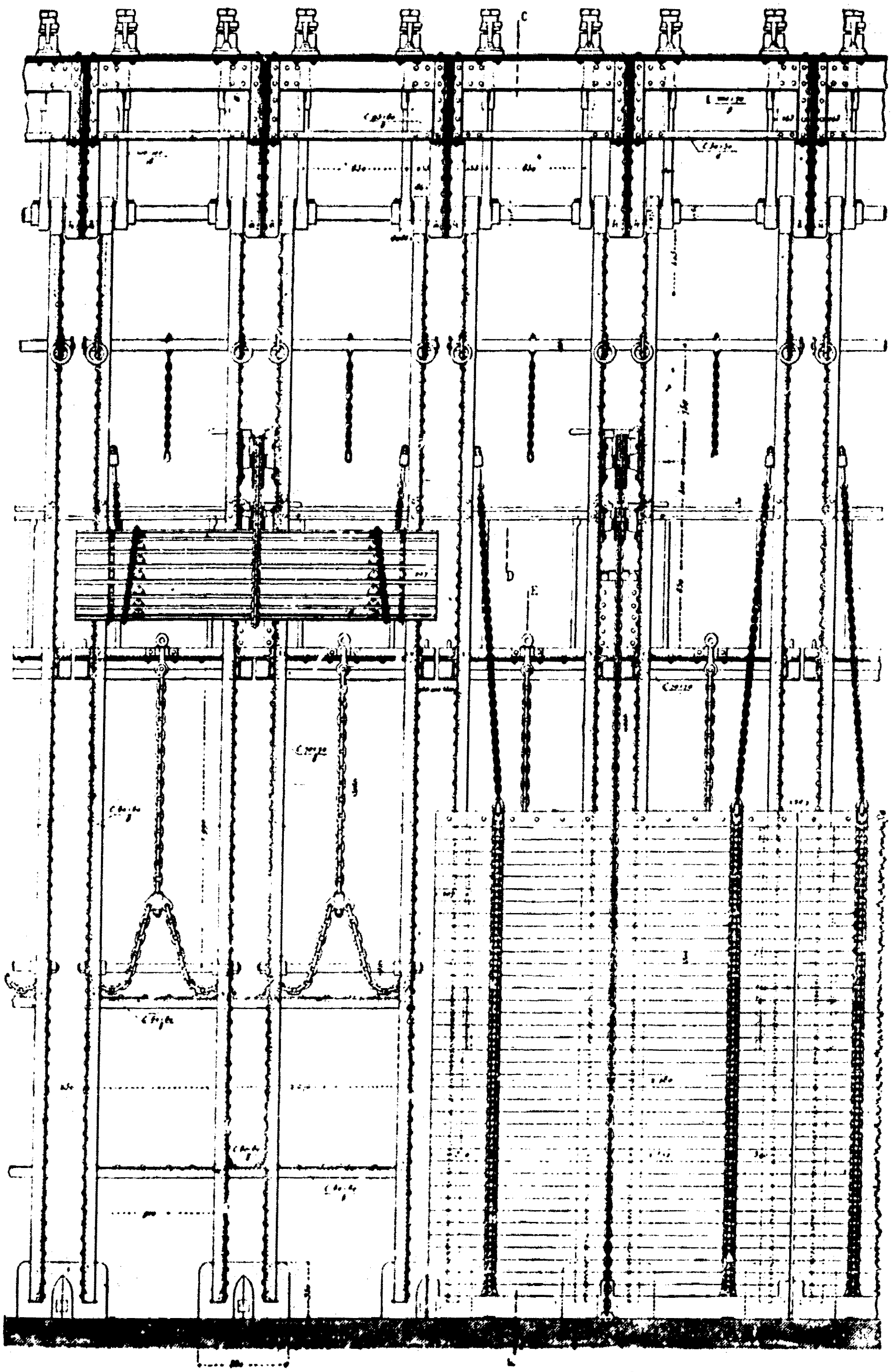
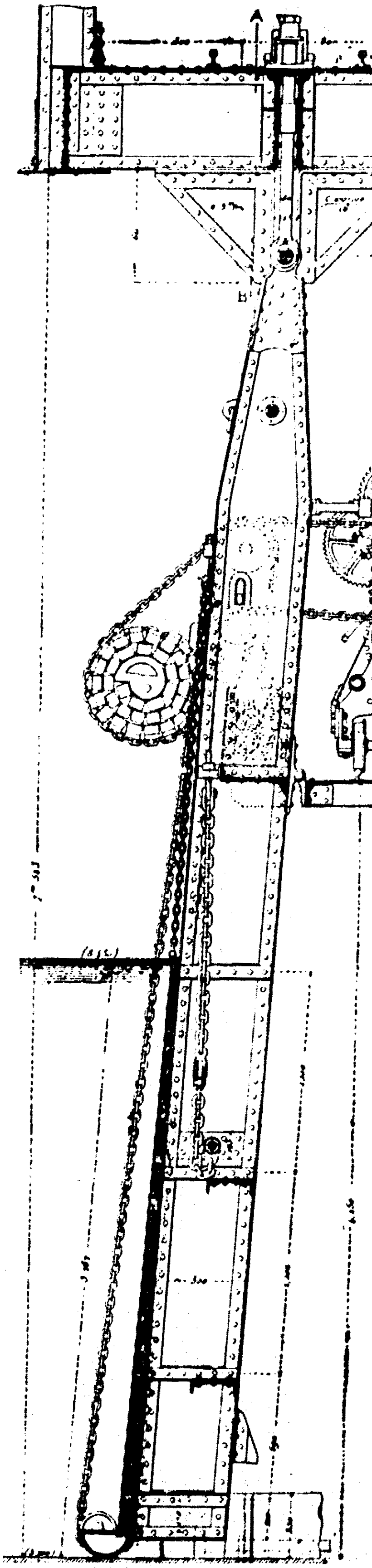


FIG. 35.—Longitudinal section in front of the uprights, along the line A B, Fig. 36.



Curtain windlass.

Elevation

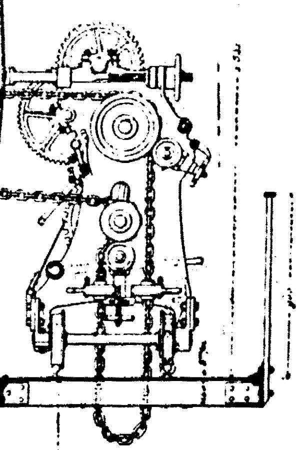


FIG. 37.

Section.

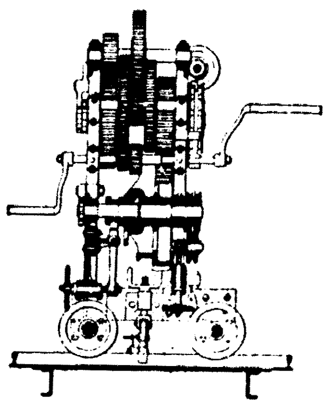


FIG. 38

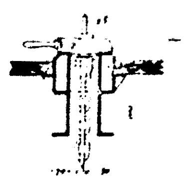


FIG. 39.—Chain stop

UPRIGHTS AND CURTAINS FOR THE WEIRS. MOVABLE DAM AT POSES ON THE SEINE.

FIG. 36.—Transverse section along C D E F (Fig. 35).

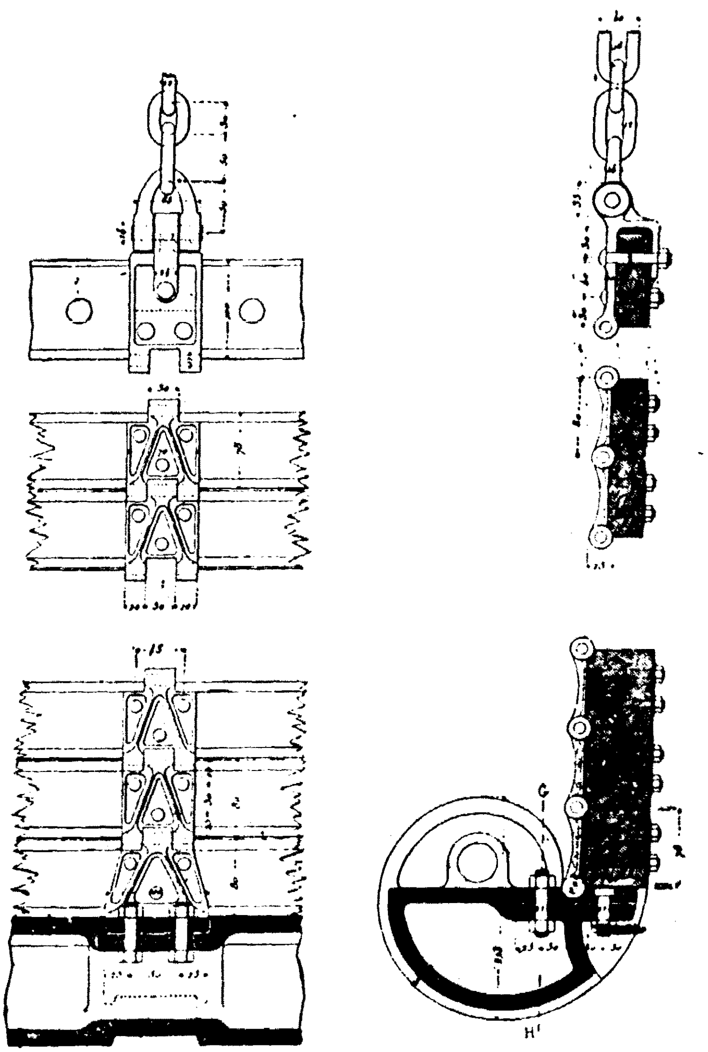
dam with a fall of 1 meter was provided for, near Andé, 10 kilometers above Poses.

The new dam invented by M. Cameré raises the upper bay at Poses to 5 meters above the sill, and thus dispenses with the proposed work at Andé.

Plate IV shows an admirable model of part of the Poses dam, which was exhibited in the Pavilion of Public Works.

Before entering into details it will be well to indicate in a general manner the principles and mode of working this new type of dam.

Cameré's curtains



FIGS. 40, 41.—Details of the curtain hinges and shoe, cross section and elevation.

Figs. 35–40 show the construction of Cameré's curtains and their method of suspension. The curtains themselves consist of wooden battens, hinged together (Figs. 40, 41) and resting against vertical supports; these supports are suspended from a bridge, shown in Figs. 42–48. Figs. 37 and 38 show the construction of the windlass for handling the curtains.

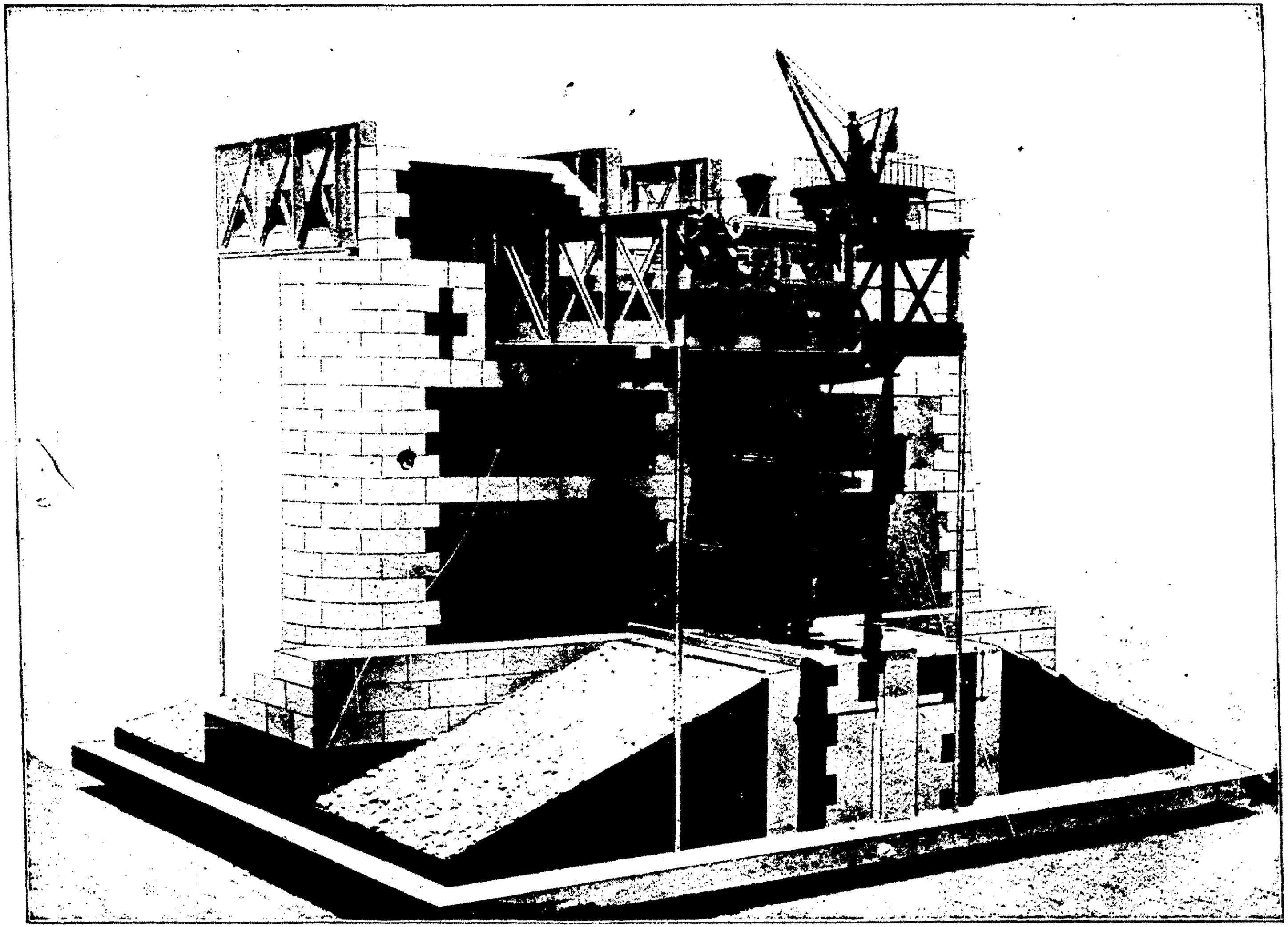
(57) The jointed curtain consists of a series of wooden bars (Figs. 35 and 36) arranged horizontally, one above another, resting against the vertical supports of the dam; the bars have a constant height, but their thickness varies with the head of water they have to sustain; they are joined together by two rows of hinges on their upstream side. (Figs. 40 and 41). A specially constructed piece is hinged to the lowest bar; this piece rests upon the flooring of the dam when the curtain is unrolled, and forms the center piece when the curtain is rolled up. It is called the rolling shoe; it is cylindrical in form, having for its base half the spire of an Archimedian spiral; the upper surface of the shoe is plain, and surmounted by three flanges whose contour forms the second half of the spire of the same spiral.

The curtain is suspended by hooks fastened above the water to the fixed portions of the dam, by two chains attached to a ring bolted to the upper bar in line with the two rows of hinges; it is moved by an endless chain worked by a special windlass. This chain descends on the downstream face of the curtain, passes under the shoe and ascends along the upstream face. The two ends prolonged above the curtain are carried by fixed guide pulleys to the curtain windlass.

The windlass is so arranged that for rolling up the curtain the two chains move together. The upstream chain rises, while the downstream chain falls, but with different velocities; the upstream chain moving faster than the other, so that the chain slides under the shoe; the resulting friction added to the traction of the chain itself causes the shoe to turn about its axis, and, successively, all the bars about their hinges, thus rolling up the curtain from below. It is rolled up wholly, or in part, so as to open wholly or in part the aperture which it closed. To unroll the curtain, the upstream chain is let go, and the downstream chain made fast.

When the lengths of the suspending chains are properly regulated so as to make the upper bar horizontal, the curtain rolls and unrolls between two vertical planes; but to avoid any error arising from defective construction or regulation, it is found best to have the curtain guided, so as to prevent lateral deviation. In the first application of this system to the Villier dam, the ends of the bars resting on the upstream face of the frames were guided by a small flange on that face. At Poses, two rows of little angle irons are fixed to the downstream bars; one side of the angle iron, projecting from the bar, strikes against the side of the upright supports in case of the lateral displacement of the curtain. To avoid obstruction in rolling, these angle irons are only placed on the outer spiral so that the curtain is only guided for half its height, but that is sufficient owing to its transverse stiffness.

Since the guidance of the curtains is assured without making use of the ends of the bars, the curtain may be prolonged beyond the up-



MODEL, BY REYNARD BROTHERS OF PARIS, OF A PORTION OF THE DAM AT POSES.

rights of the successive frames so as to project over half the opening between the succeeding frames, its width thus corresponding to that of two successive spans, so that it can in no case be carried obliquely between the uprights. These latter curtains are called double, to

MOVABLE DAM AT POSES ON THE SEINE. UPPER BRIDGES OF THE NON-NAVIGABLE PASSES.

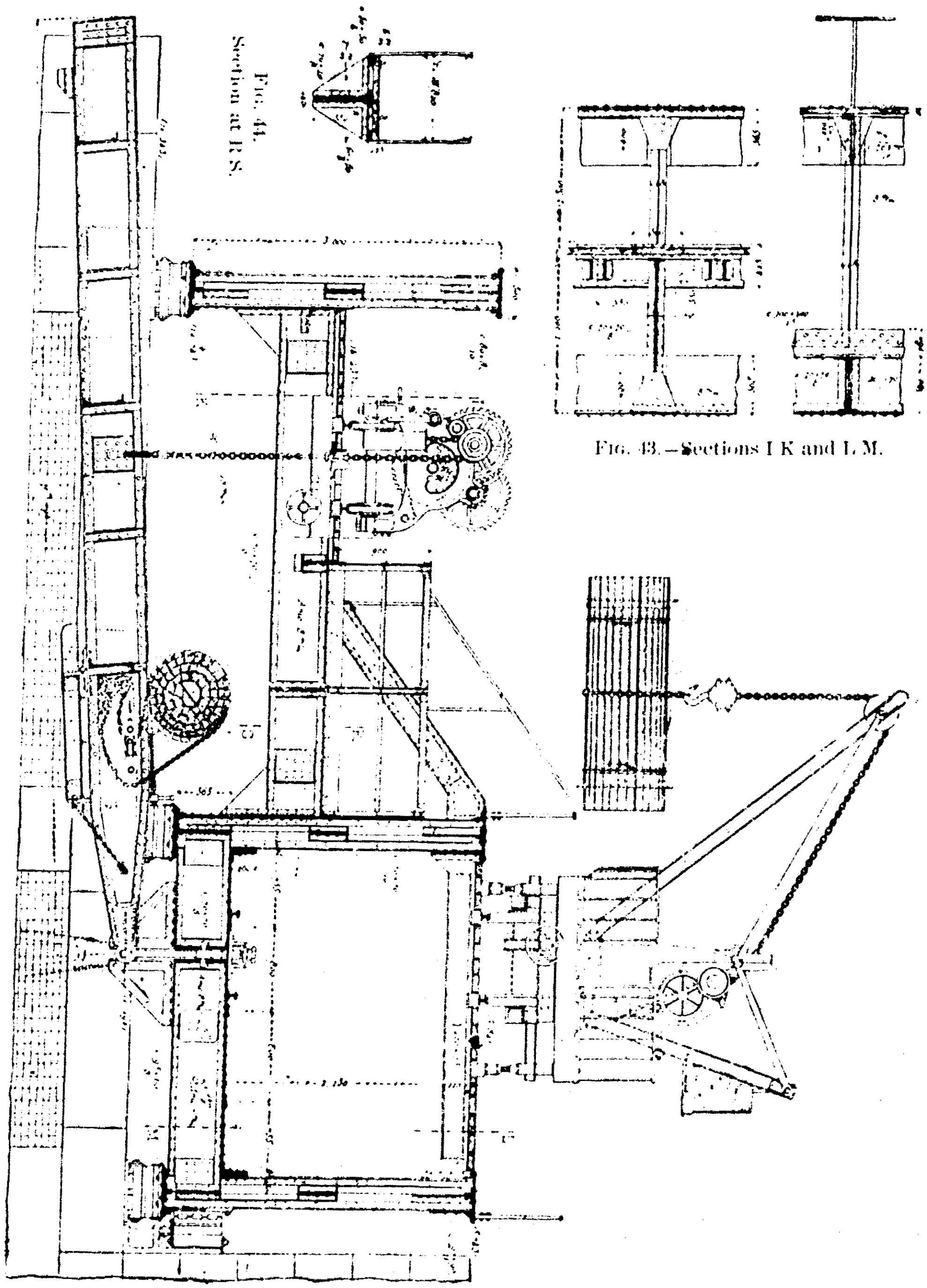


FIG. 42.—Transverse section along A B C D E F G H, Fig. 45.

FIG. 43.—Sections I K and L M.

FIG. 44. Section at R S.

distinguish them from those which only close one span. It may be observed, that in consequence of the bars projecting over the supports, they resist as if they were built in from these points, and consequently need not be stronger than the bars of the simple curtain.

(58) *Suspending bridge.*—Figs. 42–48 show the sectional plan, two elevations, and details of the suspending and hoisting bridge. The aperture, shown in the plan, is for hauling the curtains through, endwise, when they are to be taken off and stored or repaired.

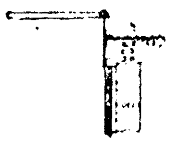


FIG. 47.—Section at NO.

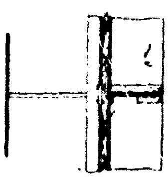


FIG. 46.—Section at PQ.

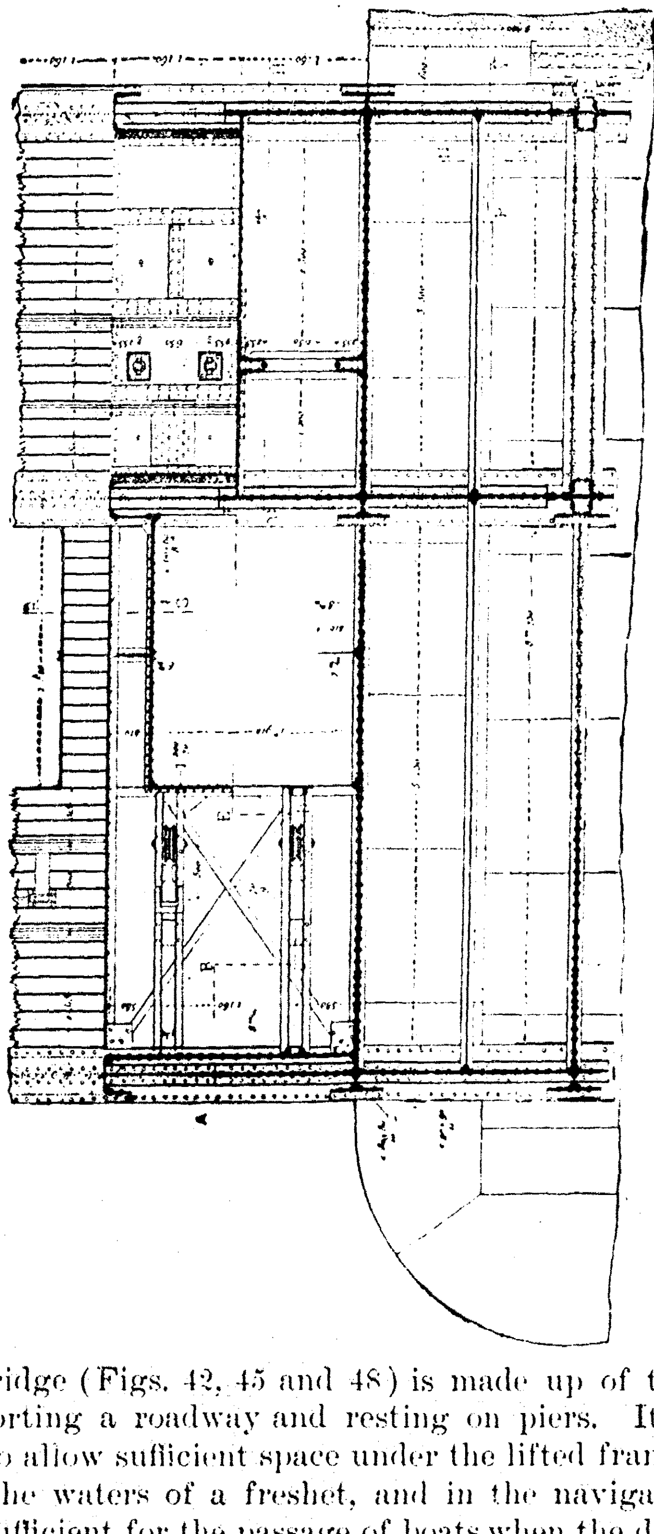


FIG. 45.—Dam at Poses. Plan and horizontal sections at different heights.

The suspending bridge (Figs. 42, 45 and 48) is made up of two lattice girders, supporting a roadway and resting on piers. It is placed high enough to allow sufficient space under the lifted frames for an easy flow of the waters of a freshet, and in the navigable passes a free height sufficient for the passage of boats when the dam is open.

The frames used to support the curtain are suspended by joints to the roadway; they are formed of uprights braced, and having their lower ends resting against square stone posts anchored in the flooring and leaving a play between it and the feet of the uprights; their upper extremities rest against brackets built for that purpose just below the principal girders. (Fig. 36).

The open spaces between the frames are closed by the double curtains above described, with horizontal bars extending from the

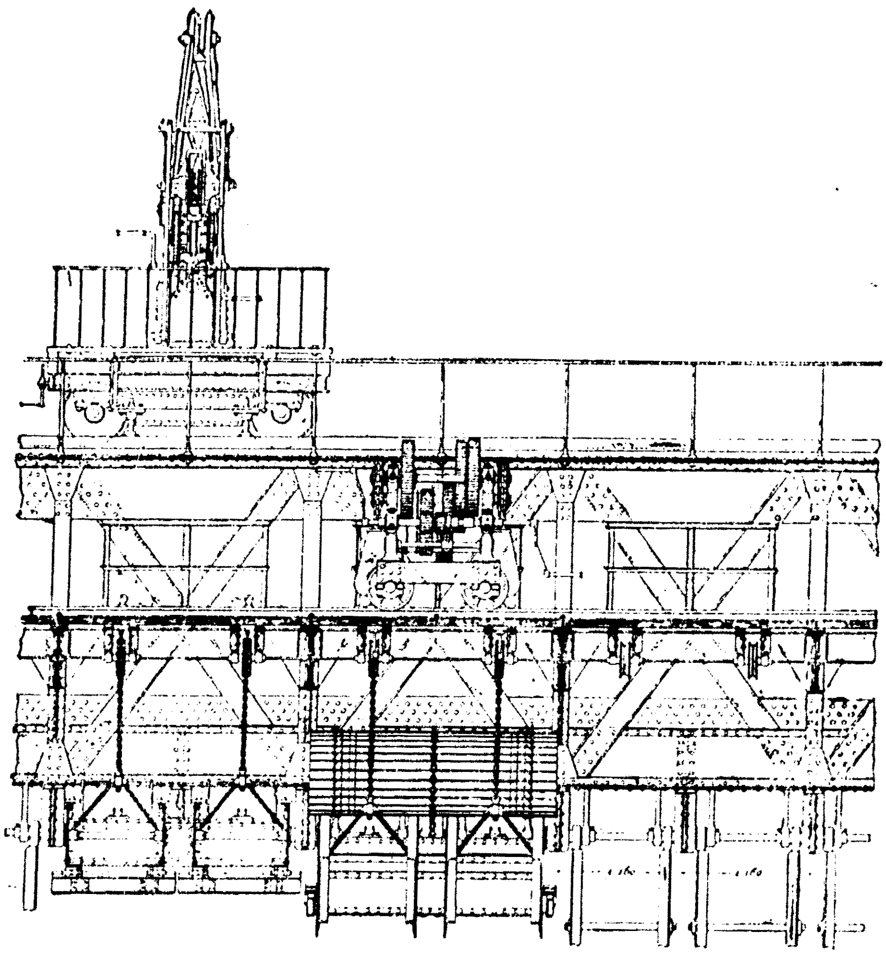


FIG. 48.—Dam at Poses. Longitudinal section along I K (Fig. 42), and upstream elevation of the intermediate girder.

middle of one span to the middle of the second span beyond it. The windlass for handling the curtains rolls on the service bridge, situated on the downstream side of the uprights and supported by them.

This bridge is formed of sections corresponding to each frame and jointed to it at a distance of 1 meter above the upper bay. The roadway of the bridge, to which the frames are suspended, acts like a horizontal beam, carrying to the braces on the piers and abutments the pressure of the water transmitted by the frames to their upper support.

(59) *Hoisting bridge.*—On a second bridge, called the hoisting bridge, a second windlass rolls, which can be hooked successively to each of the frames to raise or lower it.

To open the dam the curtains are rolled up above the water level: the sections of the service bridge are folded against their frames; then, by means of a windlass on the hoisting bridge, the frames are raised to a horizontal position and fastened, so that the pass is completely free. (Fig. 42).

To close the dam the operations are carried on in an inverse order.

Finally, to provide for the eventuality of not being able to raise the uprights toward the upstream side, their joints are placed in upright guides, which allow them to be raised to a height sufficient to clear the hurter; the frames may then rotate in a downstream direction and be raised if necessary in this direction.

(60) *Description of the Poses dam.* (See map, Fig. 49, p. 597).—On the right bank, looking downstream, are the lockmen's houses; next, the old lock and dam; next, the little lock, *e*; then the great lock next to Mouchouette Island, from which a dike 223 meters long projects up the river, extending beyond Pointe Island. Between Mouchouette Island and the left bank extends the new Poses dam, or barrage, with the raised or non-navigable passes at the right, the weir in the middle, and the navigable passes at the left.

The Seine is here divided into two branches. On the left side of the cut-off there are two new locks built side by side, each assuring a draught of 3.20 meters. The old lock on the right bank could not be preserved on account of the too great height of its tail miter sill. These locks are in all respects like those heretofore described, typical Seine locks.

A jetty, 223 meters long, is built as the downstream prolongation of the left chamber wall of the large lock; it facilitates the handling, shelters the barges, and protects them against the prevailing winds and the currents from the Poses branch.

Finally, to complete the closing of the right branch, a part of the old Poirée dam has been preserved, having its sill 1.76 meters below the present upper bay level. The branch on the left, called the Poses branch, is closed by the great Poses dam.

(61) *New principles.*—With the new system, the height being no longer limited, the level could be assumed at 8.45 meters above sea level, to avoid constructing the dam projected at Andé in the preliminary project.

The level of the sill of the navigable passes was fixed below a line passing through the tops of the regulating sills, and having a declivity equal to the mean declivity of the waters of the river; it has thus been fixed at the level 3.45 meters, that is, 5 meters below the upper bay.

The situation as indicated in Fig. 49, just above Pointe Island, offers two advantages; first, proximity to the locks and a satisfactory arrangement to all parts of the dam; second, a natural sill at the elevation of 3.05 meters, that is, at about the same level as the projected flooring.

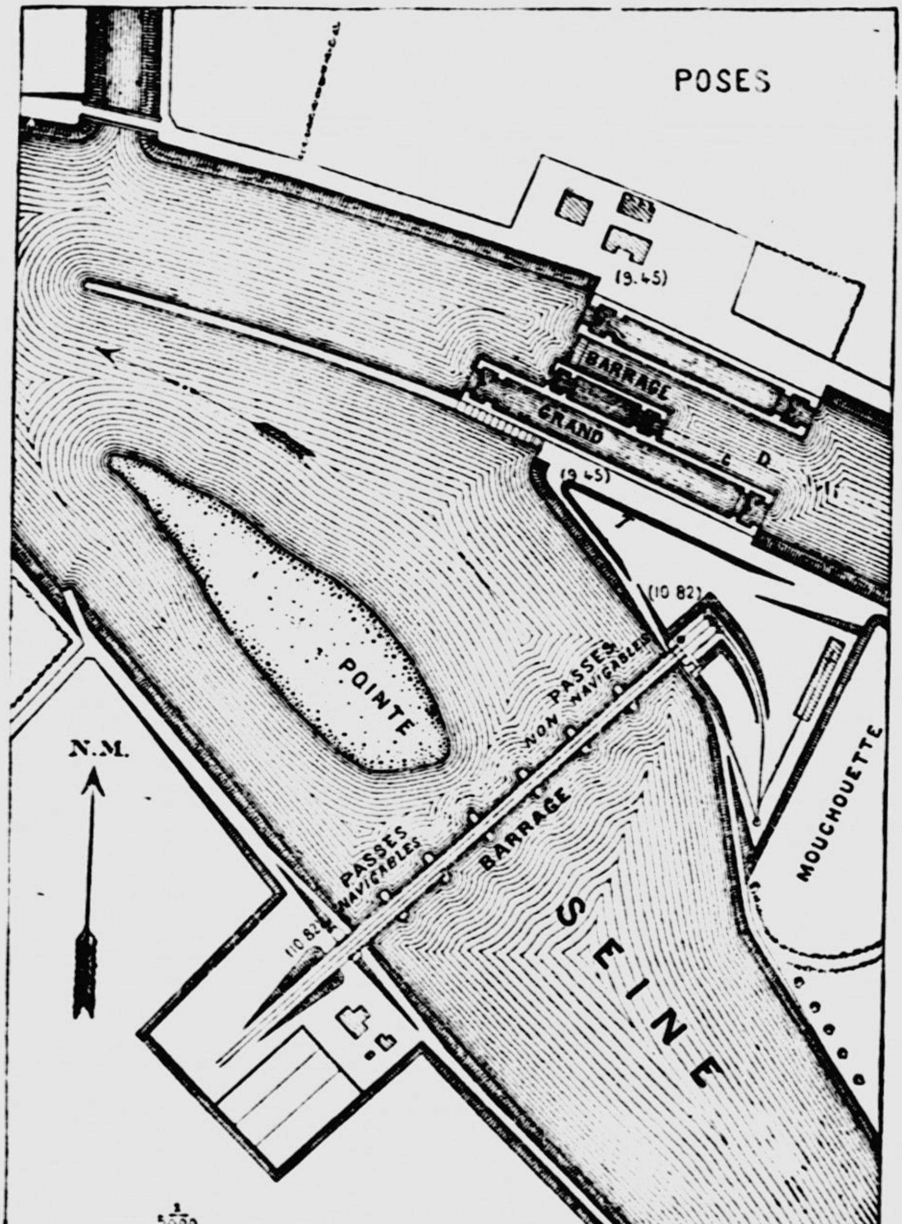


FIG. 49.--Map showing the position of the new movable dam at Poses.

The Poses dam, 235.20 meters between the abutments, is divided into seven passes: five deep and two shallow ones. The combination of the heights of the sills of the different passes was made so as to obtain a sufficient superficial flow by uniting as well as possible the transverse profile of the river at the right with the chosen location. The dam is thus divided into three distinct parts; two corresponding to the two arms surrounding Pointe Island, and the other to the cross section of the island itself. The sills are placed at the altitude 3.45 meters above tide water in the first case, and 5.45 meters in the second.

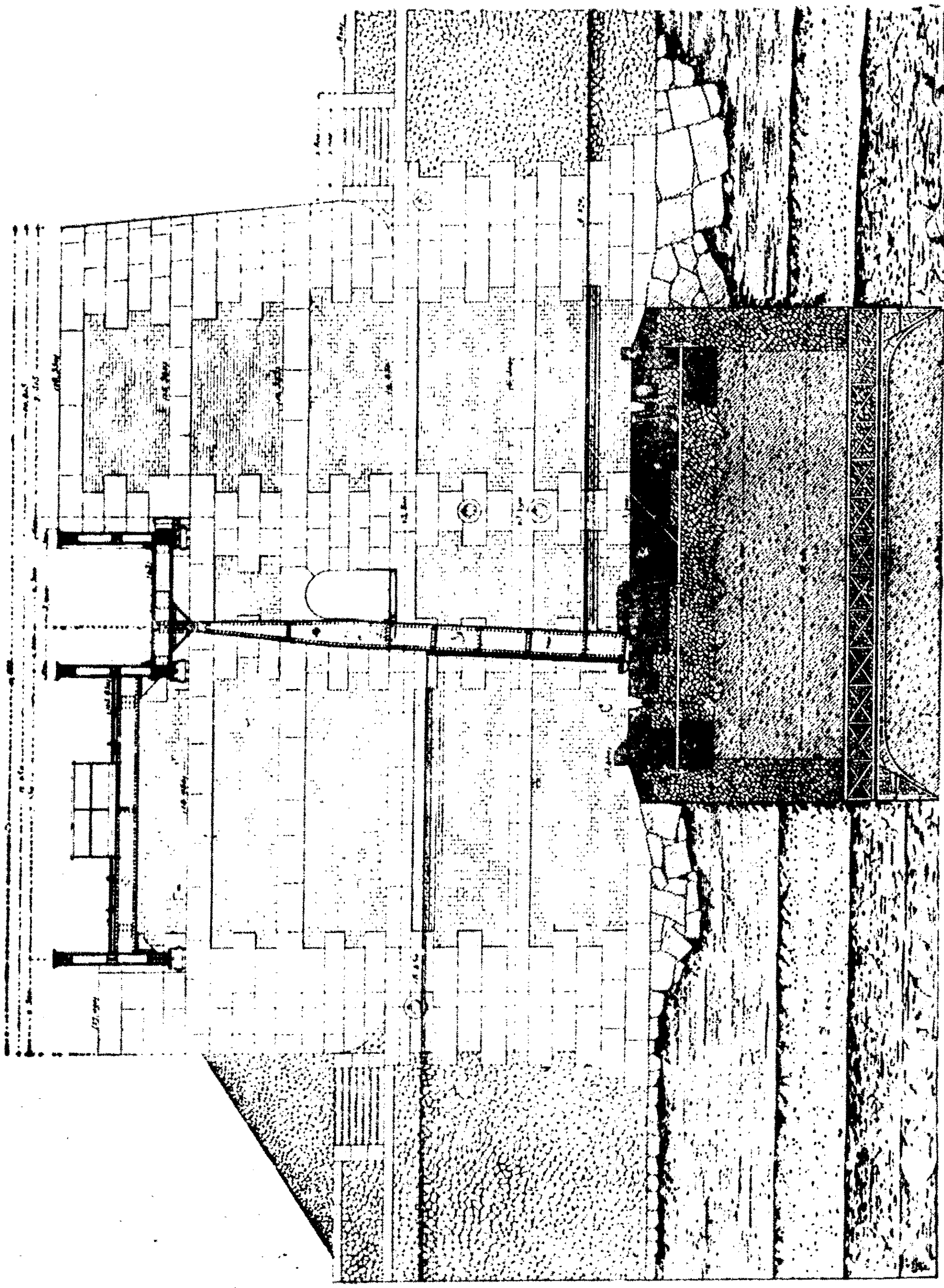


FIG. 50.—Elevation and section of the abutment on the left bank, showing the anchorage for the foundation.

(62) *Depth of foundation.*—The exceptional height of the dam required a foundation to be laid upon a solid and impermeable stratum, thus avoiding all filtration which would compromise the stability of

the structure and absorb a portion of the flow during low water, when most needed for navigation. It was found best, as in the case

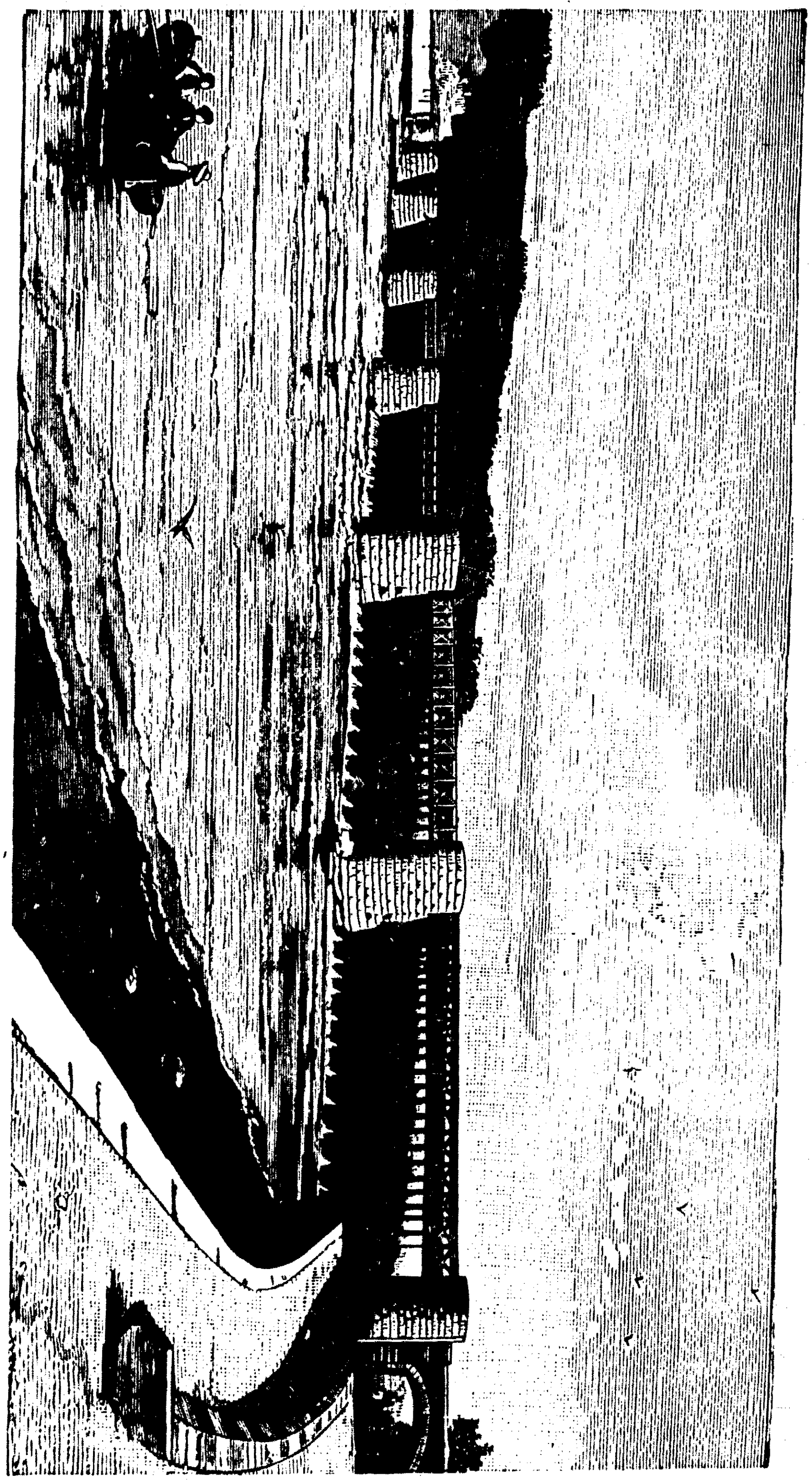


Fig. 51.—View of the Poses dam from below.

of the locks, to descend to a bank of solid chalk which is met at about 5 meters below the sea level for the whole width of the river bed.

(63) *Piers and abutments.*—The piers are 4 meters thick; on the downstream side, the starlings (Fig. 50) project a considerable amount beyond the roadway, and support masses of masonry which rise to the top of the bridge; these masses serve to resist the horizontal thrust which is transmitted by the suspended frames to the bridge.

The piers and abutments are pierced by full centered arches 1.30 meters wide and 2.30 meters high, so as to allow the service bridge to be freely carried through them. In these passages niches are made to store the curtains and windlasses.

(64) *Flooring.*—The surface of the flooring is plain, at the level 3.10 meters above the sea for the deep passes, and 5.20 meters for the shallow ones. This surface is limited on the upstream side by a sill curved up just above the level of the hurters, so as to protect them against the keel of any boat or the shock of bodies against them.

(65) *The hurters* are 1.16 meters apart, built into the flooring and projecting 0.35 and 0.25 meter above it in the deep and shallow passes respectively. They are protected by flanged iron plates fastened to them. A bolt, passing horizontally through each stone, is secured by a nut at the back. This bolt is also secured to the anchorage bar of the flooring so as to transmit to the piers the longitudinal pressure of the uprights. The hurters rest against the plate band of hewn stone.

To increase the solidity of the whole, the two limiting walls of the flooring are united by tie rods sunk in the masonry and passing between the hurters.

Finally, a row of cast-iron boxes and anchor rings have been sunk in the masonry flooring in front of and behind the hurters, so as to permit a cofferdam to be rapidly set up in case of repairs.

(66) *Upper bridges.*—The system adopted at Poses requires the establishment of two upper bridges, according to the idea of the late M. Tavernier.

First. The downstream bridge to hold the suspended frames, and, second, the upstream bridge to hold the windlasses while the frames are being raised, and also sustain, a part of the weight of the raised frames themselves. The first may be called the suspending, and the second the hoisting bridge.

The roadways of the two are for two different purposes and at different levels. The downstream longitudinal girder of the hoisting bridge is omitted, and its supporting cross girders are attached directly to the longitudinal upstream girder of the suspending bridge, thus affording easy communication between the bridges, and adding to the horizontal strength of both. The upstream roadway has an opening 1.50 by 2.50 meters, large enough to admit of passing the curtain through it endwise. (Fig. 45.)

In the non-navigable passes the facility of communication is insured by putting a third roadway above the beams of the down-stream roadway.

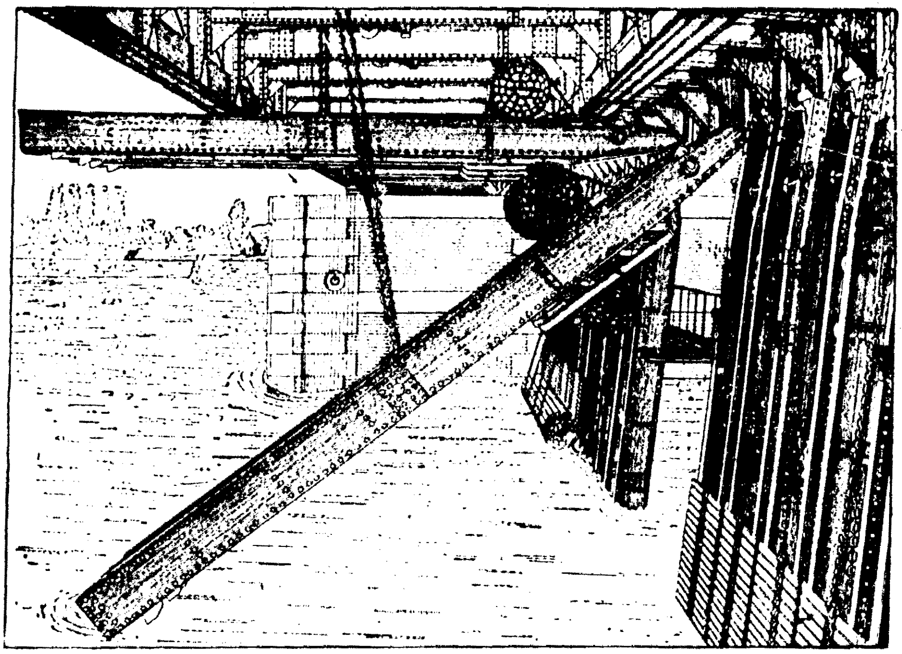


FIG. 52.—View of Poses dam from above. The raising of a frame

The lattice girders supporting the roadway have their uprights 2.32 meters apart, corresponding to the widths of the moving parts.

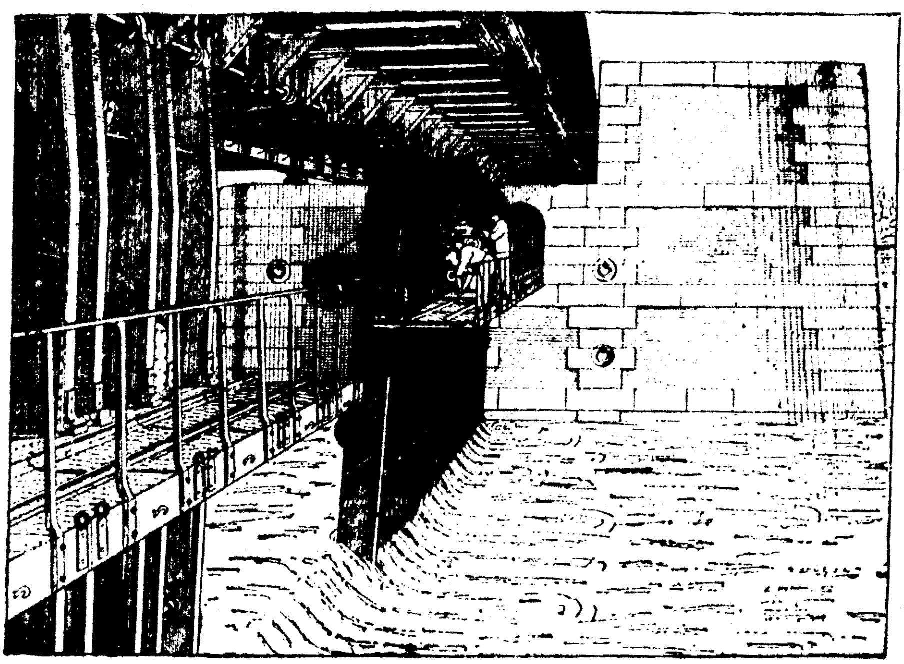
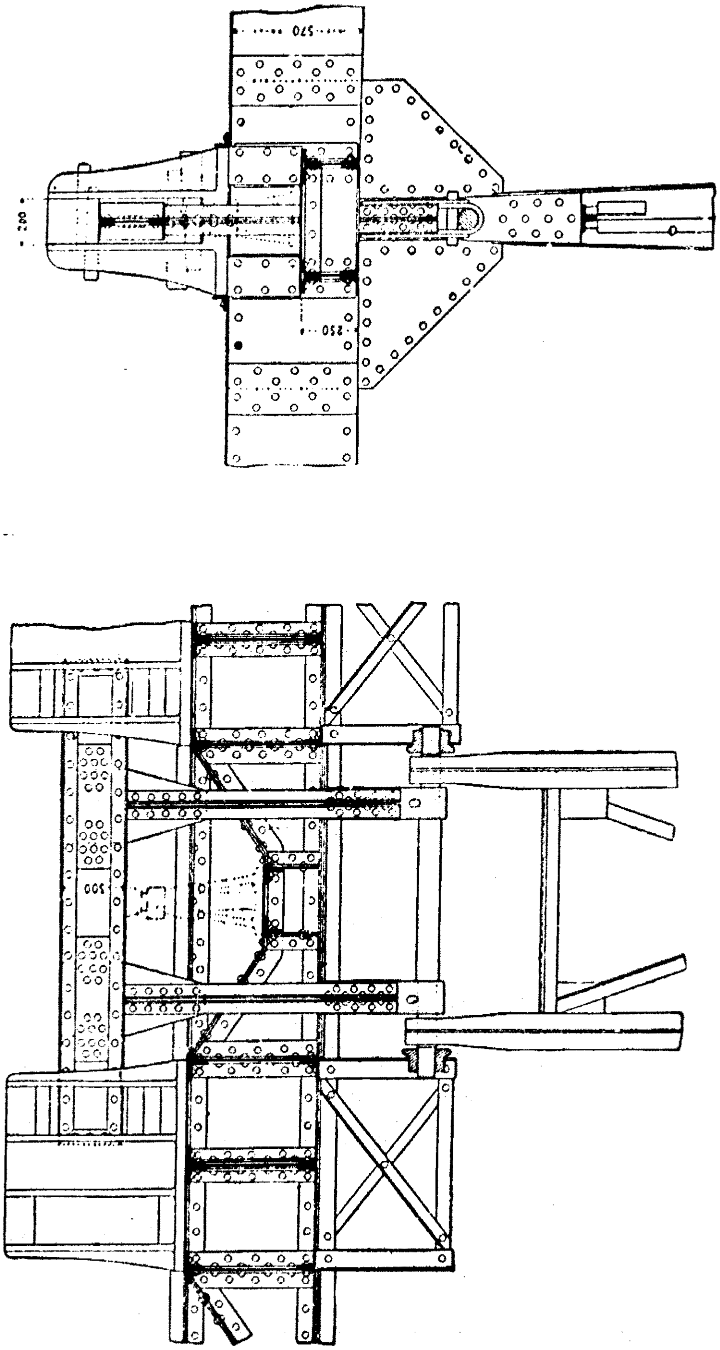


FIG. 53.—View from below. The rolling of a curtain

The cross girders take the strain of the hanging frames by means of the brackets arranged under them. These girders, 1.16 meters apart, are braced by U irons placed on each side of the rods suspending the frames. The brackets are trapezoidal in form, 0.61 meter high (Fig. 42). Upon each of their faces two angle irons are riveted, projecting on each side and forming a guide 0.125 meter wide. The heads



Figs. 54 and 55.—Mode of suspending the frames (Port-Mort dam).

at the end of the suspending bars rest upon these guides at a height 0.50 meter under the cross girders, so that the uprights can be raised to the flanges of these girders, that is, so that the uprights may clear the hurters (Figs. 54 and 55).

The width of the upstream roadway depends on its height above the water. There must be space enough from the end girder to the point where the chain comes through to work the windlass, also to give the chain a proper inclination, to avoid too much tension on it. At Poses the chain is attached to the frame at 0.90 meter below the water level, and the chain is inclined 33 degrees at the beginning. The distance between the principal girders of the upstream roadway is 7.55 meters for the navigable passes and 5.25 meters for the non-navigable.

The upstream roadway is placed halfway up the principal girder, so as to allow sufficient space below the cross girders to store the rolled curtain when the frames are raised.

The cross girders are 2.32 meters apart, united by stringers. The beams of the upper bridges rest on their piers and abutments by a hinged joint, so that the resultant of pressure always passes through the center of contact whatever may be the deflection of the beams themselves.

Expansion trucks are placed vertically between the downstream girder and the massive starling.

(67) *The uprights*, which support the curtains, are wrought-iron beams with angle irons, having their mean fibers inclined 0.065 meter per meter, so that the vertical passing trough the center of gravity of the frame with its curtain and foot bridge is on the upstream side of its upper joint. The uprights have a U-shaped section which is constant in width 2.50 meters above the upper bay for the same pass; this width is 0.50, 0.60, and 0.70 meter for the three passes respectively. Above this level the width tapers to 0.25 meter at the top.

The joint of the uprights with the suspending shaft is made by a cast-steel eye wedged onto the shaft, and terminated by a cheek which is riveted to the web of the upright. Lengthwise the uprights are arranged in groups of two, and the axes of these groups are 1.16 meters apart. The object of this division was to reduce the width of the moving pieces to 1.16 meters in case the length, 2.32 meters, of the curtains should be found too great; but as this length has been found convenient the arrangement of the uprights in subsequent dams of this type has been simplified. At Port-Mort, for example, the uprights have a double T section.

(68) *Frames.*—Each frame is formed of four uprights, united by ties 2 meters apart and having a width 0.15 meter less than that of the upright, so as to afford a passage to the hoisting chains and a lodgment for those of the frames. One of these ties is on the level of the service bridge, and upon it is a cast-iron box which holds the slack of the curtain chains. The uprights of the same frame are also tied by three shafts, viz: first, the upper suspending shaft; second, the shaft 2 meters above the service bridge, used for attaching the hoisting tackle of the service bridge; and third, that to which the hoisting chains of the frames are attached.

(69) *The hoisting chains.*—There are two hoisting chains for each frame; each chain divides into two branches, so that the end of one branch is attached to each upright, thus dividing the strain of lifting the frame into four equal portions (Fig. 35). On the downstream side of the uprights a strong wrought-iron hook with angle irons is attached, for the purpose of raising the frame in case of accident to the chains or to their attachments (Fig. 36). This can be done by lowering, along the upright, a chain, the bight of which will be held securely by the hook. Ringbolts are attached to the upstream side of the uprights, so that the frames may be slung below the upper bridge when any repairs are required.

(70) *Method of suspending the frames.*—The method adopted for suspending the frames has been somewhat simplified in the Port-Mort Dam, and we shall here give the method employed in the more recent dam. This method of suspension is shown in Figs. 54 and 55. The suspending rods are terminated by cross-heads fitted onto the rods by gibs and cotters; these wrought-iron rods have a cross-shaped section and pass between the braces of the downstream roadway, above which they are united two by two by a cross piece having the section of a double T, whose extremities can slide vertically between the uprights of two cast-iron chairs bolted to the roadway. In their normal position these extremities rest on chairs by means of regulating iron wedges. Similar wedges, placed between the upper face of the crosspiece and the upper bearings of the chairs prevent the frames from lifting.

(71) *Foot bridge.*—The foot bridge, made up of framed sections 1.16 meters longer, is constructed of U iron, to which the iron flooring is riveted; upon this flooring the rails for carrying the windlass are laid. The upstream side of the section is hinged to the downstream side of the uprights. The transverse bars of the section are prolonged, and strike against corbels riveted on the webs of the uprights, so as to keep the sections of the foot bridge horizontal when it is lowered. (Figs. 36 and 42.)

(72) *Method of attaching the curtains.*—The suspending chains are hooked to rings attached to the two outside uprights of each frame at 1.25 meters above the foot bridge. The two pulleys for rolling the curtains are placed between the intermediate uprights. The lower pulley, holding the downstream chains, is slightly smaller than the other. This inequality insures a distance between the chains equal to the thickness of the first curtain bar. Besides rolling the curtain, each side of the endless chain can be fixed upon its guide pulley by a stop (Fig. 39), carrying a finger, which enters the link of a chain when the lever is lowered. Finally, the uprights have on their upstream faces iron claws, which serve as stops to the rolled curtain.

(73) *Details of the curtains.—Dimensions.*—Each curtain corre-

sponds to an opening 2.32 meters wide and 5.35 meters high in the deep passes. The bars of yellow pine are all 0.078 meter high, with a play of 0.002 meter between the bars to allow for swelling; their length is 2.28 meters, giving a play of 0.04 meter between two neighboring curtains; this interval is sufficient, and can be closed by a joint cover if the dam reqires to be made tight.

The thickness of the upper bar is 0.04 meter, and it increases progressively downward to 0.09 meter for the deep passes. It is calculated to resist a pressure of 60 kilograms per square centimeter. The upper bar, exposed to shocks from floating bodies, is strengthened by an angle iron.

The hollow cast-iron rolling shoes are heavy enough to cause the curtain to sink easily into the water when unrolled.

The rows of hinges form a kind of chain resisting all efforts exerted on the chain in the act of rolling. These hinges are of bronze, so as not to rust; they have strong flanges, and their axles are of drawn phosphorus bronze. All the handling machinery can be carried on cars rolling on the service-bridge tracks.

(74) *Windlass for handling the frames.*—The maximum effort which can be produced by this apparatus is at the termination of the lifting, and amounts to 4,900 kilograms for the deepest passes. This effort, transmitted by the chains to the windlass, is exerted by four men at the cranks, or by a small double-cylinder steam engine mounted on the windlass. A brake serves to regulate the velocity of the descent when the frames are lowered.

(75) *To raise the frames.*—With the suspension above described and in use at Port-Mort the operation is as follows: Lifting jacks, shown in Fig. 54, are placed under the crosspieces uniting the two suspending rods of a frame above the downstream roadway. Each jack rests upon a platform arranged for this purpose in the horizontal bracing of the roadway. After placing the jack and removing the wedges which prevent the lifting, the jack is screwed up, care being taken to wedge the ends of the crosspiece as it moves up; this wedging serves to sustain the lifted frames. The chains from the windlass on the upper bridge are then hooked on, and the frames are rotated to a horizontal position and made fast to the under side of the upper bridge.

(76) *Execution of the work.*—The foundations were laid on a bank of chalk, from 5 to 5.50 meters below the sea level. Two systems were employed; first a cofferdam pumped out above a layer of beton filled in an inclosure of artificial blocks (for the abutment on the right bank, for piers Nos. 1, 2, 3, and for the floorings of the passes, Nos. 1, 2, 3, and 4.).

Second. Foundations in caissons by compressed air for piers Nos. 4, 5, 6, the abutment on the left bank, and the floorings for passes 5, 6, 7.

The surface covered by the foundations of the Poses Dam and its approaches amounts to 4,965.58 square meters; 64,637 cubic meters of masonry were laid.

(77) *Weight of the iron work.*—Weight of the iron in the bridges and frames, 1,316,991 kilograms; weight of a curtain with its chains for the deepest passes, 911 kilograms; weirs, 516 kilograms.

The final project was approved October 26, 1878. Work on the foundation began the 24th of May, 1880, the dam was completed on the 24th of September, 1885, and has given entire satisfaction since.

(78) *Cost.*—Cost per running meter:

	Francs.
Masonry foundations	13,345
Iron work:	
Upper bridges	1,871
Frames	878
Curtains, etc	421
Total	16,515

The project of the Poses Dam was drawn up by M. Cameré, and executed principally under his direction.

The figures 35–50 are taken by permission from the Portfeuille des Ponts et Chaussées.

CHAPTER VI.—VILLEZ MOVABLE DAM ON THE SEINE.

(79) The Villez Dam is situated on the Seine 145 kilometers from Paris. Figure 56 shows the general arrangement of the dam, which consists of two navigable passes and a weir having a linear opening of 201.25 meters, together with two locks. The total length of the dam is 223.15 meters.

(80) *System of closing.*—The dam is closed by a system of frames and curtains (Fig. 57). Each curtain is suspended by its upper bars from a frame over two adjacent Poirée frames (fermettes). This suspending frame is completely independent of the fermettes, being only attached to them by pins (Fig. 58).

The regulation of the height of the water is done by raising or lowering the curtains, the flow taking place underneath; the regulation, at times of low water, may be made without moving the curtains, by flash boards 0.30 meter high arranged above the curtains.

(81) *Opening the dam.*—The process of completely opening the dam is as follows: The curtain frames with their curtains are transported over the service bridge to their storehouse on the bank; the flooring of this bridge and the rails uniting the dam frames are taken up; and, finally, these frames are lowered one after another, beginning with the one in each pass farthest from the bank. The time taken for these operations, counting from the carrying away

of the first curtain, is about 22 hours, corresponding to the complete opening of one linear meter in 11½ minutes. When the freshet subsides and the water tends to fall below the normal level, the inverse operations are made and the dam is closed.

(82) *Description of the dam.*—The flooring consists of a raised portion, forming the upstream sill, united by a curved portion with a recess which holds the lowered frames; the sill is 4 meters below the upper bay; the recess protects the frames from the keels of the passing boats.

The great pressure supported by the frames requires their bearings on the flooring to be strong and secure; they are for this reason attached to iron double T bars as long as the width of the recess, and united transversely by two other double T bars. This grating is anchored, as well as built into the flooring. In constructing the flooring for the deep passes arrangements are provided for setting up a cofferdam for repairs. These arrangements consist of recesses made in the piers to hold joists, so as to separate adjacent passes; also iron boxes and rings anchored in the masonry above and below in the flooring. To aid in pumping out these temporary cofferdams, a well is sunk in each floor. These supplementary constructions were of great service in improving the sill of the dam after its completion.

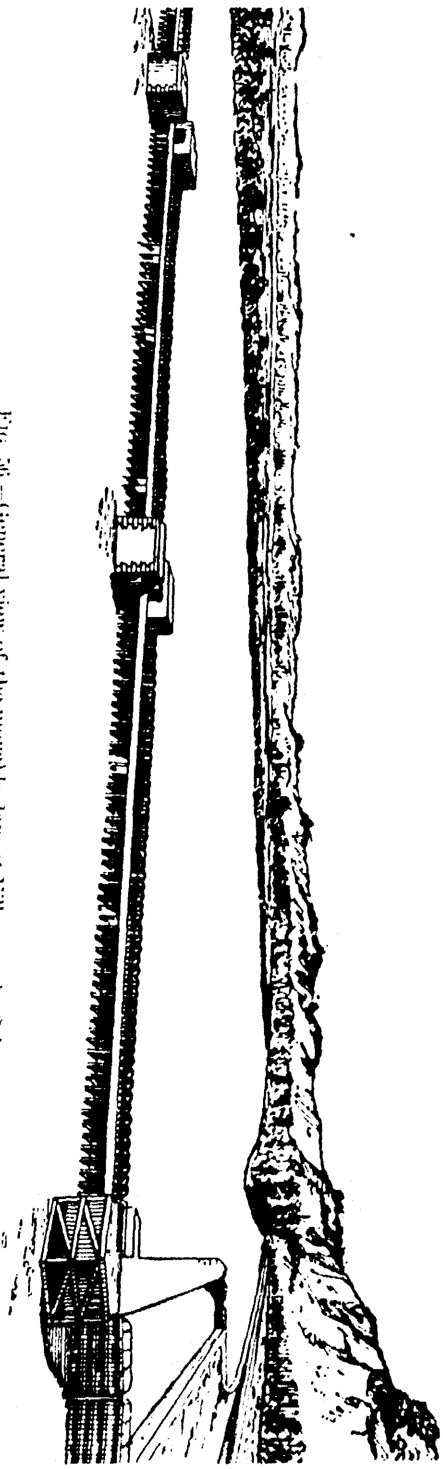


FIG. 36.—General view of the movable dam at Villez, on the Seine.

(83) *The frames.*—The frames are planned so as to present the minimum of obstruction consistent with strength. The upstream uprights of the frames have a small T iron on their face, the projecting web of which serves as a guide to the curtain bars resting on this upright. The bracing of the frames is calculated on the supposition that the pressure of the water is distributed over the whole

height of the uprights, instead of being transmitted only at the top, as in the case of needles.

A bracket placed on the downstream upright serves to widen the service bridge roadway and allows two tracks to be laid, the rails serving as braces between the frames, and replacing the catches used in the older frames.

The great frames are moved by means of flat iron bars, each in three parts, jointed together, and having a joint at each extremity.

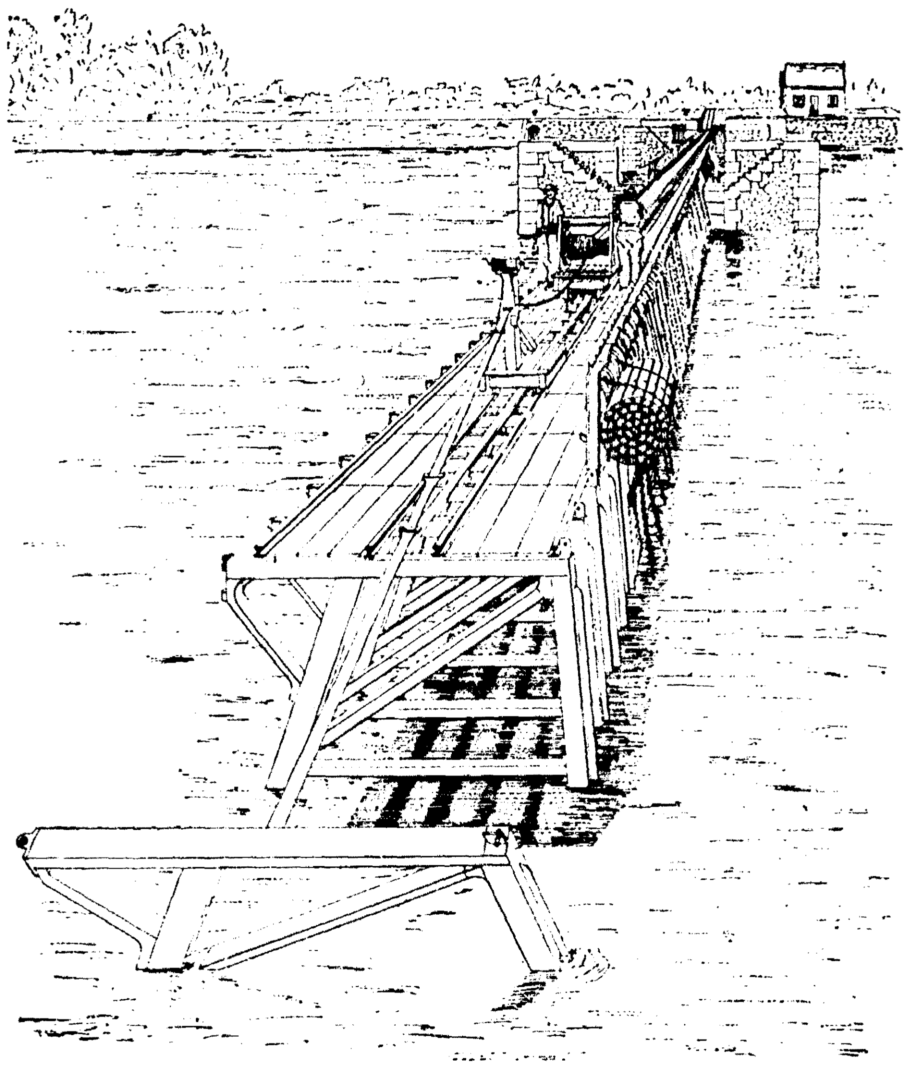


FIG. 57. Lowering the frames at Villez Dam.

(84) *Lowering the frames.*—When a frame is to be lowered the joint of one extremity of a bar is pinned to the upper cross bar of the frame and the other extremity made fast to a car movable on the track on the service bridge; this car is held by a chain passed around the drum of a windlass, the latter being held by another chain made fast to the next pier or abutment (Fig. 57). To lower the frame, it is only necessary to push the car forward and pay out the windlass chain. When the frame is lowered the flat bar fixed to the car is

detached and pinned to the side of the cross bar of the following frame still standing; the operation is repeated, and while the second frame is lowered the flat jointed bar connecting the two frames folds together forming a V, the unequal branches coming together between the two frames, without forming heaps like the chains. The frames are lifted by reversing the operation.

(85) The type of curtain adopted for this dam (described pp. 591–593) is that of M. Cameré. The dimensions of the curtain bars for the deepest passes are 1.09 meters long, 0.058 meter high, and the thickness from 0.04 to 0.08 meter. The frame supporting the curtain, which also holds it when rolled up, is an iron frame (Figs. 58 and 59),

DAM AT POSES.

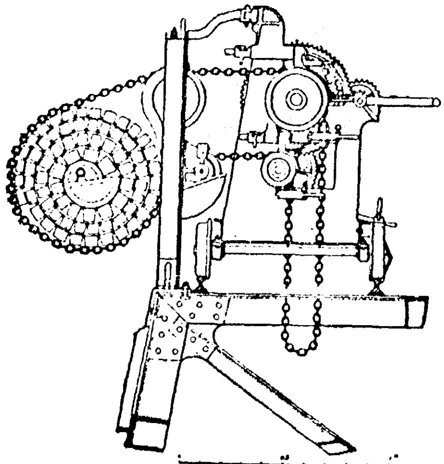


Fig. 58.—Windlass for hoisting and lowering the curtains.

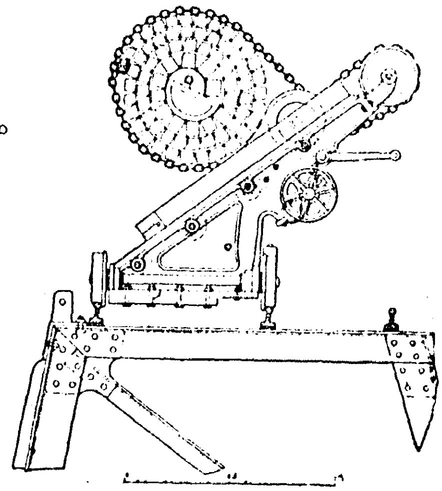


Fig. 59.—Mode of unshipping and transporting a curtain.

whose upper bar holds the hooks for the suspending chains, and whose uprights are terminated by forks fitting on the horizontal pins with heads forming part of the dam frame.

By means of these pins the curtain frame may be set up directly over the uprights of two successive dam frames and kept in this position by screws, or disengaged and turned about these pins and deposited upon the curtain car (Fig. 59).

The curtain frame has in the middle two guide pulleys which carry the curtain chain, and a box to hold the slack of this chain.

(86) The curtain is rolled or unrolled by an endless chain as follows: Each line of the endless chain passing over the guide pulleys forms two bights, one to the right and the other to the left of the curtain frame (Fig. 58); the one passing around the curtain regulates the amount rolled up. To operate the curtain, the two lines of the chain of the downstream bight pass over the chain pulleys of the windlass; the combined motion of these pulleys produces an elongation or contraction of the other bight.

(87) The windlass for handling is mounted on a car rolling on the rails of the foot bridge to bring it in front of the curtain to be moved. When placed it is clamped to one rail of the track; on the other side a movable buffer on the upper part of the windlass rests against the curtain frame and resists its tendency to turn in the upstream direction.

The windlass carries two outside chain pulleys (Fig. 58), corresponding to the curtain-frame guide pulleys; the lines of chains are put upon these and maintained in their places by rotating stops which can be lifted to allow the chains to be taken off or put on.

The pulleys are keyed to shafts driven by the windlass gearing; the lower pulley may be engaged or disengaged. When engaged it turns in an opposite direction from the upper pulley, and its circumferential velocity is a fraction of that of the other. This being so, to roll up the curtain the lower pulley is engaged, and the upper pulley exerts an effort on its chain while the lower pulley pays out its chain; on account of the difference of the velocities of the two pulleys a shortening of the bight passing round the curtain takes place, and the curtain rolls up. To unroll the curtain, the lower pulley is disengaged, its chain is made fast by a stop on the guide pulley of the curtain frame, the upper pulley turns, letting go the chain, the bight lengthens, and the curtain unrolls.

(88) The curtain frame is shipped on a special car carrying an inclined plane furnished with a windlass and chain (Fig. 59). This car is brought in front of the curtain, the screws fastening the curtain frame to the dam frame are removed, so as to allow the former to turn around its journals. The windlass chain is hooked to the upper bar of the curtain frame, and the latter turns round its journals until it rests upon the inclined plane; then by the continued action of the windlass it is hoisted upon the car by moving upon rollers fixed to the inclined plane. The curtain frame, thus completely separated from the dam frames, can be carried off on the car. It is replaced by the reverse process.

The project for the Villez dam was prepared under the direction of M. Lagrené, chief engineer, by M. M. Cheysson and Cameré, engineers; the latter superintended the work and invented the system of curtains.

CHAPTER VII.—MOVABLE FISH WAY ERECTED AT PORT-MORT DAM ON THE SEINE.

(89) A fish swimming up a river, meeting a dam, and endeavoring to ascend, seeks that point where the water is freshest; this is in the middle of the pass—corresponding to the main channel in movable dams—and not under the shelter of the fixed parts; so that fish ways, if we wish them used, should be placed accordingly.

Starting from these principles M. Caméré proposed, in 1878, to substitute for the fixed masonry fish ways hitherto constructed near the piers or abutments of movable dams, portable fish ways, each formed of a long trough of wood or sheet iron with cross partitions, resting its downstream end upon a floater and its upstream end upon the upper bar of the curtain dam properly lowered. With a construction of this kind, arranged so as to be easily shifted, it is possible to seek in the dam the best position for the way so the fish will go up naturally, and the route which they choose shall not be encumbered by any fixed obstruction.

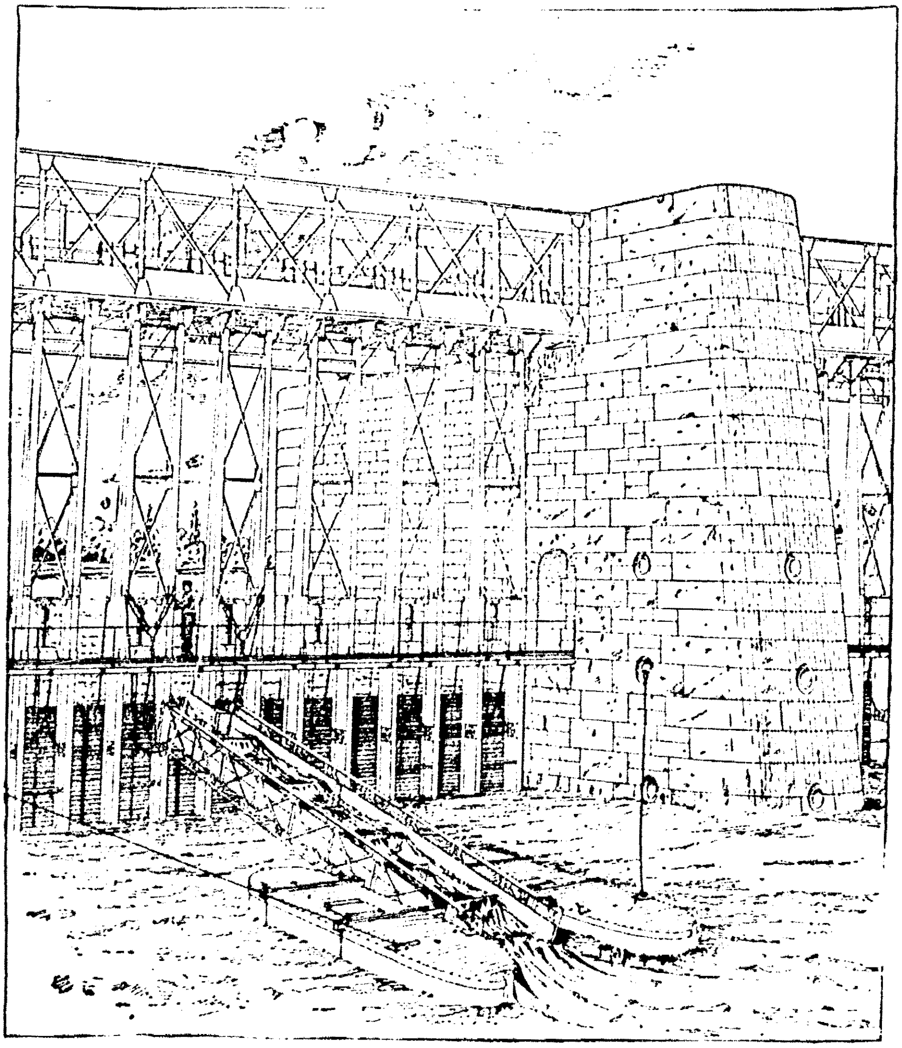


FIG. 60.—Movable fish way at Port-Mort. This dam is similar to that of Poses.

(90) The annexed figure indicates the arrangements adopted at Port-Mort. The dam is a curtain dam, like that at Poses. The wooden trough of the way is formed in two sections; the principal section rests on the floater, and is hung above on a shaft arranged on the outer faces of the uprights so as to oscillate as the lower bay rises and falls. The second section, which is fixed, is placed between

two uprights. Its extremity opens into the upper bay, and it joins the other section upon which it rests. Its length has been determined by assuming that its inclination should not be more than .020 per meter when the dam is at its full height. The length of the principal section is therefore 10.15 meters; its width beyond the frames is 1.46 meters; the partitions, 0.43 meter high by 0.30 meter wide, are 1.25 meters apart.

(91) The principal section rests upon a little iron bridge. The downstream floater is formed by two little covered boats arranged on each side of the way and firmly united.

The little section across the dam frame rests above on the upper bar of the curtains properly lowered, and laterally against the upstream face of the uprights of the dam, secured by angle irons fixed to its exterior sides. Below, it is boxed in by two cheeks arranged at the end of the principal sections, and rests on a cylindrical surface, so as to allow oscillations. The portion situated at the entrance of the trough in the upper bay is movable around an axis placed at its base. This allows the regulation of water flowing down the way according to the level of the lower bay.

(92) *Erection.*—The way is set up between two frames. To lower it it is sufficient to lower the upper bars of the two curtains on which it rests by lengthening their suspending chains. We thus obtain sufficient space above. The portion of this space not filled by the way, is closed on each side by two little hand sluices. The chains holding the suspension axle of the way are hooked in the uprights of the dam and the axle is made fast by other chains attached to the frame shaft. The fish way is brought into place with its upper extremity resting on a pontoon, while its lower extremity rests on the floaters. By attaching then the upper end of the way to the top of the service bridge the bearings placed under the beams are put upon the axle, and the floater is held by guys from the neighboring piers. The curved piece connecting the two portions of the troughs is put up across the dam frames. To remove the way the inverse operations are performed.

The movable fish way for this dam was planned and executed under the direction of M. Cameré by M. Clerc.

CHAPTER VIII.—TORCY-NEUF RESERVOIR FOR FEEDING THE CENTRAL CANAL.

(93) The great improvements for deepening the Central Canal, required the establishment of a new storage dam near Creusot. The new reservoir received the name of Torcy-Neuf to distinguish it from another called Torcy.

Torcy-Neuf is 5 kilometers northwest from the summit level of the Central Canal.

The reservoir has a surface of 166 hectares, a perimeter of 15 kilometers, a height of 14.50 meters; it contains 8,767,000 cubic meters, and doubles the amount of water heretofore available at this level.

A waste weir 12 meters long is at the left end of the dike. The supply conduits start from a tower which is built in the reservoir at the foot of the dike, and which allows the waste water to flow over the top.

(94) *The dike*, well rooted at both ends in the side of a hill, consists of a great filling of sand and clay (64 per cent of sand to 34

FIG. 61.—Map of Torcy-Neuf Reservoir.

of clay) 436.70 meters long, 5.50 meters wide at the top, and 52.90 meters, at the base; its maximum height is 16.30 meters, and its volume 129,000 cubic meters.

The slope toward the water (Fig. 62) is protected by a series of masonry pitchings 1.50 meters high, inclined 45 degrees, and separated by berms 0.90 meter wide, two intermediate ones being 2 meters wide.

The exterior slope, without revetment, is planted with acacias for a distance of 5 meters in height. The slope is 2.73 base to 2 of height.

The upper platform of the dike is 1.80 meters above the water level; it is of masonry, like the slope toward the water, and surmounted by a parapet 1.20 meters, to stop the waves. The foot of the slope rests on a revetment wall 1.50 meters thick, built in a distance of 1 meter into the solid rock (red sandstone) for the whole length of the dike. The maximum height of this wall is 7 meters.

The dike, below the revetment and the platform, rests on bare rock. To increase the tightness at the base there were three layers of puddled clay laid down within the reservoir parallel to the axis of the dike and penetrating 1 meter into the rock foundation.

The earth of the dike was vigorously rolled in successive layers, after adding water and powdered lime according to their degree of dampness; the layers being compressed from 0.10 to 0.075 meter after the operation. Corrugated rollers drawn by horses and weighing 750 kilograms, and also steam rollers weighing 5,000 kilograms were used. A horse-roller compressed 80 cubic meters per day, measured after compression, while a steam roller compressed 500 meters. The cost, including leveling, watering, addition of lime, rolling, etc., was 0.23 franc per cubic meter.

That part of the dike under the outside slope was rammed in layers of 0.20 meter thick, reduced to 0.15 meter after rolling; it rests on a natural bed carefully prepared.

(95) *The gate tower.*—The water, instead of being conveyed in mains or culverts through the dike, is let into a tower built in the reservoir at the foot of the dike. It serves to discharge the waste water and dispenses with the waste weir; this weir has been retained through fear lest the large amount of water flowing through the tower should undermine or dislocate the masonry. These apprehensions proved groundless. The experiment of passing the waste water through the tower, combined with the gate closing the tail-race, has been perfectly successful.

The gate tower is square on the outside and has in the interior a well 1.50 meters in diameter through which the mouthpieces pass. This well opens below into the tail race.

The coping of the tower is on the same level as that of the dike, that is, 16.30 meters above the bottom of the lowest mouthpiece. It has a platform 3.50 meters square, on which is placed the apparatus for moving the gates. The faces of the tower have a batter of one-twentieth.

The well terminates in a cylindrical chamber 2 meters in diameter and 2 meters deep, kept constantly full of water to break the destructive shock of the water upon the masonry. Founded on red sandstone, the tower exerts a pressure of 3.58 kilograms per square centimeter.

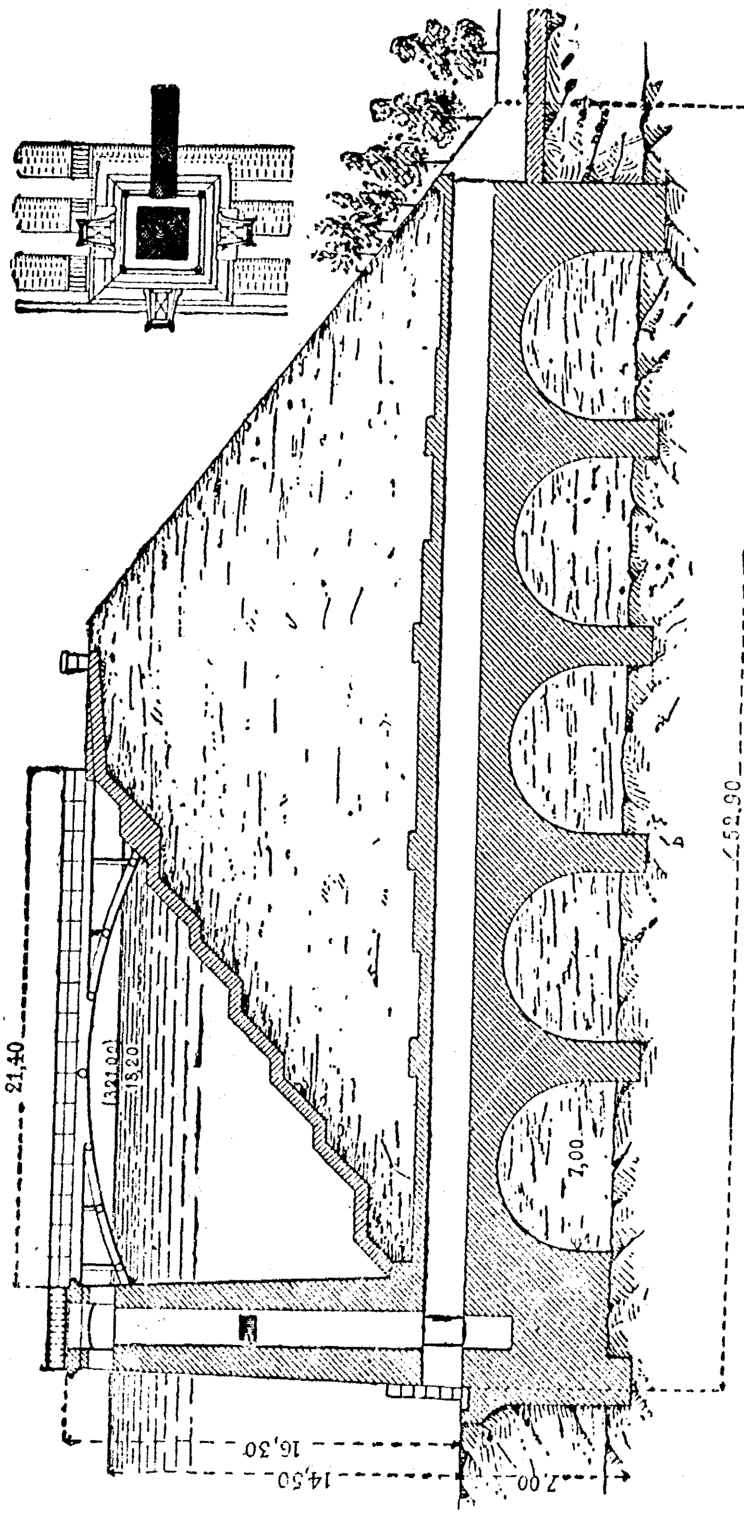


Fig. 62. Cross section of the dike, the water tower, and the culvert of the Torcy-Neuf Reservoir.

(96) There are three mouthpieces, situated vertically over each other at a distance of 4.80 meters apart. The orifices are 0.80 by 0.40 meter and are closed by special cylindrical valves. The middle

and upper mouthpieces are simple ducts of rectangular section opened in the walls of the tower; their bottoms are curved so as to intersect the walls at an angle of 45 degrees, so that the stream at the moment of opening shall strike the masonry obliquely.

The water is let into the tower by four openings, each 2.20 meters long, made at the top of its four faces; the sills of these openings are 0.40 meter below the standard level. Each of them is surmounted by an oaken gate kept in its place by U irons fastened against the sides of the openings. These gates are taken off in case of a freshet.

The tower is accessible from the dike by an iron foot bridge. The ribbed plate flooring, 21.40 meters long, 1.14 meters wide, is supported on two arches of 18.20 meters chord and 2.50 meters rise. The new system of valve towers has the advantage of economy, combined with greater security and stability for the dike, as well as affording greater facilities for repairs.

(97) The passage of the water mains through a mass of masonry in an earthen dike destroys the homogeneity of the latter; on both sides of this mass the earth has to be hand-rammed, and consequently badly done, no matter how much care is taken. The settlement of this earth leaves spaces which may cause filtrations and become sources of real danger.

With the tower, the dike is only cut at its base; the hand-ramming is reduced to a minimum; as soon as the top of the waste culvert is reached, all the ramming is done with rollers, and consequently much better. A notable economy results from dispensing with the heavy masses of masonry through which ordinarily the mains run, from the omission of the waste weir with its tail race, and from rolling by steam and horse power instead of ramming by hand.

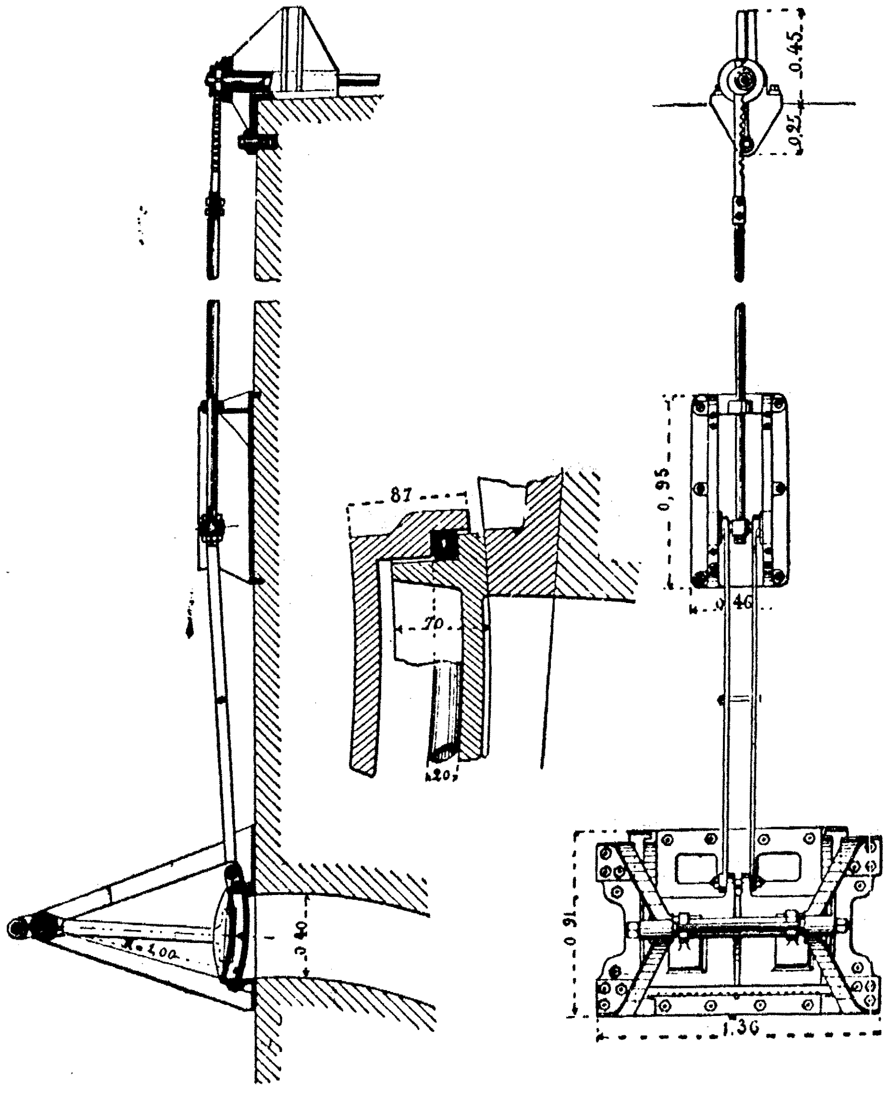
The sluices are very difficult of access in the long culverts ordinarily used, and are consequently rarely repaired. With the tower, on the contrary, when the mouth of a main has been stopped by a wooden plug, placed within the tower in a chamber arranged for this purpose, a diver can easily take down the valves and valve rods, and replace them after they have been repaired in the shop.

The long culvert under the dike can be easily inspected and repaired. The guard sluice being raised, one is not entirely cut off from the upper end; light and air come in from the tower.

(98) *Sluices.*—Rectangular sluices have the great inconvenience of moving with very considerable friction for great heads of water; use has to be made of powerful and costly jacks, whose friction increases the effort to be made; they have to be fastened by heavy irons to solid pieces of masonry, that they may not give way.

At Torcy-Neuf the endeavor has been to diminish the friction as much as possible and consequently to employ simpler moving apparatus.

The sluice (Figs. 63 and 64) is not plane but cylindrical, and firmly attached to a rigid horizontal concentric shaft; it has no opening. It turns at a short distance from its seat, which is cylindrical and concentric, without resting upon it. It includes a movable frame which it carries with it in its motion, but the latter is not attached to the shaft. The pressure of the water on this frame is exerted only at its edges; it rests and rubs only against the valve seat. The joint



FIGS. 63, 64, 65.—Torcy Neuf reservoir. Section, elevation, and details of the sluice.

between the frame and sluice is packed with a rubber ring, which does not sensibly interfere with the independence of the frame; this ring is inclosed in a slot and protected from shocks.

Comparing this with the ordinary flat sluice, the theoretical friction is reduced 92 per cent. This system, which gives entire satisfaction, is due to M. Eugène Resal. The three sluices are moved by jacks placed on a single post in the middle of the platform of the tower;

the motion is transmitted to the rods by endless chains and horizontal axles.

(99) *Guard sluice.*—The guard sluice, at the bottom of the tower, to close the waste culvert is upon the same principle. It was devised by M. Hirsch, chief engineer. It is principally of iron, 1.80 meters high and 1.10 meters wide; it consists of a strong plate iron wagonette with two pairs of wheels, rolling on vertical rails set into the walls of the masonry well (Figs. 66, 67, 68, and 69). The wagonette rises without resting against a cast-iron frame fixed in front of the

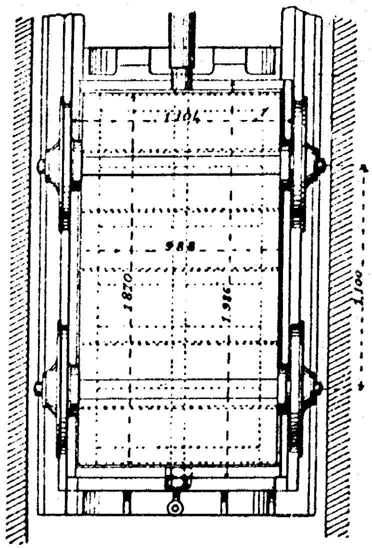


FIG. 66.

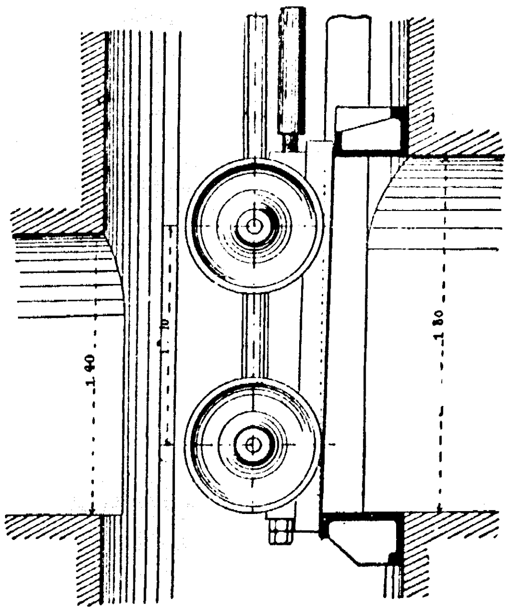


FIG. 67.

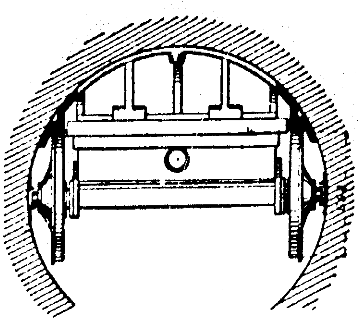


FIG. 68.

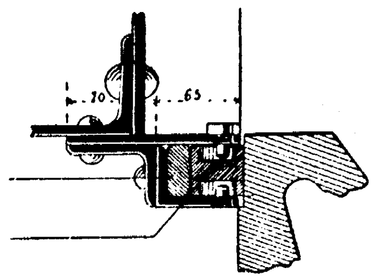


FIG. 69.

FIGS. 66, 67, 68, 69.—Torcy-Neuf reservoir. Elevation, vertical section, and horizontal section of the guard gate, with details.

culvert. The contact takes place along a slightly inclined plane by a border formed of jointed bronze rules independent of the sluice, but carried along with it in its motion. Like the other sluice, it is packed by rubber between the jointed rules and the wagonette; the faces of contact of the rules and the rubber are galvanized. The jack moving the suspending rod is placed on the platform of the tower.

The head of water on the center of the guard sluice is 13.60 meters while the pressure on a simple plain sluice having a surface of 2 square meters would be about 27,000 kilograms; the rules are only pressed against the seat with a force of 3,000 kilograms. Admitting a coefficient of 40 per cent for friction, the weight of the sluice being 1,000 kilograms, the effort to raise the sluice does not exceed 2,200 kilograms, which is easily managed by a jack with a theoretical power of 750.

This sluice was set up in 1888 and works perfectly. It affords the means, as it is raised more or less, of keeping the water in the tower at such a given constant height as may be found most advantageous. We may thus diminish at will the height of fall of the water into the tower.

(100) *Cost.*—The total cost of the work was 2,233,183.84 francs. The cost of the dike, tower, and waste weir together was 585,896.53 francs. The rest was spent for land, buildings, and the removal and reëstablishment of the roads and railroad passing through the location.

The project was prepared by MM. Desmür, engineer, and Fontaine, chief engineer.

CHAPTER IX.—NEW HIGH LIFT LOCKS ON THE CENTRAL CANAL.

(101) The French Government has just completed a number of high lift locks on the central canal to replace old ones of 2.60 meters lift. The new locks have a lift of 5.20 meters with chamber wall 8.20 meters high. The flooring is 0.25 meter below the head miter sill and 2.85 meters below the normal level. The cylindrical supply sluice (Fig. 75) is placed at the bottom of each upstream quoin under a full centered arch of 2.30 meters span and 2.55 meters height. Two small recesses serve to support a little joist dam allowing the sluice chamber to be emptied and the sluice inspected and repaired without stopping the traffic. A grating is ordinarily placed in these recesses to stop floating bodies.

(102) The lift wall is 5.20 meters high and 1.60 meters thick with the downstream face curved. The cylindrical sluice pits, 1.40 meters in diameter, are sunk in each chamber wall to a depth of 4.95 meters. From the bottom of these pits on a level with the tail miter sill, the full centered culvert begins, for filling and emptying the chamber. It extends lengthwise through the entire chamber and discharges into it by four rectangular openings equally distributed, from 0.60 to 0.80 meter wide by 0.80 to 1 meter high. The largest admits the passage of a man for inspection or repairs. The chord of the invert is 2.60 meters below the normal level, 2 meters, of the tail bay. (Fig. 70.)

Under the flooring, two files of drains begin 10 meters from the lift wall, emptying into the riprap of the tail bay. All upward pressure is thus avoided besides facilitating the foundation constructions.

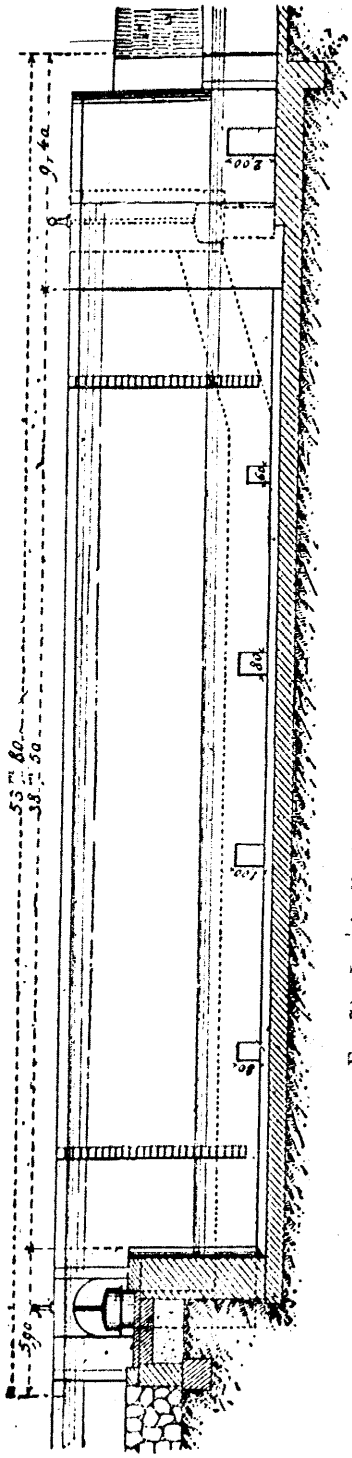
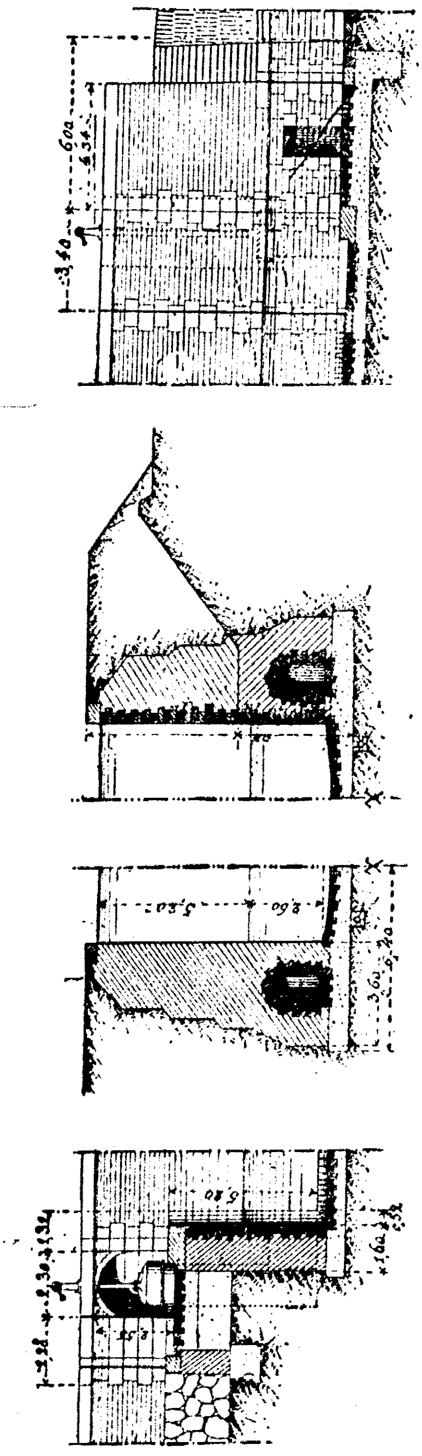


FIG. 70.—Longitudinal section of a high lift lock on the Central Canal.



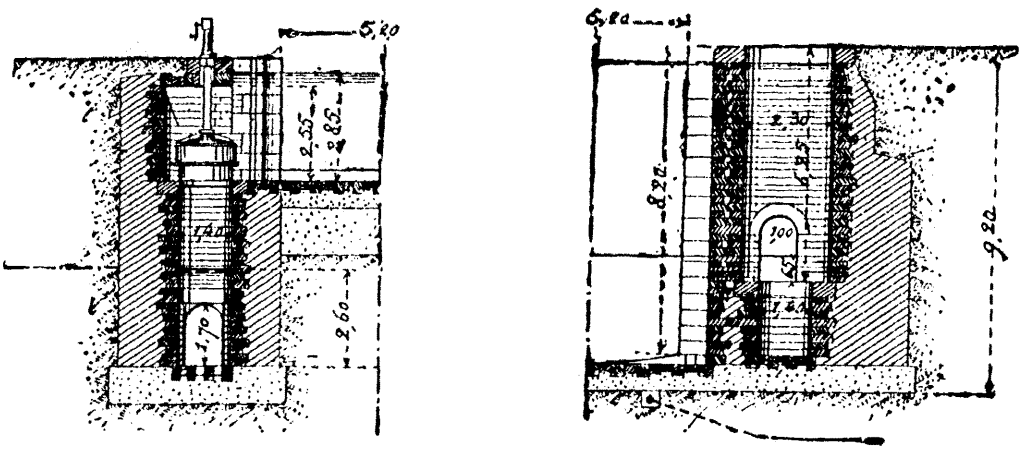
FIGS. 71-74.—Section of the head, cross sections, and tail elevation, showing the location of the culverts and the cylindrical sluices.

Each chamber wall is 3.60 meters thick at the base, and 1.20 meters at the top; it is 8.20 meters high. Two life ladders formed of iron bars are placed in little recesses in the walls.

To resist the thrust on the tail gates, the tail walls are 4.34 meters at the top and 6 meters at the base, terminated by wing walls having a batter of one-twentieth (Fig. 74).

Two recesses allow a cofferdam to be set up to separate the lock chamber from the tail bay.

A short distance upstream from the tail quoins, the lateral culvert in each chamber wall rises and empties into a large pit 2.30 meters square and 6.25 meters high, in which the cylindrical emptying valve is placed (Fig. 76). This pit, and the lock chamber form two reservoirs communicating by four rectangular orifices equally for filling and emptying. The water reaches the pit and escapes at the bottom under the boats without producing any current in the chamber. The valve seat is 0.65 meter below the level of the tail bay, so as not to make a siphon of the discharging culvert, and also to allow the inspection of the sluice by a slight lowering of the tail bay.



FIGS. 75 and 76.—Half cross sections through the axes of the upstream and downstream pits.

This sluice opens a pit 1.40 meters in diameter and 1.95 meters high, at the bottom of which, at the level of the tail miter sill, the emptying culvert begins. This latter having a great section, 1 meter wide and from 1.60 to 2 meters high, makes a circuit of the hollow quoin so as to empty into the tail bay at right angles to the axis of the lock, thus avoiding the introduction of the water with great velocity into the tail bay, and consequent erosion. One of these high lift locks has a bridge erected on the tail walls; the roadway being 1.30 meters below the coping, it is 6.80 meters span and covers, beside the boat passages, two staircases each 0.80 meter wide.

(103) *Description of the cylindrical sluices* (Fig. 77).—The lock has four cylindrical cast-iron sluices of equal size, two for filling, and two for emptying.

Each sluice consists of fixed and movable parts. The fixed parts consist of a seat 1.40 meters in diameter, built in and fastened to the masonry, and carrying three uprights in the form of flanges united by an upper crown; a hollow cylinder fixed upon the crown receiving the sluice when it is raised; a cover bolted to this cylinder and surmounted by a pipe for the passage of the lifting rod and the escape of air. The seat is placed horizontal and maintained so by means of three regulating screws embedded afterwards in cement.

The movable part is a cast-iron crown 0.467 meter in height, and 1.42 meters in interior diameter raised by a jack. It slides on a fixed part and opens or closes the space between the seat and the upper cylinder. The vertical pressure of the water is supported by the cover. The movable portion only is exposed to lateral pressures which are in equilibrium. The only weight to be raised is the

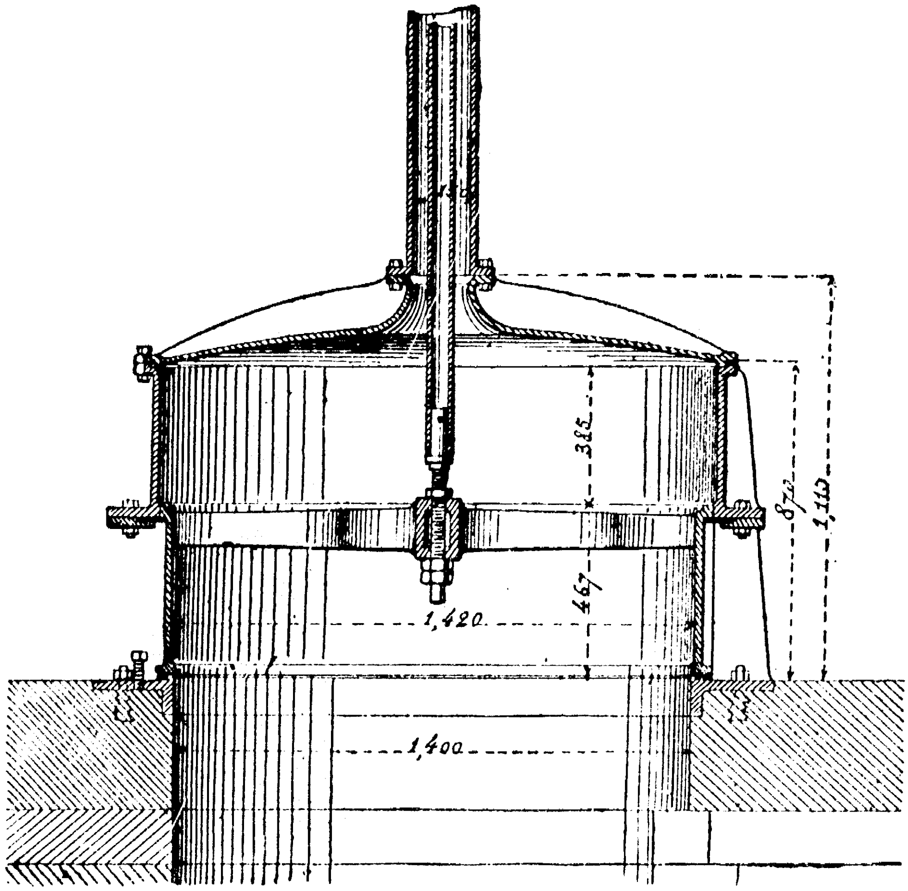
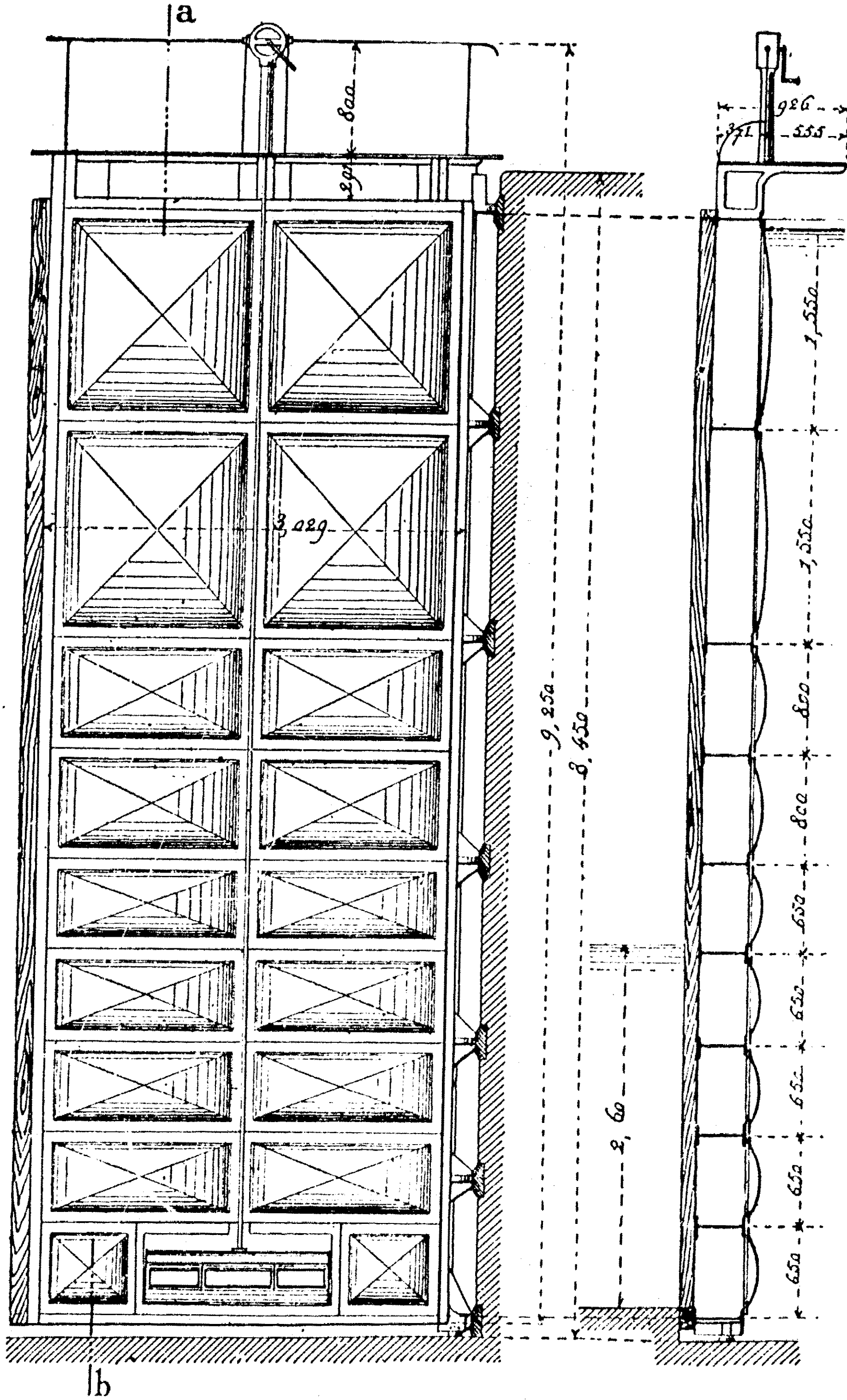


FIG. 77.—Cross section of Fontaine's cylindrical sluice; the sluice closed.

weight of the sluice, which is about 370 kilograms. The distance raised is 0.385 meter; the time of raising twelve or thirteen seconds and the effort only 7 kilograms. The downstream sluices work under a head of 5.20 meters as easily as the upstream ones under the head of 2.60 meters.

The closed sluice rests on a little rubber ring, fastened into a slot in the seat. The upper joint is made tight by a leather band, kept in place by the pressure of the water. This sluice, which has been in use for the last six years, has worked perfectly. It has the following advantages:

First. There are no resistances except the weight and friction of the water on the iron, without any pressure of the water.



Figs. 78 and 79.—Lock on the Central Canal. Upstream elevation and section of the lower gates of the canal lock.

Second. The whole section of the circular orifice is utilized by raising the sluice a height $h = \frac{r}{2}$.

Third. The head is greater than upon an equal orifice made in a vertical plane. This sluice has been adopted elsewhere for Paris and for sea locks. It solves the problem of high-lift locks with saving basins. For great reservoirs, a single cylindrical sluice of small diameter will advantageously replace the usual, complicated and expensive systems.

The use of cylindrical sluices enables all others to be dispensed with, which is an advantage with respect to tightness and repairs. The hand rails, for this reason, can be placed on the upstream side of the foot bridge, and thus sheltered from the shocks of passing boats when the leaf is opened.

(104) *Gates.*—The head gates consist of two leaves of galvanized plate iron. The tail gates are 9.25 meters high, including the hand rail; they consist of two leaves of galvanized plate iron and steel. Each has a frame strengthened by eight horizontal beams so spaced as to support about the same load, and by ten uprights united by the first set. These pieces consist of a web and four angle irons of mild steel. By the use of this metal the weight of the frame is reduced, making an economy of construction, and facilitating the setting up and the working.

The heel and miter posts, as well as the uprights, are strengthened by three wide iron bands on their downstream faces, to give them more stiffness. The skin is formed by eighteen iron plates 0.007 meter thick, built in at the edges, curved so as to have a flexure of 0.070 meter, and riveted to the upstream face of the steel frame. They show no change of form under pressure.

The pressure of the leaf against the heel post at the bottom is spread over seven iron disks upon friction plates; these last, furnished with three adjusting screws, are arranged so that all bear and work.

The collar, fixed to the anchor straps by two strong screws and nuts, has a joint besides. It can move horizontally in all directions and give the axis of rotation an exact vertical position.

Each leaf is furnished with a gridiron valve formed of two hollow cast-iron cylinders united by flanges, to be used in the case—which may never happen—when the water is so low as to uncover the sills of the cylindrical sluices.

All the gates are moved easily, even by children, by means of little simple and convenient windlasses.

(105) *Time of lockage.*—The lock, containing 1,200 cubic meters, is filled in 3 minutes 10 seconds and emptied in 3 minutes 15 seconds; the time for lockage, 14 minutes, being thus distributed:

	Min.	Sec.
Entrance of the boat	4	10
Closing the gates	0	40
Filling the chamber	3	10
Opening the gates	0	40
Exit of the boat	5	20

(106) *Cost.*—The cost of the lock was 120,000 francs, made up as follows:

	Francs.
Earth work	8,000
Masonry work	96,000
Lock gates	11,100
Cylindrical sluices	3,400
Gratings and windlasses	1,500
Total	120,000

The new lock appears to be very satisfactory, and promises to become the type to be adopted in future. The rapidity of lockage without injury to the boats from the motion of the water, and the ease of operating all the appliances, are thoroughly appreciated.

The group of locks, of which this was one, was designed and executed under the direction of M. Fontaine, chief engineer, by Messrs. Résal, Moraillon, and Variot, assistant engineers.

CHAPTER X.—CABLE TOWAGE FOR BOATS ON CANALS AND RIVERS.

(107) The principal difficulties in cable towage arise from the following circumstances:

First. That owing to the obliquity of the towrope, the irregularity of its motion, and the displacement of the joint between the rope and the cable, the cable can not have a steady motion.

Second. Whenever the towrope passes over the groove of a guide pulley it is caught there. It must pass the pulley without dragging the cable, which is a difficult matter, especially in going around concave curves.

Third. The joint between the towrope and the cable should be such that the former can not be twisted upon the latter by the torsion of the cable, otherwise the towrope will be wound upon it, besides being very difficult to detach from it.

Fourth. The towrope must be easily detached from the cable at any instant—an operation of some difficulty, as it is done by a cord 60, 80, or 150 meters long, which forms knots by being dragged on the ground or through the water.

Fifth. Uncoupling should be progressive, although we couple suddenly to a cable in motion.

(108) *System adopted.*—The system of cable towage introduced by M. Maurice Levy solves all these difficulties as follows:—

The first condition of success was, according to the author, to avoid all irregular motions of the cable. For this purpose, instead of determining the weight and tension of the cable according to the usual rules governing telodynamic transmission, he determines them by the double condition of maintaining the oscillations of the cable, whether horizontal or vertical, within certain prescribed limits, which can be made as small as may be desired. This requires that the cable should be heavy (about 3 kilograms per meter), and that it should be set up with an initial tension incomparably greater

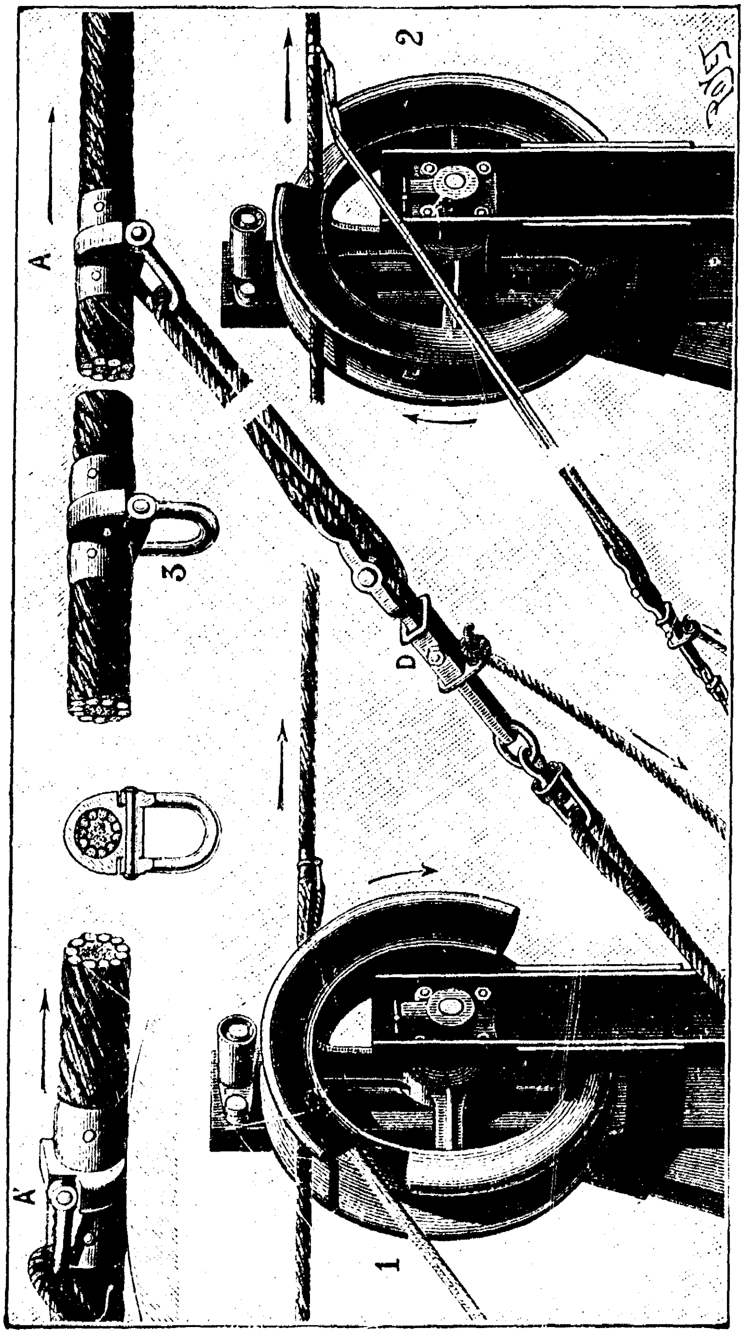


FIG. 89.—Details of the pulley and the towrope connections for cable towage. The towrope is coming on to the guide pulley at 1 and going off at 2. 3 is the ring on the cable through which it passes, to be hooked on to a finger at *d* shown in Fig. 86. A section through the cable and ring is shown, as well as a section of the cable.*

than that usually adopted in telodynamic cables. This tension, as well as the weight of the cable, depends on the length of circuit and the speed required for the boats.

*This figure is taken by permission from La Nature.

The vertical supporting pulleys are 0.80 meter in diameter, and have a depth of groove of 0.20 meter. A roller on the top of the pulley prevents the cable from leaving it, but the towrope attachment would catch between the pulley and the guide roller. To obviate this openings are made on the water side of the pulley grooves, consisting of notches extending the whole width of the groove and having their edges curved in the form of the involute of a circle (Fig. 80).

The towrope joint, or coupling, remains in the groove until it is caught by the first notch, which it follows; then, on account of the obliquity of the towrope, it descends along one edge, is carried up on the other, and passes off.

(109) The passage around convex bends in the banks presents no difficulty; it is accomplished with the aid of a horizontal pulley, or rather one slightly inclined in the direction of the two sides of the endless cable. Two types of pulleys are adopted: one 1.40 meters and the other 2 meters in diameter at the bottom of the grooves, with 0.10 meter depth of groove. The first, for curves from 200 to 300 meters radius, and the second for those of smaller radii. These pulleys have no need of notches, as the cable, with its towrope coupling, only passes on the water side and thus escapes. On account of the great tension of the cable there is no danger that the towrope will pull it off.

(110) The passage around concave angles is, on the contrary, an extremely delicate problem. In that case, the cable passing round the pulley on the land side, the towrope joint can not clear itself unless we adopt very special and precise arrangements.

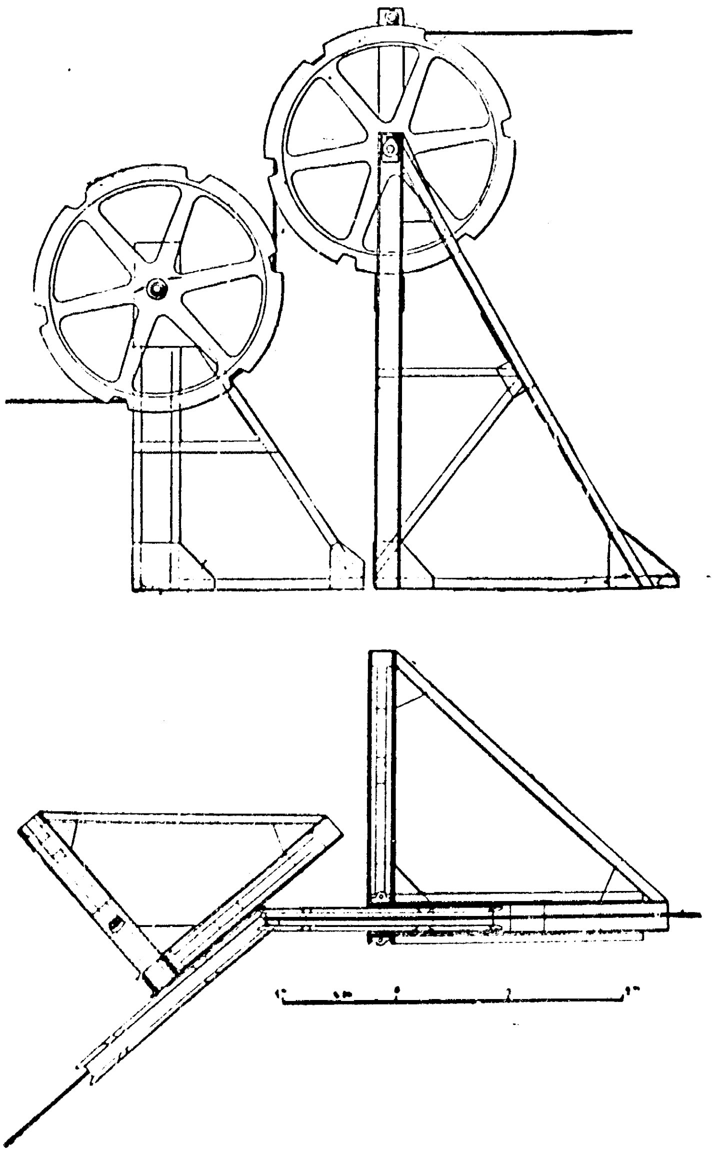
The following method was adopted (Figs. 81 and 82):

In the elevation, the plane of the lower pulley is supposed to be revolved to coincide with that of the upper one.

Two vertical pulleys are taken, having a common tangent, to the bottom of their respective grooves, one of the pulleys being in the plane of the part coming on, and the other in that of the part going off. The cable rolls upon the first (which we may suppose to be the upper one) and descends vertically along the common tangent, and then passes on to the second.

This solution permits any change of direction whatever by the aid of two vertical pulleys, and consequently it suffices to notch these pulleys like the supporting pulleys to let the towrope coupling escape. But it subjects the cable to two consecutive bends at right angles. In order to save the cable from wear, large 2-meter pulleys are used, and on account of their great dimensions the number of the notches is increased.

The expense of such pulleys with their supports would be considerable if they had to be used wherever there is a concave angle, and this arrangement is only suitable for curves with exceptionally short radii, or at the entrance of tunnels, where it may be convenient to suddenly change the direction. For the usual deviations a large pulley is used of the type of 1.40 or 2 meters, furnished with notches on the upper face (Fig. 83). This solution is derived from that of the two vertical pulleys.



FIGS. 81 and 82.—Cable towage. Elevation and plan of a double pulley for a concave angle. The cable comes on to the upper pulley and passes to the lower.

The principle of the two pulleys is very elastic. We may, for instance, take both pulleys inclined, or one vertical and the other inclined. Then we may arrange so that the first shall be an ordinary pulley 0.60 meter, and there remains only one large pulley. But the inclination of the latter, its direction relatively to that of the cable as it comes on and goes off, and the length and width of the notches, should be determined with the most perfect precision by certain rules which have been established by theory and experiment.

(111) *Method of attaching the boats to the cable.*—The towrope can not be made fast directly to the cable, because the latter being subjected to constant twisting motions would cause the former to twist around it, thereby losing considerable of its length, and rendering its detachment impossible during the journey. This detachment should be capable of being instantly done in case of an accident, or when the boat is to be stopped. For this reason cable-road grips are inapplicable; hence pairs of rings are placed at intervals on the cable (Fig. 80). One ring serves as a fixed axis of rotation to the other ring which is movable about the cable. The latter ring has two bearings around which the U-shaped shackle turns. This shackle may therefore have two rotations, one around the cable and the other around an axis perpendicular to it.

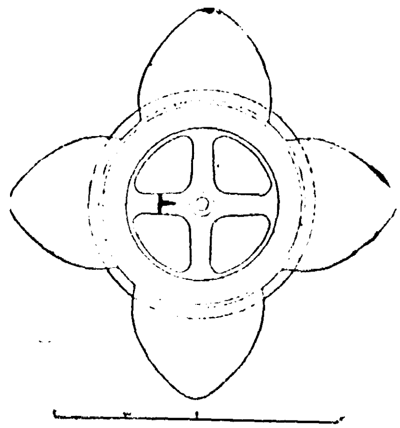
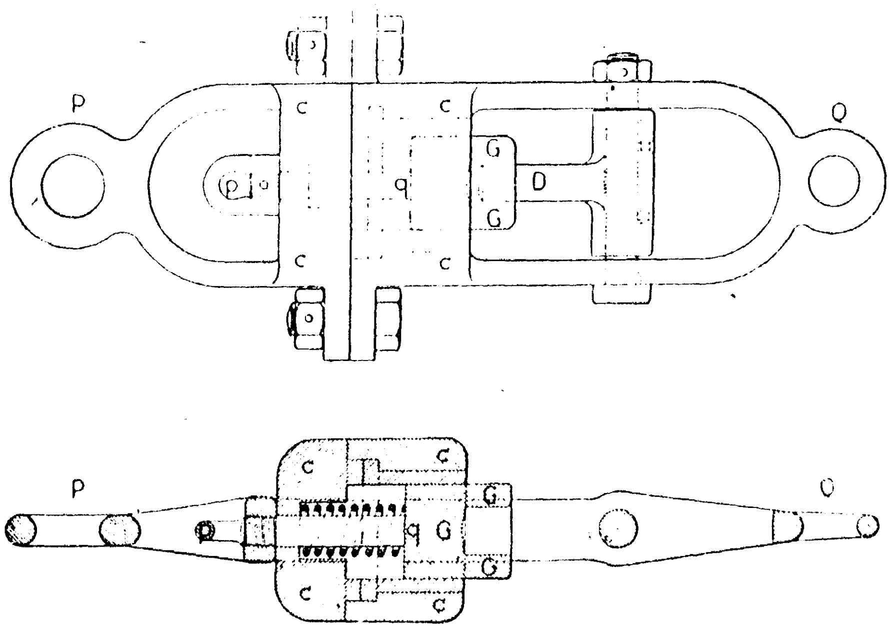


FIG. 83.—Single pulley for concave angles.



FIGS. 84 and 85.—Elevation and section of the hooking on and casting off grip.

The grip attached to the towrope consists of a hollow cylinder *c c c c*, in which the piston G G G moves; the piston rod *p q* passing through the bottom of the cylinder; one end of a spiral spring surrounding the rod *p q* rests against the bottom of the cylinder G G, and the other against the piston.

A frame P Q is placed in a diametral plane of the cylinder and attached to it; it carries a finger, D, movable around an axle; the end of the finger fits into a cylindrical cavity in the piston G G. If D is put in the cavity it is caught there. If the rod *p* is pulled the piston follows it, compressing the spring; the finger D then becomes free to turn on its axis.

The end of the towrope on the boat is permanently attached by a ring to P. One extremity of the grip cord is on the boat and the other permanently attached to *p* (Fig. 86).

The cord is for releasing the finger around which the bight of a leash is placed; this leash passes through the ring on the cable, and is permanently fastened to the grip at Q. By pulling on the cord, the finger is released, and the leash slips out of the ring on the cable.

Finally, the end of a rope 8 or 10 meters long and from 0.015 to 0.018 meter in diameter which may be called the leash, is permanently attached at Q. The other extremity is free, and terminated by an eye.

To hook on a boat, the grip lying on the towpath, the finger D free, a man takes the free end of the leash and awaits the arrival of

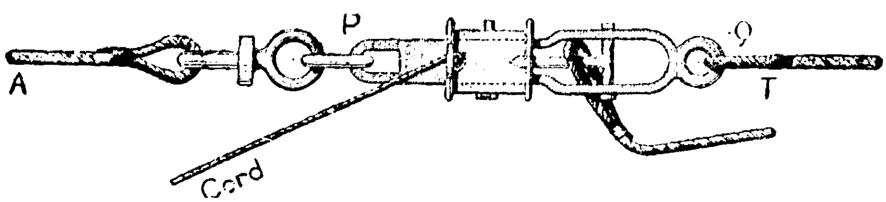


FIG. 86.—The grip with the towrope fastened to one end by the ring P.

the shackle A (Fig. 82), and passing the leash through the shackle he slips the ring on its free end on to the finger D which he makes fast, so that the grip is arranged as in Fig. 86. A is the towrope, and T the leash, going through the cable shackle. This done he returns to the boat which he has plenty of time to reach before the towrope tightens. If he wishes to stop, he attaches the grip cord to the boat and slackens the towrope, then all the pull coming on the grip cord the spring is compressed, the finger becomes free, and with it the leash. To let go slowly it suffices to slacken the rope on a bitt. But it is more convenient to have a windlass with a brake under the steersman's foot; the brake lever is so arranged that he has only to press his foot down to tighten, and to let it go to loosen. Thus the steersman, without quitting his place, by a slight motion of his foot upon the brake casts off from the cable. To slacken speed when in motion, the towrope is slackened, but can be hauled in again by the windlass. The windlass is especially useful for this purpose.

Thus the slight slowings made necessary by meeting other boats, or passing under bridges, are immediately made up and the journey is made with mathematical regularity.

(112) *Method of circuits.*—In an extended application, the circuits may cover without difficulty a distance of from 15 to 18 kilometers, and as the two machines driving two consecutive circuits may be united, it follows that the machines may be from 30 to 36 kilometers apart.

The machines thus placed, two and two in the same shed, can mutually help each other in case of accident to either. Continuous towage can go on with slightly diminished velocity, it is true, but with no stoppage.

The power used depends on the velocity desired. With a velocity of 0.70 meter per second, the velocity of horse towage, it requires only two horse power to draw a barge loaded with 350 tons, and one horse power for lighter loads.

If we adopt the velocity of one meter per second, we must multiply these figures by 2.25. One-half a horse power per kilometer should be added for power consumed by the unloaded cable. Under these conditions for a traffic of 1,000,000 tons per year, with a velocity of one meter per second, two machines of from 45 to 50 horse power would be required for each distance of thirty kilometers.

(113) The cost of the plant depends on the dimensions of the barges, their number and velocity.

Assuming the largest barges 38.50 meters, with a velocity of one meter per second, and a traffic of 1,000,000 tons per year, we may estimate the cost of the plant at 17 francs per running meter.

The cost per meter of working, under the severest conditions, and including a sinking fund for the capital, and the cost of renewing the cable not exceeding 3.18 francs, the expense of traction is 0.003 francs per ton per kilometer, if we have a traffic of 1,000,000 tons; it descends to 0.0012, if the traffic amounts to 2,500,000 or 3,000,000 tons.

This system has been devised and applied between Paris and Joinville by M. Maurice Lévy, chief engineer of roads and bridges.

A system of cable towage differing from the one above described, invented by M. Oriville, is on trial on the Saint Quentin Canal, at Tergniers.

Chapter XI.—Towage by a submerged chain, with a fireless engine.

(114) The summit level at Mauvages lies between the two slopes of the Marne and the Meuse; its length is 9,205 meters of which 4,877 are in a tunnel.

The tunnel consists of a full central arch 7.80 meters in diameter, one side of which is continued by a curved lateral wall; on the other side is the towpath, 1.40 meters wide, protected by a stone revetment. The bottom is about 6 meters wide. The pool is fed at low water from the Ornain, 25,000 cubic meters per day, and by a set of pumping engines at Vacon, furnishing 40,000 cubic meters, making in all 65,000 cubic meters per day.

(115) *A system of chain towage* has recently been established here with towboats driven by the Francq-Lamb system capable of working without smoke. The Francq-Lamb system, the invention of Lamb and improved by Francq, as it is generally employed on tramways, consists in using steam produced from water at a high temperature contained in a reservoir fed at some point on the road from a fixed source of supply. It includes, independently of the locomotive, a stationary boiler, with a reservoir of superheated steam which may be used at starting, or at some point on the road, to feed the fireless locomotive. This system thus avoids filling the tunnels with smoke, which would be a serious inconvenience.

At the same time the system has been modified by placing the *steam boilers* as well as the reservoirs on board the towboat. This arrangement, would not be thought of for a locomotive, but it presents no difficulty on a boat, as it only occupies 14 or 15 cubic meters of space, and the additional weight is unimportant.

(116) *Description of the boats* (Figs. 87 and 88, A, B, D).—At the bow and on the stern are two guide pulleys for the chain. Two boilers, C, with safety appliances, rated for 17 kilograms of effective pressure. Abaft the engine are the receivers for the superheated water, by which the engine is driven, when the boat is in the tunnel. Above the engine are the drums around which the chain passes.

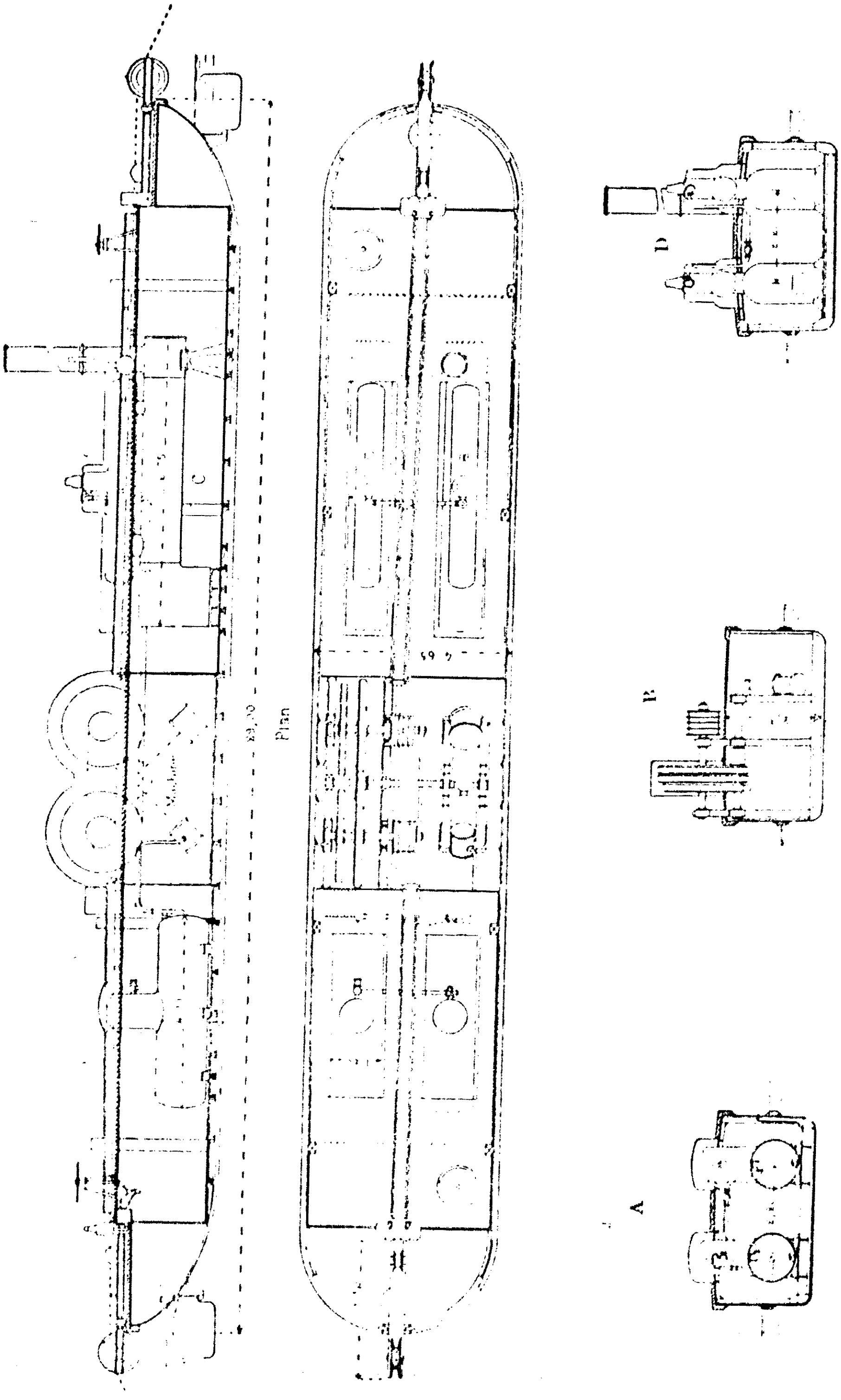
Fig. 88 shows the plan, and Figs. A, B, and D the cross sections through the receivers, through the engine and chain drum, and through the boilers.

Each of the two towboats is 29 meters long, 4.65 meters wide, and 2.30 meters deep. The hull is of steel plate; its draught is 1.10 meters including coal and water for a trip of 9 kilometers each way.

The engine is placed in the middle of the boat; at one end are the boilers and at the other the receptacles for the superheated water. The effective power of the engine, measured on the first towrope, is 18 horses. It is a compound condensing engine with two inclined cylinders furnished with reversing gear.

There are two tubular boilers registered for 17 kilograms effective pressure; each of these is surmounted by a long horizontal steam chamber united to it by large openings; the water level rises just into these chambers which carry all the safety apparatus. On the other side of the engine are the superheated water receivers which, with the generators, furnish the steam requisite for working the boat through the tunnel. They are steel cylinders surmounted by a dome and communicate with the generators by a steam pipe and cock united to the interior of the reservoir with a perforated pipe for heating the water.

Before it is sent to the cylinders the steam in the receivers is brought to the usual pressure of 5 or 6 kilograms. The reser-



Figs. 87 and 88. The longitudinal section of the chain tow boats.

voir for the expanded steam is placed in the interior of the receptacle for the superheated water, thus always affording very dry steam for the cylinders.

The expansion apparatus (for regulating the pressure of the steam to be admitted into the cylinders) is moved by a working beam acting on an adjustable lever and completely regulating the use of the expanded steam.

The mechanism employed is exactly that used in the Francq locomotives, except that the generators are carried by the boat instead of being stationary.

(117) *Daily trips of the boats.*—Every day one of the two towboats makes a trip. Its speed is 2 kilometers per hour; in the tunnel it is reduced to 1,500 meters, and often 1,200 meters per hour.

Starting at 7 o'clock in the morning, with a pressure of 5 or 6 kilograms, it goes an hour in the open canal, during which the pressure augments to 10 or 12 kilograms, and even 16 or 17 when the load is very heavy. During the passage through the tunnel, which is about 4 hours, the fire is allowed to fall, and the boat is driven only by the steam in the receivers. On coming out of the tunnel the pressure has fallen to 4 or 5 kilograms, which is sufficient to finish the journey in the open canal, which usually takes an hour. After an hour for rest the boat returns to the original starting point.

During the passage through the tunnel no smoke is emitted, so that it can be seen through from one end to the other.

The boat easily tows from twenty to twenty-five barges, carrying 4,000 to 5,000 tons of useful load, with the effective work of the engine of from 16 to 17 horse power.

The coal burned with a file of sixteen barges attached does not exceed 3 kilograms per horse power, per hour, measured on the towrope of the first barge.

The toll has been fixed at 0.005 franc per ton per kilometer. The number of hands employed is six—two engineers, two stokers, and two sailors; one of the four in the engine room takes a day off to rest or work in the repair shop.

(118) *Cost.*—The total cost is as follows:

	Francs.
First towboat	120,000
Second towboat	143,000
Chain	49,000
Sundries	63,000
Total	375,000

The cost of working is about 20,000 francs, which is largely covered by the tolls, which amount to about 24,000 francs derived from a traffic of 600,000 tons per year.

The plans were prepared under the direction of the general inspector, Frécot, by M. Holtz, chief engineer.

CHAPTER XII.—SYSTEM FOR SUPPLYING THE CANAL FROM THE MARNE TO THE RHINE AND THE EASTERN CANAL.

(119) Two important groups of pumps serve to supply the canal from the Marne to the Rhine and the Eastern Canal, in that portion between Toul and Mauvages, the summit level of the first canal. These establishments are those of Valcourt, Pierre-la Treiche, and Vacon.

(120) The establishments of Valcourt and Pierre-la Treiche are situated on the Moselle, near Toul; they use the falls of the dams constructed for the canalization of that river, and serve to supply, during the dry season, the great pool, Pagny-sur-Meuse, of the canal from the Marne to the Rhine, where the north branch of the Eastern Canal takes its rise.

Each establishment comprises two Fontaine turbines, each driving three horizontal pumps. The connection between the turbines and pumps is made direct by cranks on the hollow shafts of the motors to which the connecting rods of the pumps are attached. (Figs. 89 and 90.)

The six pumps of each establishment send their water to a single air reservoir from which the main conduit issues.

The data applicable to these establishments are as follows:

	Height of the fall.	Water per second.		Power:	
		Min.	Max.	Min.	Max.
	Meters.	*Cu. m.*	*Cu. m.*	*H. P.*	*H. P.*
Valcourt	4.00	3.25	6.00	173	320
Pierre-la Treiche	2.50	6.50	8.125	217	270

The heights to which the water is raised are 40.65 meters and 40.20 meters.

(121) *Cost.*—

	Francs.
Machine and workshop appliances	274,600.00
Cost of laying the cast-iron pipes, including the cost of the pipes themselves	248,173.33
Pump houses, land, etc	569,192.23
Other expenses	542,297.75
Total	1,634,262.31

These machines annually raise 5,000,000 cubic meters of water. Allowing 6 per cent as interest and sinking fund, we find 0.48 franc as the cost of raising annually 1,000 cubic meters of water 1 meter. The annual expenses of working 100 days, and repairs, are 20,000 francs; that is, for 1,000 cubic meters raised 1 meter, 0.10 franc; if we add to this the cost of the establishment, 0.48 franc, given above, we shall find the total cost (0.58 franc) of raising 1,000 cubic meters 1 meter.

(122) *Establishment at Vacon.*—The other establishment, at Vacon, consists of five boilers, two horizontal steam engines, and two horizontal piston plunger pumps, raising 40,000 cubic meters per day a height of 37 meters. The cost of the establishment was 1,250,000

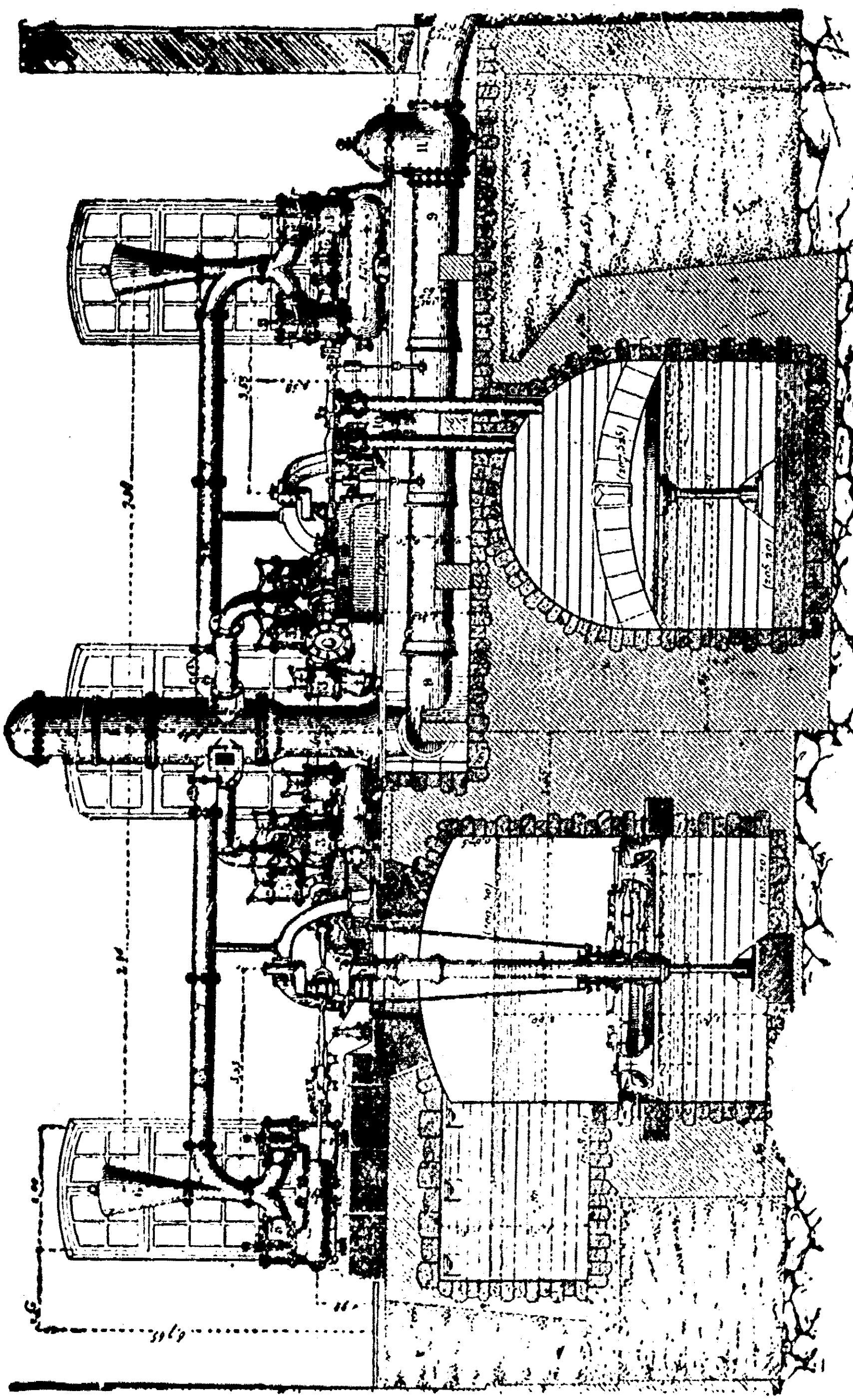


Fig. 89.—Vertical section through the pumping station at Pierre-la Treiche, showing the situation of the two Fontaine turbines, each driving three pumps.

francs. Making the same calculations as before, we find the total cost of raising 1,000 cubic meters of water 1 meter by steam power to be 0.93 franc. The two sets of works were erected under the direction of Inspector-General Frécot by Messrs. Poincaré, Holtz, Bizalion, and Thoux, chief engineers, and M. Picard, assistant engineer.

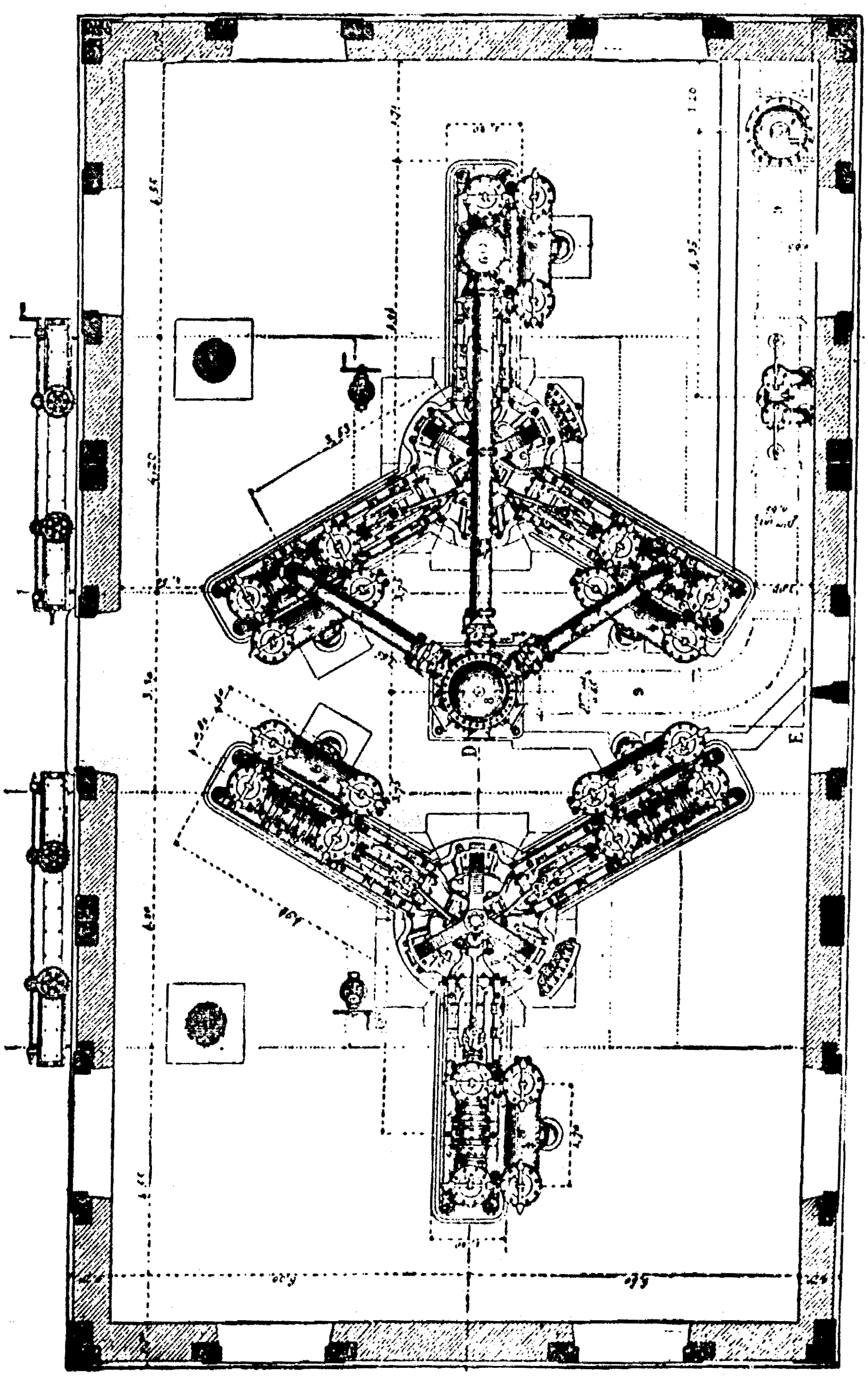


Fig. 90.—Plan of the pumping station at Pierre-la Treiche.

CHAPTER XIII.—OSCILLATING BRIDGE OVER THE DAMES CANAL LOCK.

(123) A very common arrangement in canals consists in placing a permanent bridge on the lower end of a lock, using the tail walls as abutments.

This arrangement, though economical in construction, is an obstacle in working, especially in ascending, by obliging the driver to untackle, that is, to suspend the traction precisely at the moment when the traction should be greatest to overcome the resistances to the boat's entrance to the lock.

To remedy this difficulty a new type of movable bridges has been introduced, called an oscillating bridge. One of these has lately been built over the Dames Lock on the Nivernais Canal, which gives great satisfaction to the boatmen.

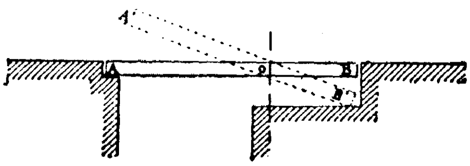


FIG. 91—Diagram of the bascule bridge.

Fig. 91 shows the principle of the bridge; the hatched edges are sections of the bridge abutments: A B is the iron roadway movable around a horizontal axle O, placed a few centimeters back from the abutment face (on the side opposite the towpath), and divided by this axle into two unequal parts O A and O B, the first about double the second. When the roadway is in its normal position the extremity A rests on the abutment on the towpath side, while the other is held on a level with the coping by a particular system of sliding bolts. This abutment contains a little depression, so that the roadway may, by tipping, take the position A' B'. The towrope passing between A and A' obviates the necessity of untackling, and thus renders the traction continuous. An oscillation in the contrary direction brings back the roadway to its normal position, A B. The roadway has a fixed and a movable counterpoise, and when these are properly adjusted and the sliding bolts pulled out by means of a lever arranged for the purpose the bridge is opened by the weight of a man at B, and by his weight at A closed and locked by the sliding bolts.

This system is due to M. B de Mas, chief engineer of roads and bridges.

CHAPTER XIV.—BALANCED GATES ON THE RHONE AND CETTE CANAL.

(124) The Rhone and Cette Canal crosses the Lez River through a circular basin 50 meters in diameter, 1,500 meters from the mouth of the river in the Mediterranean.

Until 1886 the two branches of the canal, one the prolongation of the other through the basin, were terminated by two openings reduced to 6.60 meters in width, called semi-locks, which were closed with a plank dam during the time of freshets in the river. These freshets, though short and infrequent, could not be foreseen; they came frequently at night.

The closing of the canal required a number of hands, which were not easily obtained at a short notice, and the work took from three to four hours for each opening. If the openings were not closed in time large quantities of silt were deposited, which on some occasions have interrupted the traffic for a month. The annual amount of dredging exceeded 12,000 cubic meters, costing more than 15,000 francs per year on account of the insufficient method of closing the openings.

To the effect of the river must be added that of the sea. The water, driven in by gales of wind, is forced up the river like a tide, and, spreading through the openings into the canal, leaves additional masses of sand to be dredged out.

The frequency of these storms, together with the impossibility of keeping the openings closed, on account of the traffic, has led to the adoption of balanced gates of a new type at the river crossing.

(125) The programme was as follows: To construct at each opening a cheap work, utilizing the existing masonry walls and fulfilling the following conditions:

First. The openings must be closed at any height of the water by one man in a very short time.

Second. They must be able to be opened under a head of from 0.50 to 0.75 meter by two men in a few minutes.

Third. The vertical section of the space to be closed is 7.65 meters wide by 3.60 meters high; the maximum head of water from a freshet to be 1 meter.

Fourth. In the normal condition there must be a free passage the whole width, 6.60 meters, of the opening, a draught of 2.40 meters, and a vertical opening from 3.80 to 3.90 meters above the water line.

Fifth. A final condition for the preservation of the work was that nearly all the pieces of metal or wood, and the mechanical appliances, should be normally out of water, and that when immersed they should spontaneously emerge, both for inspection and repair.

(126) *Description of the gates.*—The work consists of a cylindrical sluice turning about a horizontal axle with little friction. This cylinder has a radius of 3.80 meters and consists of a plate-iron skin 0.008 meter thick, 7.65 meters wide, with a developed length of 4.20 meters along its right section. It is riveted on four horizontal double T flanges 1.05 meters apart. The whole is braced internally by special irons. The end generatrices of the skin are strengthened by longitudinal angle irons; the one intended to strike against a hurter in the flooring serves, besides, to increase the surface of contact.

The sluice thus constructed is supported at each end by a number of iron double T arms coming together in each side of the opening in the hollow quoin prepared in the masonry for the axle, to which they are united by a cast-iron hub. These arms, four in number on each side, are united at right angles to the corresponding flanges. The junction of the arms with the outer skin and flanges is completed by an iron plate cut in in the form of the segment of a circle and riveted flat upon the arms, and edgewise on the projecting skin, by means of a curved angle iron.

The wrought-iron axles, 0.25 meter in diameter, are inserted 1 meter above low water into cast-iron hubs, and each one rests on two pillow blocks, one, the bearing pillow block, close to the masonry, the other 2.50 meters behind. These axles are perpendicular to the chamber walls.

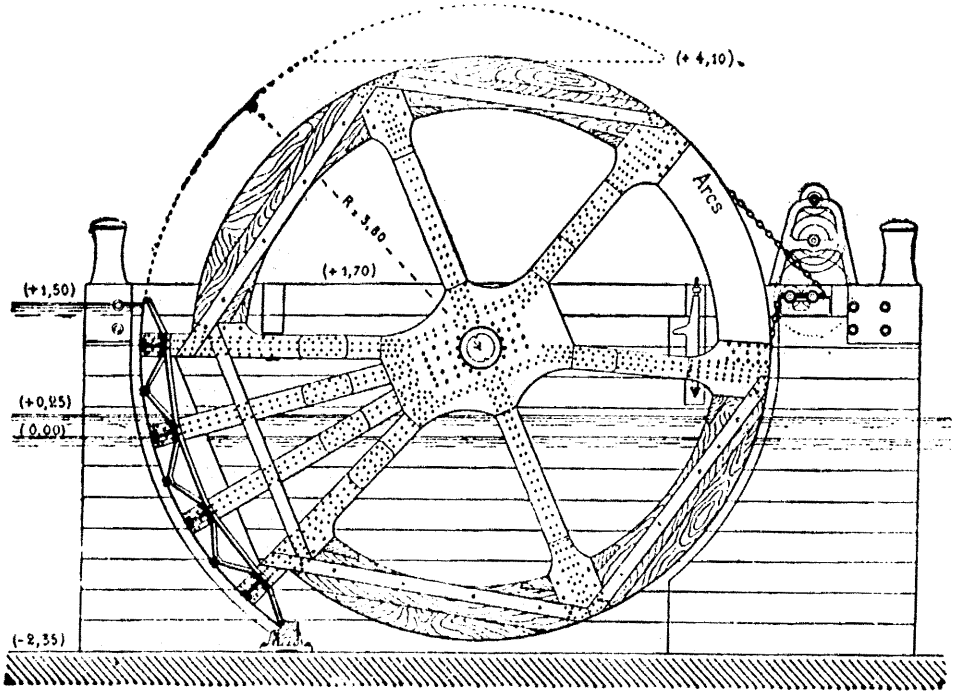


FIG. 92. Segmental balance gate at Croisée-du-Lez.

To balance the gate around its axle, a cast-iron segment of a rim is placed on each side opposite the sluice, its weight being accurately calculated. Each counterpoise is united to the hub by two arms in line with those connecting the edges of the sluice. This arrangement balances the structure if it is completely immersed in air or water. In reality, part must be in and part out of water. At the moment when the lower side of the sluice enters the water, and where the counterpoise emerges, there is produced, in virtue of the Archimedean principle, a thrust on one side and a diminution of thrust on the other, the moments of which add and constitute a considerable resistance to the motion, attaining as a maximum 5,000 or

6,000 kilograms at the distance of 1 meter. This effort, eight or ten times the passive resistance of friction, would destroy the advantages of the system. The following simple arrangement removes the whole difficulty. The additional resisting moment due to the upward pressure of the water at any instant will evidently be annulled, if an equal and upward thrust is produced symmetric with the axis of rotation; the total resultant will pass through the axis and tend to lift it, and thereby diminish the friction.

A wooden rim completing that formed by the counterpoise and the sluice, calculated so that the moment of its volume per unit of angle shall be equal to the mean moment of the sluice, including the arms, etc., solves mathematically the case of the plane of flotation passing through the axis, and approximately for the case of any plane of flotation.*

Each portion of the wooden crown, formed of two segments of one-sixth of the circumference, is united at one end to one of the outside arms of the sluice; and at the other end to an arm of the counterpoise. It is strengthened in the middle by another double T arm fixed to the hub perpendicular to the mean radius of the sluice.

Iron hanging ties, strongly stretched, complete the connection and give great stiffness to the wheels thus formed, which are contained in the hollow quoins and thus protected from the shock of the barges.

With a view of rendering the closing of the sluice easier than the opening, the theoretical equilibrium has been voluntarily broken, by hollowing those ends of each counterpoise which emerge first during the closing.

Finally, the intermediate arms sustaining the wooden crowns, which are horizontal in their normal position, can be fastened on the upstream end by movable wooden wedges, and on the downstream side, by strong wrought-iron bolts so as to prevent the gate from being accidentally displaced. In closing, the cylindrical sluice strikes its lower edge against an oak hurter 2.10 meters below low-water mark, and the upper edge is at 1.50 meters above that limit.

(127) *The opening and closing* are easily effected by means of two chains passing around a groove in the rim of the wooden crowns and counterpoises and pulled in one direction or the reverse by means of chain pulleys worked by windlasses. Generally the windlasses are thrown out of gear. To start the gate, the wedges are removed, the bolts opened, and one of the windlasses is put in gear and worked by one man, who makes the opening in forty or sixty seconds; to open the gate under a head of 0.50 or 0.75 meter, both windlasses are used, and two men, one on each side, effect the operation in five or six minutes.

* This ring being there for the sake of its volume, and not for weight or strength, the use of wood is naturally indicated.

This apparatus solves completely the problem, and assures rapid opening and closing of the two openings in times of freshet or high tide. Although recently established, there has been considerable diminution in the silting, and in the interruptions in the traffic. These interruptions were formerly for several consecutive days per year, now, they amount to a few hours for each freshet, and generally the boats can pass notwithstanding an ordinary freshet. The solution is therefore perfectly satisfactory.

(128) *Cost.*—The iron frame-work of the two gates with their accessories, hurters, windlasses, etc., including the cost of setting up, amounted to 27,295.54 francs. It was begun in 1885 and finished in 1887.

The plan was made, and the work executed by M. Guibal, engineer, under the direction of MM. Delon and Lenthéric, successive chief engineers.

CHAPTER XV.—BRAYE-EN-LAONNOIS TUNNEL.

(129) *An example of the use of compressed air in tunnel construction.*—The canal between the Oise and the Aisne passes through the ridge separating the basins of these two rivers, by a tunnel 2,360 meters long, the bottom being at a distance of 122 meters below the highest point.

The geological formation is that portion of the Tertiary known as the Eocene, and the stratum the Suessonian. This Suessonian stratum is made up of a layer of plastic clay between two layers of sand, viz, the Soissonnais above and the Bracheux below. Above the Soissonnais sand comes the Paris chalk which constitutes the ridge.

The tunnel is driven through the lower layers of the Suessonian: but near the head on the Oise slope the layers form a pocket, the point of which, 300 meters from the head, penetrates the crown of the tunnel for a distance of 0.30 meter into the layer of Tertiary Soissonnais sand. The water filtering through the upper sands accumulates upon the layer of clay, and at the beginning of the work filled the ground for a height of 15 or 16 meters, and rendered these sands, which are very fine, liquid. Also, the water soaked into the upper part of the layer of plastic clay, which, besides the impermeable clay beds, contained permeable beds of lignites and agglomerations of shells.

In these formations on the Oise slope the driving of the tunnel presented the greatest difficulties, increasing as the thickness of the clay roof, which served as a protection against the fluid sand, diminished. At each instant thin layers of clay, intercalated between the lignites and the shell agglomerates, kept breaking, resulting in cavings in and inpourings of sandy mud, stopping the work.

(130) *Use of compressed air.*—To remedy this state of things it was proposed to use compressed air, and the plant for this purpose

was thus set up near the head. It consists of seven portable engines of 220 horse power, driving eight compressors, which furnish to the working chamber, every 24 hours, 50,000 cubic meters of air under a pressure of 1 kilogram above the atmosphere.

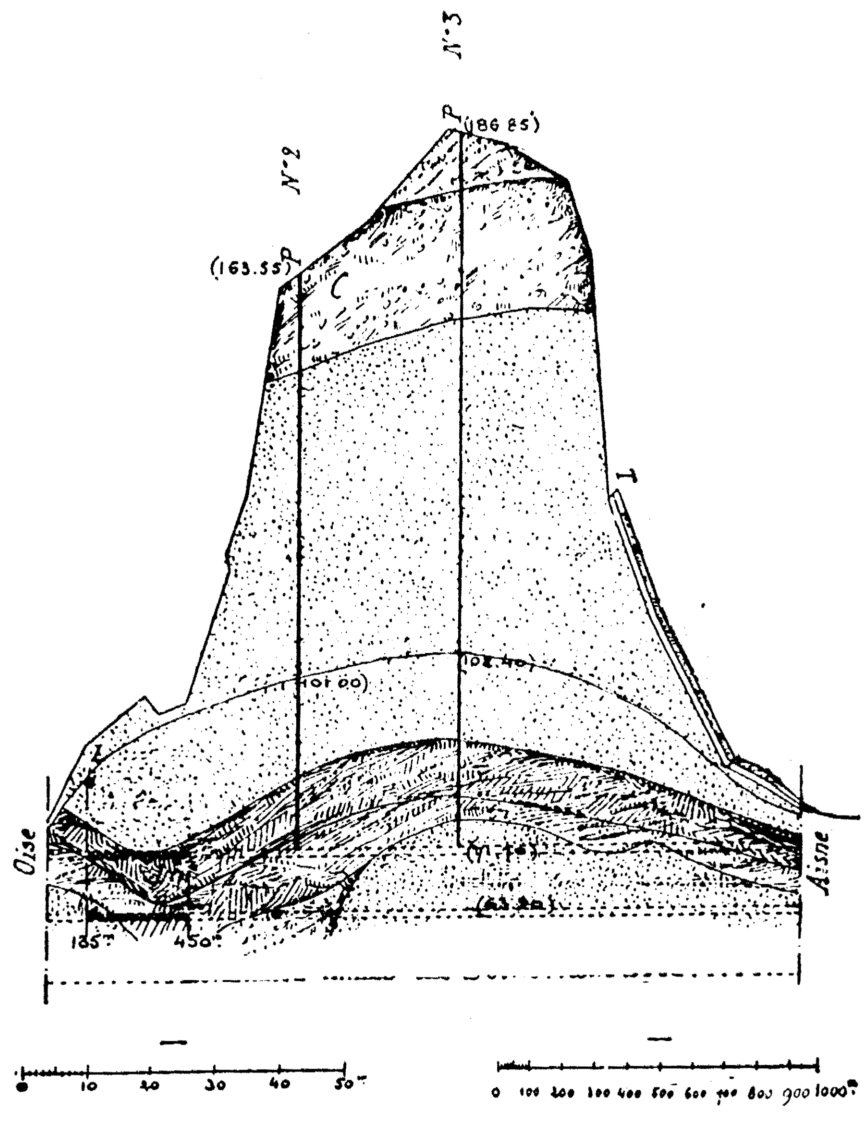


FIG. 93.—Geological section of the range of hills between the Oise and Aisne valleys through the axis of the tunnel. The upper layer is miry clay; the next is limestone rock; then Soissonnais sand down to the dark stratum; the curved line, marked 101, denotes the water level. Below the sand is a stratum of dark clay containing lignites, which ignited when the water was driven off. Below this is a stratum of compact blue clay, and just in a pocket projecting down into the tunnel is a mass of Soissonnais sand. Below the blue clay is a mass of Bracheux sand. The portion of the tunnel giving the greatest difficulty and requiring the use of compressed air is situated between 135 and 450 meters from the head.

In front of the machinery building a series of reservoirs was set up of 91 cubic meters' capacity, with the air at a pressure of from 4 to 6 kilogrammes (absolute pressure) which served, especially in the beginning, to drive out the excavated material, as will be explained presently.

The working chamber at the face of the tunnel was formed by a masonry wall, perforated by air locks (Fig. 95) giving admittance to and exit from the chamber.

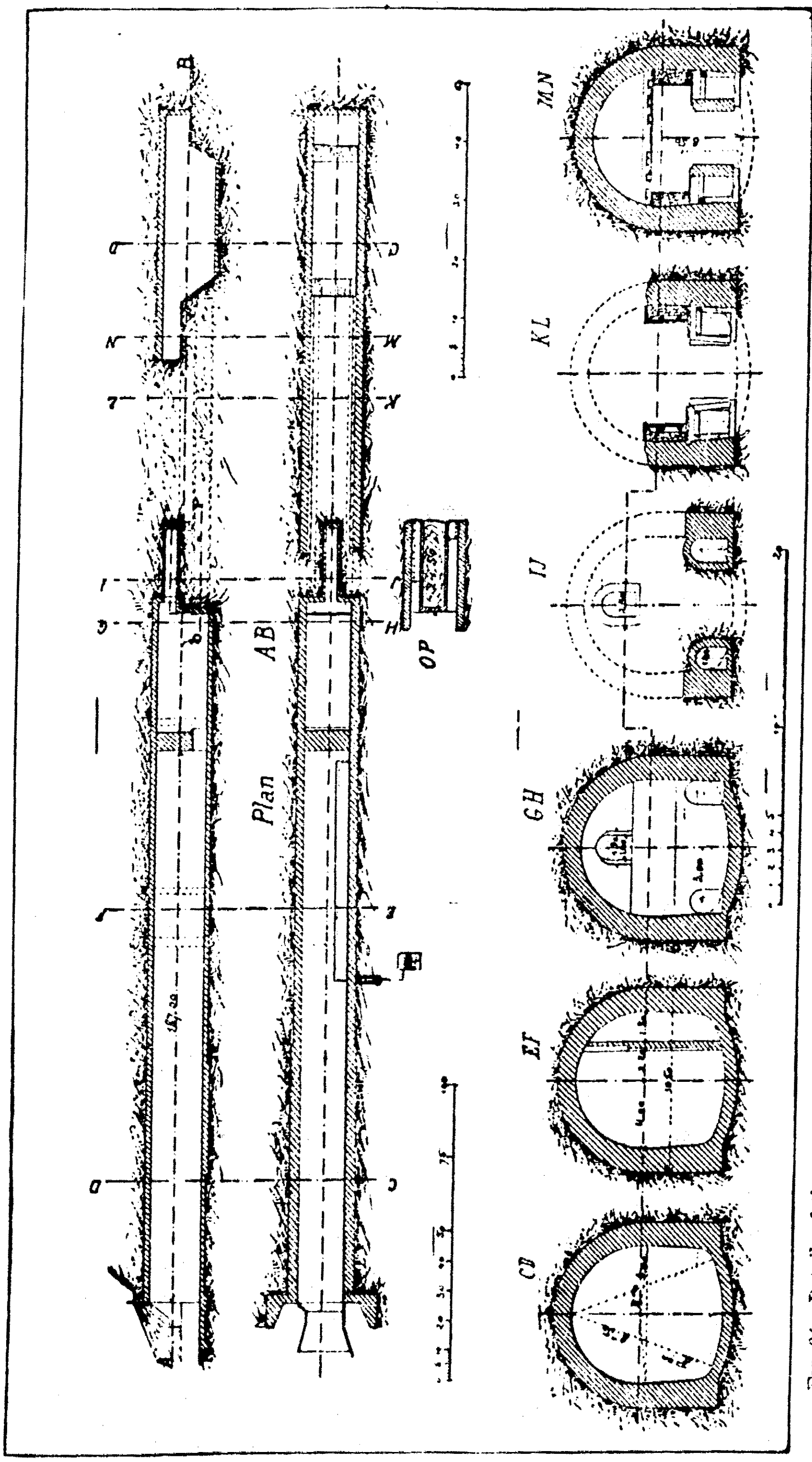


FIG. 94.—Details of the construction of the tunnel. Longitudinal section along the axis A B of the tunnel. Horizontal section plans along A B and O P. Cross sections C D, E F, G H, I J, K L, M N.

(131) The first wall or dam was 10 meters thick and 120.50 meters from the head; but the second, which was at 187 meters from the head, will be here described, as it was an improvement on the first:

This dam was formed by a wall 6.70 meters thick above and 8 meters below, so as to contain the lock and pieces of frame work, which had to project into the working chamber. It was constructed of béton held by masonry walls. Five openings were made, three below and two above, the lower ones only being supplied with locks, the upper ones being closed by a stone wall.

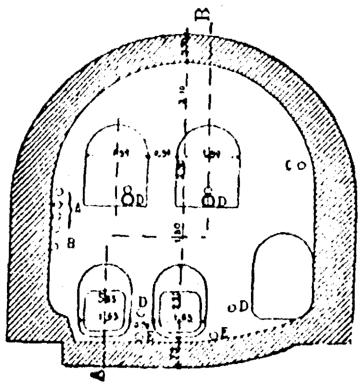


Fig. 95.

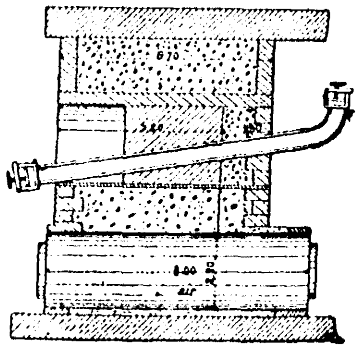


Fig. 96.

Sections of the air lock.

Fig. 95—A, air-supply pipe; B, pipe enclosing the electric wires; C, pipe inclosing the telephone wires; D, pipe for discharging the excavation spoil; E, drain pipe; F, entrance of the high-pressure air pipe, used to blow out the excavation spoil. Fig. 96 is the section through the broken line A B. The lower cylinder is the air lock: the curved tube, marked F, at one end was used to blow out the excavation spoil.

Each lock was 8 meters long, 1.65 meters wide, and 2.20 meters high; it was provided with a lining consisting of wrought iron rings, with India rubber washers, bolted together, and with two air tight doors closing against seats faced with India rubber, one opening from the outer air into the lock, and the other from the lock into the chamber; the latter could be opened from within the lock or from the working chamber by means of a double set of levers for that purpose. Above each door, cocks were placed, one on the interior and one on the exterior of the lock, for the introduction or escape of the compressed air.

(132) *Mode of removing the excavation spoil.*—The lock had a small railroad track, and cars could be carried through it; four pipes also passed through it, two above and two below. These pipes, 0.40 meter in diameter and inclined 0.05 meter per meter, ended in the working chamber by an upward bend into which the spoil was thrown. Each end of this pipe was tightly closed by a stop valve. The exterior valve being closed, the pipe was filled from the interior, then closing the interior valve, opening the exterior, and at the same time opening a cock, putting the curved portion of the pipe in connection with the pipe bringing air from the reservoirs at a pressure of at least 4 kilograms, this pressure drove out the spoil in a few seconds. The exterior valve was then closed and the operation repeated.

Two drain pipes 0.35 meter in diameter passed through the lock on the floor; they had cocks which served for the drainage of the chamber, the water being driven out by the compressed air.

Gramme dynamos, driven by a 15 horse-power engine, supplied the Edison lamps for lighting the chamber, and a telephone united it with the central office.

Great difficulties were found in keeping the working chamber tight. The compressed air forced its way out over the extrados of the arch, between the masonry and the earth, along poling boards required for supporting the ground, and also through the masonry joints. It was only by building a masonry buttress, from 40 to 50 centimeters thick, that the pressure in the chamber could be brought up to 1.8 or 2 kilograms, under which condition the arch was completed, for a distance of 200 meters from the head, at the rate of 12 or 15 meters per month.

(133) *Accidents by fire.*—In August, 1884, the work was arrested by an accident which cost the lives of seventeen workmen. The compressed air had penetrated into the pyrites lignites, driven off the water, and oxidized the pyrites; the heat thus produced had ignited the lignites, and the gas from this combustion had asphyxiated the victims.

(134) *Accessory constructions.*—To reëstablish access to the lock another issue was opened for the products of the gas combustion, by making six vertical bore holes, starting from the outside and carrying them to the points where the fire was most active. On the other hand, the finished part of the tunnel was ventilated by compressed air carried into the air lock and allowed to escape. After awhile the air became pure, and on the 4th of October the ground in the working chamber was shored up, and on the 30th the forced ventilation by compressed air was discontinued. The surface water, no longer kept back, penetrated to the seat of the fire and extinguished it; but this water remained hot a long time; six months after, that which trickled through had a temperature of 30° C. It was at this time that the lock was transferred from 120.50 to 187 meters from the head, as above described.

As the combustion of the lignites was always to be feared, provision was made for securing an active ventilation through the whole of the open tunnel, by sinking a shaft a little on one side and connecting it with the crown of the arch by a short inclined drift 109 meters from the head. This shaft was closed at the top and provided with a Pelzer fan 1.80 meters in diameter, with a minimum exhausting capacity of 15 cubic meters per second. (See Fig. 97).

That the suction of the fan should be felt in front of the lock the tunnel was divided into two unequal parts by a vertical longitudinal wall 1.80 meters from the right wall of the tunnel surrounding the ventilation mouth, and prolonged to within 4 meters of the lock.

The work with compressed air was recommenced, but it was very difficult to keep up the pressure, and it was determined to interrupt the construction for a certain length and begin 20 meters farther on, so as to leave a massive dam of unbroken ground between the old and new chamber. For this purpose both compartments of the old working chamber were closed by masonry walls.

To permit the continuation of the work, three arched galleries were driven, two below on a level with the flooring, and one above

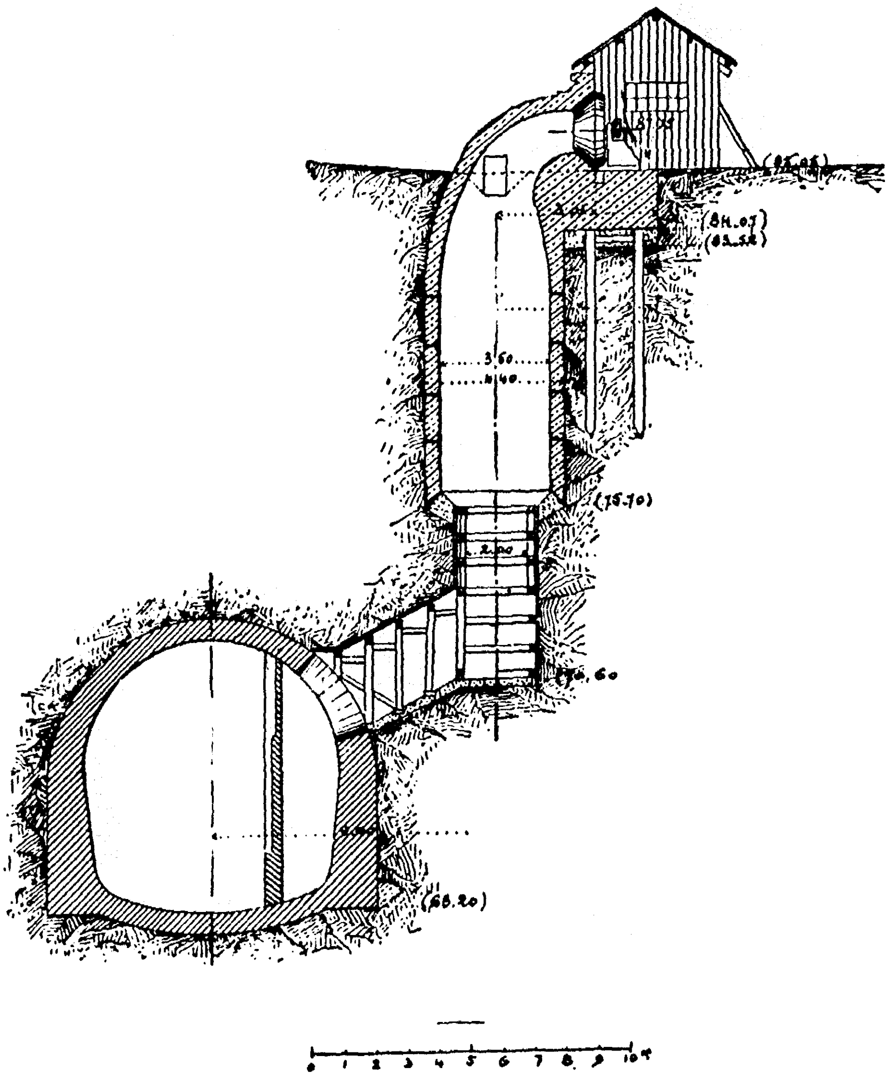


FIG. 97.—Method adopted for ventilating the tunnel.

(Fig. 94), but the upper one had to be immediately closed on account of leaks. The lower galleries being driven through clay, no leaks were perceived after they had been lined with masonry, one for 24.50 meters and the other for 10.25 meters of their respective lengths.

The pressure went up as the work advanced from 2.3 to 2.4 kilograms with two-thirds of the motive power, and this was the normal pressure used in completing the work. In this way the driving of the lower galleries continued until the bottom of the pocket, 300 meters from the head, had been passed, then they turned back toward the head and constructed the arch upon the abutments built by the aid of the lower galleries. This step was successful, and allowed the work to be finished.

Details of the work.—While the lower arched galleries were being driven the lower story of the abutments of the arch between the references 63.20 and 65.85 meters was built; then, when the galleries were recommenced, by means of timbering they constructed in the same way the lower story, which formed one of the side walls of the gallery. In the beginning, the other wall on the shaft side was simply protected with poling boards, but the swelling of the clay which broke the timbers, reduced the section, and stopped the running of the cars, obliged them to build on this side a wall 0.60 meter thick, strengthened by spurs 1 meter thick and 1.50 meters apart. These little walls were constructed for the whole length of the lower galleries. These galleries also served to construct another story of abutments between the references 65.85 and 68.40 meters, which was built by means of a gallery driven astride the lower abutment; see Fig 94, section KL. The communication between the two galleries was made by the space between the timbering, by taking out the horizontal shores between two frames.

This upper gallery was open for a length of 10 meters at a time; they laid the masonry abutments at one end, and drove the gallery at the other, changing the connecting apertures with the lower gallery as they advanced. As soon as the masonry work was finished, they filled the rest of the gallery with blocks of dry stone so as to allow no space. This work went on at the rate of 1.50 meters per day, occasionally interrupted by the ignition of the lignites. When they arrived at a point 397 meters from the head a rise was put in, and a length of 4 meters of the arch completed. From this point the work was carried on in both directions, but principally toward the Oise, at the rate of 12 meters per month.

The layer of fluid sand extended 0.50 meter into the top of the upper gallery, but it had become so dry by the action of the compressed air, that they were able to put in the crown packing planks, one at a time, after making a space with a spade and driving it in with a mallet. The water did not begin to run until these planks were put in, and owing to the opening of the lower galleries its level had fallen 5 or 6 meters, which facilitated the work.

While the work of finishing the arch toward the Oise continued, it was slowly progressing toward the Aisne. On the 25th of September, 1888, the arch having been completed to 409.50 meters, the use of compressed air was discontinued and, on account of the rising of the beds of clay, the rest, up to 450 meters, was finished without it, by taking proper precautions.

(135) *Cost.*—The first 450 meters of the tunnel were finished in October, 1888, and cost 6,720 francs per running meter.

The work was done under the direction of M. Boeswillwald, chief engineer of roads and bridges, and M. M. Guillon and Pigache, assistant engineers.

CHAPTER XVI.—NAVIGATION OF THE SEINE FROM PARIS TO THE SEA.

(136) At the beginning of the century the navigation of the Lower Seine was often interrupted by low water and by freshets. Great difficulties and even dangers were encountered in passing the bridges and dams. Ascending only by horse towage, consuming from Rouen to Paris fifteen days for ordinary freight, and four or five for accelerated freight, the boats were rarely able to be loaded to their full depth, from 1.80 to 2 meters. The cost of freight was 16 francs per ton from Rouen to Paris, and the annual traffic did not exceed 77,000,000 kilometric tons.

Without undertaking to describe the improvements made in the navigation of the river before 1878, it is sufficient to say that with the works recently constructed, many of which have been described in detail, the river between Paris and Rouen has been divided into nine reaches by the construction of locks and dams, with a minimum draught of water of 3.20 meters, and no difficulties are experienced either from low water or the passage of locks. The towpaths are in order, but they have been abandoned, the transport being made by steam, either by freight boats or towboats; the journey is made by the former in 28 hours, and by the latter, towing a convoy, in 3 days. The price of freight, which was from 12 to 15 francs per ton in 1840, 10 to 12 in 1859, 8 to 9 in 1869, is now from 4 to 5 ascending, and from 2.75 to 3.50 francs descending, and will diminish progressively as new boats are built to utilize more completely the improvements of the route.

Indeed, the traffic* since the completion of the canalization, has considerably augmented. The total tonnage between Paris and Rouen, including that taken on the way, was in 1881, 227,307,266 kilometric tons, and in 1888 it was 389,668,346.

(137) *Cost.*—The cost of the works of canalization amounts to 88,553,000 francs. If we compare this total expense with the actual traffic we find the interest at 5 per cent on the first cost, divided by the number representing this traffic to be, $\frac{5}{100} \times \frac{88,530,000}{389,568,346} = 0.011$ per kilometric ton, and it is certain that the cost of freight has diminished very much more than that.

All the works constructed from 1878 to 1888 were directed by MM. de Lagrené, Boulé, and Cameré, chief engineers.

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* M. Cameré pointed out to the author a new steamer of 600 tons burden, built for the coasting trade, just returned from a voyage to Spain.

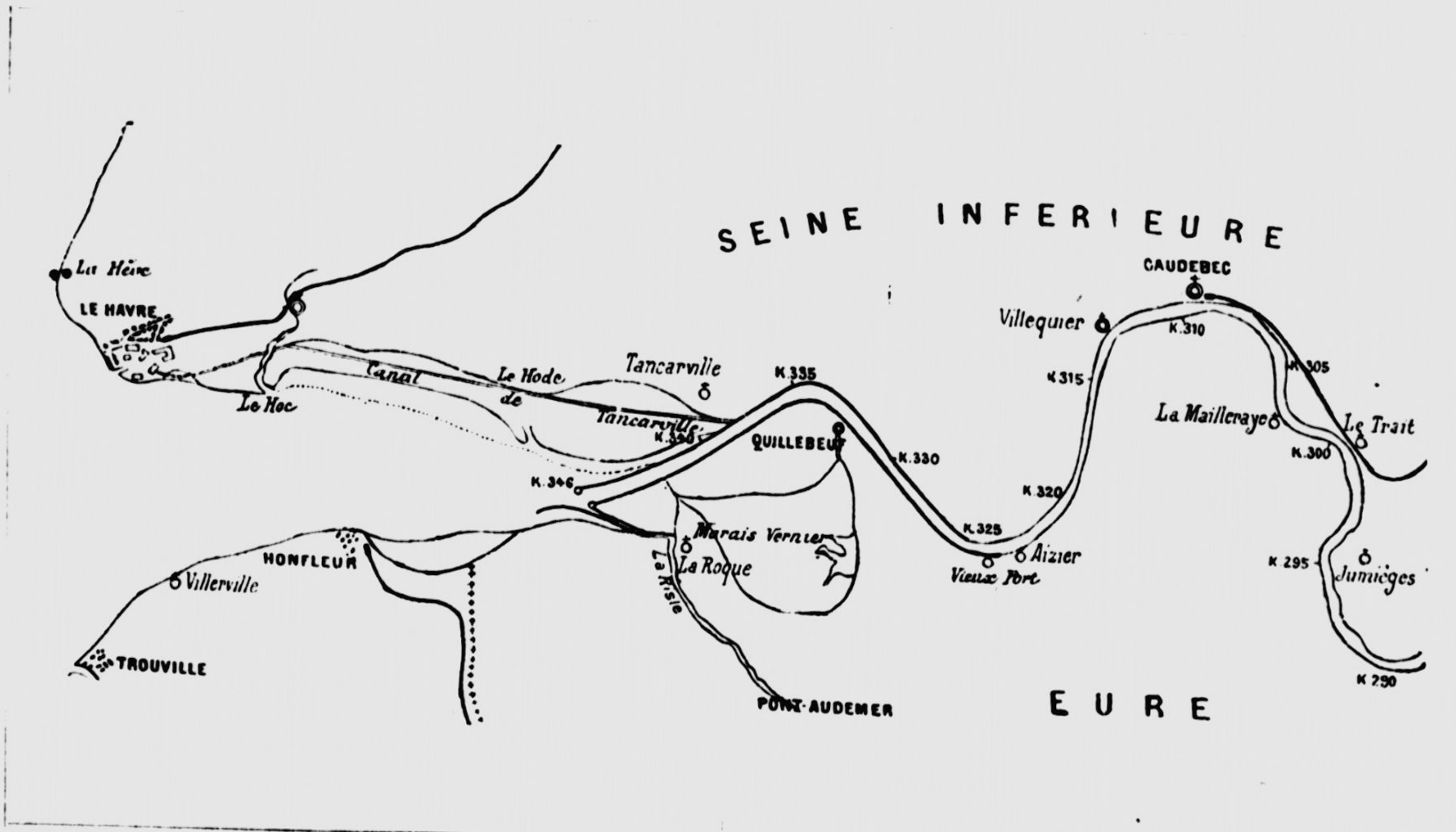

FIG. 98.—Map of the tidal Seine.

CHAPTER XVII—EMBANKMENT WORKS FOR THE IMPROVEMENT OF THE TIDAL SEINE.

(137) The object of the improvement of the tidal Seine is to facilitate the access of vessels to the port of Rouen, situated 125 kilometers from the sea. Of this distance half required improvements to render it navigable, and this comprised the parts between La Mailleraye and the sea below Honfleur. The breadth of the river bed between La Mailleraye and Villaquier was 1,000 meters, at La Vacquere 1,500 meters, at Quillebeuf 3,000, below La Roque 7,000, and above Honfleur 10,000 meters (Fig. 98).

(138) *Depth of water.*—This vast extent of water was filled with banks of shifting sand, which were constantly changing place through the action of the strong currents of the ebb and flow of the tide, and it often happened that in the course of a few days the position of the channel would be shifted from one side of the river to the other. The depth was also variable and insufficient. During the highest tides there was a depth of 4.30 meters below Quillebeuf, and only 1.76 meters at high neap tides, and many dangerous rocks and shoals impeded the navigation above this point. These perils encountered at intervals of the voyage were considerably augmented by the tidal wave or bore, and vessels were stranded by its powerful action without the possibility of receiving assistance. Under these circumstances the navigation was confined to vessels of from 100 to 200 tons burden. The voyage from the sea up to Rouen occupied four days; a great number of wrecks marked the route, freights between the sea and Rouen rose to 10 francs per ton, and the rate of insurance was one-half per cent.

(139) *Improvements.*—Such was the state of things in 1848, when the improvements were begun, which consisted in building training walls, sometimes on one side, sometimes on both sides, extending from La Mailleraye to the mouth of the Risle, a distance of 43 kilometers. The distance between the training walls was 300 meters at La Mailleraye, and gradually increased to 500 at the Risle. Towpaths were built between La Mailleraye and Rouen. The works were finished in 1867 and cost about 14,000,000 francs.

These training walls are constructed of random work built of blocks of chalk taken from the cliffs on the banks of the river; some are raised above the level of the highest tides, while others are capable of being submerged, so that they may have less influence in promoting the accumulation of deposits. High walls are used on the right bank as far as Tancarville, and on the left as far as La Roque. Beyond these points the walls are low. At La Roque the top of the wall is 1.34 meters above low water at neap tides, and 2.10 meters above low water at the spring tides. The right embankment is 0.45 meter higher than the left.

The stones from the neighboring quarries were soft and subject to the action of frosts, currents, and particularly the tidal wave or bore, a powerful volume of water preceding the flood tide, rushing up the river, and dashing against the banks with great violence; this has undermined and sometimes destroyed the original walls.

(140) *New improvements.*—Very extensive repairs, or rather reconstructions, which are yet going on, were necessary, which bring up the total cost of the walls to the sum of 28,000,000 francs since the beginning. In these reconstructions the same materials are employed, but to protect them against the frost and the bore they have been covered by a facing 0.25 meter thick. To defend the base against being undermined at the places where the bore is violent, a concrete apron was built, 3 meters wide and 0.40 meter thick, secured with piling and planking on its outer edge.

The cost of the walls thus reconstructed amounts to 250 francs per running meter. These reconstructions, begun in 1880, are rapidly progressing, and already from 25 to 30 kilometers are finished; they were indispensable and will make the walls last a long time.

(141) *Alluvial land.*—Behind the training walls, and in parts formerly occupied by the shifting sands, alluvial meadows have been formed to an extent of over 8,400 hectares in 1880.

They are divided into three classes: land made over to the river-side proprietors; land belonging to the state, and land in the course of formation.

First. The state made over 2,613 hectares to the river-side proprietors and received an indemnity of 1,398,200 francs.

Second. An area of 3,710 hectares yields a profit to the treasury every year by rent of the pasturage, which in 1878 amounted to 295,575 francs.

Third. An area of 2,077 hectares is in the course of formation.

These meadows are of excellent quality, and they are actually worth 4,000 francs per hectare. When all the alluvial lands now forming are definitely constituted, the total value of the lands thus reclaimed will be 33,600,000 francs. Finally, it should be understood that these calculations only include the lands above the actual limit of the training walls, and that the influence of these works extends a long distance beyond them into the estuary.

(142) *Results.*—The results have surpassed all anticipations. The channel has become fixed and deepened between the walls more than 2 meters, so that vessels of 2,000 tons can navigate the river, the depth being at low tide 5.50 meters and at high tide 6.50 meters. The charge for freight between Havre and Rouen has been reduced one-half, that is, to 5 francs per ton, and the insurance for Rouen is the same as for Havre. The traffic has consequently increased from 500,000 tons in 1860 to 1,600,000 tons in 1888.

(143) The effects of the training walls have been confined to the channel between them, but their deepening influence extends little

beyond their extremities. The estuary channel is constantly shifting. In M. Vautier's report he traces on the chart of the estuary twelve totally different locations of the main channel beyond the walls, from 1874 to 1880.

A prolongation of the southern bank below the Risle was carried out in 1870, but a proposed prolongation of the northern bank was refused, and the works finally stopped, for fear of endangering the approaches to Havre, the second port of France, by the silting up of the estuary.

(144) The following account by Prof. Vernon-Harcourt, the eminent hydraulic engineer, of his experiments on a model of the lower Seine created great interest among the members of the Congress for Inland Navigation at its Paris session in 1889, and its author made, by special invitation, a Report on the Canalization of Rivers and the Different Systems of Movable Weirs.

THE PRINCIPLES OF TRAINING RIVERS THROUGH TIDAL ESTUARIES.*

The conditions affecting the training of rivers in the nontidal portions of their course by jetties, or rubble embankments designated as training walls, are well understood. Training walls substitute a straightened uniform channel for irregularities and varying widths, improving the flow of the current and rendering it uniform, so that scour occurs in the shallow, narrowed portions, and more uniformity of depth is attained. In very winding rivers, the additional precaution has to be taken of somewhat reducing the width where the deepest channel shifts over from the concave bank on one side to the concave bank on the opposite side at the next bend lower down, so as to reduce the shoal which is found near the point of contrary flexure by concentrating the current at this place.

The training of the outlets of sediment-bearing rivers into tideless seas is determined by the same principles: for a definite discharge is directed and concentrated between training walls or piers, so as to scour a channel across the bar formed, in front of the outlet, by the accumulation of deposit dropped by the enfeebled issuing current. The increased velocity of the current through the contracted outlet carries the silt into deeper water, where it is either borne away by any littoral current, or again forms a bar, after a lapse of time depending on the depth, which can be removed by an extension of the training works.

The training also of the upper part of the tidal portion of rivers has been effected on similar principles to the nontidal portion, with satisfactory results, even though the problem is, in this case, complicated by the changes in the direction of the current, and the requisite maintenance of the tidal capacity.

In the lower parts, however, of tidal rivers, where the tidal flow predominates, it is difficult to determine the proper width for a trained channel, which, while narrow enough to secure an adequate depth, should not very materially check the tidal flow to the detriment of the outlet. Moreover, where the estuary is large, considerable doubt may exist as to the best direction for the training walls; and the establishment of training walls in a wide estuary, where the flood tide is charged with silt, has resulted in extensive accretions,† and corresponding reduction of tidal capacity, by the concentration of the tidal flow and ebb in the trained channel, and a consequent enfeeblement of the currents at the sides, favoring deposit. The principles, indeed, upon which the training of tidal rivers should be based are in a very un-

* From the proceedings of the Royal Society, Vol. 45, p. 504.

† Instit. Civ. Engin. Proc., Vol. 84, pp. 246 and 295, and Pls. 4 and 5.

defined and unsatisfactory condition, as exemplified by the conflicting opinions of engineers whenever important training works through estuaries are proposed, as exhibited with reference to the schemes for training works in the upper estuary of the Mersey,* for which the Manchester Ship Canal promoters sought powers in 1883 and 1884, and as at present exist about the extension of the training works in the Ribble estuary.† This is due to the various conditions involved, which differ more or less in each case, and thus render it difficult to lay down general rules for guidance from arguments based on analogy. One of the most important considerations is the form of the estuary; and in this respect no two estuaries are alike, as their form is the result of complex geological and hydrological conditions; and it suffices to contrast the Mersey and the Ribble, the Dee and the Tay, the Clyde and the Tees, the Seine and the Loire, to indicate the varieties of forms which may have to be dealt with. Other circumstances affecting the problem are the rise of tide, the tidal capacity and general depth, the fresh-water discharge, the silt introduced by the flood tide or brought down by the river, the condition of the sea bottom in front of the mouth, and the direction in which the tidal current enters the estuary. The positions also of ports established at the sides of estuaries require special consideration in determining the proper line for a trained channel. These numerous and variable conditions have often led engineers to enunciate the opinion that each river must be considered independently by itself. This view, however, if strictly adhered to, by excluding the experience derived from previous works, would prevent any progress in the determination of general principles for the improvement of navigation channels through estuaries; each training work would form an independent scheme, based upon no previous experience, and might or might not produce the results anticipated by its designer. Unfortunately also it is impossible to proceed with training works by the method of trial and error; for besides the cost of modifying the lines of training walls, if the desired results are not produced, these works generally effect such extensive changes in an estuary that it would be impracticable to restore the original conditions, or to modify materially the altered position.

(145) It might be possible to deduce general rules for training works from a careful consideration of a variety of types of estuaries, especially those in which training works have been carried out; and I have commenced an investigation of this kind. This method of inquiry, however, requires a variety of data which it is difficult to obtain for most estuaries, and must depend upon a careful estimate of the relative influence of each of the variable conditions, and a train of reasoning from analogy which might not be accepted by engineers as conclusive. Accordingly, it would be of the very highest value to river engineers, and of considerable interest from a scientific point of view, if a method of investigation could be devised which might be applied to the special conditions of any estuary, and the results of any scheme of training works determined approximately beforehand in a manner which could be relied upon from the fact of their depending on an assimilation to the actual conditions of the case investigated, and not on arguments based upon the effects of similar works under more or less different conditions. The following description is therefore given of the results of investigations, carried on at intervals during more than two years, with reference to the proposed extensions of the training works in the Seine estuary, which appear to afford a fair assurance that a similar method, applied to any estuary would indicate the effect of any scheme of training works, provided the special conditions of the estuary were known.

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* Evidence before select committee of Lords and Commons on the Manchester ship canal bills, sessions 1883 and 1884, and Instit. Civ. Engin. Proc., Vol. 84, p. 309, Fig. 7.

† Instit. Civ. Engin. Proc., Vol. 84, p. 260, Fig. 1.

INVESTIGATIONS ABOUT THE SEINE ESTUARY.

(146) The training works in the lower portion of the tidal Seine, commenced in 1848, had reached Berville in 1870, when the works were stopped, in the interests of the port of Havre, on account of the large unexpected accretions which were taking place behind the training walls, and at the sides of the wide estuary below them.* The original scheme, proposed in 1845 by M. Bouniceau,† comprised the extension of the trained channel to Honfleur on the southern side of the estuary, and the prolongation of one or both of the training walls towards Havre at the northwestern extremity of the estuary, as in any scheme the interests of both these ports, on opposite sides of the estuary, have to be considered. The works are acknowledged to be incomplete; and great interest has been evinced, particularly within the last few years, in the question of their extension, so that the shifting channel between Berville and the sea may be trained and deepened, and the access to Honfleur improved, without endangering the approaches to Havre. The objects desired are distinctly defined, but the means for attaining them have formed the subject of such a variety of schemes that hardly any part of the estuary below Berville has not been traversed by some proposed trained channel, except the portion lying north of a line between Hoe and Tancarville points, which is too far removed from Honfleur to be admissible for any scheme. Altogether, including distinct modifications, fourteen schemes have been published in France within my knowledge, seven of them having appeared within the last five years. The schemes also exhibit great varieties in their general design ‡ (Figs. 99, 101, 102, 103, and 105), illustrating very forcibly the great uncertainty which exists, even in a special case where the conditions have been long studied, as to the principles which should be followed in designing training works. It is evident that no reasoning from analogy could prevail among such very conflicting views; and having had the subject under consideration for a long time, the idea occurred to me in August, 1886, of attempting the solution of this very difficult problem by an experimental method, which might also throw light upon general principles for guidance in training rivers through estuaries. The estuary of the Seine is in some respects peculiarly well adapted for such an investigation, for old charts exhibit the state of the river before the training works were commenced, and recent charts indicate the changes which the training walls have produced, while the various designs for the completion of the works, proposed by experienced engineers, afford an intereresting basis for experimental inquiries into the principles of training works in estuaries. If, in the first place, it should be possible to reproduce in a model the shifting channels of the Seine estuary as they formerly existed, and next, after inserting the training walls in the model as they now exist in the estuary, the effects produced by these works could be reproduced on a small scale, it appeared reasonable to assume that the introduction, successively, in the model of the various lines proposed for the extension of the training walls would produce results in the model fairly resembling the effects which the works, if carried out, would actually produce.

(147) When the third Manchester ship canal bill was being considered by Parliament, in 1885, Prof. Oborne Reynolds constructed a working model of the portion of the Mersey estuary above Liverpool on behalf of the promoters of the canal, with the object of showing that no changes would be produced in the main channels of the estuary by the canal works, which have been designed to modify very slightly the line of the Chesire shore above Eastham. This model was, I believe, the first experimental investigation on an estuary by artificially producing the tidal

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* Instit. Civ. Engin. Proc., Vol. 84, p. 241, and Pls. 4 and 5.

† Étude sur la Navigation des Rivières à Marées. M. Bouniceau, p. 152, Pl. 2.

‡ Instit. Civ. Engin. Proc., vol. 84, p. 247, and Pl. 4, Fig. 9.

action of flood and ebb on a small scale, and Prof. Reynolds's experiment showed that a remarkably close resemblance to the main tidal channels in the inner estuary could be produced on a small scale.

As the Mersey model did not extend into Liverpool Bay, the tidal action produced was very definitely directed along the confined channel representing the "Narrows" between Liverpool and Birkenhead; and this tidal flow was not perceptibly influenced by the relatively very small fresh-water discharge. In the Seine, however, there is no narrow inlet channel to adjust exactly the set of the flood tide into the estuary; and the fresh-water discharge of the Seine, with a basin about eighteen times larger than the Mersey basin, forms an important factor in the result. The tide in a model of the Seine has to be produced in the open bay outside the estuary at a suitable angle which had to be determined; and it was essential for the success of the Seine experiments that accretion should be produced in the model of the Seine estuary under certain circumstances, which was a condition which did not enter into the Mersey problem. Accordingly, the very interesting and valuable results obtained by Prof. Reynolds, in his model of the Mersey, could afford no assurance that experiments involving essentially different and novel conditions would lead to any satisfactory results. I therefore restricted the requirements for my experiments within the smallest possible limits, and contented myself with the simplest means, and the limited space available in my office at Westminster.

(148) *Description of model of the Seine estuary.*—The model representing the tidal portion of the river Seine and the adjacent coast of Calvados, extending from Martot, the lowest weir on the Seine, down to about Dives, to the southwest of Trouville, was molded in Portland cement by my assistant, Mr. Edward Blundell, to the scales of $\frac{1}{40000}$ horizontal and $\frac{1}{400}$ vertical. The first is the scale of some of the more recent published charts of the Seine—and even at that scale the model is nearly 9 feet long—whilst I made the vertical scale one hundred times the horizontal, as the fall of the bed of the tidal Seine is very slight, and the rise of spring tides at the mouth, being 23 feet 7 inches, amounted to an elevation of the water in the model of only 0.71 inch. There are two banks at the mouth of the estuary, between Havre and Villerville Point, known as the Amfard and Ratier banks, which emerge between half tide and low water, and divide the entrance to the estuary into three channels. Through all the changes in the navigable channel at the outlet, these banks always appear in some form or other in the low-water charts, either connected with the sand banks inside the estuary or detached. On examining the large chart drawn from the survey made by M. Germain in 1880, I found that rock and gravel cropped up to the surface over a certain area on these banks, and accordingly I introduced solid mounds at these places to represent the hard portions of the Amfard and Ratier banks, which are permanent features in the estuary. As a rocky bottom is found near Havre, and also at Villerville Point on the opposite side of the outlet, Amfard and Ratier banks are doubtless the remains of a rocky barrier which in remote ages stretched right across the present mouth of the river. Where the rocky bottom lies bare, near Havre and Villervile, the model was molded to the exact depths shown on the chart of 1880; but in other places the cement bottom was merely kept well below the greatest depth the channel had attained at each place, whilst the actual bed of the estuary in the model was formed by the flow of water over a layer of sand.

(149) *Arrangements for tidal and fresh-water flow.*—The mouth of the Seine estuary faces west, but the tidal wave comes in from the northwest, and the earliest and strongest flood tide flows through the northern channel between Havre and the Amfard bank; whilst the influx through the southern Villerville channel occurs later, and is stronger toward high water. Accordingly, the tidal flow had to be introduced from a northerly direction, at an angle to the mouth of the estuary; and the line of junction of the hinged tray, producing the tidal rise and fall, was made

at an angle of about 50° to a line running from east to west in the model, so that the tidal flow approached the estuary from a point only about 5° to the west of northwest. The tray was made of zinc, inclosed by strips on three sides to the height of the sides of the estuary; and it was hinged to the model, at its open end, by a strip of india-rubber sheeting along the bottom and sides, so as to make a water-tight joint with sufficient play at the sides to admit of the tray being tipped up and down from its outer end. The rise and fall of the tray was effected by the screw of a letter press, from which the lower portion had been detached, by raising and lowering the upper plate of the press, half of which was inserted under the tray. After the requisite amount of sand had been introduced to raise the bottom to the average level, the model was filled with just enough water for the surface of the water to represent low water of spring tides when the tray was down and the screw at its lowest limit; and the tray was made of such a size that, when the screw was raised to its full extent, the water in the model was raised, by the tipping of the tray, to the level representing high water of spring tides. The water representing the fresh-water discharge of the Seine was admitted into the upper end of the model from a tap in a small tin cistern; and the efflux of a similar quantity of water was provided for at the lower extremity of the estuary, on its northern side near the tray, by a cock with a larger orifice placed at such a level as to allow the water to flow out into a second cistern, of similar size, during the higher half of the tide.

(150) *First results of working the model.*—The construction of the model was commenced in October, 1886, and its working was commenced in November. Though the Portland cement was convenient for molding in a small space and in the absence of appliances, it did not prove satisfactory for retaining water at first. The model was purposly made in two halves, and the straight joint was subsequently made water-tight; but, nevertheless, cracks occurred at various places through which the water leaked, and they had to be repaired as they appeared; and the bottom of the model was eventually coated with thick varnish, and after a time the leaks ceased. The flexible india-rubber hinge, from which I had anticipated some trouble, leaked very little from the beginning, and on being fitted with greater care in introducing a tray of somewat different form, no leakage occurred.

Silver sand was used in the first instance for forming the bed of the estuary. From the outset the *bore* at Caudebec indicated by a sudden rise of the water, and the reverse current just before high water near Havre, called the "*verhaule*," were very well marked. The *verhaule* is evidently a sort of back eddy, on the northern shore, occasioned by the influx of the tide, and by the final filling of the estuary from the southern channel; whilst the *bore* appears to result from the concentration of the tidal rise by the sudden contraction of the estuary above Quillebeuf. The period given to each tide in working was about twenty-five seconds, which appeared fairly to reproduce the conditions of the estuary.* After the model had been worked for a little time, the channels near Quillebeuf assumed lines resembling those which previously existed, and a small channel appeared on the northern shore, by Harfleur and Hoc Point, which is clearly defined in the chart of 1834. The main channel also shifted about in the estuary and tended to break up into two or three shallow channels near the meridian of Berville, where the influences of the flood and ebb tides were nearly balanced. The model, accordingly, fairly reproduced the conditions of the actual estuary previous to the commencement of the training walls, though the channel in the estuary did not attain the depth, as represented by the proportionately large vertical scale, which the old channels possessed, owing, doubtless, to the comparatively small scouring influence which the minute currents in

* According to the formula in the paper by Prof. O. Reynolds on his Mersey model, read at the Frankfort Congress in August, 1888, the tidal period would be nearly twenty-three seconds.

the model possess. The sand, in fact, can not be reduced to a fineness corresponding to the scale of the model, whilst the friction on the bed is not diminished equivalently to the reduction in volume of the current. Silver sand has been used on account of its being readily obtained, its purity, and absence of cohesion, as it was hoped that the water by percolating freely through it would more readily shift it. A film, however, seemed by degrees to form over its surface, reducing considerably its mobility, and as the action of the water on it consisted merely in rolling the particles along the bottom, this sand did not prove satisfactory for producing the requisite changes when the training walls were inserted in the model. It became, therefore, essential to search for a substance which the water could to some extent carry in suspension for a short period.

(151) *Trial of various substances for forming the bed of the estuary.*—Some substance was required, not necessarily sand, insoluble in water, easily scoured, and therefore not pasty or sticky, and sufficiently fine or light to be carried in suspension to some extent by the currents in the model, and not merely rolled along the bottom like the silver sand. A variety of substances of low specific gravity, and in powdered form, were accordingly tried in succession during the first half of 1887. Pumice in powder proved too sticky, and flour of sulphur was too greasy to be easily immersed in water. Pounded coke was too dirty to be suitable, and particles of it floated. Violet powder became too pasty in water, and fuller's earth and lupin seed exhibited similar defects. The grains of coffee grounds were too large in water, and moved up and down in the currents too readily, whilst fine sawdust from boxwood and lignum vitæ swelled in water and was carried along so very easily by the stream that no definite channels were formed in it. The powder obtained from Bath brick, which was experimented upon for some time in the model, both without and with training walls, yielded more satisfactory results, as, besides affording shifting channels like the silver sand, it accumulated at the sides of the estuary when the training walls were introduced in the model. It, however, gradually became too compact, so that the current could no longer produce much effect on it; but as it is probable that some sticky material is used in the manufacture of Bath bricks, it is quite possible that if I had succeeded in my endeavor to obtain the silt of the river Parret, from which the bricks are made, in its natural state, the material might have proved more subject to scouring influence.

At last, in July, 1887, I found a fine sand, on Chobham Common, belonging to the Bagshot beds, with a small admixture of peat. This sand, besides containing some very fine particles, was perfectly clean, so that water readily percolated through it; and it accordingly combined the advantages possessed by silver sand with a considerably greater fineness.

(152) *Results of working model with Bagshot sand.*—The bed of the estuary having been formed with the sand obtained from Chobham Common, after the model had been worked for some time, the channels assumed a form very closely resembling the chart of the Seine estuary of 1834.* Accordingly, the first stage of the investigation was duly accomplished by the reproduction of a former state of the estuary in the model, with the single exception of a decidedly smaller depth in the channels, except in places where the scour was considerable; which is readily accounted for by the circumstances of the case. It is probable that with a larger model, and especially if the bed was not so nearly level as in the Seine, the depth would approach nearer to the proper distorted proportion as compared with the width.

The close correspondence of the channels in the model with an actual state of the estuary in its natural condition, confirms, in a considerably more complicated case, the results previously achieved by Prof. Reynolds with reference to the upper estuary of the Mersey, and affords a fair certainty that, with adequate data, the natural condition of any estuary could be reproduced on a small scale in a model.

*Instit. Civ. Engin. Proc., vol. 84, Plate 5, fig. 1.

Introduction of the existing training walls in the model.—The second stage of the investigation consisted in the introduction of training walls into the model, corresponding in position to the actual training walls established in the estuary down to Berville. These walls, formed with strips of tin, cut to the corresponding heights at the different places, and bent to the proper lines, were gradually inserted in sections; and the model was worked between each addition, to conform, as far as practicable, to the actual conditions. The fine particles of the sand accreted behind the training walls, and the channel between the walls was scoured out, corresponding precisely to the changes which have actually occurred in the estuary of the Seine. The foreshores at the back of the training walls were raised up in some parts to high-water level, whilst in other places the accumulation was somewhat retarded by the slight recoil of the water from the vertical sides of the model, and by the wash over the vertical training walls, these forms being necessitated by the great distortion of the vertical scale of the model. On the whole, however, the accretion and scour in the model correspond very fairly to the results produced by the existing training walls in the estuary. The accretion, moreover, in the model, extended beyond the training walls on each side, down to Hoc Point on the right bank, obliterating the inshore channel close to Harfleur, which had been reproduced in the model, and down to Honfleur on the left bank, corresponding in these respects also to the actual changes in the estuary.* The main channel also, beyond the ends of the training walls, was comparatively shallow, and was unstable, reproducing the existing conditions in the estuary.

The experiments relating to this stage extended over a year and a half, taking up all the time that could be spared to them by myself and my assistant during that period; they formed the turning point of the investigation, and have the interest of being, as far as I am aware, the first attempt at putting training walls in a model, and obtaining the resulting accretion on a small scale. Without the accomplishment of this stage, it would have been useless to continue the investigation; and its satisfactory attainment proved so difficult in actual practice, that for a long time it seemed probable that the attempt must be abandoned.

(153) *Application of system to ascertain the probable effects of any training works.*—As the first and second steps in the investigation, by the aid of the model, had furnished results which corresponded very fairly with the actual states of the estuary of the Seine before and after the execution of the training works, the final stage of the investigation, for ascertaining the probable results of any extensions of the training walls, could be reasonably entered upon. In selecting the lines of training walls to be experimented on, it appeared expedient to adopt those which have been designed, after careful study, by experienced engineers, both on account of the results from these being far more interesting than those of a variety of theoretical schemes, and also in the hope that some assistance might thereby be rendered to French engineers in the prosecution of this important work. Moreover, the schemes exhibit sufficient variety to admit of their being taken as types of schemes for throwing light upon the principles on which training works should be designed in estuaries. Accordingly, the third stage in the investigation consisted in extending the training walls in the model, in accordance with the lines of some of the schemes proposed; and, after working the model for some time with each of the extensions successively, the several results were recorded, as shown in figs. 99-106. The lines of training walls experimented on in the model were taken, with one exception, from five out of the seven most recent schemes proposed, as these five schemes are, I believe, the only ones which are still put forward for adoption. The lines shown on Fig. 107, represent merely a theoretical arrangement of training walls, inserted for a final experiment in the model, to ascertain the effect of

* Instit. Civ. Engin. Proc., vol. 84; compare plate 5, fig. 1, and plate 4, fig. 1.

the most gradual enlargement of the trained channel which the physical conditions of the estuary would have admitted of at the outset, whilst maintaining the full width at the mouth.

(154) *Scheme A.*—The first arrangement of extended training walls introduced into the model taken from a scheme, some of the main features of which were proposed in an earlier scheme in 1859,* and which was put forward in an amended form in 1886.† The design, as inserted in the model, consisted of an extension of the parallel training walls from Berville down to Honfleur, and the formation of a breakwater across the outlet, from Villerville Point, on the southern shore of the estuary, out to the Amfard bank, thus restricting the mouth to the channel between Amfard bank and Havre. The lines of these works were formed in the model with strips of tin, as shown on Fig. 99; the northern training wall was kept low, and the southern wall was raised to the level representing high water of neap tides; whilst the strip representing the breakwater was raised above the highest tide level, thus forcing all the flood and ebb water to pass through the Havre Channel. The results obtained in the model with these arrangements, after working it for about six thousand tides, are indicated on the first chart (Fig. 99). The channel between the prolonged training walls had a fair depth throughout, partly owing to the concentration of the fresh-water discharge between the walls, and partly from the retention of some additional water in the channel at low water, by the hindrance to its outflow offered by a sandbank which formed in front of the ends of the training walls. A deep hole was soon scoured out in the narrowed outlet by the rapid flow of the water filling and emptying the estuary at every tide. The absence, however, of connection between the direction of the flood tide current through the outlet and the ebbing current from the trained channel, aided by the accretion of sand in the sheltered recess behind the breakwater, led eventually to the formation of two almost rectangular bends in the channel, one just beyond the training walls and the other near Hoc Point, in the model. This tortuous channel, moreover, was shallow, except at the bends and the outlet, and a bar was formed a short distance beyond the outlet. The contraction of the mouth of the estuary by the breakwater interfered so much with the influx of the tide into the estuary as to render it impossible to raise the tide inside to its previous height, and the reduction in height of the tide was clearly marked at Tancarville Point in the model. Sediment accumulated in the estuary beyond the trained channel, being brought in by the rapid flood current, and not readily removed by the ebb, except in the trained channel and near the outlet; and this accretion, by diminishing the tidal capacity, gradually reduced the current through the outlet, and consequently the depth of the outlet channel. A considerable accumulation of sand took place outside the breakwater, along the southern seacoast, so that the bank opposite Trouville in the model was connected with the shore, and the foreshore advanced towards the end of the breakwater (Fig. 99).

(155) *Scheme B.*—The second arrangement of training walls inserted in the model below Berville, was taken from a scheme proposed in 1888, representing a modification by another engineer of the design from which Scheme A was copied.‡ It comprised the retention of the breakwater from Villerville Point to the Amfard bank, the most essential feature in Scheme A; but the extension of the northern training wall was dispensed with, whilst the southern training wall was prolonged,

* "La Seine comme Voie de Communication Maritime et Fluviale," J. de Coene, 1883, p. 11, and plate 7.

† "Projet des Travaux à faire à la Embouchure de la Seine." L. Partiot, Paris, 1886.

‡ Mémoires de la Société des Ingénieurs Civils, Mars, 1888, Paris, pp. 257 and 273, and Pl .162, Fig. 2.

in a continuous curve, from Berville to Honfleur (Fig. 100), and eventually to the Amfard bank, connecting it there with the extremity of the breakwater (Fig. 101.)

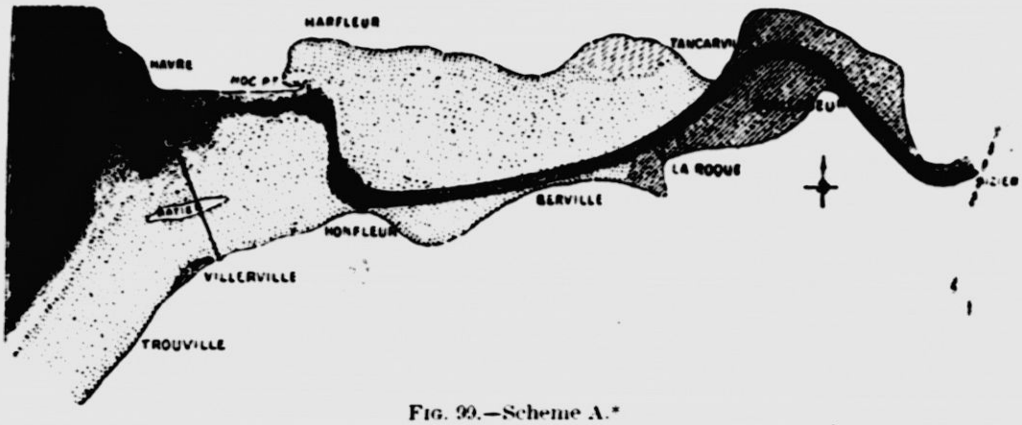

FIG. 99.—Scheme A.*

A slight widening out of the existing trained channel by an alteration of the end portion of the northern training wall, completed the arrangement of the model.

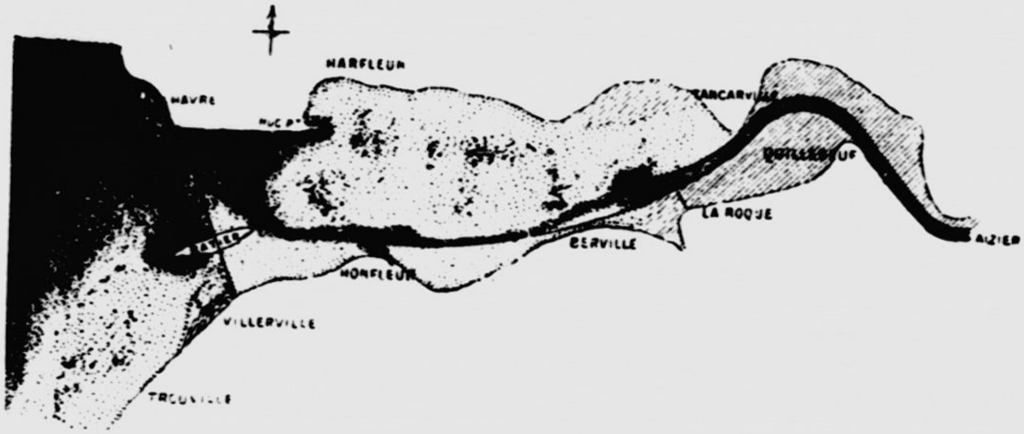

FIG. 100—Scheme B.

The results obtained by inserting the training wall down to Honfleur, and then working the model for about 3,500 tides, are shown in Fig. 100; and those obtained

FIG. 101—Scheme B_2

after the prolongation of the southern training wall to the breakwater, and working the model for about 3,700 tides, are shown in Fig. 101. The channel followed pretty nearly the concave line of the prolonged southern training wall, between

* The existing training walls stop at Berville.

Berville and Honfleur in the model, except near Berville; but the depth of water was less regular than in the previous experiment, owing to the diminished concentration of the ebb from the absence of the northern training wall. The channel between Honfleur and Amfard was tortuous as before, but its direction was different. The deep hole at the outlet, the bar beyond, and the advance of the southern foreshore beyond the breakwater, reappeared again with very similar features to those in the first scheme, except that the sandbank did not quite reach the outside face of the breakwater at low water. (Compare Fig. 100 with Fig. 99.)

(156) The results which followed from working the model with the southern training wall prolonged to Amfard are shown in Fig. 101. The main alteration from the former experiment naturally occurred between Honfleur and Amfard in the model, a continuous channel being formed along the new piece of concave training wall; whilst the general depth inside the estuary was improved as far as the meridian of Hoc Point. The channel, however, above Honfleur was not improved, owing apparently to the want of uniformity between the directions of the flood and ebb currents in the model. The other features remained very similar to the former case, except that the end of the sand bank beyond the breakwater was slightly eroded, whilst deposit took place between the extended training wall and the breakwater. (Compare Fig. 101 with Fig. 100.)

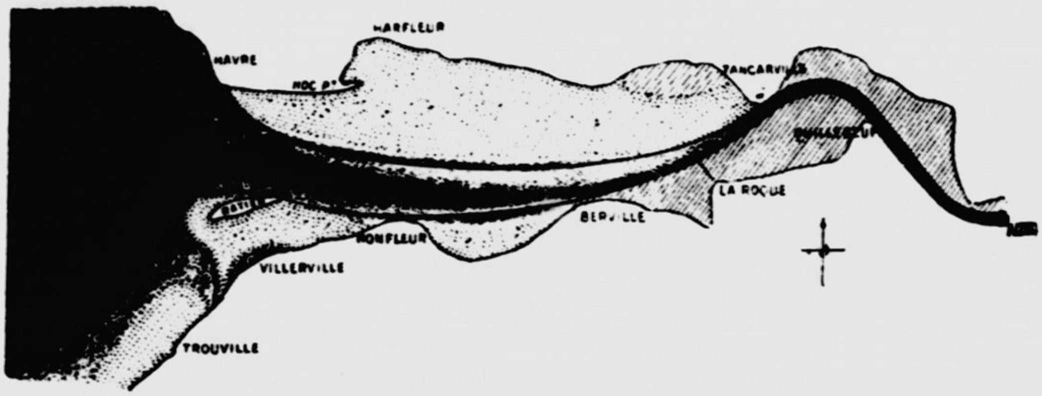

FIG. 102.—Scheme C.

(157) *Scheme C.*—The third arrangement of training walls experimented upon in the model was chosen from a design published in 1885.* It consisted of an enlargement of the original trained channel below Quillebeuf, by a modification of the southern training wall from Quillebeuf, and of the northern training wall from Tancarville, and the extension of the northern wall to Amfard and Havre, and the southern training wall to Ratier, as shown on Fig. 102. The trained channel was thus given a curved, gradually enlarging form, and was directed into the central channel of the model, between Ratier and Amfard, the Villerville and Havre channels being practically closed near low water. The effects of working the model for about 6,500 tides with this arrangement of training walls are indicated on the chart (Fig. 102). The main channel kept near the concave southern training wall for some distance below Berville, and then gradually assumed a more central course between the training walls towards the outlet, passing out just to the south of the Amfard bank. The channel thus formed had a good, tolerably uniform depth, together with a fair width, owing apparently to the flood and ebb tides produced in the model following an unimpeded and fairly similar course. Deposit occurred behind the training walls on each side; and the foreshore advanced in front of Trouville in the model, in consequence of the shutting up of the Villerville Channel.

* La Seine Maritime et son Estuaire. E. Lavoinne. Paris, 1885, p. 140, and Instit. Civ. Engin. Proc., Vol. 84, p. 248, and Pl. 4, Fig. 9.

(158) *Scheme D.*—The fourth arrangement of training walls adopted in the model was selected from the most recent design* proposed by an engineer who had previously submitted schemes in 1881† and 1886.‡ The trained channel was widened out by an alteration of the southern wall from Quillebeuf, and the northern wall from Tancarville, more than trebling the width between the training walls at Berville in the model; and the walls were extended in sinuous lines to Havre on the northern side, and Honfleur on the southern side, as shown on Fig. 103, thus forming a winding trained channel rapidly enlarging near its outlet. The model, with

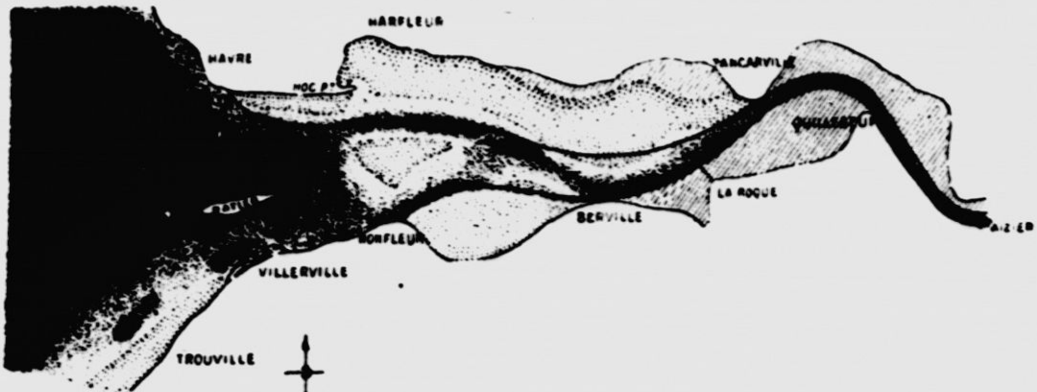

FIG. 103.—Scheme D.

these lines of training walls, was worked for about 5,000 tides, with the results indicated on the chart. Deep channels were scoured out close along the inner concave faces of the training walls in the model; but shoals appeared over a considerable area of the newly trained channel; a bar stretched across the deep channel where it shifted over from the south to the north training wall, about half way between Berville and Honfleur; and a large sand bank, emerging above low water, occupied the center of the outlet opposite Honfleur. Deposit also occurred at the sides of the estuary behind training walls.

(159) As it was of importance to ascertain to what extent accidental modifications in the arrangement of the sand in the preparation for an experiment might affect

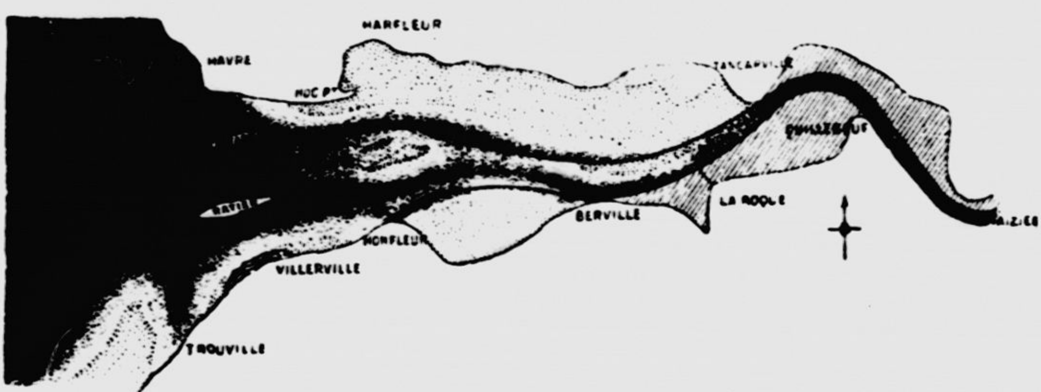

FIG. 104.—Scheme D *bis*.

the result, the lines of training walls described above were inserted a second time in the model, after the subsequent scheme E had been experimented upon, render-

* Déposition de M. Vauthier devant la Commission des Ports et Voies Navigables de la Chambre des Députés, Paris, 1888, p. 17, and Pl. 4.

† Rapport sur les Améliorations dont sont encore susceptibles la Seine Maritime et son Estuaire, L. L. Vauthier, Rouen, 1881, p. 16, and Annex 29.

‡ Dire à l'Enquête ouverte sur l'Avant-projet des Travaux d'Amélioration de la Basse-Seine, 1886, L. L. Vauthier, Paris, Pl. 1.

ing it necessary to replace afresh both training walls, and to remodel the sand so as to represent approximately the present condition of the estuary. The model was prepared for this second experiment in the usual way, without any special endeavor to secure coincidence with the first experiment in the initial arrangement of sand banks and channels. The condition of the low-water channels in the model, after working the model with this arrangement of training walls for the second time for about 5,400 tides, is shown on Fig. 104. The main features of the trained channel in the charts of the two experiments exhibit a very fair resemblance, considering the modifications which any alterations in the initial condition might produce, and the naturally variable state of the channels in a wide outlet. The deep channels reappear in the second chart at the inner concave faces of the training walls, with intervening shoals; a large sand bank is again visible at low water along the north training wall opposite La Roque and Berville in the model; and the sand bank in the center of the outlet of the trained channel opposite Honfleur emerges again, though smaller in extent owing to alterations in the channel; and the deep place at the end of the southern training wall close to Honfleur is the same in both charts.

(160) *Scheme E.*—The fifth arrangement of training walls introduced into the model was taken from a design* published in 1888, which is a modification of a

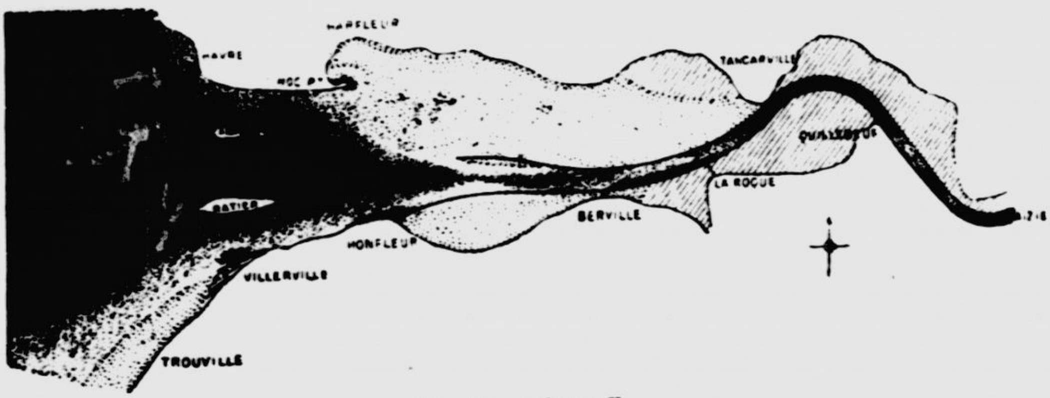

FIG. 105.—Scheme E.

scheme, presented in 1886, by a committee of experts appointed by the French Government to consider the question.† In the scheme as laid down in the model the trained channel in the bend between Quillebeuf and Tancarville, where the depth was greatest, was enlarged in width by setting back the southern training wall; the original width of the channel was retained at the point of inflection opposite Tancarville, and the channel was widened out below La Roque by a modification of the lines of both training walls down to Berville. The training walls were also extended beyond Berville in sinuous lines, as shown on Fig. 105, the southern wall being carried down to Honfleur, and the northern wall not quite so far. The portion forming the last bend of the northern training wall was kept low, whilst the others were made high, according to the design. Both in this and the preceding arrangement of training walls experimented on the expanding trained channel was somewhat restricted in width along the portions near the changes of curvature, to make it conform to the principles which experience has laid down for training winding rivers in their nontidal course, as previously mentioned. The results obtained.

*De l'Amélioration du Port du Havre et des Passes de la Basse-Seine. Baron Quinette de Rochemont. Paris. 1888, excerpt Mémoires de la Société des Ingénieurs Civils, 1888, p. 324, Pl. 162, Fig. 1.

†Commission d'Étude des Améliorations à apporter au Port du Havre et aux Passes de la Basse-Seine—Raport de la Commission, Paris. 1886, p. 61, and chart.

after working the model for about 3,700 tides, are represented on the chart (Fig. 105). The channel between the training walls was somewhat shallow in places, and though a deep channel was formed along the inner concave face of the southern wall between La Roque and Berville, a shoal emerging above low water appeared along the concave face of the last bend of the northern training wall. This bank appeared to be due to the protection the extremity of the bend afforded from the action of the flood tide in the model, whilst the ebb followed the central flood-tide channel, instead of passing over to the concave bank, as would have occurred with the current of a nontidal river. The main channel beyond the training walls, which, though of fair depth, was somewhat narrow and winding, was also unstable, for in the early part of the experiment its outlet was in the central channel between Ratier and Amfard in the model, whilst at the close of the experiment it had shifted, as shown, to the Havre Channel. Accretion occurred behind the training walls in the model, and some silting up took place in the Villerville Channel and along the foreshore in front of Trouville, owing apparently to the preference of the main channel for the other outlets, and the diminished capacity of the estuary resulting from accretion.

(161) This arrangement of training walls was further investigated by working the model for about 6,300 tides more, with the results shown on Fig. 106. The chief features of the estuary in the model showed only slight changes from the state previ-

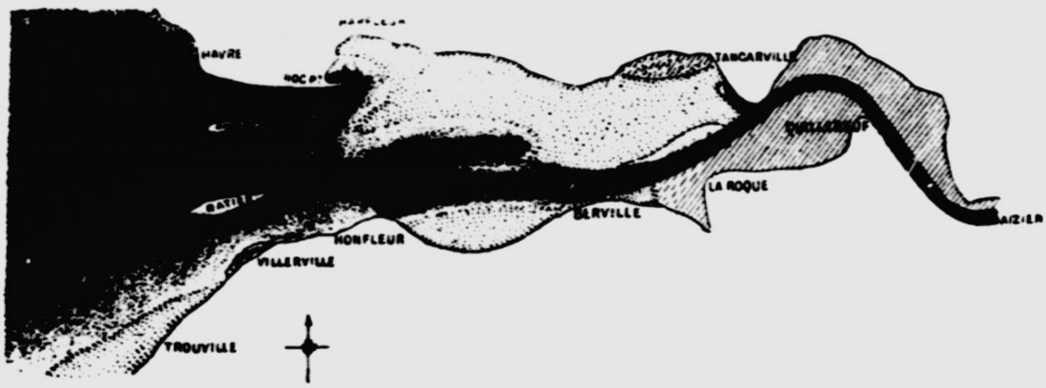

FIG. 106.—Scheme E *bis*.

ously recorded (Fig. 105), with the exception of the main channel, which had shifted again to the central outlet, whilst the northern foreshore above low water extended over part of the former site of the channel. The two conditions of the estuary, represented by Figs. 105 and 106, have therefore the interest of exhibiting in the model a shifting channel such as actually exists at the present time in the Seine estuary below Berville.

(162) *Scheme F.*—The last experiment was made on an arrangement of training walls inserted in the model, making the trained channel expand as gently as practicable between Aizier and the sea, whilst retaining the natural width at the outlet (Fig. 107). This is the form of channel which theory indicates as the most suitable,* for whilst it facilitates the influx of the flood tide, it prevents, as far as possible, the abrupt changes in the velocity of a river in passing from its estuary to the sea, which are so prejudicial to uniformity of depth in a channel. It was therefore of interest to ascertain what results would be produced by this theoretical arrangement of training walls in the model, which, in order to leave the outlet free, and thus avoid favoring a progression of the foreshore outside, had to provide a wide channel near Honfleur compared with the restricted width available at Quillebeuf. The direction of the channel between Aizier and Quillebeuf, together with the cliffs bordering the river at Quillebeuf and Tancarville Points, determined the maximum width obtainable at Quillebeuf and the direction of the channel from Aizier to Tan-

* Rivers and Canals, L. F. Vernon-Harcourt, p. 236.

carville; and the extension of the training walls in the model from this point was regulated by the necessity of passing close to Honfleur at the south, and not impeding the approach to Havre on the north. The effects produced in the model by working with this arrangement of training walls for about 7,300 tides are indicated on the chart (Fig. 107). The southern training wall was kept above high-water level all the way to its termination at Honfleur in the model, but the northern training wall was gradually reduced in height from nearly opposite Honfleur towards Havre. The trained channel had a good width at low water throughout, in spite of the distance apart of the training walls in the model, the whole channel being below low-water level, except near the southern wall between Berville and Havre, and against the northern wall nearly opposite Hoc Point, where banks emerged slightly above low water. The channel, moreover, was distinctly, though slowly, improving with the continuance of the working, and the banks diminishing. There was also a fair depth in the channel, the shallowest place being opposite Berville, whilst a deep place was formed just above, near the southern wall between La Roque and Berville. The depth in all the outlet channels was well maintained: and though deposit naturally took place behind the northern training wall, no accretion was visible along the foreshores outside.

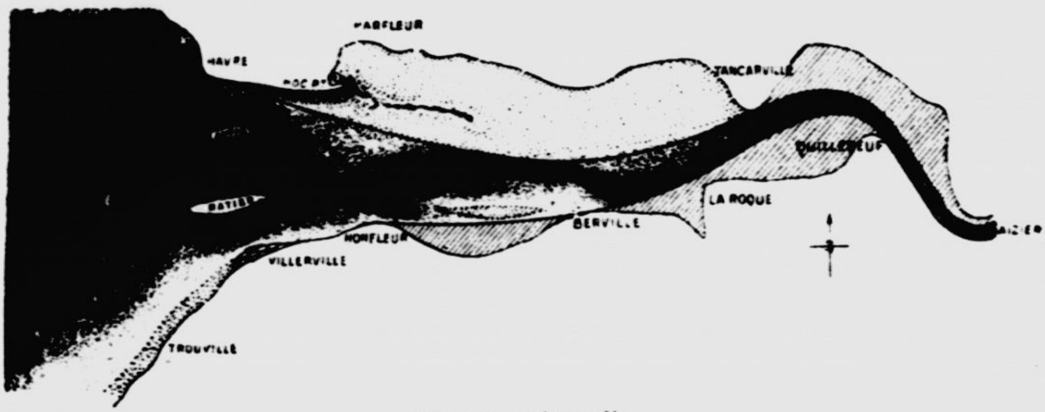

Fig. 107.—Scheme F.

CONSIDERATIONS AFFECTING EXPERIMENTAL TRAINING WORKS.

(163) The value of experiments resembling those just described depends entirely upon the extent to which they may be regarded as producing effects approximately corresponding, on a small scale, to those which training works on similar lines, if carried out in an estuary, would actually produce. If the effects of any training works could be foreshadowed by experiments in a model, the value of such experiments, in guiding engineers towards the selection of the most suitable design, could not be overestimated.

Some of the influences at work in an estuary can not possibly be reproduced in a model—such as winds and waves. Winds coming from different quarters are variable in their effects: but the direction of the prevailing wind indicates the line in which the action of the wind has most influence, which may be exerted in reënforcing the flood or ebb currents, and may aid or retard accretion by blowing the silt-bearing stream more into or out of the estuary. Waves are the main agents in the erosion of cliffs along open seacoasts, and in stirring up sand in shallow places: and the material thus put in suspension may be transported by tidal currents, aided by wind, into an estuary, and be deposited under favorable conditions. These circumstances affect the rate of accretion, which can not be investigated experimentally, as it is impossible to reproduce in a model the proportion of silt in suspension, which, moreover, varies in any estuary with the state of the weather and tide, and the volume of fresh water discharged. Inside an estuary, also, waves in storms may erode the shores at high tide, and modify the low-water channels, but the first effect is very gradual, and the second is intermittent, only occasionally occurring.

The main forces acting in any tidal estuary are the tidal ebb and flow and the fresh-water discharge, which are constantly at work; and they regulate the size of the channels in an estuary, and for the most part their direction, as well as the limits of accretion. These are the forces which can be reproduced in miniature in a model, as proved by the close concordance in the channels obtained by experiment with the actual conditions of the Mersey, and with a previous state of the Seine estuary; and this similarity of results would not have occurred if the other influences noticed above were at all equally potent.

Training walls mainly modify the direction and action of the tidal ebb and flow and fresh-water discharge; and therefore it is reasonable to suppose that the results in a model, due to these alterations, would correspond to their actual effects in an estuary, provided the important element of accretion could be also reproduced. This was satisfactorily accomplished in the second stage of the investigation, proving that the miniature influences produced in the model corresponded, in this case also, with the forces acting in the estuary. Accretion is promoted by training walls in an estuary where matter is carried in suspension; but the action of waves in modifying the channels is stopped by the intervention of training walls. Accordingly, the further the training walls are extended, and the more an estuary is protected by works such as those indicated in Figs. 99–101, the more is the modifying influence of waves eliminated, and therefore the more are experiments in a model likely to correspond with the conditions of estuaries under similar conditions.

(164) Other considerations also afford grounds for supposing that the effects observed with training walls in a model fairly correspond with the results which such works would produce in an estuary. The charts of the experiments show that definite results followed from certain lines inserted in the model, and that modifications in these lines were followed by modifications in results. (Compare Figs. 99–101 and Fig. 103 with Fig. 105.) Moreover, the results produced with the model agree very closely with the results which, in the two earliest schemes experimented upon, it was stated, before the experiments were begun, would follow, if the works indicated by lines in the charts were actually carried out in the Seine estuary.*

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*Compare the observations relating to Scheme A and Fig. 99, with the following extract from Instit. Civ. Engin. Proc., vol. 84, p. 356: "The narrowing of the mouth of the estuary of the Seine would at first promote scour, and increase the depth in that part of the channel, and for a little distance above and below. This contraction, however, would impede the influx of the flood tide, and cause changes in the velocity of the current through the narrow neck, and in the wide estuary above, promoting the deposit of silt brought in by the tide. This accretion would be greatly aided by the prolongation of the training walls to Honfleur, so that eventually the greater portion of the estuary comprised between Tancarville, Hoc Point, and Honfleur would be raised to high-water level. This large reduction in tidal capacity would reduce the tidal current through the narrowed entrance, and consequently diminish again the depth in the channel. Moreover, this reduction of tidal flow in and out of the lower estuary would favor the natural heaping-up action of the sea on the sands outside; so that eventually, not only would the initial deepening of the narrowed outlet be lost, but the good depths in the bay outside the estuary would be imperiled."

Compare also Fig. 102, with the following extract from Instit. Civ. Engin. Proc., vol. 84, p. 250: "The continuously concave southern training wall, whilst very favorable to Honfleur, will unduly keep the ebb current to that side, and therefore away from Havre. Also, the extension of the wall along the Ratier Bank will act like a groyne, and, arresting the silt-bearing southern current, will connect Trouville Bank with the shore, and lead to a large accumulation of deposit in front of Trouville. * * * and also the low walls proposed will not prevent accretion."

It would be impossible to determine by experiment the time any changes in an estuary would occupy. The figures, in fact, giving the number of tides during which each experiment was worked, are not even intended as an indication of the rate of change in the model, and much less as any measure of the period required for such changes in an estuary, but merely as a record of the comparative duration of each experiment. It was observed, however, that the changes were most rapid where the modifications effected by the lines of walls inserted in the model were greatest (Figs. 99-101), and slowest where the lines in the model produced the least alterations. (Figs. 102 and 107.)

PRINCIPLES FOR TRAINING TIDAL RIVERS DEDUCED FROM EXPERIMENTS.

(165) The foregoing investigations, viewed merely as experiments, without any reference to their bearing on the Seine, may serve for indicating some general principles applicable in training tidal rivers through wide estuaries. Direct experiment for each estuary is undoubtedly preferable to abstract reasoning, where such experiment is possible, as it reproduces the special conditions of the estuary to be investigated. Nevertheless general principles may be of value in guiding the choice of designs to be investigated, so as to avoid waste of time in testing unfavorable schemes, and also in cases where the conditions of an estuary are not sufficiently known to afford a correct basis for experiment.

The experiments may be divided into three classes, namely:

(1) Outlet of estuary considerably restricted, and channel trained inside toward outlet. (Figs. 99-101.)

(2) Channel trained in sinuous line, expanding towards outlet, but kept somewhat narrow at changes of curvature. (Figs. 103-106.)

(3) Channel trained in as direct a course as practicable, and expanding regularly to outlet. (Figs. 102 and 107.)

The experiments of the first class exhibited a deep outlet, and a fairly continuous channel inside, where the training works were prolonged to the outlet. The channel, however, was irregular in depth near the outlet; and a bar appeared in front of the outlet outside. The breakwater also, extending across part of the outlet, favored deposits both inside and outside the estuary, by producing slack water in the sheltered recesses.

The second class of trained channel was designed to profit by the scour at the concave face of bends, so clearly exhibited at the first bend of all the charts, and to continue the depth thus obtained by restricting the width between the bends, on the principle adopted for winding nontidal rivers. Experiment, however, did not bear out the advantages anticipated from this system, probably owing to the variable direction of the flood tide at different heights of tide, its being checked in its progress by the winding course, and not acting in unison with the ebb from the difference in its direction and the width of the trained channel near the outlet. The main stream in a nontidal winding river always follows a tolerably definite course; whereas the flood tide tends gradually, as it rises, to assume as direct a course as possible. The difference, therefore, in the conditions of a nontidal and tidal river, in this respect, is considerable.

(166) The third class of trained channel afforded a wide, tolerably uniform channel in the experiments; the flood tide was less impeded in its progress than with the other forms of training walls, and appeared to act more in concert with the ebb.

The experiments, accordingly, indicate that the only satisfactory principle for training rivers, through wide estuaries with silt-bearing currents, is to give the trained channel a gradually expanding form, with as direct a course as possible to the outlet. The rate of increase of width between the training walls must be determined by the special conditions of the estuary. If the outlet is very wide and the gradual expansion in width can not be commenced a considerable distance up an estuary, some restriction in width at the outlet may be expedient to avoid a too-rapid expansion. It is evident that the widening out adopted in the last experiment (Fig. 107) was carried to its utmost limits, from the continuance of sand banks inside the trained channel, and that, regarding merely the improvement of the channel, it might have been preferable to restrict its width at the outlet as effected in Scheme C (Fig. 102). At the same time it must not be inferred from the existence of these sandbanks that the distance apart of the training walls was much too great in the last experiment; for the width apart of the training walls necessitated the inclusion of a greater extent of sand banks within the trained channel at the outset, and also rendered the rate of improvement in the channel more gradual, so that the improvement in the channel both in direction and depth was still progressing at the close of the experiment, and the sand banks in the channel were in process of removal and not being formed. The choice in such cases, where the widening out can not be commenced far up, appears to lie between the utmost improvement of the channel at the expense of accretion on the foreshores outside and the maintenance of the depths over the foreshores beyond the outlet, accompanied with a somewhat less good channel in the estuary. In some cases, deposit on the foreshores at the side beyond the outlet might be of no importance, and then the river channel should be primarily considered; but if, on the contrary, accretion on the foreshores outside is undesirable, the outlet must be maintained by a greater widening out of the training walls. The actual direction of the training walls must be determined, in each case, by the general direction of the channel above, the situation of ports on the estuary, the position of the outlet, and the set of the flood tide at the entrance.

(167) *Concluding remarks.*—In terminating this record of my investigations and the general principles for training works which they seem to indicate, I desire to acknowledge the care with which my assistant, Mr. E. Blundell, has carried out the tedious task of working the tides in the model, and prepared the charts of the experimental results from which the illustrations accompanying this paper have been drawn out. Eddies at sharp edges, due to distortion of scale, appear to have excessive scouring effect in a model; whilst the action of the more regular currents exhibits a deficiency in scouring power, as previously noted. Though the actual depths of the channels, however, are too small for the distorted vertical scale, reliance, I think, may be placed on the general forms and relative depths of the channels obtained in a model. It is possible that the inadequate depth might be remedied by the employment of a finer or lighter material for forming the bed of the model, or by using a liquid of greater density than water; but sand and water have the unquestionable advantage of being the substances which actually effect the changes in estuaries.

PART II—TIDAL, COAST, AND HARBOR WORKS.

CHAPTER XVIII.—CALAIS HARBOR WORKS.

(168) In 1875, before the beginning of the improvements just finished, the condition of the port was as follows: The depth in the outer channel on the bar, maintained by the action of the littoral currents and that of the sluicing basin, varied from zero to 0.75 meter below the zero of the charts (this zero being the mean level of the Mediterranean at Marseilles). The other depths below this datum were as follows:

Channel between the jetties, 1.50 to 2.50 meters below zero.

At the foot of the wharf built against the western jetty for the channel mail steamers, 3 meters below zero.

In the outer harbor, 0.72 meter above zero.

In the dock, 0.72 meter above zero.

Total length of the quays, 2,330 meters.

Area of the western dock, 2 hectares.

The entrance lock to this dock, 17 meters wide, had a single pair of gates, and could only be used by vessels during one or two hours of high tide. The rise of the tide is about 7 meters. The width of the quays did not anywhere exceed 30 meters, which was entirely too narrow for the traffic along the Calais-Dover route, requiring, as it did, branch lines, sidings, and facilities for transporting the freight between the ships unloading and the Calais station.

Also, there were no adequate means of communication between the port and the network of water ways connected with it, so that in 1875 the total tonnage entering and leaving the port was 840,000 tons, but the weight of merchandise imported and exported did not exceed 215,000 tons.

For want of sufficient depth on the bar the mail service between Dover and Calais was the only one which could be run at fixed hours day and night, and even this was more or less irregular.

The new works, created in virtue of the laws of December 14, 1875, and August 3, 1881, which are now completed, have wholly changed the condition of the port from what it was 14 years ago. These new works (see Fig. 108) may be described as follows:

(169) *Exterior and interior channel.*—By dredging, and by the combined action of the two sluicing basins, a minimum depth of 4

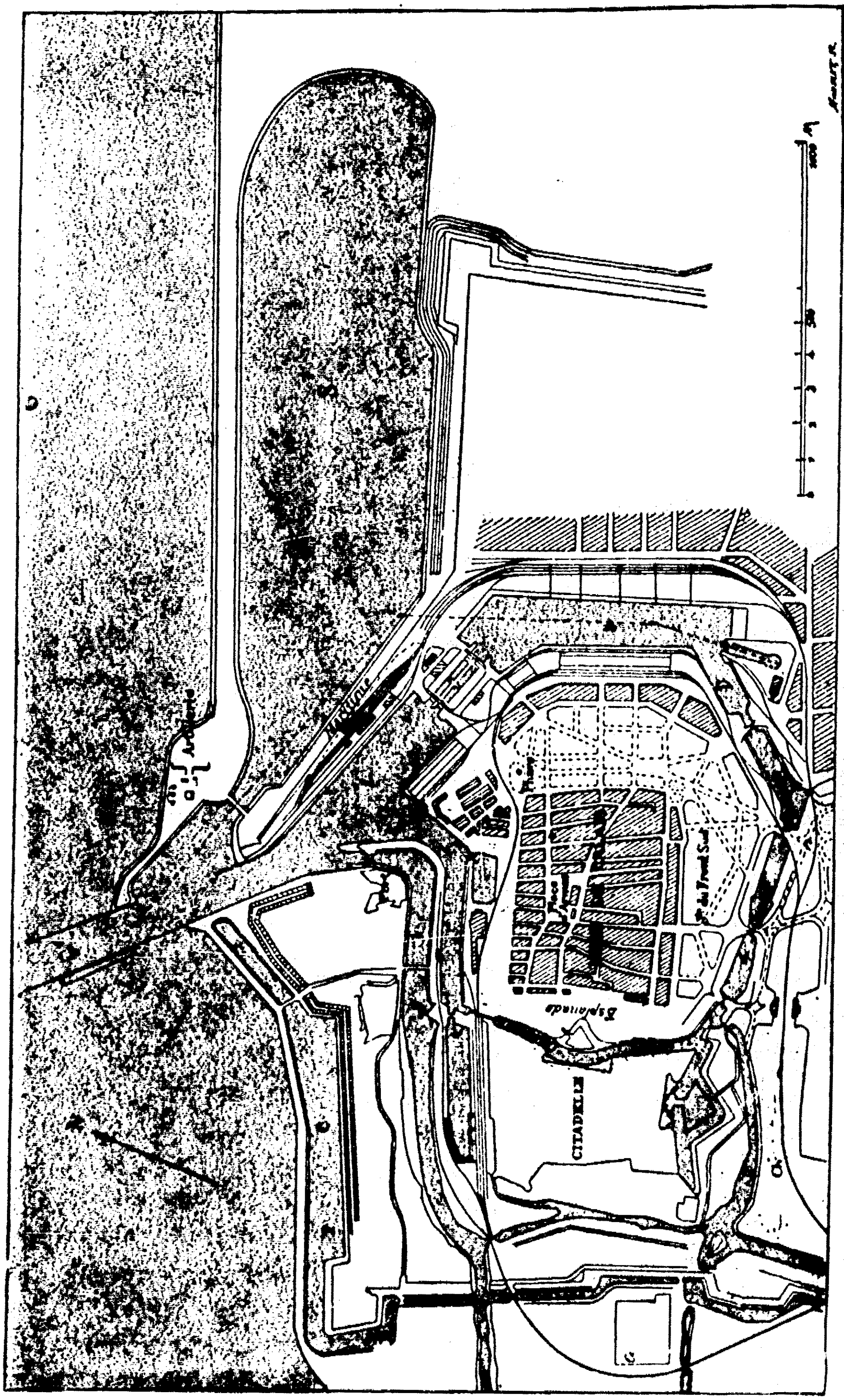


FIG. 108.—Plan of Calais Harbor: A, eastern dock; B, inner basin, connected by a series of basins with the Calais Canal; C, western dock; S, the new sluicing basin; V, outer harbor; d, the old sluicing basin; h, channel between the jetties.

meters below low water has been obtained on the outer pass and in the channel between the two jetties.

(170) *Scouring or sluicing basin.*—The sluicing basin has an area of 90 hectares; it has been excavated to a depth of 5 meters above the zero of the charts, except in the center where a deeper channel has been made to the opening of the sluicing lock.

The volume of available water stored at high tide above the reference + 5 is 1,600,000 cubic meters. This volume can be discharged, with a fall of from 4.25 to 6 meters, in from 45 to 60 minutes.

(171) The sluicing lock is made with five openings, each 6 meters wide, closed by balance gates turning around a central axle The sill of these openings is placed at low-water level, —0.72 meter. The sluicing water is so directed as to strike upon the inner channel, 250 meters from the extremities of the jetties, where a great deal of sand is deposited, and where the dredging is difficult. The sand is carried to the bar, whence it is easily removed by dredges.

(172) *Outer harbor.*—The new outer harbor has an area of 6 hectares; it is bordered on the northeast and southwest by quays which are connected by return walls to the entrance lock of the eastern dock. The mean width is 160 meters, and the depth 4 meters below zero, except at the foot of the southwestern quay, where the channel is cut 7 meters deep to allow large ships to remain afloat.

This quay is 240 meters long, and its foundations are sunk 10 meters below zero. Here sheds are built and rails laid for the use of ocean steamships, so that they can call at Calais, and can load and unload without entering the dock. The northeast quay is for the steamboat service between Calais and Dover, and contains the railroad station, and berths for four steamers from 100 to 120 meters long, drawing 3.50 meters. The quay itself is 370 meters long and has a depth of 3.5 meters at its foot.

(173) *Eastern dock.*—Entrance to the eastern dock is obtained by means of two parallel locks whose sills are placed 1.75 meters below zero; their depth is 5.70 meters below the mean sea level (3.92 meters) and their widths are 21 and 14 meters, respectively; they will lock ships 135 meters long, and are each divided by a pair of intermediate gates, so as to economize the water when locking small vessels. At high tide vessels can go through the locks. The gates, capstans, drawbridges, etc., are worked by hydraulic machinery.

The area of this dock is 12 hectares, including the inner basin, with which it communicates. Its width is 170 meters at the entrance, 120 at its southern extremity, and 70 in the inner basin; close to the locks the width is increased so as to give more room to vessels entering or leaving.

The depth is 0.50 meter below the sills. The total length of the quays around this dock is 1,500 meters.

The inner basin is excavated to low-water level, and the effective length of the surrounding quays is 350 meters. The width of the western quay is 100 meters and that of the eastern 140.

(174) Sheds are constructed on the west side by the chamber of commerce, and all quays are provided with railroad tracks by the Northern Railroad Company.

(175) *Graving dock.*—A dry dock 155 meters long, entered through a lock, can accommodate vessels 150 meters long. It is provided with pumping machinery arranged so as to empty the dock in 3 hours.

(176) *Canal dock.*—Between the east and west docks is a canal dock, covering 4 hectares, for the use of barges; it is surrounded by a quay 1,600 meters long, and extends from the new eastern dock, with which it is connected by two locks, to the citadel canal, by which it communicates with the citadel lock and the old port.

Communication between this dock and the citadel lock can be cut off by means of a guard lock, the gates of which may be moved whatever may be the force of the current, thus forming a dam in case of accident to the citadel lock, either against the sea or against the water in the dock.

(177) The Pierrettes canal runs into the citadel lock below the guard lock. It may be used to separate the old sluicing basin from the drainage canal. The gates of the guard lock are closed against the water in the basin, when the Pierrettes canal is used to discharge its flood waters into the sea through the citadel lock, the level of this canal being 1 meter below the Calais canal. The Pierrettes canal is usually kept closed by a movable dam.

Five bridges, two of which cross the locks, provide for the traffic between the two sides of the canal.

(178) The Marck canal, which receives nearly all the surface water from the lowlands on the right of the Calais canal, formerly discharged through a bridge dam into the Calais canal, in the center of the town of St. Pierre. The water could run into the sea through the citadel lock only when the latter was being emptied. These waters were so abundant as to require the level in the Calais canal to be frequently and excessively lowered. To avoid this and preserve a constant level in the Calais canal in times of freshet, the Marck canal has been diverted so as to discharge directly into the outer harbor. The Calais canal has also been straightened, enlarged, and deepened so as to allow the passage of vessels of 300 tons burden, the largest that can be accommodated on the northern water ways between Belgium and France.

(179) The Calais improvement works began in 1876. The sluicing basin and its lock, the outer port, the lock of the eastern dock, and the northern part of the basin itself, had to be constructed on the beach. The southern portion of the same dock had to be excavated across the line of downs and the works which protected the town of St. Pierre from the sea situated about 2 meters above the highest tide. All the excavations had to be made in the fine beach sand

and downs, and upon it the harbor works had to rest. Again the foundations could not be made without protection against the sea.

Fortunately the contour of the port and the general arrangement of the works permitted the formation of a series of coffer dams, corresponding to several groups of projected improvements, which could be undertaken separately. The utilization of the first fillings for the quays and permanent dikes as coffer dams, greatly reduced the amount of temporary earthwork. The slopes, slightly exposed to the sea, were covered with rocks from the chalk formation and held by wattling. When more exposed, they were covered with sand resting on straw so placed that the stalks lay in the direction of the greatest slope, and were held by horizontal lines of wattling; between these lines the straw was loaded with hard limestone, pointed and laid in courses with their tails downward, and strongly rammed together. In the most exposed portion the revetment of the slope was formed by stone pitching. The foot of the slope rested against a line of sheet piling which was reinforced by a mass of beton sunk 1.50 meters in the sand. The stone pitching was laid upon a bed of well rammed clay 0.30 meter thick, spread upon the slope to prevent the sand from being washed away. This pitching was 0.50 meter thick and set in Portland cement. A curved form decreasing in declivity was given to the new sea front of the dike to better protect it against the action of the waves.

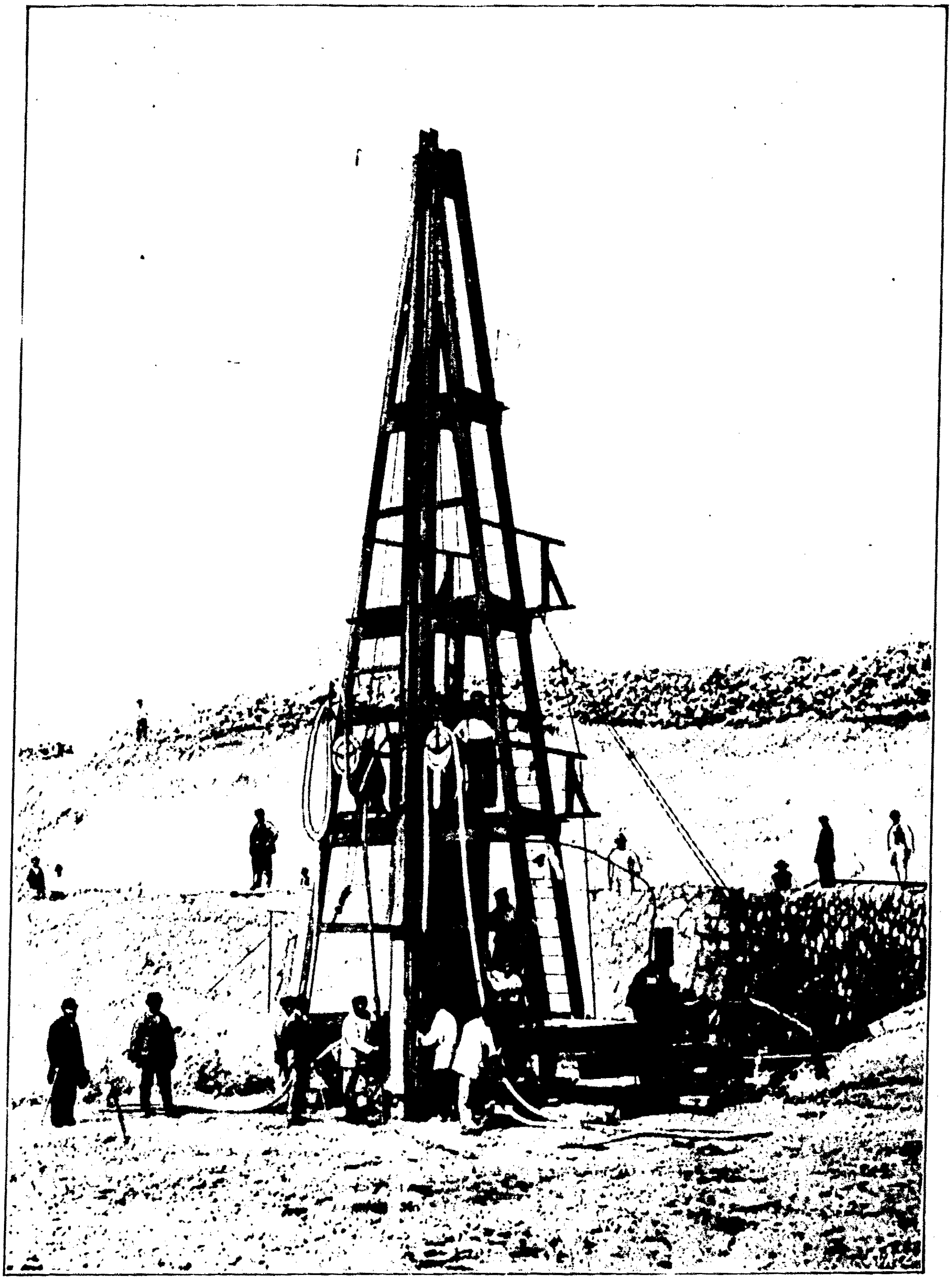
The engineers, seeing the great difficulty of driving piles through the sand, had recourse to the method of sinking them by means of water jets.

Before using the water jets, to drive a panel of sheet piling 2.50 meters high and 180 long required 900 blows from a ram weighing 600 kilograms, and occupied from 3⅝ to 14¼ hours, or an average of 8½ hours. The resistance of the sand was such that the thickness of the piling had to be increased from 0.08 to 0.12 meter, and even then the wood was frequently broken.

The first trials of the jets gave such remarkable results that the method was subsequently employed to sink most of the foundation walls of the quays.

The water jet was forced into the sand by means of a hand pump through an iron nozzle 0.027 meter in diameter, connected to an India-rubber hose (see Plate V). This so facilitated the work that a panel of seven or eight planks was sunk in one hour and nine minutes, and in many cases the time was reduced to fifteen minutes. The number of blows did not exceed fifty, and were only necessary to overcome the friction between adjacent panels, which were tongued and grooved to make a tight joint. The weight of the ram on a single pile 3 meters long was sufficient to sink it immediately, and the former thickness of 0.08 meter for the panels was restored.

This dike was finished without accident, but, several years later,



CONSTRUCTION OF THE QUAYS OF THE DOCKS AT CALAIS. PROCESS OF SINKING THE PILES BY MEANS OF WATER JETS.

during the high tide of an equinoctial storm a great breach was made in it; this was closed and the profile of the dike modified as shown in Fig. 109. The height and thickness are the same as before,

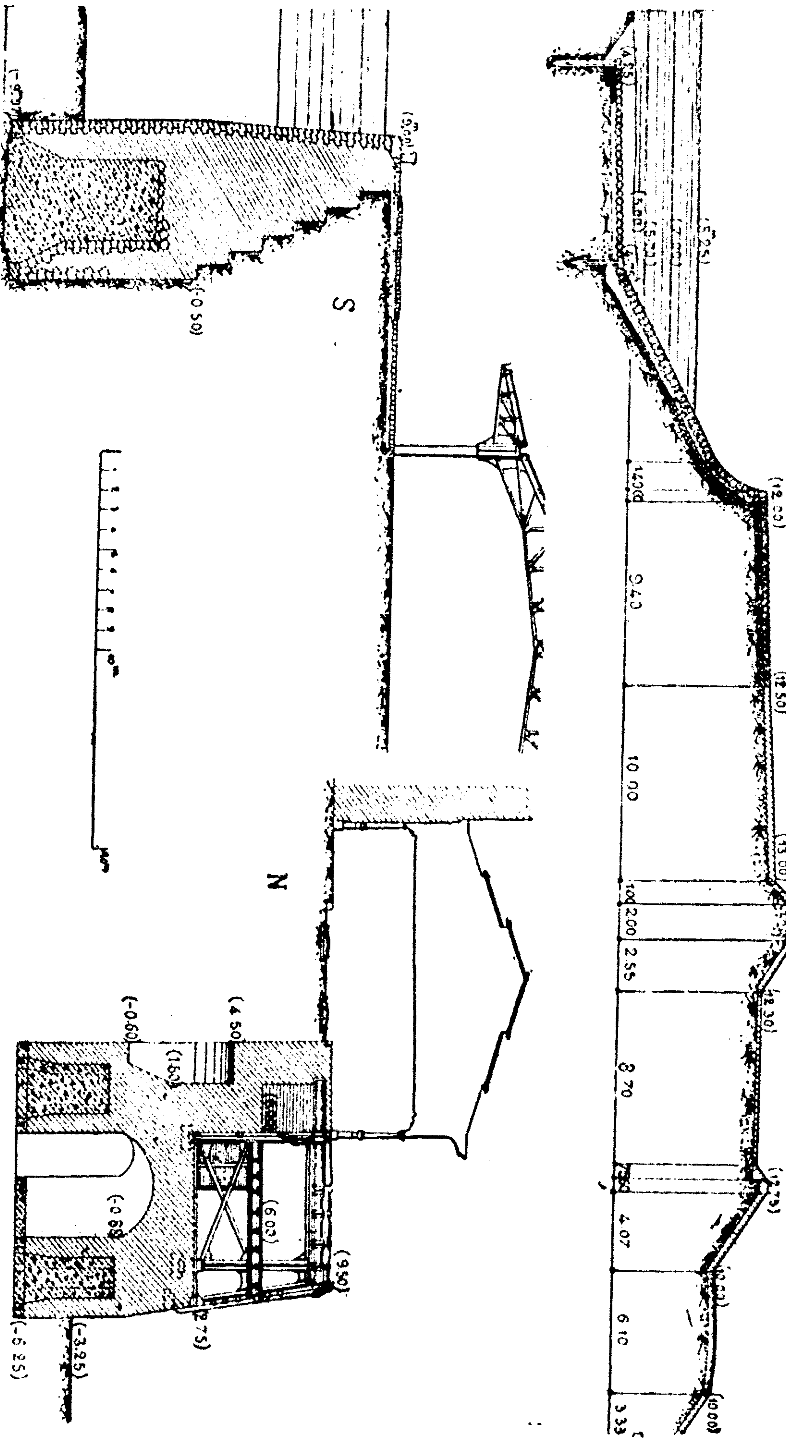


FIG. 109.—The upper figure shows the cross section of the northwest dike. Figs. N and S show cross sections of the northeast and southwest quays, respectively.

but the top had a slope of one-tenth from the edge of the stone pitching, for 10 meters back from this crest, with a stone flagging prolonged by a belt of puddled clay from 0.25 to 0.30 meter thick.

At 30 meters from the edge a turf banquette 1.50 meters high formed the last barrier to the water. Finally a masonry berme 10 meters wide was constructed at the foot of the dike, following the declivity of the beach. Thus reconstructed, the dike has resisted the most violent storms.

(180) *Dredging of the channel.*—The work of deepening the outer channel was carried on at first by a Dutch company, and then by the Fives-Lille Company. The quantity extracted at the end of 1888 by both companies was 1,472,933 cubic meters, and the price last paid was 0.92 francs per cubic meter, raised and carried 1 mile. A careful study of the plan of the soundings made from month to month

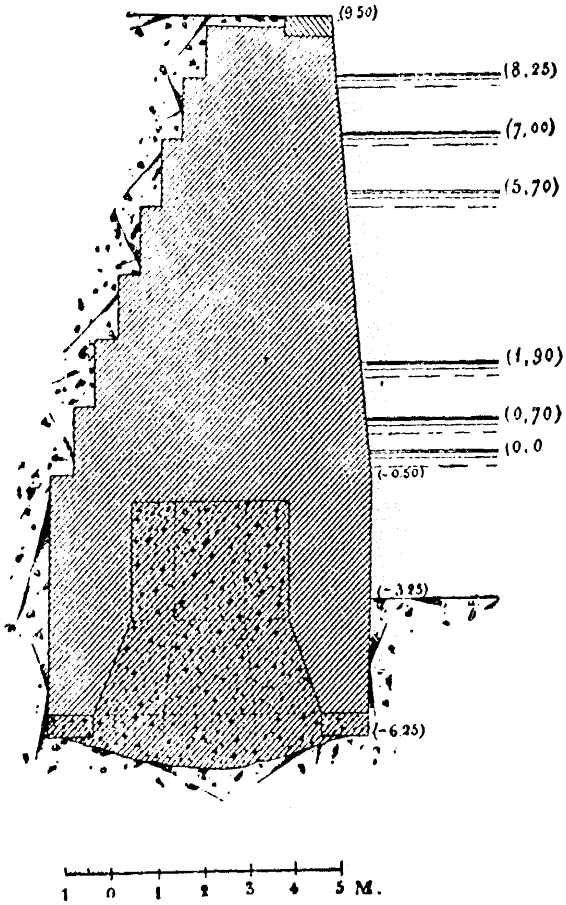


FIG. 110.—Cross section of the wall of the northeast quay of the outer harbor.

during the last seven years shows that, by dredging out annually 170,000 cubic meters, the outer and inner channels may be maintained at a depth of 4 meters below datum; this, at the price of 0.92 francs per cubic meter, amounts to 85,000 francs.

(181) The sluicing lock, which serves to discharge the water accumulated in a basin of 90 hectares area, has five openings, each 6 meters wide, separated by piers 3.50 meters thick. The wetted perimeter of these openings has been arranged so that a discharge of 1,600,000 cubic meters can take place in an hour under a head varying from 6 to 4½ meters.

(182) *Outer harbor quays.*—The northeast quay, 570 meters long, shown in section by N Fig. 109, is for the Calais and Dover mail steamers. The station and lines of the Northern Railroad Company are placed here.

The quay wall is nearly vertical and flush, except that at equal distances along it there have been made four recesses 55 meters long and from 8 to 9 meters deep. In these recesses the iron landing stages are arranged in three stories, for the landing and embarkation of passengers and freight. The two central recesses, which are opposite the railroad station, are 120 meters long; the others 100; the rest of the quay may be used for a fifth steamer, or for the dredges and tugs belonging to the port.

The plane portion of the wall between each recess has a uniform section of 7 meters thick at the base and 2.70 meters at the top. The foundations are sunk to the reference —6.25 meters, that is, 2.75 meters below the bottom of the outer harbor, and the total height is 15.75 meters. Near the base the face of the wall is vertical; above it has a batter of one-tenth. The thickness of the vertical portion is 7 meters, but above it is reduced by steps as shown in Fig. 110.

At the right of the landing stage the total thickness of the wall is 13.75 meters for a length of 64 meters; in this wall two recesses are made, each 22.50 meters long and separated by a wall 10 meters thick. The bottom of each recess slopes slightly to keep it clear of water. The depth of the lower is 8.95 meters, and that of the upper 8.20 meters. The quay is formed of two parallel walls; the outer, an extension of that of the quay and 4 meters thick, comes up to the level, 2.25 meters; the other, 4.50 meters thick, extends to the top of the quay; the two walls are connected by an archway parallel to the quay. The second wall, hollowed out behind by little arches, contains a staircase between the middle and upper landings.

Each landing stage is formed of six frames perpendicular to the face of the wall, which, with the lateral walls, carry the floor beams of the middle and upper landings. Each frame consists of three uprights, one inclined and the other two vertical; the bases of the two latter rest upon iron plates imbedded in the masonry; the columns are stiffened by cross braces. These columns support the middle deck, and the upper deck is supported in a similar manner, as shown in Fig. 109-N.

(183) The southwest quay (S. Fig. 109) is reserved for the use of the ocean steamers calling at Calais. It has a depth of 7 meters below low tide; the foundations were sunk to a reference —10 meters; its coping is +9 meters, and its total height 19 meters. This foundation was accomplished in a special manner, which will now be explained.

(184) *Foundation of the northeast and southwest quays of the outer harbor.*—The width of the foundation was 7 meters; to make a

trench 7 meters wide and 5 meters deep in the fine sand and lay the quay walls inside required the construction of a costly cofferdam, and even then the results were not absolutely sure. The method by compressed air was equally expensive but surer.

After some very successful experiments it was decided to apply, for sinking the masonry curbs 7 meters by 6.50 and 5 meters high, the process so successfully used in driving the wooden piles at Calais.

These curbs were placed side by side. The exterior walls are

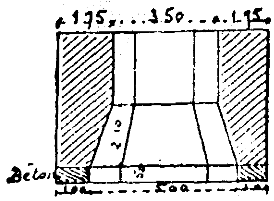


FIG 111.—Vertical section of a curb.

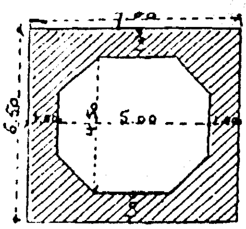


FIG. 112.—Lower plan.

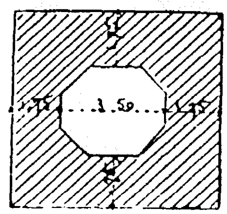


Fig. 113.—Upper plan.

vertical, the interior walls are vertical for a distance of 0.50 meter. They are 1 meter thick, and are shown in Figs. 111 to 113. The base is of concrete made in a mold, which is taken off when the concrete is set; the rest is built up of masonry laid in cement. The blocks thus formed (Pl. VI) are not sunk until ten days after they are finished. This operation consists in exposing the sand beneath the block to the action of powerful water jets, thus throwing a mixture of water and sand from without into the cavity within, and pumping the mixture of sand and water thus obtained in the middle of the curb. For this purpose a centrifugal pump, driven by a portable engine of 10-horse power, was employed; the suction pipe was suspended from high scaffolding, the orifice being placed a little below the level of the bottom of the block. Four direct-acting force pumps were used to drive the water into the sand, each pump throwing 600 liters per minute, with a pressure of 2 kilograms, through three nozzles connected to the pump by India rubber hose, which passed over a light, portable staging above the curb.

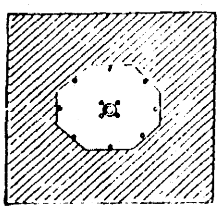
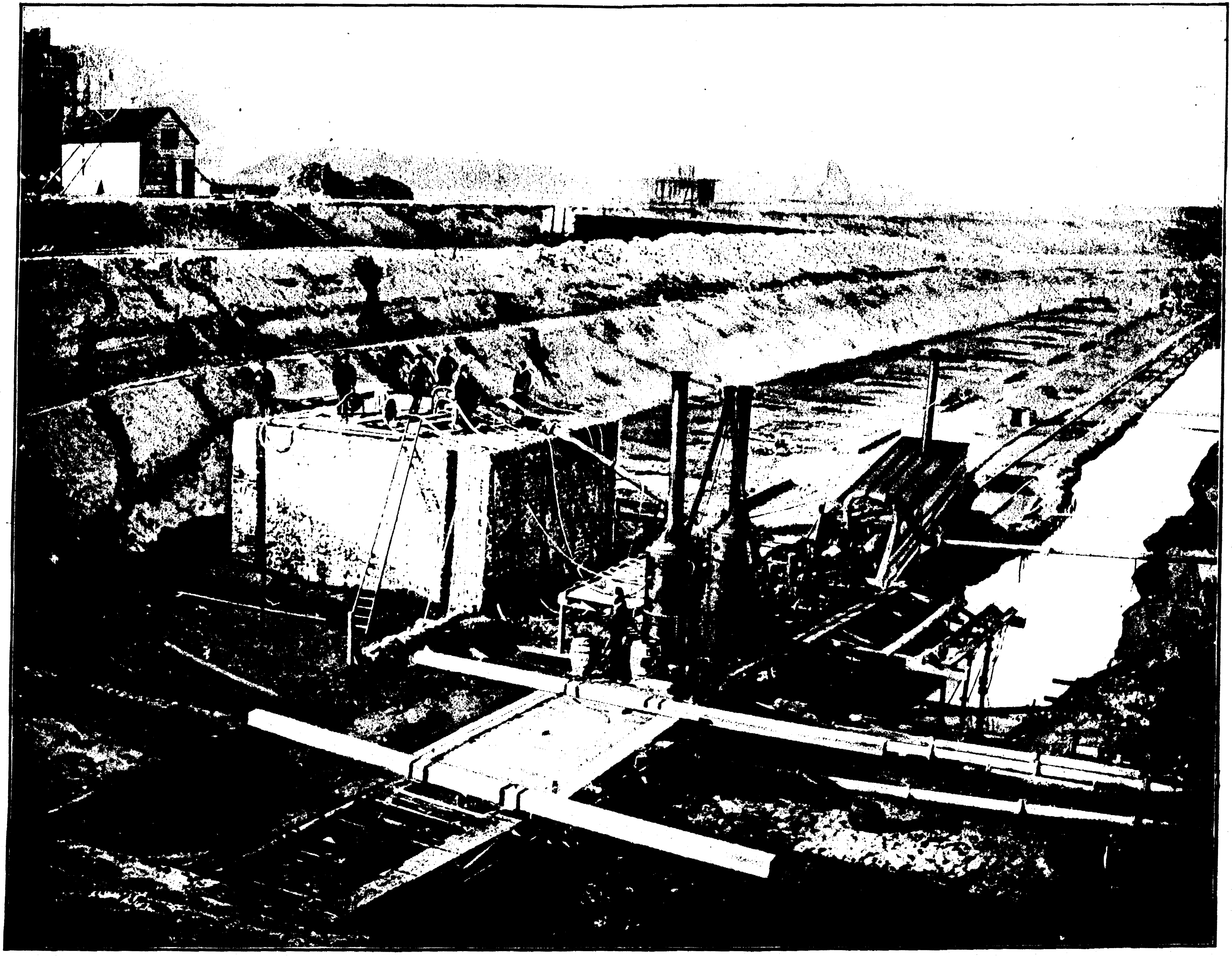


FIG. 114.—Arrangement of the jets.

The whole plant was mounted on four platform cars and ran upon rails laid parallel to the face of the quay.

Plate VI shows the general arrangement, and Fig. 114 shows the arrangement of the twelve jets. Eight of them were arranged around the sides of the octagonal opening, and the four others around the suction pipe of the centrifugal pump. Three of these played around the mouth of the suction pipe diluting the sand, augmenting the efficiency and diminishing the danger of choking. The twelfth pipe was united to the suction pipe, into which it discharged just above



CONSRTUCTION OF THE OUTER HARBOR QUAYS AT CALAIS. PROCESS OF SINKING THE MASONRY FOUNDATION CURBS BY MEANS OF JETS OF WATER.

its lower extremity. This arrangement, devised by Mr. Delanoy, kept the pump clear. The jets from the nozzles, all working simultaneously, mixed the sand and water together, and this mixture was drawn out by the centrifugal pump. Care was taken during the operation that the quantity of water forced in should be the same as that pumped out, so that the level of the water in the curb should be just below the ordinary level of the water in the surrounding sand. In this way there was no danger of the sand on the outside caving in, and only a quantity of sand not much greater in bulk than that of the curb was taken out.

As one of these blocks sank, two spirit levels were placed upon the top, by which it was easy to see whether it was sinking vertically, and if it was not, it was regulated simply by lowering or raising nozzles on one side or the other so as to force it more or less into the sand.

When the curb had reached the bottom, after a descent of 4 or 5 meters, the sand was allowed to settle and the opening was filled with hydraulic béton. This layer when hardened formed a tight tamp, which resisted the under pressure of the water; the empty space was then pumped out and filled with béton cement up to the level, where it could be filled with masonry.

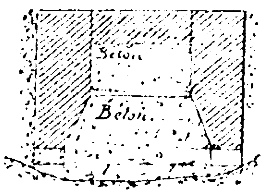


FIG. 115.—Section of a finished curb.

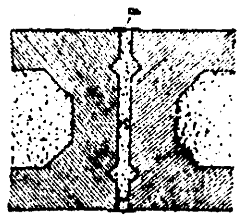


FIG. 116.—Method of cementing two consecutive blocks together.

The method adopted for the whole work was as follows: A general plan was prepared indicating the dimensions and position of each curb, with a space of 0.40 meter between each, which is to be filled afterwards. The positions of the curbs were then marked out on the ground.

Experiments had shown that in sinking such a row of foundations, if every alternate curb was sunk, the condition of the intermediate ground was unaffected. The work was begun by sinking all the curbs numbered 1, 3, 5, etc., and then those numbered 2, 4, 6, etc., until all were sunk. The curbs were none of them filled until all were in place, in order to avoid any trouble which might arise from the displacement of the sand under the foundations. When all the curbs were sunk they were filled and then these consecutive blocks were cemented together, as follows: On the front and back of the blocks iron plates (Fig. 116) were sunk down to the foundations by means of water jets. These plates closed the space between two consecutive blocks, the sand between the blocks was then cleared out by the nozzles and pump, and the space filled with béton, made of hydraulic mortar.

Upon the blocks thus united together the foundation of the wall was built in masonry laid in Portland cement. Pl. VI shows this whole operation.

The facility with which these blocks were sunk permitted the engineers in charge to augment the dimensions of the blocks for the foundation of the southwest quay, as well as the depth to which they were sunk. They were 8 meters square and 8.75 meters high, and weighed 800 tons. These blocks were sunk with the same accuracy as those of smaller dimensions for the northeast quay, but some difficulty was experienced in cementing the blocks together, on account of the water forcing its way under the iron plates. The time of sinking the small blocks of the northeast quay to a depth of about 4.50 meters varied from ten to thirty-five hours, the mean time was reduced to about twenty-three hours, and the mean volume displaced per hour was 6.35 cubic meters.

The time of sinking the larger blocks, 8 by 8 by 8, varied from 22 to 119 hours, with a mean of 45.

The sinking of the still smaller blocks, 4 by 4 by 4.45 meters, was relatively easier, the mean volume displaced per hour being 12.5 cubic meters.

The total length of the quay walls of the outer harbor, constructed under the shelter of the dikes between 1884 and 1888, is 770 meters. The corresponding expense in round numbers was 2,750,000 francs, including the plant. The expense of sinking the curbs was 99,000 francs. This expense corresponds to a total volume displaced of 31,253 cubic meters, which makes the cost 3.17 per cubic meter of sand extracted and masonry put in its place. The cost of removing the sand between the sunken blocks and replacing it with beton was 27,540 francs, thus bringing up the total cost of sinking the solid walls to 3.84 francs per cubic meter, including the labor and the cost of the plant.

(185) *Eastern dock locks.*—The communication between the outer harbor and the eastern dock is established by two parallel locks of the same length but unequal widths. The larger has a clear width of 21 meters. The level of the lowest part of the invert is 1.75 meters below the zero of the charts. Gate chambers are formed in the masonry to receive one pair of gates at one end of the lock, two pairs at the other, and one between. The maximum length of the lock chamber is 133.51 meters. This length can be divided in two parts, which are, respectively, 57.50 meters and 76 meters, by means of the intermediate gates. The smaller lock is similar, and has a width of 14 meters. On the left side of these locks two arched longitudinal culverts are made; one, 2.10 meters wide and 3.60 meters high,

forms the prolongation of the culvert of the western quay upon the dock, and is intended to carry off the flood water from the Calais canal, the water from the dry dock, and that from the boat locks.

(186) Culverts for filling and emptying are also placed in the central pier and in the chamber wall on the right side of the smaller lock. The first is 2.20 meters wide, the second 1.60 meters wide, and the height, 3 meters, is the same in both.

Communication is made between these outlets and the locks by transverse branches, and the flow of the water regulated by valves and sluices.

(186) *Lock gates.*—Each leaf is 12.25 meters wide, 9.80 meters high, and 1.10 meters thick for the flood and 1.30 for the ebb gates. The iron frame consists of eight horizontal girders, spaced from 1.34 to 1.36 meters, connected at the ends with two uprights, and having four intermediate standards 2.32 meters apart.

The leaves rest on pivots at the bottom, and at the top they are held by iron trunnions passing through collars anchored in the masonry.

The 14-meter lock is furnished with gates similar in all respects to those just described. The total weight of each leaf is 85 tons for the larger and 50½ for the smaller lock.

(187) *Turning bridges.*—Four turning bridges are constructed across these locks to provide for the public traffic, two at the lower end and two at the upper. They are of similar construction, and differ only in length, 47.13 and 35.80 meters. Each bridge has an iron superstructure and a double wooden flooring. It consists of a single span turning on a pivot set in the lock wall.

The framework of each bridge consists of two main girders resting on the ends of a box girder, and united by cross-ties, which are themselves connected under the flooring by stringers. The foot path is carried on brackets mounted on the outside of the main girders, which have the form of a parabola above and below. The height of each girder is 3.30 meters at the right of the box girder and 2.70 meters at the ends.

When one of the bridges is in use it rests upon the center pivot, and also on three locking brackets, one at the end of the span, another near the pivot, and a third at the breach, or tail end.

When the bridge is opened the locking brackets are withdrawn and the superstructure rests principally upon the pivot and partially on the breach rollers. During the rotation the rollers bear a maximum load of 5 tons and roll on a cast-iron track.

The total weight of the superstructure of one large bridge is 265 tons, including counterpoise of 45 tons placed in the breach, used to tilt the bridge, so as to set free the supports. The weight of one of the smaller bridges is 190 tons, including the counterpoise of 30 tons.

188. *Apparatus for handling.*—The sluices, gates, bridges, capstans, etc., are moved by hydraulic power distributed from a central station erected near the lock.

The green heart wood sluices slide in grooves cut in the granite facing of the polished walls. The lock gates are opened and closed by hydraulic presses and tackle: two presses for each leaf placed side by side, one for opening and the other for closing the gates. The opening and closing chains pass over two pulleys, one above the other, in the wall near the heel post. They pass over a series of guide pulleys attached to the upper part of the leaf, and are secured to a ring bolt in the wall. The controlling valve, worked by a hand lever, is so arranged as to make a communication between one of the cylinders with the pressure main and the other cylinder with the exhaust main. The arrangement of the admission and exhaust ports is such that it is possible to vary at will the relation between the tension on the chain in operation, and the resistance offered by the one which corresponds to the reverse movement. A small auxiliary press, placed at the end of the closing cylinder, forces the closing piston to the end of its stroke during the process of opening the gates, so as to facilitate the unrolling of the slack of the chain between the walls.

By this novel arrangement the opening and closing of the gates can be effected by one operator, who can always hold the leaf in either direction against the force of the waves.

(189) The machinery for working the turning bridges moves the pivot, arranged so as to tip and rotate independently, the tilting and locking presses, and the two rotating tackle presses.

The pivot turns in a cast-iron cylinder, filled with glycerine maintained at a pressure of 50 kilograms per square centimeter, upon a circular lubricated surface; it carries at its upper part the cylindrical rolling joint which serves for the tilting.

The tilting presses act by vertical plungers placed under the principal girders of the breech.

When the bridge is raised by the tilting presses the locking presses throw on or off the breech brackets which support the bridge when it is in use.

The chains are coiled around an iron drum placed under the superstructure on a level with the supporting box-girder.

Four 1-ton capstans are placed along each of the outer sides of the lock; three others of 5 tons, and two of 1 ton, are arranged on the central wall between the two locks for hauling the vessels. These capstans are driven by small three-cylinder hydraulic engines so arranged that they can be worked by hand if the water gives out. They are so placed that they can be utilized for opening the gates or turning the bridges in case the accumulator gives out, and in such a case a hand pump specially constructed serves to work the sluices and the tilting presses.

The central hydraulic machinery which supplies the water under pressure, for working the presses which have been described, is contained in a building situated to the north of the locks. It consists of two groups of pumps, each driven by a 50 horse-power engine, and two accumulators of 736 liters capacity each.

The machinery is sufficiently powerful to supply the Chamber of Commerce with water under pressure, and to drive other hydraulic machinery situated on the quays.

The applications of hydraulic power above described are due to M. Barret, engineer of the Marseilles docks, who prepared the plans, which were carried out by the Fives-Lille Company under the direction of the engineers of the port.

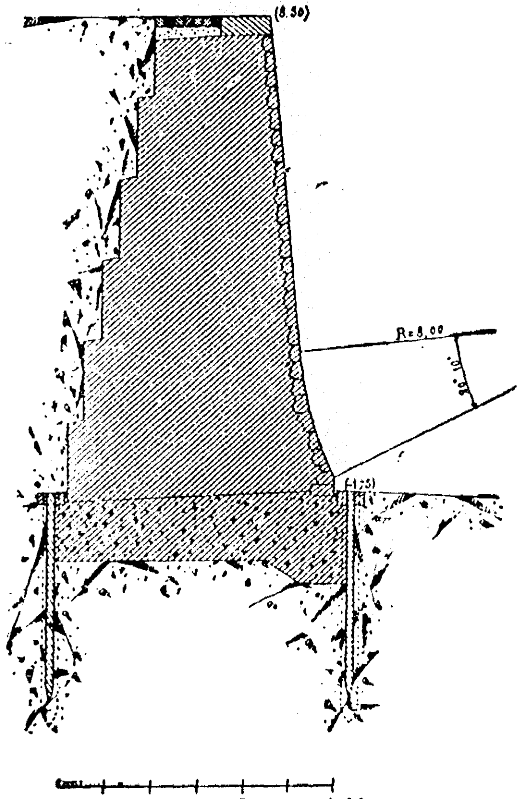


FIG. 117. Profile of the wall of the eastern dock.

(190) The quay walls of the eastern dock have a total length of 1,505 meters. These walls rest on a béton foundation 2 meters thick, carried down to a depth of −3.75 meters. The normal profile of the walls has a height above the foundation of 10.25 meters and a thickness of 5.80 meters at the base and 2.50 meters at the top. This difference in thickness is obtained on the outside by a batter of one to ten, followed by a curved face of 8 meters radius, and on the land side by a series of steps 0.37 meter wide; (See Fig. 117). In the smaller basin beyond, where the height of the wall is only 7.75 meters, the thickness is reduced to 4.20 meters at the base and 2 at the

top. These profiles are modified for the western quay, on account of a culvert 2.10 meters wide and 3.60 meters high, placed at the back and used for carrying off the flood waters of the Calais Canal into the outer harbor, as well as the water from the dry dock and the boat locks.

(191) *Foundations.*—The width of the foundation upon which the walls rest is 6.30 meters. It consists of a mass of béton sunk to a depth of 2 meters within a coffer dam formed of piles and sheet piling. The dimensions of the piles were 0.30 by 0.25 by 4.50 meters in length; the planks forming the sheet piling were 0.10 meter thick.

The estimated cost of these coffer dams was 450,000 francs. The application of the water jet process enabled these dams to be constructed not only in very much less time than had been estimated, but reduced the cost to 160,000 francs, thus realizing an economy of 290,000 francs.

This economy resulted not only from the diminished cost of sinking the piles and sheet piling, but by allowing the use of smaller piles and thinner planks. Pl. V shows the operation of sinking the piles.

The total cost of constructing the quay walls of the dock and the inner basin was 4,000,000 francs.

(192) The western quay is specially reserved for handling and storing valuable merchandise which has to be protected against the weather, and which is only allowed to remain a very short time. It is provided with railways and sheds. The normal width of the quay is 100 meters, divided as follows:

First. An open zone 11.50 meters wide extending the whole length of the quay, carrying a track for hydraulic traveling cranes, and two other tracks for freight traffic.

Second. A zone of 48 meters wide, including a great central hall 40 meters wide formed by two parallel roofs each 20 meters wide, and two exterior awnings each 4 meters wide.

Third. A collection of five tracks, one placed under the awning next to the dock, the remaining four occupying an uncovered space 18 meters wide. The track standing nearest the sheds is used chiefly as standing room for wagons to be loaded or unloaded. The four others serve as sidings for full or empty cars and the making up and dispatching of trains.

Fourth. A paved road 16.50 meters wide, including space for a track which will subsequently be laid along the outer sidewalk.

Fifth. A sidewalk 6 meters wide running along a series of blocks for a depth of 50 meters along the quay, to be reserved for the construction of stores, depots, and other establishments required for a marine station.

Beyond the quay proper the public domain extends along a zone 70 meters wide, including the belt of 50 meters occupied by the blocks reserved, just referred to, and by an outer street 20 meters wide, upon which railway tracks will be laid to accommodate the stores when they are constructed.

(193) The eastern quay is reserved for the storage of a low class of merchandise, such as wood, iron, minerals, charcoal, etc., which can remain exposed to the weather without damage. The total width of this quay is 140 meters, divided as follows:

First. Three lines for loading and unloading cars. The middle line is reserved for a traveling crane.

Second. An open space 67.50 meters wide.

Third. Five tracks occupying a total width of 21 meters.

Fourth. A macadamized road 13 meters wide.

Fifth. A zone of 10 meters fenced in and occupied by two branch lines connecting the central Calais station with the maratime terminus.

Sixth. An outer street 15 meters wide.

(194) *Hydraulic cranes.*—A system of mains has been laid down, starting from the central hydraulic station and extending around the dock, to supply the various cranes, etc., established on the quay. These include 10 traveling cranes of 1,500 kilograms each, 2 double-power traveling cranes of 5,000 and 2,500 kilograms, and 6 movable winches of 750 kilograms, 1 fixed double-power crane of 20,000 and and 40,000 kilograms.

(195) *The dry dock* is constructed at the southern extremity of the eastern dock, and a space has been reserved alongside for the construction of two similar docks when they shall be required. An unloading stage for timber occupies provisionally the space reserved for these two docks. This work comprises three different parts—the entrance lock, the dock itself, and the culverts.

The entrance lock is 21 meters wide, like the great lock of the eastern dock. Its side walls have two recesses for the reception of the caisson gate which closes the entrance.

The dry dock has a total length of 141.25 meters measured along the flooring from the inner recess of the caisson gate to the base of the rounded edge. The maximum thickness of this gate being 4 meters, the useful length of the dock is 138.50 or 152 meters, according as the gate takes its bearing against the inner or the outer recess. The width of the flooring between the bottom altars is 9.30 meters, including the side draining channels which run round the floor of the dock.

The first four altars starting from the bottom are 0.35 meter high and 1.30 meters wide. The width of the dock at the level of the fourth altar is thus 19.70 meters; a width requisite for the accommodation of the light-draft paddle steamers used for the channel service. From this level to that of the coping the dock has two intermediate steps 1.25 meters wide, to serve for shoring, and to facilitate the passage of the workmen. The width at the coping is 27.40 meters.

Several stairways are placed along the walls, and a timber slide is provided at the extremity of the rounded end.

A culvert 1.25 meters wide and 2.50 meters high, opening into the lower end of the dock near the inner recess of the caisson gate, is built behind each wall, and small transverse culverts run from it to the lateral channels on each side of the flooring. The culverts carry off the water to the pumping well when the dock is emptied or drained.

The well under the engines and centrifugal pumps is arranged so as to serve in future for the filling and draining of the two other docks not yet built. The engines and the pumps are calculated to pump out the dock in 3 hours at the most.

A set of small centrifugal pumps serve to keep the dock clear while in use.

The great pumps are driven by belting from two upright engines which together develop 800 horse power.

The cost of constructing the dock amounts in round numbers to 2,700,000 francs

(196) *The barge dock* forms the prolongation and end of the Calais Canal, and communicates on the eastern side with the eastern dock and on the west with the old port. The flooring is placed at the reference 1.95 meters, that is to say, 2.80 meters below the normal level of the canal (4.75 meters). The boats never draw more than 1.80 meters.

The quay walls of this dock are of solid masonry, set in hydraulic cement upon a bed of béton 0.70 meter thick. The height of the wall is 4.45 meters; its thickness varies from 2 meters at the base to 1.10 meters at the top, with a batter of one-fifth or one-sixth.

Two locks connect the eastern branch of this dock with the new eastern dock; they are 38.50 meters long and 6 wide, separated by a wall 7 meters thick. The gates are of oak and worked directly by hydraulic pressure.

(197) *The guard lock* is built at the lower end of the western branch of the boat basin, and is arranged so as to form a dam either against the sea or against the canal. Its gates must not only be able to resist the pressure of the water in both directions, but they should also be capable of being opened and closed against the stream, whatever may be the direction or the velocity of the current. The length of the lock is 26 meters, and its clear width 7; it is closed by two pairs of miter gates, each of which consists of two vertical wings of unequal width united to the same heelpost. When these are closed they form an angle slightly less than a right angle: when the lock is open each wing comes into its appropriate curved recess—in plan the quadrant

of a circle—formed in the side wall of the lock, and corresponding in shape to that of the gate.

The lock is closed when the narrower wings of the gates are brought together against the miter sill. In opening and closing, the second wing of each leaf remains within the curved recess, in which it moves with a slight play between itself and the curved wall. On each side of the lock are two separate culverts, starting from the lock head and tail and emptying into the curved recesses above referred to. These culverts can be opened or closed at will by a system of sluices, in such a manner that the pressure of the water discharged from them can be exerted against the exterior face of the wider wing of the leaf, at the head or tail end, whenever there is a difference of level at the two ends of the lock. If the culvert communicating with the lower end is closed, the gates will shut themselves if the direction of the fall is from the upper to the lower end. If this state of things is reversed, the sluice controlling the upper end of the culvert must be closed and that at the lower end opened.

Five bridges have been constructed over the Calais Canal and barge dock to maintain the railroad and boat communications.

(198) *Cost.*—The cost of the boat basin was as follows:

	Francs.
Earthwork and masonry	3,800,000
Lock gates and apparatus	290,000
Bridges	310,000
	4,400,000

The designs of the works above described were prepared under the direction of MM. Stoecklin, Plocq, and Guillain, chief engineers, and M. Vétillart, engineer of the port of Calais.

I wish to acknowledge my special obligations to M. Vétillart for descriptions and photographs.

Chapter XIX.—The new outer harbor at Boulogne.

(199) The situation of the port of Boulogne in 1878, when it was decided to make a deep harbor here, was as follows:

A bar was formed near the entrance to the jetties, rising to a height of 1 meter above the zero of the charts. The entrance to the interior channel, between two jetties 70 meters apart, exposed to all the winds from the west, was inaccessible at high tide for ships drawing more than 5 meters.

The bottom of the inner harbor, with a surface of 13 hectares, was 3 meters above zero. The dock, accessible through a lock 21 by 100 meters, and having a surface of 6.87 hectares, had its bottom 0.60 meter above zero.

The difficulties of access and the insufficient depth in the channel prevented this dock from doing its full service.

Notwitstanding all these difficulties the annual tonnage exceeded 983,000 tons, the number of passengers was 130,000, and the duties collected exceeded 7,500,000 francs.

(200) *Project for a deep-water harbor.*—There was a littoral current of 3 knots per hour in front of the port between the two rocky points of Heurt and Crèche, where the sand was always washed away but no shoal made. If, therefore, a breakwater 8 or 9 meters deep be erected from north to south, through shoals parallel to the direction of the current, and in a line with these two points, it will be exposed to erosion rather than to silting. If this breakwater be connected with the coast at its two extremities, and a principal entrance reserved toward the west, this pass will preserve its depth and no serious disturbance will be made in the régime of the coast.

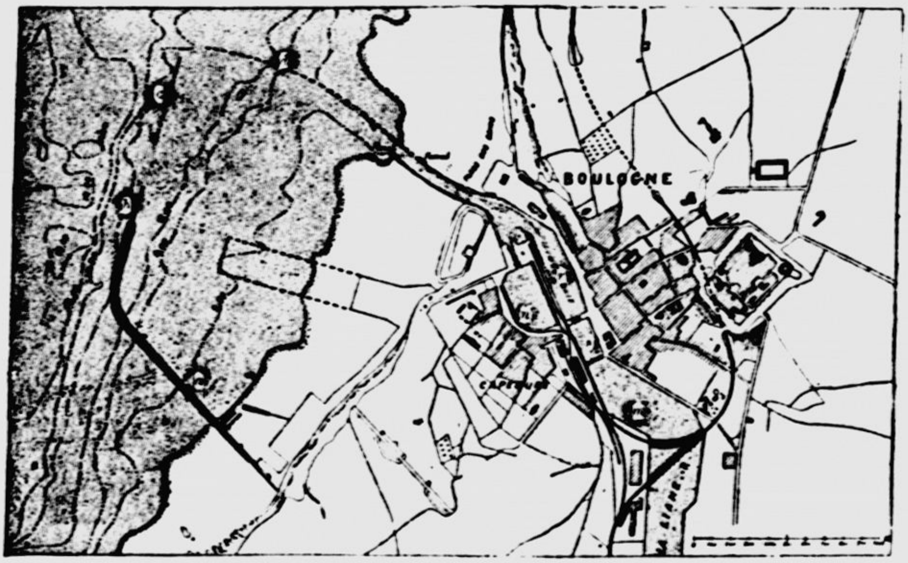


FIG. 118.—Plan of the port of Boulogne: *a*, the southwest dike; *b*, the dike parallel to the coast; *c*, the isolated mole; *d*, the northeast dike. The Liane River flows through, *m*, the storage basin, *s*, the inner basin, *r*, the inner harbor, then out through the jetties S.

The port thus formed will be in no danger of silting up. The project of M. Stoecklin, prepared according to the above principles, is represented in Fig. 118.

It consisted in making, in front and to the south of Boulogne, a new harbor nearly rectangular in shape, with an area of 300 hectares, having two passes open to a depth of 8 meters at low tide: in the interior, landings and quays are built, accessible at all times for steamers drawing 5 meters of water.

(201) The perimeter of this harbor is formed of three dikes, one parallel, and the others nearly at right angles to the shore. The first has a total length of 1,100 meters divided into two portions by an intermediate pass, called the western pass, 250 meters wide. The north branch, *c*, comprised between the west pass and the north pass

which separates it from the northeast jetty, *d*, is to form a mole 500 meters long, and separated from the land. The southern branch, *b*, 600 meters long, unites with the southwestern dike *a* by a curve of 350 meters radius. This last dike is nearly perpendicular to the shore, where it is united with the rocks. It is 1,650 meters long, including the curved portion.

The northeast dike, *d*, which completes the inclosure, is the prolongation for 1,440 meters of the actual northeast jetty. Its northwest extremity is separated from the isolated mole by the north pass, 150 meters wide.

(202) The object of the proposed improvements was as follows:

First. To furnish a harbor of refuge for the fishermen and coasters.

Second. To facilitate the access to the inner harbor by protecting the entrance into the channel against the waves at all times, and providing approaching vessels with a shelter where they could await in security a favorable time and tide.

Third. To provide quays accessible at all times for channel steamers as well as for coasters and fishing vessels.

(203) *Work done from* 1879 *to* 1889.—The work began in July, 1879. At the foot of the abrupt cliffs bordering on the sea between Boulogne and Portel they built two wharves, having a surface of 7 hectares included between two retaining walls, and these wharves were connected by a road with the city, and by a railroad with the northern railroad station. Quarries were opened at the foot of Portel cliffs and united with the wharves by inclined planes. They then constructed a little haven, included between the shore end of the southwest dike and two jetties 100 meters and 270 meters long, to facilitate the loading of the materials intended to form the substructure of the proposed dikes. It was only after these first works were finished that they could proceed with the construction of the dikes. The part of the inclosure of the deep-water harbor already finished includes the branches *a* and *b*. These two branches constitute in reality one and the same jetty, *a* beginning perpendicular to the coast, *b* parallel with it, and the two united by the arc of a circle of 350 meters radius. (Fig. 119).

This jetty, which forms a breakwater in the direction of the southwest and west, begins at a point on the coast between Boulogne and Portel, at 1,750 meters to the south of the actual entrance to the harbor. Its total length is 2,110 meters, including 1,265 meters for the dike *a* from its beginning, 360 meters for the curve, and 485 meters for *b*.

The profile of the dike consists of two distinct parts corresponding to the substructure and the superstructure. The substructure is formed by a mass of natural and artificial riprap, composed of a central core of stones weighing 100 kilograms apiece, resting on the bottom and rising to a level of 1 meter above low tide. The slopes of

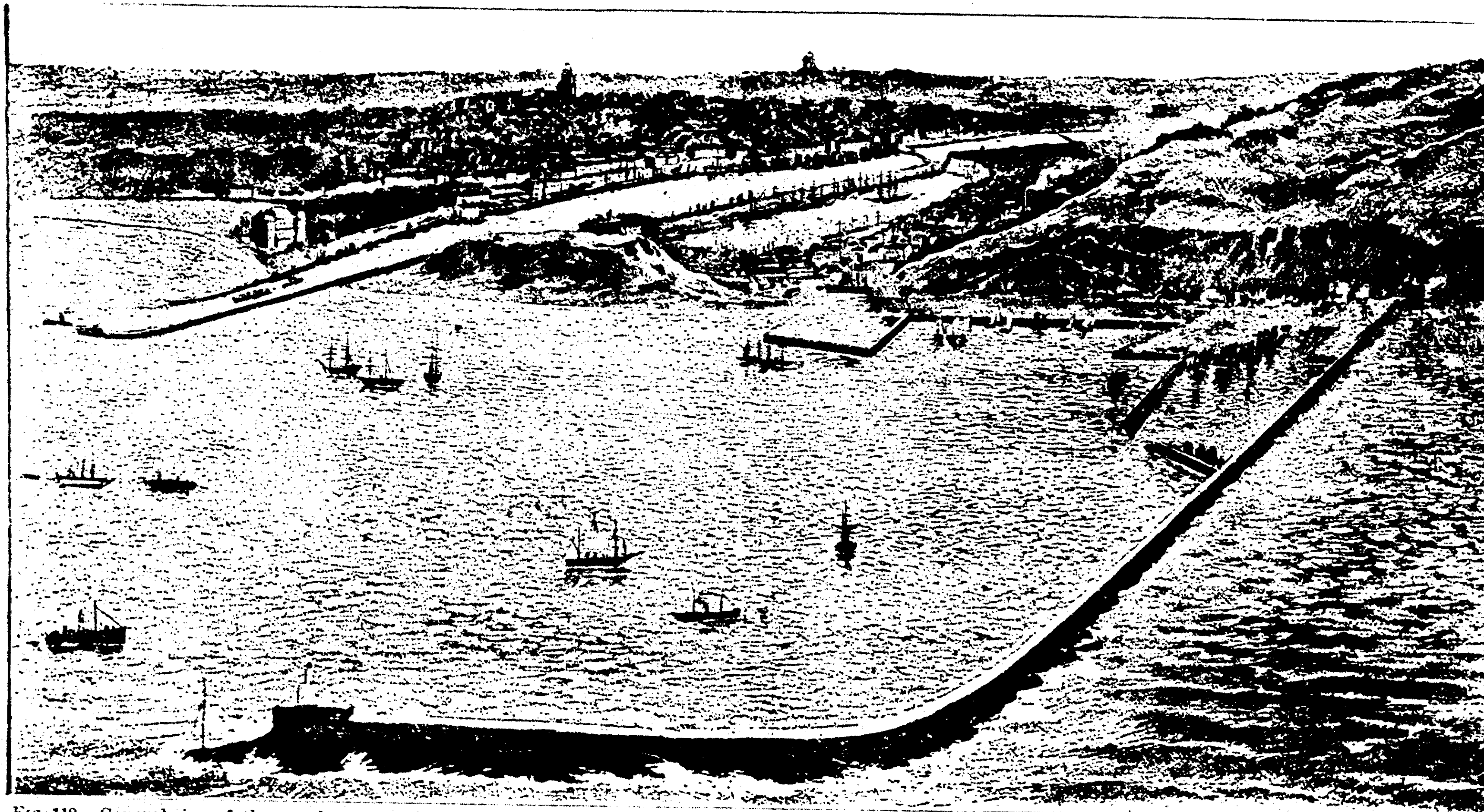


FIG. 119.—General view of the new deep-water harbor at Boulogne. On the right is the jetty, 1,750 meters long, perpendicular to the shore. Within is a sheltered haven formed by two small jetties, 100 and 270 meters long, respectively. On the left is seen a great landing, covering an area of 7 hectares. At the extreme left are the jetties leading to the inner harbor, the inner basin, and the storage basin.

this first mound are covered on the shore side, for a thickness of 2.50 meters, by what is designated as "rubble of the first category." It is a stone pitching made up of rocks weighing 500 kilograms each. On the side toward the sea the slope is protected, first, by a revetment of rubble work, made up of rocks weighing 6,000 kilograms apiece, called "rubble of the second category," and, second, by béton blocks of uniform dimensions weighing 33 tons each. (Fig. 120).

Between the references +2 and +4 meters rises a mass of masonry 9 meters wide, serving as the foundation of the masonry wall which constitutes the superstructure of the dike.

The profile of this wall is trapezoidal, 6.90 meters high, 7.66 meters wide at the base, and 6 at the top.

The upper platform rises to the reference 10.90 meters, that is, 2 meters above mean high water. It is surmounted by a parapet 1.40 meters high and from 2.50 to 2 meters thick. On each side of the

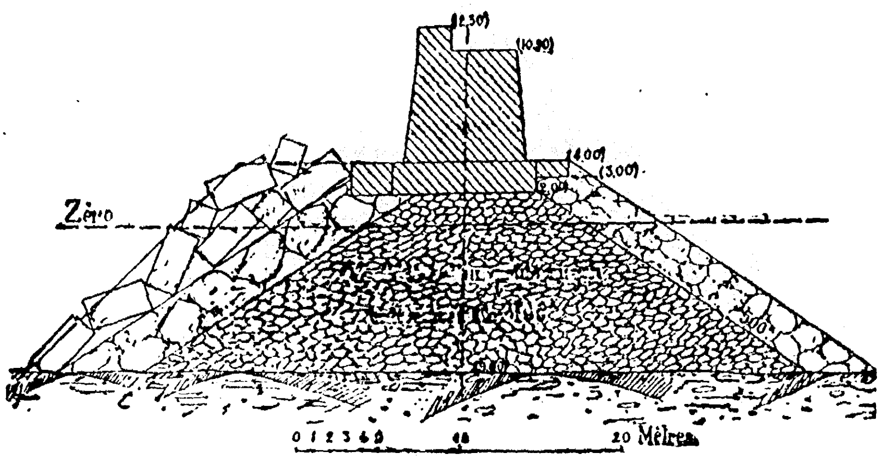


FIG. 120.—Cross section of the parallel dike *b*.

wall and on a level with the lower platform the slopes are consolidated by masonry bermes formed of isolated blocks, each 6 meters long, which serve to protect the foot of the wall and also afford a path for the workmen and materials at low tide. The thickness indicated for the wall was adopted at a distance of 1,350 meters from the beginning of the dike.

The width at the top is only 4 meters for a distance of 1,120 meters from the shore; then it is made 5 meters for a distance of 1,350.

All along the curve which forms the part of the dike most severely exposed to southwest winds and storms the width is 6 meters; the outer slopes have been loaded with several layers of artificial blocks, and the exterior bermes raised to the reference of 5 meters. A slope communicates between the upper platform of the dike and the interior berme, to facilitate the supply of materials during the construction, and increase the time of the work for each low tide. The dike is terminated by a provisional pier-head signal, and by a luminous buoy. The field work included a double organization corresponding to high and low tides. The sinking of the artificial blocks and the rocks for the revetment took place at high tide. The latter were transported and sunk by means of hopper barges towed by a little steamer; each of these barges carried a weight of 100 tons.

The artificial blocks were unloaded at high tide by means of a special wrought-iron barge having three vertical pits, with which at each trip of the barge they could sink three blocks, but this operation required a certain precision, and generally only one trip could be made at each high tide.

The loading and discharge of the riprap was possible, on the contrary, with waves 0.50 meter high, which allowed the use of more than half of the tide. At low tide the stones required to complete and even up the central core were sunk, as well as a great portion of the natural and artificial blocks which were to form the revetment of the side slopes. For the heavy rock work they made use of tip wagons; for the great blocks they employed three-wheeled trucks, the platform of which could be raised and tipped by means of jacks. These trucks ran upon rails laid on the bermes of the walls already constructed.

They were able to utilize, at low tide, four-fifths of the number of tides; during the winter they could only succeed in preventing the dispersion of the interior mass by the action of the waves. The advancement was difficult at first, and to avoid the loss of material they were obliged to stop the riprap work from November to April. Experience showed that the only way to prevent accidents, and to extend and preserve the advancement attained during the good season, was to construct, as soon as the platform emerged to a sufficient height, isolated blocks of masonry which loaded and consolidated this platform. These blocks were to make a part of the bermes and the foundation of the walls, but they rested sometimes as isolated blocks, and could settle until they had attained a state of stable equilibrium. At the end of about a year the blocks situated in the central part of the dike were united so as to form the foundations of the wall. At the moment of stopping work all the joints exposed to the waves were filled with rapid-setting cement. When the work recommenced this mortar was removed, the joints were cleaned, and new cement was placed on all the parts against which new masonry rested.

The total cost, from 1879 to 1889, of the organization of the works and the construction of the southwest and parallel dikes (*a* and *b*), amounts in round numbers to 14,500,000 francs. Besides, 1,850,000 were expended in constructing the first part of the wharf, and 2,000,000 were used up in dredging in the interior harbor and the entering pass.

(204) *Results obtained—Improvements to be made.*—Although the programme of 1878 has not yet been completed the following results may be considered as already obtained.

First. The entrance to the interior channel is completely sheltered against the southwest winds and tempests, which are the most frequent and violent in this region; it is even partially sheltered against the tempests and winds from the west.

Second. The régime of the currents at the entrance of the port has been completely modified. The current of flow passed formerly at the head of the jetties, at the moment of high tide, with such velocity during certain tides as to render the entry of the port impossible for great ships; it is carried to-day beyond the dike and is only felt at the entry of the port as a feeble eddy.

Third. The protection obtained at the entrance of the port against the waves and currents, has permitted the deepening of the exterior pass and the channel, and the maintenance without difficulty of the depths already obtained. These depths are to-day more than 4 meters below zero in the exterior pass, and 2 meters between the jetties. They are sufficient to allow the regular service of steamers between Boulogne and Folkestone, a service organized more than three years ago.

Fourth. The dike already forms a little haven of 50 acres sufficiently sheltered from the southwest and west winds, which will be of great service as soon as the dredging giving it a depth of 6 or 7 meters shall be finshed.

With regard to the modifications of the beaches, it may be stated that the anticipations of the authors of the project are realized. There is a tendency to erosion at the bottom, in front of the parallel dike, indicating that the depth in the passes of the harbor will be kept in order naturally if the primitive project is entirely realized. The beach situated on the south of the southwest branch has risen notably in its upper parts, the slope has become more steep, but its foot does not appear to have changed, and the great current which follows the lateral branch will not permit it to advance. On the interior of the harbor, that is to say, on the north of the dike, there is a little silting, produced on account of the calm obtained, but, as has been foreseen, this silting is of no importance and can easily be removed by dredging.

These excellent results have allowed the completion of the programme of 1878 to be adjourned without prejudice to local interests. The conditions of access to the port of Boulogne are such to-day that the quays and wharves projected for the deep-water harbor, always accessible to the steamers and fishermen, may be carried to the inner harbor. The deepening of the harbor and the construction of the new quays will be immediately carried out.

(205) As to the construction of the dikes, it is possible that when the work is recommenced the engineers will consider them useless for the security of the harbor, the complete closing of which had been originally planned; a simple prolongation of the actual parallel

dike for a length of 500 or 600 meters will probably be sufficient to assure an excellent shelter against great storms.

But the works must be completed by important dredging, to assure, over a sufficient extent, the depth of 8 meters requisite for ship navigation.

The project for the deep-water harbor at Boulogne was drawn up by M. Stoecklin, general inspector. The works were carried out successively under the direction of MM. Plocq, Guillain, and Vétillart, chief engineers, and Barreau and Mommerqué, assistant engineers.

CHAPTER XX.—PORT OF HAVRE—BELLOT LOCK.

(206) *Bellot lock.*—The Bellot basin for the use of the transatlantic steamers connects with the Eure basin by a lock 30 meters wide. The lock is furnished with ebb gates separating the two basins. It is crossed by a drawbridge of a single span and double track. Hydraulic capstans placed on each wing wall are designed to facilitate hauling the ships. All the working apparatus is moved by hy-

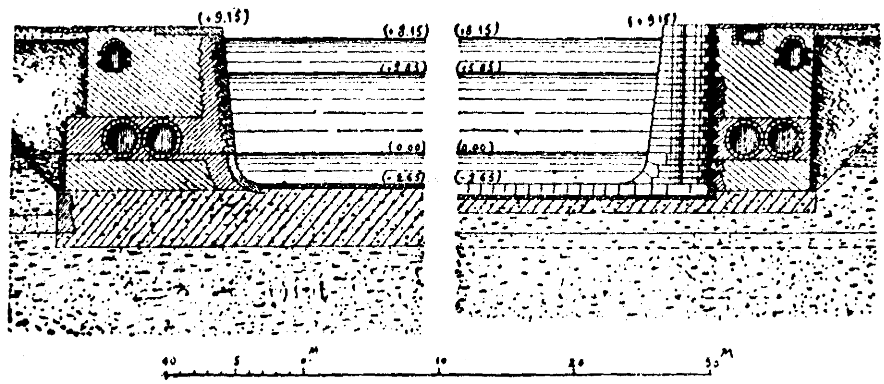
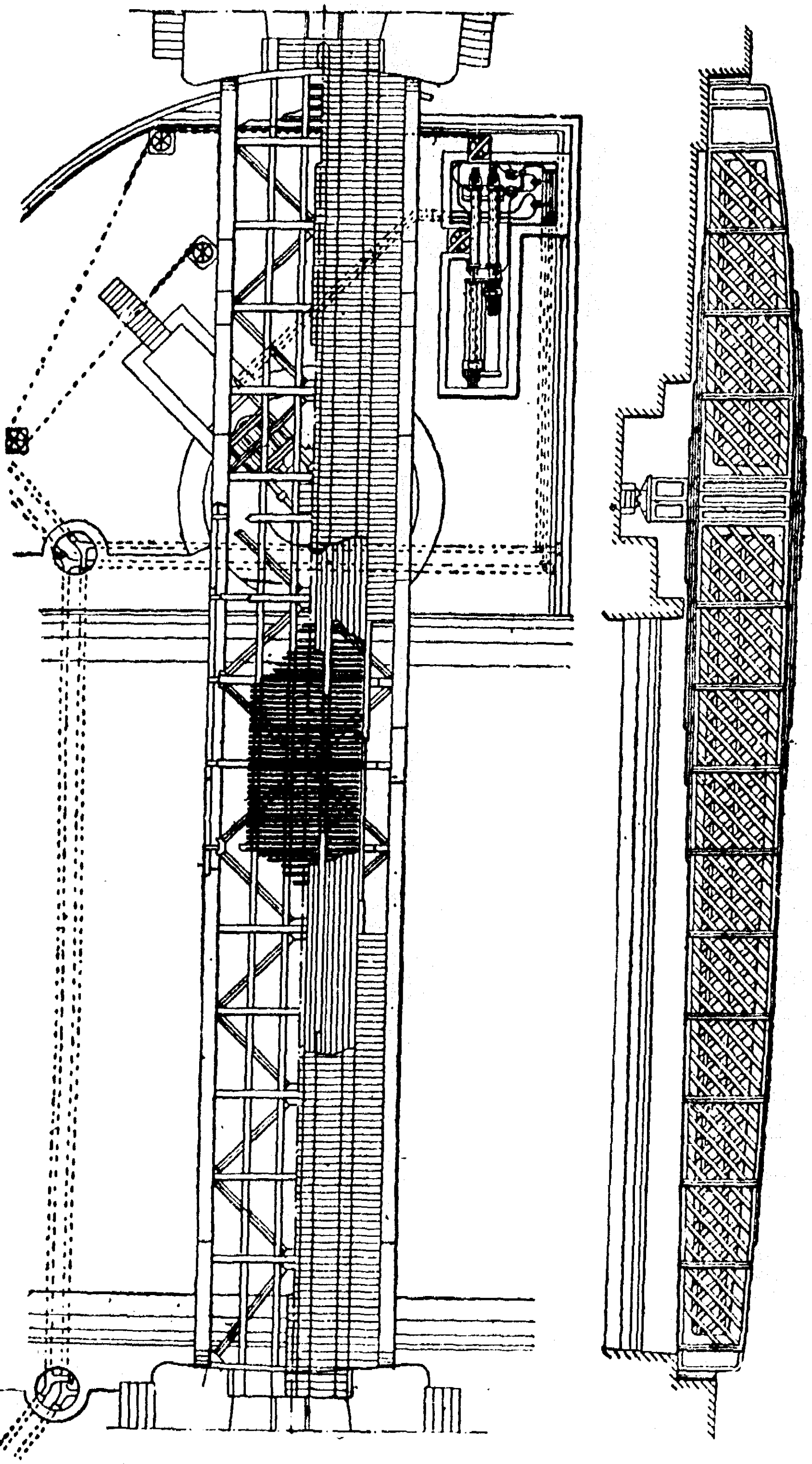


FIG. 121. Transverse section of the Bellot lock.

draulic power. The chamber walls of the lock are vertical, and unite with the invert by circular arcs of 2 meters radius; their thickness is 7.70 meters, and the sill is placed at the reference −2.65 meters, which gives a draught of 8.30 meters at low tide.

(207) *Iron drawbridge.*—The iron bridge just mentioned is 53.25 meters long—36 meters for the span, 17.25 meters for the breech, and 7.72 meters wide. It consists of two girders forming the parapets, with a variable height from the extremity to the point where the tension is a maximum. These girders are united by cross girders and wind ties. The longitudinal girders have a height of 2.10 meters at their extremities, and 4 meters at the right of the pivot. They are formed of a trellis of channel iron inclined at 45 degrees and spaced 0.85 meter between the axes. The uprights divide the girder into fourteen panels 3.40 meters wide. The plate-iron transverse beams are 80 centimeters high and 3.40 meters apart; they rest on the lower plate of the side girders, and are united by stringers placed

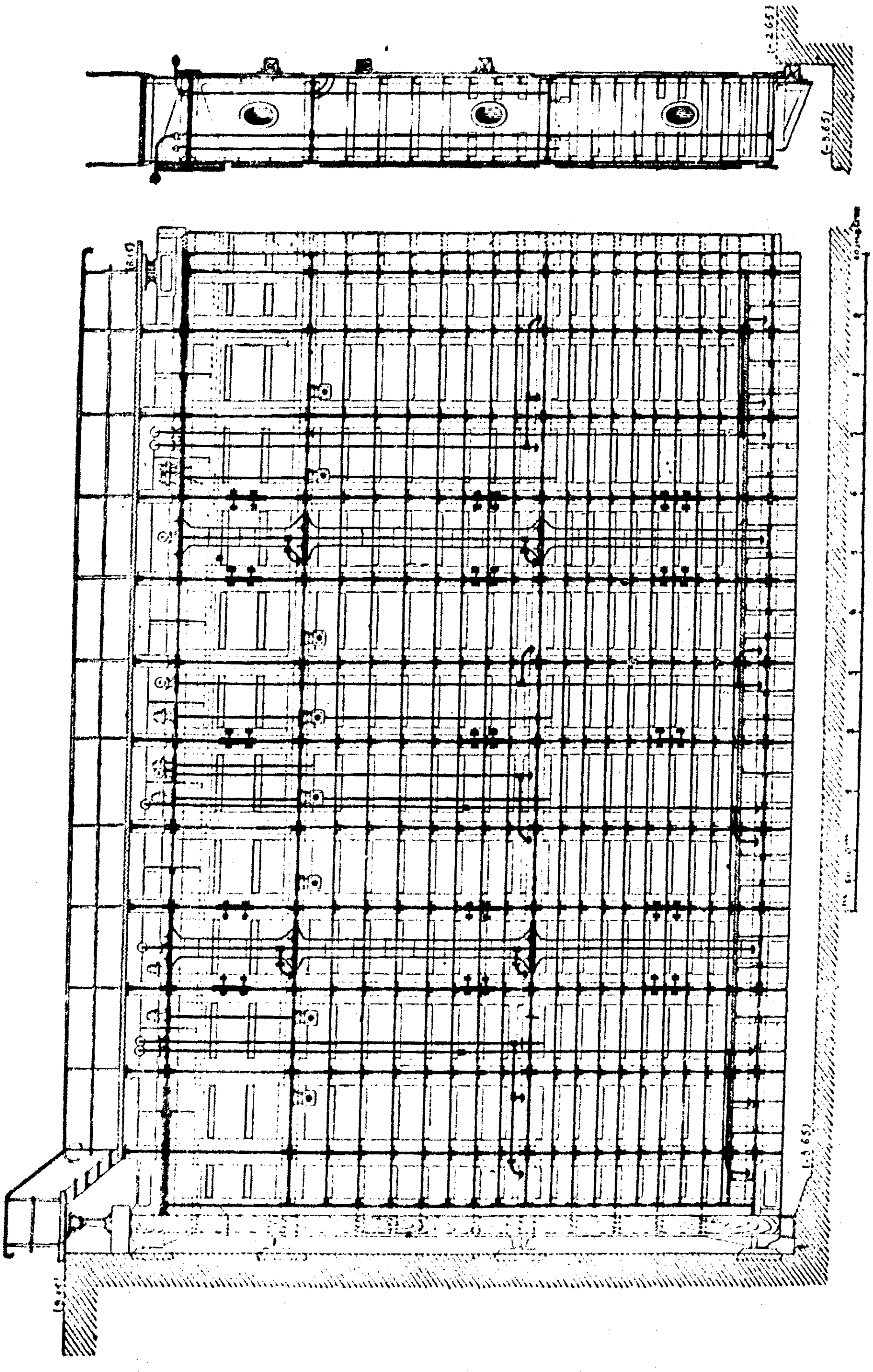
under the rails of the railroad and under the plates of the roadway. The bridge is calculated to allow the passage on the railroad of the heaviest locómotives of the Western Company (14 tons per axle), or



FIGS. 122 and 123.—Elevation and plan of the revolving bridge over the Bellot lock.

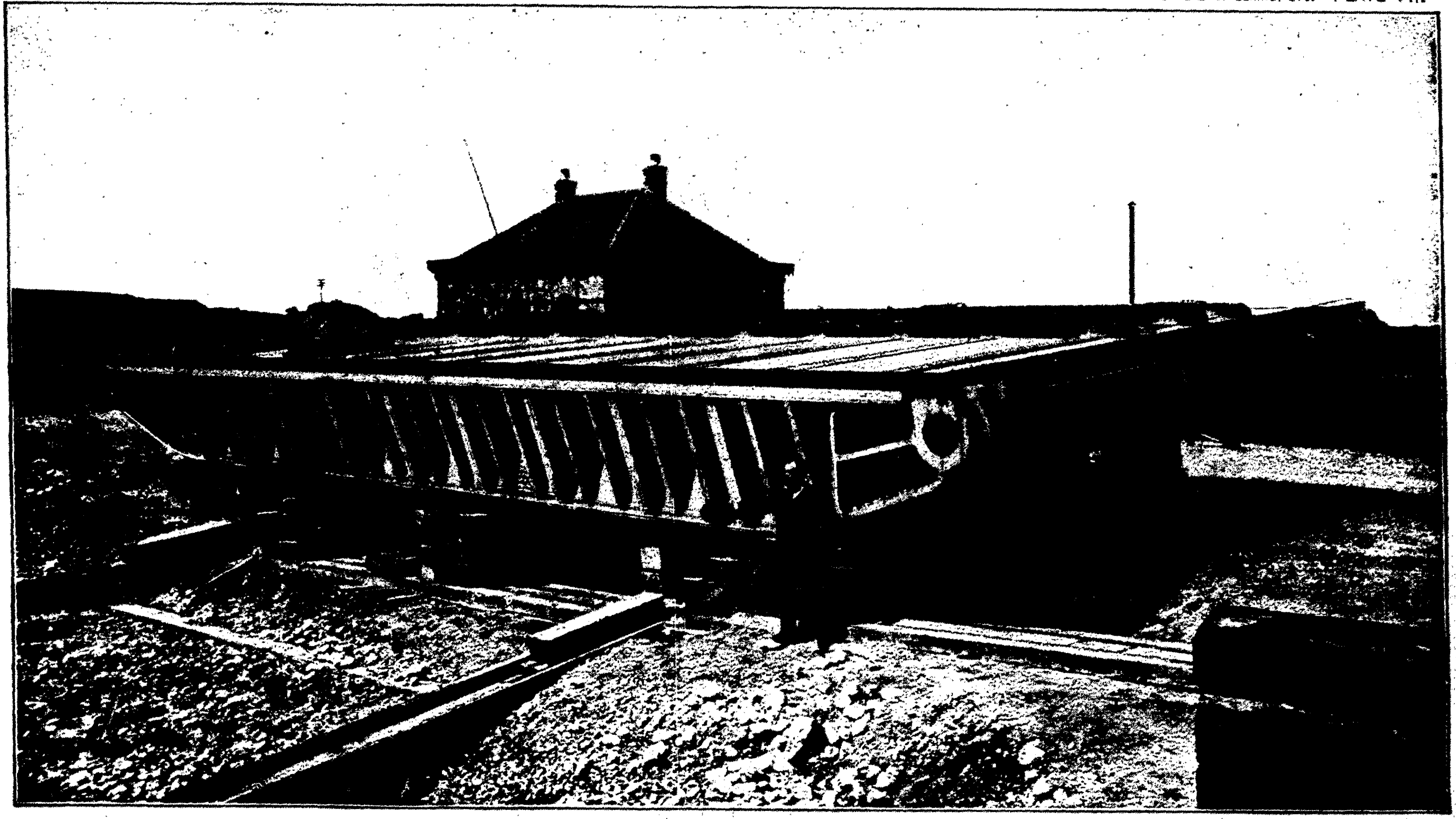
the simultaneous passage upon each of the roadways of two files of carts weighing 11 tons per axle.

(208) *Lock gates.*—The lock gates (see Plate VII) are of plate iron, each leaf 16.515 meters wide and 10.90 meters high. These gates retain the water in the Bellot basin at the reference 7.85 meters, that



FIGS. 124 and 125.—Elevation and section of a leaf of the gates of the Bellot lock

is to say, at 10.50 meters above the level of the invert. They are calculated on the hypothesis that the level of the water in the Eure basin may by some accident fall to the zero of the charts. The sys-



HAVRE. LOCK GATES OF THE BELLOT BASIN.

tem of construction adopted consists of verticals supporting the exterior skin and resting on two horizontal crossbeams, one on the upper part and the other on the lower. The skeleton consists of:

First. A frame made by an upper cross girder, a lower cross girder, and two tubular pits forming the heel and miter posts.

Second. Nine vertical ribs spaced 1.393 meters apart.

Third. Two horizontal intermediate girders to brace the uprights.

Fourth. Horizontal U-shaped plates unequally spaced and serving to stiffen the skin which forms the two faces of the gate.

The space included between the lower horizontal girder and the first intermediate, counting from below, constitutes a series of water-tight chambers intended to ballast the leaf; the rest of the space included between the lower horizontal girder and the second intermediate one forms air chambers. Above this second horizontal girder the compartments communicate with the water of the Bellot basin.

Two vertical water-tight shafts, with manholes and ladders conveniently placed, afford access to the different portions of the gate. The pivot, which is placed in the invert, is of forged steel. It is the same with the upper pivot of the leaf. The anchor which serves as the hub of the pivot and which transmits to the masonry the pressure of the leaves, the pivot step, and the two intermediate counterforts which maintain the direction of the heel post are of cast steel. The anchorage straps which transmit the pressure to the masonry rest on steel plates 0.06 meter thick, and are embedded in the granite forming the quoin. The air chambers, which are not sufficiently tight to avoid leakage, are cleared by means of compressed air.

(209) *Hydraulic apparatus.*—The Bellot lock is furnished with hydraulic apparatus which works the bridge, the gates, the sluices, and the hydraulic capstans. All these pieces are worked by water under pressure from a central station. The pressure is 52 kilograms per square centimeter.

The general arrangement of the apparatus for operating the bridge is as follows: The two supporting beams of the bridge rest upon a box girder, which is itself placed upon a pivot contained in the cylindrical step resting on a metallic wedge. This wedge, acted on directly by a hydraulic press, gives a vertical movement to the cylinder and consequently raises the entire bridge. (Fig. 126).

The advantage of this mode of raising the bridge is as follows: The pivot undergoes no displacement with respect to the cylinder, and a constant contact of the metallic surfaces subsists through the whole motion. A leak in the stuffing box would not, consequently, produce any accident, the bridge being held by the wedge in its position.

The rotation of the bridge is effected by the action of a pair of twin pulleys. To facilitate this motion and avoid the great friction of the metallic surfaces in contact, the cylindrical step carries in its upper part a stuffing box, forming a tight joint between the pivot and the cylinder. Water under pressure, introduced in the small slots made in surfaces of contact, supports the bridge without raising it, and effects the rotation upon the water itself.

The bridge when closed rests on two supports upon each side of the chamber walls at its extremities. During the motion of lifting

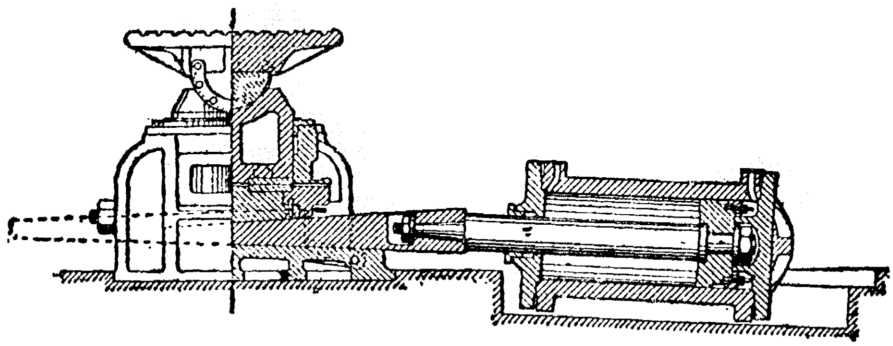


FIG. 126.—Lifting press and wedge of the revolving bridge.

it turns around a semicylinder fixed under the framing, and engages in a circular cavity made in the upper part of the pivot. During the rotation the bridge rests on its pivot, and upon the breech rollers, which are four in number, two on each side. The amount of water used for lifting the bridge is 462 liters, and for lowering, 378 liters;

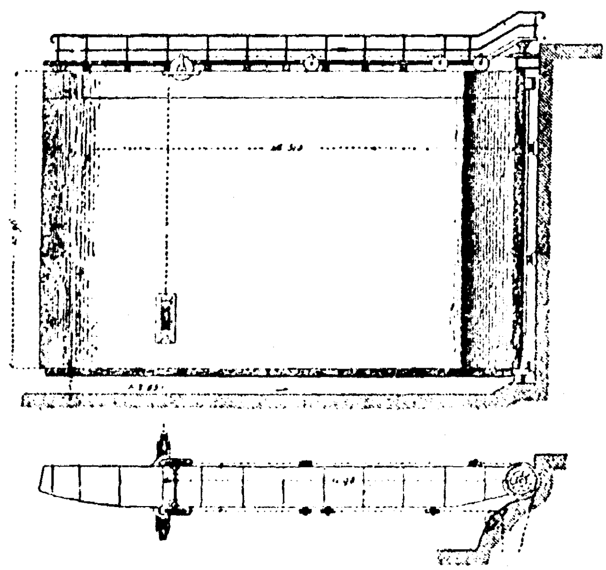


FIG. 127.—Elevation and plan of a leaf of the Belot lock gates.

for turning, 150 liters when a partial power is used, and 292 liters when the maximum power is used. This last is regulated according to the force of the wind, which is the principal obstacle to the motion. The total quantity used for the double operation of opening and closing is 1,140 liters or 1,340 liters, according as the greater or the less power is used. The time required for opening is two minutes.

(210) *The opening of the gates.*—The apparatus for moving the gates comprises one for opening, and another for closing them. The first consists of a cylinder with a plunger forming a pulley; the second is identical, with the single difference that the cylinder, instead of having a simple plunger, is furnished with a piston which has a much longer stroke, so as to raise the slack given to the closing chain and so allow the passage of ships. Both chains are fastened to the bottom of the lock. After passing around the guide pulleys placed on the gates they pass around the tackles of the opening and closing apparatus, placed side by side, and set in motion by a single valve.

The lower guide pulleys are mounted on a swivel block, allowing them to take the different directions, followed by the chain. (Figs. 127 and 128).

The quantity of water used for opening or closing is 308 liters.

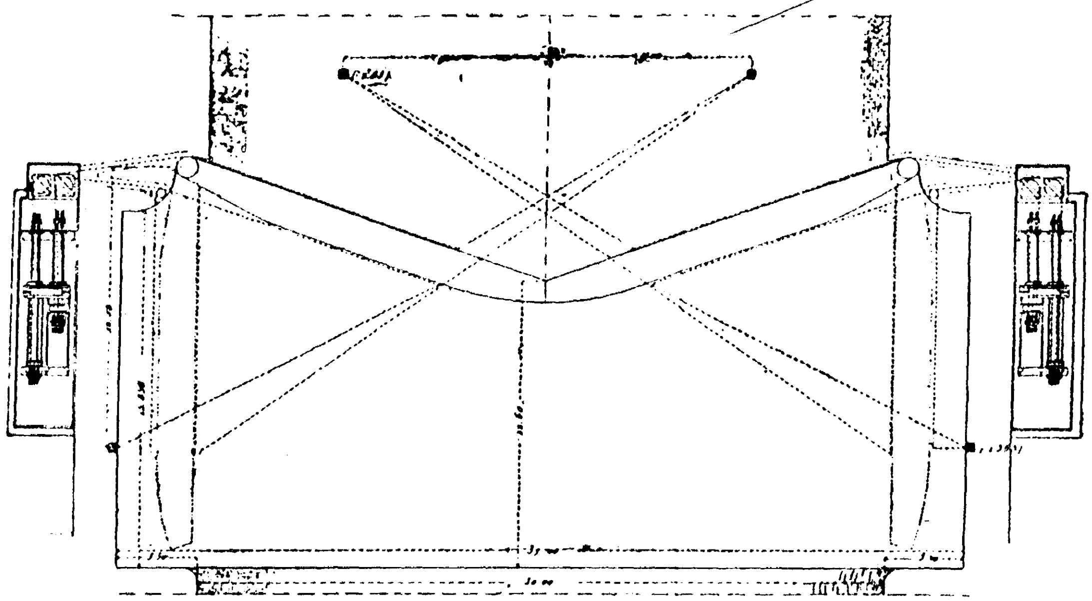


FIG. 128.—Complete plan of the lock gates and the operating apparatus.

The sluices used to close the culverts between the Eure and Bellot basin are cylindrical, 2.08 meters in diameter. The apparatus for working them is calculated on the hypothesis of a change of level of 3 meters; it consists, for each sluice, of a cylinder with a piston attached directly to the valve rod.

The accumulator, to regulate the pressure, has a capacity of 755 liters, and the load corresponds to a pressure of 52 kilograms per square centimeter.

A steam engine of 15 horse power is provided, to take the place of the accumulator in case of need.

The compressing pumps consist of three sets of plunger pumps, coupled to the same shaft by three cranks 120 degrees from each other.

The amount furnished is 53 liters per minute. This quantity allows a complete opening and closing of the bridge every twenty-five minutes, which is sufficient to guarantee the service in case of accident to the pipes.

Cost.—The cost of the lock is estimated at 1,980,000 francs. The engineers who prepared the project and directed the works are, MM. Bellot and Quinette de Rochemont, chief engineers: Renaud E. Widmer and H. Desprez, assistant engineers.

IRON DOCK SHEDS.

(211) *Description of the sheds.*—The first principle laid down in the construction of the sheds was to diminish, as much as possible, compatible with an economical construction, the number of the supports.

The pillars, which rise in the middle of the covered surfaces, take up the place of merchandise and are a notable obstacle to traffic. This hindrance is especially sensible at Havre, where the transportation by carts has an important place.

For the southern sheds (Pl. VIII) there are two spans of 27.50 meters. The roof trusses are spaced 16 meters and united by longitudinal lattice girders parallel to the quay.

The principal dimensions are given in the following table:

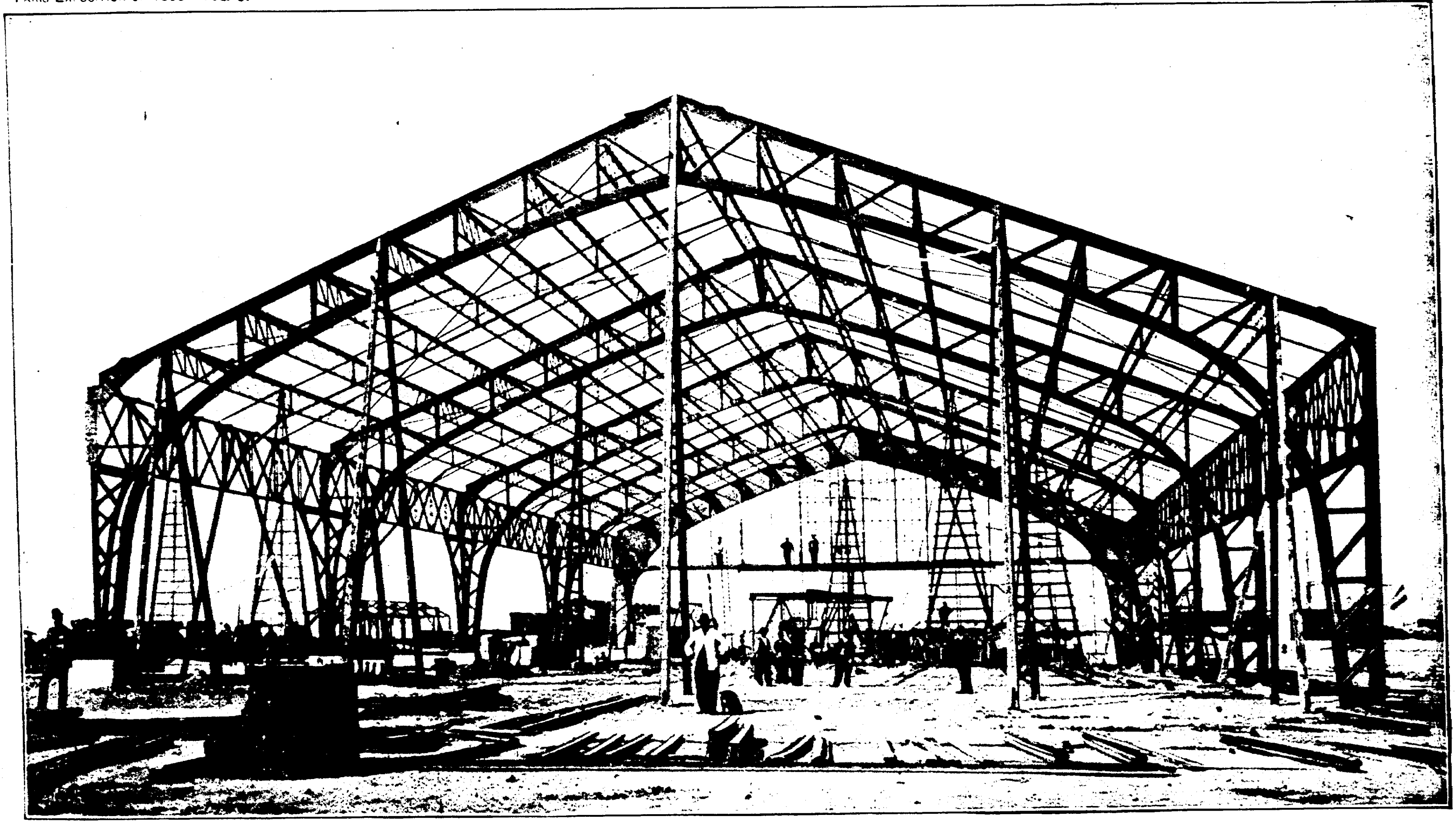
	Meters.
Span of the trusses	27.50
Distance apart of the principal trusses	16.00
Total height	12.60
Height of the side doors	4.75
Construction of the purlins (lattice):	
Height of the purlins	0.60
Distance apart of the purlins	1.75

The cost of the sheds varies according to their dimensions. The cost of this shed was 42 francs per square meter, covered.

CHAPTER XXI.—PORT OF HAVRE—IRON WAVE BREAKER ON THE BREAKWATER AT THE SOUTH SIDE OF THE OUTER HARBOR.

(212) Three sloping breakwaters are placed at the entrance of the port of Havre, two on the north bank and one on the south bank of the channel. To prevent the ships from running into the masonry of these works, and to permit the passage of pedestrians along the channel, a wave-breaker has been constructed on the sill of each of the breakwaters. The northern wave-breakers are of wood, that at the south is of iron. It is 100 meters long and its plan is curved. It has a height of 8.50 meters, measured from the sill of the breakwater (at the reference 2.15 meters) to the footpath which forms the coping, at the reference of 10.65 meters.

It consists (Fig. 129) of sixteen trusses 6 meters apart: each truss consists of (1) a bedplate, *e e*, united to a vertical web by two angle



FRAME WORK OF THE IRON DOCK SHEDS AT HAVRE.

irons built into the masonry; (2) a corner post, *a b*, formed of two channel irons placed back to back and united to the plate by two channel-iron beams; (3) a diagonal brace, *e d*, equally of channel iron, united at the extremity to the plate, next to *a b*, and to the two diagonal beams *c s* and *m n*, and supporting at its upper extremity the end of the roadway; (4) a horizontal beam, *a d*, placed in the upper part; (5) two intermediate pieces, *t u*, and *v x*, uniting the corner post and the diagonal brace *e d*. The corner post has a batter of one-fifth.

The trusses are united by flush iron parapets, and also by seven horizontal rails of channel iron, riveted, behind the corner post, upon the diagonal beams and upon the two intermediate pieces; besides, they are connected on the interior by iron tie-rods.

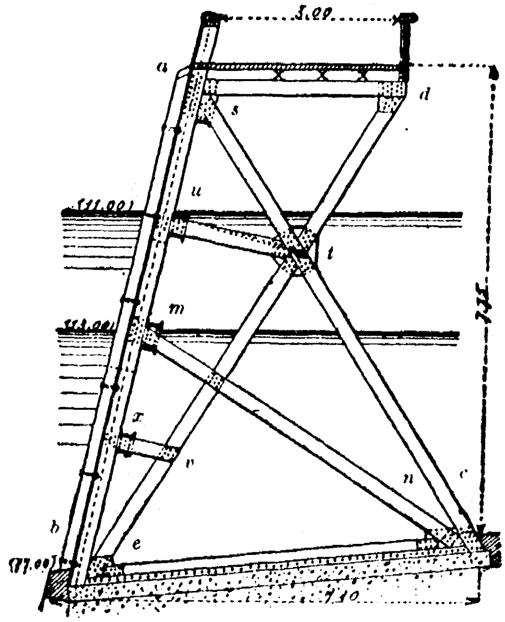


FIG. 129.—Iron wave breaker.

Between two consecutive trusses there are three intermediate posts identical with the corner posts and spaced 1.50 meters. They rest upon horizontal rails, and their feet are imbedded in the masonry sill.

The corner posts are cased with oak. The footbridge is formed of of four courses of double T iron supporting an oak flooring. It is furnished with two wrought-iron parapets 0.80 meter high, surmounted by wooden hand rail. It is 3 meters wide.

The iron is galvanized. The oak casings are protected by large headed nails driven in below just to the level of the water; they are tarred above.

The trusses are put together in the breakwater chambers, then raised and fastened without any difficulty. The design was prepared and the work directed by MM. Quinette de Rochemont and Maurice Widmer, engineers, under the orders of M. Bellot, engineer in chief.

CHAPTER XXII.—CANAL FROM HAVRE TO TANCARVILLE—SINGLE GATE OF THE TANCARVILLE LOCK.

(213) The canal from Havre to Tancarville was built to facilitate commerce between Havre and the Seine and to avoid the dangers of traversing the estuary by canal barges. It begins at Havre and enters the Seine near Tancarville, 96 kilometers below Rouen. Its total length is 25 kilometers.

The canal is formed of a single bay. The position of the water level, intermediate between high tide and low tide at Havre, and the high tide and low tide at Tancarville, required the construction of two locks, one at Havre and the other at Tancarville. In order to be able to lock boats under all circumstances each one of these locks is furnished with gates closing in both directions.

The Tancarville locks are furnished with four single-leaf gates (Figs. 130–133). These four gates have in plan the same dimensions. They only differ in height. Their upper part is 0.05 meter above the maximum high water which they have to sustain. At their lower part they bear 0.20 meter against the masonry sills. The flood gates are, respectively, 9.85 and 9.25 meters in height. The ebb gates are 7.85 and 7.25 meters. Their maximum width is 4.02 meters. Their length is 18.75 meters. When they are put in the lock chamber they rest 0.20 meter behind the face of the wall.

Each of these gates is built so as to float, whatever may be the height of the surrounding water above its minimum level, which is that of low tide (2.75 meters). For this purpose a horizontal beam with a flush web is placed at this level, which forms a tight deck and constitutes a compartment of the lower part of the gate, where the ballast is placed, and where the water can never get in. Upon this horizontal deck three vertical lattice beams are placed, upon which are put two horizontal belts. These belts support vertical members on which the sheet-iron skins are riveted.

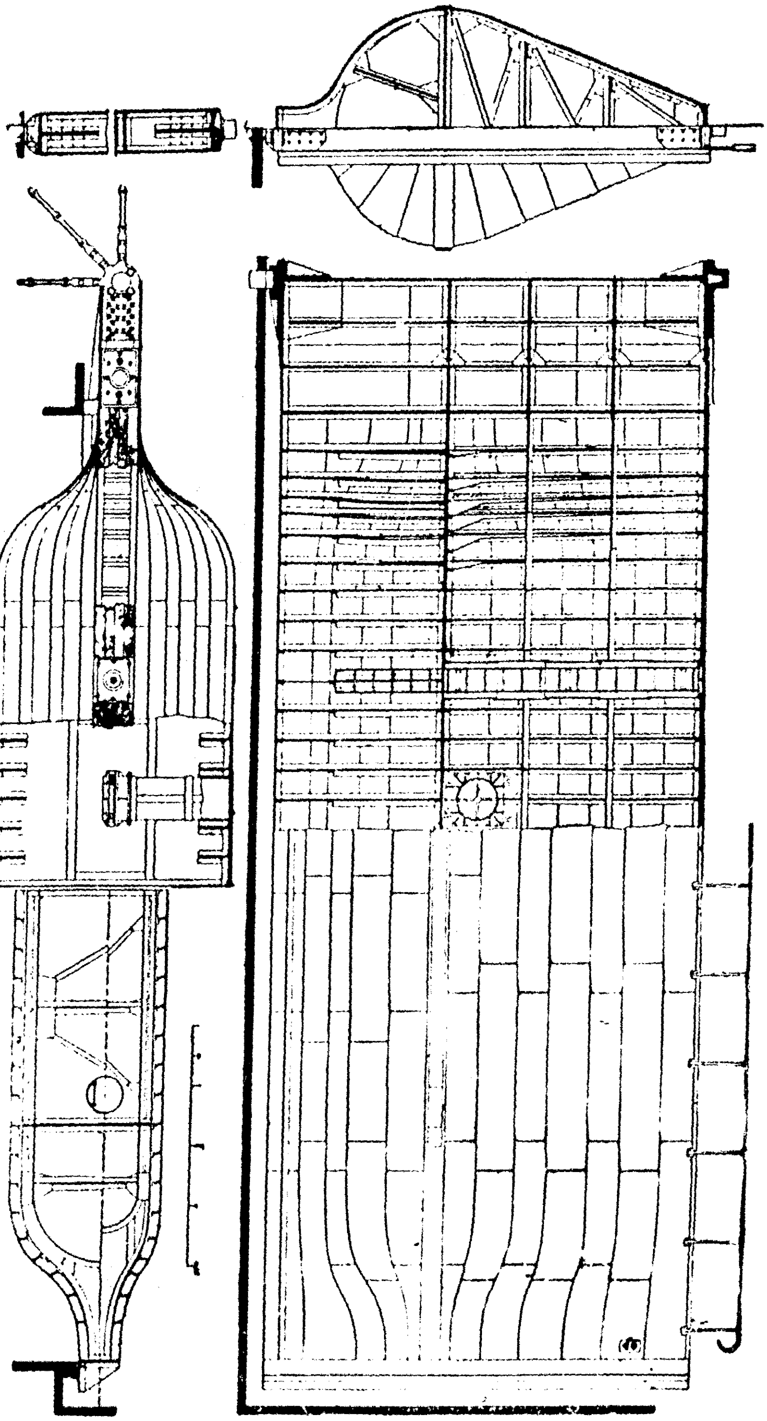
The gate is completed at one of its extremities by a rectangular compartment 2.25 meters long, and is furnished with a trunnion at its upper part and a bearing at its lower part. The trunnion works in a collar fixed in the masonry, and the bearing rests on a pivot fastened into the invert.

Wooden casings fixed to the gate insure the tightness of the contact of the leaves and sill.

Iron culverts, capable of being closed by sluices, allow the water in the canal to penetrate freely into the gate above the tight deck, so that when the water rises above the reference 2.75 meters the equilibrium is not disturbed.

Iron shafts rise from the deck just to the upper part of the gate, so that the lower compartment can always be inspected and the ballast handled. They are ordinarily closed by a tight cover.

The gates were constructed in the locks themselves, which were pumped out for the purpose. The compartment, 2.25 meters long, which forms the heel post, was carried from the workshop all put together. It was placed immediately upon the pivot and served as a base for mounting the rest of the leaf.



Figs. 130, 131, 132, and 133.—Elevation, half plan, and sections of the Tancarville lock gate.

When a gate has to be repaired the sluices of the culverts are closed at low tide. The tide rises, lifting the gate, which is made fast to the side of a barge to avoid any chance of accident, and is then carried into the dry dock at Havre. It is brought back and placed upon its pivot during ebb tide. At low tide the collar is put on and the culvert sluices are raised.

This new system of gate was invented by M. Bellot when he was chief engineer at Havré. It presents several advantages over the system in general use. In certain cases, especially at Tancarville, there is economy in the masonry. Great difficulties are avoided in making the gate itself, the dimensions of which need not have great precision in order that its tightness be absolute.

Slight variations in the form of the leaves do not prevent this tightness.

When the gates are exposed to the waves or a strong current the miter gates are exposed to shocks which are liable to break the collars. The one-leaf gates only beat upon their edges and the chance of accident is very much less.

Finally, the operation is simplified, and the closing of one leaf is effected without the attention which is required in miter gates. The superiority of the system is also shown in the various accidents which would have broken miter gates when the single leaf has resisted perfectly.

The designs for the Tancarville gates were prepared and the work directed under the orders of MM. Bellot and Quinette de Rochemont, chief engineers, by M. Maurice Widmer, assistant. The gates were built by M. Baudet, Donon & Co., constructors, Paris.

CHAPTER XXIII.—SLIPWAY BUILT BY THE CHAMBER OF COMMERCE AT ROUEN FOR THE REPAIR OF SHIPS.

(214) The port of Rouen has been completely changed since 1887. Actually none of the old quays are left: they have all been replaced by new ones. A timber basin bordered with quays 1,185 meters long with an area of 125,000 square meters has been finished, also a petroleum dock having accessible banks of 1,460 meters with six landing stages and an area of 115,000 square meters.

(215) The chamber of commerce has lately built a slipway according to Labat's system which may be described as follows:

The transverse slipway at Rouen is 90 meters long; it can accommodate ships 95 meters long and weighing 1,800 tons. The slope is 20 per cent; its width is 51.30 meters, and the travel of the cradle is 31.51 meters, corresponding to a rise of 7.16 meters.

It can be traversed in 5, 3½, or 2 hours according to the coupling of the winding gear.

When the cradle is at the bottom of its course, the level of the keel blocks is 4.50 below high water; when it is at the top, this level is 1 meter above high water.

The inclined plane is formed of forty-two beams (Figs. 134, 135, 138) resting on piles united together by bridle pieces. These beams support steel rails.

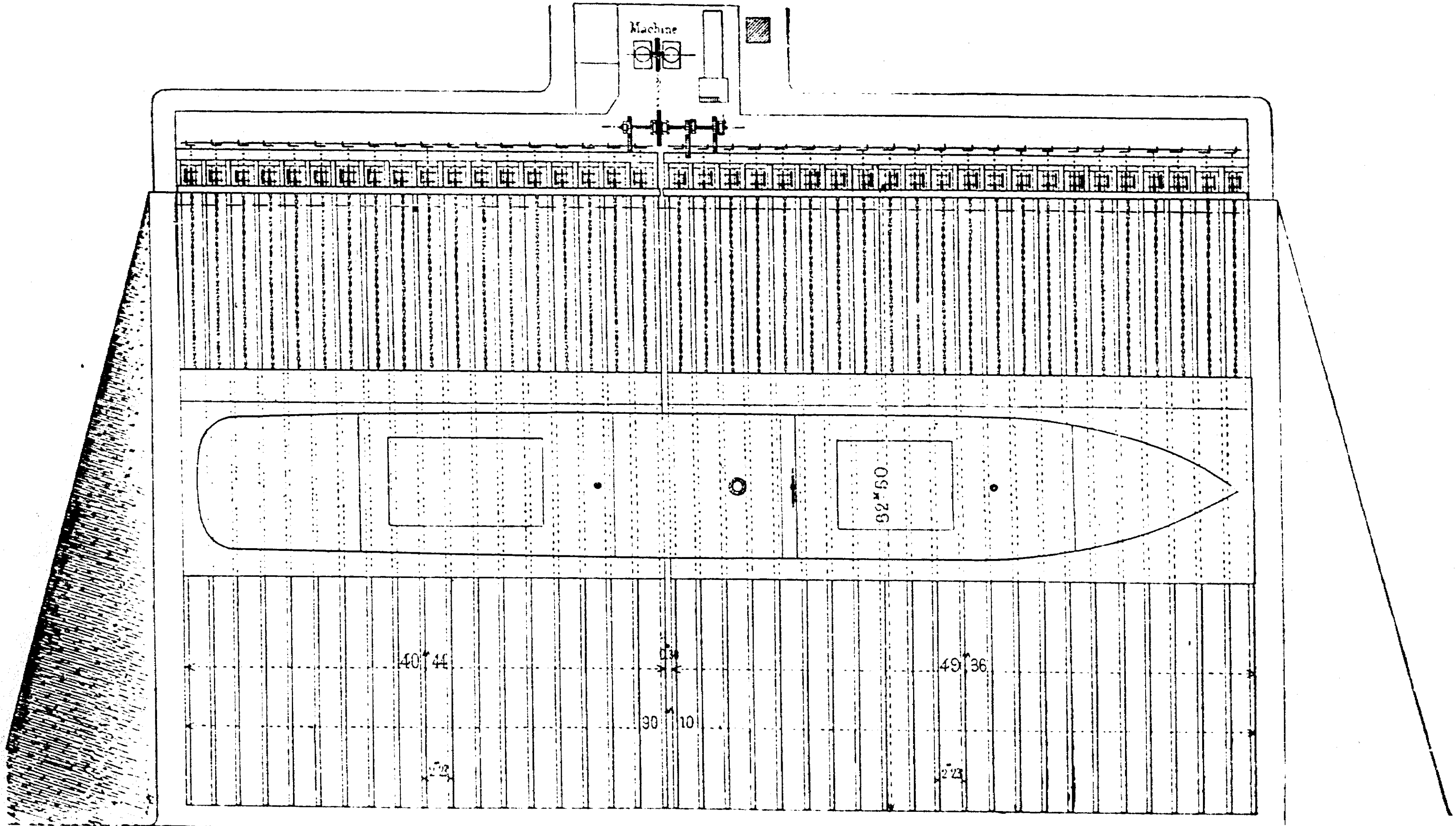


FIG. 131 Slipway at Rouen General plan

SLIPWAY AT ROUEN.

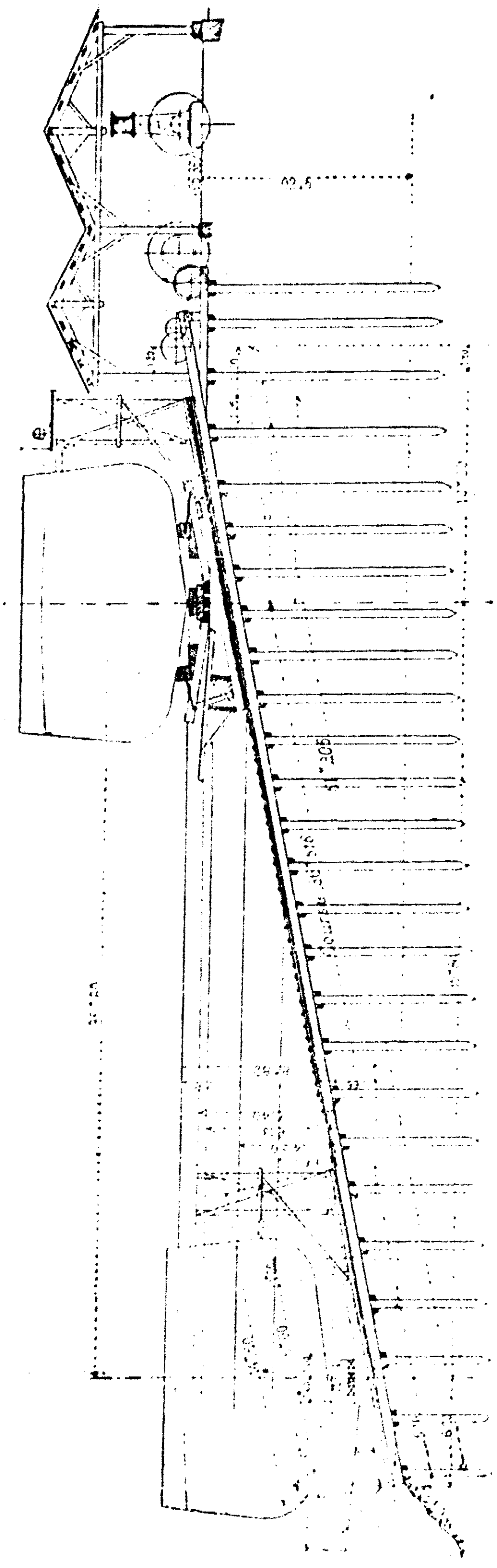


FIG. 135. Cross section of the slipway.

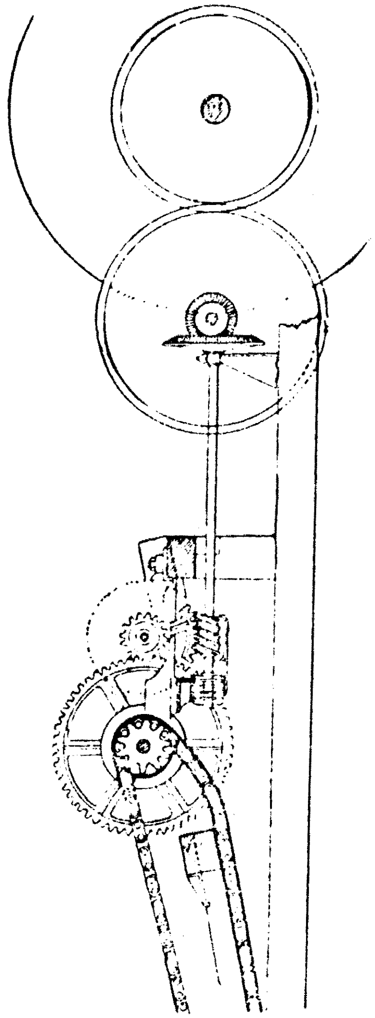


FIG. 136. Hauling machinery.

The cradle is formed of forty-two box-girders firmly braced, corresponding to the forty-two beams of the inclined plane; each girder carries also a steel rail. Between these two sets of rails, strings of rollers are placed on which the cradle-truck rolls.

The cradle is divided into two parts, 49.36 and 40.44 meters in length; which can be worked together or separately, so as to raise a large ship or two small ones. On the land side the cradle carries a service bridge high enough to be always out of water.

The hauling chains, forty in number, are attached to movable sheaves placed midway between the beams of the cradle: these pulleys being connected by a compensating cable (Fig. 137) which divides equally the tension between all the chains. This cable passes alternately around one of the movable pulleys and a pulley fixed to the cradle. Its ends are attached to the cradle.

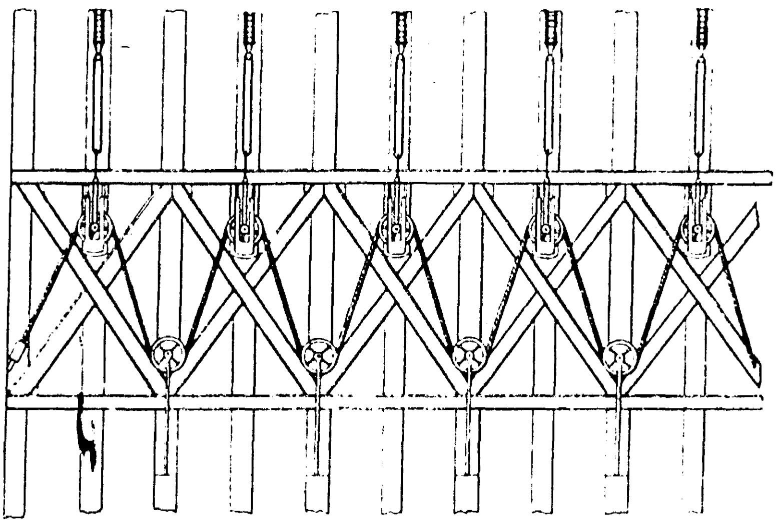


FIG. 137.—Method of attaching the compensating cable to the cradle.

Each traction chain passes round a winch drum driven by an endless screw, which is itself driven by bevel gearing and a counter shaft (Fig. 136) extending the whole length of the slip. The engine gives a power of 50 horses measured on the shaft.

(216) *The rollers.*—The rollers are independent of the roadway and the cradle. They are of chilled iron, 0.14 meter in diameter, and 0.18 meter long. Each has a ridge in the middle which runs in a groove in the rails; they are united by iron rods, which keep them at the constant distance of 0.56 meter apart. Independent rollers have the advantage, over a system of wheels fixed to the cradle, of avoiding the axle friction; rolling friction only has to be overcome, which is estimated at 3 per cent, besides avoiding inequalities of pressure, combined with simplification in construction.

(217) The compensating cable is of steel 50 millimeters in diameter: it distributes the total force of traction equally upon forty tension chains. The pulleys are all 0.60 meter in diameter, the movable

ones sliding in guides 0.20 meter long. In case of the rupture of a chain, the movable pulley will be carried to the bottom of its guide, the compensating cable will continue to pull upon it and will distribute its load equally among the other chains.

In case of the rupture of the compensating cable, the cradle trucks will descend a few centimeters and the movable pulleys will be caught by frames arranged above the guides. The chance of rupture of the cable is small, as it is exposed to a tension of only 3½ kilograms per square millimeter.

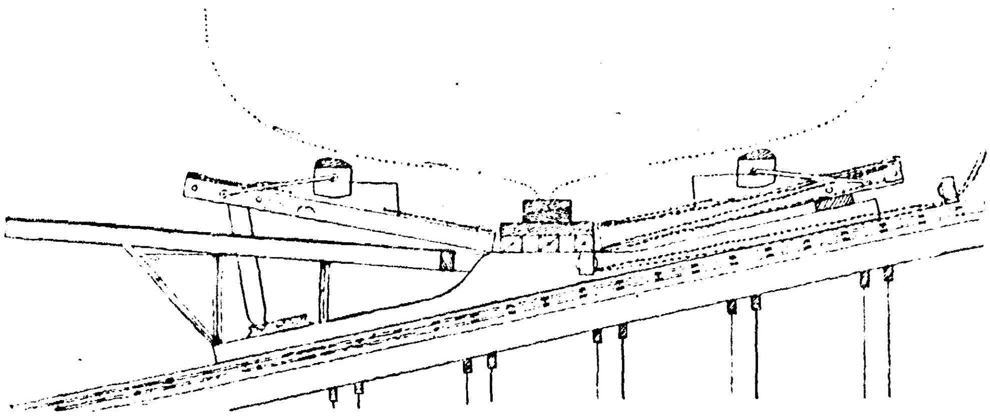


FIG. 138.—Details of the shores.

(218) *Cost.**—M. Labat constructed this slipway at Rouen for 740,000 francs, which was divided as follows:

	Francs.
Earthwork	40,000
Foundations and inclined plane	240,000
Cradle	180,000
Traction tackle	220,000
Engine and shed	60,000
Total	740,000

CHAPTER XXIV.—PORT OF HONFLEUR.

(219) *Sluicing basin with a feeding weir for filling it.*—Honfleur Harbor is exposed by its situation upon the south bank of the Seine estuary to silting. To preserve the channel, a sluicing basin with an area of 54 hectares has been constructed, filled directly from the sea at high tide by means of a weir with rotating gates. (Fig. 139).

The sluicing lock has four openings, each 5 meters wide, separated by piers 2 meters thick, surmounted by a stone bridge. Without entering into the details of its construction and cost it will be interesting to know how it is closed.

* For drawings and information I am indebted to the notice of this work presented to the Paris Congress for harbor works by M. G. Cadart, engineer of roads and bridges.

The apparatus for closing the sluicing lock (Figs. 140 and 141) consists, for each opening: First. Of two guard sluices, 2.45 meters wide, which prevent leakage as well as the inopportune opening of the revolving gate by the waves striking it from without: Second. Of a revolving gate against which the head of water for the sluicing presses when the guard sluices are raised.

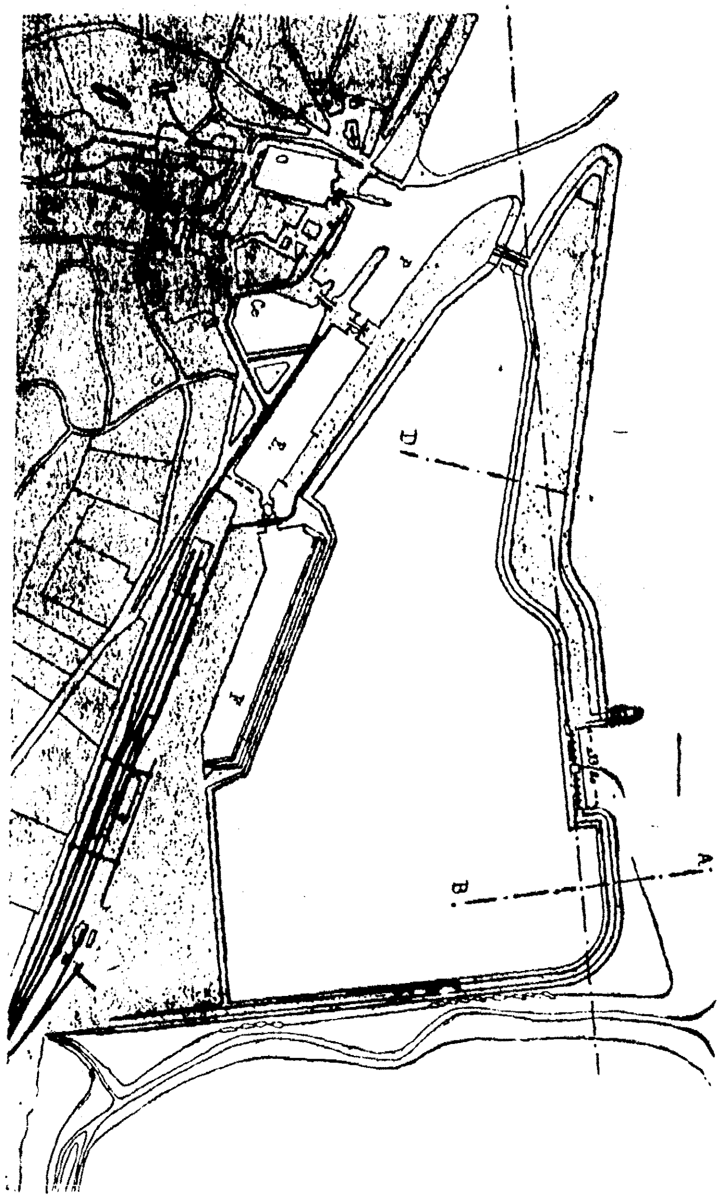


FIG. 139.—Plan of the port of Honfleur and the sluicing basin. D, B, basin; P, outer harbors; E, eastern dock; O, western dock; F, fourth dock; C, central dock; on the outer side is the feeding weir; on the left are the lock gates.

Each sluice carries two racks which gear with pinions keyed to a horizontal shaft above, which four men turn by means of winches placed on the piers or abutments of the lock. These racks raise first a valve placed at the base of the sluice, which uncovers two orifices 0.20 meter high by 1.70 meters wide; these orifices empty the chamber between the sluices and the revolving gate. The effort to raise the sluices is consequently reduced to that of lifting their weights. The

APPARATUS FOR CLOSING THE SLUICING LOCK AT HONFLEUR.

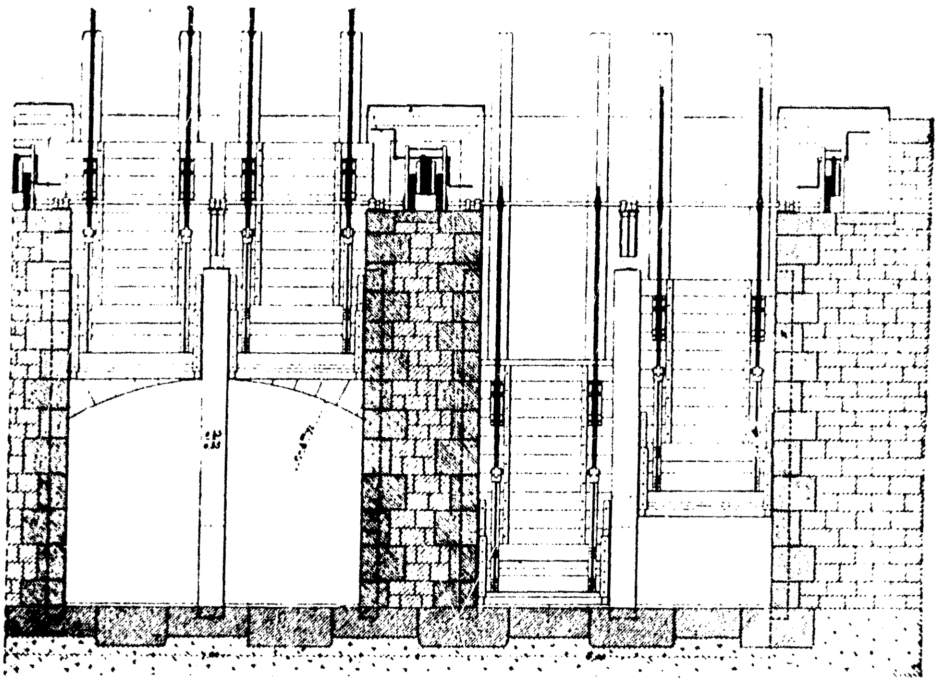


FIG. 140.—Vertical half section.

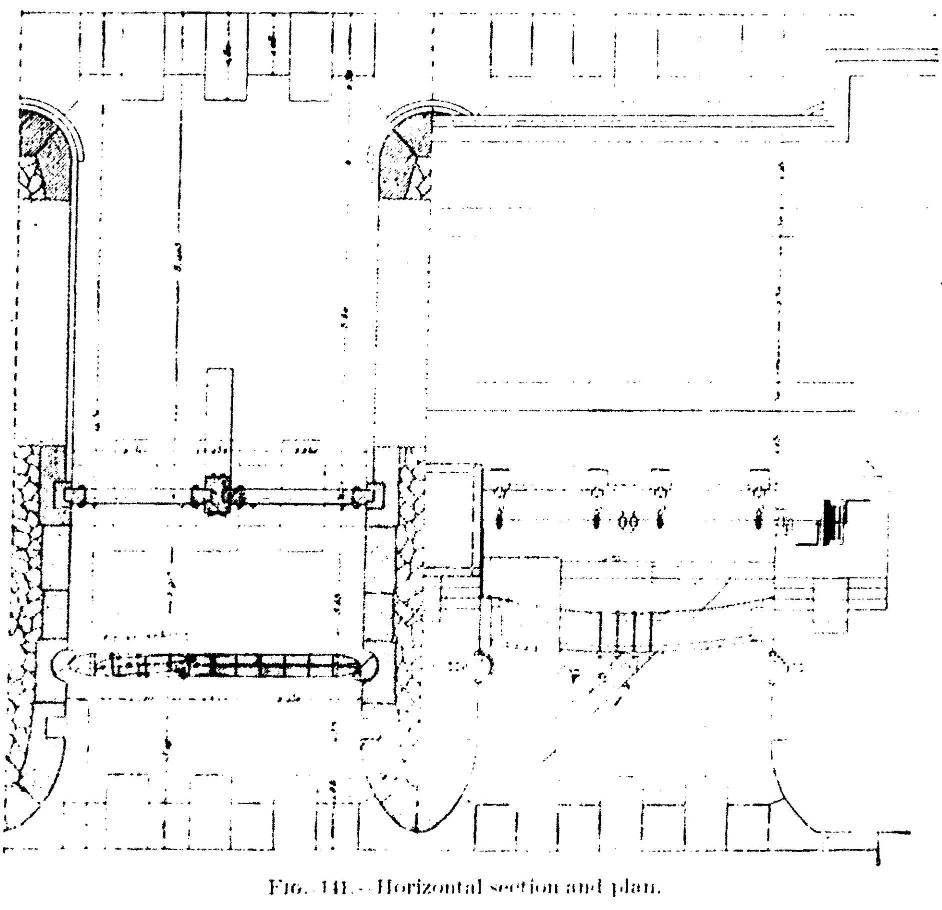


FIG. 141.—Horizontal section and plan.

rack carries a stop which, when the valve is raised, catches the sluice and raises it to the top of the arch of the bridge. The preliminary operation of raising the two sluices takes two gangs of four men an hour.

The axle of rotation of the revolving gate is 0.09 meter from the middle, and in order to facilitate the closing of the gate against the scouring current, there is in the great panel (Fig. 141) a valve turning around a very eccentric vertical axle, which instantly opens under the pressure of the water as soon as the stop which holds it is turned.

The great gate, the two panels of which become unequally loaded, rotates suddenly into the plane of the axis of the lock. To close the great gate, it is sufficient, after closing and fastening the rotating valve, to incline it slightly to the lock axis by means of a cable fixed to it and passing round the drum of one of the winches. The difference of head existing within and without the gate causes a difference of pressure on the two panels and closes the gate.

(220) *Construction of the gates.*—Each gate is made up of uprights of oak 0.40 meter thick, firmly held at their extremities by beams of double T iron forming bridle pieces. The plates of these beams are embedded in the wood, so as to avoid any projection. The uprights are held together by three horizontal bolts extending the whole width of the gate; two belts of wrought iron strengthen the whole. The axle of the gate is formed by a double T beam terminated by two pivots and joined with horizontal bridle pieces. The pivots are of steel, 0.210 meter in diameter.

Cost.—The cost of constructing the gates and sluices of the basin, with the winches, etc., amounted to 132,169 francs.

(221) *The feeding weir.*—The problem to solve consisted in introducing layers of surface water into the basin at will during high tide. Preliminary experiments showed that these layers are always very much clearer than those at the bottom, and that by their use the basin would be prevented as much as possible from silting up. As there were only 2½ hours at each tide which could be used, a layer of water 0.60 meter in height by 100 meters in length suffices to fill the basin. This length was divided into ten openings, 10 meters wide, closed by three movable gates (Fig. 142). These gates, turning around a horizontal axis, are each held by a chain fixed to their upper parts. All these chains pass around guide pulleys, and their extremities are fixed to the same frame mounted on rollers, so that the reciprocating motions of the frame give simultaneous movements of rotation to all the gates. Hydraulic presses move the frames, either to raise or to lower the gates. A weir with a movable crest is thus obtained, which allows the introduction into the basin of a layer of water of constant thickness, notwithstanding the variations of the sea level, which do not exceed 0.40 or 0.50 meter during the time of filling.

Description of Fig. 142.—A, movable gates, turning around a horizontal axle placed at the lower part near the flooring; each gate consists of eight vertical beams of plate and angle irons connected above and below by two similar crossbeams; it is covered on the upstream side with a plate iron skin, 8 millimeters thick, terminating below in the form of a semicylinder, so as to always remain in contact with the wood casing built into the flooring sill. On the downstream side, at a height of 1.70 meters, is a horizontal beam made of plate and angle irons fixed to the vertical beams; to this crossbeam the traction chains are attached. The end verticals of the gate are cased with wood. The gate is represented in the figure in its vertical position; that is, when the weir is closed; and also a gate in a horizontal position, although in reality it never takes it. The figure shows the inclination of the gate during the process of filling the basin when the level of the sea is 11.82 meters. *a*. Forked bearings and journals, two for each gate. The form of these bearings allows the gates to be removed for repairs without having to take them apart under water. *c*. Plate iron apron, 45 centimeters wide, hinged to the base of the gate and furnished with a leather band which covers the joint of the gates with the sill. This apron drags upon the flooring, following the motions of the gate, and prevents obstructions which might produce accidents at the moment of lifting. *d*. Two tennons for each gate, fixed to the upper beam, just over the rotation journals. These tennons are forged in a single piece, with a plate which serves to bolt them upon the web of the beam; it is by means of these tennons that the bolts hold the gates fast against the frame so that they may be able to sustain the pressure of the rising tide while the storage basin is empty.

B. Framework holding the moving mechanism for rotating the gates. It is formed of two vertical lattice beams 1.25 meters high; these beams, spaced 60 centimeters apart, are jointed below to a horizontal beam, 1.20 meters wide, having a flush web pierced with holes for the passage of the chains. These three beams are braced by cross partitions of iron, 8 millimeters thick, numbering six per span. A third vertical beam, 60 centimeters high, sustains the crossbeams of the footbridge. These latter are united by four courses of crossbeams supporting the planks of the service bridge and the rails for a moving crane. On the reservoir side is a sidewalk on corbels, projecting 70 centimeters, and held by plate iron brackets and angle irons.

D. Guide pulleys of the chains; they are cast-iron grooved chain pulleys, their grooves lined with bronze. They revolve on iron shafts, 60 millimeters in diameter, having supports cast in a single piece and bolted under the web of the horizontal beam.

E. Guide pulleys of the chains, of the same model as the preceding but keyed to the shaft. The plumber blocks, inclined at 45°, are fixed at 60 centimeters apart upon the upper plates of the vertical beams; the shaft of these pulleys is 65 millimeters in diameter at the bearings and 90 millimeters in the middle. The plumber blocks are furnished with a half lining in bronze, and an iron cap.

F. Reciprocating frames for rotating the gates simultaneously. Each frame is formed of two plate-iron beams 300 millimeters high, 75 thick and 250 apart, united by transverse ties G; a gate chain is attached to each.

G. Cross girders, having their ends bolted upon the sides of the moving frame so that they can be removed. The chains are fixed upon these cross girders by means of turn-buckles which allow their length to be regulated, so that at the closing all the gates shall come against the framework. The frame, by its reciprocating motion, determines the simultaneous rotation of the gates.

The chains are round, 30 millimeters in diameter. They contain, each one, 59 links, 85 by 38 millimeters of opening, and two end links 124 by 38 millimeters.

R. Iron rollers, twenty for each frame. These rollers are 18 centimeters in diameter, 42 long. Their iron axles, 4 centimeters in diameter, turn in boxes fixed on the vertical beams of the frame.

b. Chair supporting the bolts.

t. Bolt shaft.

SLUICING BASIN AT THE PORT OF HONFLEUR.

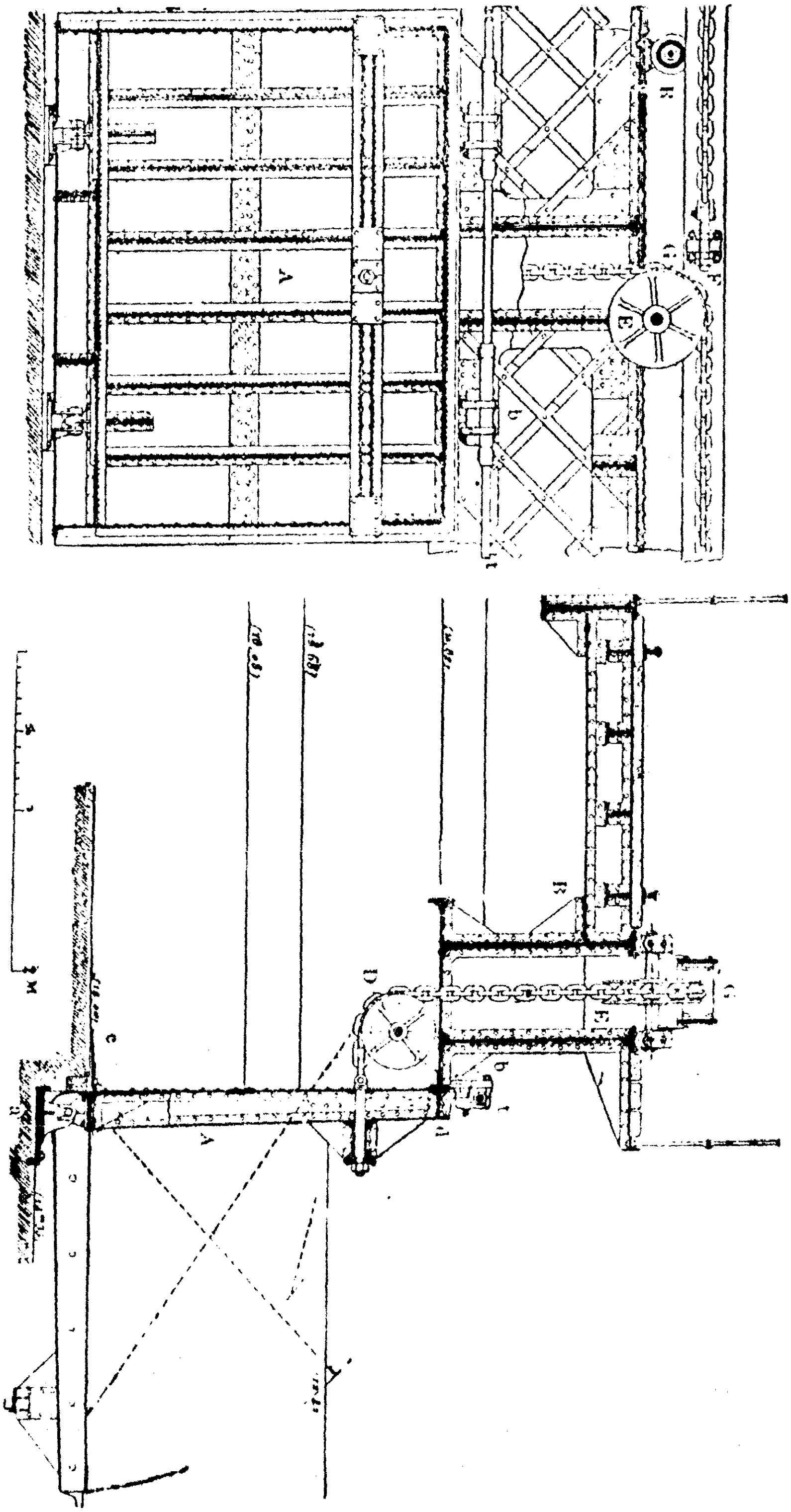


Fig. 112.—Partial elevation and cross section of the feeding weir gates of the sluicing basin.

(222) The feeding weir consists of:

First. Ten openings, formed by nine piers and two abutments. These openings are each 10 meters wide and 11.75 meters long. Their invert in the highest part is at the reference 14 meters,* so as to allow the filling of the basin in the lowest tides, the highest attaining the reference of 13 meters. The flood gates occupy a space of 10.20 meters wide and 6.45 long, corresponding to each opening. A building on the central pier contains the hydraulic machinery and the lodging of the machinist.

Second. Thirty iron flood gates, three for each opening, turning on horizontal bearings embedded in the invert of the opening. These flood gates rise from the invert (reference 14 meters) to the level of the equinoctial high tide, which reaches the reference 11.82 meters.

Third. An iron frame work built on piles and supporting the upper edge of the flood gates; it carries the guide pulleys of the lifting chains and the rollers upon which the frames move, and forms at the same time a bridge of communication on which a three-ton crane runs, which allows any piece to be taken out and replaced very rapidly.

Fourth. The transmitting mechanism, consisting of chains and a movable frame. This last is jointed to a rod driven by two twin presses moved by water under the pressure of 70 kilograms per square centimeter. The other extremity of the frame is drawn by a counterpoise intended to overcome the passive resistances of the apparatus during the opening of the flood gates.

Fifth. The mechanism for keying, intended to maintain the flood gates against the frame work, to permit them to resist the pressure of the rising tide just to the moment of filling. This mechanism consists of a shaft carrying a series of pins, two for each flood gate, driven by a little special hydraulic press.

(223) The movement of the gates is effected by means of two coupled hydraulic presses. A little double-cylindered steam engine of 9 horse-power works the pumps for filling the accumulator, or, if necessary, drives the water directly into the cylinders of the great presses.

The accumulator contains 600 liters of water at a pressure of 70 kilograms per square centimeter.

The water discharged by the hydraulic apparatus during the lowering of the gates is collected in an iron tank placed on brackets let into the wall of the engine room. From this reservoir the pumps take the water required for their use. This is an important economy, since the apparatus has to be fed with fresh water brought from the city.

*The datum plane for Honfleur is 16.087 meters above that adopted for the rest of France.

The complete operation of the weir consists: first, at the moment of high tide, the basin being empty, in gradually lowering the gates, so that their crests shall be covered by a sheet of water 0.60 meter thick; second, in raising the gates when the basin is full, that is to say, generally, with a difference of level if not nothing at least insignificant.

(224) *Cost.*—The expense of constructing the feeding weir amounted to $1,224,888.30 francs.

The sluicing operations are entirely successful, and it is only sufficient to make one or two at each tide to keep the outer channel clear.

The feeding weir works regularly, but, at the same time, the intense current produced on the approaches to the weir, when the revolving gates are lowered, does not exclude absolutely the lower turbid layers of water.

The preliminary plan was made by M. Arnoux, and the work was directed by MM. Leblanc and Widmer, engineers.

The contractors were M. Hersent for the lock, and the Fives Lille Co. for the iron work of the weir.

Figs. 139–141 are taken by permission from the Portefeuille des Ponts et Chaussées.

CHAPTER XXV.—PORT OF HONFLEUR—SIPHONS BETWEEN THE STORAGE BASIN AND THE FOURTH LOCK—AUTOMATIC SIPHONAGE.

(225) As has been stated, Honfleur Harbor is exposed, by its situation upon the south bank of the Seine estuary, to considerable silting up, against which constant efforts have to be made. The storage basin of 54 hectares affords the principal means of keeping the passes free by sluicing.

When great sluicings are not made, communication is opened between the docks and the storage basin, in order to increase the efficiency of the sluicing given by the navigation locks, and to reduce the silting of the docks by raising as much as possible the level of the water of these last, before the opening of the ebb gates and introduction of the flood, which is very much loaded with sand. This communication ought not to be opened more than five or six times a fortnight, to reëstablish the level in the dock when this level has fallen below that of the storage basins on account of the sluicing. The level of the storage basin being generally above that of the dock, there was great interest in making a tight closing. This motive, joined to that of economy, led to the adoption of a system of siphons. These siphons are six in number. The saddle is placed above the ordinary level of the basins (12.30 meters).

(226) The apparatus for filling and emptying is based upon the following experiments. When a small hole is made in the wall of a siphon in operation, in the portion where the pressure is below that of the atmosphere, the siphon does not become clear if the hole is

very small. The external air is sucked by this orifice into the siphon, and it issues in great bubbles which break upon the surface. By enlarging the orifice, or by piercing other holes near the first, we finally clear, *i. e.*, empty the siphon.

In opening the sucking orifice to bring about the clearing, we observe that the flow of the latter diminishes progressively until it attains a value very near zero, and, for an opening slightly more, the clearing is nearly instantaneous. It is evident that this principle may be applied to the filling of siphons of great capacity.

Small siphons are filled easily and rapidly, either by the emptying of a reservoir full of water, or by means of a sucking-pump. A little siphon pierced with a sucking orifice properly arranged will work as a filler for siphons of greater dimensions, if we unite the pierced sucker of the first to the top of the second. To stop the action it

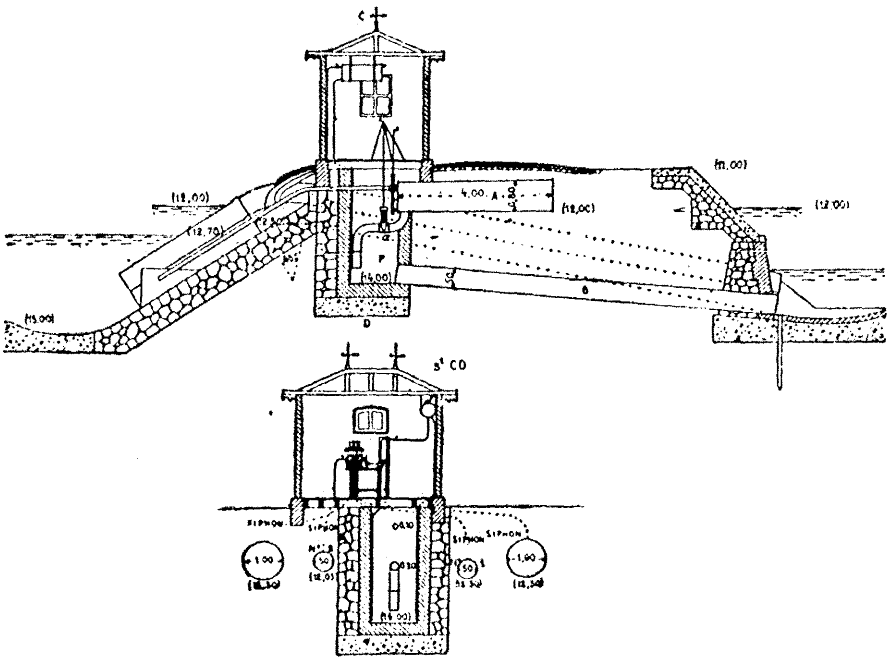


FIG. 143. Sections of the siphon at Honfleur.

will suffice to clear the siphons by putting them in communication with the atmosphere by an orifice sufficiently large.

(227) This stated, the process of filling can be understood: it is as follows: A valve *a* (Fig. 143) is opened which allows the water in the reservoir A to flow into the pit P, and thence, through the conduit B, into the lower bay; at the same time the upper part of the reservoir A is connected with the top of the filling siphon, No. 1. The capacity of the reservoir A is calculated so that all the air contained in the siphon is sucked in and replaces the water which runs out by the valve *a*. When the siphon is filled, which is indicated by a gauge, the stopcocks and the valve *a* are closed. The siphon No. 1 contains an air sucker formed by a copper pipe 0.02 meter in diameter, which goes through the siphon wall perpendicularly, and

returning along the axis of the siphon, terminates a litte beyond the top by a rose. The object of this arrangement is to divide the air at its entrance into the siphon and to obtain the rapid drawing of air bubbles toward the discharge. The aggregate of all the orifices of the rose is above one-tenth of the section of the pipe of 0.02 meter. When the difference of level is equal to or above 0.80 meter, experience shows that this sucker may be put in free communication with the atmosphere without clearing siphon No. 1. For siphons of the same cross-section the size of the sucker orifice depends on the difference of level, and the sucker belonging to siphon No. 1 is contrived for a difference of about 1 meter.

The sucker just described is put in communication with a siphon No. 2, which has the same diameter as No. 1, but is placed 0.25 meter higher. The air contained in No. 2 is drawn out by this siphon and the siphon fills, as the corresponding manometer indicates. This siphon contains a sucker identical with the first, but with a slightly less section (0.015 meter instead of 0.02 meter). The two sucking siphons are put in communication with a third siphon, called a culvert siphon; when the manometer indicates that the first culvert siphon is filled, a second culvert siphon, connected with the first, is filled, by taking care not to uncover a new distributing orifice until after the complete filling of the preceding siphon. One man fills all the siphons. This operation requires from ten to twelve minutes. The siphons filled, the reservoir A is filled by putting it in communication on one side with the siphons and on the other with the upper basin. All the air contained in this reservoir is sucked out by the siphons and replaced by water from the upper basin. The communication should be closed when the water in both basins is sensibly at the same level. To stop the action of the siphons they are cleared by opening the stopcock of 0.02 meter, which puts them into communication with the atmosphere. The complete clearing takes place in seven or eight minutes.

(228) *Automatic filling.*—Independently of the process of filling that has just been described, and which has worked since 1884, these siphons fill naturally and automatically whenever the sluicing basin is filled. The water then covers the saddle of a siphon 0.06 meter in diameter, which goes down into the well and fills by overflow. This siphon fills a second of 0.13 meter in diameter placed 0.33 meter above it; and these two siphons united fill three others of 0.20 meter in diameter placed at 0.28 meter above the second. This collection of fillers is united with siphon No. 1, which is 0.50 meter in diameter, by a stopcock. When this cock is open all the siphons fill in one hour and a half or two hours, for a difference of level which ought to be above 0.40 meter. This is the necessary time for the decantation of the water taken at the moment of high tide in the sluicing basin. This collection of filling siphons, arranged in a series, has worked regularly without aid of any person since the year 1886.

The collection previously described only works occasionally.

The siphons were planned and built by M. Picard, under the direction of M. Boreux, chief engineer.

CHAPTER XXVI.—TRAVERSING BRIDGE OVER THE DOCK LOCKS AT THE PORT OF ST. MALO-ST. SERVAN.

(229) *Position and general arrangement.*—The new road uniting the cities of St. Malo and St. Servan passes over the two locks 18 meters wide, of the two docks, by means of traversing bridges moved by water under pressure.

These bridges are similar, each one having a total length of 38.80 meters—22.80 meters for the span and 16 meters for the breech. The total width is 8 meters, the width of the wagon road 5 meters, and that of the sidewalk 1 meter.

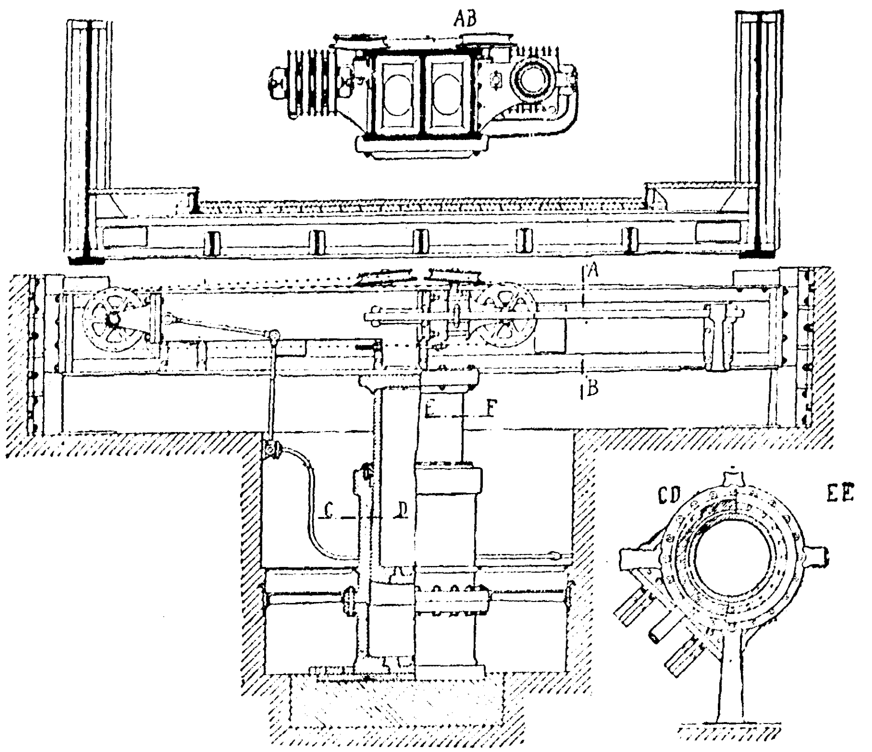


FIG. 144.—Section of the traversing bridge—Section A B of the box girder—Sections C D and E F of the lifting press.

The roadway is carried by two principal girders with flush webs, having the form approaching that of a solid of equal resistance: the maximum height being 2.814 meters. The upper flange is curved, the lower straight. The cross girders are spaced 2 meters.

(230) *The lifting press* (Fig. 144), 1.06 meters in interior diameter, is placed vertically in a masonry pit exactly under the centre of gravity of the bridge, and supports an iron box girder on whose extremities cast-iron sleepers are placed directly under the principal girders, and designed to support the whole weight; laterally it is fitted to pieces of iron which move in vertical guides.

In order to diminish the quantity of water at the pressure of 60 atmospheres Mr. Barret, engineer of the docks at Marseilles, invented a special apparatus, called a recuperator, which forms, with the lift-

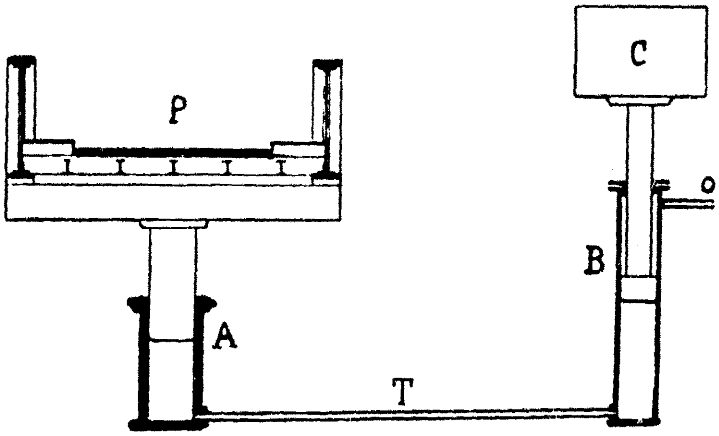


FIG. 145.—Diagram of the operation of the recuperator.

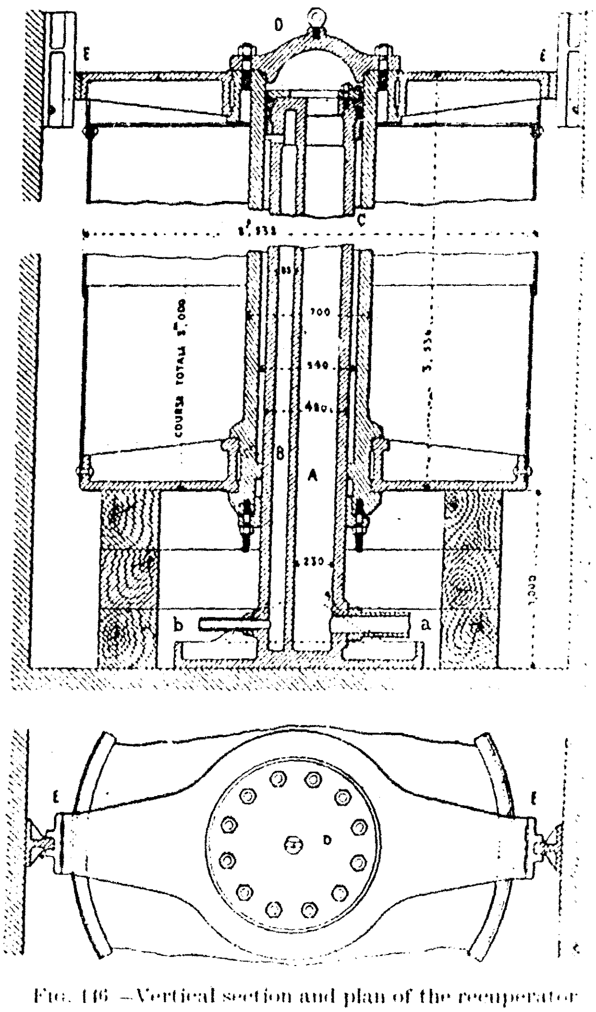


FIG. 146.—Vertical section and plan of the recuperator

ing press, a sort of hydrostatic balance, allowing the work produced by the descent of the bridge to be stored up and utilized for raising it afterwards.

(231) *The recuperator.*—The working of the species of hydrostatic balance of the recuperator press may be represented by the diagram (Fig. 145).

The press A communicates directly, by the pipe T, with the recuperator B. The latter consists of a vertical cylinder, in which a piston supporting a loaded box, C, moves. The load is regulated so that the bridge, P, in descending drives the water of the press under the piston of the recuperator and raises the whole system. A pipe, *a*, allows water under pressure to be introduced at will into the annular space over the piston of the recuperator, between the piston rod and the cylinder, or to allow this water to escape. In the case of the introduction of this water the pressure exercised in the annular space is added to the weight of the load. The piston of the recuperator descends and drives the water into the lifting press. In case of the escape of the water the pressure in the annular space is relieved; the weight of the bridge again becomes greater and raises in its turn the piston and its load.

The preceding theoretical arrangement was modified in practice so as to avoid having to take away the load of the piston each time that it was necessary to change the packing. The apparatus is reversed, the piston and piston rod are fixed, while the cylinder is movable and carries the load; so that to change the packing it is only necessary to raise the cover of the cylinder. Fig. 146 shows the arrangement adopted.

The piston rod, A, is a hollow cast-iron cylinder 48 centimeters in diameter, which rests upon a circular foot 1.40 meters in diameter, strengthened by flanges. The rod is furnished above with iron rings, forming a piston of 54 centimeters in diameter, packed with two leather collars all kept in place by a cast-iron follower bolted down. (Fig. 147).

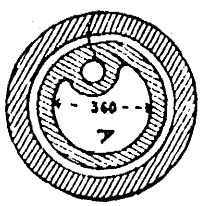


FIG. 147.—Horizontal section of the recuperator press.

The interior of the rod (Fig. 146) forms a communication, through the pipe, *a*, between the lifting press and the movable cylinder of the recuperator. This last is 54 centimeters in interior diameter and 80 millimeters thick. It has an enlargement below and a stuffing box for the passage of the rod. To bring the water from the accumulators into the annular space, C, left between the rod and the cylinder, the cylindrical passageway, B, in the piston rod itself, forms the prolongation of the pipe, *b*, and leads into the annular space through a hole pierced laterally below the piston.

The base of the cylinder carries externally two flanges which form a circular groove for holding in place the iron plate which serves as the bottom of the loaded box. This plate is made of two pieces put together with bolts. The box is cylindrical, of plate-iron 8 millimeters thick, 2.352 meters in diameter, and 3.25 meters high. It is guided above by a cast-iron support having two arms with shoes, E E, at their extremities, which run on two cast-iron guides, 3.45 meters long, built into the masonry. Three oak frames placed above each other, at the foot of the rod, form a support 1 meter high upon which the loaded box rests when it is at the bottom of its course.

(232) The withdrawal and replacement of the bridge requires, besides the working of the hydrostatic balance formed by the central press and the recuperator, some accessory operations. We must be able, in case of necessity, to lift the loaded box to the top of its course, and on the other hand lower or lift separately the box girder, and in case of repairs, the plunger of the central press. These operations are accomplished by the accumulators and the distributing apparatus placed in the pavilion and arranged for this purpose.

The weight of the recuperator is less than that of the bridge.

When the bridge is to be raised, the box being at the top of its course, it is sufficient to open the valve, which puts the annular space comprirsed between the piston and its cylinder in communication with the water under pressure, so that the latter, acting on the lower face of the box, compensates for the difference between the weight of the bridge and that of the box, and produces the upward motion of the bridge.

To lower the bridge it is sufficient to allow the water to escape from the annular space: the bridge descends then by its own weight and lifts the recuperator. The horizontal motion of the bridge is obtained by two hydraulic presses fixed horizontally on the vertical walls of the box girder (Fig. 144) and moving with it. They carry at each extremity a tackle block with three pulleys, around which the traction chain passes. One serves for the advance motion and the other for the return. The conducting water pipes form a joint with the cylinder presses. The bridge can move upon two pairs of rollers fixed just behind the position it normally occupies—that is, when the pass is closed—and upon four pairs of movable rollers, which are made to slide upon a cast-iron frame by the action of a hydraulic press, which pushes them under the bridge as soon as it is raised. The rollers are fixed in pairs upon a balanced beam, so that the weight of the bridge shall be divided equally over the numerous points of support. The rectilinear movements of the bridge are limited at each extremity by buffers built into the masonry.

The complete withdrawal and replacement is made in three or four minutes. One man is sufficient. He is placed in the pavilion which contains the operating keys, the recuperator, and a service hand pump, intended to force in, if necessary, water enough to move the bridge. The water under pressure is brought through one pipe and returns in another to the pavilion constructed between the two rolling bridges and containing the pumps and accumulators.

(233) *Opening and closing the bridge.*—The pavilion contains three

pieces of distributing apparatus. When it is required to open the pass the lockman moves the valve of the first apparatus, and the water under pressure from the central machine and the recuperator is forced under the piston of the central press, which raises the sleeper and consequently the bridge. Then he opens the valve of the second apparatus and the movable rollers slip under the bridge; he then lowers the bridge upon the rollers by opening and discharging from the lifting press. When the bridge rests upon the rollers he prolongs a little the discharge of the water so that there is a play of 0.03 meter between the sleeper and the plates of the beams. Finally he opens the valve of the third apparatus and the rectilinear motion is produced. When it is required to put the bridge in place, the lockman opens the valve of the third apparatus and the bridge is brought vertically over its first position; then he opens the valve of the first apparatus, which lets the water under pressure into the central press. When the bridge is sufficiently raised the valve of the second apparatus allows the movable rollers to be brought back; then, on opening the valve of the first apparatus, the bridge sinks to its normal position, and at the same time the water in the central press runs into the recuperator and is stored there. The total weight of the bridge is 181,500 kilograms; the price, including the mechanism, the recuperator, and the piping, amounts to 200,000 francs. This bridge was planned and made by M. Robert, engineer of roads and bridges, under the direction of M. Mengin, chief engineer.

Figs. 145–147 are taken by permission from the Portefeuille des Ponts et Chaussées.

CHAPTER XXVII.—HYDRAULIC WORKS AND PNEUMATIC FOUNDATIONS MADE AT GENOA.

(234) *Graving docks and accessory works.*—The Duke of Galliera bequeathed to the Kingdom of Italy several million francs for the improvement and extension of the harbor of Genoa. Among these improvements were particularly specified the construction of two graving docks, capable not only of answering the present requirements but also those which might arise in future. A special commission of engineers was appointed to find the best means of fulfilling these obligations. The commission, considering the exceptional technical difficulties which this work presented, advised the opening of an international competition requesting proposals for the work, with the processes for its execution, and requiring guaranties therefor. The administration adopted this advice.

Eight competitors responded to this invitation of the technical commission, and after a long examination they reported in favor of the project presented by MM. C. Zschokke and P. Terrier.

The works to be constructed include principally the Quai des

Graces, the western quay, the two docks, the quay which unites them, the pumping machines, and the caisson gates.

(235) The Quai des Graces is 200 meters long and 75 wide. Its coping is 3 meters above the level of the water. The retaining wall is formed of masonry piers founded by compressed air upon rock at the reference − 8 and united by brick arches. In the space of 12 meters between the piers the filling of the quay is protected by stone pitching.

(236) *Western quay.*—The foundations of this quay having been previously made the wall alone had to be constructed.

(237) *Graving docks.*—The two docks are parallel. The distance apart of their axes is 77.37 meters. Their principal dimensions are as follows:

	No. 1.	No. 2.
	Meters.	*Meters.*
Maximum interior length at the quay level including the entrance chamber	179.38	219.94
Width at the same level	29.40	24.90
Width of entrance at the same level	25.28	18.48
Width at the water level	24.80	18.00
Width at the sill	21.06	14.64
Height of the water on sill at mean tide	9.50	8.50
Height of water on the lowest point of the dock	10.00	9.00

The two docks, although of different dimensions, are constructed in the same manner. Each entrance has two recesses for the caisson gate.

Dock No. 2 is provided with two other recesses which are respectively 90 and 130 meters from the entrance, and which allow a second gate to be placed therein, thus dividing the dock into two separate chambers, 90 and 110 meters, or 130 and 70 meters.

The transverse section of the gate chambers is a trapezoid. The interior has five altars in dock No. 1, and four in No. 2.

The wells for pumping out the dock are in the walls toward the entrance. The eastern wall of dock No. 2 contains a special culvert for discharging the water of the two compartments independently, which the second caisson gate allows to be placed at the bottom of the dock. The walls approach and close in the shape of an ogive at the end opposite the entrance.

From one part to the other of the ogive inclined planes, parallel to the axis of the docks, allow the descent of wagons to the bottom in order to transport the material required for repairing ships. These inclined planes are flanked with staircases for the descent of the workmen. The invert of the docks has a longitudinal declivity of 1 to 100. It has the same transverse slope from the axis toward the walls, along which little gutters take the drainage to the discharging well.

The revetment for all the parts of the work which are exposed to shocks or subject to strains is of hewn stone. The other parts of the revetment are of brick. The flooring is of sandstone on brick foundations.

(238) *Head walls.*—The head walls are united with the Quai des Graces and the western quay by continuous walls, founded at the reference —8.

Pumps.—The pumping house is placed between the two basins at the entrance. Three centrifugal pumps, driven by as many compound condensing engines, are placed in a dry pit at the reference —8. Two of these pumps can clear either basin filled with water, in five hours, which corresponds to a discharge of 4,000 cubic meters of water per pump per hour. Two other pumps, driven by special motors, provide for the leakage; each one can discharge 250 cubic meters per hour. The steam is furnished for these machines by six boilers.

(239) *The three caisson gates* are of plate steel. They are surmounted by a bridge large enough to give passage to wagonettes or cars. They are furnished with a number of sluices sufficient to assure the filling of one of the basins in an hour at the most.

EXECUTION OF THE WORKS.

(240) *Character of the foundation.*—The soil upon which the works had to be founded is a calcareous stratified rock of the Miocene formation, with very shelving banks, covered with fine layers of sand and rock ruins. The formation is very variable, both as to the quality and hardness of the rock.

The water has washed away the soft parts and left the hard, so that the surface of the rock presents a series of projections with the hollows filled with sand and fragments; hence the same arrangements had to be made as if the rock had been completely porous, by substituting a béton bottom for the natural soil. The submarine operations were as follows: First, the blasting of the rock; second, the removal of the sand and rock blasted, and, third, the laying of the masonry on the bottom thus cleared.

Two solutions of the problem.—The thickness of the banks and their great depth under water precluded, for the boring, any arrangement employing machinery set up above the level of the water. The same circumstances would have rendered the extraction of the pieces of rock by dredges very difficult. Again, the sinking of béton under water at such great depths would have given only mediocre results.

Recourse must be had to pneumatic processes. Two solutions presented themselves. One was that adopted for the construction of the docks at Toulon and for the basin at Saïgon. It consisted in constructing the masonry of the flooring and side walls upon several great floating caissons and producing by the increasing load of this masonry their gradual immersion and descent into the soil at the bottom, then filling the working chamber with béton when the cutter had arrrived at the chosen bottom upon which the work was to be erected. This is in reality the extension of the process in use for the foundation of bridge piers. It is perfectly satisfactory when absolute tightness is not required in the work, but this is not the case with the dry-dock. It is impossible to disguise the fact that the iron imbedded in the masonry, the plates forming the diaphragm between the upper masonry and the béton filling the working chamber, exclude precisely the conditions of homogeneity and continuity of the masses which such constructions are expected to fulfill. The metal interposed must necessarily alter with time and produce leaks. It is also very difficult to spread upon such a great floating caisson the increasing load of masonry in a manner sufficiently uniform to avoid all changes of form, and to work without ever deviating from a horizontal plane, first in grounding the caisson upon an irregular bottom, and then in building it upon a rocky bottom. The changes of form and the fissures which they would cause were particularly to be feared at Genoa, where the immersion had to be made in a part of the harbor not entirely sheltered against the waves and where the blasting of the foundations presented great difficulty. Another solution must be found. That which the contractors proposed, which was adopted by the technical commission, consisted in removing the rock and laying the masonry under water in great diving-bells furnished with the apparatus necessary for rapidly effecting the horizontal or vertical displacement of those machines best adapted to the boring and extraction of the blasted material and the introduction of new.

This process permitted the direct building of the foundation upon the prepared bottom, avoiding risks of change of form and of rupture in the perfectly homogeneous and continuous masonry, in which no portion of iron remained imbedded. It allowed the different portions of the work to go on independently. These were the motives which decided the contractors to adopt this solution and to construct for realizing it:

First. A movable caisson for blasting out the rocks.

Second. Two other movable caissons for the construction of the walls for the quay and basin.

Third. A great floating caisson for the extraction of the rocks and for the construction of the flooring.

(241) *Caisson for blasting out the rocks.*—The blasting caisson (Fig. 148) is 20 meters long and 6.50 meters wide. The working chamber does not differ from those ordinarily used for the construction of bridge piers, except that the walls are lighter, as they do not have to bear the load of the masonry above the bottom.

Pigs of iron placed between the beams of the roof balance the under pressure and keep the caissons on the bottom. Two horizontal plate-iron cylinders, 2 meters in diameter and 5.50 meters in length, are fixed above the frame parallel to the transverse axis of the caisson and in symmetric positions in respect to this axis. They are open at their lower parts. A tube connects one with the other and puts them in communication with the compressed-air pipes which supply the working chamber. Water is allowed to ascend in the cylinders, to fill them, when the caisson is kept at the bottom for blasting. The water is forced out by means of compressed air when the caisson is to be raised and changed in position.

This substitution of water for air in the cylinders, which has for effect the gradual augmentation of the water displaced by the system, can be regulated at will and continued just to that degree necessary for the equilibrium of the load, so as to assure the stability of the caisson upon the bottom; the slightest effort then suffices to lift the apparatus. The caisson is surmounted by two shafts with air locks for the entrance of workmen. A third is reserved to add, if necessary, a lock for the materials extracted.

The caisson is suspended by twenty-four chains to as many jacks resting on a heavy staging, which in turn rests on two barges furnished with all the apparatus necessary for a rapid displacement.

(242) *Boring apparatus.*—The boring apparatus made by M. Sulzer at Winterthur, is arranged in the following manner: The platform of the caisson is divided lengthwise into three equal belts by four double T-irons, the lower wings of which serve as a rolling track for three trunnions on rollers. Each of these trunnions has a collar at its lower part to which one of these boring machines is suspended by a joint. The trunnion moves the length of the platform, the collar slightly unscrewing along the whole trunnion, so that the point of articulation of the boring machine may occupy every position of a plane within the limits of one of the three belts, and the tool may also turn in each of its positions in all directions so as to pierce sloping holes at will. The boring machines are driven by water under pressure brought from an accumulator on the boat, by jointed piping which descends along the central shaft, runs along the platform, and feeds the tools in all positions and inclinations given them. As the boring progresses the boring tool is prolonged by hollow rods screwed together. The diameter of the boring bit is 10 centimeters for the holes exceeding 2 meters in depth, and 6 centimeters for the others. Two double-acting twin pumps, furnishing water under pressure, are placed in a boat fastened to the caissons. They are driven by two portable engines of 25 horse power each. The water, taken from the sea, is driven into an accumulator and kept under pressure by the steam taken from the engine boilers. The steam acts on the upper surface of a plate, fourteen times the

PORT OF GENOA. BLASTING CAISSONS.

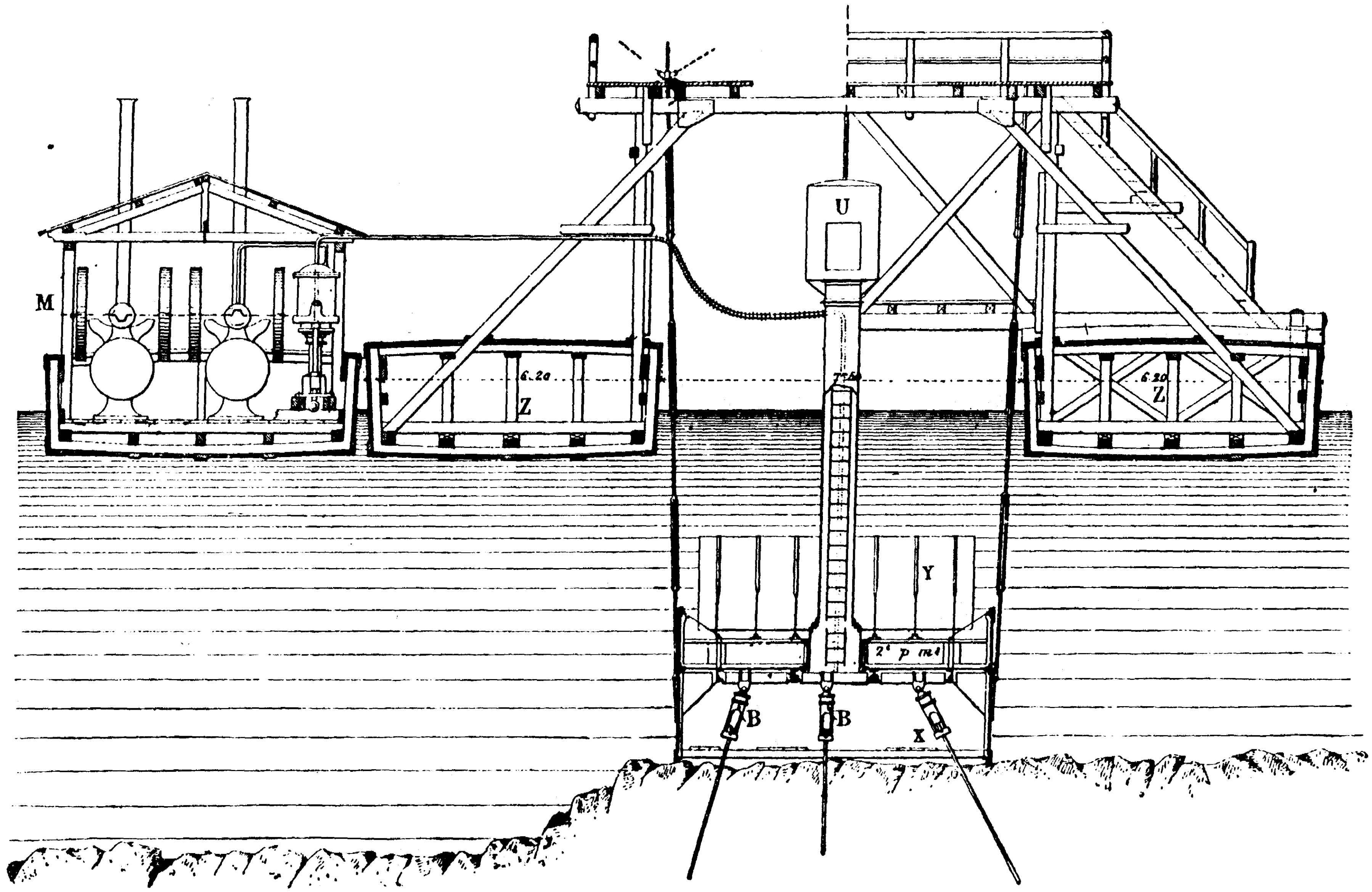


FIG. 148.—Transverse section of the movable caissons used for drilling the rock for the purpose of submarine blasting. X, the working chamber; Y, the lightering chamber; Z, pontoons supporting the caisson; U, lock for the workmen; B, drills (Brandt's system); M, two steam engines, driving pumps feeding an accumulator from which water under pressure is conveyed to drive the boring machines.

section of the piston, which transmits directly to the water the pressure of 60 or 70 atmospheres, necessary for boring. This arrangement avoids the great load which would have to be placed upon the barge with an accumulator so weighted as to be capable of giving such a great pressure." When the boring of the holes has been completed, just to the required depth, over the whole surface covered by the caisson, they are filled with cartridges or dynamite gelatin, the wires are attached to a floater which is passed under the cutter, the

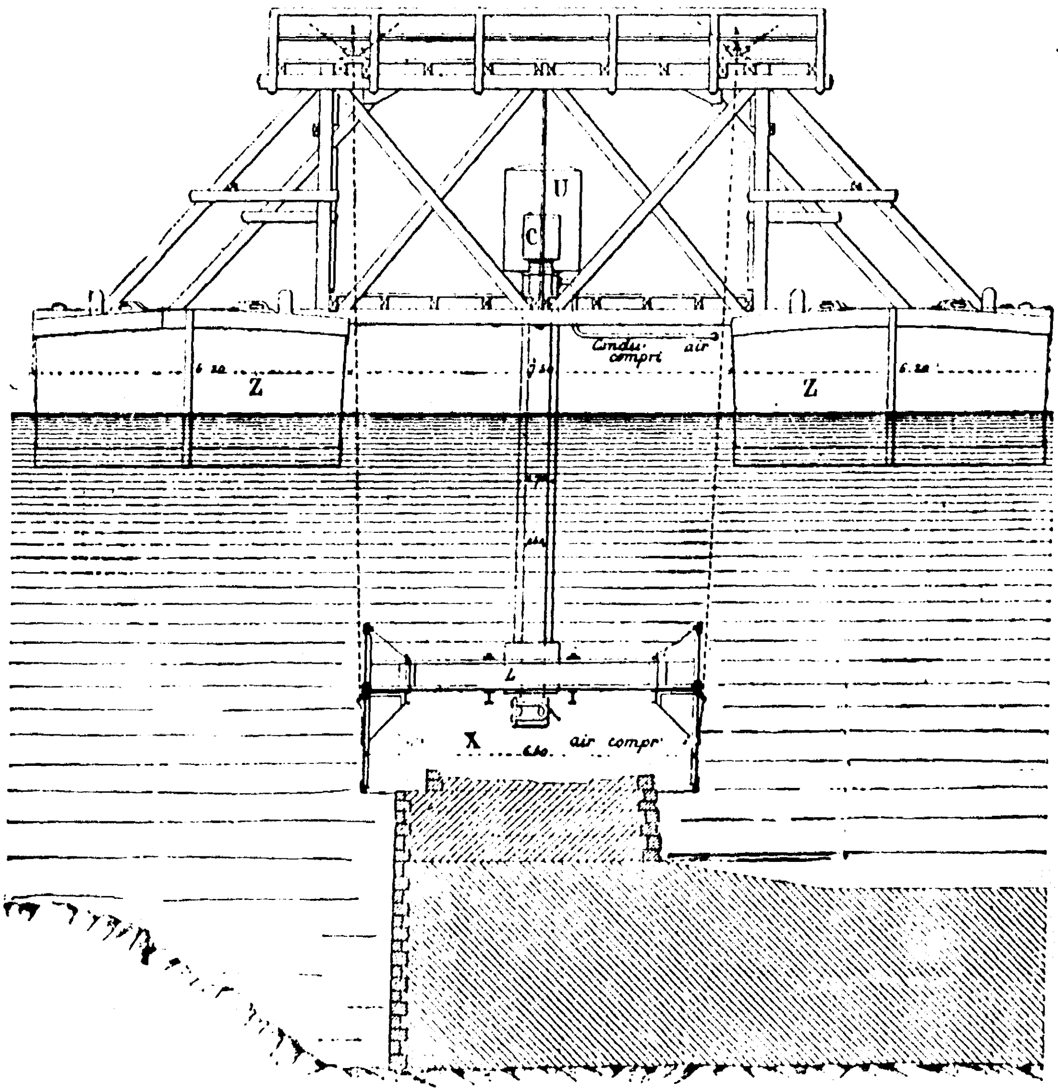


FIG. 149.—Port of Genoa. Transverse section of the movable caisson.

caisson is raised and moved by the supporting barges, and the mines exploded by an electric battery. By experience in regulating the distance between the holes and the amount of the charges, they succeeded in giving to the fragments of rock broken off the dimensions most convenient for use.

(243) *Movable caisson for the construction of the quay walls.* (Figs. 149-150).—These two caissons, which served also for the removal of

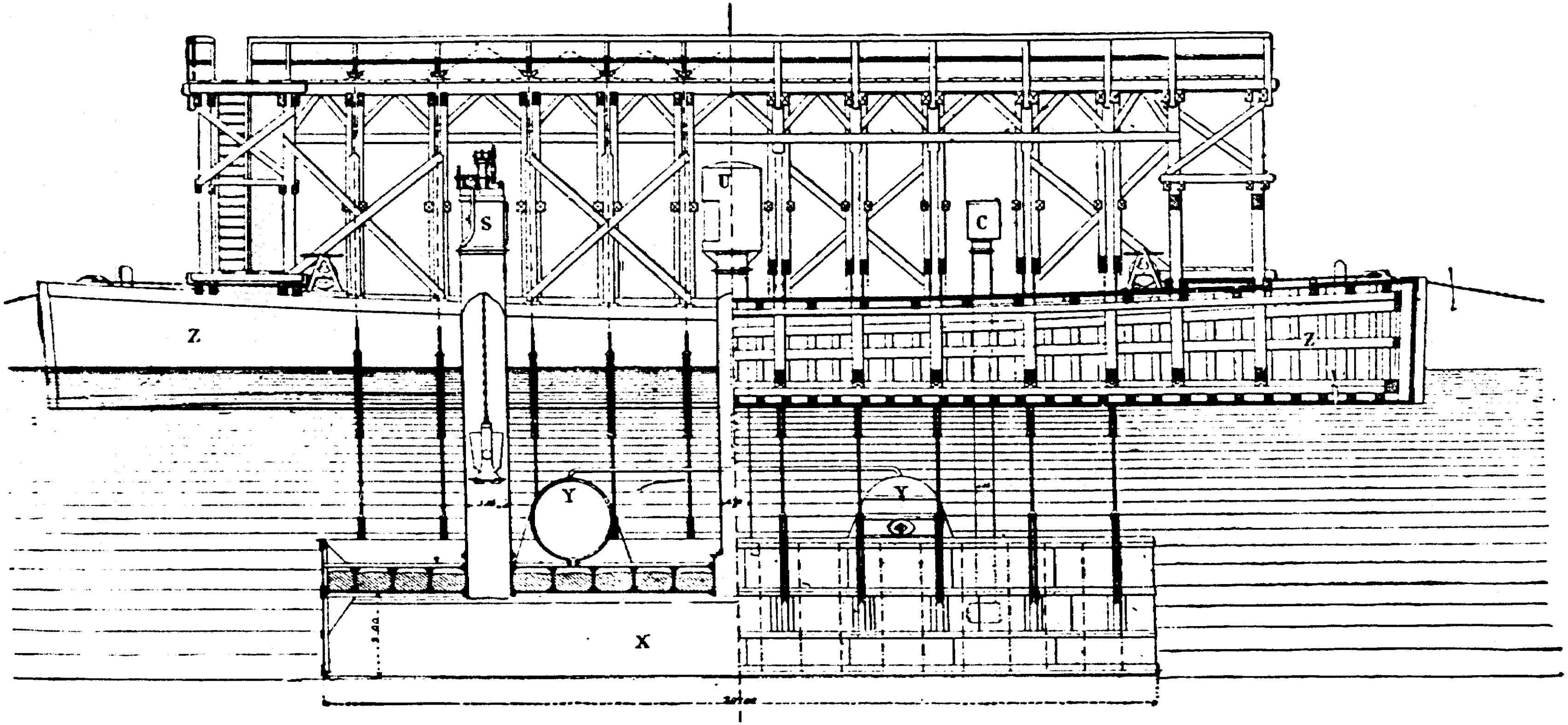
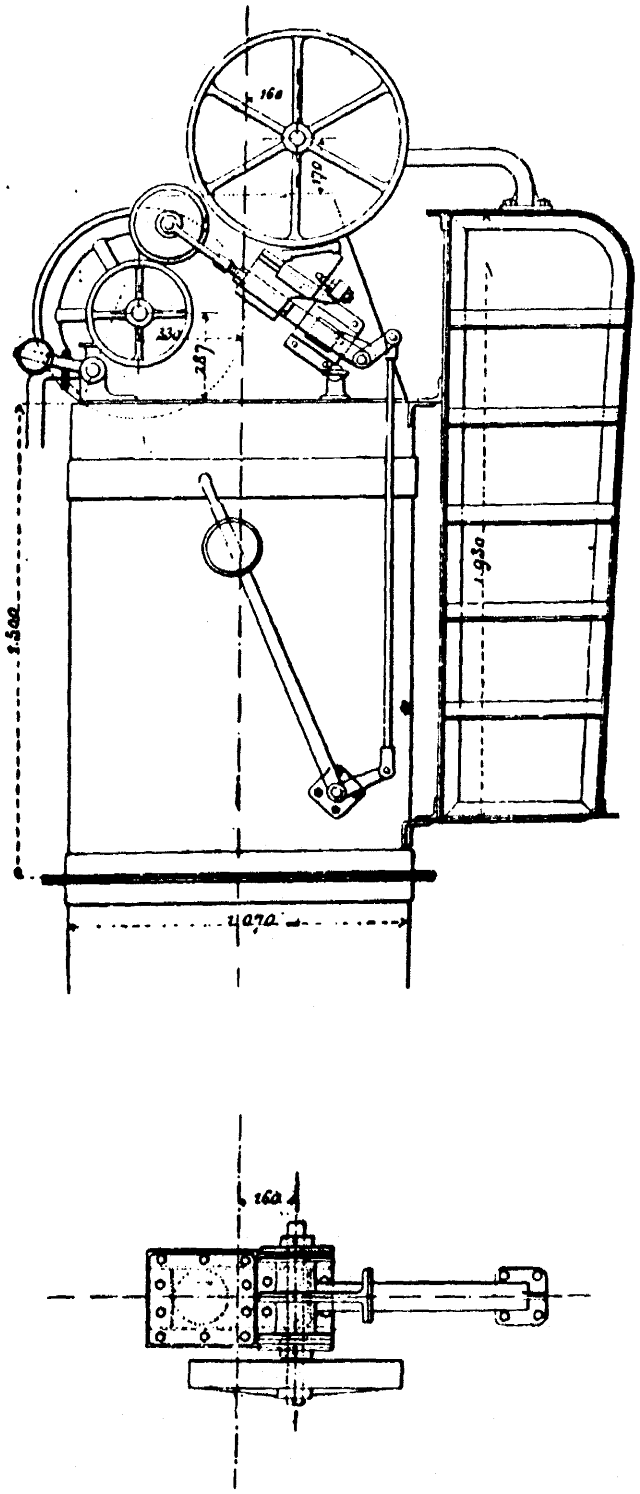
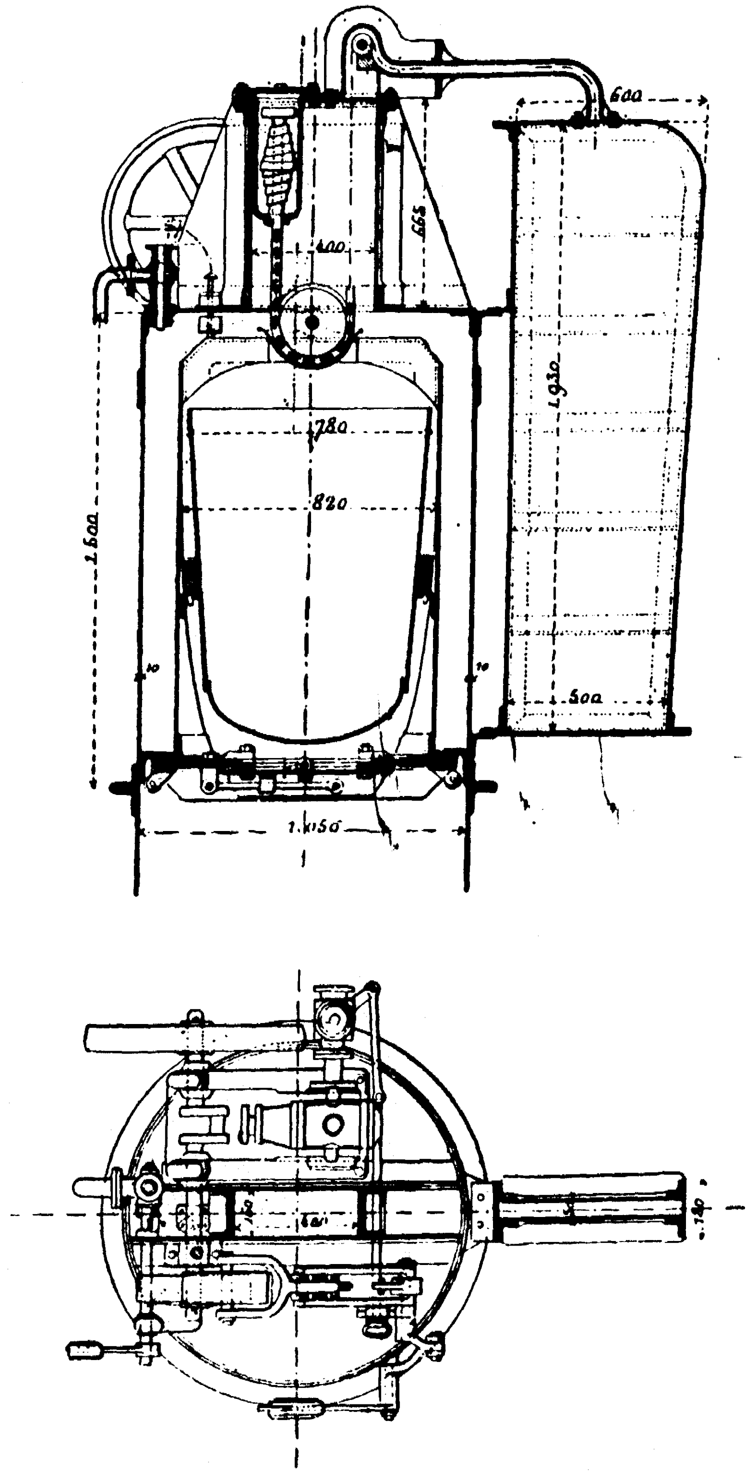


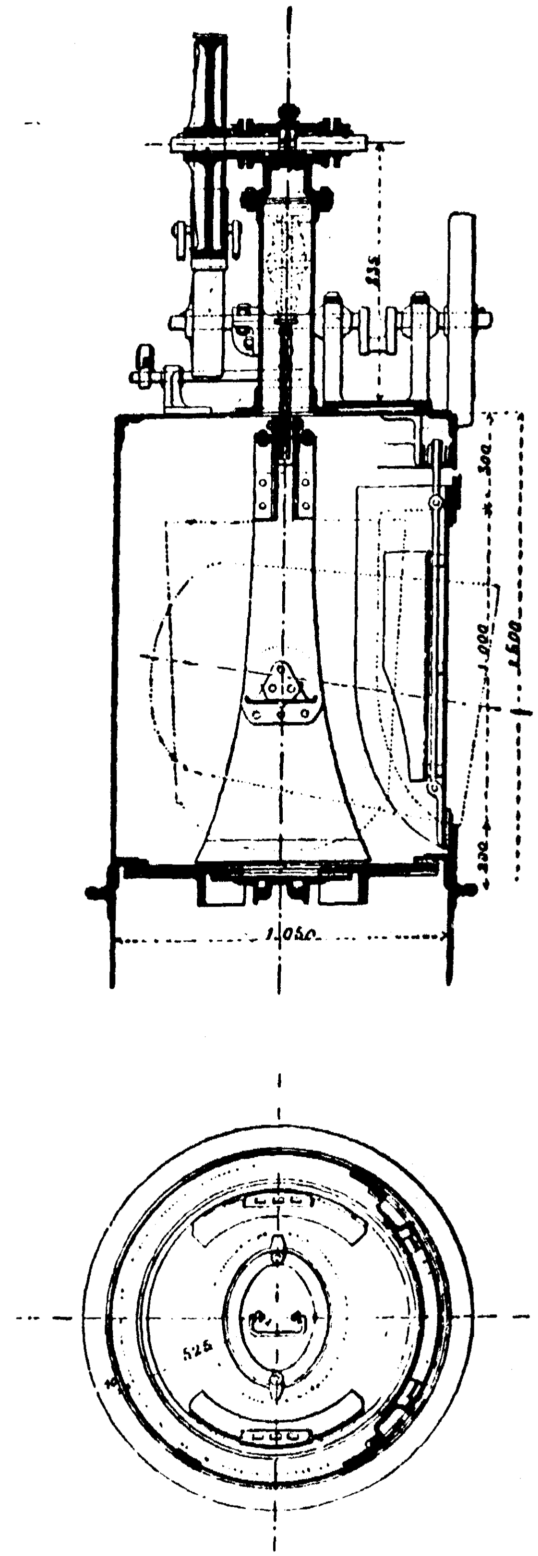
FIG. 150.—Elevation and longitudinal section of the movable caissons used in laying the masonry under water. X, the working chamber; Y, the lightering chamber; Z, the pontoons supporting the caisson; U, S, C, locks for the men, materials, and béton, respectively.



FIGS. 151 and 152.



FIGS. 153 and 154.
Details of the excavation lock; for description see p. 729.



FIGS. 155 and 156.

the broken material, were 20 by 6.50 meters, and 18 by 5.60 meters. They were constructed, ballasted, and suspended like the one just described. They were provided with a man lock, and a second lock for the removal of the spoil and the introduction of the materials, and a third for the introduction of béton.

(244) At Rome, before the invention of Zschokke's excavation lock, the spoil was removed through locks placed upon shafts 0.70 meter in diameter. These shafts were supplied with iron ladders inside, serving in case of need for the removal of the spoil and for the use of the workmen. The spoil loaded into buckets of about 35 liters, was raised by an elevator fixed to the upper part of the lock and put in motion by a cable transmission.

The insufficiency of this method, especially for raising large blocks, was immediately recognized, and the company put into use its newly invented excavation lock, which merits especial consideration. It is represented in Figs. 151–156, in the new form which it had at the works at Genoa and Bordeaux.

(245) *Description of the excavation lock.*—This lock forms the upper part of a shaft 1.05 meters in diameter, having its sections united by external angle irons. A circular interior angle iron, projecting into the shaft, is placed at the bottom of the lock. An iron plate 0.90 meter in diameter, surmounted by two frames supporting a turning bucket, is suspended at the end of a chain passing round the drum of an elevator placed at the top of the lock. The bucket and its supporting plate move freely through the height of the working chamber and the shaft, but are stopped in their upward movement by the striking of the plate against an india-rubber ring which lines the lower face of the projecting angle iron below the lock. At the moment when this striking is produced an automatic motion of levers acting upon a double stopcock puts the lock in communication with the outer air. The escape of the compressed air produces an increasing pressure and a complete adhesion between the plate and the angle iron. The outside rolling door, bordered with india-rubber, which the interior pressure no longer holds against the cylinder, is opened. The bucket is turned toward the opening and its contents (400 liters) discharged. The bucket is then tipped back, and the exterior door closed; by a reverse movement of the stopcock, the communication between the working chamber and the lock is re-established. The compressed air rushes into the lock. The equilibrium is again established on both sides of the moving plate, and nothing stops the descent of the bucket into the working chamber. The elevator is raised by a portable engine and cable, when the local conditions allow this mode of transmission, as was the case at Rome. Elsewhere the motion is transmitted from a Schmied motor fixed upon the platform of the lock and worked sometimes by compressed air, and sometimes by water under pressure.

This little light lock, very easy to move, allowed the rapid removal of very considerable quantities, and quite large blocks without requiring for its management the presence of a single man in the compressed air. It was not arranged for the passage of the workmen who went in easily through the old entrance, the lateral locks for removing the spoil having been taken away.

The new excavation lock, employed in its first form ten years ago, has been very much improved, and, in view of the works executed at Bordeaux and Genoa, it is placed in the exhibition (Machinery Hall) with its latest improvements adopted in 1888.

The chain drum is driven by means of two friction wheels by a Schmid water motor taking its supply directly from the city reservoir situated 100 meters above the sea.

The two caissons served not only to introduce the béton, but also to lay the masonry and the revetment in brick and cut stone of small dimensions. When the hewn stones were of too great dimensions to be carried in through the locks they were lowered outside by means of a floating crane, the caisson, which had to be removed for this operation, was replaced, and the workmen found in the working chamber the stones to be set up.

(246) *Great floating caisson.*—The great floating caisson shown in Fig. 157 is intended for raising the fragments of rocks made by the explosion of the mines just described, and for laying the béton flooring. It is 38 meters long and 32 meters wide, that is, 1,216 meters of surface. These dimensions were required on account of those of the flooring. The widest of the two floors is 36 meters, that is, 2 meters less than the length of the caisson.

The caisson, which is now floating in the port of Genoa, consists of three essential parts:

First. The working chamber, 2 meters high, surrounded by two tight plate-iron envelopes, one vertical, forming the exterior walls, the other inclined, covering the interior faces of the braces from the roof to the cutter.

Second. The equilibrium chamber, which rises above the first to a height of 3 meters. It is completely enveloped with plate iron and traversed by shafts giving access to the working chamber.

Third. The iron reservoirs or regulating pits, which rest upon the equilibrium chamber without communicating with it, and which are open at their upper parts above the level of the sea. These pits are four in number. Two of them extend the whole length of the caisson parallel to its walls and 1 meter from the latter. They are 3 meters wide and 8.60 meters high. The two others, at right angles to the first, are placed symmetrically with respect to the shorter axis of the caisson. They are also 8.60 meters high, and their width is 3.50 meters. These four pits are connected, and the rectangular

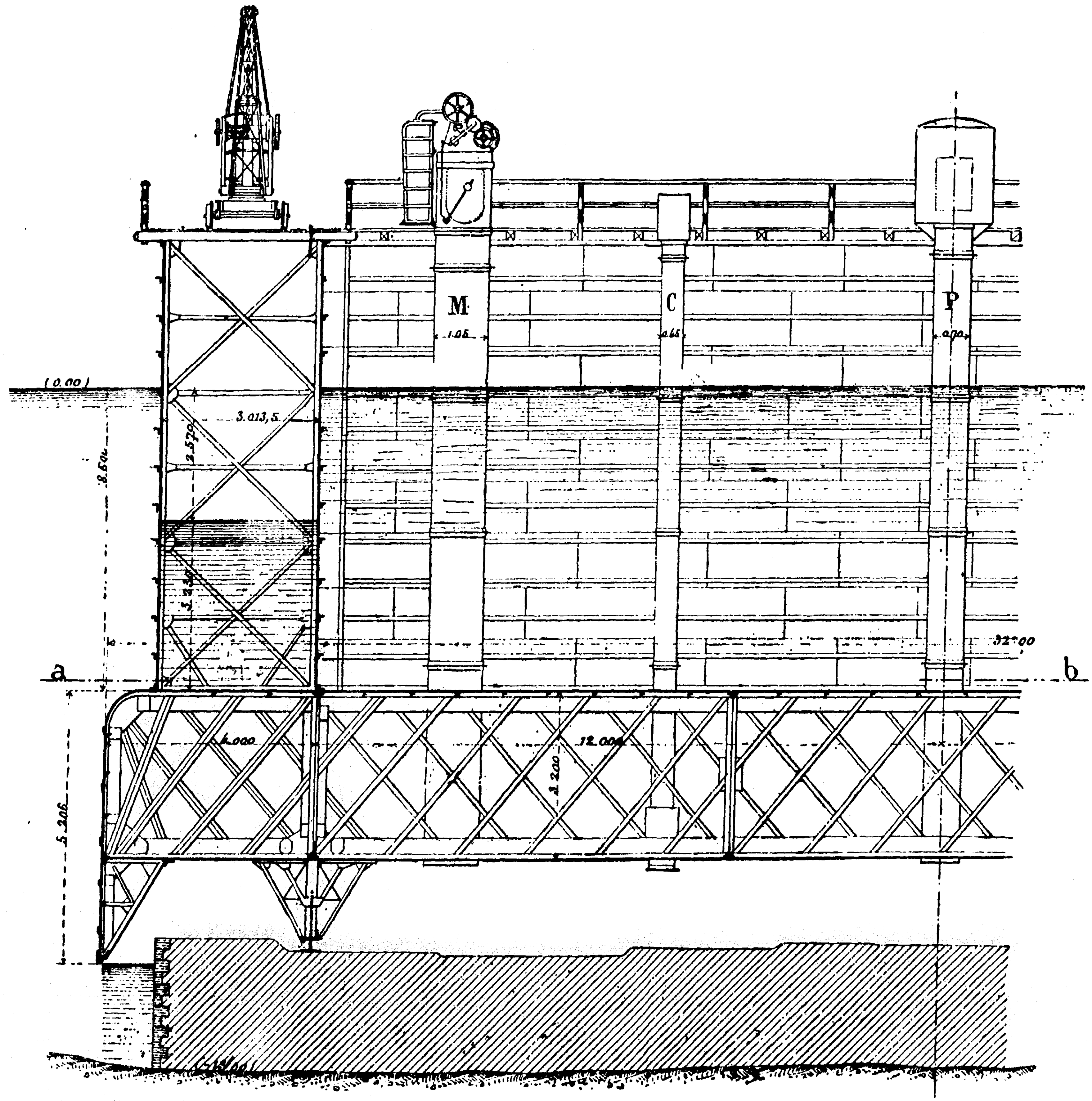


FIG. 157.—Great floating caisson used in laying the flooring of dock No. 2; transverse section. M, Shaft for the materials, 1.05 meters; P, Shaft for the workmen, 0.70 meter; C, Shaft for the béton, 0.45 meter interior diameter.

central portion formed by their interior walls communicates by a pipe with the sea. The walls and braces of the four pits form the framework to support the service bridges and stagings which lead to the different air locks, and carry the tracks, cranes, etc., required for the handling of the excavations and the materials.

Arrangements have been made for filling the equilibrium chamber with water or compressed air, as may be necessary, and for changing, at will, the level of the water in the regulating pits, which may even be completely emptied by means of pumps. The apparatus is thus maintained in equilibrium under all circumstances (Figs. 158-161). The caisson unloaded draws 2.55 meters, making the ceiling of the working chamber 0.55 meter below the level of the sea. It is brought into the condition of stability required for working, by placing enough iron ballast between the braces and over the ceiling, to make it sink 5.10 meters, which allows the ceiling of the upper chamber to be 10 centimeters out of water. The immersion will go on increasing as water enters the equilibrium chamber and into the regulating pits, unless compressed air is introduced into the working chamber.

If one equilibrium chamber is filled with water, and if the central tank is maintained in communication with the sea by the pipe, of which we have heretofore spoken, the cutter may be lowered to the reference (−8) even if compressed air is introduced into he working chamber. We may then, if the working chamber remains filled with air, lower the cutter to the reference −9, by allowing the water to rise 1.15 meters in the regulating pits; and to the reference −11.50 meters if the water level in these pits is brought to 2.50 meters below the sea, etc.

To raise the caisson rapidly it is sufficient to pass compressed air from the working chamber into the equilibrium chamber and to diminish thus the load of water in the latter, taking care always to open the discharging orifices made in the walls of the pits so as to lower the level of the water which they contain as the caisson rises. But this process, which prevents access to the working chamber, is only applicable if we wish to obtain a rapid rise. If, on the contrary, it is required to raise the caisson while the work is going on in the chamber we must empty first the regulating pits by means of pumps and then begin by forcing out the water contained in the equilibrium chamber by means of compressed air.

To facilitate these different operations several great pipes, furnished with stoppers, have been arranged in the equilibrium chamber above the braces. These allow the introduction of sea water or provide for its expulsion by compressed air. The air from the working chamber is passed into the equilibrium chamber through a valve in a pipe which passes at the height of the service bridge

PORT OF GENOA. POSITIONS OF THE CAISSON IN ITS DIFFERENT STATES OF EQUILIBRIUM, SCALE $\frac{1}{300}$.

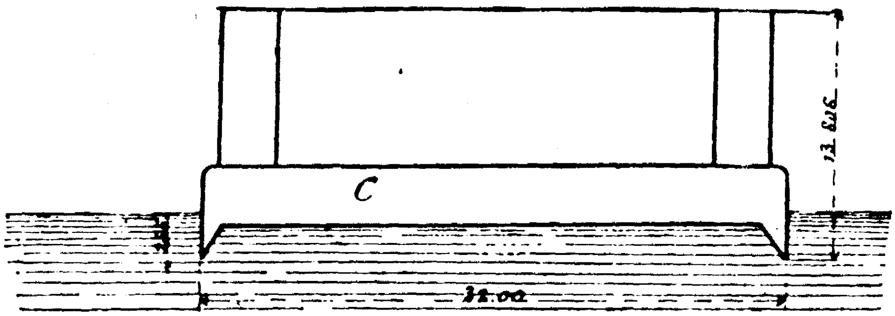


FIG. 158.—Without ballast.

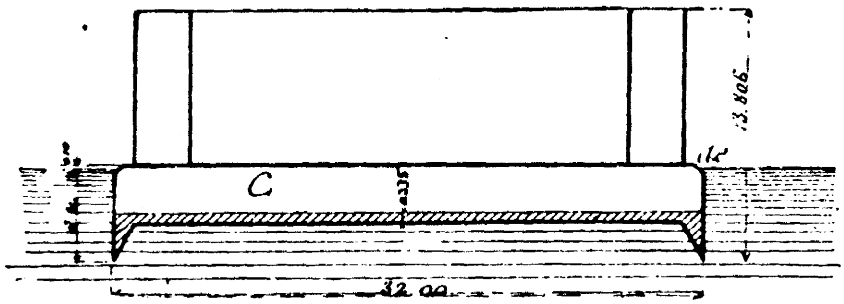
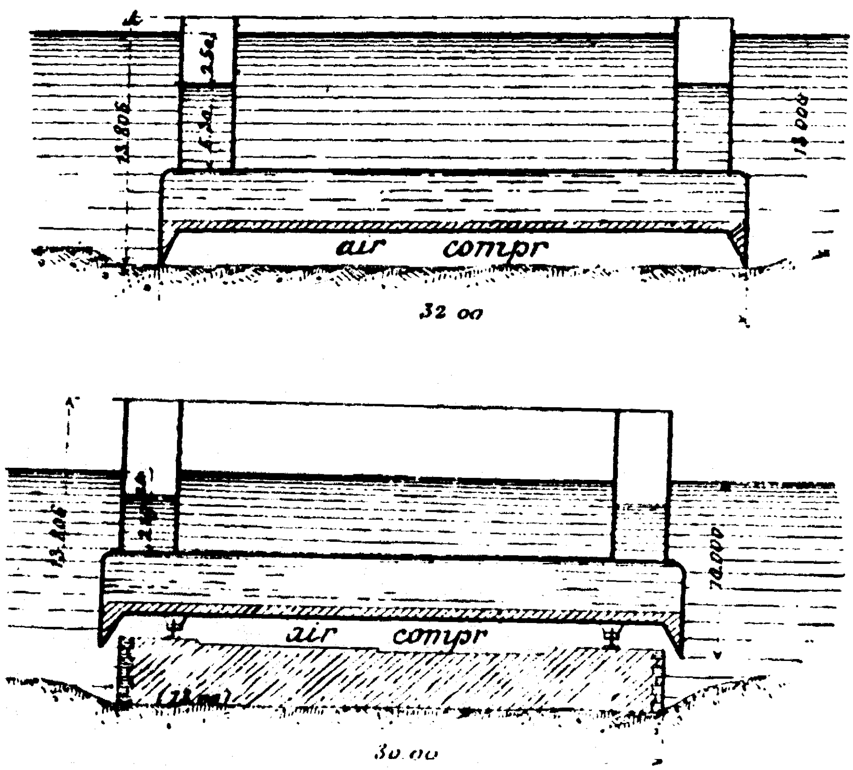


FIG. 159.—With ballast.



FIGS. 160 and 161.—Caissons at work.

roadway. Another pipe allows air to be sent directly from the compressors into the equilibrium chamber. The regulating pits are put in communication with each other and with the sea by pipes 0.45 meter in diameter furnished with cocks operated on the service bridge.

The weight of ballast and the dimensions of the pits depend on the depth at which the work goes on with a stable caisson. At Genoa the arrangements were made for a depth of from 8 to 14.50 meters.

To be able to remove without too much difficulty the fragments of rock caught under the cutter a file of screw-jacks is arranged in the working chamber upon which, when necessary, the weight of the caisson may rest. These jacks rest on two open beams fixed under the ceiling, parallel to the longitudinal walls which they must lift, and at 4 meters distance from them.

The rock fragments are taken out by six excavation locks. The béton is spread along the whole length of the flooring in superposed layers of 0.50 meter thickness. Little brick walls are built as this goes on along the longitudinal borders of the mass, which prevent the béton from running over. In the transverse direction, on the contrary, the béton is left to take its natural slope. The walls would be useless there, besides breaking the homogeneity of the mass.

(247) *Method of laying the flooring.*—When the béton has been spread over a thickness of 50 centimeters the caisson is vertically raised and a new layer placed above the preceding. When a first mass 1.50 meters thick has been thus deposited in three superposed layers, the apparatus is moved the whole of its width in the longitudinal direction of the flooring, and grounded so that the longitudinal cutter shall come to rest at the foot of the cross slope of the first mass at S_1 (see Fig. 162). A layer of 50 centimeters is then deposited, the caisson is then raised, and, by a slight longitudinal displacement in the contrary direction from the preceding, the cutter is brought to touch the slope of the first mass, no longer at its foot, but 50 centimeters above it (at the point 2). A second layer is then spread upon the first, taking care to fill up, above the cutter, the little triangular prism 50 centimeters high formed by the two transverse slopes, between which the cutter is placed in its preceding position. The caisson is again raised 50 centimeters high, moved lengthwise, a third layer is spread, and at the same time the second little prism is filled up.

We have thus a second mass 1.50 meters thick joined to the first, and the caisson is then moved to commence a third in the same manner. When the layer of 1.50 meters extends continuously the whole length of the flooring the same operations are gone through with, by successive displacements upon this bed, as were previously made on the rocky bottom. But care must be taken that the new positions of the caisson should not be directly over the preceding, in order to have a series of little triangular transverse prisms to be filled up under the cutter, etc. We thus obtain a homogeneous and perfectly tight flooring.

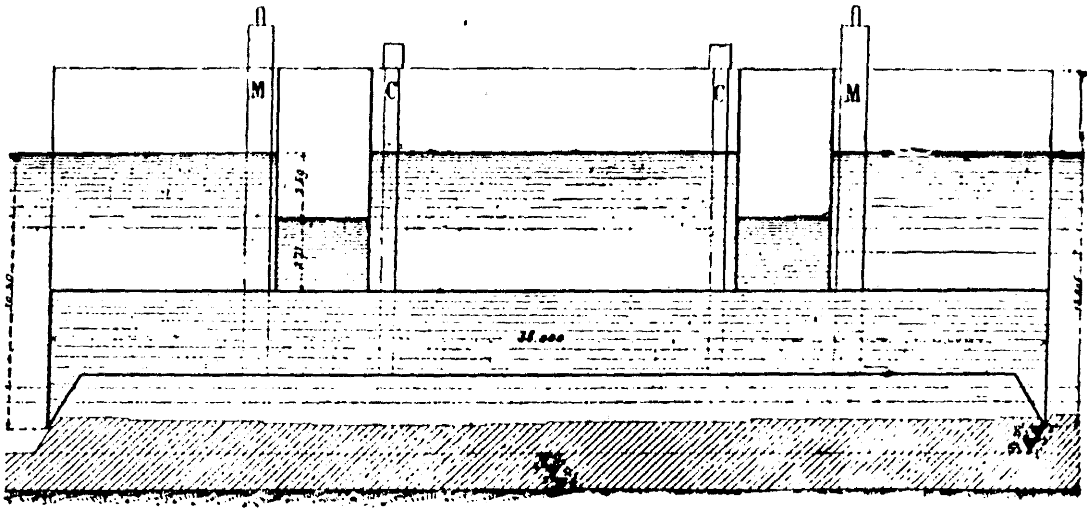


FIG. 162.—Method of laying the flooring of a basin. The numerals 1, 2, 3, 1^1, 2^1, 3^1, indicate the different positions of the cutting edge of the caisson; the letters S_1, S_2, S_3; S^1_1; S^1_2, represent the triangular prisms of béton placed under water, corresponding to the respective positions of the cutting edge 2, 3; 1^1, 2^1, 3^1.

In order not to allow the caisson to be floating during these operations it is supported upon two rows of jacks resting upon iron plates placed on the layer of béton previously spread.

(248) *Supply of compressed air, etc.*—The air-compressors, which supply the pneumatic apparatus above described, are placed on the

PORT OF GENOA. QUAI DES GRACES. QUAY WALL IN ARCADES.

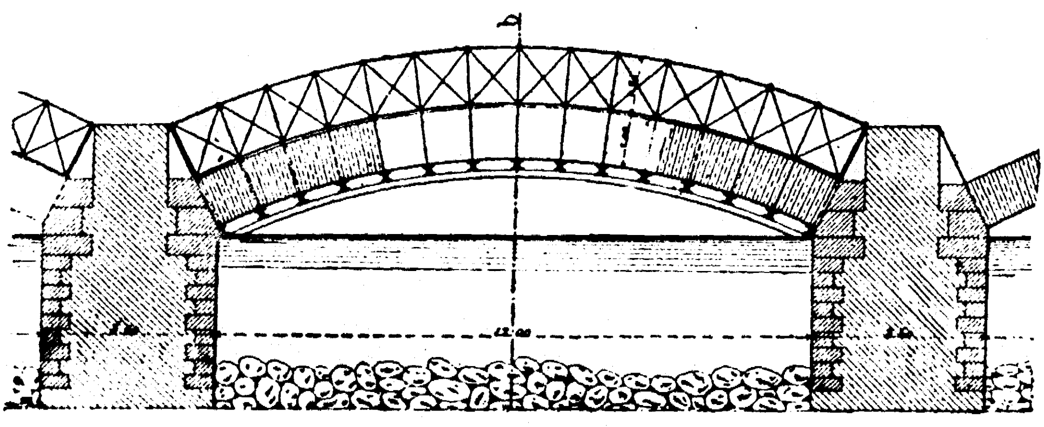


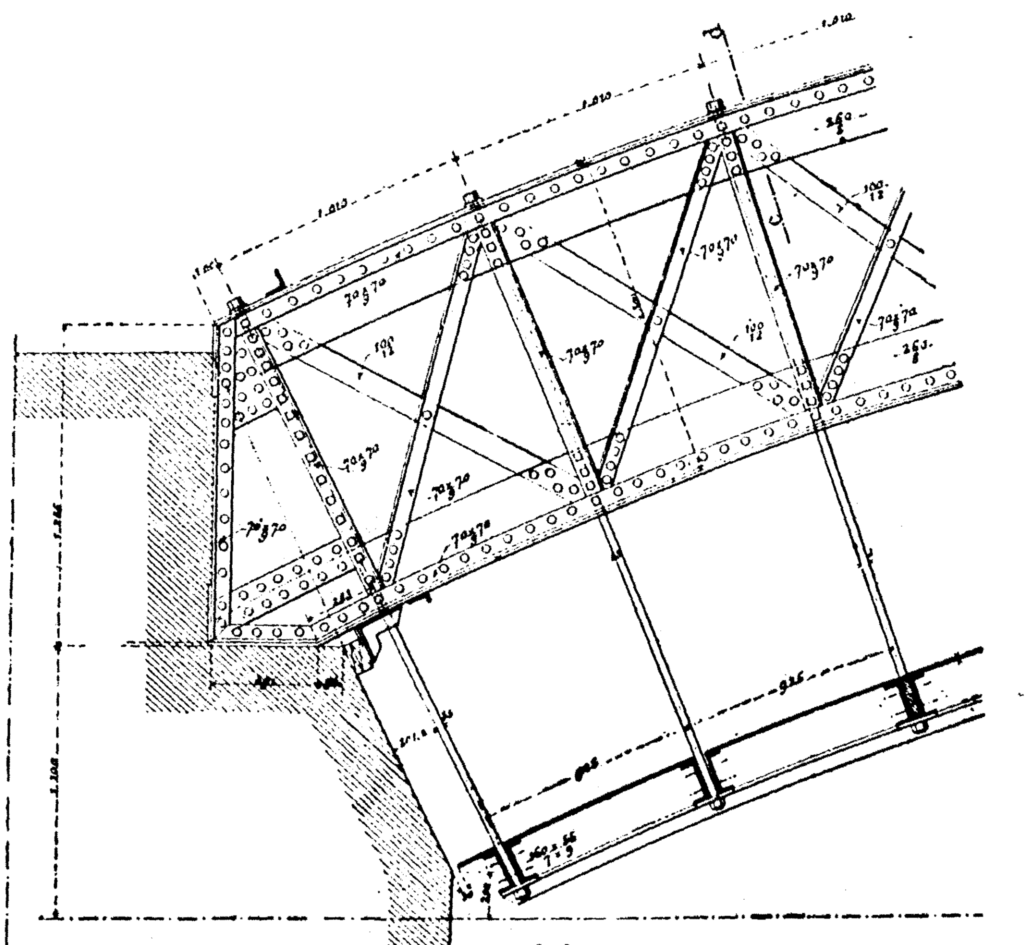
FIG. 163.—Longitudinal section of one of the centers.

land, in a shop, by the side of the four 150 horse power engines which drive them. The supply pipes which lead to each caisson are placed on rafts. These pipes are made of sheet iron, with india rubber joints, so as to prevent rupture from their constant working due to the motion of the waves.

The free air spaces are lighted by Gramme arc lights, and the caissons by incandescent lamps. The boilers are placed in the same shop as the compressors.

A system of electric bells puts the caissons in communication with the engine shops, and informs the engineer of the quantity of air requisite, by which he regulates the working of the compressors.

(249) *Centers of the arches for the Quai des Graces.*—The springing line of the arches between the piers of the Quai des Graces is at



1: 20.

FIG. 164.—Details of the iron centers. Radius of the upper plate, $R_1 = 15.475$ meters; radius of the lower plate, $R_2 = 14.175$ meters.

the reference −0.20, and the construction of these arches required the use of quite solid centers, as the rise is reduced to 1.40 meters for a span of 12 meters. It was, therefore, very difficult to find a type of center which could be set up above the level of the water. In order to find a support it would have been necessary to go down 6 meters below this level.

The contractor therefore decided to construct a special center adopted for these exceptional conditions. It is formed (Fig. 163) of curved beams of 13.90 meters span, having their lower plates curved exactly to the form of the extrados of the arch to be constructed, and they had to be arranged so as to coincide with this curve when placed. The lattice beams are arranged so that long bolts could be placed in line with the verticals, directed along the plain joints of the arch (Fig. 164), and having their heads borne by the upper plate on the beams. The nuts, screwed to the bases of these bolts, carried pairs of channel iron beams, laid along the generatrixes of the intrados of the arch so as to support the plates serving as bolsters. Upon these plates, suspended instead of supported, the arches were constructed. To remove the center, the bolts were taken away after unscrewing the nuts. The system of channel iron beams and intrados plates were then placed upon a raft, by which they were taken away to be set up again; at the same time the lattice beams were removed by a floating crane and again placed between the piers, which had to be united with a new arch.

Experience has shown this new arrangement of centers to have given, in all respects, satisfactory results.

CHAPTER XXVIII.—FOUNDATION OF THE JETTIES AT LA PALLICE, THE PORT OF ROCHELLE.

(250) The foundations of the two jetties in the outer harbor of La Pallice (Fig. 165) had to be laid below the level of the lowest tide.

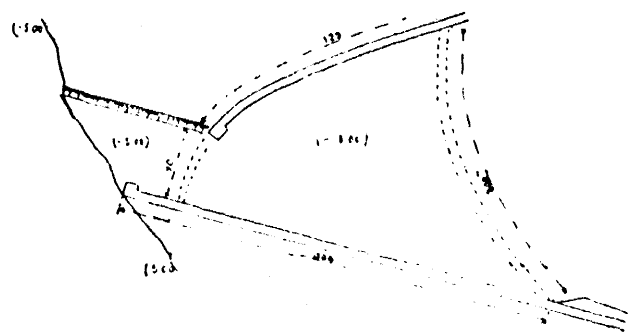


FIG. 165.—Port of Rochelle. Plan of the outer harbor of La Pallice.

The specifications required them to be made of great blocks of masonry, 20 meters long by 8 broad, separated by an interval of 2 meters and carried up to the level of 1.50 meters; the choice of methods for carrying out the work was left entirely to the contractors.

Above this series of blocks arose the body of the jetty, which was carried over the spaces between the blocks by little segmental arches of 3 meters span.

The constructors, MM. Zschokke and Terrier, made use of movable caissons for the foundation of these blocks; the spaces between the blocks, which it was afterwards decided to fill up, was accomplished by a special apparatus which will hereafter be described.

(251) *Process adopted for the construction of the blocks.*—As the blocks had to be built on the coast, without shelter against the sea, and especially against the southwest gales, the contractors could not employ the usual system of caissons, and build upon the interior flooring of the caisson, which the sea would have carried away and destroyed. They therefore made use of the movable caissons which they had successfully employed at St. Malo; by their use they were able to lay the foundations dry at sea, without leaving a particle of iron in the masonry; they were able to lay twenty-four monolithic submarine blocks with 160 meters of surface, amounting to 1,150 cubic meters each.

(252) *Description of the caissons and air locks.*—Two similar iron caissons were built by MM. Baudet & Donon, 22 meters long by 10 meters wide, with two superposed compartments (Figs. 166 and 167).

PORT OF ROCHELLE. OUTER HARBOR OF LA PALLICE. CAISSONS.

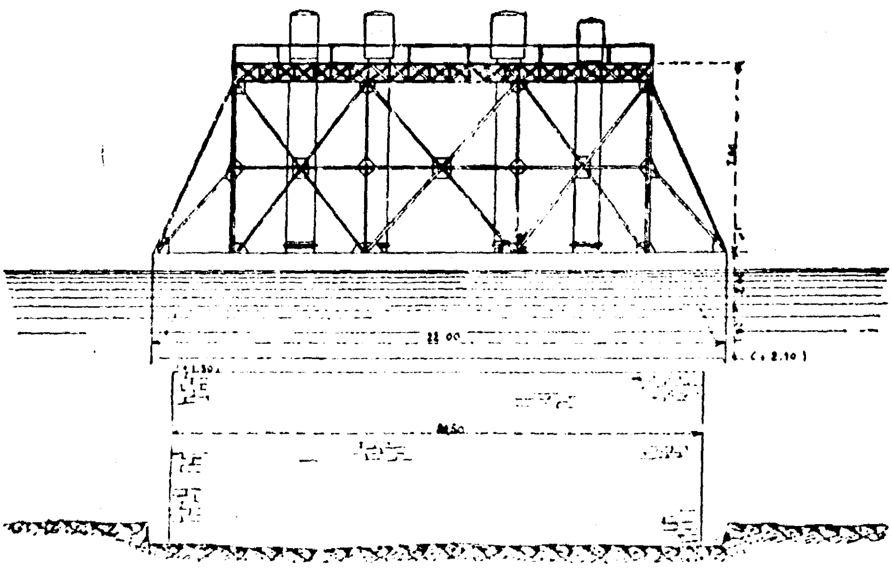


FIG. 166.—Caisson raised from the block.

The lower compartment was the working chamber, 1.80 meters high, and the upper one the equilibrium chamber, 2 meters high, and completely tight; a platform was placed on the latter which carried a scaffolding 7 meters high, supporting a second platform 16 by 4 meters. Four locks and shafts led from the platform to the working chamber. Two of these passages carried the ordinary air locks, and two others served for the discharge of the excavations and the introduction of the cut stone.

At Rochelle the caisson worked easily at several hundred meters from the shore, and the waves during the tempests passed over the scaffolding. The winches of the locks could not, therefore, be driven by portable engines and cables, hence Schmid motors were used, supplied by the compressors set up on shore. The caissons weighed

110 tons each. They carried between the braces and on the lower platform a permanent load of 220 tons of masonry. They were set up on the shore, moved down on rollers at low tide to the bottom of an inclined plane, launched at the next high tide, and towed near to the grounding place. The draught of water, with the equilibrium chamber filled with air and the working chamber filled with water, was then 3.30 meters. The grounding was an operation always delicate and sometimes dangerous. It was necessary to go down exactly upon the location of the block to be constructed, against the waves, and especially against strong currents. It was anchored to six fixed points, one of which was furnished by the jetty behind, and five others by buoys strongly anchored. The anchoring lines passed over the grooves of pulleys fixed above the upper platform and terminated at winches placed on the platform. By hauling and letting go with these winches the position of the caisson, and its alignment were regulated.

The height of the water above the bottom at low tide was, for the first blocks, below the draught of the floating caisson. It was sufficient then to let it go down with the tide. When it struck upon the bottom the valves were opened, giving access to the water in the equilibrium chamber, and the surcharge prevented the caisson from rising with the tide.

The depth increasing as the work advanced, the low water did not bring the cutter to touch the bottom. In this case the valves were opened when the caisson was lowered, and the entry of the water into the equilibrium chamber produced the grounding.

The load was then more than sufficient to fix the caisson on the bottom, but a new load was necessary to balance the under pressure of 400 tons, produced by the introduction of compressed air in the working chamber, and to assure the stability of the apparatus. This surcharge of about 220 tons was given by cast-iron ballast which was stowed upon the upper platform.

(253) *Work in the caisson.*—The first care of the workmen going into the working chamber was to put the caisson on a level by digging at first under the highest portions of the cutting edge.

They then proceeded to remove the upper layers of the bottom just to the limestone bed which was judged proper to serve as the foundation of the block.

The operation of raising the caisson during the laying of the masonry was done with the aid of twenty-four great screw-jacks with steel rods 1.80 meters long and 0.10 meter in diameter (Figs. 167 and 168). These rods passed through brass nuts set up on the smaller bases of reversed plate-iron cones, the larger bases being riveted to the ceiling of the working chamber. The rods were in line parallel to the wall and 1.50 meters from it. The lower extremity terminated in the form of a hemisphere, carried in a hollow of the same form in a cast-iron plate resting on the masonry, which thus avoided all rigid connection between the suspending pieces of the rod and the plate.

(254) When the masonry was commenced the twenty-four jacks, having been raised to the end of their course, had their plates 0.80 meter above the ground. A layer of masonry 0.80 meter thick could then be laid. They then took the support on this layer to raise the caisson. As there was to be overcome in this first operation not only the weight of the apparatus, but the friction of its walls in the ground, they worked at the same time as the screw-jacks, six hydraulic jacks of 30 tons each. The caisson being thus raised 0.40 meter they kept as points of support one jack out of two, that is twelve in all, and took away the other twelve jacks to build 0.40 meter of height under their plates (Figs. 167 and 168). They then carried the

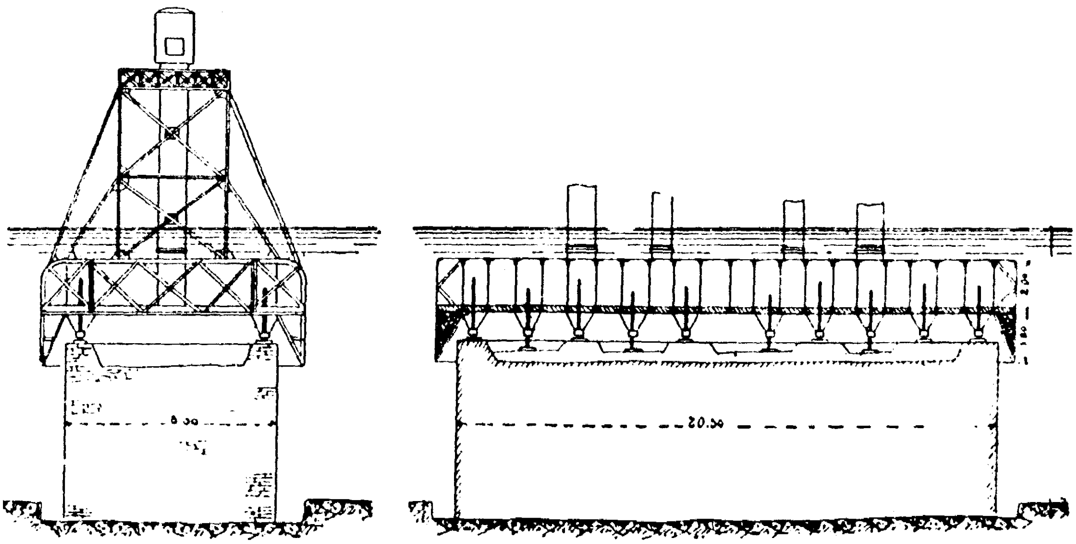


FIG. 167.—Transverse section. FIG. 168.—Longitudinal section.

Caisson resting on jacks.

caisson upon these twelve jacks, raised it, and then placed the twelve others to lay the masonry under. They had thus, around one block, and just to the walls, a continuous belt of masonry 1 meter thick and 0.40 meter high. By a double working of the jacks identical with the preceding, they raised the caisson again 0.40 meter and carried the height of the surrounding belt to 0.80 meter (Figs. 167 and 168). They then filled with masonry the portions within the belt, which completed the second course of 80 centimeters. They proceeded in the same manner until the block rose to the reference 1.50 meters.

(255) High waves interrupted the work sometimes for several weeks, during which the caisson, exposed to the tempests, had to rest upon its twenty-four jacks. First, they limited themselves to removing the under pressure and allowing the water to come into the working chamber, and placed a number of struts between the

walls of the caisson and the partly finished block. Experience having shown that these precautions were insufficient, they built upon the block four great pillars of masonry reaching up to the ceiling, upon which the caisson rested during the interruptions of the work.

They worked night and day in the caissons (except during the incessant stoppages caused by heavy seas). An average of eight hours out of the twenty-four was used for laying the masonry, the sixteen others to raise the caisson and to carry the stone into the working chamber. Fifteen masons worked in the caisson, with thirty laborers, laying 50 cubic meters of masonry per day. These hands did not include those employed on the service bridge for carrying materials and for the preparation of the mortar on shore. The caissons were raised by sixty men, forty-eight to work the twenty-four jacks, and twelve for the six hydraulic jacks. It took on an average one and three-quarter hours to raise the caisson 0.40 meter.

(256) *Displacement of the caisson.*—When a block was finished they waited to the next high tide to disengage the caisson.

The reference of the top of the block being 1.50 meters and that of the high tide 5.40 meters, with a draught of water of 3.30 meters, there was a margin of about 0.60 meter for the grounding.

The operation of displacement consisted in withdrawing the cast-iron ballast, which was deposited upon the boat, in replacing the six anchorages at low tide, and in driving out the water from the equilibrium chamber and allowing the caisson to rise with the tide. At the moment of high tide they pulled with the winches upon the anchorage chains toward the open space, and they let go on the opposite side until the caisson was brought over its new anchorage. They then repeated the operations already described for immersion.

(257) The difficulty of this operation arose because the caisson had to float nine hours, often in the night, from the moment when it lost its support upon the finished block to the moment when the following low tide allowed it to be grounded anew. If a tempest arose when the caisson did not cover the block they could, although not without risk, precipitate its immersion, but the danger would be very much greater if a sudden change of weather, as was often the case in these regions, had overtaken the caisson floating at the moment when one could not disengage it from the block nor ground it again upon it, hence they did not move the caisson except when the weather appeared to be favorable and the tide sufficiently high. It was not possible always to fulfill this double condition, except by waiting five or six weeks, during which the materials were unused and the workmen idle.

These operations of incontestible boldness were repeated twenty-four times.

(258) *Access to the caisson* was from the jetty, which was built as the first blocks were laid, and by a service bridge constructed upon the last blocks not yet finished.

This service bridge rested on an iron framework having its uprights of channel iron fixed in the masonry. It was constructed as light as possible, so as to not offer much resistance to the waves, but at the same time solid enough to give passage to the cars loaded with materials for the work. Over this bridge passed the electric wires for lighting, the two air pipes which supplied the working chamber, and the air for driving the little motors of the excavation locks.

The level of this service bridge was constant, while the platform surrounding the locks varied according to the height of the caisson on the block. When the platform was sensibly higher than the service bridge the two were joined by a safety planking, carrying rails upon which the little cars were raised by means of a winch driven by one of the little compressed-air motors of the locks (Fig. 165).

(259) *Removal of the submarine rocks of the outer harbor of La Pallice.*—After an ineffectual attempt to make use of the great caisson for the purpose of removing the rocks of the outer harbor, the contractors proposed to close the entrance to this harbor by sinking four new blocks, also to close all the spaces between the blocks already sunk, and thus establish an immense cofferdam within which 120,000 meters of rock could be removed by the ordinary processes. These four blocks were accordingly sunk, and the wall above them raised to the reference + 10 meters, *i. e.*, 15 meters above the foundation.

(260) *The junction of the blocks.*—The principal difficulty of the work consisted in closing under water the openings which had been left between the blocks, which the débris rolled in by the sea had already in part obstructed. These openings were of a plain rectangular section in the straight portions of the jetties. Their width varied from 2 to 3 meters, according to the position which had been given to the caissons in grounding them. In the curved portions of the northern jetty the foundation blocks, constructed along a polygonal plan, left between them trapezoidal spaces. The conditions of tightness, which it was absolutely necessary to satisfy, did not allow the béton to be run in under water, which would have never reached the solid foundation, and which, besides, would not have set against the sides of the block already covered with marine vegetation. The little sides of the openings could not be closed by panels to make an inclosure open at the top which could be pumped out. The panels would not have reached the bottom through the deposits which covered it, and the little open inclosure would have been constantly broken in upon. Again, the irregularity in form of these spaces, the force of the current which passed through them, and the entire absence of all shelter from the sea were sufficient motives to prevent the employment of a movable caisson, which M. Zschokke had previously employed with complete success for the

junction of the St. Malo locks in the Seine. A new process must be found which would resist the sea, and allow the openings to be filled with masonry, laid dry, after the spaces between the blocks had been cleaned out.

(261) The contractors proposed the following arrangement, which was approved by the engineers. They converted each opening into a little caisson formed by the two walls of the block to be united, by the arch originally provided between these blocks, and by two lateral iron panels (Fig. 169).

At the reference of the springing line of the arch (+ 2 meters) the mass of the jetties was behind the faces of the blocks. It was necessary in order to have a complete ceiling to prolong the arches

METHOD OF CLOSING THE SPACE BETWEEN THE BLOCKS.—PUTTING IN THE PANELS.

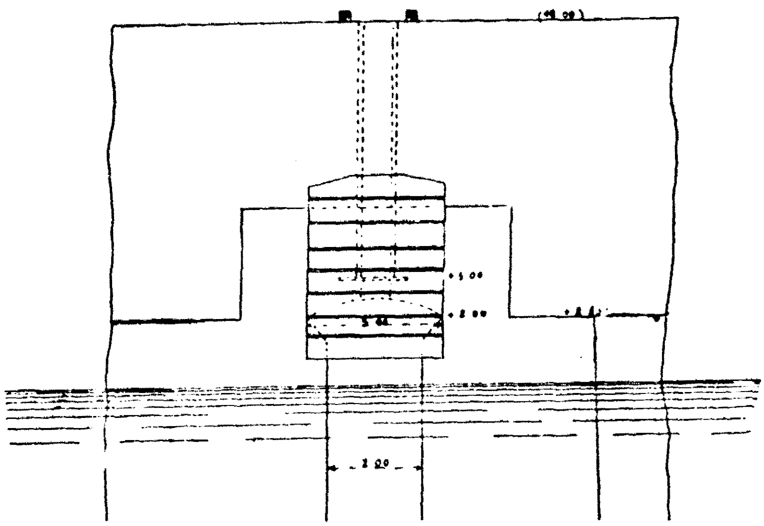


FIG. 169.—Front elevation.

until they were vertically over these walls, and to load them 3 meters high with the quantity of masonry necessary to resist the under pressure. They made a vertical cylindrical opening in the arch 0.70 meter in diameter, by prolonging which they embedded, above the extrados, a plate-iron collar and angle irons serving for a passage of a shaft 0.70 meter in diameter (Fig. 169). They raised the jetty to the reference + 8, leaving the interior of the mass above the aperture for the lock placed upon its shaft.

Two strong beams placed at the same reference, +8, across the masonry, carried two winches, each placed perpendicularly to the two wall faces (Fig. 170). These winches served to handle the iron panels which completed the working chamber. The panels were formed of horizontal elements of plate iron with India-rubber bands between them, and angle irons 0.40 and 0.50 meter high, which could be put together anywhere by bolts (Fig. 172). These elements were curved at their extremities, which rested upon the longitudinal walls of the two blocks. The upper element was also curved upon its longitudinal upper face so as to completely close upon the masonry wall above the arch. The angle irons of the elements were pierced with holes for the attachment of tie-rods with turn-buckles (Fig. 170), which served to bring together and tighten the panels

WALLS UNDER THE PANELS.—METHOD OF HOLDING THE PANELS.

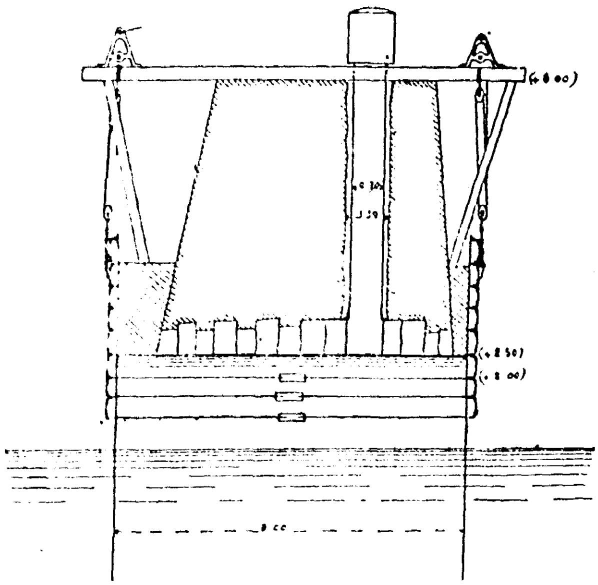


FIG. 170.—Longitudinal section.

upon the two opposite faces. Two panels were made for each arch; they were placed face to face, with a number of elements determined by the vertical distance between the intrados of the arch and the surface of the layer of the detritus which obstructed the bottom of the opening. The panel thus prepared was suspended by tackles

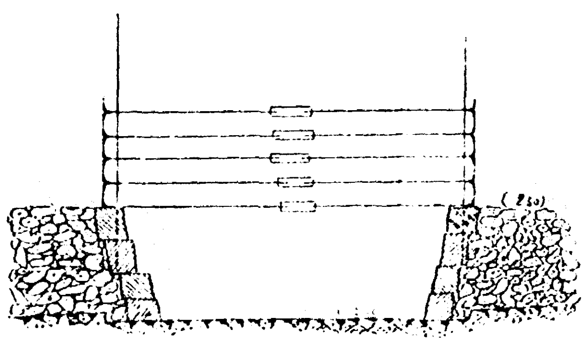


FIG. 171.—Transverse section.

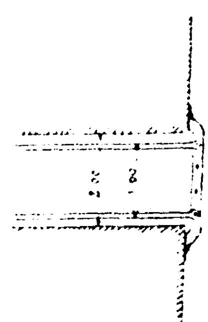


FIG. 172.—Longitudinal section.

from the two winches, lowered at low tide, and maintained, at first, at the height necessary for the angle irons and their lower elements to be placed a little below the intrados of the arch, and a little above the low-tide level. Men went into the opening and placed the two tie-rods of the lower angle iron without tightening them too much. Then the two panels were lengthened by the height of the next element. The second set of angle irons was put on under the intrados, and two new tie-rods were placed. They proceeded in the same manner until the lower angle iron and the panels touched bottom, and they had already a resistance sufficient to withstand the currents and the rising tide or even the waves if the sea became rough. At the following tide they tightened the tie-rods of the upper elements and made with clay, quick setting cement, and hemp, a tight joint between the parts of the first element and the faces of the blocks; they drove out the water by introducing compressed air under the arch, and then, working in the compressed air, they put on the lower elements and luted the joints.

(262) They thus arrived at the bottom of the panel; then they came to a mass of stones and debris coming from the construction of the blocks. They united this débris together below the panel by sacks of quick-setting cement, and then began to clean out the space, at the same time holding the débris under the panel, and on the outside, by little walls made with cement (Fig. 171). These little walls thus formed the prolongations of the panels and allowed the men to descend to the foundations of the block, and to begin laying the masonry there.

As the masonry rose, the tie-rods which were met were replaced by short iron rods, curved and embedded in the masonry, and connected to the flanges of the panels by a hook driven upward so as to be able to be pushed down and thus release the panel.

When they arrived at the reference 1 meter they stopped, all the hooks were pushed down by bars, the upper tie-rods taken off, and the panels, becoming free, could be used in another place.

The rest of the space under the arch was finished in the open air at low tide.

The construction of these great blocks began in May, 1884, and terminated in June, 1888. During this time the two caissons constructed twenty-four blocks.

The depth at which the blocks were laid varied from the reference, −0.76 to −5.35 meters, and their heights from the reference, 1.50, 2.21 to 6.25 meters.

The total cubic mass was 18,000 cubic meters; it was paid for at the rate of 70.49 francs per cubic meter, the excavated rock and cement being provided by the Government.

PART III.—BRIDGES AND VIADUCTS.

CHAPTER XXIX.—THE NEW STEEL BRIDGE AT ROUEN O.. THE SEINE.

(263) The new bridge at Rouen was constructed to replace a suspension toll bridge built in 1836.

The bridge (Figs. 173–175) consists of steel arcs resting on masonry piers and abutments. It is unsymmetric, a condition which was imposed by the peculiar circumstances of its situation. It is formed of three spans of 40, 48.80, and 54.60 meters, with rises of 2.50, 3.70, and 4.87 meters, besides a straight portion of 16.80 meters span with an intermediate support on columns. The complete length of the work is 176.30 meters. The width of the bridge between parapets is 20 meters—14 for the roadway and 6 for the two sidewalks. The quays on the two banks are not parallel; they are at an angle of 4° 5'; the two spans of the bridge are therefore slightly skew. The foundations were made by means of compressed air, except those for the rear abutment on the left, which was founded on piles. The steel arcs are nine in each span—five under the roadway, two under the sidewalks near the edges, and two at the sides. The seven intermediate arcs have plates 0.60 meter wide; the thickness of these plates is 0.033 meter for the five arcs under the roadway and 0.022 meter for the two intermediate arcs. The border arcs have plates 0.30 meter wide and 0.022 meter thick. The heights of the arches are as follows:

	At the crown.	At the springing lines.
Span –	*Meters.*	*Meters.*
40.00	0.422	0.652
48.80	0.522	0.802
54.60	0.622	1.002

The arches alone are of steel. The spandrels and upper roadway are of iron. The spandrels are formed of uprights, braced crosswise only, and not longitudinally: their spacing varies from 2.57 to 2.67 meters, according to the span. The upper roadway is formed of longitudinal bearers resting on the uprights of the spandrels, and united by crossbeams supporting brick arches 0.11 meter thick, having a span varying from 1.13 to 1.18 meters. The arches under the roadway are of solid brick; those under the sidewalks of hollow brick. Toward the keystone the longitudinal bearers disappear, and

New bridge over the Seine at Rouen, France.

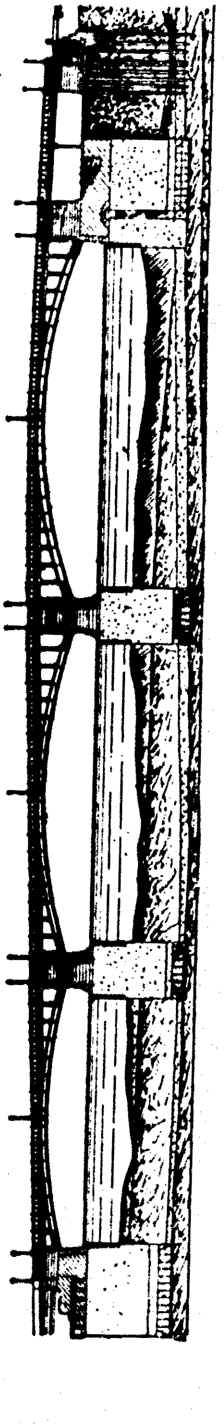


Fig. 173.—Elevation.

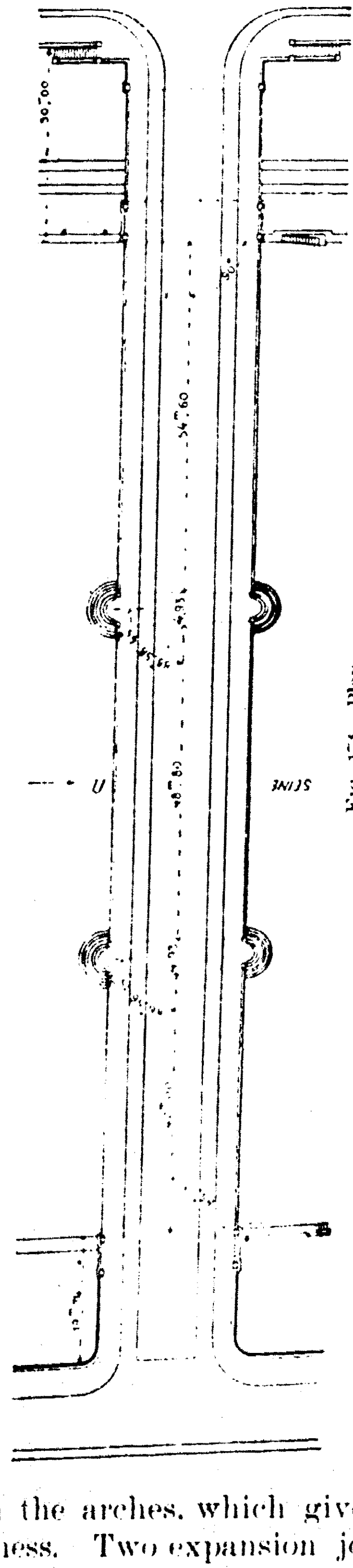


Fig. 174.—Plan.

the cross girders rest directly upon the arches, which gives to the work an appearance of great lightness. Two expansion joints are arranged for each bearer. The span on the right is formed of eight steel beams 0.346 meter high, with widths of plate of 0.40 meter for the intermediate beams, and of 0.25 meter for the end ones. These beams are united by iron cross girders supporting the arches of the roadway and sidewalks. The arches were built on centers resting on piles. The same center served for the three spans. It consisted of nine trusses from 2.70 to 2.20 meters apart.

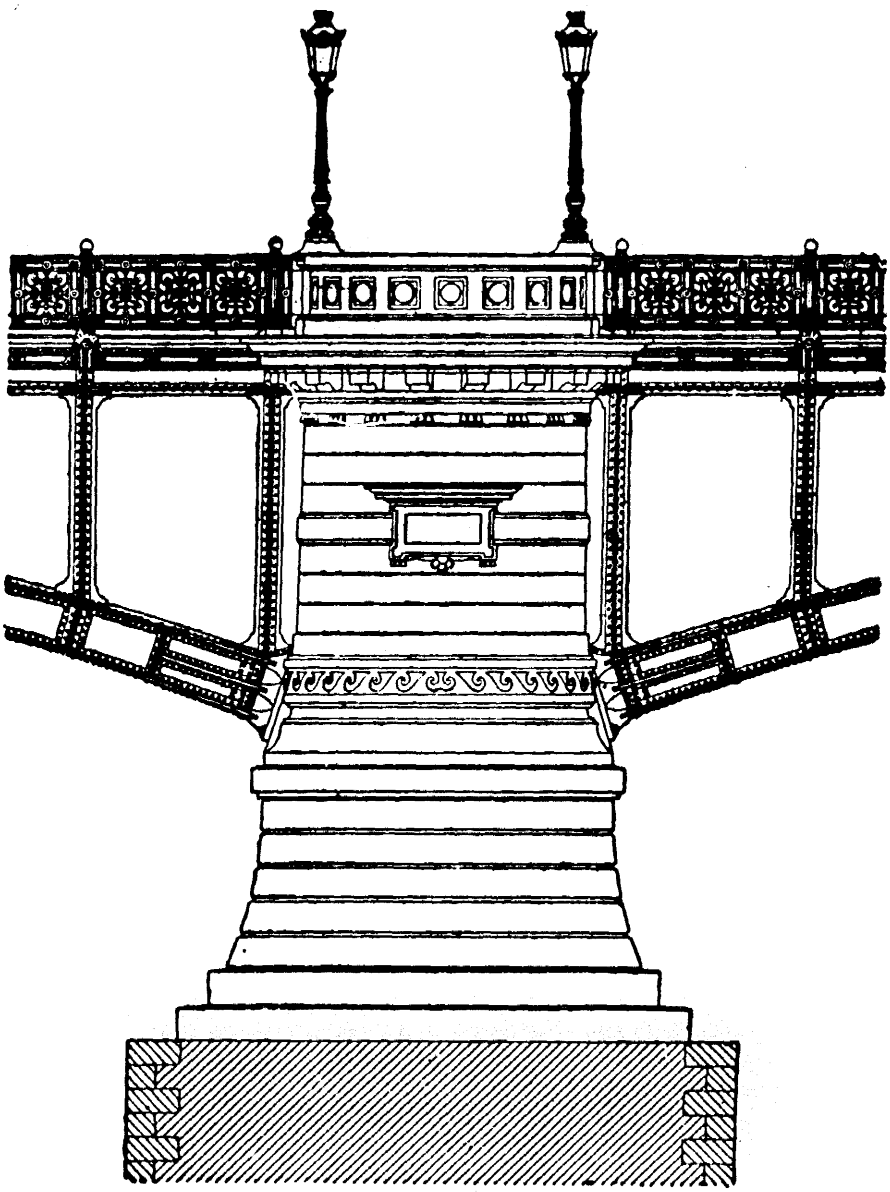


FIG. 175.—Upstream elevation of pier No. 2.

(264) *Cost.*—The cost of the bridge proper was 2,900,000 francs. The excavations, made by means of compressed air, cost 12.15 francs per cubic meter; the masonry 53.50 francs per cubic meter. The prices per kilogram of the metals were as follows: Steel, 0.57 franc; iron, 0.45 franc; ornamental cast iron, 0.34 franc; ordinary cast iron, 0.24 franc.

The plans for the bridge were prepared by M. Junker, engineer, and M. Lavoinne, chief engineer. It was erected under the superintendence of M. Mengin, chief engineer, and Cadart, assistant. M. De Dartein, professor of architecture in the Polytechnic School and in that of Roads and Bridges, made the architectural and decorative designs for the work.

CHAPTER XXX.—RECONSTRUCTION OF THE ROADWAY OF THE SUSPENSION BRIDGE AT TONNAY-CHARENTE—ALTERNATELY TWISTED CABLE.

(265) The road from Bordeaux to St. Malo crosses the Charente above the port of Tonnay-Charente, 6 kilometers above Rochefort. At this point the mean width of the river is 80 meters. On the right bank is a hill, on which the town is built. On the left bank is an extensive alluvial plain nearly horizontal, situated slightly above high tide.

The toll bridge, constructed in 1842, consisted of three spans, united upon the left bank with a masonry viaduct passing over by a continuous declivity of 0.05 per meter, the difference of level between the roadway of the bridge and the plain. Ships, which come up to Charente, have a free space of 22 meters above high water under the central span.

The foundations were established on the rock on the right side and upon piles for the two piers. As to the abutment on the left, and the viaduct of approach, it was founded simply on the natural soil by means of a masonry platform resting on a layer of sand 1 meter thick. Considerable settling took place during the work, but afterward a state of equilibrium was established and no motion was observed in the masonry.

(266) In 1883 it was decided, in consequence of the rupture of the suspension bridge while it was being tested, to reconstruct it, under conditions much better, both as to the stability and the preservation of the work. (Fig. 176).

The total opening between the two abutments is 206 meters, divided into three parts; two end spans of 58 meters, and a central one of 90. The necessity of resting no load upon the left bank viaduct, founded as we have said very lightly, induced the engineer to carry the whole load on the piers taking the points of support on these piers and bringing the lowest point of the parabola on a level with the viaduct so that the traction of the cables should be nearly horizontal without any vertical component. The three span roadway is held at each end:

First. From the axis of the piers to 13.65 meters on each side by five oblique cables called rigid.

Second. By five cables with parabolic curvature to which the suspension rods are attached carrying the roadway. These last cables have only to sustain 62.70 meters of the cable in the central spans and 44.35 meters at each of the side spans. Their deflection is 5 meters in

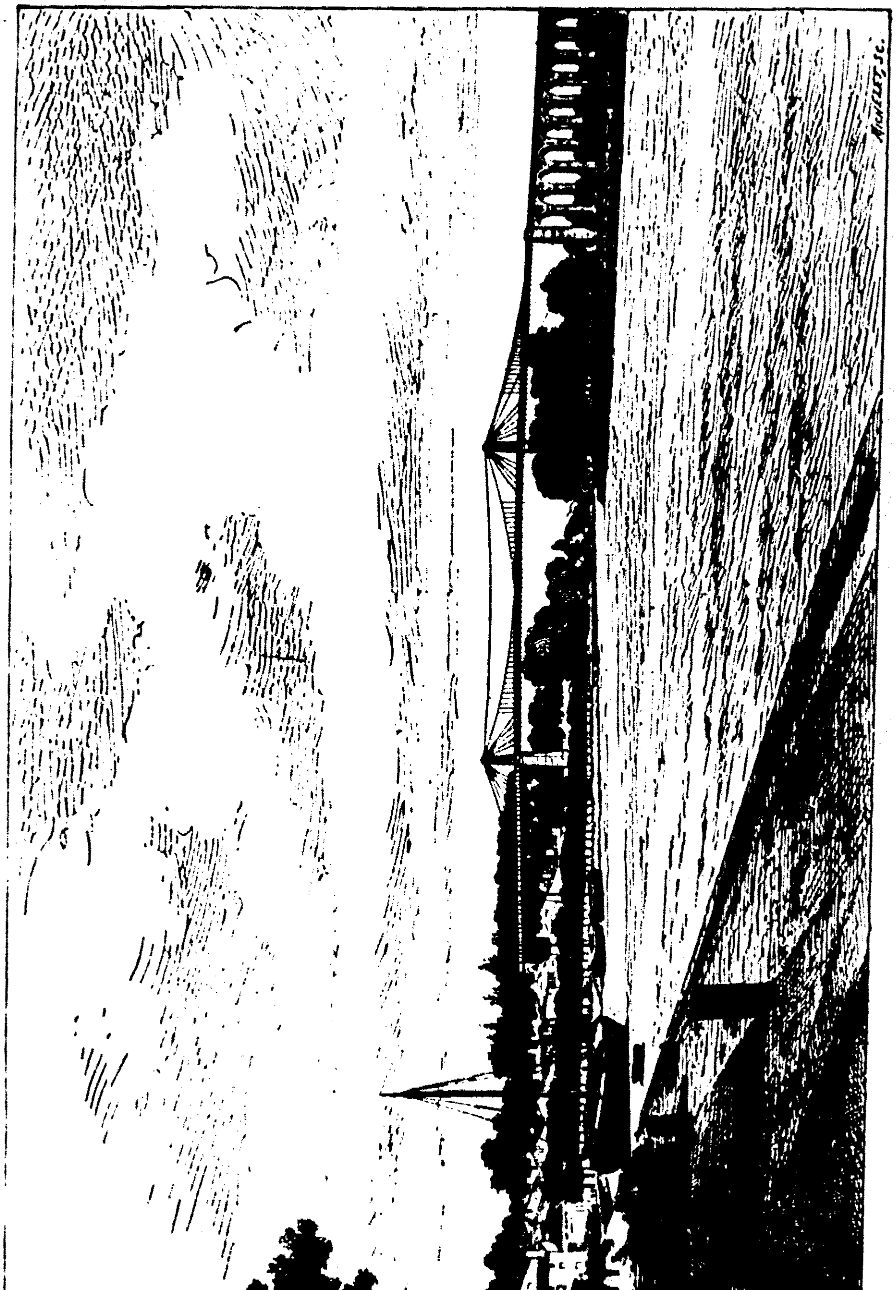


Fig. 176.—Suspension bridge at Tonnay-Charente.

the central span, 7.79 meters for the span on the left bank, and 7.17 meters for the span on the right.

The piers supporting this structure, not having the dimensions sufficient to form abutment piers, can be exposed only to compressive stress. For this purpose the difference of tension, resulting from the different positions of the proof load, is met by cables or retaining guys, four on each side per span, joining the tops of the piers and anchored at the base of the abutments.

(267) In order that the piers shall undergo no overturning effort there is arranged at the top of each an expansion truck rolling within certain limits upon an iron plate. This truck carries the steel pin 0.160 meter in diameter which serves to unite the suspension cables and the guys. It carries besides two pins 0.09 meter for the oblique cables.

The towers are of iron. At their upper part they are solidly united by an arched roadway with ribbed plate iron flooring and a parapet, so that the trucks and suspension joints may be easily inspected. The suspension rods are united to the cable so that they may be taken off and replaced easily without interrupting the traffic.

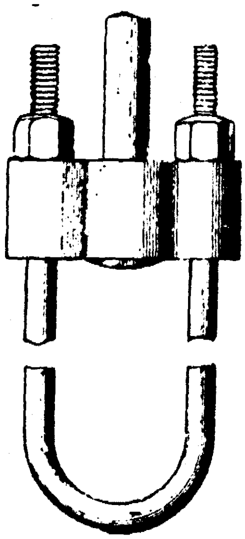


FIG. 177.—Method of attaching the cables.

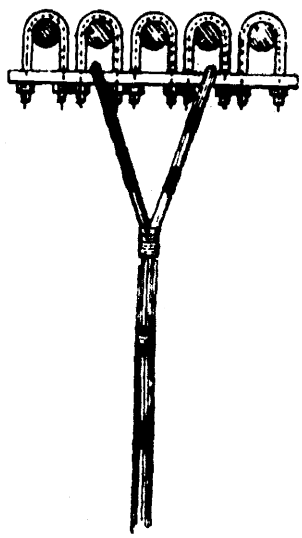


FIG. 178.—Method of attaching the suspension rods.

For this purpose the head of each suspension rod, instead of being carried above the cable according to the old custom, is suspended below by five little stirrups (Fig. 178).

(268) By the aid of this simple arrangement the removal of these cables offers no difficulty. When the screws of all the little stirrups are taken away the cable hangs freely, subjected only to the tension of its own weight. It is only required to unscrew the great stirrup, which at each extremity holds the cable passing through holes arranged for this purpose in the cast-iron back piece, where it is wedged through a conical hole (Fig. 177). The same series of operations reversed allows the cable to be replaced.

The guys are furnished also at their extremities with mild steel stirrups; this permits them to be changed and allows the tension to be regulated. All the cables and guys are attached to the top of the piers as has been indicated.

Each suspension cable is attached by means of a back piece and two steel straps to a rectangular bar, one end being inserted in a hole made in the masonry on one side, and the other resting against an iron bar embedded in the pit walls. Facilities for the removal of the cable are thus provided. As an extra precaution, there is a second anchorage formed of two bars embedded in the masonry and united to the first system by rods with plates and nuts.

On account of its situation the bridge is particularly exposed to the wind. Without entering into the details of its construction, we may say that the roadway was made very rigid, and that wind bracing was used, consisting of a system of diagonal flat bars placed in the plane of the upper crossbeams; also by sets of guys attached to the crossbeams and anchored on the shore.

(269) *The cable.*—All the cables except the suspension rods are of twisted wire arranged in concentric layers and twisted alternately in opposite directions (Fig. 179).

FIG. 179.—M. Arnodin's alternately twisted cable, one-third of the natural size.

Consequently all the wires in the same cable, except the central one, have the same length, and when the cable is stretched all the wires are equally elongated. This is a property which belongs only to cables with straight wires, and to those which are alternately twisted. The tensions of the different wires produced by the elongation of cables twisted in the ordinary way, as in American cables have very different values. These cables manufactured by M. Arnodin may be called alternately twisted cables.

The alternately twisted cables have a very much greater flexibility, which will be easily understood when we consider that the points of contact are fewer, and consequently the adhesion much less. The ratio of the hollow to the full portions is much greater than in the simply twisted cable; it varies from 0.15 to 0.30, according to the number of wires. Before the cable is manufactured the wires are passed through a bath of inoxidizable composition; then, as each layer or crown is added, the cable passes anew through this bath, so that all the wires and all the layers are covered, and the interior spaces between tangent circumferences are filled with this composition.

(270) The vertical suspension rods are the only ones which have parallel wires, in order not to complicate their attachment to the transverse beams and the parabolic cables.

The old roadway weighed 1,354 kilograms per running meter, and would only allow the passage of two 5-ton carriages at a time.

The new superstructure weighs 1,368 kilograms per running meter, and will permit two carriages of 7 tons to rest on the same cross beam. Hence, without altering sensibly the weight of the superstructure, which was a necessary condition on account of the state of the piers, they were able to obtain a much greater strength and stiffness in the new structure.

(271) *Cost.*—Suspension superstructure, etc., 264,976.70 francs; administration expenses, demolition of the old superstructure, masonry, etc., 34,826.42 francs; total, 299,803.12 francs.

The reconstruction of the superstructure was planned and carried out by M. Arnodin, under the supervision of M. Potel, chief engineer and Caparon, assistant.

I am indebted to Mr. Arnodin for information and drawings.

CHAPTER XXXI.—THE LIFTING BRIDGE AT LA VILLETTE, PARIS.

(272) The port of Villette consists of two basins of unequal lengths (70 and 30 meters), separated by Crimée street, which has a daily traffic amounting to four thousand vehicles. A channel 60 meters

LIFTING BRIDGE AT LA VILLETTE, PARIS.

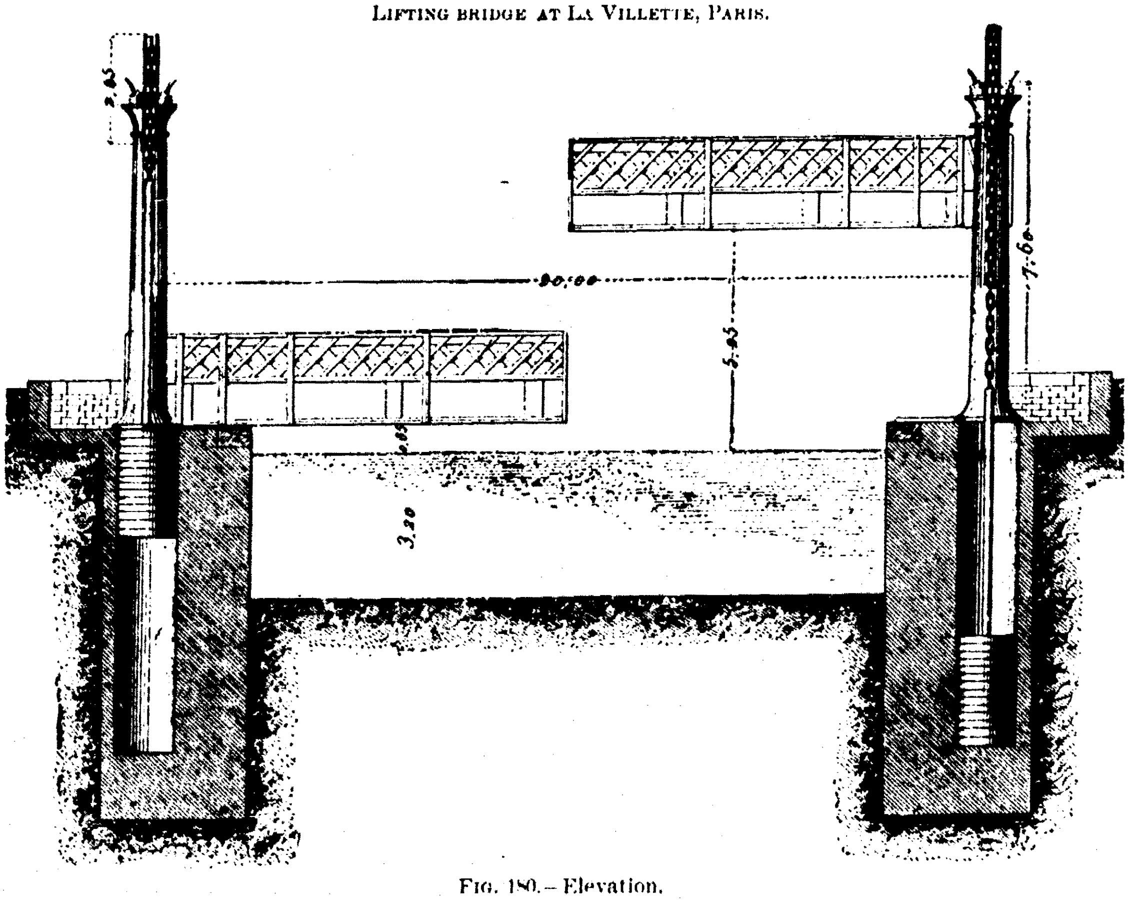
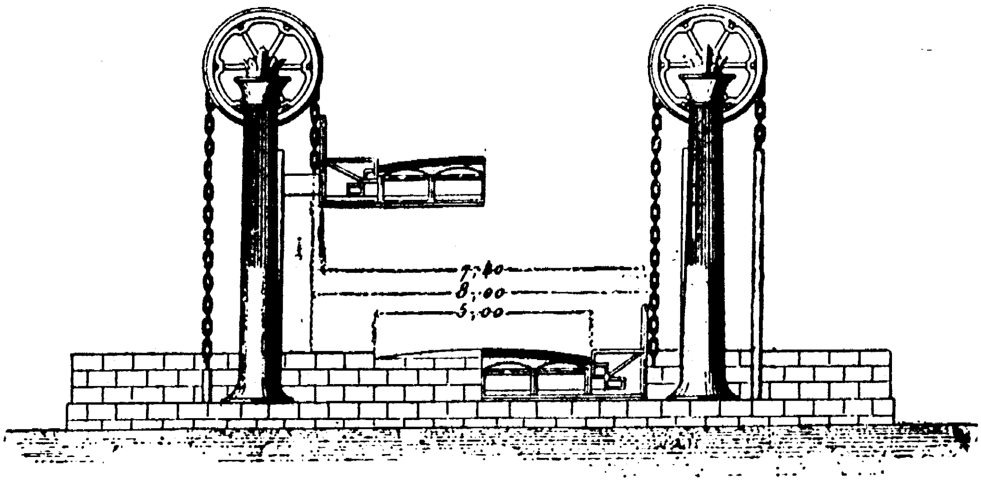


FIG. 180.—Elevation.

long and 11 meters wide connects these basins. This channel was widened to 15 meters, and a lifting bridge (Figs. 180 and 181) was erected over it. This bridge weighs 85 tons: it is balanced by four counterpoises, one at each corner, descending into a dry masonry pit. The visible portion of the mechanism consists only of chains and guide pulleys with their supports, which are decorative cast-iron columns. The bridge being balanced, the only efforts to be overcome, both in ascent and descent, are those due to the friction and rigidity of the moving parts, which are estimated at about 5,000 kilograms. The moving mechanism consists of two cylinders placed under the abutments of the bridge, having their piston heads permanently attached to the superstructure. The necessary synchronism of motion in the pistons is accomplished by a shaft, with beveled wheels at each extremity, which in turn drives two transverse shafts provided with spur wheels gearing into racks placed on each upright post (Fig. 182).



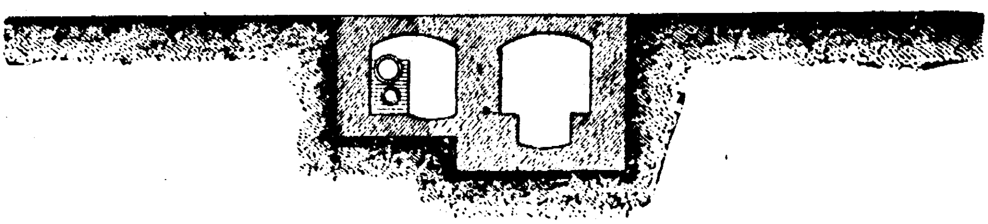


FIG. 181.—Transverse section.

In order that the pressures under the pistons shall be exactly equal, two conduits are placed in the superstructure, which communicate with the interior of the piston rod, and empty, one above, and the other below the piston (Fig. 183).

The lower surface of the piston is double the annular upper surface. When the pressure acts upon both faces the bridge rises; when the pressure acts only on the upper face, the lower being connected with the exhaust, the bridge descends; hence the whole valve work is reduced to a three-way cock (Fig. 184), connecting the bottom of the cylinder with the admission or the exhaust.

LIFTING BRIDGE AT LA VILLETTE, PARIS.

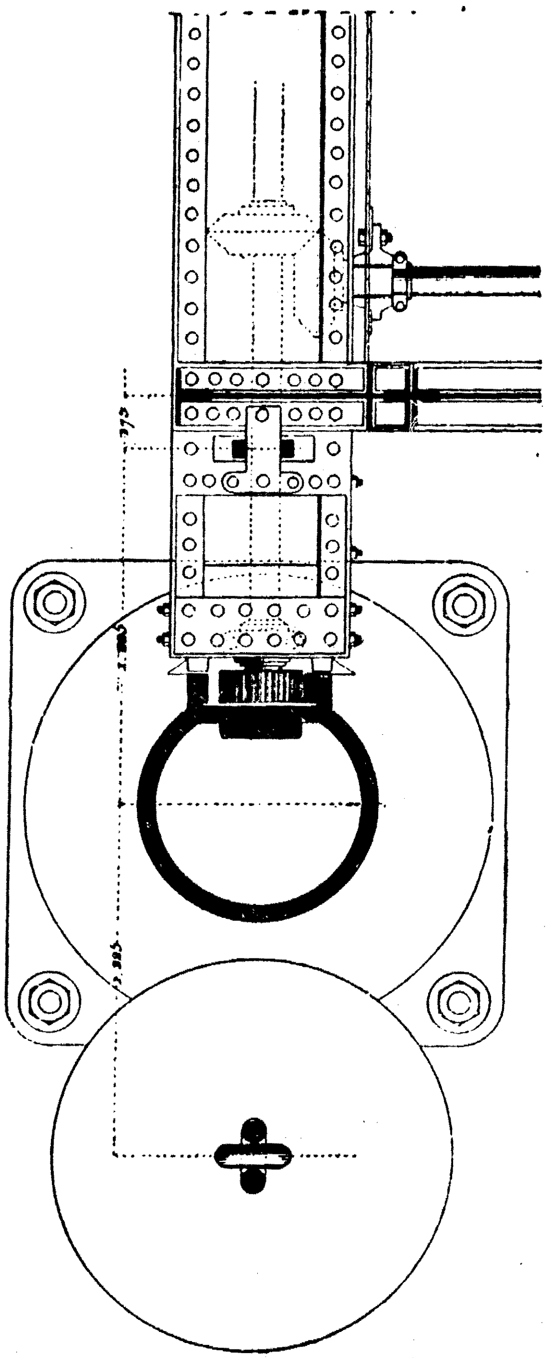


FIG. 182.—System of guiding the bridge.

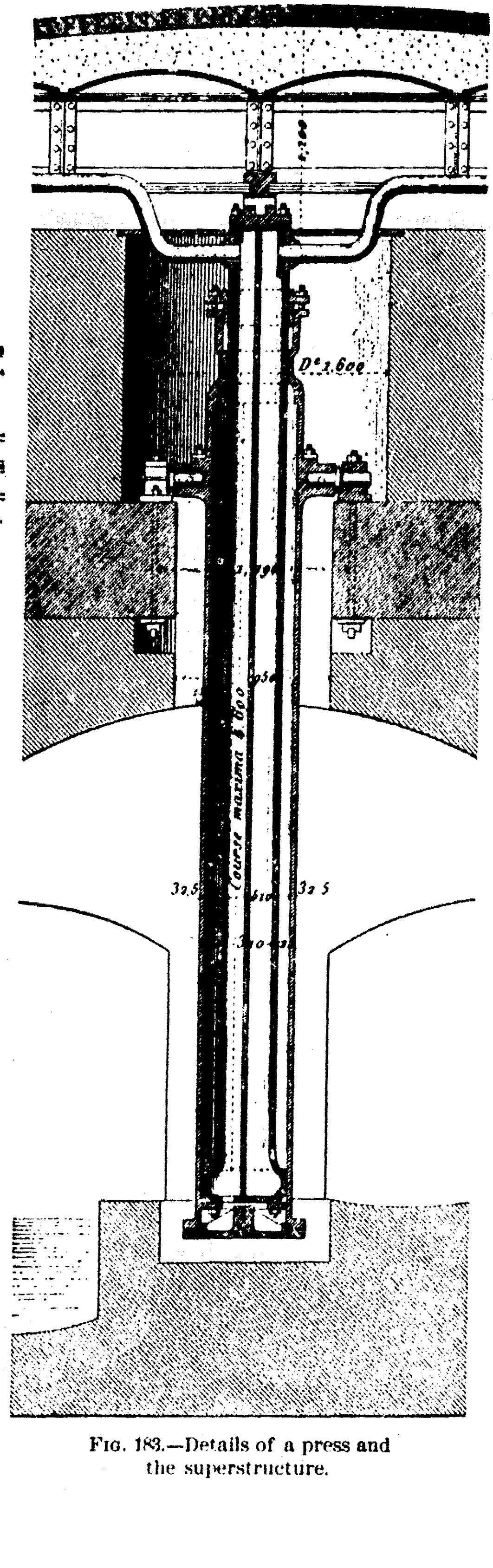


FIG. 183.—Details of a press and the superstructure.

To facilitate repairs, and to make up for a certain amount of play, the cylinders are suspended on trunnions, so as to oscillate lengthwise of the bridge.

The pistons being hinged to the superstructure the latter might move about the trunnions were it not maintained in its upright position by guides. These guides consist of four tenons projecting from the ends of the beams into channels made for that purpose in the iron columns (Fig. 182). These tenons are united two and two at each end of the bridge by a very rigid piece to which the lifting chains are attached.

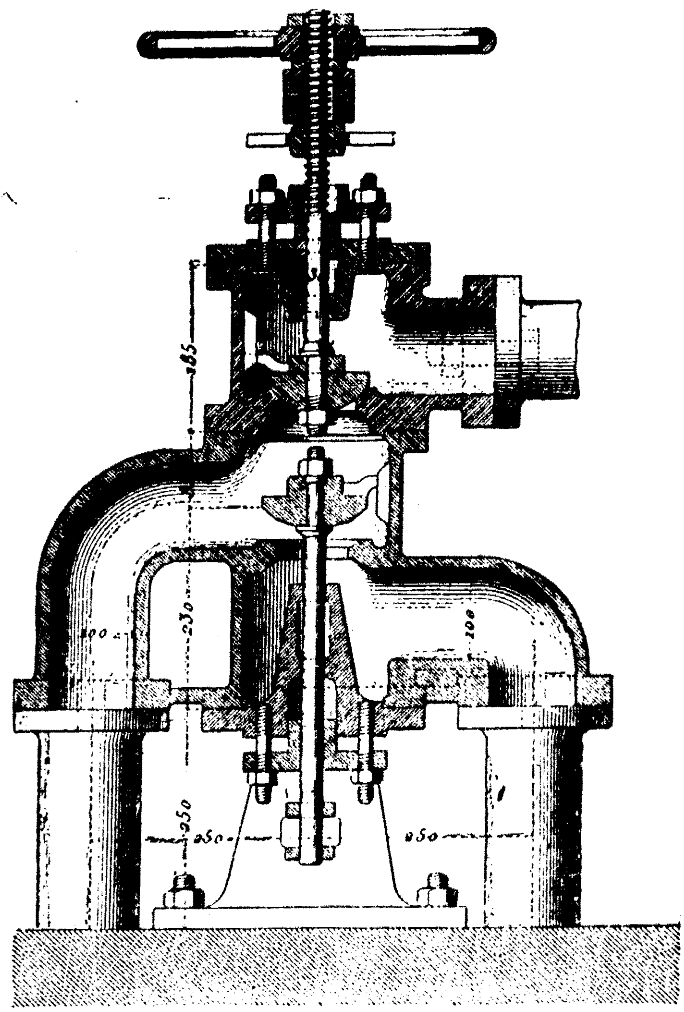


FIG. 184.—Three-way cock for the lifting bridge at La Villette.

(273) *The roadway.*—The stringers and crossbeams carry a wrought-iron paneling upon which is laid a mixture of sawdust and wooden splinters mixed with hot tar, and upon this mass, properly curved, a wooden pavement 0.10 meter high is placed (Fig. 183).

The intermediate mixture weighs about 1,000 kilograms and costs, when placed, 100 francs per cubic meter.

Resistance and elasticity.—A trial panel with an intermediate thickness of only 0.015 meter resisted satisfactorily a blow of 8 tons falling from a height of 0.30 meter, there being no permanent change of form or rupture of the filling.

The bridge is frequently operated by a child. Its complete lift is 4.60 meters, and the time of lifting 50 or 60 seconds.

The cost was 140,000 francs, not including the masonry.

The bridge was built by M. L. Le Chatelier, engineer, under the direction of M. Humblot, chief engineer.

I am indebted to M. Chatelier's article for the drawings and information contained in this chapter.*

A working model of this bridge was shown in the pavilion of the city of Paris.

CHAPTER XXXII.—THE GARABIT VIADUCT.

(274) *History.*—M. Boyer, the engineer in charge of the preliminary survey for locating the railroad between Marvejols and Neussargues, found that he could avoid constructing the road on the side of a very broken range of hills, and thus save a distance of 20 kilometers, by crossing the Truyère at Garabit cut, where the valley narrows, being bordered on each side by elevated planes.

The adoption of this line necessitated the construction of an immense viaduct 120 meters above the river.

Under these circumstances M. Boyer applied to M. Eiffel asking him to prepare the preliminary plans and estimates for such a viaduct, similar to the one built across the Douro, at Oporto, eighteen months before.

The reply of M. Eiffel showed that such an exceptional structure could be erected, which would be entirely satisfactory both as to its stability and its cost; and that M. Boyer could thus adopt the new line on the plateau, cross the valley by a viaduct 122 meters above the stream, and still make a saving of three millions of francs over the road as originally projected, and at the same time have a much better working line.

Under these circumstances the project for the viaduct furnished by M. Eiffel was approved, and he was authorized to construct it under the supervision of MM. Bauby and Lefranc, chief engineers, and MM. Boyer and Lamotte, assistant engineers.

(275) *Description.*—The Garabit viaduct is built over the River Truyère at Garabit, for the railroad from Marvejols to Neussargues. It crosses a deep valley and passes over an undulating plateau (Fig. 185). It carries a single line of rails. The iron portion has a total length of 448.30 meters, which is prolonged at its extremeties by masonry viaducts forming abutments. The rails are at a reference of 835.50 meters—that is to say, 122.20 meters above the deepest part of the valley.

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* Annales des Ponts et Chaussées, Sixth Series, Vol. 11.

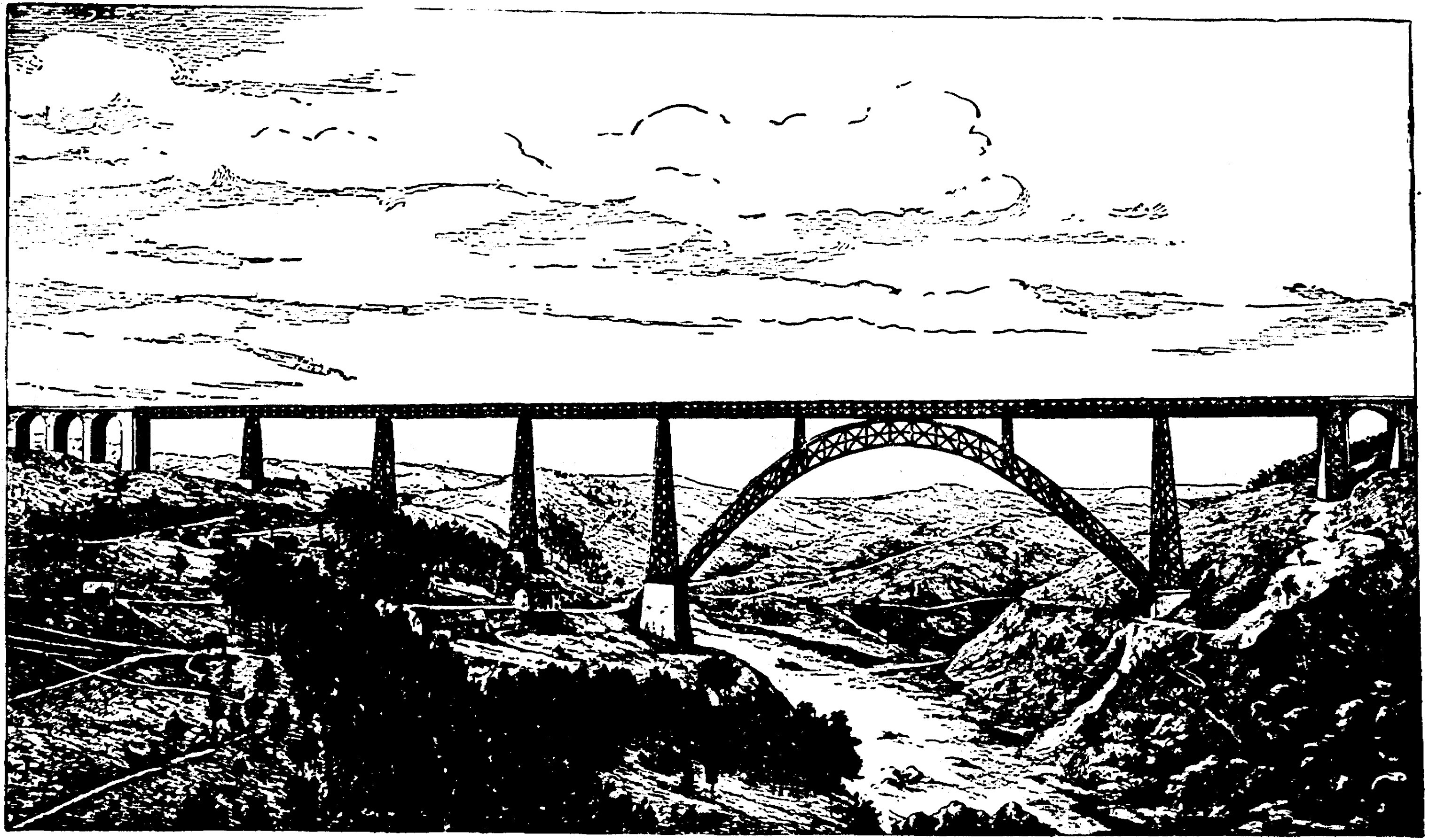


FIG. 185.—The Garabit viaduct.

The iron viaduct (Fig. 185) is composed of straight girders resting upon masonry abutments at the ends, and upon intermediate wrought-iron piers on each side of the valley, and upon struts standing upon an iron arch of 165 meters span. We shall now give a description of these parts:

(276) The horizontal superstructure is not continuous for its whole length, it is interrupted at the two struts upon the arch, and consist, properly speaking, of three consecutive portions.

First. That on the Marvejols side, which extends from the Marvejols abutment to the first strut on the arch.

Second. The central portion, which is included between the two struts.

Third. The Neussargues portion, which extends from the second strut of the arch to the Neussargues abutment.

The portion on the Marvejols side consists of five spans, as follows: Two end spans of 51.80 meters divided into fourteen panels of 3.70 meters each, giving a total length of 103.60 meters; three intermediate spans of 55.50 meters, giving 166.50 meters; finally a flush panel resting on the abutment having a width of 0.24 meter; total, 270.34 meters.

The central portion consists of three equal spans of 24.64 meters, divided into six panels of 4.106 meters, and giving total length of 73.92 meters. Finally the girder on the Neussargues side has two equal spans of 51.80 meters forming fourteen panels of 3.70 meters, giving a total length of 103.60 meters, to which must be added the full panel upon the Neussargues abutment, 0.24 meter, making a total of 103.84 meters.

The two end portions are fixed upon the great iron piers which form the abutments of the arch. They are able to expand freely on each side; and to allow for the motion produced by the variations of temperature there exists upon the abutments a play of 0.25 meter for the Marvejols portion, and 0.10 meter for the Neussargues portion between its ends and the stone guard, and a play of 0.10 meter between its extremity and the central portion on the struts.

The central girder is fixed at the two middle points, and rests freely on the struts.

(277) The roadway (Fig. 189) is placed 1.66 meters below the flange of the longitudinal girder, which thus forms a parapet of great stiffness.

The girders are 5.16 meters high and 5 meters apart. The upper and lower members have the form of a T, and are united by a simple lattice and by vertical struts.

Each of the members consists of a vertical web 600×15 and two horizontal angle irons $\frac{100 \times 100}{12}$ and a uniform flange 500×10. Supplementary plates are added wherever the calculations require it, as shown on the drawings. The lattice bars are T-shaped, and consist of a flange and two angle irons, and, in the central girder, simply of a web and two angle irons. The uprights have a double T section formed by two angle irons $\frac{80 \times 80}{10}$ and a web 8 millimeters thick.

Above the supports, these uprights are replaced by a strong flush panel to guarantee the transmission of the efforts coming from the lattice bars. (The dimensions are usually given in millimeters).

The transverse girders are attached to the longitudinal girders at the uprights of the panels. They have the form of a double T consisting of a web 700×8 and four angle irons, $\frac{70 \times 70}{7}$. This transverse girder is supported in the middle by two struts, each formed of two angle irons $\frac{80 \times 80}{10}$ put together. These struts are attached to the feet of the uprights. They are united at their lower parts by a tie rod formed of two angle irons $\frac{80 \times 80}{10}$. Finally, two bars similar to the struts, which they cross at their middle point, are attached to the uprights below the transverse girder and to the center of the tie rod, thus forming, with the uprights, the transverse girder, the tie rods and the struts, a very stiff bracing (Figs. 189, B and C).

The cross-girders are united to each other by five rows of longitudinal bearers. They consist, in the lateral girders, of a web 550×7 and four angle irons $\frac{90 \times 90}{10}$, but in the central girder, where the span of the cross-girders is greater, the angle irons are $\frac{90 \times 90}{13}$, the web being the same.

These bearers carry the metallic flooring, which is composed of iron plates 0.240×120 and sufficiently strong to support the weight of a locomotive in case of derailment; also, the principal girders form a parapet strong enough to prevent the fall of the derailed engine. Besides this advantage, the flooring, which is almost continuous, presents a second, viz, that of forming an almost perfect wind-bracing to the girder at the level of the roadway.

A lower wind-bracing, consisting of a single lattice in which each bar is formed of two angle irons $\frac{70 \times 70}{8}$, gives the two girders the greatest solidity to resist horizontal displacement. The girders rest upon hinged supports, some movable and others fixed. Each support consists of an upper part of wrought-iron which is fixed under the flanges of the girders and which carries a slot in which is lodged a wedge to regulate the level of the superstructure. This wedge rests on a lower piece of cast-iron having a slot so arranged as to gear with that of the upper piece and prevent lateral motion. The lower

GARABIT VIADUCT. CENTRAL PORTION.

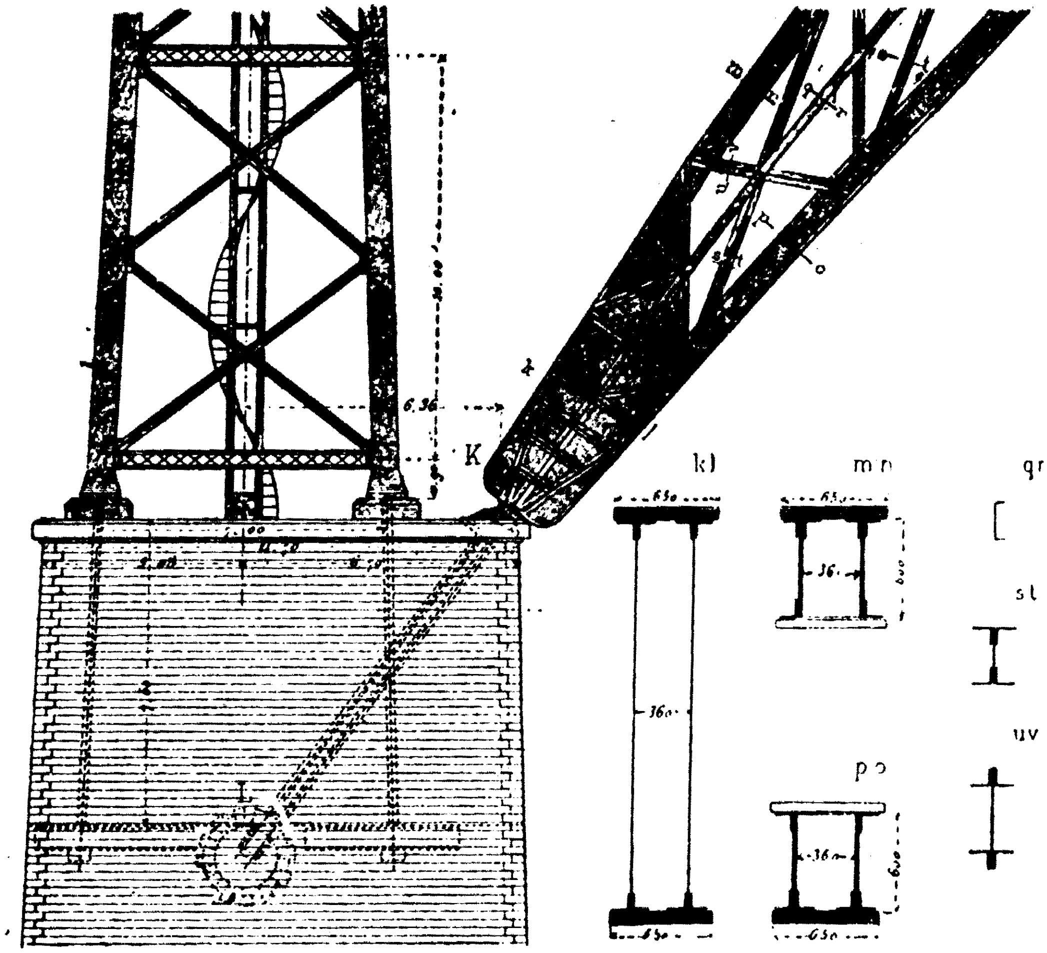


FIG. 186. Elevation.

Fig A. Sections k l, m n, o p, q r, s t, u v.

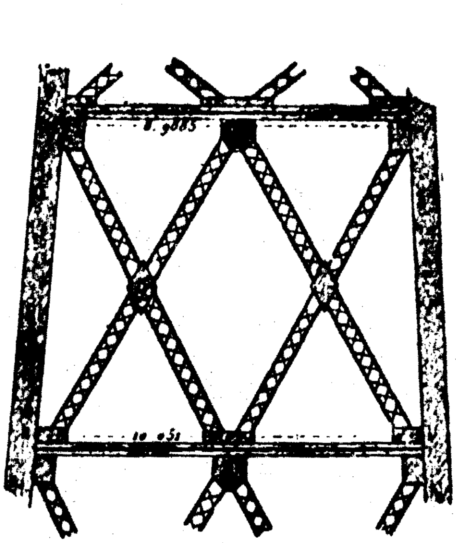


FIG. 187. Wind bracing of the extrados between the bottom of the arch and the first strut

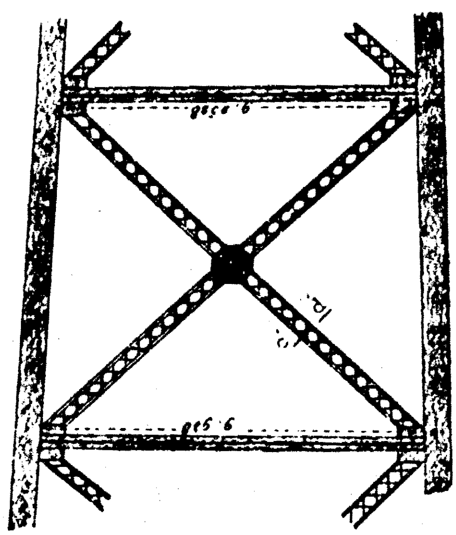


FIG. 188. Wind bracing on the intrados between the two struts.

piece has different forms according as the support is fixed or movable. In the case of the movable support, this piece has a less height and rests on cast-iron rollers. These latter have the form of segments which may be increased in number by bringing them nearer together. They rest upon a cast-iron plate. The use of hinged supports has the advantage that the vertical reaction of the supports always passes through its axis, a condition of absolute necessity for iron piers of great height.

(278) *The arch.*—The great arch has a chord 165 meters long; its rise is 51.853 meters, and its height at the crown 10 meters. It consists of two lattice-work principals placed symmetrically with respect to the middle plane of the arch, but in oblique planes thereto. The planes of these principals, which are 20 meters apart at the origin, approach each other toward the crown, where the distance of separation is only 6.28 meters, measured at the extrados; hence the inward slope per meter is 0.11008 with respect to the vertical. This arrangement gives great stability to the arch, enabling it to resist the most violent winds. The principal ribs are cruciform in section; the mean fiber is a parabola. It has a great height at the crown, and terminates in a point at each springing line where it rests on the abutments by a knee joint. This form obviates the use of spandrels, the stresses of which are difficult to ascertain by calculation, and may vary considerably by expansions or the displacement of the rolling load, while their unusual dimensions would require an enormous amount of iron.

The rigidity which this form gives to the principals enables them to resist, independently of all the accessory pieces, changes of form resulting from the unequal distribution of the loads; and it has, besides, the advantage of avoiding all uncertainty as to the point in which the resultant of the forces strikes the abutment, since it can only be the point of contact of the pivot with the cushion stone, which remains the same whatever may be the alteration in form of the arch.

The intrados and extrados members of each arched girder are connected by a lattice and by vertical struts, except in the panel next the springing lines, which is flush (Pl. IX).

These members, with their open interior faces (Fig. 186), consist of two webs 0.60 meters high, strengthened by two angle irons, and riveted to the flanges by four angle irons. The flanges themselves are formed of a variable number of plates 0.65 meter wide.

The verticals and trellis work are of angle irons and flat bars (Fig. A).

The principals are united by horizontal braces, each formed of four angle irons (70 millimeters) united by a plate iron trellis, except at the base, where there is a full web properly strengthened. Again, in the plane of each of these braces is a vertical wind bracing, each bar having the section u′ v′, Fig. C, united by a trellis of flat bars, except at the lower panel which is flush. Finally the connection of the two arcs is completed, both at the intrados and the extrados, by bracing (Figs. 187 and 188), each brace consisting of a square box trellis formed of four angle irons with a double lattice of iron plate bars on their faces (Pl. IX).

(279) *The iron piers* are in the form of the frustrum of a pyramid, their edges or standards being girders properly braced (Fig. 186).

In the Douro bridge, built by the same constructor, the standards were box girders. In this case, for the faces of piers at right angles

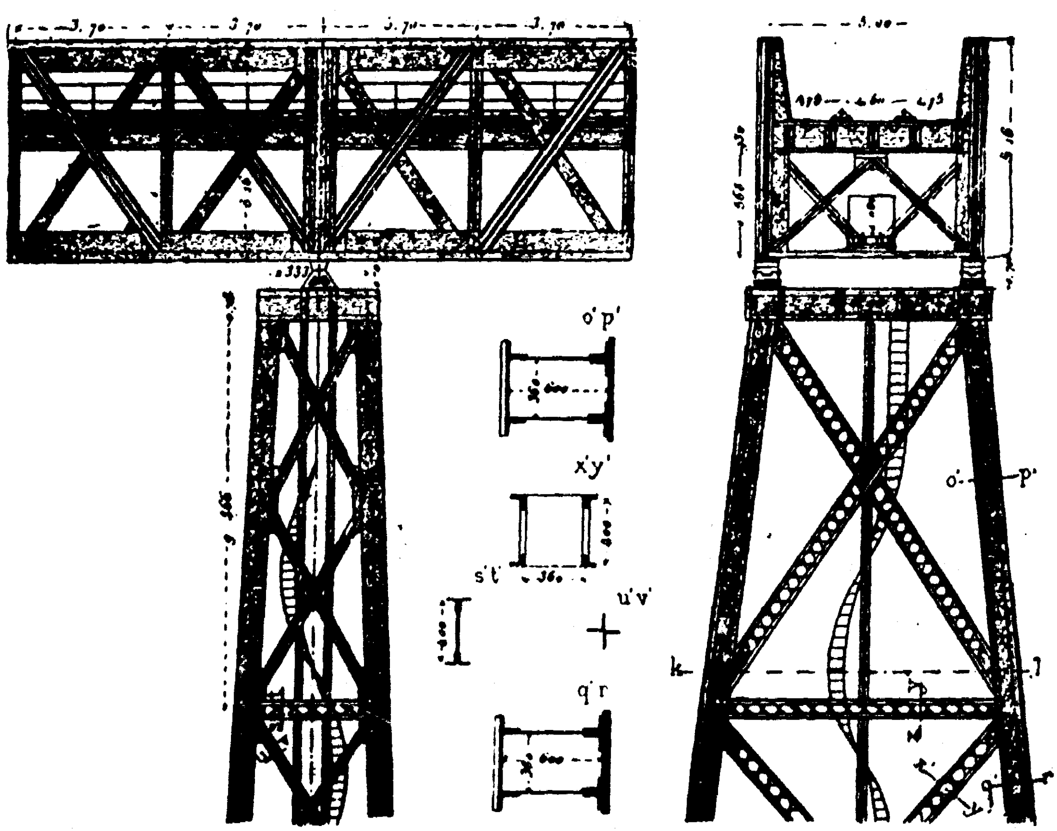


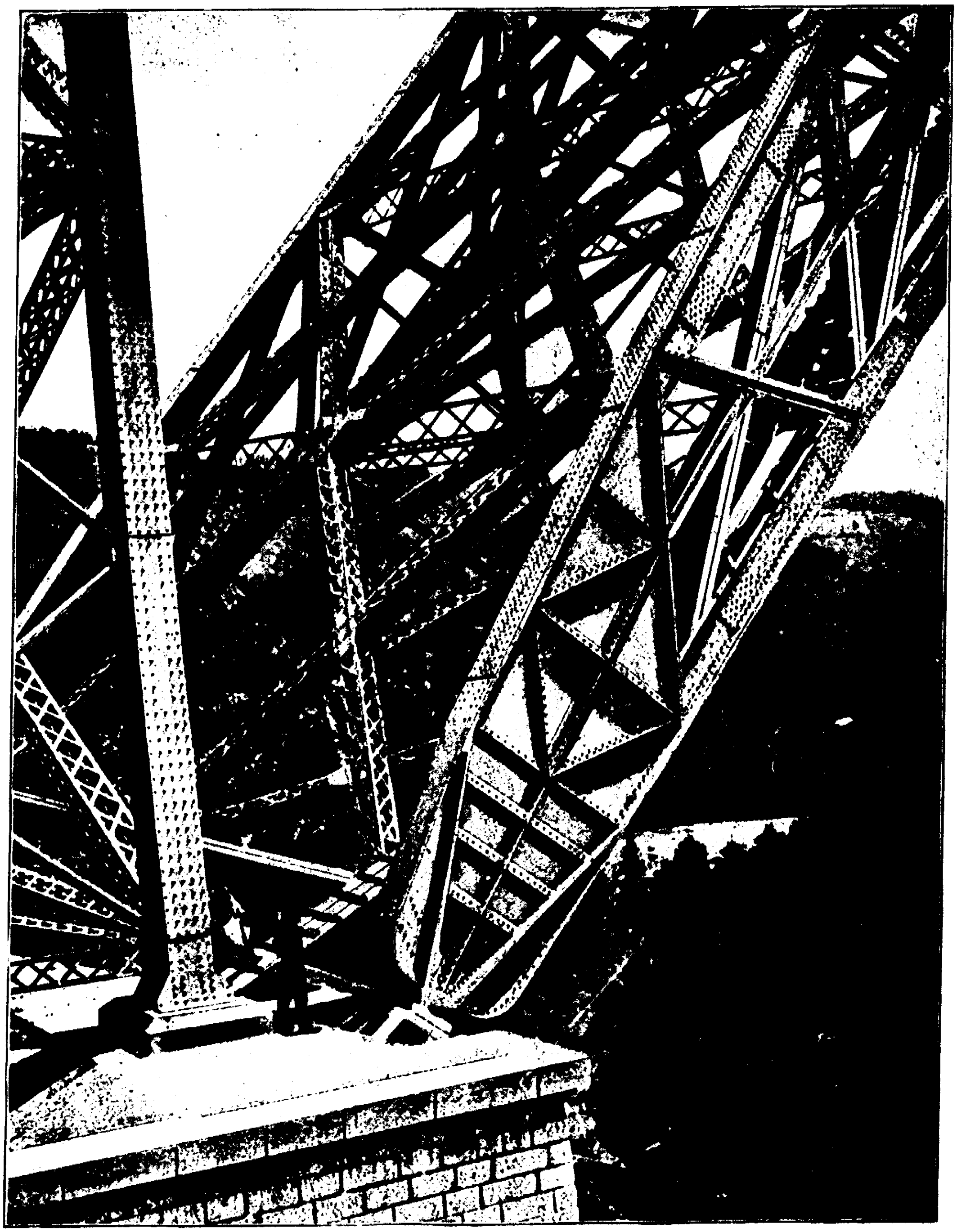
FIG. 189. Side elevation. Fig. C. Cross sections o′ p′, s′ t, u′ v, q r, x′ y′. Fig. B. End elevation.

to the roadway, which resist the force of the wind, the standards have a U shape, in which horizontal and diagonal braces are inserted, having the form of box trellis girders (Pl. IX).

This arrangement allows easy access and is capable of resisting compression as well as tension.

(280) *Principal dimensions.*—The piers (Fig. 189) are of the following heights, counting from the viaduct on the Marvejols side, measured from the masonry foundation, viz. 24.51, 36.46, 51.20, 60.73, and 60.73 meters.

The batter in the piers 1, 2, 3 is 0.08272 per meter; in Nos. 4 and



GARABIT VIADUCT. THE LOWER PORTION OF THE ARCH WITH ITS SUPPORTING PIER.

5 it is 0.11088 in the plane of the great face. The transverse batters are 0.0386 and 0.0388, respectively.

The piers are divided into panels 10 meters high, measured along the axis of the standard. Each pier terminates in a coping, which receives the supports of the superstructure. The piers, as well as the arch, are anchored in the masonry, as shown in Fig. 186.

In each pier a spiral staircase is placed, so that every part may be inspected.

(281) *Stresses.*—The plans for the masonry work were wholly prepared by the Government engineers.

The calculation of the stresses in the ironwork were made by M. Eiffel, and verified by M. Boyer by other methods and found correct.

The stress was to be limited to 6 kilograms per square millimeter under the combined action of the loads and the wind.

The surcharge was to consist of a locomotive weighing 75 tons drawing a train of cars weighing 15 tons each.

The effect of the wind was supposed to be 150 kilograms per square meter while the trains were running; and 270 while they were not, at which time the traffic would be suspended.

In the calculation, the wind was supposed to act uniformly on the side towards it, and to act solely on the trellis bars on the opposite side. To this there was added its effect on the train, which, as the train is partly protected by the upper members of the girder, was estimated as acting on 1.6 square meters per running meter. This figure, 1.6, was adopted by M. Nordling in calculation of the great viaducts on the Orleans Railroad system, which were also constructed by M. Eiffel.

The effects produced by the load and wind are such that the members of the arch may be regarded as bearing 2 kilograms per square millimeter under the ordinary load, 2 kilograms per square millimeter from the effect of the surcharge alone, and 2 kilograms per square millimeter from the effect of the wind, so that the section of the members is one-half greater than it would be if the effect of the wind had been neglected.

The influence of temperature is very slight when added to the loads. The maximum pressure at the crown of the arch under a variation of 30 degrees is only 0.63 kilogram per square millimeter.

(282) *Erection of the ironwork.*—At the commencement of the work the country around the viaduct was a complete desert. It was necessary to begin by building offices and lodgings for the overseer, and for the engineers when they visited the grounds, storehouses for the materials, repair shops, lodgings for the workmen, stables for the horses, and also a school for the children of the workmen. On account of the difficulty of access M. Eiffel erected a service bridge on a level with the foundation of the chief pier, 33 meters above the stream. The head of this bridge was united with the national highway by a road built on the side of the ravine. On this

road a storehouse was erected for the iron, with traveling cranes for unloading the wagons which brought it from Neussargues station. The platform of the bridge supported two lines of railroad, by which the materials were brought. All the foundations were laid on very resisting schist.

The masonry constructions presented no difficulty. While the iron

GARABIT VIADUCT. ERECTION OF THE IRON ARCH.

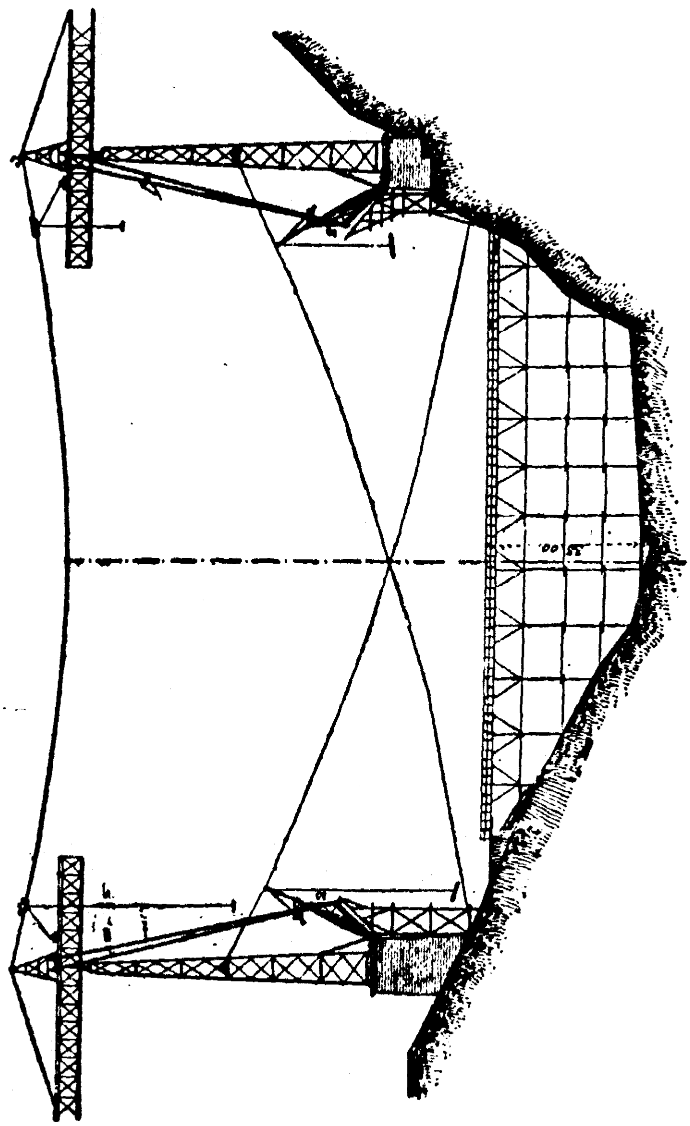


FIG. 190.—Beginning of the process of erection.

piers were in process of erection two portions of the superstructure of the bridge were set up on the right and left banks. When all was ready these portions were pushed forward so as to overhang the central piers by a distance of 22.20 meters over the arched space. The end of each portion of the superstructure was made fast by twenty-eight steel cables to the masonry abutments of the accessory viaducts, and then preparations were made for raising the arch by building two principal scaffoldings in front of the two foundations of the abutment piers up as high as the pivots.

The upper parts of the scaffoldings were curved so as to form a center for the members of the intrados of panels 1 and 2, which were arched; then the outer extremity of this arch was held by twenty steel cables made fast to the overhanging superstructure (Fig. 190),

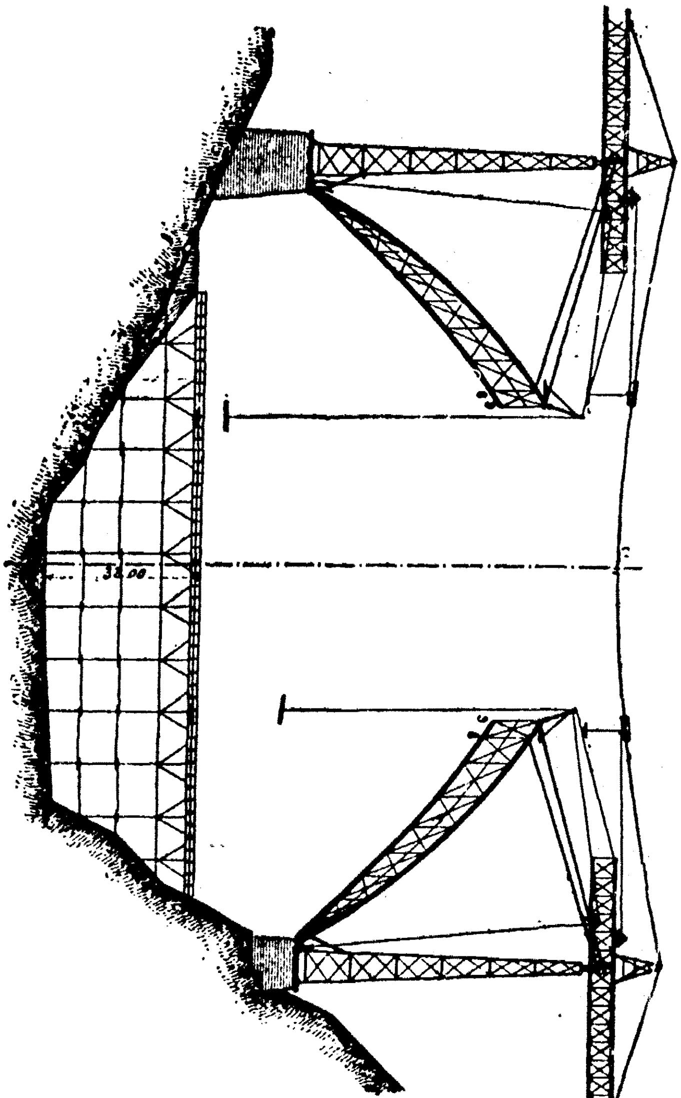


Fig. 191.—Appearance in an advanced stage of erection.

and then they proceeded to erect the overhanging arch by attaching new pieces to those already riveted in place.

When the overhanging portion erected balanced that of the lower part, which occurred at the fifth panel, a new set of cables uniting vertical strut 5 with the upper superstructure was put in, and the work was continued to strut 9 (Fig. 191).

Again, twenty-four cables starting from struts 8 and 9 were made fast to the superstructure, and the work so progressed until the crown was reached (see Plate X). The erection went on simultaneously on each side.

(283) *Methods of raising the pieces.*—The pieces were raised in two different ways; the heavy pieces were brought by cars on the service bridge exactly under their intended position. Rolling shears, placed on that portion of the arch already built, supported powerful winches which raised these heavy pieces (Fig. 190).

For the light pieces, there were erected above the central piers two wooden stagings 10 meters high, which held a steel-wire cable tramway spanning the distance of 177 meters between the piers. The cable carried two cages, one for each side (Fig. 191).

The cables were made with great care with a hemp core surrounded with eight strands, each of nineteen wires of 0.0024 meter in diameter. It withstood a tensile stress of 125 kilograms per square millimeter, and each wire could be bent double eight times before breaking.

The diameter of the cable was 0.043 meter, and the weight, 6.5 kilograms per running meter. The rupture of one cable would have required an effort of 85 tons, and during the erection no cable had to bear a load exceeding 15 tons.

(284) *Proofs.*—The proof load was made up of a train formed by a locomotive weighing 75 tons, drawing cars of 15 tons. The deflection observed in spans loaded separately was from 0.016 to 0.019 meter.

The arch loaded along its whole length by a train of 405 tons had a deflection of 0.008 meter. The same train occupying, successively, half the length of the arch gave a deflection of 0.010 meter.

In the proofs for rolling load, the maximum deflection in the spans was from 0.015 to 0.018 meter, and that of the arch at the crown 0.012 meter. The horizontal displacement of the superstructure during the passage of a train was from 6 to 8 millimeters. After each proof the parts of the structure resumed their exact primitive position.

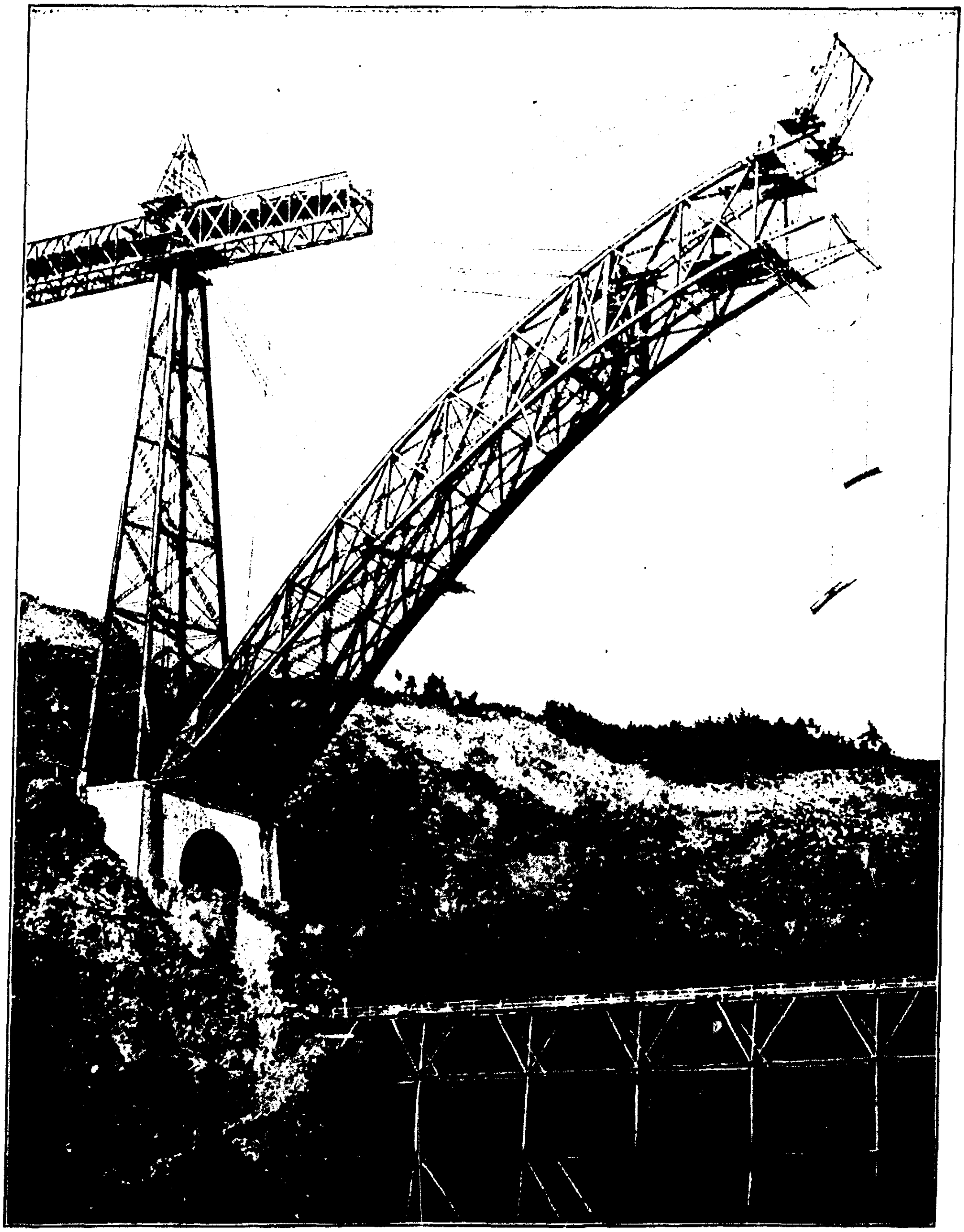
(285) *General information.*

Weight of the metal employed	kilograms	3,326,414
Amount of masonry	cubic meters	20,409
Cost:		
For the ironwork	francs	2,350,000
For the masonry	do	850,000
Total	do	3,200,000

The works were begun in January, 1880, and terminated in November, 1884.

M. Eiffel was assisted by MM. Emile Nouguier, Maurice Koechlin, M. Compagnon, and M. J. B. Gobert.

I am indebted to the Eiffel Co. for valuable information, plans, and drawings of this most interesting work.



GARABIT VIADUCT DURING THE PROCESS OF ERECTION.

Chapter XXXIII.—Gour-Noir Viaduct.

(286) The Gour-Noir Viaduct is situated on the railroad from Limoges to Brive near Uzerche, 4 kilometers beyond this last locality, where it crosses the river Vezère at an angle of about 50 degrees.

This river winds through a deep and very precipitous valley; sudden freshets are frequent, and the direction of the current varies with the freshets. For this reason it was preferred to cross the river with an arch of great span, and as there was excellent building material in the vicinity this arch was projected with a span of 60 meters. The work (Fig. 192) is built for two tracks and has a width of 8 meters between the parapets. Its total length is 108.46 meters. The radius of the intrados is 36 meters, that of the extrados 44 meters; the rise is 16.10 meters. The thickness of the arch at the keystone is 1.70 meters, at the springing lines 4.20 meters. The spandrels are open with six small arches with a span of 4.30 meters each. The wing walls are flush in elevation, but their filling is hollowed out in the interior by hidden arches of 6 meters span. Communication between these arches is made by openings 1.50 and 1.55 meters in diameter and with the outside by a manhole 0.80 meter in diameter. Between the spandrels and the wing walls are the buttresses, 2.85 meters wide at the top, which allows the establishment of refuges rendered necessary by the length of the work. In the part between the buttresses there is a parapet of open-work limestone, the only part of the work not of granite. To augment the stability different batters were given to different parts of the construction. The mean pressure at the keystone is 16.60 kilograms per square centimeter, and the maximum pressure is 33.20 kilograms. On the ground under the foundation the pressure does not exceed 9.80 kilograms.

The centers are made by seven trusses, 1.56 meters apart, each formed of a lattice beam 4.40 meters high, on which rests a system of pieces in the direction of the radii and having a fan-shaped appearance. The rigidity of this fan is insured by two courses of bridle pieces. Each truss rests upon the lower support by means of interposed sand boxes. The lower supports, that is to say, all the parts below the sand boxes, are eleven in number, each one consisting of nine piles.

From the nature of the river bed it was impossible to shoe the piles and drive them in the ordinary manner; the piles were placed, and held by cement, in holes, some of which were bored out, and others hollowed out by stonecutters using steel drills under the shelter of cofferdams.

Cost.—The cost of the viaduct was 235,202 francs. The projects were made and the works executed under the direction of M. Doniol, inspector-general. The engineers were M. Daigremont, chief engineer, and M. Draux, assistant.

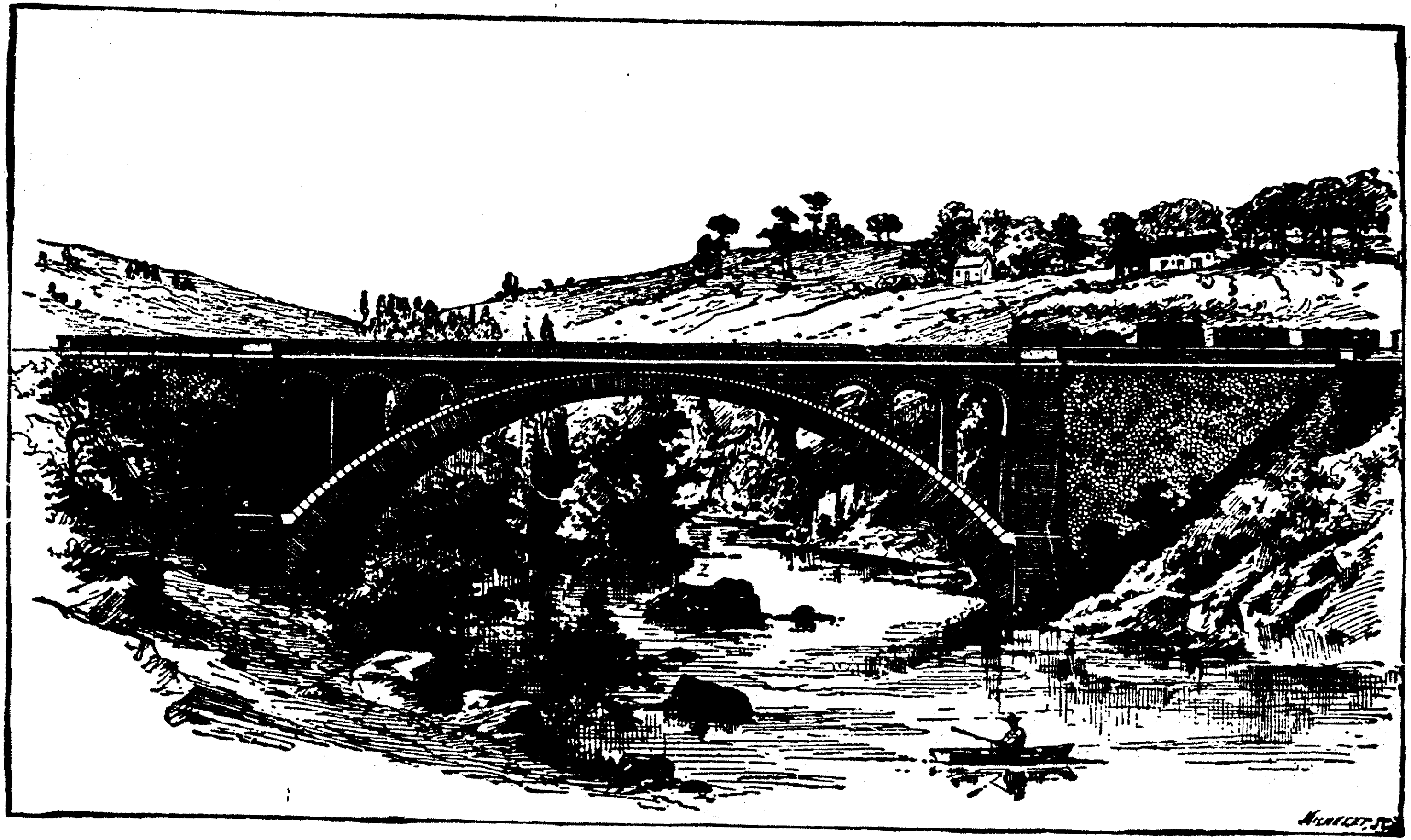


Fig. 192.—Gour-Noir viaduct.

CHAPTER XXXIV.--VIADUCT OVER THE RIVER TARDES.

(287) The viaduct on the railway from Montluçon to Eygurande crosses the Tardes near Evaux, and has an iron superstructure resting on masonry supports. It consists of three spans, the middle one 100.05 meters, the two others are each 69.45 meters (Figs. 193 and 194).

The piers at the top are 4.50 by 8 meters. These dimensions increase from the top to the bottom. The pier on the left side is 59.95 meters high, that on the right 48.02 meters. The abutments are 14.50 by 9.40 meters, with a hollow interior.

The roadway consists of two great girders 8.30 meters high, with double lattice faces distant 5.50 meters from center to center. The track is placed above. The tops of the girders are 0.80 meter wide and form a sidewalk above the latter. The distance between the parapets is 6.30 meters. The two girders are united by two courses of horizontal wind braces, one below and the other above, and by vertical struts. The rails are supported by wooden stringers resting upon stringers of iron united to the cross girders spaced 2.55 meters. The roadway is curved with a radius of 250 meters at the entrance and exit of the superstructure. A parabolic arc was intercalated between each curve and the right line portion of the middle structure. The rails are 91.33 meters above the valley.

The piers are founded on compact granite rock and the abutments upon hard tuffa.

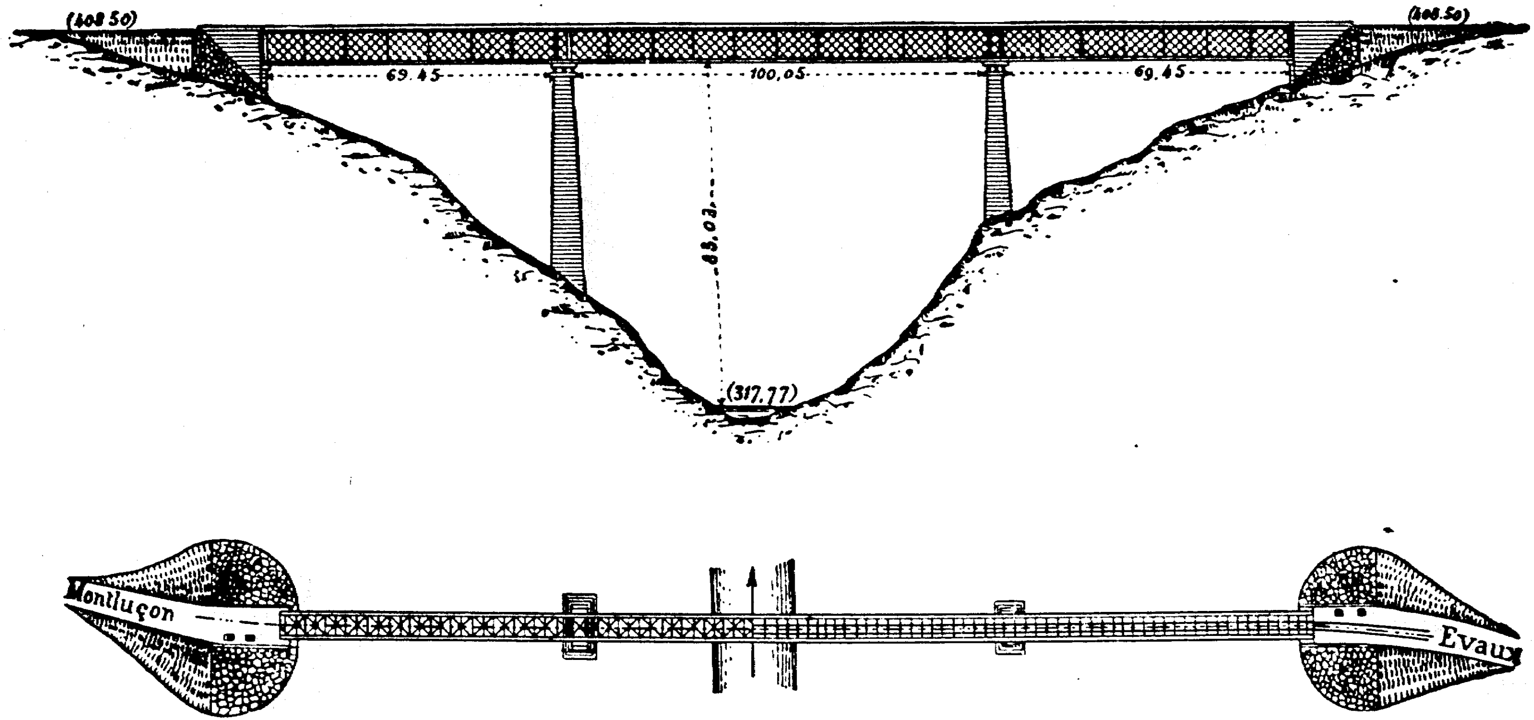
(288) *Cost.*—The total expense was 1,400,000 francs, that is, 107 francs per superficial meter of the vertical projection. The pressure upon the masonry piers, including their own weight and that of the superstructure, with the proof loads, was 7 kilograms per square centimeter. It reached the figure of 9 kilograms by taking account of the moment of the wind against the roadway during the passage of a train extending along the whole length.

The greatest stresses to which the iron is subjected under the different proof loads and the effect of the wind are the following: 6 kilograms per square millimeter for the members of the girders, the cross-beams, and the sleepers under the rails; 5 kilograms per square millimeter for the lattice, the horizontal wind braces, and the vertical struts; and 4 kilograms per square millimeter for the rivets.

Besides, the members of the lattice girders as well as the wind braces were strengthened, so that during the operation of launching the stress did not exceed at any point 8 kilograms per square millimeter.

The work was planned and carried out under the direction of M. Daigremont, chief engineer, and N. Guillaume, assistant.

The contractor was M. Eiffel.



FIGS. 193 and 194. - Elevation and plan of the Tardes viaduct.

Chapter XXXV.—Consolidation of the side slopes at La Plante.

(289) The railroad from Hôpital-du-Grobois to Lods passes behind the town of Ornans in a deep cut through caving gravel. The cut was almost completely opened, when on account of the winter rains of 1882-'83 they perceived a rising of the roadway amounting to 2 meters in height, combined with a general advancement of the upper slope without any change in its form. At the same time the bridge which crossed the cut (Fig. 195) was exposed to such a thrust that its keystone rose 0.21 meter and the upper abutment advanced 0.64 meter, notwithstanding a strong bracing rapidly made to stay it against the lower abutment. Finally, openings in the hill at a distance of 90 meters from the crest of the cutting were observed, covering a space of about 3.30 hectars of ground. A number of borings showed that the mass of gravel in which the cutting was opened rested upon stratified marl, but at the separation there was a thin layer of plastic clay very wet by the abundant exudation. The cutting having taken away the thrust of the hill, the latter slipped bodily upon the soapy layer of compressed clay, raising the soil of the roadway which was stopped by the opposite slope. To prevent this slipping the following means were employed: It was thought best to first divide the mass in motion into sections by the aid of fixed pillars. These pillars were made by great dry stone spurs of 2 meters thick, having a length proportioned to the importance of the mass in motion. These spurs rested on the side of the cutting upon great masses of masonry 5 meters thick and 3 meters wide, themselves buttressed against the lower wall of the cut by means of a reversed arch placed under the roadway. Although these constructions presented a great resistance against the motion, it was also advantageous to drain the water of exudation beforehand, and to thus dry the mass immediately in front of the cut. These points being settled, it was only necessary to oppose the motions of the intermediate masses placed between two consecutive spurs and partially drained by them. For that purpose a revetment was built formed of arches of 7-meter span, the axis having an inclination of one-third to the vertical. These arches were 1 meter thick at the crown. They were supported by a rear wall having a uniform thickness of 3 meters. Finally, to catch all the exudations which escaped from the spurs, these arches were covered with dry stone and all the water was collected in a drain which went from one end of the walls to the other. This last work had such dimensions that it could be inspected easily, and the satisfactory condition of the drainage could be told at each instant, by means of manholes. On account of the longitudinal undulations of the stratified marls on which the wall is founded, the rear wall of this last, which con-

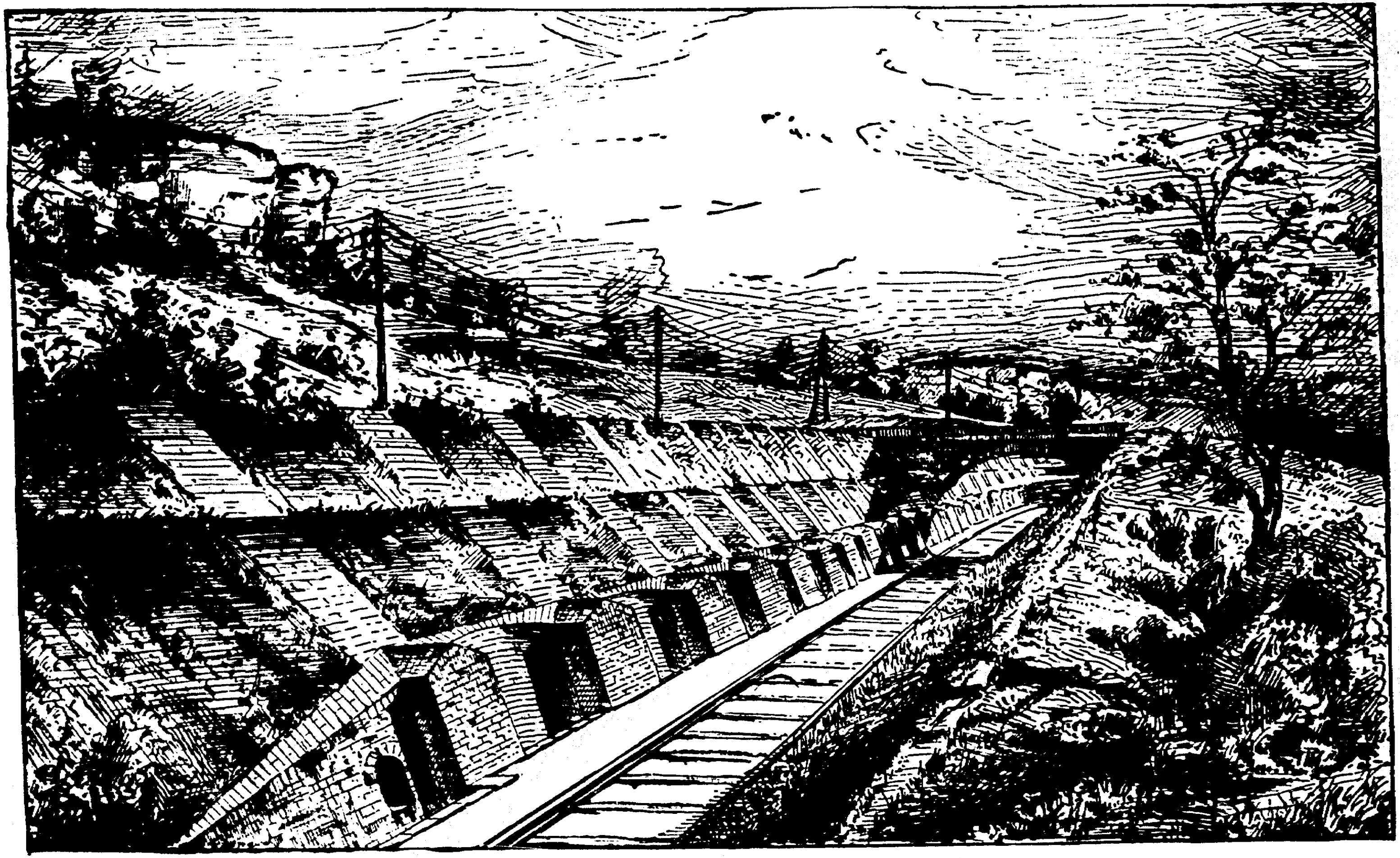


FIG. 195.—Side slopes at La Plante after the completion of the work of consolidation.

tains the culvert, is more or less imbedded in this subjacent layer; but at no point did the plane of slipping pass above the top of the arch in order to avoid crushing this work. It is understood that in the portions built into the stratified marl the thickness of the wall foundation is reduced as much as possible to allow the construction of the culvert. The drainage system worked perfectly, the amount of water caught amounted sometimes to 350 liters per minute, and went down to 10 liters in the season of great droughts.

These different works were not carried out without great difficulty, and from the first great masses were obliged to be moved to erect in the middle of the slope a banquette of 2 meters.

Since March, 1885, when the works were finished, the motion has entirely ceased.

The length of the cut consolidated is 416.77 meters; the surface in motion was about 3.30 hectares, and its mass attained 150,000 cubic meters. The total cost of consolidation amounted to 391,770.46 francs, which made the cost per running meter of the consolidation, 940 francs.

The work was planned and carried out under the direction of Inspector-General Cabarrus by M. Chatel, chief engineer, and Barrand, assistant.

Chapter XXXVI.—Tunnel through Cabres Pass on the Railroad from Crest to Aspres les Veynes.

(290) The prolongation of the Livron and Crest Railroad to Aspres les Veynes contains, at Cabres Pass, a tunnel 3,770 meters long. This important work is laid out in a right line 3,306.14 meters from the crest head; then it is prolonged with a curve of 800 meters radius for 393.44 meters, and terminates in a right line 70.42 meters long. It rises in an incline of 0.020 for 14 meters, of 0.015 for 472 meters, and of 0.009 for 2,358.77 meters to attain its summit at the altitude of 884.086 meters, whence it descends toward the station at Baume by a declivity of 0.003 for a distance of 925.23 meters. The Cabres Tunnel has been planned with two tracks, although the line has only one; this arrangement was made to facilitate ventilation, which a single-track section would not have been enough to guarantee; it allows trains to cross, and diminishes the danger of a derailment in the middle of such a long tunnel.

The tunnel is to be completely lined with masonry, varying from 0.50 to 0.80 meter, according to the nature of the strata. A flooring will extend through the whole length, and a central drain to collect the water. Refuge niches are established at distances of 50 meters in each wall, and a storage chamber is placed also at the middle of the tunnel.

The most important point of beginning is the crest head; on this side two 55 horse power steam engines are placed, which drive the air compressors to work the rock drills, the ventilators, and a gramme dynamo furnishing the electric lighting, for a part of the gallery and the works adjacent to the tunnel, during the night. The work of the drills produced a mean advancement of from 5 to 7 meters per day. Sometimes this advancement was stopped on account of explosive gas which was given off in great quantities and rendered

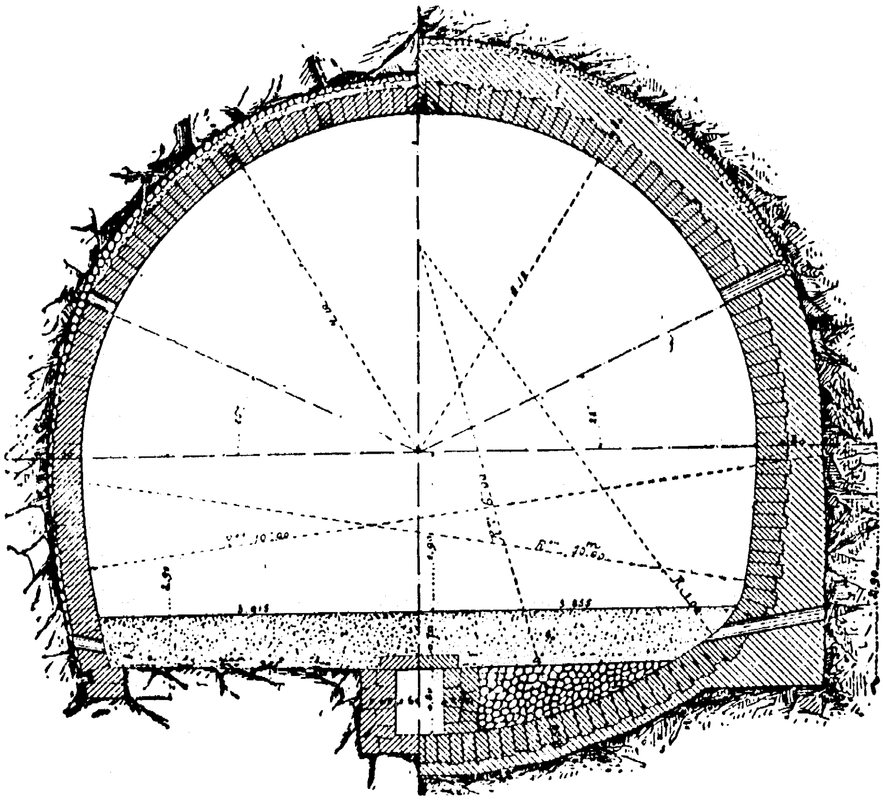


FIG. 196.—Half sections of the Cabres Pass Tunnel.

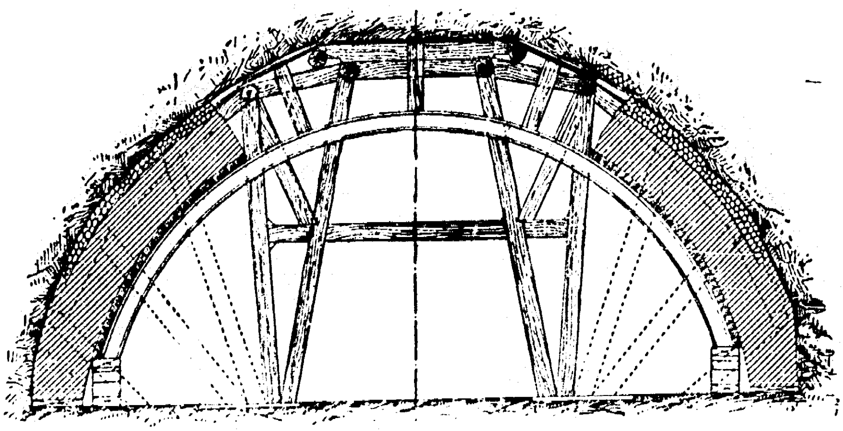


FIG. 197.—Center used in Cabres Pass Tunnel.

an exceptional ventilation indispensable. In view of preventing the danger, ventilation by suction was substituted for forced ventilation. Precautions were taken by the use of safety lamps, the explosion of the mines by electricity, the periodical examination of the air, etc. The suction produced by a conduit 0.50 meter in diameter and 2,000 meters long having ceased to be sufficient, a vertical shaft was sunk 1,920 meters from the crest head. A natural current then established itself and carried away the explosive gas. If necessary, an exhausting fan might be placed at the upper orifice to aid the natural draft. This tunnel was driven in the layers of marl belonging to the Oxfordian strata, which swells and rises by contact with air, and requires a strong revetment. The contractors used for centers iron arcs, which had the advantage (Fig. 197) of occupying very small space.

(291) *Cost.*—The cost is estimated as follows:

	Francs.
Driving the tunnel	3,770,000
Masonry	2,639,000
Total	6,409,000

That is, 1,700 francs per running meter.

The works are executed by M. Pesselon, engineer, under the direction of M. Berthet, chief engineer.

Chapter XXXVII.—Cubzac Bridge over the Dordogne.

(292) The railroad from Cavignac to Bordeaux crosses the Dordogne valley at 913 meters below the bridge constructed at Cubzac for the national roadway No. 10. The free height under the roadway was determined by the condition of putting no obstacle to the free passage of vessels going up to Libourne. This condition, together with the configuration of the ground, required the construction of great works extending over a length of more than 2 kilometers, consisting of:

First. An iron viaduct on the right bank with a slope of 0.008 for a length of 294.58 meters. (Fig. 198 and 199).

Second. An iron bridge of 561.60 meters over the Dordogne, in a straight line with the first.

Third. Upon the left bank, which was flat and low, at 2 meters below the level of the highest waters, an iron viaduct 599.23 meters long, continued by a masonry viaduct 579.23 meters long. These two last works are on a curve 1,500 meters radius, and have a slope of one centimeter per meter. The viaduct of the right bank rests on masonry piers. It is formed of six spans of 44.98 meters each, with an upper roadway. The principal beams are diagonally braced with vertical uprights. The panels are 3.46 meters span.

The Dordogne bridge rests on iron piers and includes eight spans, the two end ones being of 60, and the six intermediate 73.60 meters long. Its principal beams have a double lattice web of 3.20 meters opening without uprights. The roadway is 26 meters above low water. The iron viaduct on the left side rests on masonry piers like those on the opposite bank. Its general aspect is the same, but on account of the curvature, its thirteen spans of 44.98 meters are independent.

The masonry viaduct consists of 40 arches of 12-meters span. It

CUBZAC BRIDGE OVER THE DORDOGNE RIVER.

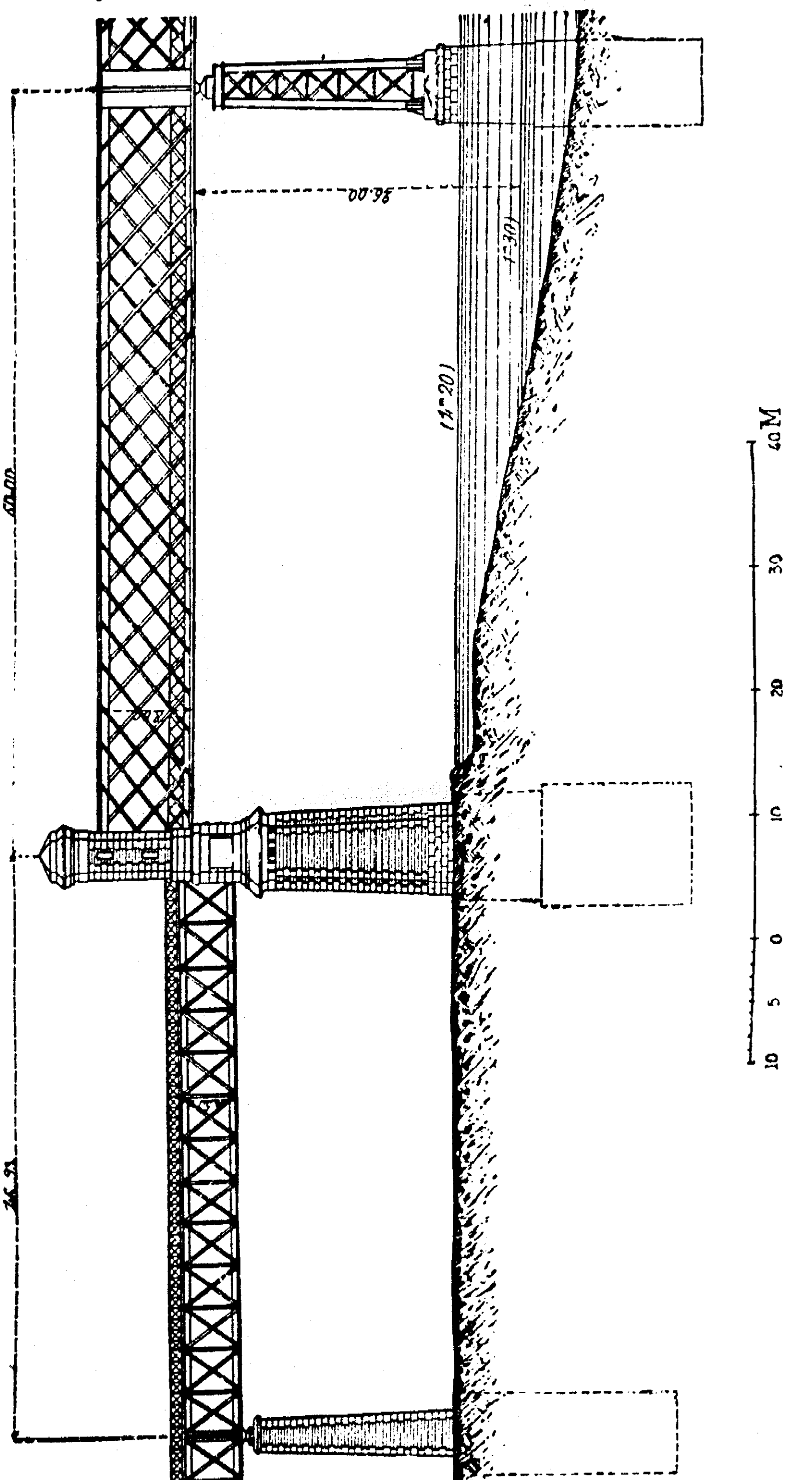


FIG. 198.—Partial elevation of the Cubzac bridge and its viaduct (right bank).

has a width of 8.46 meters at the springing lines, with an exterior batter of 0.03 meter per meter carried to 0.05 meter for the buttresses.

(293) *The Dordogne bridge* rests on two abutment piers and on seven river piers. The calcareous marl rock on which its foundations rest in perfect security is 17.50 meters below low water. Compressed air was used in making the foundations; the caissons of the

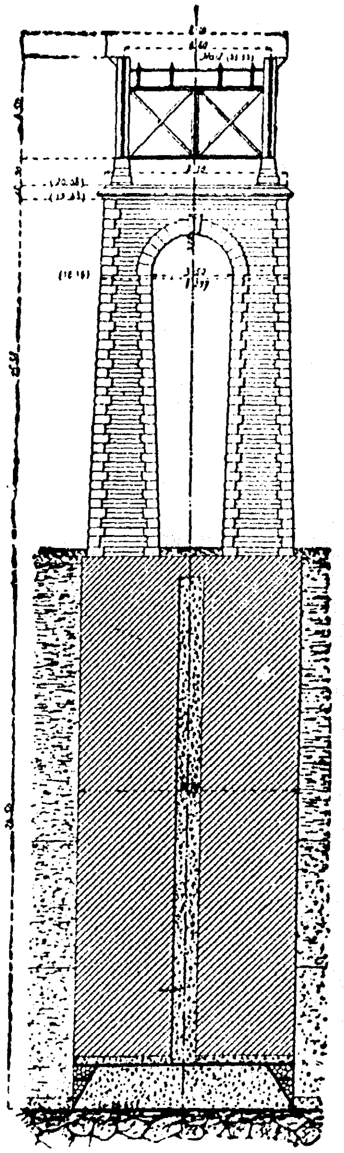


FIG. 199.—Elevation of a pier of the viaduct of approach left bank).

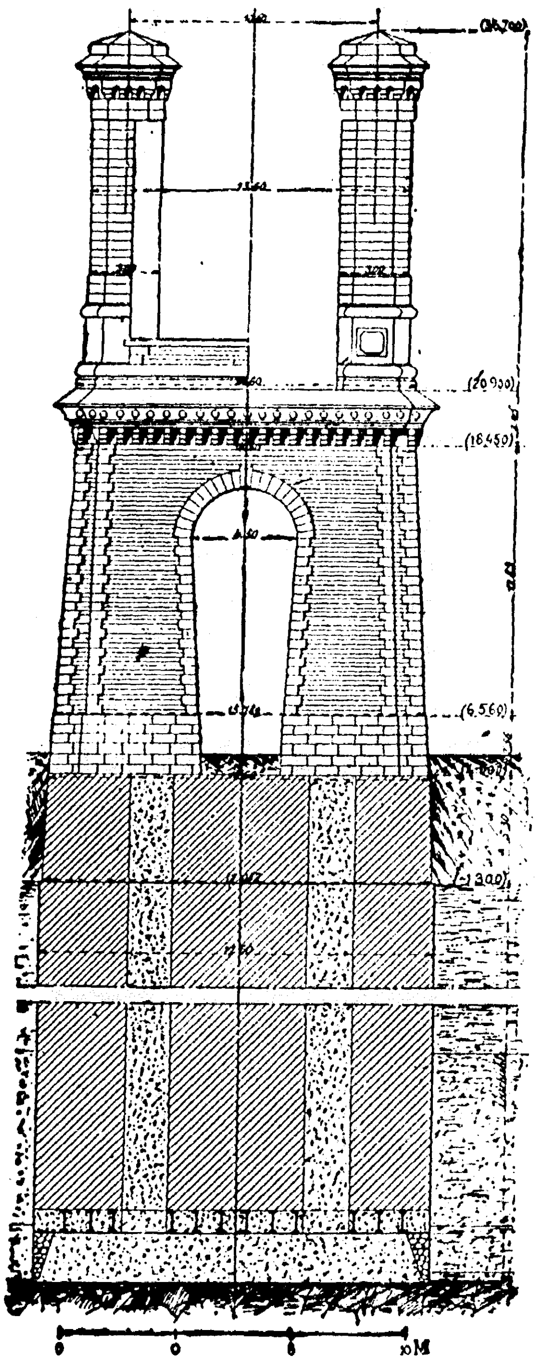


FIG. 200.—Elevation of an abutment of the Cubzac bridge over the river Dodogne.

abutments are rectangular with rounded angles. They were 17.60 meters long by 9.80 meters wide. (Fig. 200).

The height of the working chamber was 2 meters; its plate-iron ceiling, 6 millimeters thick, was sustained by lattice beams 0.97 meter high, united to the caisson walls by vertical gussets terminated by struts, thus consolidating the iron plates. Heavy angle-iron beams, placed around the periphery, which were in turn strengthened by outside plates 22 by 2 centimeters, stiffened the cutting edge. The sinking was accomplished by gradually lowering the air pressure when the pits had attained the required depth.

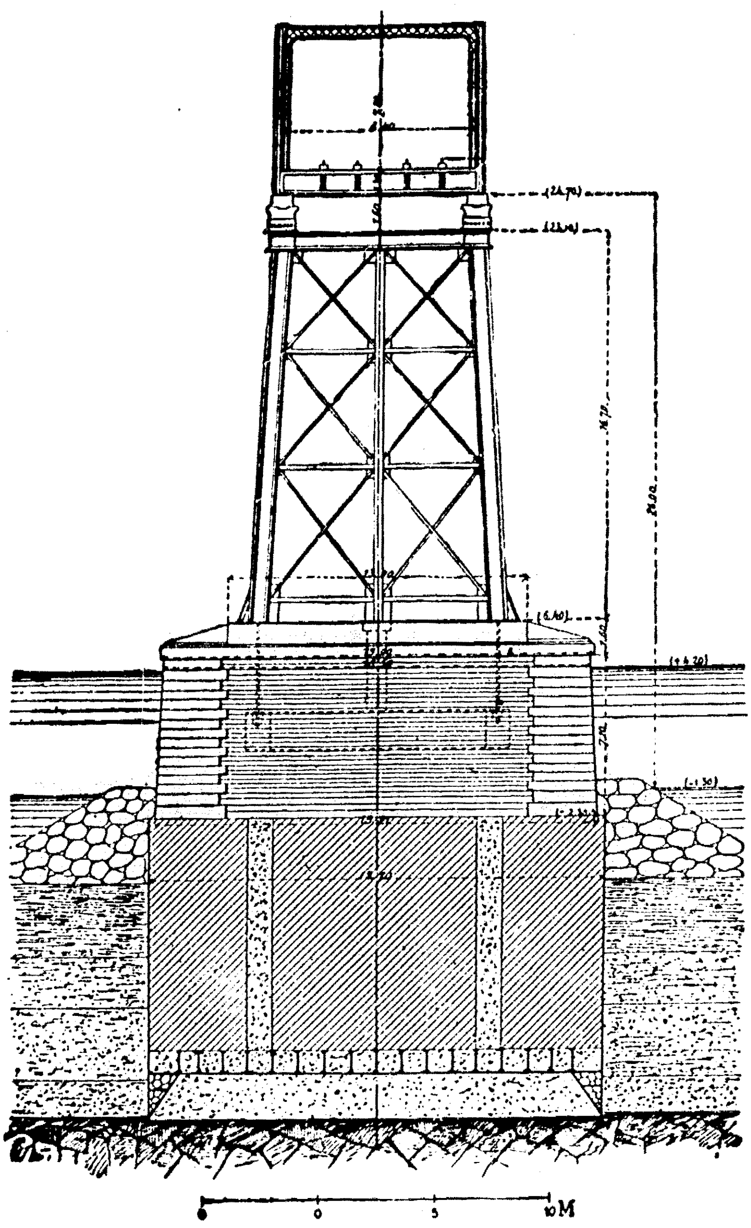


FIG. 201.—Elevation of an iron pier of the Cubzac bridge.

All the piers rested on limestone except the fourth (the deepest), which descended 29.20 meters below high-water level into a layer of compact gravel. Under the pressure of three atmospheres, attained in the caisson in summer, the work became extremely difficult and even dangerous; the lateral pressures were so intense that the pier, notwithstanding its weight, remained in equilibrium and could not descend more than 3 or 4 centimeters, even by suddenly lowering the air pressure. It was not therefore possible to go down 4 meters further to the rock under the gravel bank.

The iron pier supports (Fig. 201) are anchored in the masonry by means of eight iron tie rods 0.10 meter in diameter, and four of 0.05 meters, bolted under a flooring of iron beams. The iron framework consists of six standards united by struts and braces and surmounted by a coping on which are placed the supports of the superstructure. The bridge is anchored upon the central pier and provided on the other piers with steel expansion trucks. The principal girders are braced at their upper parts by lattice girders 0.58 meter in height; at their lower part by plate iron girders carrying the stringers.

The horizontal wind bracing is obtained, below, by the plate-iron flooring riveted to the stringers and the cross girders; above, by lattice bracing.

(294) *The launching* was effected by means of rollers moved by levers, on each of the piers: but, on account of the great length of the bridge, this operation was divided into two parts, forming two fields of erection, one on the right bank and the other on the left. The same staging served for both halves of the roadway. The erection took place as the launching went forward, and the junction of the two halves was made on the central pier.

The weight of each half of the superstructure was 1,700 tons, and its length 280 meters. The peculiarities worthy of notice in this operation are:

The application of supporting rollers with double oscillation, dividing equally the load on two rollers placed under the two webs of the double beams.

The launching levers were moved by means of a steam engine set up on the superstructure for the last spans.

Buffers, riveted upon the heads of the beams on the piers, were used to prevent the fall of the superstructure in launching, on account of lateral displacement which might be occasioned by the winds or any other cause.

The first two spans were launched by hand power. The launching of the second required 120 men; the third and fourth would have required at least from 250 to 300 men. With the employment of such a great number of hands, separated from each other by a distance of 75 meters, the operation could not have been made with perfect uniformity, and the total effort would have been far from corresponding to the sum of the partial efforts. To obviate this difficulty the contractors substituted for the hand levers a system of traction by a steam engine arranged so as to drive simultaneously all the levers requisite for the operation.

(295) *Apparatus with a universal joint, for launching by steam.*—This system consists of an iron frame resting at its central part on a steel axle.* This axle allows the frame to oscillate, like a balance beam, lengthwise of the bridge. The frame itself carries at each end another frame, oscillating transversely and carrying independent rollers.

The lower axle of the principal frame allows the system to tip longitudinally, and thus guarantees the constant contact of the two rollers on the same end with the bottom of the bridge.

The transverse axles allow the transverse frame to tip in the case of a difference of level between the two members of the same girder, and thus equalize upon the four rollers the load supported by the apparatus.

The rollers are 0.50 meter in diameter. Each apparatus is calculated to support 240 tons, that is, 60 on each roller.

A rachet wheel is keyed to the shaft of each outer roller, and the rollers are moved by long levers turning freely on the shafts and carrying pawls. These levers are united transversely by braces, and longitudinally by jointed connecting rods to which bars and chains are attached. Each chain passes over a chain pulley at the overhanging end of the bridge, and thence to the transverse shaft driven by the engine, whence it is wound on a drum placed in the rear.

A friction coupling is placed on the motor shaft, to interrupt the forward motion of the levers and to regulate their return, which is done automatically by the action of counterpoises.

Each of these counterpoises is formed of two weights suspended a certain distance from each other, so that both act at the beginning of the returning movement; then, as the levers approach the vertical position, the resistance diminishing, the first counterpoise rests upon a platform, leaving the second to act alone until in its turn it ceases to act; the levers then having passed the vertical position, their own weight suffices to bring them back. A cord around a second drum, keyed to the same shaft as the first, holds a counterpoise, and thus tightens the chain after each oscillation of the levers.

This system of launching by steam was perfectly satisfactory, giving a regular and gentle forward movement to a mass weighing 1,700 tons, at the rate of 6 inches per hour.

Cost.—The total cost of these works amounted to 9,040,000 francs.

The plans were made and the work carried out by MM. Prompt and Girard, engineers.

The ironwork was constructed and the superstructure of the bridge launched by MM. Lebrun, Daydé and Pillé.

*A horizontal bar rounded on the top.

CHAPTER XXVIII.—THE CRUEIZE VIADUCT.

(296) The Crueize Viaduct is situated on the line from Marvejols and Neussargues at the point where it crosses the river Crueize, 9 kilometers from Marvejols station. It consists of six arches of 25 meters span and has a total length of 218.80 meters. The maximum height of the rails above the lowest point of the valley is 63.30 meters. It is founded on gneiss. It has two tracks, and its width is 8 meters between the parapets. At the right of the buttresses of the piers this width is 10 meters. The arches of the intrados consist of two quarters of circles having, respectively, 12.915 and 12.085 meters radii. This arrangement has for its object to give a slight slope, at the same time maintaining the level of the springing lines of the two adjacent arches. This mode of obtaining the slope has the advantage of bringing the resultant of the pressures toward the center of the pier.

The arches are 1.30 meters in thickness at the crown and 2.60 meters at the joints of rupture. The spandrils are lightened by three longitudinal archways of 1.20 meters span. The piers have on all sides a batter decreasing gradually from the base to the top. This equalizes the pressure upon the different courses, and leaves the edges continuous.

At the same time, to facilitate the laying of the edge stones, a series of right lines 5 meters long, forming an inscribed polygon in the theoretical curve, is substituted for the curve itself, the curve corresponding to a constant pressure upon the different courses. This substitution is not observable in the work itself.

The buttresses are placed against the piers and rise just to the top. They are 2 meters wide at the springing and project at the spandrel 1 meter at the level of the plinth. The maximum depth of the foundation is 10 meters and the mean depth 6.50 meters. The mean pressures per square centimeter of the different sections of the piers are from 8.20 to 10 kilograms. The use of cut stone is limited to the coping.

The centers were sustained by a double row of rails passing through the masonry piers. The first support, carrying the foot of the rafters, consisted of the two rails; the second, placed 4 meters below, was formed of a single rail upon which rested, by an intervening plate, the braces sustaining the principal rafters. The centers for raising were placed on the upper flooring of the service bridge used in erecting the piers.

The total cost was 1,289,893.43 francs, which gives per square meter of vertical projection in sight, the foundations not included, 165.80 francs.

The engineers were M. Bauby, engineer in chief, and M. Boyer, assistant.

CHAPTER XXXIX.—CONSTRUCTION OF THE CASTELET, THE ANTOINETTE, AND THE LAVEUR BRIDGES.

(297) These bridges have single arches of 41.20, 50, and 61.50 meters of span, respectively; the first erected over the Ariége at Castelet, the second over the Agout near Vielmur, the third at Laveur.

The adoption of a great arch, authorized for the three bridges by the incompressibility of the foundation, was justified at Castelet (Fig. 202) by the inclination of the line to the river and the violence of the rapids between the rocks, in a bed encumbered with blocks and with an indefinite depth.

At Vielmur, 50 meters, by the depth of the river foundation, 8 meters, which made it economical to build a great arch, founded directly on the rock (Fig. 203).

Finally at Laveur, 61.50 meters, where the foundations were facilitated by the vicinity of a fine bridge of the eighteenth century (Fig. 204).

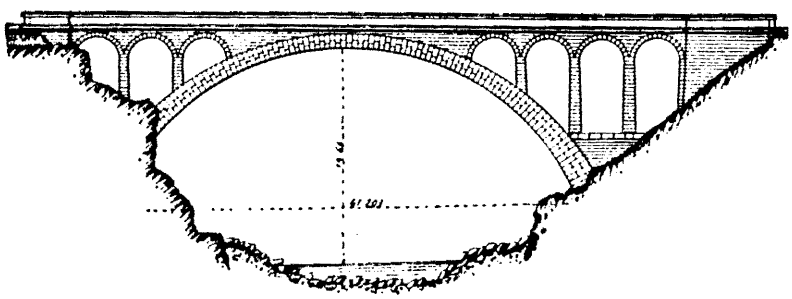


FIG. 202.—Elevation of the Castelet bridge.

The parapets, spandrels, and head bands have a batter of one-thirtieth for Castelet bridge and one twenty-fifth for the others. This has the advantage of decreasing the stress on the joints of rupture and of offering greater transverse resistance.

In the spandrel of the great arch are smaller full-centered arches, of 4.50 meters span for the Laveur, and of 4 meters for the others. This arrangement, pleasing in appearance when the openings are properly chosen, has succeeded perfectly, notwithstanding the theoretical objection arising from the danger of distributing the loads in isolated zones, and the practical objection of the tendency to fissures produced near the springing lines.

At Castelet and Antoinette the open viaducts continue to the extreme abutments; at Laveur they rest against two strong pilasters, which cast heavy shadows and stand out prominently from the neighboring portions of the work. This separation has been accentuated by lowering the level of the parapet above the 8-meter arches, and stopping the architrave and coping of the great arch at the pilasters.

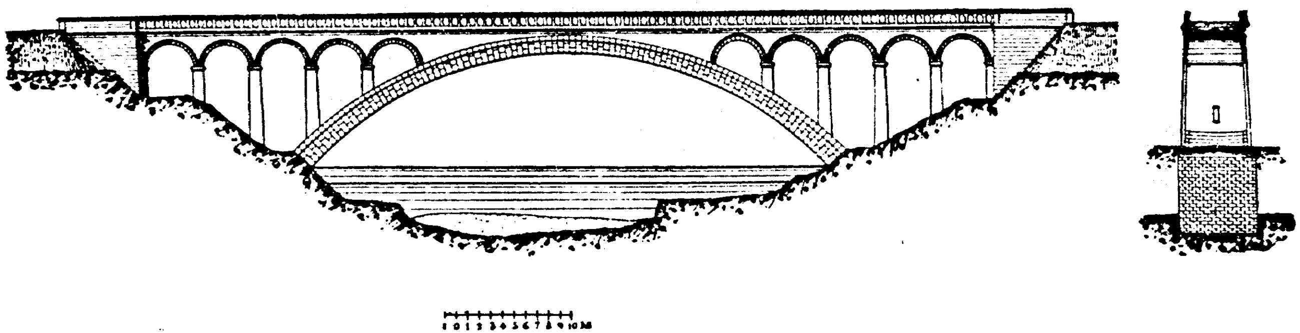


FIG. 203.—Elevation of the Antoinette bridge, and transverse section of the viaduct with little arches.

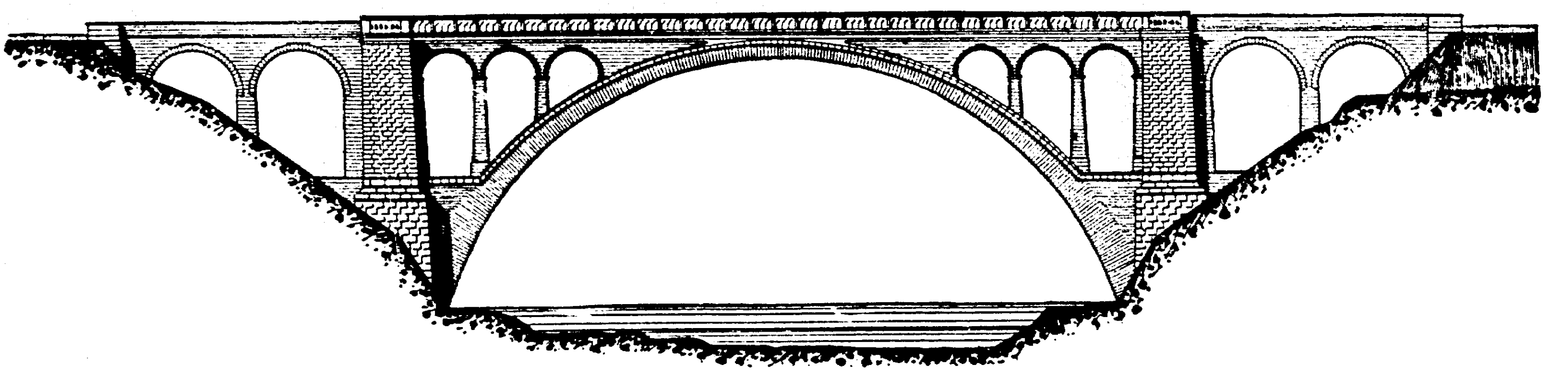


FIG. 204.—Elevation of the Laveur bridge.

The extreme abutments are reduced by containing hollow wells. The principal dimensions of the great arches are as follows:

	Castelet.	Antoinette.	Laveur.
	Meters.	*Meters.*	*Meters.*
Span	41.203	50	61.50
Rise	14	15.90	27.50
Radius of the intrados above natural ground	*22.20	†31	‡31.20
Thickness of keystone	1.25	1.50	1.65
At springing lines		2.283	
At joint 30° with the horizon	2.25		2.81
Width:			
Between the parapets	5.65	4.50	4.50
At the keystone	6.276	4.936	4.80
At the joint 30°	7.016		6.048
At the foundation	7.209	6.93	7.000
Ratio between the solid and hollow portions above ground	2.98	2.18	1.95
	Cu. meters.	*Cu. meters.*	*Cu. meters.*
Masonry	1,547.28	2,403	6,618.67
	Francs.	*Francs.*	*Francs.*
Total cost	207,000	224,000	485,000

* On 13[illegible] 15.″ † On 99° 42′ 54″. ‡ On 148° 6′ 54″.

(298) *Centers—Bolsters and Sheathing.*—A sheathing .025 meter thick, on which is drawn the position of all the voussoirs, is nailed upon the bolsters 10 by 14, spaced from the key to the springing line, from 25 to 50 centimeters for the Castelet; from 30 to 45 centimeters for the Antoinette, and from 21 to 45 centimeters for the Laveur bridge.

Trusses.—Each center consists of five trusses, the end ones being slightly heavier; each truss consists of two stories resting one on the other by means of nine files of sand boxes.

The back pieces are triple in the Castelet (Fig. 205), double in the Antoinette (Fig. 206), and single in the Laveur bridge (Fig. 207). They are supported by radial struts (except in the Antoinette bridge, where the river supports could not be numerous, the alternate struts are radial, and the intermediate ones are replaced by two) equally inclined to the soffit, forming a fan-shaped frame.

At the Castelet and Antoinette bridges the fan (back pieces, struts, and the beam) rest directly on the sand boxes. At the Laveur bridge, on account of the height, another story has been introduced, consisting of vertical king-posts and diagonal-struts, forming a series of triangles whose vertices support the sticks of the fan.

(299) *Portion below the sand boxes.*—At Castelet (Fig. 205) the upper portion is supported by two double rafters inclined to the horizon by the angles 43°, 19°, and 0° formed of pieces held by straps, and also by an iron tie rod. The lower rafters rest freely on sheets of lead laid upon oak sleepers built into a masonry apron.

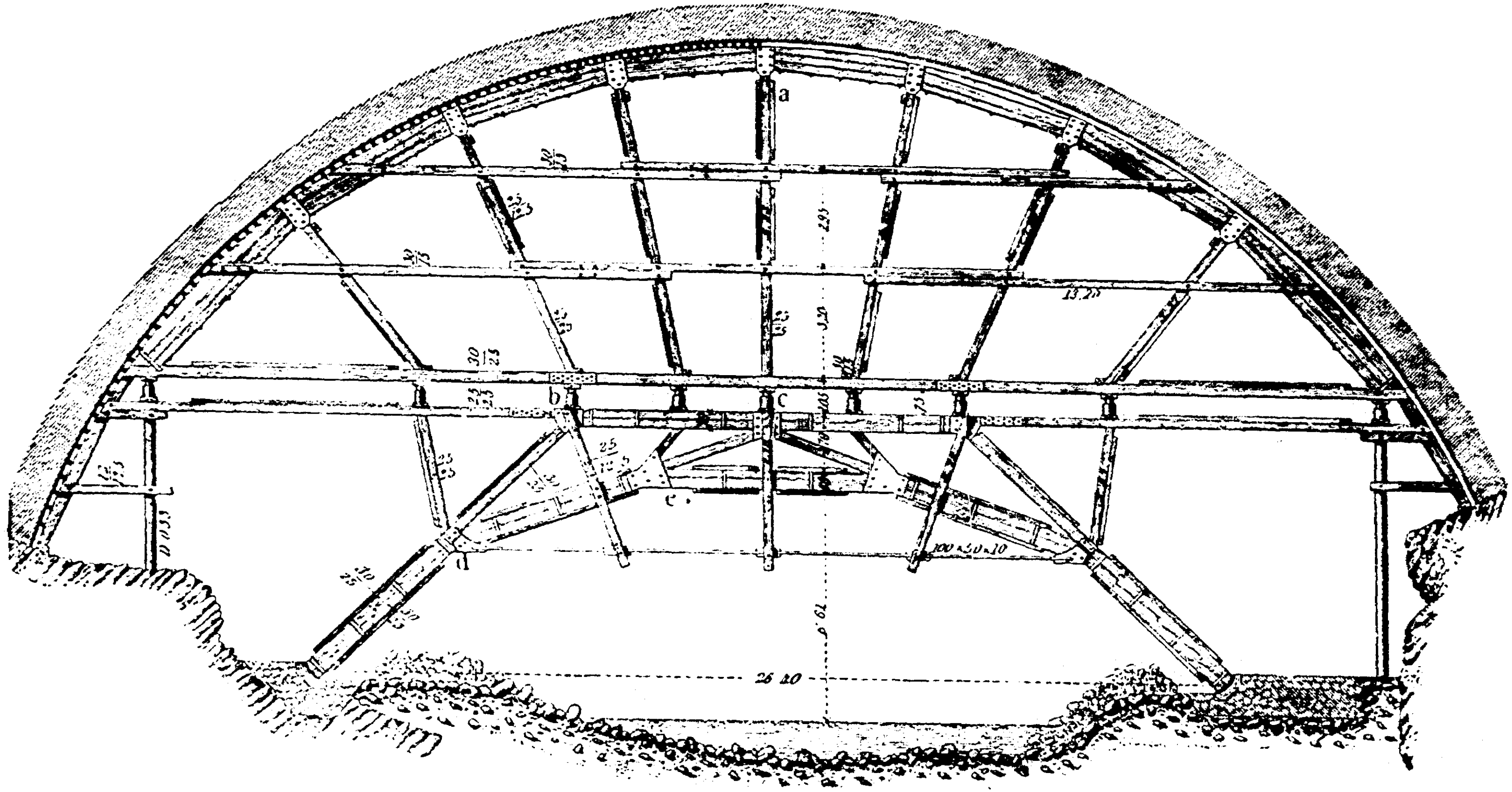


FIG. 205.—Center for the Castelet bridge. Elevation of a truss.

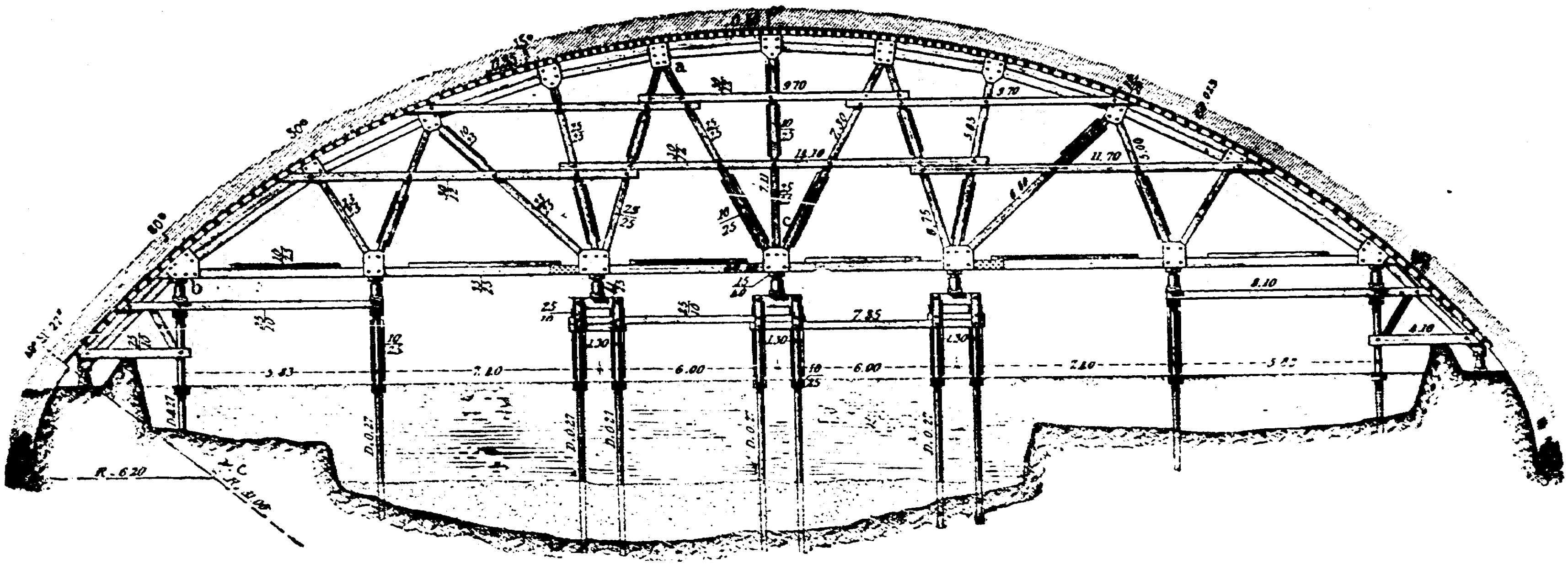


FIG. 206.—Center for the Antoinette bridge. Elevation of a truss.

LAVEUR BRIDGE. METHOD OF ERECTING THE GREAT ARCHES.

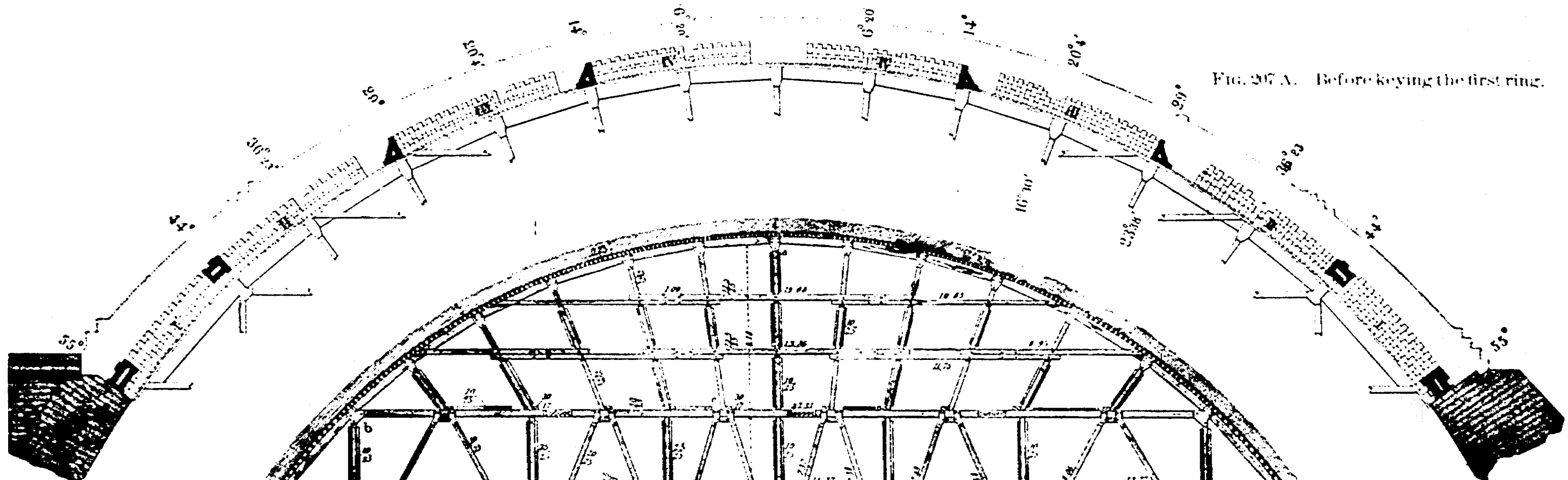


FIG. 207 A. Before keying the first ring.

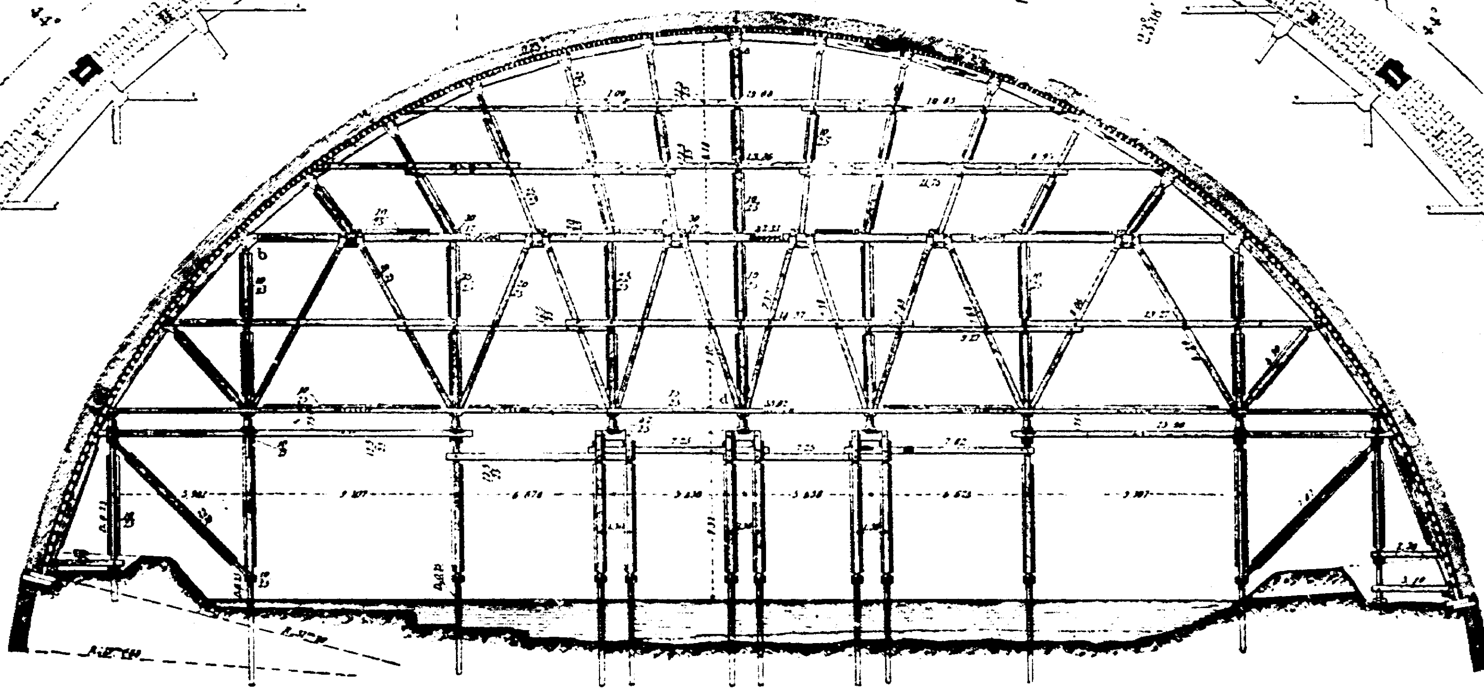


FIG. 207.—Center for the bridge: elevation of a truss.

At Laveur (Fig. 207) the center rests on nine supports, three of which are double, united by bridle pieces forming seven files of piles, two of which serve as wave breakers and wind braces.

At Antoinette (Fig. 206) there are only four supports, for, both of the centers resting on piles, the rocky bottom would not permit of their being driven in the usual way. Holes from 1.50 to 2 meters in depth were made in the bottom, slightly exceeding the diameter of the pile. The pile was cut off flat and protected by sheet iron against crushing. The holes were cleared by divers, the piles lowered and held by cement, and when necessary by wooden wedges.

This system, which was necessary on account of the nature of the bottom, was much more expensive than ordinary piling, but it was justified by the very slight settlement observed in the arch.

(300) *Construction of the arch—Castelet.*—The arch was constructed of two rings (Fig. 207 A). The thickness of the first ring was, from 60 to 40 degrees (maximum), 1 meter; from 40 to 20 degrees (mean), 0.75 meter; from 20 degrees to the keystone (minimum), 0.50 meter. Upon the heads only a single row of voussoirs was placed. The first ring was divided into six portions by wooden frames of two

LAVEUR BRIDGE.—SUPPORTS FOR THE VOUSSOIRS OF THE GREAT ARCH DURING ERECTION.

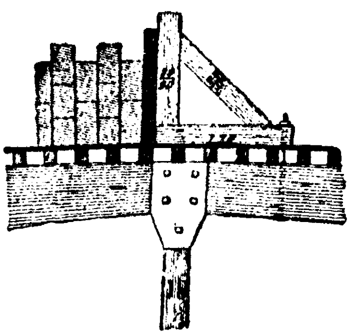


FIG. 208.—Support for the first ring.

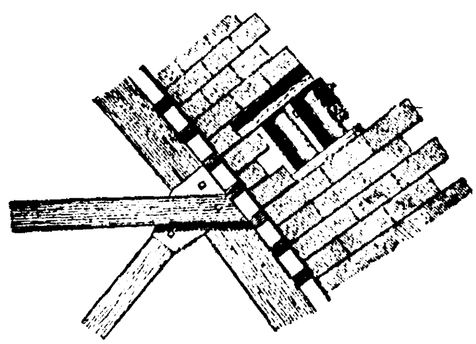


FIG. 209.—Support for the second and third rings.

kinds (Figs. 208 and 209), thus forming six great monolith voussoirs, the joints of which were not keyed until the ring had been completed.

The keyed joints were firmly calked with powdered mortar. The second ring was made in four portions, and there were for the two rings eight keyings.

The arch was constructed in forty-two days of effective work. The settlements were, on the center, 53 millimeters; on removing the center, sixty days after the second ring had been keyed, 2.02 millimeters.

(301) *For the Laveur bridge* (Fig. 207 A).—The first ring was divided into fourteen portions or monoliths; the second into six, and the third into four, having in all twenty-three keyings. The arch was constructed in eighty-two days of effective work. The settle-

ments on the center were, on the downstream head 16.75 millimeters, on the upstream head 20.07 millimeters, and after striking the center, one hundred and thirty days from the time the third ring was keyed, 0.62 millimeter.

(302) *For the Antoinette bridge.*—In the first ring there were twelve monoliths; in the second eight, and in the third four; twenty-three keyings for the three rings.

The arch was constructed in forty-four and one-half days of effective work. The settlements were, on the center 0.13 meter, after striking the center, a few days after keying the third ring, 0.6 millimeter.

I am indebted to M. Séjournée's article (Annales des Ponts et Chaussées, sixth series, vol. 12) for the drawing of the centers, figures 205-209, and information respecting the erection of the three bridges.

Chapter XL.—The Céret Bridge.

(303) The Céret bridge is situated near a city of the same name on the Tech. It consists of a great arch of 45 meters span connecting two viaducts. (Fig. 210).

The adoption of a great arch, made possible by the solid ground on the banks, was justified by the necessity of avoiding the difficult and expensive foundations in the bed of a deep river exposed to heavy freshets.

The spandrels of the great arch are hollow, consisting of a viaduct of full centered arches of 3 meters span, carried along to two strong pilasters which form prominent features of the bridge. They are still further marked by having a stone parapet above the great arch, while that above and beyond the pilasters is of cast iron.

The spandrels and head band of the arch have a batter of $\frac{1}{40}$. The arch and pilasters rest on a projecting base capped with cut stone.

The width of the bridge between the parapets is 4.62 meters, and the thickness of the great arch at the crown 1.40 meters.

The head band is of hewn stones of large dimensions; the thickness of the voussoirs of the arch is about 0.42 meter.

The stones of the head band and those of the soffit are in rustic work, projecting 0.10 meter from the spandrel. The head bands of the little arches are roughly dressed and flush with the spandrel face.

The soffit is entirely of knotted ashlar, of the same width as the voussoirs of the head band, *i. e.*, from 0.60 to 0.90 meter in depth and 0.60 meter long. This is one of the characteristics of the arch.

There is a hydraulic mortar capping 0.10 meter thick over the extrados, which is also covered with one of asphalt, with gargoyles for drainage.

The filling consists of a layer of sand 0.10 meter thick covered with gravel.

The plinth, 0.40 meter thick, projecting 0.45 meter from the face of the spandrels, is sustained by a series of modillions which requires an appreciable reduction in the width of the work under the plinth.

Similarly the thickness of the parapet has been reduced to a minimum 0.20 meter above the grand arch.

At intervals, pilasters reënforce the parapet. The stone is granite; the greatest pressure is, at the keystone, 27 kilograms per square centimeter. On the foundation it is 14.20 kilograms.

(304) *Centers.*—The center of the great arch consisted of four trusses 1.35 meters apart, formed of a fixed portion below the sand boxes, and a movable one above them. The fixed portion consisted of seven uprights supporting the sill, on which the boxes rested, and braced together with bridle pieces lengthwise and crosswise. Three of these uprights rested on framework supported by piles driven into the bed of the river. The pressures of the three others were borne by shores set at 45 degrees with the same support.

The movable portion consisted of a series of back pieces resting on the uprights placed at the right of the sand boxes. Struts like the sticks of a fan resisted the flexure of the back pieces; a horizontal sill united the feet of all the uprights and rested on the sand boxes. The bolsters were on the back pieces and a sheathing 0.025 meter thick covered them.

The fourth back piece from the keystone placed below the general level of the sand boxes was supported by a secondary movable truss resting on two sand boxes corresponding to the angle 67° 30′ from the point where the voussoirs began to rest on the center.

The sand boxes rested on the sill by means of stringers. These boxes were protected from humidity by means of a pine box filled with plaster, the upper layer of which had been set.

The uprights of the movable truss were bolted to the back pieces by means of iron gussets 0.003 meter thick.

The center contained 362 cubic meters of wood; the iron weighed 5,482 kilograms. The cost was 41,635 francs.

The great arch was built in its entire thickness up to the angle 67 degrees from the keystone.

The first nine courses which did not rest on the center, were built with a templet, or form, upon which the position of each course was marked.

Above the angle of 60 degrees the arch was erected in double rings, each in four blocks. The lowest block rested on three courses, having their joints filled with sheets of lead 0.02 meter thick and having a space of 0.10 meter between the edges of the sheets and those of the stones.

The upper block was supported by joists uniting the triangular frames bolted upon the back pieces.

The four blocks were built simultaneously. The key block was loaded to 22 degrees as soon as the block starting from 60 degrees had attained 45 degrees.

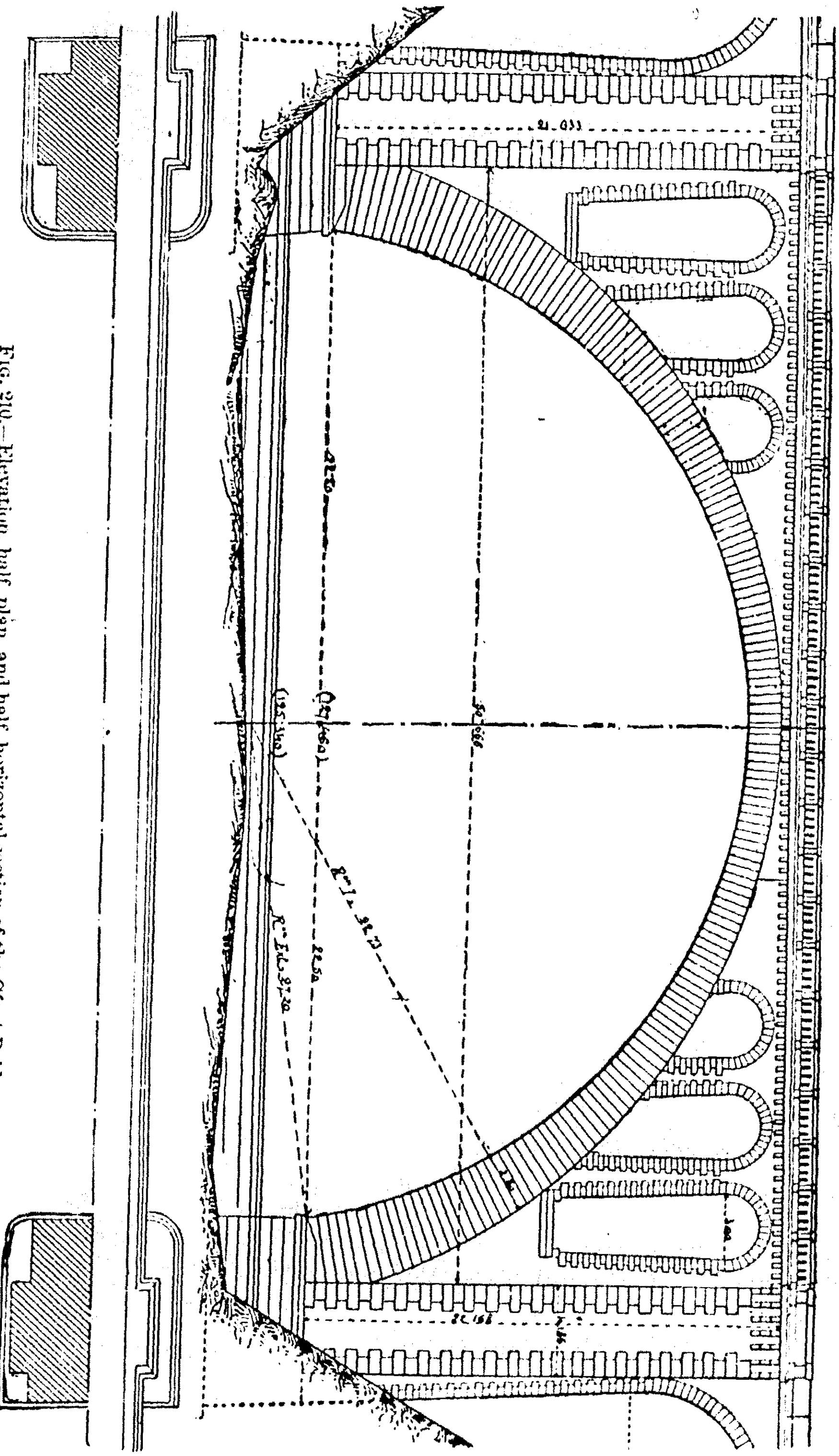


FIG. 210.—Elevation, half plan, and half horizontal section of the Céret Bridge.

They keyed the joints at 60 degrees, taking out as much as possible of the lead. The empty joints were filled with cement mortar nearly dry, and driven in with mallets; the thickness, on account of the pressure, being reduced from 0.02 to 0.01 meter.

The second ring was also constructed in four blocks limited by the same angles as the first.

The center was struck two months after the second ring had been keyed.

There was no apparent motion of the arch.

Cost.—The cost was 712,775.49 francs.

The plans were made by M. Velzey, under the direction of M. Tastre, chief engineer.

CHAPTER XLI.—THE CROSSING OF THE GARONNE AT MARMANDE.—THE USE OF MASONRY CAISSONS.

(305) The railroad from Marmande to Casteljaloux crosses the frequently submerged plain of the Garonne, for a length of 4,500 meters, which was covered in the flood of June, 1875, to a depth of from 2 to 4.50 meters. The plan (Fig. 211) shows the principal bed

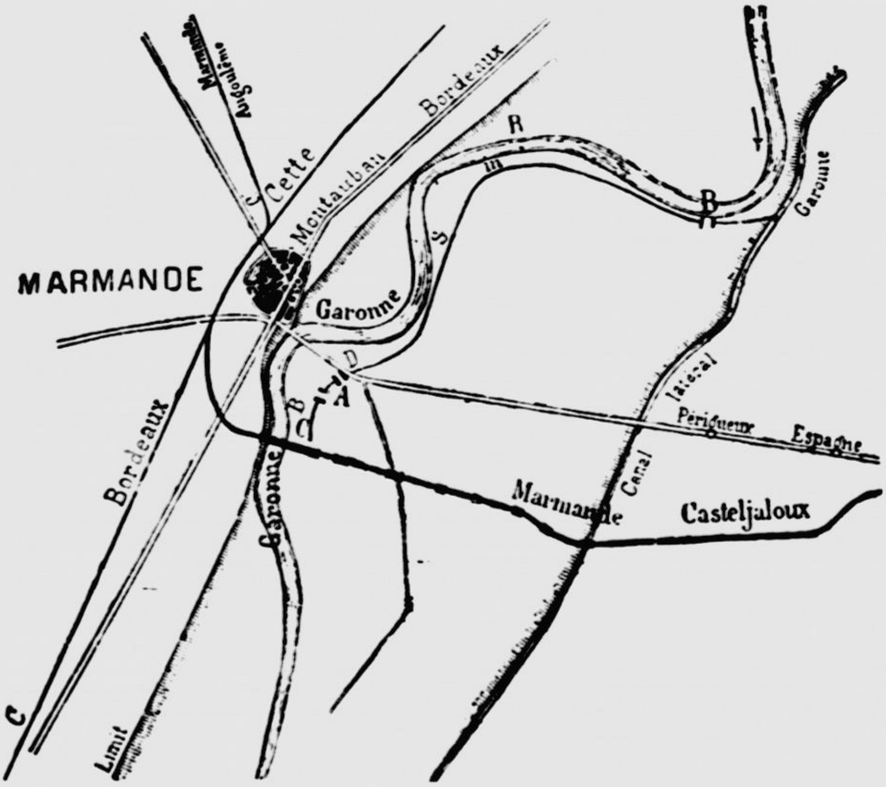


FIG. 211.—Plan of the submersible plain of the Garonne near Marmande.

of the Garonne with the dikes. The dike on the left hand, which affects particularly the railroad, gives way ordinarily at A and at B. The breach at B does not give rise to strong currents, for the mass of water which fills the space above the railroad between the Garonne and the lateral canal forms a buffer. On the contrary, the breach at A occasions strong currents which fall directly on the railroad. Great openings have been made for the disposal of this portion, amounting in all to 5,080 cubic meters; the maximum discharge (freshet, 1875) was estimated at 10,000 cubic meters per second.

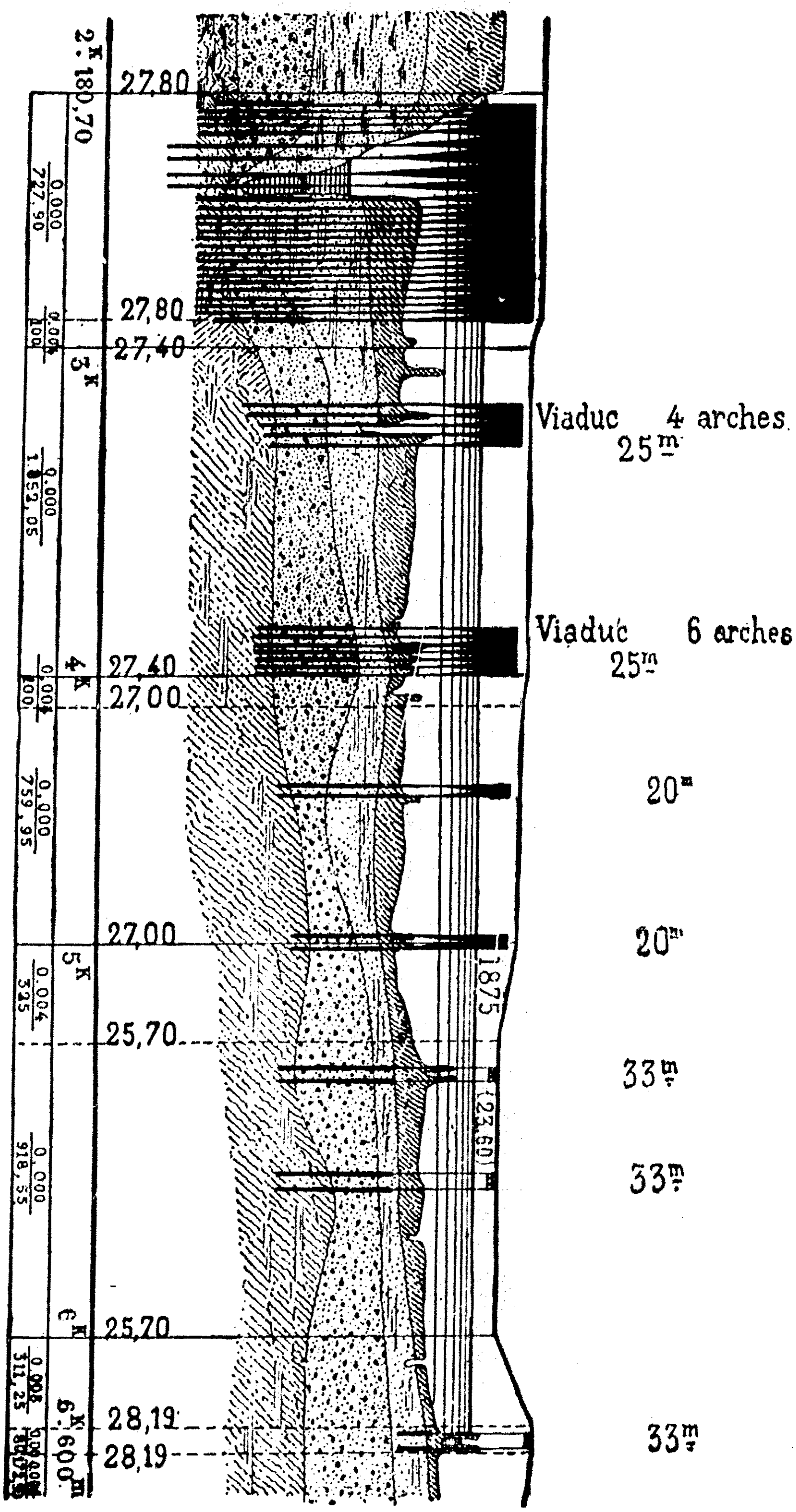


FIG. 212. Longitudinal section of the roadway across the submersible plain of the Garonne.

In order to leave more free space under these works, for floating bodies, and to present to the flowing water, washing the side slopes, a greater obstacle, the level of the rails has been raised in the part [illegible] exposed to the strong current, the force of the current diminishing [illegible] the Garonne to the canal. The profile lengthwise is a [illegible] united by slopes of 0.004 meters. The soil consists of [illegible] alluvial deposit covering a very heavy compact clay [illegible] tertiary). The foundations of all the important works [illegible] meter at least into the marl; the Garonne bridge is built [illegible]. Masonry work was built under the three highest piers of the longitudinal section, at slight expense. Iron was used under the lowest pier. The Garonne bridge consists of four 20-meter elliptic arches of 5 meters rise; five elliptic arches of 56 meters span and 10 meters rise, sixteen 20-meter elliptic arches of 5 meters rise. The two viaducts at the end have arches of 25 meters span and 6.25 meters of rise, one of four, and the other of six arches. (Fig. 212).

The two elliptic isolated arches are of 20 meters span and 5 meters rise. The two iron superstructures are 33 meters span. The foundations of the 36-meter arches were made by the use of compressed air, with iron caissons. The foundations of the 20-meter arches were made by the same system, part with ordinary iron working chambers, and part with masonry working chambers mounted on curbs. An abutment was founded upon a curb of a rectangular form, this form never having previously been employed. The curb was joined to the masonry by iron tie-rods 4.50 meters long imbedded in the masonry. For filling, béton has given the best results; in every case the filling is terminated by pouring in cement.

(306) The foundations of twenty such works were made by means of masonry working chambers, but of a form slightly different from those previously employed. (Figs. 213–219).

First, the bases of all the foundations were elliptical. (Fig. 215). The base was somewhat strengthened.

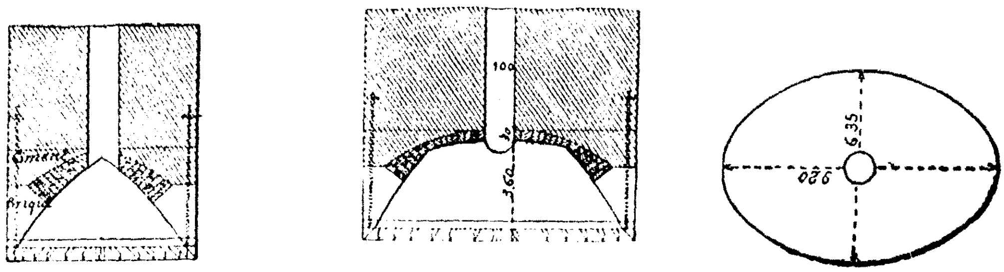
Second, the angle irons of the brackets were arranged with exterior wings, and the curbs were filled with brick masonry which gave them a great solidity. (Fig. 216).

Third, the working chamber of an ogival form consists of cement masonry 1 meter thick. The method of making these twenty foundations was as follows:

A pier of about 6 meters in height was constructed, including the exterior mastics, leaving the masonry and mastics to set for a month at least before sinking. (Fig. 217).

They then proceeded to sink this first part. (Fig. 218). When this was at the bottom they constructed the rest of the masonry and waited a month again to make sure of the setting. They then began with compressed air. (Fig. 219). Only a single severe accident was the sudden fall of 1.70 meters of the foundation in going through a layer of movable gravel. To prevent the recurrence of a similar fall during the period of work, they made, when traversing dangerous layers, sudden changes of pressure every six hours. All the arches were constructed in rings, leaving the joint of rupture on the center (as these centers were very strong they did not key the joints of rupture until after the second ring had been finished).

MASONRY CAISSONS USED IN CONSTRUCTING THE FOUNDATIONS OF THE VIADUCTS BUILT TO CROSS THE SUBMERSIBLE PLAIN OF THE GARONNE.



FIGS. 213, 214, and 215.—Longitudinal and transverse sections, and plan of a pier with its masonry compressed air working chamber.

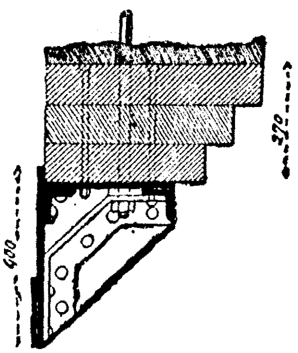


FIG. 216.—Detail of the cutting edge and wooden curb.

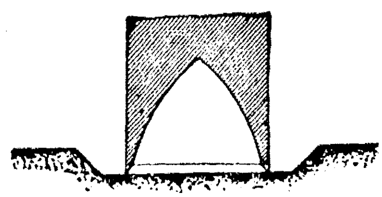


FIG. 217.—Pier before sinking.

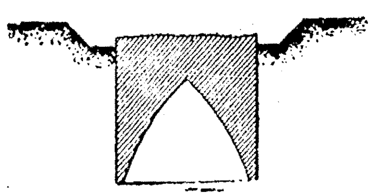


FIG. 218.—Pier during the process of sinking.

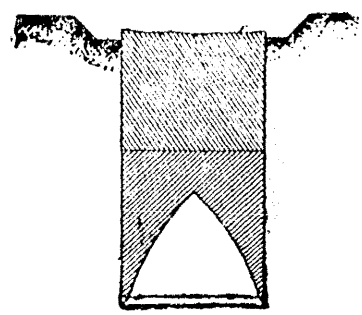


FIG. 219.—Pier completely sunk.

The centers of the 20-meter arches were struck twenty days after they were keyed. Those of 36 meters, forty days after.

(307) The cost of the substructure for the crossing of the Garonne plain amounts to 3,895,950.21 francs for a length of 4,338 meters, *i. e.*, 898,000 francs per kilometer.

The inspectors-general were MM. Croizette-Desnoyers, Vernis, De la Tournerie, and Renoust des Orgeries; the chief engineers, MM. Faraguet, Chardard, Pugens, and Pettit; the engineers, Bernadeau, Séjourné, and Guibert.

CHAPTER XLII.—OLORON BRIDGE UPON THE GAVE D'OLORON RAILWAY FROM PAU TO OLORON.

(308) The bed of the Gave d'Oloron, at the point where it is crossed by the railroad from Pau to Oloron, is confined between two banks from 15 to 18 meters high and has a width which varies from 25 meters at low water to 52 meters in freshets. Freshets attain the height of 5.49 meters, with a velocity of 4.50 meters per second. The bottom of the bed is formed of schistose rocks mixed with banks of marl under a thin layer of sand and gravel. The difficulty of crossing the town of Oloron in a cut of 123,000 cubic meters, and of establishing a station of 8 hectares of surface at the end of the bridge, required that the rails should be placed 23.04 meters above low water. The marble quarries in the vicinity offered excellent materials for the construction. These considerations led to the crossing of the river with a single arch of 40 meters span, which allowed the foundation of the supports to be made almost without a cofferdam, in an impermeable soil. The total length, including the abutments, is 88.70 meters. The width between the parapets is 10 meters. The two abutments of the great arch are opened by full centered arches of 9.20 meters span. (Fig. 220).

The head bands of the great arch have the same dimensions as the arch itself, 1.30 meters at the keystone and 2.60 meters at the joints at 30 degrees. The extrados curve is the arc of a circle determined by these three points. Its radius is 24.15 meters.

The arch rests against two strong cut-stone pilasters, tangent to the intrados curve near the springing line. These pilasters project 0.30 meter from the surface of the spandrels under the plinth and have a batter of 0.05 per meter. The spandrels, on the contrary, are vertical and made of masonry, like the intrados and the surfaces of the abutments.

To reënforce slightly the arch at the joint of rupture the extrados is limited by a tangent to the arc of a circle above defined, drawn at the extremity of the joint at 45 degrees.

The mean pressure on the keystone is 11.31 kilograms per square centimeter. The mean pressure on the joint of rupture is 12.46 kilograms. A longitudinal arch of 1.50 meters, with two arches of 1.65 meters opening, sustained by pillars 0.90 meter wide at the springing lines, are placed above the spandrel of the arch. The maximum height of these pillars is 9.01 meters, and their thickness at the base 1.20 meters. They are united between them by two stories of arches 0.50 meter wide. The end abutments are 15.30 meters high on the right bank and 11.50 meters on the left.

The center of the great arch was built on two temporary masonry piers 2 meters thick, 25 meters apart, and upon two wooden piers placed against the abutment. The rapidity of the current and the rocky bottom would have rendered the establishment of intermediate points of support difficult and costly.

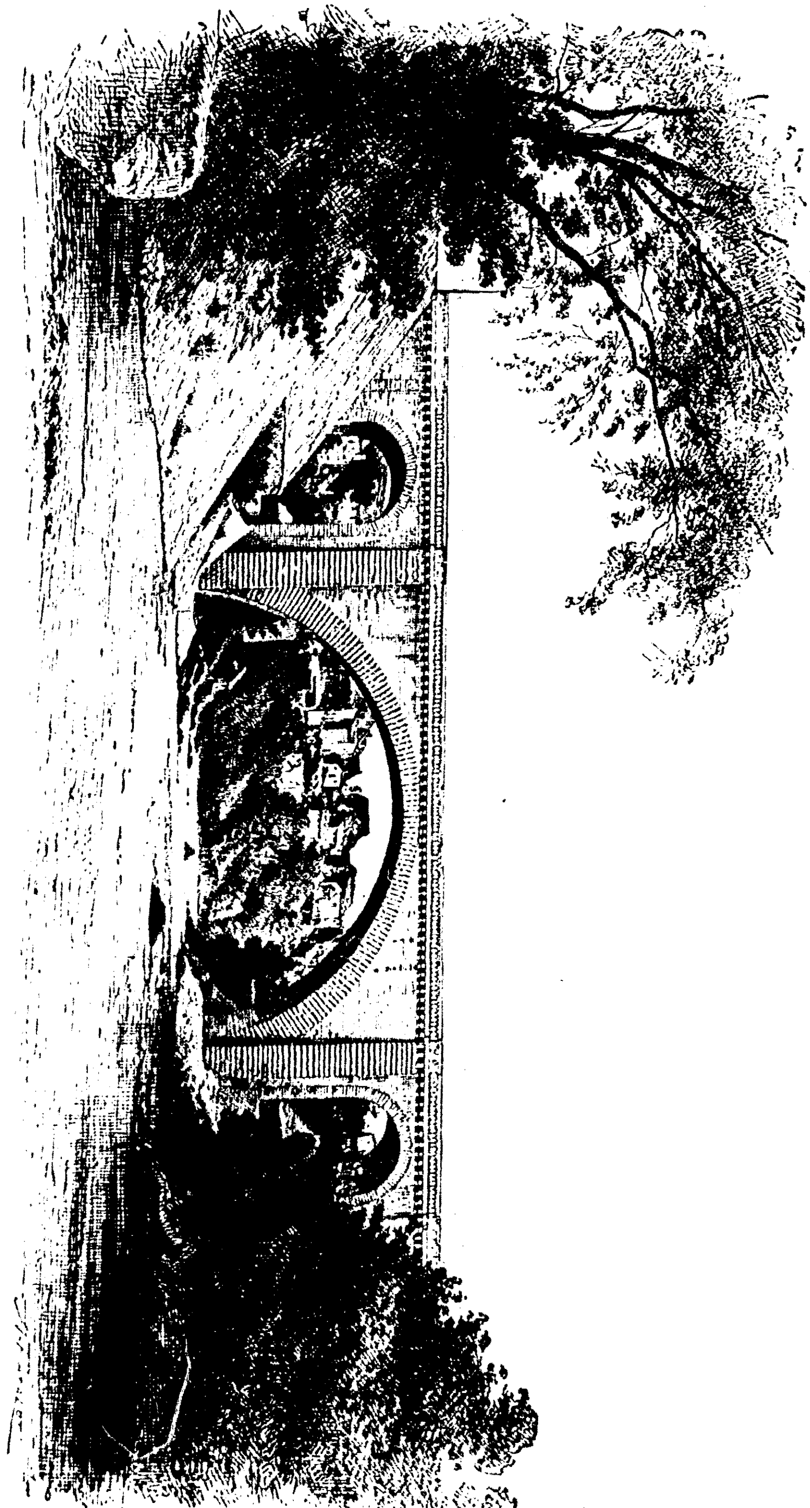


Fig. 230. Bridge over the Gave d'Oloron.

The center consisted of five stiff trusses, 1.84 meters apart, and two head trusses situated at a distance from the first of 1.17 meters. This arrangement was required by the necessity of immediately constructing the portion of the arch next to the head band, on account of the upper voussoirs being single stones 1.30 meters long, while the body of the arch for a length of 8.30 meters was made in two rings, each having half the thickness of the arch.

The center rested on sixty sand boxes, with cast-iron pistons. The center was set up by means of a very light temporary bridge upon the courses below the great bridle pieces.

Up to the joints of 30 degrees the arch was constructed along its whole thickness, then the center was loaded with a weight equal to one-third of the weight of the first ring, which had a thickness of 1.30 meters at the 30-degree joints and 0.65 meter at the keystone. It was keyed in a single point at the crown.

The second ring was constructed from the springing line and keyed like the first. The center was struck fifty-nine days after the second ring had been keyed. The settling was only 0.003 meter. The settlement on the center had been 0.03 meter.

The total cost was 467,793.46 francs, that is, 4,579.17 per running meter.

The Oloron bridge was projected and the work was executed under the direction of MM. Croizette-Desnoyers and Vernis, general inspectors of roads and bridges, by M. Lemoyne, chief engineer, and La Riviere, Maurer, and Biraben, assistant engineers.

CHAPTER XLIII.—THE GRAVONA BRIDGE.

(309) The Gravona bridge is situated on the railroad from Ajaccio to Corte, about 15 kilometers from Ajaccio. The river Gravona, which takes its rise in the high mountains in the center of the island, is frequently exposed to freshets, which attain in this place, where the bed is particularly narrow, a maximum height of 9.53 meters. These special conditions require the avoidance of any obstacle whatever to the current, and that the river shall be crossed without any support in its bed. The abundance of granite in the vicinity allowed the work to be built of masonry. It consists of a single circular arch, 43.53 meters span, 16.80 meters rise, and 22.50 meters radius. It is founded on the compact granite which comes down to the water's edge. The bridge (Fig. 221) has a single track, and its width between the parapets is 4.10 meters.

The arch has a thickness of 1.40 meters at the keystone. The radius of the extrados is 27 meters, and it has at the joint of rupture a thickness of 2.80 meters. It is covered with a layer of hydraulic mortar 0.10 meter thick.

The spandrels are in a vertical plane: they are prolonged back from the abutments to the natural soil by wing walls projecting 0.45 meter from the spandrel and having an exterior batter of 0.04 meter. The interior filling in this work between the spandrels is by means of stones carefully arranged by hand. The work is surmounted by a plinth 0.40 meter high and projecting 0.45 meter from the spandrel wall. This plinth is formed of two courses, and rests upon a series of brackets. On the plinth there is a full masonry parapet. The entire work is constructed of granite masonry from the neigh-

FIG. 221.—The Gravona bridge. Railroad from Ajaccio to Corte.

boring quarries. The arch is of cut stone 1.40 meters thick at the keystone. The granite material used in the arch may be considered as resisting a load of 600 kilograms per square centimeter. The pressures are: at the key, 26.60 kilograms; at the joint of rupture, 31.80 kilograms; and upon the foundation, 14 kilograms.

The impossibility of establishing with security points of support in the river required the construction of a special kind of center. A provisional mass of masonry was therefore raised on each bank upon which was established the center supports, having a maximum span reduced to 29.63 meters. For raising the center a suspension bridge was employed made of two cables, whose extremities were made fast to solid frames embedded in a coffer covered with riprap. The transverse girders were formed of beams attached to the chain by ropes, and upon these beams a planking supported a light railroad carrying the materials. The flooring of this bridge was 7 meters below the intrados at the key. The arch was constructed in two successive rings from the joint at 45 degrees, corresponding nearly with the angle of sliding. The termination of the arch was effected on the 1st of August, 1884.

The center was struck almost automatically on account of the progressive contraction of the wood under the action of heat.

The apparent elasticity of the arch at the moment of placing the keystone of the second course seemed to indicate that the center already had slightly settled from the arch. Thirty days after the keying the center had settled several centimeters. No settling took place in the arch.

The cost was 119,000 francs, that is, 83 francs per square meter of elevation.

The projects were prepared and the works executed under the direction of MM. Delestrac and Buffet, general inspectors, by MM. Gay, Dubois, and Margerid, chief engineers, and MM. Descubes and Fonan, assistants.

PART IV—CIVIL CONSTRUCTION AND ARCHITECTURE.

CHAPTER XLIV.—SPECIMENS OF IRON CONSTRUCTION IN PARIS.

(310) The great retail store of M. Jaluzot, called Magazins du Printemps, destroyed by fire in 1881, has been rebuilt by M. Sedillé, architect, with the assistance of eminent engineers, both for the foundation and the iron framework.

The ground has an area of 3,000 square meters, and it was required to make an available floor space of 21,000 square meters and have the whole well lighted from the top and sides.

These requirements precluded the use of walls, either within the building or on the outside.

The floorings of the various stories, many of which were to hold heavy goods, were required to be especially strong, and the loads to be placed in the upper portions of the building made it necessary for the architect to adopt iron as the material for the construction of the pillars, and to employ stone simply for decorative purposes; for ordinary hard stone supports a pressure of about 30 kilograms per square centimeter, while iron will support from 600 to 800.

Now, the load on some of the pillars from 7 to 8 meters apart was 350,000 kilograms, which would have required stone pillars more than a meter square; hence iron pillars were adopted.

Again, the establishment of heavy piers on isolated spots required the foundations to be made by sinking pits in various parts of the ground; but the soil consisted of fine sand mixed with water and clay.

(311) Three borings, made to the depth of 35 meters, 96 meters, and 53 meters, respectively, produced a flow of 2,400 cubic meters of water per day. At a depth of 2 meters the soil was sand and gravel which showed a density sufficient to support a load of from 6 to 8 kilograms per square centimeter.

It was therefore determined to sink cylindrical pits from 2.50 or 3 meters in diameter to the depth of 2 meters, the maximum load being 350,000 kilograms and the minimum 250,000.

(312) It now remained to determine how these pits should be sunk. It would be dangerous to use the ordinary cofferdams from which the water is pumped out and béton run in. Such a process, by removing the very abundant supply of surface water, would cause the settling of the surface sand, would break up the soil, and endanger the foundations of the surrounding structures. For this

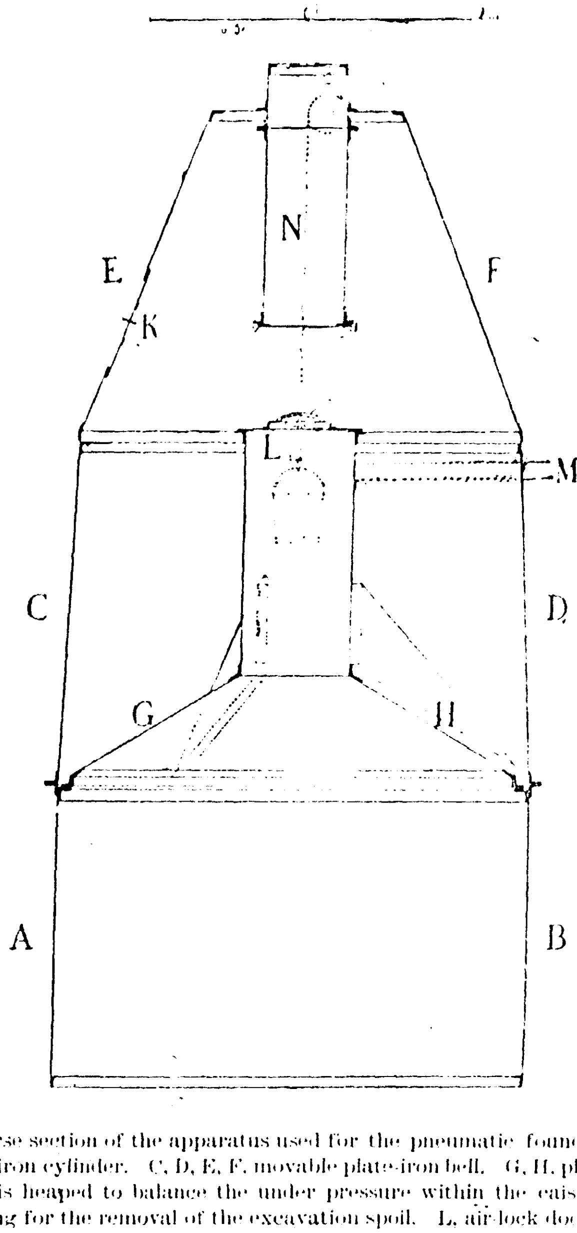


FIG. 222.—Transverse section of the apparatus used for the pneumatic foundations. A, B, foundation caisson; a plate-iron cylinder. C, D, E, F, movable plate-iron bell. G, H, plate-iron deck on which the excavation spoil is heaped to balance the under pressure within the caisson. K, entrance for workmen, and opening for the removal of the excavation spoil. L, air-lock door giving access to the caisson. M, inlet pipe for the compressed air. N, movable pipe for the introduction of the béton.

reason the architect adopted the method of sinking them by compressed air, and employed this process for the first time in making foundations in the city of Paris.

(313) M. Zschokke, who has made a specialty of river and harbor work was called to make these foundations, which he did with great

rapidity. For each foundation of a pier a cylindrical caisson AB (Fig. 222) was employed, from 2.50 to 3 meters in diameter and 2 meters high, made of plate iron 4 millimeters thick, strengthened above with two circular angle irons 60 by 60, and at the lower part, by plate iron, 200 by 10 millimeters, forming the cutting edge. This caisson was to pass through the layer of water. It is surmounted by two conical frustrums, EF and GH, both of iron and united by an iron bell, CD, which is bolted to the upper belt of the caisson. These two upper cones, one interior, GH, inclined at 30 degrees, the other exterior, EF, at 60 degrees, formed the air lock necessary for the process. They are each furnished with a door communicating with the interior of the lock at K, and from the interior of the lock to the interior of the caisson at L. Stopcocks serve to equalize the pressure between the two without being obliged to open the doors. At the upper part there is a winch to raise the buckets.

An India rubber pipe 70 millimeters in diameter which passes through the two cones furnishes the compressed air, at 0.5 atmosphere, from an air compressor. This air forces back the water and allows the workmen to work freely in the interior of the caisson which slowly descends. The excavation spoil raised in the caisson is thrown out upon GH, and thus gives the caisson an increasing load necessary to balance the under pressure of the compressed air, beside the resistance due to the friction of the ground against the iron wall. Before running in the béton the excavation spoil is thrown off, being compensated by the weight of the apparatus. The introduction of the béton is made through the movable tube N, fixed to the upper part of the cone EF, by means of successive lockages. As it is introduced it is well rammed, and when it arrives at the desired level for laying the stone blocks the supply of compressed air is kept up for several hours, to prevent the water from rising, and to allow the hydraulic mortar time to set. This done, it only remains to take away the double cone forming the air lock, and to remove it to another caisson. Twenty-four hours suffice to make the complete foundation of a pit 2.50 meters in diameter; ten hours for sinking and excavating, and fourteen hours for running in and ramming the béton.

Finally, to avoid the heating resulting from the compression of the air, a continuous jet of spray was introduced. These different operations terminated, the cones were taken away, leaving in the foundation the metallic caisson which enveloped the cylindrical column of béton and added to its resistance.

Thus the foundation of the forty-six iron pillars in the interior of the Printemps were laid. In like manner the stone pillars of the exterior facades, and the grand vestibule or hall were made.

The loads which these foundations had to bear varied from 230 to 350 tons. For this reason, at certain points heavily loaded, the diameter of the foundation was made 3 meters instead of 2.50, the diameter adopted for most of the other caissons.

(314) *Foundations for the steam engines.*—The use of dynamo-electric machines for lighting the new edifice requires a Corliss steam engine of 500 horse power, and it was necessary to take special precautions in making the foundations for it. Accordingly, the architect decided on the construction of an iron caisson 12.75 meters long, 4 meters wide, 2 meters high, and 0.006 meter thick, to lay the foundations below the sheet of water by means of compressed air. This was successfully accomplished and filled with a mass of béton 1.20 meters high. On this mass stones of enormous size were placed to receive the supports for the four principal shafts.

(315) *Iron work.*—What was required in the new store was space and light. By increasing the number of stories upon the ground of 3,000 meters, an area of 21,000 meters of flooring was easily obtained.

TRANSVERSE SECTIONS OF THE PILLARS OF THE MAGAZIN DU PRINTEMPS.

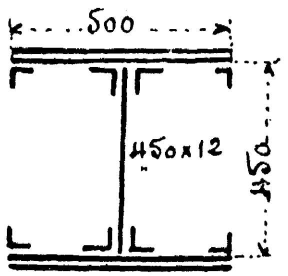


FIG. 223.—Exterior. I. Least loaded.

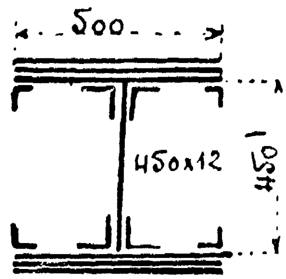


FIG. 224.—Interior. II. Least loaded

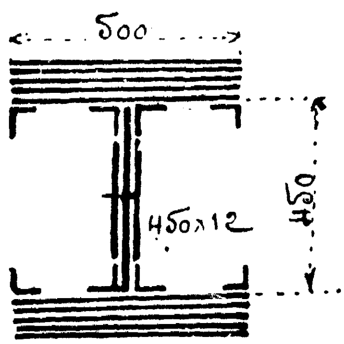


FIG. 225.—Interior. III. Most loaded.

As to the light, it had to be obtained through the sides, and through the glazed roof of the central nave. Consequently there must be no interior wall and no exterior wall around the edifice, but simply isolated iron pillars of as small a number as possible.

(316) The contract for the iron work of this important construction was given to Baudet, Donon & Co., whose reputation and great workshops were a guarantee of rapid construction. To determine the resistance of these pillars the section of which was fixed at 50 centimeters on each side, in order to leave the necessary spaces for the conduits, it was necessary to take account of the exact loads

IRON FRAME WORK OF A PARIS STORE (THE MAGAZIN DU PRINTEMPS).

which the pillars would have to support. These loads are of two kinds, the dead load and the rolling or accidental load.

The dead load is composed of the weight of all the parts of the construction which form the flooring. The multiplicity of stories of small heights rendered it important to diminish as much as possible the thickness of the flooring. The architect obtained this result by using for floor timbers the smallest specimen of double T-iron girders in use, that is to say, T of 80 millimeters, with a span not exceeding 2 meters. The filling was formed of hollow brick laid in plaster upon iron beams 14 millimeters thick. For the calculations, the dead load upon the flooring was estimated at 280 kilograms per square meter: the accidental, or live load, at 520 kilograms.

The loads on the different floorings being thus determined, the sections of the pillars were calculated by considering them as built in at each story, on account of the beams being strongly fastened to their brackets. The loads may be thus described:

	Kilograms.
First. Upper flooring of the cellar	1,200
Second. Of the ground floor	800
Third. Mezzanine story	800
Fourth. First story	800
Fifth. Second story	800
Sixth. Third story	800
Seventh. Flooring above the third story	500
Eighth. Roof truss	300
Ninth. Pillars, etc	600
Total per square meter	6,600

(317) These pillars, loaded according to their position, may be divided into three classes:

First. Pillar on the perimeter (Fig. 223).

Second. Pillar on the interior least loaded (Fig 224).

Third. Pillar on the interior most loaded (Fig. 225).

I. Surface to be carried, 7.80 by 3.20 meters, = 25 square meters. 25 by 6,600 = 165,000 kilograms.

Web 450 by 12	square milimeters	5,400
4 plates 500 by 12	do	24,000
4 Angle irons, 100 and 100, by 12	do	9,600
4 Angle irons, 80 and 80, by 10	do	6,400
Total		45,400

Load per square millimeter $\frac{165000}{45400}$ = 3.6 kilograms to resist crushing.

II. For an interior pillar least loaded $\frac{230000}{57400}$ = 3.87 kilograms.

III. For the most heavily loaded $\frac{348000}{90400}$ = 3.85 kilograms.

For the short double T beams R (load per square millimeter) = 6.3 kilograms.

For the longest beams R (load per square millimeter) = 6.7 kilograms.

Strength of the pillars to resist rupture by flexure for cases I, II, and III, calling the height of the pillar in the cellar 3 meters, and its width 0.5, we have by Love's formula, $1.55+0.0005\left(\frac{3}{0.5}\right)^2=1.568$; hence,

I. R = 3.6 by 1.568 = 5.75 kilograms per square millimeter.
II. R = 3.87 by 1.568 = 6.07 kilograms per square millimeter.
III. R = 3.85 by 1.568 = 6.03 kilograms per square millimeter.

Pl. XI shows the frame work in construction, and exhibits the form and arrangement of the pillars and floor beams.

Acknowledgment.—I wish to express my indebtedness to Messrs. Sedillé and Baudet for explanations and documents.

Chapter XLV.—The Eiffel Tower.

(318) The investigations of M. Eiffel upon high iron piers for railroad viaducts like that at Garabit, led him to consider that such piers might be erected to a height very much greater than they had yet attained.

The principal difficulty hitherto found in the erection of high iron piers is, that, generally, a system of heavy lattice bracing is placed on their faces to resist the action of the wind; as the pier is increased in height the base also increases, and this lattice bracing, on account of its great length, becomes of imaginary rather than real utility.

There is, therefore, great advantage in dispensing entirely with these large and heavy accessory pieces, and giving to the pier such a form that all the shearing stresses shall be concentrated in its edges, these being reduced to four great columns united simply by widely separated horizontal bands.

Imbued with these ideas, M. Eiffel made the calculations for a great pier 120 meters high and 40 broad at the base.

These researches finally led to the studies for a tower attaining a height of 300 meters.

The project for such a tower was carefully prepared by MM. Nouguier and Koechlin, engineers of the Eiffel Company, and M. Sauvestre, architect. It was brought before the French Society of Civil Engineers by M. Eiffel, and thus summarily described.

(319) *Description of the proposed tower.*—The frame work consists essentially of four uprights, forming the edges of a pyramid with curved faces; each upright has a square section decreasing from the base to the top, and forms a curved lattice caisson 15 meters square at the base and 5 at the top.

The uprights are 100 meters apart from center to center at the base, and are firmly anchored in a solid mass of masonry.

At the first story, 70 meters above the ground, the uprights are united by a gallery 15 meters wide running from pier to pier around the whole construction, and having an area of 4,200 square meters.

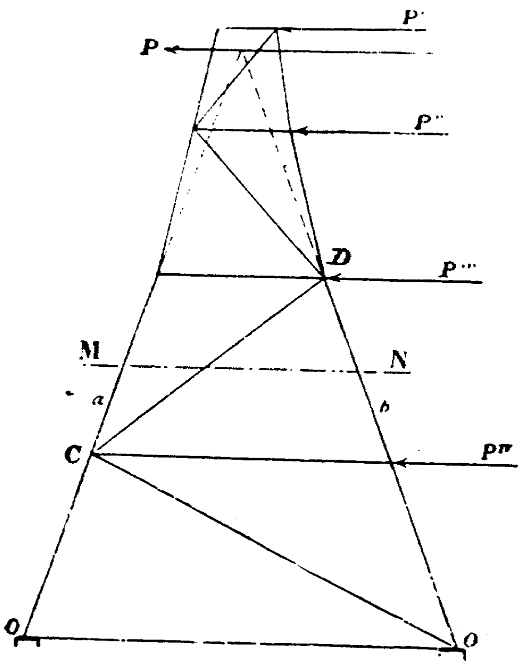


FIG. 226.—Resistance of a simple lattice.

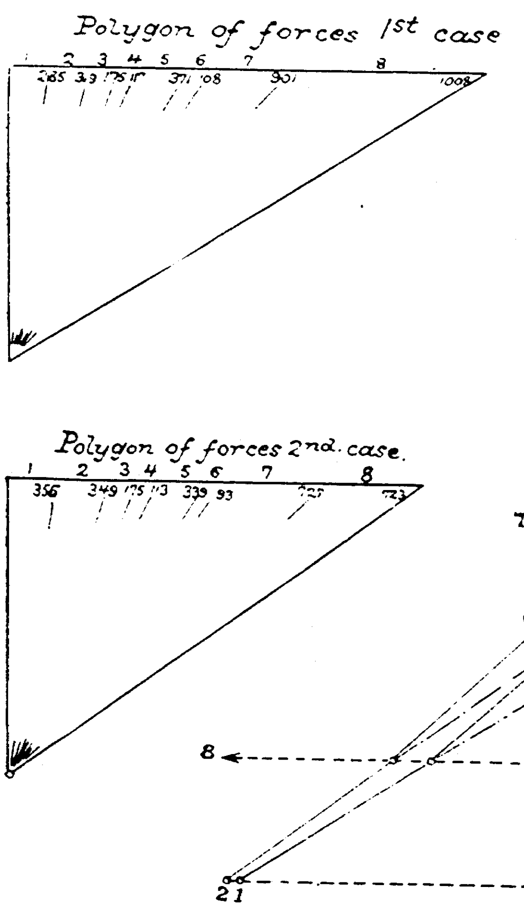
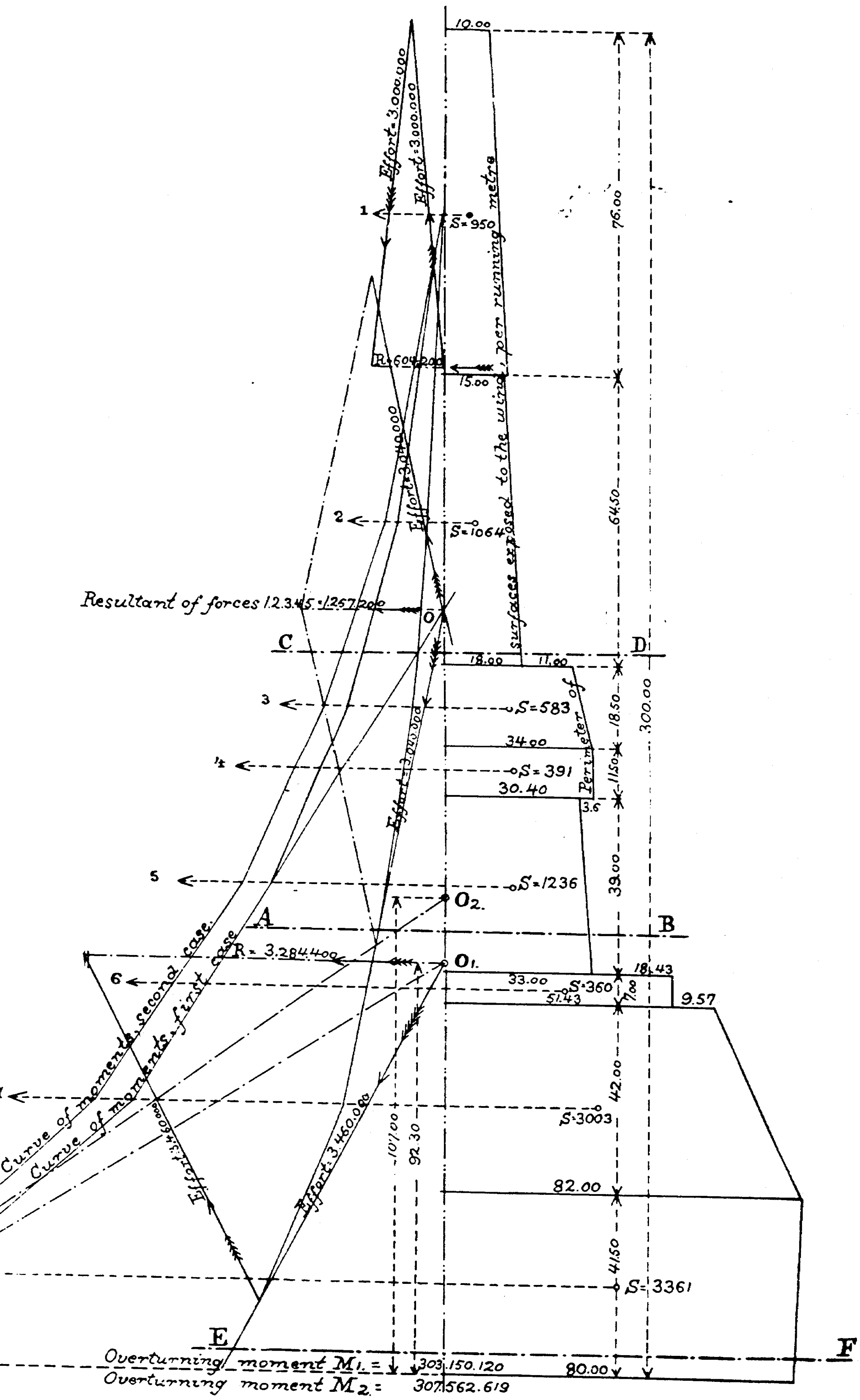



FIG. 227.—Diagram of the stability of the Eiffel Tower when exposed to the pressure of the wind. Two cases.

At the second story there is a platform 30 meters square. At top, a cupola, and a balcony with an area of 250 square meters. At the lower part of the tower an imposing arch of 80 meters span and 50 rise is placed in each face, which, by its broad open-work head band and its ornamented and variously colored spandrel, forms the principal decorative feature.

(320) *Strength and stability of the tower; force of the wind.*—The force or pressure of the wind may be decomposed as follows:

Suppose for an instant that we have in one face of a pier (Fig. 226) a simple lattice forming a surface resisting the shearing stresses of the wind; let the horizontal components of these stresses be P^I, P^{II}, P^{III}, P^{IV}.

To calculate the stress in the three pieces cut by any plane M N, it is sufficient to determine the resultant P of all the exterior forces acting above this section, and to decompose this resultant into three forces passing through the pieces cut.

If the form of this system is such that for each horizonal section M N, the two uprights Oa and Ob intersect on P, the effort on the lattice bar C D is nothing, and it may be dispensed with. The application of this principle constitutes one of the peculiarities of M. Eiffel's system. It is therefore evident that the direction of each element of the uprights follows the direction of a curve traced upon the chart (Fig. 227), and in reality this exterior curve of the tower is no other than the curve of the moments of flexure due to the wind.

(321) *Hypotheses in reference to the pressure of the wind.*—The uncertainty of the effects of the wind, and the data to be adopted both as to the intensity and the amount of surface struck, requires the adoption of particularly prudent hypotheses.

With regard to the *intensity of the pressure of the wind* two suppositions have been made. The first assumed the wind to act on the tower with a constant pressure of 300 kilograms per square meter; the second, that the intensity increased uniformly from 200 kilograms at the base to 400 at the top.

(322) As to the surface struck, it was assumed, notwithstanding its apparent exaggeration, that the upper half of the tower should be treated as if the lattice work were replaced by closed surfaces: that upon the intermediate part, where the open spaces are much greater, each anterior face should be reckoned four times the real surface of the iron; below (the gallery of the first story and the upper portions of the arches) the anterior surfaces should be counted full; finally, at the base of the tower, the uprights should be counted as full and struck with twice the force of the wind.

These hypotheses are more unfavorable than those usually adopted for viaducts.

With these surfaces the calculations have been made under both hypotheses of the intensity of the wind, and the results given in the annexed chart (Fig. 227) show that the two funicular polygons thus obtained are nearly identical. In the hypotheses of the uniform wind of 300 kilograms per square meter upon the whole tower, the horizontal effort upon the whole construction is 3,284 tons, and its point of application is situated 92.30 meters above the masonry base.

The overturning moment is $M_1 = 3,284 \times 92.30 = 303,150$ ton-meters.

(323) As to the moment of stability, the weight of the construction is as follows:

	Tons.
Metal	4,800
Rubble flooring	1,650
Sundries	50
Total	6,500

The base of the tower being 100 meters, the moment of stability $M_s = 6,500 \times \frac{100}{2} = 325,000$ ton-meters, which is greater than M_1.

(324) In the second hypotheses, *i. e.*, the wind varying in intensity from 200 to 400 kilograms per square meter, the total horizontal effort is only 2,874.4 tons, but its point of application rises to 107 meters above the masonry base. The overturning moment in this case is $M_2 = 2,874.4 \times 107 = 307,562$ ton-meters. This is very nearly the same as M_1, and is still below M_s.

(325) *Anchorage.*—The stability is still further augmented by anchoring each of the four standards of an upright to the massive base by means of iron ties embedded in a mass of masonry sufficient to double the coefficient of safety. (Figs. 232 and 233).

(326) *Deflection.*—If we take Claudel's designation of winds given below, the calculated deflection will be as follows :

Designation of the wind.	Velocity per second.	Pressure per square meter.	Deflection.
	Meters.	*Kilos.*	*Meters.*
Very strong breeze	10	13.54	0.038
Reefing breeze	12	19.50	.055
Very strong wind	15	30.47	.086
Gale	20	54.16	.153
Hurricane	24	78.00	.221

(327) *Resistance of the tower against the wind.*—First case, wind 300 kilograms pressure from base to top. Second case, wind increasing uniformly from 200 at the base to 400 at the top.

Corresponding surfaces and pressures.

No. of the elements.	Height of the elements of surface.	Surface of the elements.	First case of the wind.		Second case of the wind.	
			Pressure per square meter.	Total pressure.	Pressure per square meter.	Total pressure.
Top.	*Meters.*	*Sq. meter.*	*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*
1	76.0	950	300	285,000	375	356,250
2	64.5	1,064	300	319,200	328	348,992
3	18.5	583	300	174,900	300	174,900
4	11.5	391	300	117,300	290	113,390
5	39.0	1,236	300	370,800	274	238,664
6	7.0	360	300	108,000	258	92,880
7	42.0	3,003	300	900,900	242	726,726
8	41.5	3,361	300	1,008,300	215	722,615
	300.0			3,284,400		2,874,417

(328) *Determination of the stresses in the uprights.*—The prolongation of the section A B meets the axis at O, the point of application of the resultant of the forces 1, 2, 3, 4, 5. We may therefore decompose this force of 1,267,200 kilograms in the direction of the uprights, which gives for each of them a stress of $\frac{3040000}{2}$ kilograms.

The stress in the lower part of the uprights is $\frac{3460000}{2}$ kilograms.

The stress in the upper part of the uprights is $\frac{3000000}{2}$ kilograms.

(329) *Calculation of the section of the base of the uprights.*—Total weight on the foundations, 6,500,000* kilograms. Overturning moment, 303,150,120.

Load on the base of an upright from its own weight—

$$\frac{6,500,000}{4} = 1,625,000 \text{ kilograms.}$$

Load on the base of an upright due to the effect of the wind—

$$\frac{303,150,120}{2 \text{ by } 100} = 1,515,750.$$

Total loads, 3,140,750 kilograms.

Section of a standard at its base, 80,148 square millimeters.

Section of an upright = 80,148 by 4 = 320,592 square millimeters.

Load per square millimeter = $\frac{3,140,750}{320,592}$ = 9.8 kilograms per square millimeter.

M_1 = 303,150,120 the overturning moment, first case.

M_2 = 307,562,619 the overturning moment, second case.

CONSTRUCTION OF THE EIFFEL TOWER.

(330) The idea of a tower 300 meters high is not a new one. In 1833 the celebrated English engineer Trevithick proposed to erect a

*This refers to the first project; the weight of the metal in the actual structure is 7,300,000.

cast-iron tower 1,000 feet high, 100 feet in diameter at the base, and 12 feet at the top. But this work was never begun.

On the occasion of the Centennial celebration in 1876 Messrs. Clarke, Reeves & Co. proposed to construct at Philadelphia a wrought-iron tower 1,000 feet high, and 150 feet at the base.

In 1881 M. Sébillot proposed the erection of a tower 300 meters high to light Paris electrically, but this plan was never adopted.

(331) *Situation.*—It was finally decided that the tower should be built on the Champs de Mars in front of the Jena bridge, M. Eiffel receiving a subsidy of 1,500,000 francs and the tower to revert to the city of Paris after a lapse of twenty years, M. Eiffel and his representatives having the income derived from the tower up to that date.

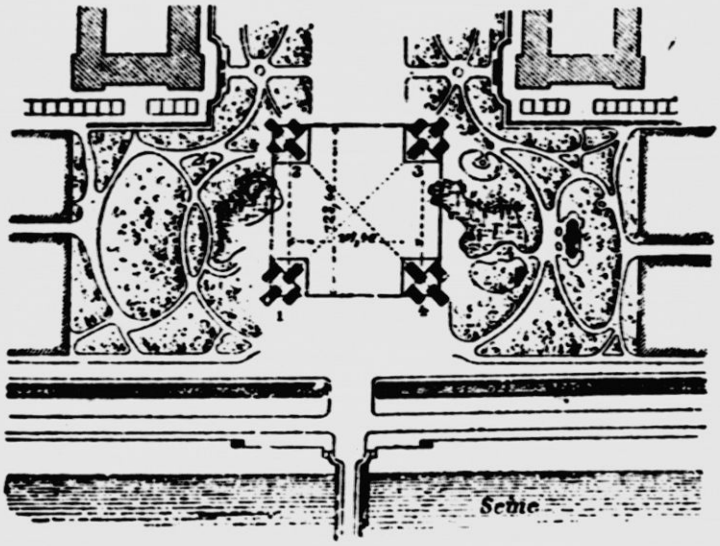


FIG. 228.—General plan of the foundations of the Eiffel tower.

(332) *Foundations.*—The base of the tower consists of four piers which bear the names of the four cardinal points, the two next the Seine being the north and west, the others being east and south.

It was absolutely essential that the piers should be erected on firm ground and so careful soundings were made to determine its nature.

(333) *Soundings.*—A great number of borings in the Champs de Mars showed the strata to be arranged as shown in Fig. 229, that is, the lower layer consists of a bed of plastic clay resting on the chalk formation and capable of supporting 3 to 4 kilograms per square centimeter.

This clay bed slopes slightly from the Ecole Militaire toward the Seine, and underlies a bank of compact sand and gravel, a good material for foundations.

Fig. 228 shows the general plan of the foundations. For the two piers, No. 2 and 3, the made ground was 7 meters above the level of the Seine, and below that level there was a bed of gravel 6 meters thick affording favorable conditions for an excellent foundation; the piers were accordingly built upon a layer of cement concrete 2 meters thick. (Fig. 232 and Plate XIII).

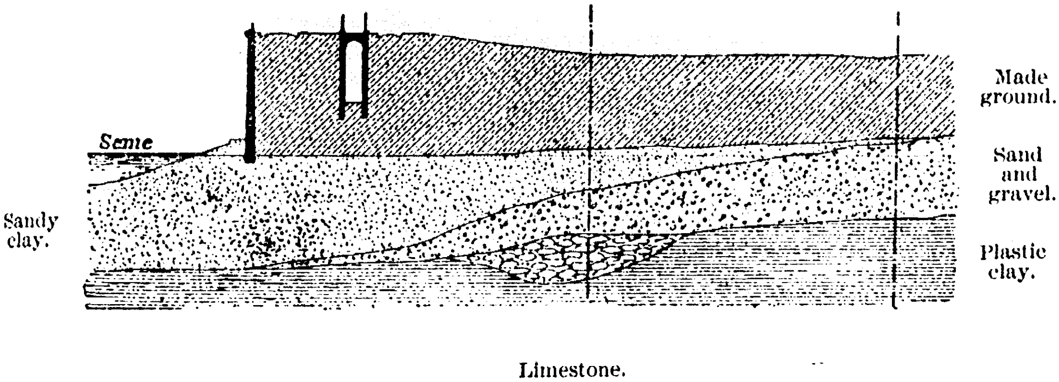


FIG. 229.—Longitudinal section of the Champ de Mars through the axes of piers 1 and 2.

(334) *Use of compressed air.*—The other two piers, Nos. 1 and 4, were differently founded.

The bed of sand and gravel occurred at the level 22 (above sea level), that is, 5 meters below the level of the Seine (27), and it was overlaid by soft alluvial deposits from the river.

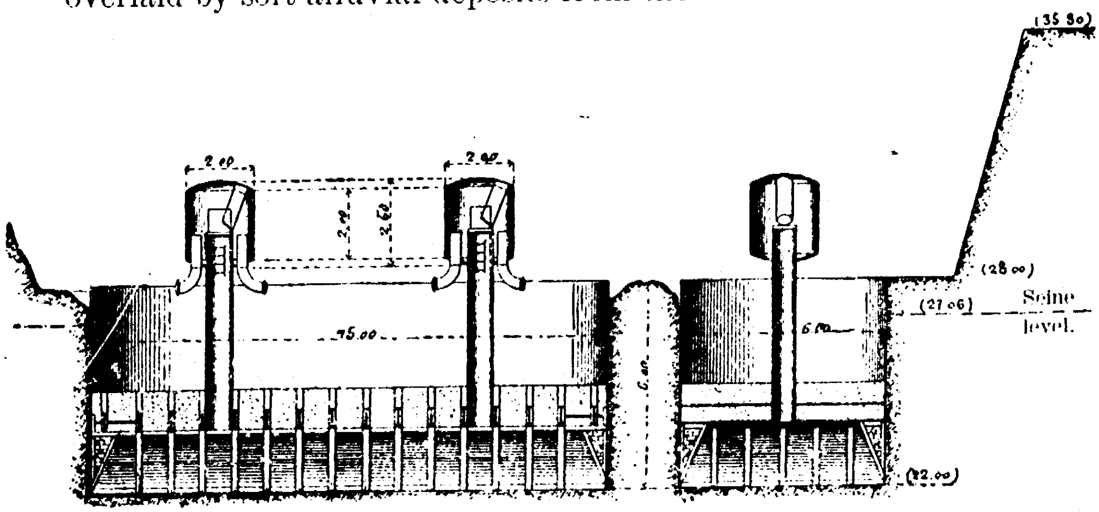


FIG. 230.—Longitudinal and transverse sections of the iron caissons.

In order to make sure, a preliminary bell or caisson 1.50 meters in diameter (Fig. 222) was sunk in the center of each pier, and it was ascertained that, below the sand and gravel, sand, ferruginous sandstone, and a bank of chloride of calcium were found at the bottom of a depression washed out of the plastic clay.

There was no difficulty, therefore, in making the foundations by using compressed air with four iron caissons 15 meters long and 6

EIFFEL TOWER.

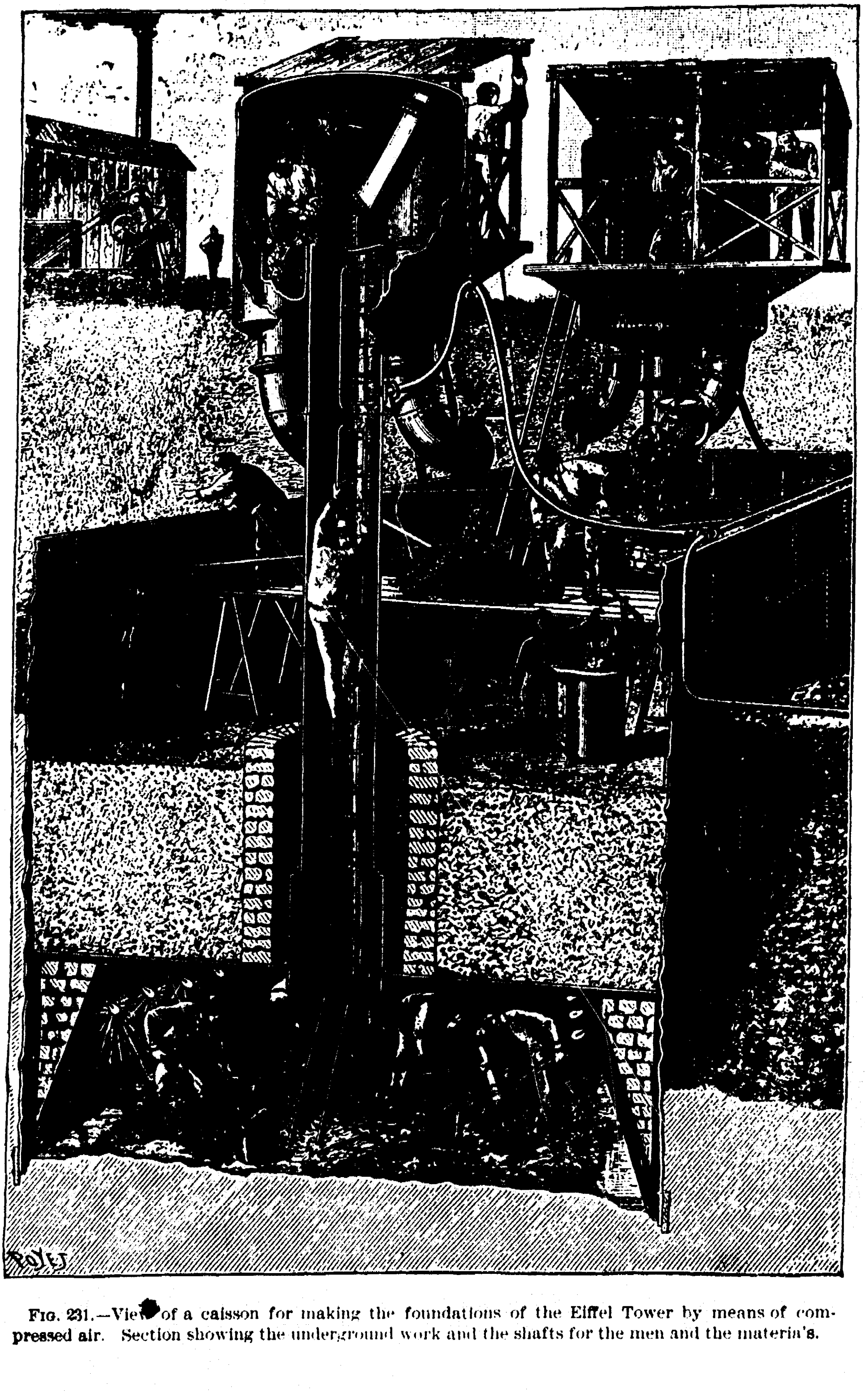
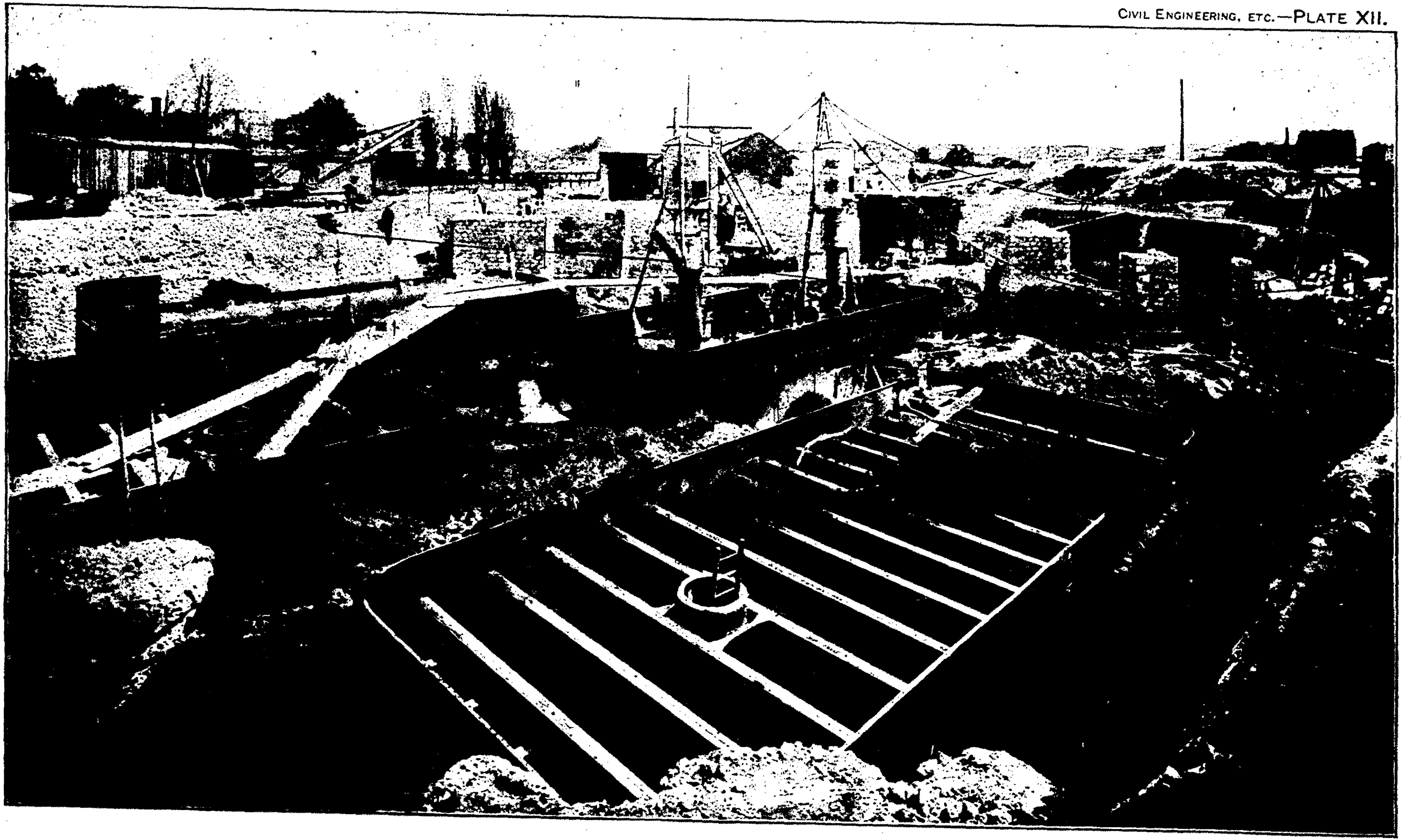


FIG. 231.—View of a caisson for making the foundations of the Eiffel Tower by means of compressed air. Section showing the underground work and the shafts for the men and the materials.



THE EIFFEL TOWER. IRON CAISSONS USED WITH COMPRESSED AIR IN BUILDING THE FOUNDATIONS OF A PIER.

meters wide for each pier, and sunk 5 meters below the level of the river.

Figs. 230 and 231 show the arrangement and dimensions of one of these caissons, and Plate XII shows all four caissons of one of the piers, in the process of sinking.

(335) *Description of the ironwork.*—Each of the four uprights of the tower is a huge frame 15 meters square whose edges transmit the pressure to the ground by masses of masonry placed under each; there are four of these masses for each pier. The top of each of the masses, which takes the thrust, is at right angles to the direction of the edges of the upright; the mass itself is pyramidal in form, having its vertical face in front and its oblique face behind. Its dimensions are so calculated as to bring the resultant of the oblique pressures to a point very near the center of the foundation.

This oblique pressure amounts to 565 tons without that of the wind, and 875 with that of the wind.

(336) *Details of the foundation.*—Upon the bottom of piers Nos. 1 and 4, *i. e.*, at a depth of 14 meters, the vertical pressure is 3,320 tons with the wind; this, spread over a surface of 90 square meters, gives a load of 3.7 kilograms per square centimeter.

Upon piers 2 and 3 the pressure on the ground at a depth of 9 meters is 1,970 tons, which, spread over a surface of 60 square meters, gives a pressure of 3.3 kilograms per square centimeter.

The masses of concrete are 10 meters long by 6 meters wide, arranged as in Fig. 232. The concrete is made of 250 kilograms of Boulogne cement for each cubic meter of sand. The masonry is of Souppes stone set in the sand cement. The use of cement was requisite for attaining a rapid setting, thus avoiding any settling.

At the center of each mass two great anchor bolts 7.80 meters long and 0.10 meter in diameter are imbedded, which, by means of two iron **I** bars and anchorage plates, hold on to the principal portion of the masonry (Fig. 233).

This anchorage, not necessary for the stability of the tower, which is maintained by its own weight, gives an excess of security against overturning, and, moreover, it was utilized in the erection of the oblique standards.

The masonry, subjected to a load of from 4 to 5 kilograms per square millimeter, is capped by two courses of cut stone from Chateau Landon, having a resistance of 1,235 kilograms per square centimeter. The pressure under the iron shoes is not more than 30 kilograms per square centimeter, hence the coefficient of safety is 40.

It may be seen from these figures, and from the materials selected, that the foundations have been so laid that there can be no doubt as to their perfect security.

Besides the separate foundations for each standard there is a masonry base, carrying no load, but designed to support the metal moldings which decorate the pedestal of the uprights.

The walls which carry this pedestal are laid on arches and form a square 26 meters on a side, the whole of the substructure being filled with earth except those piers in which chambers are reserved for the elevator engines and boilers (Pl. XIII).

(337) The two lightning conductors for each pier are carried down in cast-iron pipes 0.50 meter in diameter and 18 meters long, which

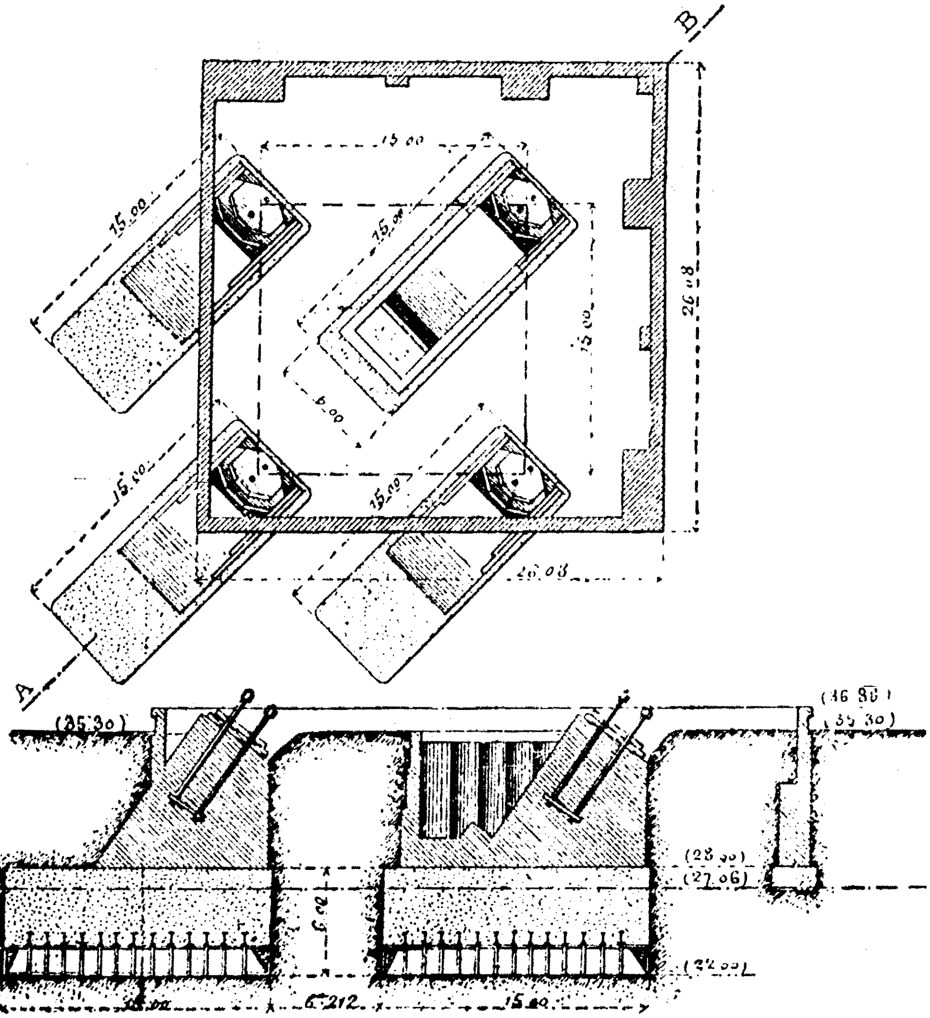


FIG. 232.—Plan, and section along A B, of pier No. 1.

are sunk below the water-bearing stratum and are in direct communication with the ironwork of the tower.

(338) *The hydraulic jack of 800 tons.*—Before describing the erection of the tower it may not be out of place to give an account of the powerful hydraulic jack used to adjust the heavy standards.

To be perfectly sure that the four supports of the tower shall be in exactly the same horizontal plane, a space has been provided under each of the shoes of a standard in which a hydraulic jack of 800 tons power could be placed so as to raise or lower any upright in the

THE EIFFEL TOWER. VIEW OF A PIER WITH ITS INCLOSING WALL.

structure for the insertion of steel strips or wedges between the bed-plate and the shoe. Figure 237 shows the jack in section, and figure 238 taken from La Nature, shows it in operation. The cyl-

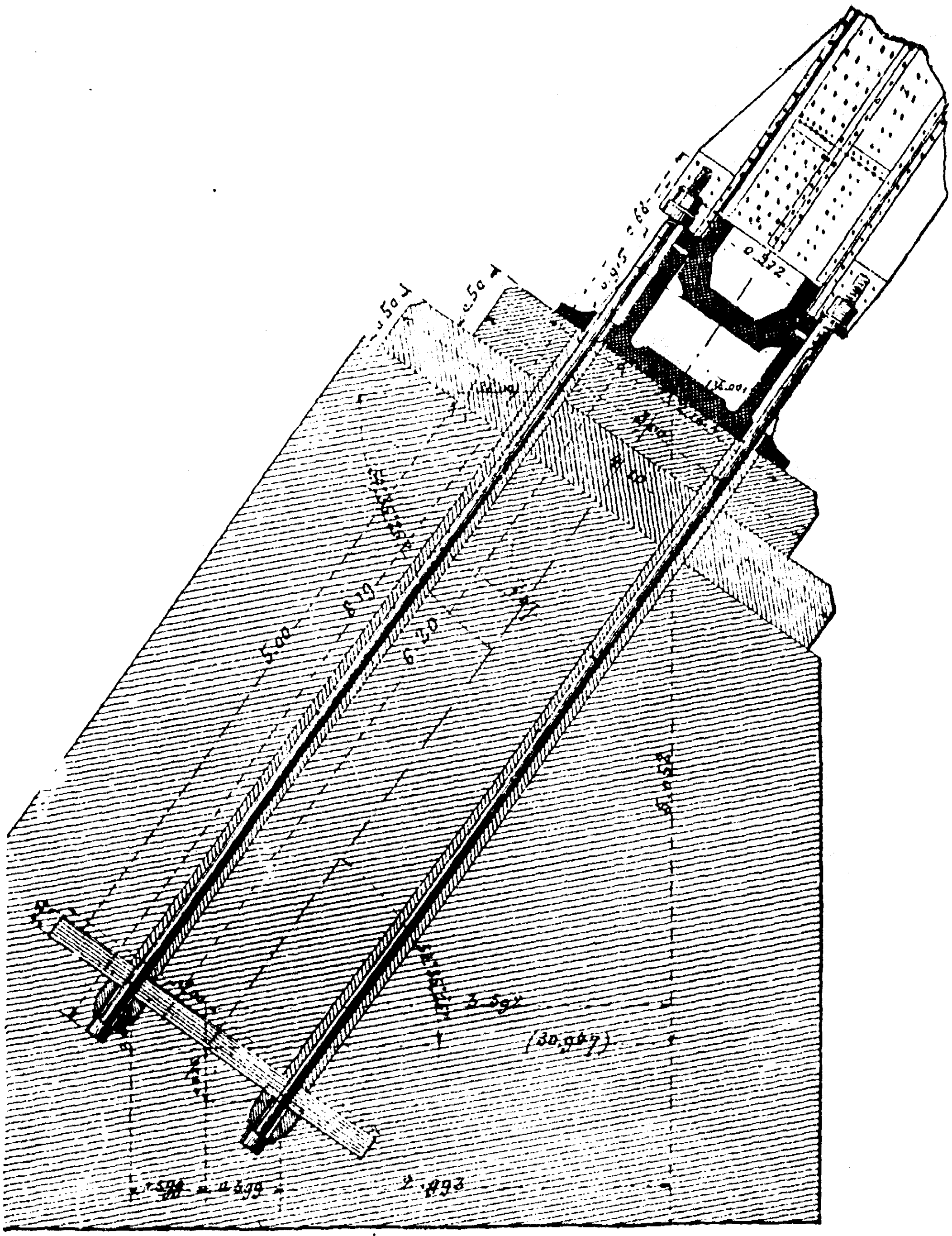


FIG. 233.—Anchorage of the foundations. Details: showing one of the cylindrical base plates 2.16 by .36 meters (weighing 5¼ tons) for supporting the cylindrical flanged shoe, 0.912 meter in diameter bolted to the standard. An 800-ton hydraulic jack is placed in the hollow space below the shoe, for raising and supporting the standard (see p. 821). Steel strips or wedges are inserted between the upper rim of the base plate and the flange of the shoe, to keep the standard at the proper height.

inder is of wrought iron 95 millimeters thick and the piston is 430 millimeters in diameter.

(339) *Erection of the first story.*—By the end of June, 1887, the foundations were completed and the erection of the ironwork began. The lower parts of the columns were erected by braced shears 22 me-

Fig. 234.—Erection of the tower. Appearance in August, 1887.

ters high, in the form of the letter A. They were made of timber and provided with a pulley at the top, over which a chain passed to a winch on the ground (Fig. 234).

The sections of the standards, in the form of caissons 0.80 meter square, weighing from 2,500 to 3,000 kilograms each, were successfully placed on each other and joined, first by pins, then by bolts. After the sections came the latticework and braces uniting the portions of the standards already erected, fixing them in their relative positions and consolidating the whole structure.

Behind the gangs of adjusters came the riveters, who removed the bolts and replaced them by rivets driven hot, forming the permanent junction between the pieces. When the structure had reached the height of 15 meters, the shears were replaced by special cranes. The inclination of the standards naturally tended to overset them, but this tendency would not be effective until a height computed to be 30 meters was reached; so that up to this height the standards could be erected, so far as their stability was concerned, just as if they were vertical. Besides the calculated theoretical security, there was that resulting from the anchorage, which was more than sufficient in this case to prevent any movement.

The erection proceeded steadily until the height of 30 meters was reached. The weight of the pieces already placed in position exceeded 1,450 tons.

(340) *Erecting scaffoldings.*—To continue the erection, wooden scaffoldings 30 meters high were built on piles, and planted so as to sustain at their tops the three interior standards of each pier. At the top of each scaffolding was a strong platform on which were placed sand boxes such as are used on the centering of arched bridges.

Accessory brackets, which were afterwards removed, were attached to the standards, their horizontal faces resting on the sand boxes, thus forming the support of the iron pier on the wooden scaffolding. This support once obtained, the work of erection went on up to the level of the first story of the tower.

The sand boxes afforded a means of rectification in case of any deviation of the structure from its true position. If the column required to be lowered a little, some of the sand could be run out, and the iron work then sank to the desired position. If, on the contrary, the column had to be raised, it was easily done by hydraulic jacks placed on the platform beside the sand boxes, and acting against the temporary bracket. In this way the work was under perfect control.

In the construction of the twelve scaffoldings just described, 600 cubic meters of wood were used, and the erection was continued to a height of 50 meters. At this level the horizontal girders were laid, uniting the four piers and forming the first story.

The special cranes which were used had a range of 12 meters: this was sufficient to be within reach of the four standards. The cranes had a power of 4 tons each, and were worked upon the inclined girders forming the guides for the elevators.

When the piers had attained a height of 55 meters the first great belt of horizontal girders was put in, running from pier to pier. These girders, 7.50 meters high and weighing 70 tons each, were so constructed as to adapt them to the inclined faces of the converging columns. These conditions, in addition to the great height at which they were to be placed, rendered it necessary to erect for this purpose *a new scaffolding* 45 meters high, with a platform 25 meters long. Four such scaffoldings were erected, one for each face of the tower.

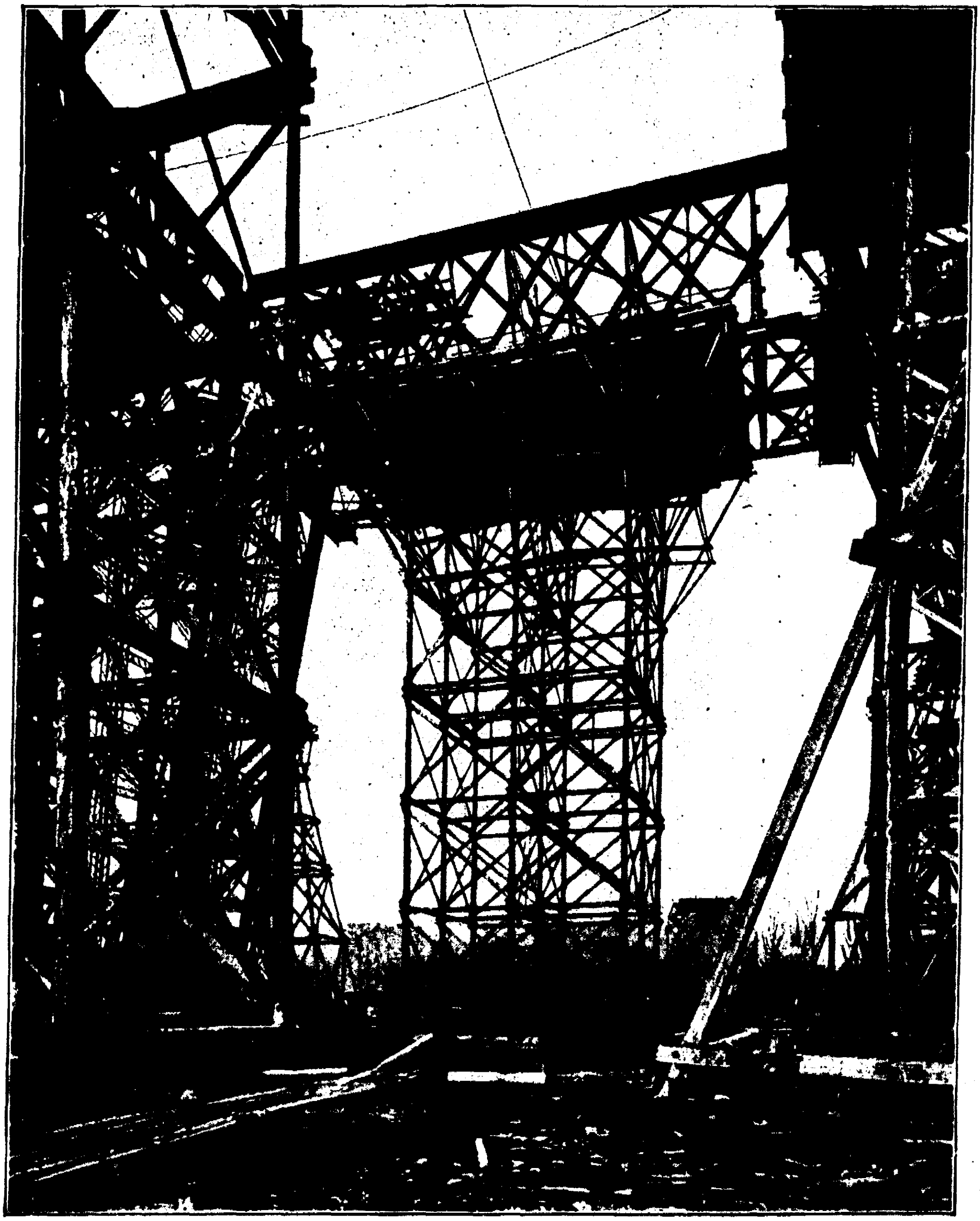
The central parts of each of the horizontal girders were hoisted and riveted on these scaffoldings; the adjacent portions were then added to the right and left so as to unite the four piers, the operation being carried on simultaneously for all four faces.

Plate XIV is a near view of this scaffolding and its superimposed girder. When these girders were joined together they formed a strong horizontal frame which took the thrusts due to the obliquity of the four piers.

(341) *The erecting cranes.*—We shall now describe the construction of the erecting crane above alluded to. Up to a distance of 15 meters the pieces were raised by shears and winches, but when that height had been reached the following special crane was devised by MM. Guyenet and Eiffel, which is thus described by M. Nansouty: It consists (Fig. 235) of a long jib, turning on a pivot mounted on a frame having the form of a triangular pyramid upside down. The pivot is placed in the axis of the pyramid, with the pivot step at the apex. The base of the pyramid is the operating platform, and one of the sides of this base is connected to a frame formed of two longitudinal and two transverse beams. This last frame supports the whole weight, and transmits it to the inclined elevator guides which were erected with the piers. The flanges of these guides are pierced with holes at equal distances. Similar holes are bored in the longitudinal beams of the frame carrying the crane; by means of these holes the two are bolted together.

(342) *Method of raising the crane.*—When all the pieces within the range of the crane had been raised and riveted together, it was necessary to raise the crane in its turn; this was accomplished thus: A strong iron beam, through the center of which passed a large screw, is bolted horizontally upon the guides at about 2.50 meters above the crane frame. The screw passes through the frame, and is secured by a nut. Now if the bolts are withdrawn from the frame and the guides, the crane will hang from the iron beam suspended by the screw. By turning the nut, the frame slowly ascends to its new position, the bolts are replaced, and the work goes on. When the crane is again to be raised (supposing the nut to be near the end of its course) the crossbar is detached, carried up, again bolted to the guides, the screw put in, and the process is repeated.

Two jacks were placed under the frame in case of the rupture of the principal screw.



THE EIFFEL TOWER, NEW SCAFFOLDING, 45 METERS HIGH, USED IN JOINING THE ISOLATED PIERS.

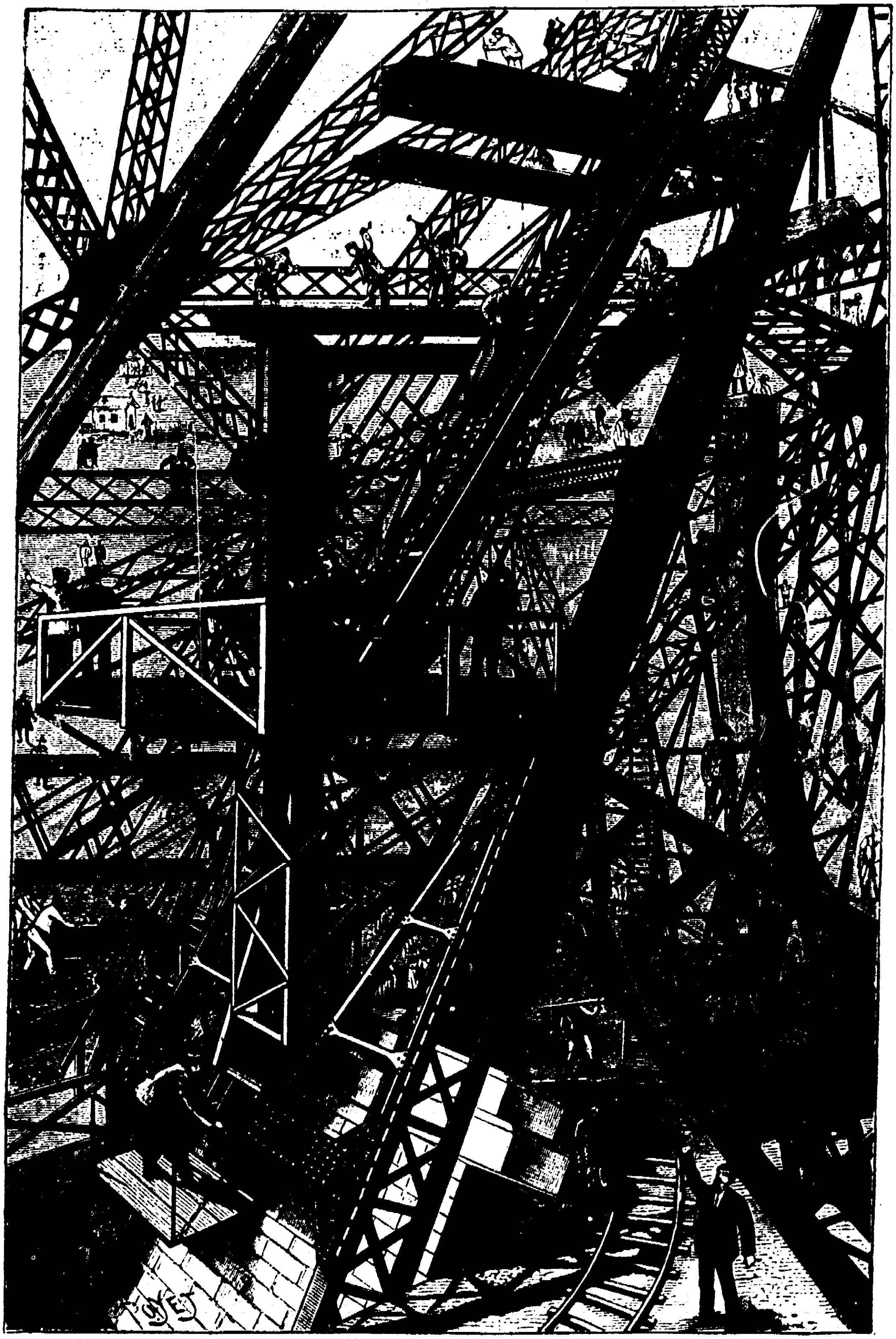


FIG. 235.—The erecting cranes especially devised by MM. Guyenet and Eiffel, used in the erection of the first and second stories.

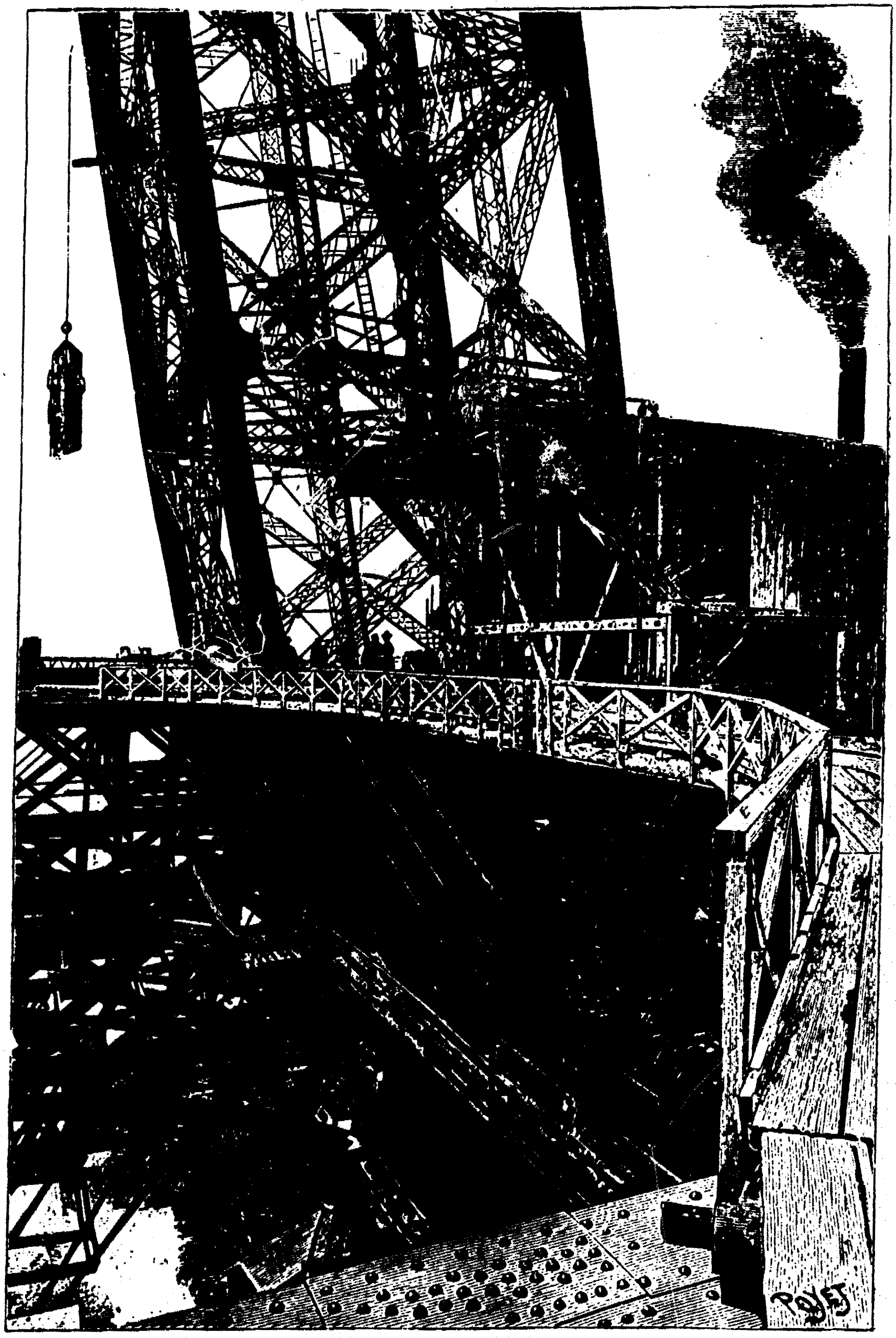
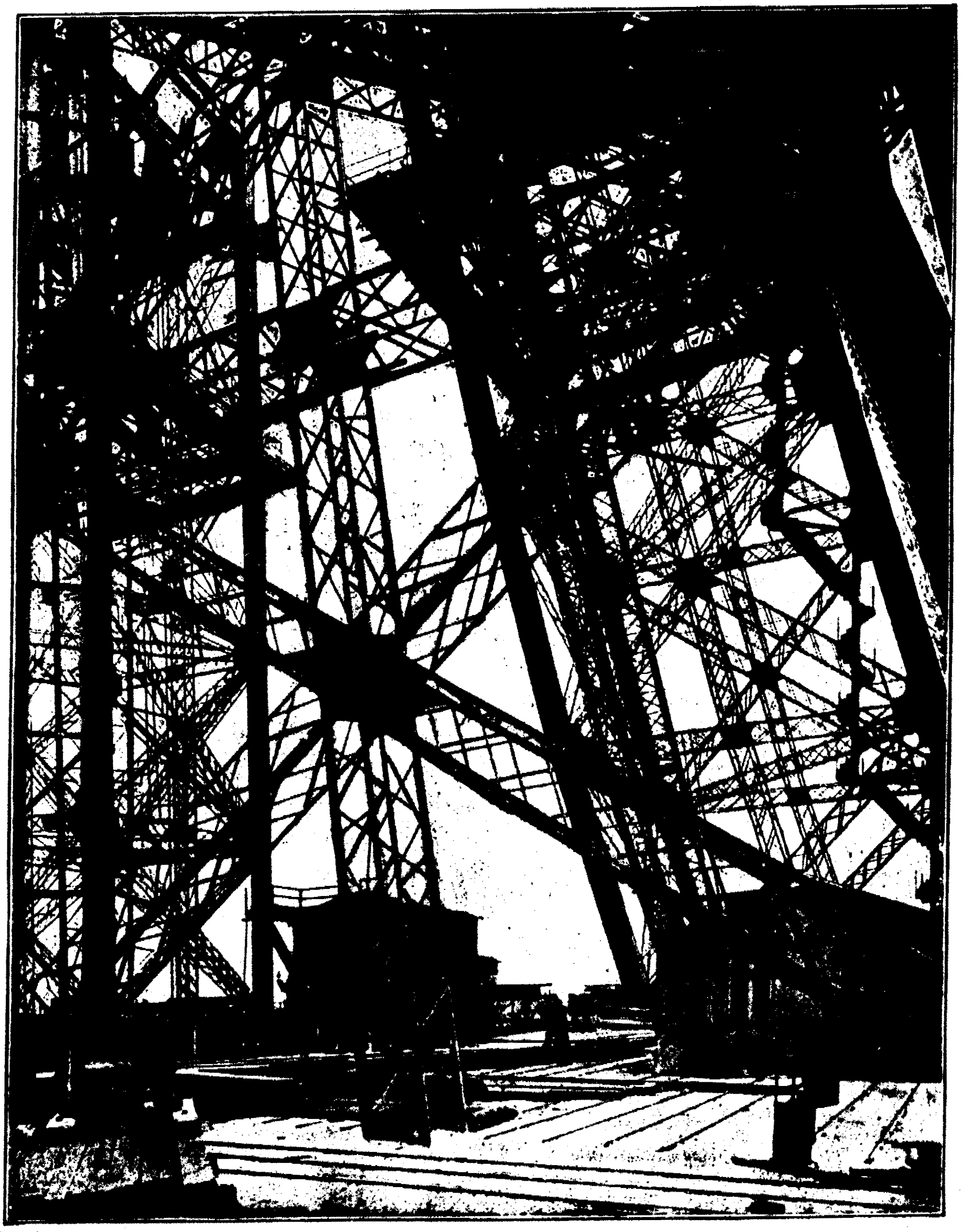


FIG. 236.—View of the first story, showing one of the four piers of the tower and the shelter for the portable hoisting engine, the circular railroad, etc.



THE EIFFEL TOWER. DETAILS OF THE IRONWORK OF THE STRUCTURE.

Another peculiarity of this crane is the mechanism by which the range is changed. This is effected as follows

The ties of the jib are attached to an axle mounted on rollers and moving vertically on the crane post by means of a screw and nut. This simple device allows the range of the loaded jib to vary from 3 to 12 meters.

It is susceptible of yet another movement about a horizontal axis by which its verticality is assured whatever be the inclination of the guides upon which the frame moves. This is accomplished by a screw fixed to the frame, which drives a nut placed in the pivot step. Again, the suspending hook is furnished with a hand screw. The pieces to be riveted may, so to speak, be mathematically adjusted.

Four of these cranes were used upon the four piers up to the height of 150 meters. Each one weighed 12 tons and could lift 4 tons.

(343) *Erection of the first and second stories.*—The piers between the first and second stories were rapidly erected by the same method as that employed below, *i. e.*, by means of four cranes working on

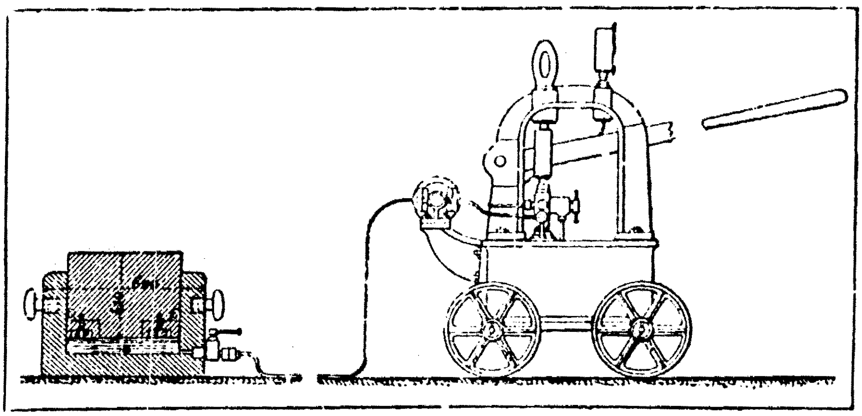


FIG. 237.—One of the 800-ton hydraulic jacks.

the elevator guides. But a new arrangement was made, after the completion first story, for lifting the material, the distance to the ground being too great for one set of cranes to lift it to its position.

On the first story a circular railroad was laid down, and a crane set up driven by a portable engine of 10-horse power, which lifted the materials from the ground and deposited them on cars, by which they were carried to one of the four cranes which raised them to their final position. (Fig. 236 and Pl. XV).

The work advanced with such rapidity that on the 14th of July, 1888, the fireworks, celebrating the national fête, were discharged from the second platform, 115 meters above the ground.

(344) *Use of the 800-ton jack.*—"When preparations were made to join the four pillars, in pairs, by horizontal beams, above the second story, it was found, as had been the case on the first story, that there was a slight difference between the piers. The difference arose from

the fact that the piers 2 and 3 were a little higher than the others, the difference being between 5 and 6 millimeters. As no alteration of the parts could be made on the spot, the discrepancy was corrected

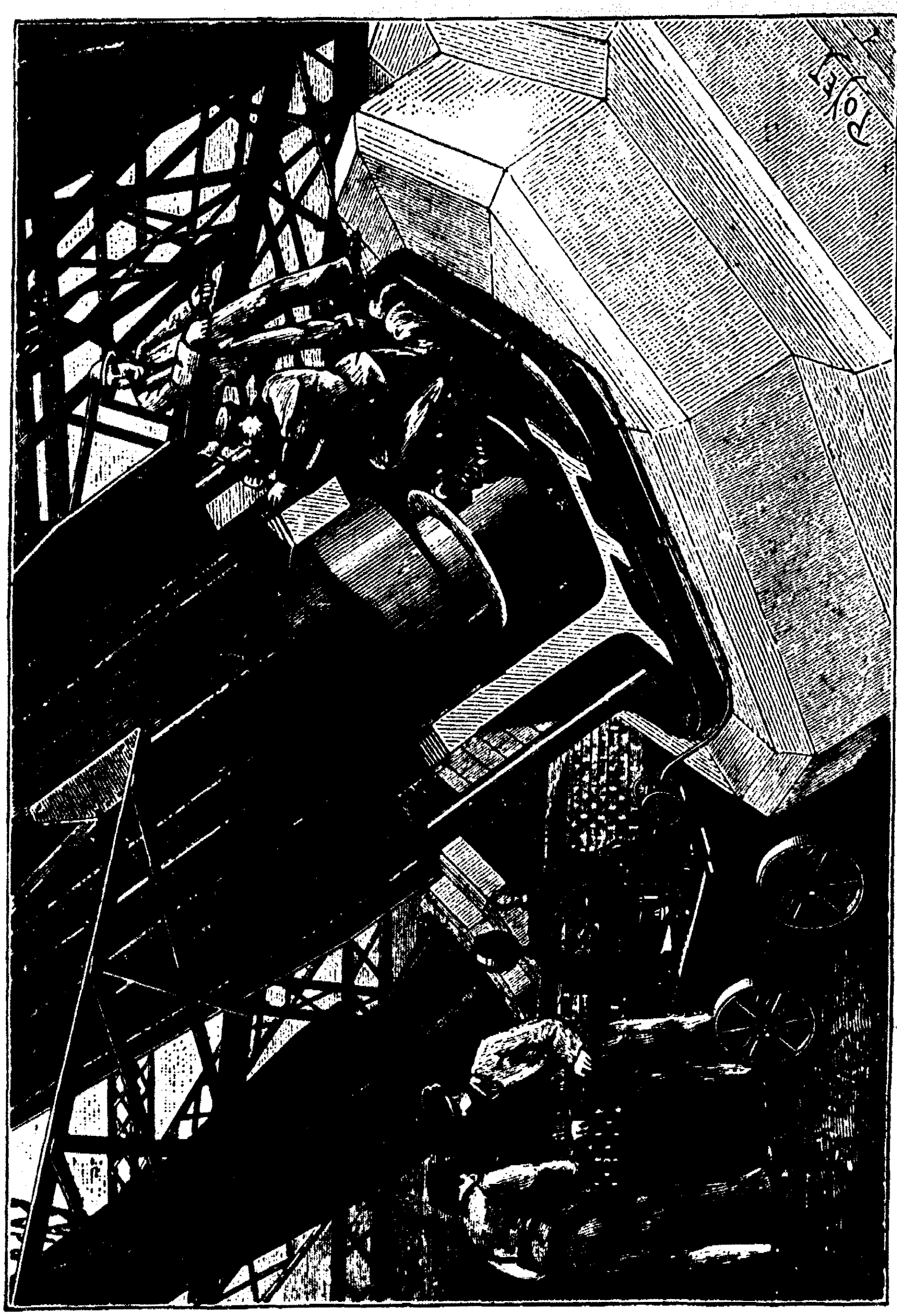


FIG. 238.—Operation of lifting one standard of the tower by an hydraulic jack, for the purpose of driving in the wedges.

by lowering these two piers and slightly widening the distance between them. This operation was affected by means of the hydraulic jacks above described."* (Figs. 237 and 238.)

* Tessandier.

(345) *The erecting cranes above the second story.*—Above the second story, *i. e.*, above 115 meters, considerable modification had to be made in the system of erection. (Fig. 239 and Pl. XVI).

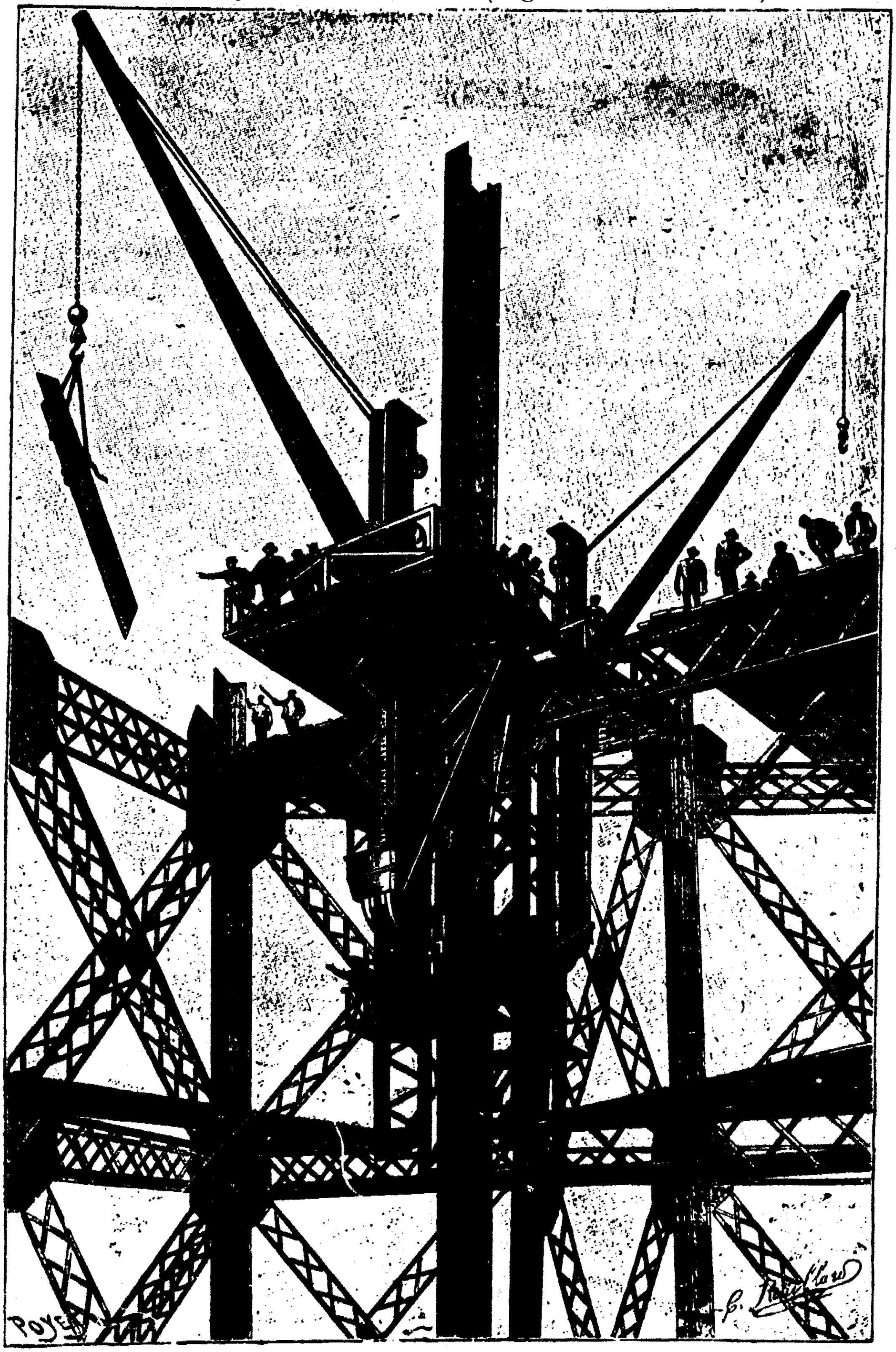


FIG. 239.—Arrangement of the crane for constructing the tower above the second story. Height 215 meters. December, 1888.

The oblique elevator guides no longer exist, but are replaced by vertical ones belonging to another system (Edoux). This system was introduced because the curved form of the tower, by bringing the columns together, had considerably reduced the horizontal section. Instead of four cranes, two were sufficient. To support these two cranes and provide a substitute for the elevator guide ways, M. Eiffel made use of the vertical guide pillars introduced between the second story and the top of the tower. The cranes were like those already used, but so modified as to adapt them to be hoisted against a vertical guide instead of resting on the inclined ones. To balance them they were fixed back to back on the central elevator guide pillar. To increase the surface of support three iron frames were also bolted to the pillar. These frames were 3 meters high, and wide enough to allow the crane frame to be bolted to their vertical sides. Safety appliances were used as before, and, in addition, the cranes and auxiliary frames were firmly united together by a system of temporary beams, so as to form one solid structure.

A whole panel of the tower, 10 meters in height, could be erected without shifting the cranes.

The three squares thus placed one above another formed a vertical road of 9 meters, upon which the cranes could move by the lifting screws.

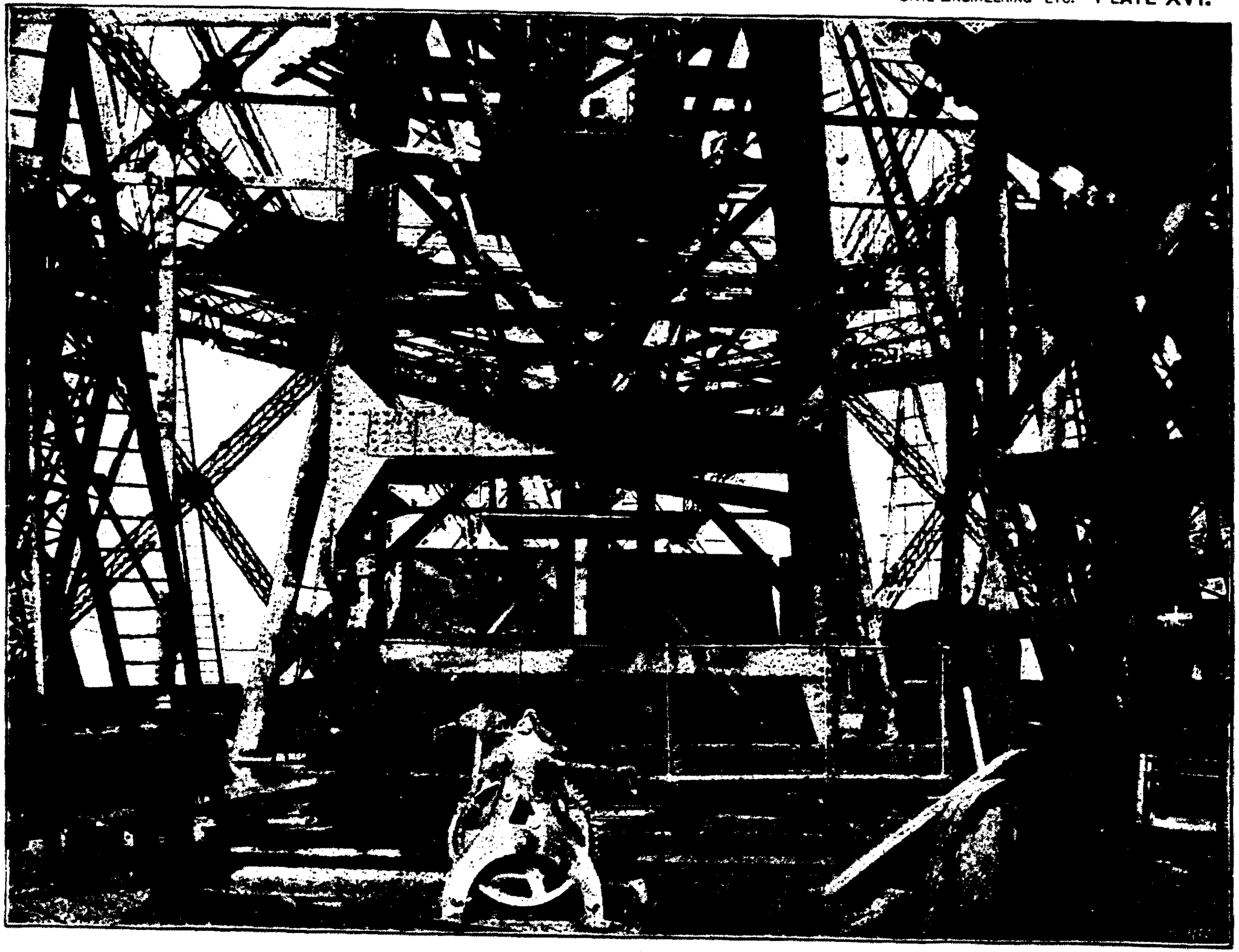
(346) *Method of shifting the cranes.*—When a crane had traveled up the three sets of squares and had to go higher, another set of three squares was placed in position, the crane was then moved up, and the first three squares were free to be used subsequently. Jacks were placed under the squares as well as under the cranes, so that in case of the failure of the bolts the cranes would remain in position (Pl. XVI).

The time required to make the shift from one panel to another was about 48 hours, a short time when it is considered that the total weight to be moved amounted to 45 tons.

The erection above the second story may be thus summed up: A steam winch on the first story raised the material from the ground, a second winch of the same kind on the second story raised it to this level, *i. e.* 115 meters. A third steam winch, set up on an intermediate flooring of the Edoux elevator, 197 meters high, brought the pieces to the cranes, which put them in position.

(347) *Protection of the workmen.*—The workmen were provided with movable platforms furnished with a hand rail and screen. These were first placed in position by carpenters, and occupied successively by the adjusters and riveters. Only one accident happened by falling and that was at the beginning of the work.

(348) *Top of the tower.*—The upper portion of the tower terminates in a cornice, supporting the campanile and the light-house. The lower part of the campanile consists of a covered gallery, 16 me-



THE EIFFEL TOWER. THE ERECTING CRANE USED ABOVE THE SECOND STORY.

ters on each side, and will accommodate 800 persons. It is fitted all around with glazed sashes, which can be opened or closed at will, the closing of the windows being necessary in strong winds. (Fig. 240).

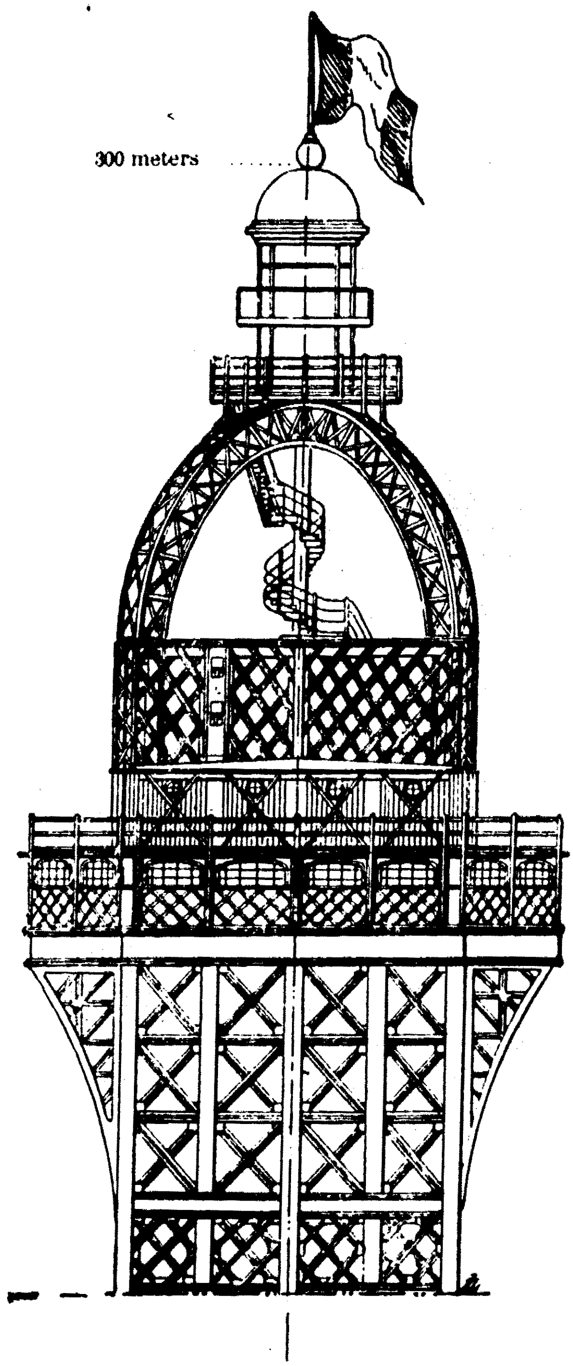


FIG. 240.—Campanile of the tower.

The summit of the tower, formed of four lattice arches placed diagonally to the square section, supports the light-house.

Above the cupola is a small terrace 1.40 meters in diameter, to which access is obtained by a ladder in the lantern. This terrace, which is 300 meters above the ground, is specially designed for the anemometers and other meteorological instruments.

(349) *Staircases.*—In the east and west piers there are straight staircases 1 meter wide, with numerous landings, giving easy access to the first floor and consisting of three hundred and eighteen solid oak steps. The former is used for descending and the latter for ascending, and it is estimated that a file of 2,000 persons per hour could be accommodated by them.

From the first to the second story a spiral staircase, 0.60 meter wide, is arranged in each of the piers; two of these staircases are for the ascending and two for the descending visitors. They also will accommodate 2,000 persons per hour.

From the second story to the top there is a spiral staircase 160 meters high, which is simply a service staircase and not open to the public.

(350) *Arrangement of the first story.*—Upon the first story, which covers an area of 4,200 meters, an arcaded open gallery is arranged for visitors who wish to enjoy the view of Paris, its environs, and the exhibition. This promenade is 283 meters long and 2.60 meters wide. There are also four large restaurants, capablé of containing from 500 to 600 persons each. They are built in different styles of architecture and are called the Russian, the Anglo-American, the Alsace-Lorraine, and the French restaurants.

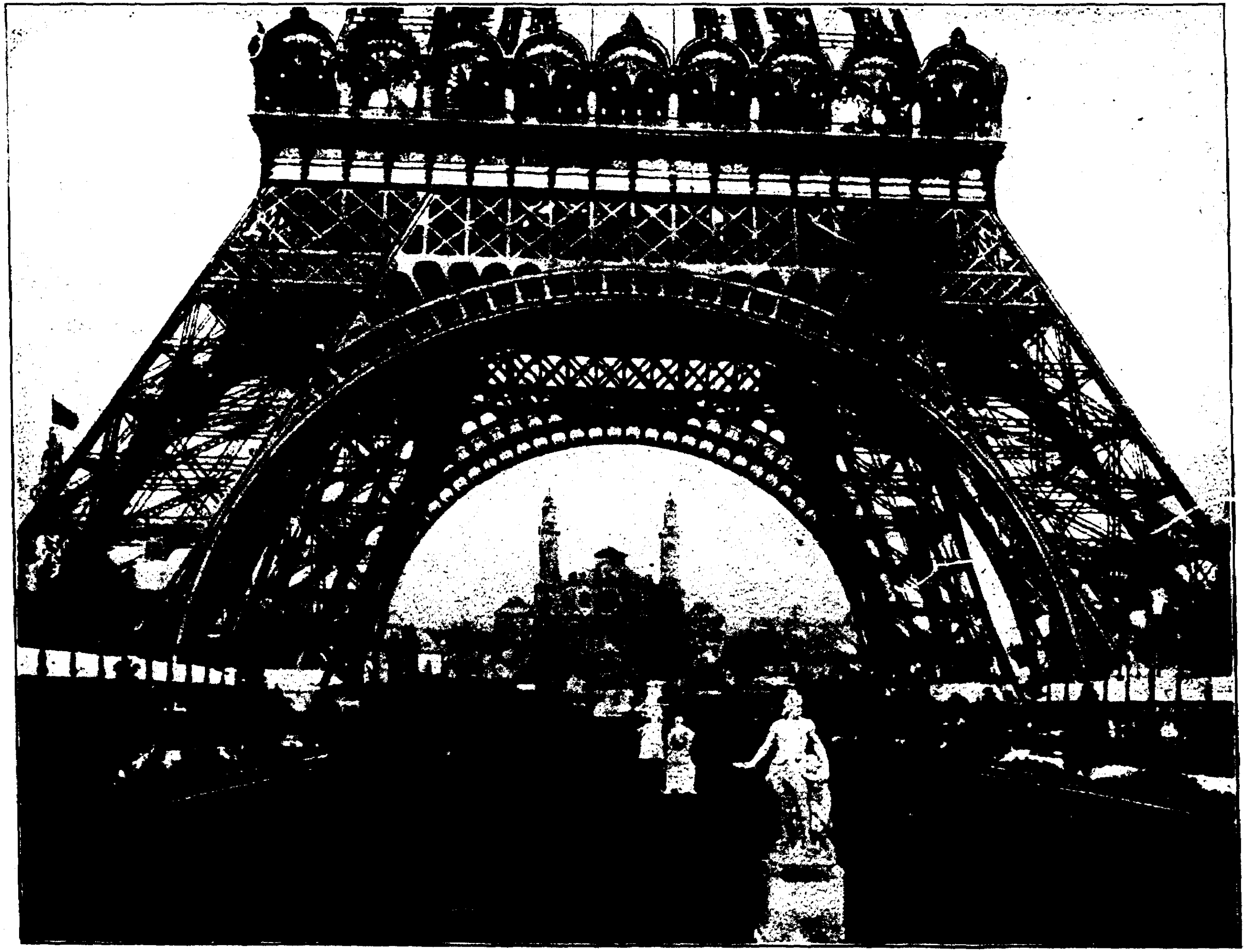
A general view of the lower part of the tower and the first story is given Plate XVII.

(351) *The second story* has a surface of 1,400 square meters. It has a covered gallery forming a second promenade 150 meters long and 2.60 meters wide. The central part contains the stations for the elevator, and at one end is the office of the newspaper printed, stereotyped, and published here, called the "Figaro de la Tour Eiffel," the rotary printing press being worked by a gas motor.

(352) *The third story* is octagonal in shape, consisting of four sides 12 meters in length and four small ones of 2 meters.

An iron staircase of ten steps leads up to the private rooms of M. Eiffel, and to those devoted to scientific observations. From these a straight staircase of thirty steps leads up to the springing lines of the iron lattice arches supporting the campanile; thence a spiral staircase leads, at the top of these arches, to an iron cylinder containing a ladder of twenty steps leading to an octagonal lodge with a balcony. Through an iron trapdoor at the top of ten steps more we come into the lantern itself. Passing through this, up one more ladder, we come out upon a small balcony containing the flagstaff, and at a height of 300 meters above the ground.

(353) *The elevators.*—Independently of the staircases, the ascent is facilitated by a certain number of elevators of different systems, viz: (1) The Roux-Combaluzier and Lepape system; (2) the Otis; (3) the Edoux.



THE EIFFEL TOWER. THE FIRST STORY.

From the ground to the first story there are four elevators, two on Roux-Combaluzier and Lepape system, and two on the Otis system. From the first to the second stories the ascent is effected by the two Otis elevators, which run continuously from the ground to the second story.

Finally, from the second story to the third, the Edoux system is used. Its starting point is from a platform erected halfway between the second and third stories. It is worked by water power with a vertical piston having a cage on the top. This cage affords the means of transit to the third story, a distance of 80 meters above the intermediate platform. It is attached by chains to a second cage forming a counterpoise. This cage brings the passengers from the second story, 80 meters below, up to the intermediate platform. In this way the passengers, by changing from one cage to the other at the intermediate platform, make the ascent of 160 meters from the second to the third story.

(354) *Time of ascent.*—The Roux-Combaluzier and Lepape system takes 100 passengers, who are landed at the first story within the minute, at a speed of 1 meter per second.

The Otis elevator cage holds 50 passengers, but has an ascensional velocity of 2 meters per second.

The Edoux elevator cage accommodates 63 persons, the ascensional velocity is 0.90 meter per second, and the time is 1½ minutes for each course and 1 minute for changing cages, *i. e.*, 4 minutes for the ascent from the second to the third platform.

All the elevators are furnished with safety apparatus. They are operated by hydraulic power, the water furnishing this power being raised by steam pumps of 300 horse power.

The elevators can take up to the first and second stories 2,350 persons per hour, and 750 persons up to the third, the complete ascent occupying 7 minutes. By means of the staircases and elevators combined the tower can be visited by 5,000 persons per hour.

The mechanical features of these elevators are described in the report on class 52.

(355) *Verification of the verticality of the tower.*—This was accomplished when the tower had attained a height of 220 meters by MM. Thuasne and Seilhac. This verification consisted in observing whether the median lines on each face of the tower were situated in the principal planes of the tower. By a median line of a surface is meant a line situated in a vertical plane and passing through the center of gravity of that surface. A principal plane is a vertical plane passing through the lines A A (Figs. 241, 242). For this purpose points *a*, *b*, *c*, *d*, *e*, *f*, and the intersection of the diagonals of the lattice situated upon the median lines of the four faces were selected.

The median lines being thus traced on the tower, the operation consisted in observing, with a theodolite placed in the plane A A and properly adjusted, whether the points a, b, c, d, e, f coincided with the vertical wire of the telescope when rotated in a vertical plane.

VERIFICATION OF THE VERTICALITY OF THE TOWER.

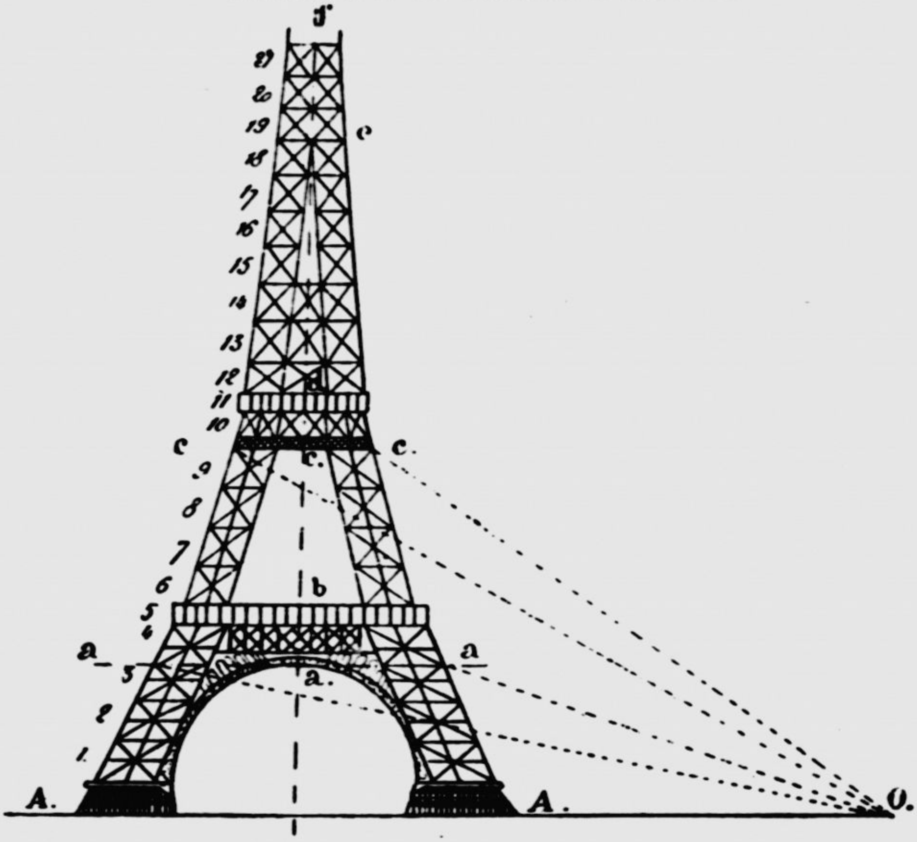


FIG. 241.—Elevation.

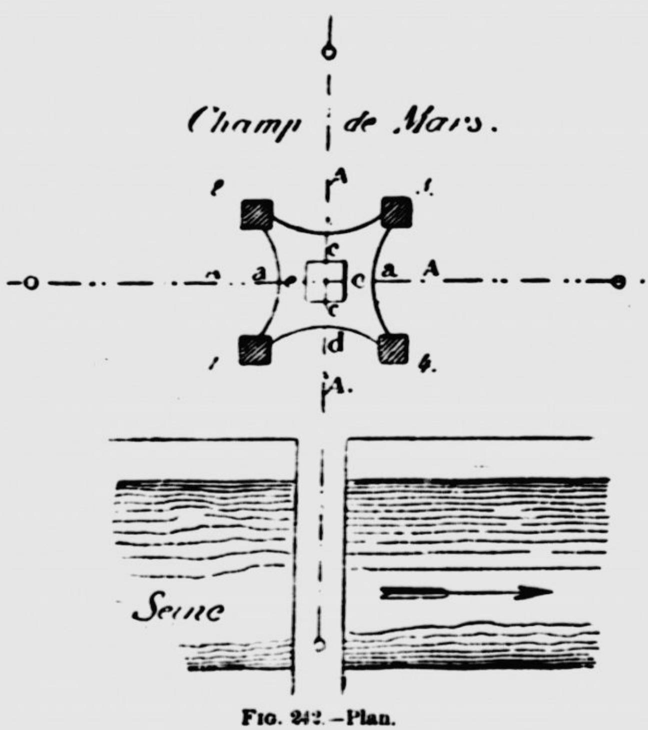


FIG. 242.—Plan.

These observations were made upon each of the four planes (4–1), (1–2), (2–3), (3–4) at points situated upon the lines A A, A A at distances from the axis of the tower varying from 160 to 300 meters.

One of these stations of observation was upon the Jena bridge about 250 meters from the axis of the tower.

The vertical wire of the telescope was found to coincide absolutely with all the points *a*, *b*, *c*, *d*, *e*, and the crossings of the diagonals; hence all these points were in the principal plane. Similar observations made at three other stations showed the tower to be absolutely vertical.

(356) *Uses of the tower.*—M. Eiffel thus described the uses of the tower in an address to the members of the "Société centrale du Travail Professionnel:"

The construction of the tower will enable us to observe, with new effects of light a prospect of incomparable beauty, before which no one can fail to be deeply impressed with the grandeur of nature, and the power of man. But besides its soul inspiring prospects, the tower will have varied applications for our national defense as well as in the domain of science.

(357) *Strategical operations.*—"In case of war or siege it would be possible to watch the movements of an enemy within a radius of 70 kilometers, and to look far beyond the heights on which our new fortifications are built. If we had possessed the tower during the siege of Paris, in 1870, with its brilliant electric lights, who knows whether the issues of that contest would not have been entirely changed? The tower would have provided the means of easy and constant communication between Paris and the provinces with the aid of optical telegraphy, the processes of which have attained such remarkable perfection". (Nansouty.)

It is situated at such a distance from the defensive forts as to be out of the reach of the batteries of the enemy.

(358) *Meteorological observations.*—It will be, moreover, a wonderful meteorological observatory in which may be studied the direction and force of the atmospheric currents, the electrical state and chemical composition of the atmosphere, its hygrometry, etc.

(359) *Astronomical observations.*—As regards astronomical observations, the purity of the air at such a height, the absence of the mists which often cover the lower horizons in Paris, will allow many physical and astronomical observations to be made which would be often impossible in our region.

(360) Scientific experiments may be made, including the study of the fall of bodies in the air, the resistance of the air according to speed, certain laws of elasticity, the study of the compression of gas and vapors by an immense mercurial manometer having a pressure of 400 atmospheres; a new realization on a large scale of Foucauld pendulum, showing the rotation of the earth, the deviation toward the east of falling bodies, etc.

It will be an observatory and a laboratory such as has never before been placed at the disposal of savants, who from the beginning have encouraged the undertaking with their warmest sympathies.

My wish has been to erect a triumphal arch for the glory of science and the honor of French industry, as striking as those reared to military conquerors by former generations; and to express in a most emphatic manner that the monument I raise is placed under the invocation of science, I have inscribed in golden letters under the great frieze of the first story and in the place of honor the names of the great savants who have honored France for the last century.

Between the brackets is a frieze on which are inscribed in golden letters, perfectly legible from below, the names of the men who have honored French science.

On the Paris side: Petiet, Daguerre, Wurtz, Perdonnet, Delambre, Malers, Breguet, Polonceau, Dumas, Clapeyron, Borda, Fourrier, Bichat, Sauvage, Pelouse, Carnot, and Lamé.

Trocadero side: Séguin, Lalande, Tresca, Poncelet, Bresse, Lagrange, Belanger, Cuvier, Laplace, Dulong, Chasles, Lavoisier, Ampère, Chevreuil, Flachat, Navier, Legendre, Chaptal.

Grenelle side: Jamin, Gay-Lussac, Fizeau, Schneider, Le Chatelier, Berthier, Barruel, de Dion, Gouin, Jousselin, Broca, Becquerel, Coriolis, Cail, Triger, Giffard, Perrier, and Sturm.

Towards the Ecole Militaire: Cauchy, Legrand, Regnault, Fresnel, Prony, Vicat, Ebelmen, Coulomb, Poinsot, Foucault, Delaunay, Morin, Hauy, Combes, Thenard, Arago, Poisson and Monge.

Plate XVIII gives a general view of the complete structure.

(361) *Statistics.*—The weight of the iron contained in the tower is about 7,300 tons. The weight of the rivets is 450 tons and their total number 2,500,000. Of this quantity 800,000 were hand driven on the tower for uniting the parts already prepared. The number of metallic pieces is 12,000, which, on account of their varying form and position in space, required special drawings.

Forty draftsmen and computers worked steadily for two years to complete the plans, specifications and computations.

It took ten draftsmen from 8 o'clock in the morning to 10 o'clock at night for one month to prepare the drawings for one panel, *i. e.* 10 meters of the tower. The drawings were made with great precision up to the ten-thousandth of a meter.

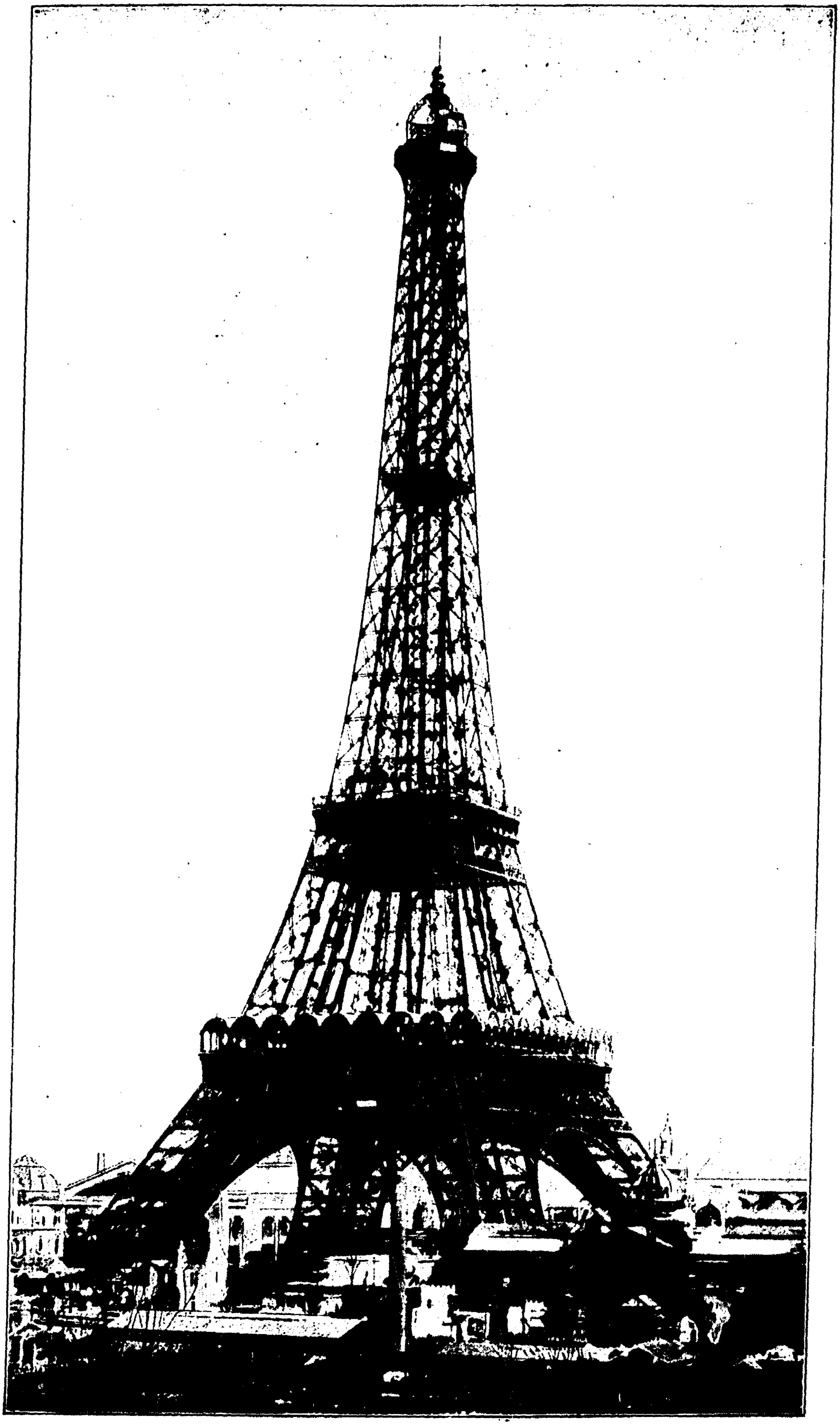
The plans of the tower comprised 500 drawings and 2,500 working drawings for the whole 27 panels. Each piece of which the tower was built was designed, shaped, and bored at the works at Levallois-Perret and was found to fit exactly into its place when it reached the Champ de Mars.

From 150 to 200 men were employed, at the rate of 0.80 to 1 franc per hour.

(362) *Color.*—The tower is painted a chocolate color, which is described as a reddish bronze, from the foot to the first story; from the first to the second story the same tint, but lighter; from the second story to the top it becomes lighter and lighter until the cupula is almost yellow.

(363) *Cost.*—

	Francs.
Foundations, masonry, pedestal	900,000
Erection, metal, city duties on the iron	3,800,000
Painting, four coats	200,000
Elevators and machines	1,200,000
Restaurants, decorations, different buildings	400,000
Total	6,500,000



COMPLETE VIEW OF THE EIFFEL TOWER.

(364) *The Montyon prize in mechanics.*—The French Academy of Sciences has just awarded the Montyon prize of mechanics to M. G. Eiffel as a mark of their appreciation of his skill in the erection of iron structures.

(365) *Acknowledgment.*—I wish here to express my obligations to MM. Eiffel, Salles, and Nouguier for numerous courtesies received, as well as for information, printed descriptions, and heliographs, of which liberal use has been made in this report.

Figures 231, 235 to 239, inclusive, are from copies of La Nature, and Figs. 233, 234, 240 to 242, inclusive, are from Nansouty's book on the Eiffel tower.

Supplementary note.—In order to show some of the opposition to M. Eiffel's scheme for a tower 300 meters high the following extract from Engineering is appended:

On the 5th of November, 1886, the finance committee of the Paris Exhibition voted a credit of 1,500,000 francs as a subsidy for the unique and monumental work M. Gustave Eiffel had undertaken to construct, and which was to be one of the great original features of the exhibition. The idea of erecting a tower 1,000 feet in height was received with a very general feeling of distrust and even of dismay; not that anyone doubted the capability of the bold and successful engineer to complete the work to which he had pledged himself, but the misgivings were very general as to the effect that such a novel construction would have upon the architectural features of the Exhibition, and a widespread cry of influential voices went up from Paris as a protest against the engineering outrage that was to be inflicted upon the French metropolis. It is rather curious, now that the tower is completed and the great consensus of public opinion is loud in its approval, to recall the remonstrances addressed to M. Alphand, the Director-General of Works, against the proposed column. "We wish—authors, painters, sculptors, architects, enthusiastic lovers of beauty—which has hitherto been respected in Paris—to protest with all our energy, and with all the indignation of which we are capable, in the name of art and of French history now menaced, against the erection in the heart of our capital of the useless and monstrous Eiffel tower, which public satire, often full of good sense and a spirit of justice, has already christened the Tower of Babel. Without falling into extravagance we claim the right to assert that Paris stands without a rival in the world. Above its streets and boulevards, along its quays, amidst its magnificent promenades, abound the most noble monuments which human genius has ever put into execution. The soul of France, creator of chefs-d'œuvre, shines forth from this wealth of stone. Italy, Germany, Flanders, so justly proud of their artistic heritage, possess nothing comparable, and from all corners of the universe Paris commands admiration. Are we, then, going to allow this to be profaned? Is the city of Paris to permit itself to be deformed by monstrosities, by the mercantile dreams of a maker of machinery; to be disfigured for ever and to be dishonored? For the Eiffel tower, which even the United States would not countenance, is surely going to dishonor Paris. Everyone feels it, everyone says so, everyone is plunged into the deepest grief about it, and our voice is only a feeble echo of universal opinion properly alarmed.

"When foreigners will come to visit our exhibition they will cry in astonishment: 'Is this horror that Frenchmen have invented' intended to give us an idea of the taste of which they are so proud? And they will be right to mock us, because the Paris of the sublime architects, the Paris of Jean Goujon, of Germain Pilon, of Puget, of Rude, of Barye, will have become the Paris of M. Eiffel. Nothing further is wanting to prove the justice of what we say than to realize for an instant this tower dominating Paris, like a gigantic and black factory chimney, crushing, with its barbarous mass, Notre Dame, the Sainte Chapelle, the Tour St. Jacques, the Louvre, the dome of the Invalides, the Arc de Triomphe; all our monuments humiliated, all our architecure shrunken, and disappearing affrighted in this bewildering dream. And during twenty years we shall see, stretching over the entire city, still thrilling with the genius of so many centuries, we shall see stretching out like a black blot the odious shadow of the odious column built up of riveted iron plates." And so forth, and so forth. To this vehement protest were attached the names of many of the best-known men of France—Meissonier, Gounod, Garnier, Sardou, Gerome, Bonnat, Bouguereau, Dumas, Coppée, etc. But these well-meant ill-judged remonstrances were not heard, and to-day the Eiffel tower stands completed, the marvel of the exhibition and the glory of the constructor. The noble monuments of Paris apparently thrill as much as they did before with the genius of the centuries, and the grand proportions of the Arc de l'Etoile do not seem to have suffered because a great French engineer has achieved a triumph of construction. If foreign criticism was not set forth in such brave words as those we have quoted above, it was none the less hostile; but foreign criticism is generally more or less colored by jealousy, and is therefore not of much account.

CHAPTER XLVI.—THE MACHINERY HALL.

(366) The enormous machinery hall is justly considered the boldest work of the exhibition; it illustrates the extraordinary progress of engineering, and its new lessons in the art of construction are already beginning to be applied.

(367) *The Osiris prize.*—A committee of French journalists to whom was assigned the task of awarding the Osiris prize of 100,000 francs to the most important work of the exhibition, after having paid a just tribute to the palaces of the fine and of the liberal arts, constructed by M. Formigé, and to the central dome by M. Bouvard, decided to give it to the constructors of the machinery hall. M. Dutert, the architect who conceived the idea, prepared the plans, and superintended the erection, received 20,000 francs; M. Contamin, who prescribed the dimensions and calculated the strength of all the ironwork, 15,000 francs; to the five assistant architects and engineers, 3,000 francs each; the other 50,000 francs were distributed among the workmen.

(368) *History.*—In 1878 M. de Dion made a bold beginning by constructing the gallery of machines with a single iron arch without a tie-rod, the trusses forming one solid piece with the piers, and built into the masonry; but these trusses were of only 30 meters span, and the height did not exceed 25 meters.

In the railroad station at St. Pancreas, in London, the trusses have in appearance no intermediate point of support; in reality the ends are united by tie-rods concealed beneath the flooring; the span is only 73 meters.

In 1889 the system adopted had already been employed by Oudry in the construction of the swinging bridge at Brest, for a few iron viaducts, and in some railroad stations in Germany, but it had never before been applied on so gigantic a scale.

Before entering upon a detailed description of the construction and erection of this remarkable building it may not be out of place to show by the following extract from one of the Paris journals,* what impression the sight of this vast edifice produced upon the enlightened public.

If the Eiffel tower was an unexpected surprise, a triumph of originality and of daring skill, the machinery hall was found to be only one degree less marvelous; and this because the progress of modern architecture and of the science of engineering had, from one decade to another, led us up to this superb realization of the unexplored possibilities of both. Never before, in the opinion of engineers of all countries who have visited it, has a building, proportionately to its vast dimensions, been constructed with such a wondrous combination of solidity, lightness, and grace, the general effect being enhanced by the flood of light freely admitted to all parts of the palace. The Government is therefore to be most heartily congratulated, on national and artistic grounds alike, upon the initiative which it has taken to permanently preserve this magnificent building, together with those set apart to the fine and liberal arts, in addition to the grand central dome.

The machinery hall is, indeed, the most prodigious outgrowth of the joint ingenuity and skill of architect and engineer. To bring under one roof all the machinery that was to be exhibited was a problem which almost defied solution. The task, however, was happily surmounted by the coöperation of M. Dutert, the eminent architect, and MM. Contamin, Charton, and Pierron, engineers. M. Dutert, who conceived the entire plan of the work, tracing it out even to its minutest features, superintended the decorative details. Taking up this vast conception of an artist, M. Contamin stamped upon it the hall-mark of science by calculating the efforts of the materials, estimating their resistance, and insuring the due solidity and equilibrium of the whole structure. He it was who superintended the operation of fitting together the ribs and girders and general framework resting upon the solid squares of masonry constituting the foundations. The palace is 420 meters in length, and 115 in width, covering a superficial area of 48,335 square meters, or about 11½ English acres.† It is estimated, indeed, that should the building be ultimately converted into a military riding school, it will afford ample space for exercising 1,200 horses at a time. Some further idea of its commanding proportions may be conveyed by the statement that the Vendôme column, with its well-known statue of Napoleon I, might easily be erected within the four walls, as it would leave 7 meters to spare between the head of the figure and the apex of the arched roof; that the span of the girders supporting this roof, which is 48 meters in height, would shelter the Arc de Triomphe; and that the nave of the Palais de l'Industrie is only half the length and half the width of that of the Palais des Machines. There is sufficient "free play" at the top of the arching girders to allow of the slight displacement that takes place under the action of heat and cold. The only points of support are, in fact, at the base of the girders and where these latter meet each other in the center of the roof; but these chief ribs, be it noted, are connected by longitudinal girders, the whole framework being otherwise strengthened, on each side of the building, on the most approved principles. The method which was followed enabled the constructors to carry out their plans with the minimum of materials commensurate with necessary strength and artistic effect; and the entire cost of the palace (7,514,095 francs, of which 5,398,307 francs was for ironwork alone)

* Galignani's Messenger, July, 1889.

† The nave alone, not including the lateral galleries.

was correspondingly lessened. Over the summit of the roof is a narrow gallery for workmen.

Each of the arched girders running up the sides of the building consists of two ribs, an inner and outer one, solidly bound together, above and below, crosswise, one regular square alternating with an elongated one, the only real point of support being, as we have said, in the masonry at the base, inasmuch as the girders meet each other lightly, with a sort of elastic touch at the apex above. The total weight of material over the grand nave is only 7,400 tons, a little more than the mass of iron used in the construction of the Eiffel tower. On either side of the machinery hall is a gallery 15 meters in width, to which access is obtained by broad staircases, as also by lifts. One point deserving special mention is that the contract for the building was divided between two firms. One-half of the palace, that on the Avenue de Labourdonnais side, was constructed by the Compagnie Fives-Lille, and the other half, stretching to the Avenue de Suffren, by the Société Cail. The former company put its girders into position in heavy sections, some of these weighing 48 tons apiece, whilst those of the other contractors were set up in fragments of 3 tons. Had steel been used, the framework would have been much lighter than it is, but the idea of resorting to it was abandoned on the two-fold ground of expense and the necessity of hastening the execution of the work. Those who believed that iron was ill adapted to the requirements of art as applied to industry have been agreeably surprised by the happy results achieved by M. Dutert and the engineers who so ably coöperated with him in this veritable palace of wonders.

The internal decorations, under the glass roof arching downwards toward the sides, are most effective, the chief tone being of a rosy yellow giving rise to some curious effects of the sun's rays. Thus, toward evening, all the panes over the right side of the nave assume a rosy tint, whilst those opposite are of a light-green hue, the contrast suggesting that between rubies and emeralds. Ten large panels and one hundred and twenty-four smaller ones have been painted by MM. Alfred Rubé, Philippe Chaperon, and Marcel Jambon; the former representing the arms and commercial or other attributes of the leading capitals of the world (Berlin, of course, excepted), and the latter the escutcheons, etc., of the minor cities and towns, including all the *chefs-lieux* of French departments. Over the chief entrance in the Avenue de La Bourdonnais, is a large rose window in different colors. The ornamentations on the outside are exceedingly striking. The vast arch over the porch is decorated with a foliated design showing between the leaves various implements of labor. On the lintel is the inscription "Palais des Machines," in decorative faïence, the groundwork being an olive branch. This is supported by two groups 10 meters in height.* The first, by M. Barrias, represents electricity, and is composed of two female figures. One of these, by a finger touch, sends an electric flash through the globe, whilst the other, resting in a recumbent position on a cloud, stretches forth her hand to her companion; they symbolize the two opposite currents. The second group, by M. Chapu, shows a female figure personifying steam, and a workman clasping her in his arms. A colored window above sets forth the arms of the various powers taking part in the exhibition. In the center of the gable at the opposite end are some colored panes depicting the battle of Bouvines,† and facing the Ecole Militaire is a window dedicated to the "Chariot of the Sun."

Those who enter the machinery hall from the general industries gallery pass through a central vestibule which from its rich decoration, may be regarded as a sort of *salon d'honneur*. Here is a handsome cupola covered with colored panes and mosaics, the former showing the leading agricultural products of the country, such as flax, hemp, wheat, and maize. The painted pendentives represent the arts,

* See Plates XXI and XXII. † Plate XX.

sciences, letters, and commerce. The numerous other allegorical subjects ornamenting the vestibule have been greatly admired. At the foot of the handsome staircase leading to the gallery are two splendid bronze figures, each bearing a cluster of twenty incandescent lamps.

Such, in brief, is the general outline of the building itself. It may be urged that the Palais des Machines affords evidence that a fresh era in architecture has been inaugurated, that *ceci tuera cela*, and that the age of stone is to be succeeded by the age of iron. We do not think so. It is true that the engineers are just now triumphant in many directions. The chief of the state is an engineer; an engineer, M. de Freycinet, is minister of war; M. Alphand, another engineer, was one of the organizing directors of the Universal Exhibition; and the name of the engineer, Eiffel, has become something more than a household word. With respect to the architectural question, however, it is evident that engineers can dictate to architects only in the case of immense buildings whose distinctive characters is, after all, that of use rather than ornament. Those, however, who look at the interior of this machinery hall for the first time can not form an estimate of its imposing dimensions; its architectural lines do not draw the attention upwards, and so its roof appears lower than that of the smallest Gothic cathedral. Nobody, at a glance, would imagine that he stood in the highest covered building in the world.

The motive power is distributed by means of four shafts extending from one end of the building to the other, the total force actually at work being equal to 2,600 horse power, although 5,640 horse power may be developed if necessary. This is more than double the power placed at the disposal of exhibitors in 1878. In 1855 the figure stood at 350 and in 1867 at 638. There has, therefore, been a remarkable progression. Visitors may watch the machinery in movement from two traveling cranes, or *ponts roulants*, as they are more correctly described in French, which move to and fro on rails at some height above the shafts. The bird's-eye view thus obtained proved so startling to an Annamite the other day that he turned suddenly pale, or pale yellow, on glancing down at the iron monsters which to his untutored and superstitious gaze seemed to be harboring destructive designs upon the passing crowds, and he looked as though he were ready at a moment's notice to prostrate himself at the feet of some modern Moloch! The steam boilers occupy a place in a covered court facing the Avenue de Lamotte-Piquet, and it should here be stated that the machinery on the Quai d'Orsay is set in motion by the engines in the machinery hall, a motor turning a dynamo for the transmission of electricity to the agricultural hall. Most of the engines exhibited in the Palais des Machines belong to the Corliss, Sulzer, and Wheelock systems, and are generally of the compound type, but others will also be studied with interest by technical judges.

The general arrangement of the exhibits may be described in a few words. As the visitor passes through the palace from the Avenue de Suffren to the Avenue de Labourdonnais, he finds that the first half on his right is devoted to those relating to civil engineering, the ceramic arts, cabinet-making, mechanism of various kinds, electricity, agriculture, mining, and metallurgy, printing, and paper-making; and the other half, on the left, to railway material, and spinning, weaving, and iron working machinery, etc., and the special places set apart to Switzerland, Belgium, the United States, and England. Between the machinery hall and the general industries gallery is a court in which electrical apparatus of all kinds may be seen in full working order at night. It constitutes one of the most novel and attractive features of the exhibition. The focus of one great lamp consists of a cluster of 15,000 small incandescent lights.

(369) *Extract from the official specifications.*—The following extract from the official specifications will give an idea of the great pressures which the foundations were required to sustain.

The great nave consists of nineteen bays, varying in length as follows: Two at the end, of 25.295 meters each; sixteen intermediate, of 21.50 meters, and one in the middle, of 26.40 meters. There are twenty principal girders (Fig. 247), the two end ones being heavier than the others. These principal girders are connected at the top by two ridge purlins, with a walk and parapet above them, and on the sides by eight lattice purlins, and two plate purlins at the right of the main gutters. Between the principal girders each bay is divided into four parts by three girders at right angles to the purlins, to which they are attached. These latter hold the minor purlins and sash bars, with the iron framing for the roof covering. Laterally, the principal girders are connected by lattice girders at the first floor level of the side galleries, and under the gutter by lattice arches and open iron work. The weight of the nave was estimated at 7,709,100 kilograms, and the thrust of each principal girder amounted to 115.000 kilograms, including a weight of snow and the effect of a strong wind blowing at the rate of 40 meters per second.

(370) *Foundations.*—The foundations for the Machinery Hall were begun on the 5th of July, 1887, and were finished on the 21st of December. The structure, according to the specifications just given, consists of an immense nave 110 meters wide and 420 long, with two side galleries 15 meters wide, containing a single story 8 meters above the ground, with grand stands at each end, supported on iron pillars. Access to this story is obtained by four great staircases.

The twenty great curved girders of 110 meters span form the framework of the building; they are jointed at the top and at the springing lines. The axles on which they rest are on a level with the ground. The bed plates or cast-iron bearings, which take up the thrust of the arch and transmit it to the masonry, had to be made strong enough to support a vertical load of 412 tons, and a horizontal thrust of 115 tons.

As provision had to be made for a system of underground pipes for water, steam, drainage, etc., it was impossible to use underground tie-rods; it was, therefore, absolutely necessary to make the foundations of the piers or abutments of the great girders strong and deep enough to assure the perfect security of the edifice. The twenty great girders rest on forty masonry piers entirely hidden in the ground; they are designated by the letters A, B, C, etc. (Fig. 243).

(371) The nature of the soil is suitable for foundations, where it has not been previously disturbed, but unfortunately for the present occasion, the Champ de Mars has, during the last century, been the site of exhibitions beginning with that of 1789 and ending with the recent one of 1878, when a deep deposit of sand was removed and replaced with rubbish.

On this old gravel pit a portion of the foundation had to be made (this portion is shaded in the figure).

Numerous borings had shown the strata (Fig. 244) to be as follows: made ground and gravel, for a depth of 7.50 meters; plastic clay, 7.50 meters; quartz sand, 1.50 meters; plastic clay, 3.10 meters; clay, 5.40 meters; marl, 19.40 meters to the chalk.

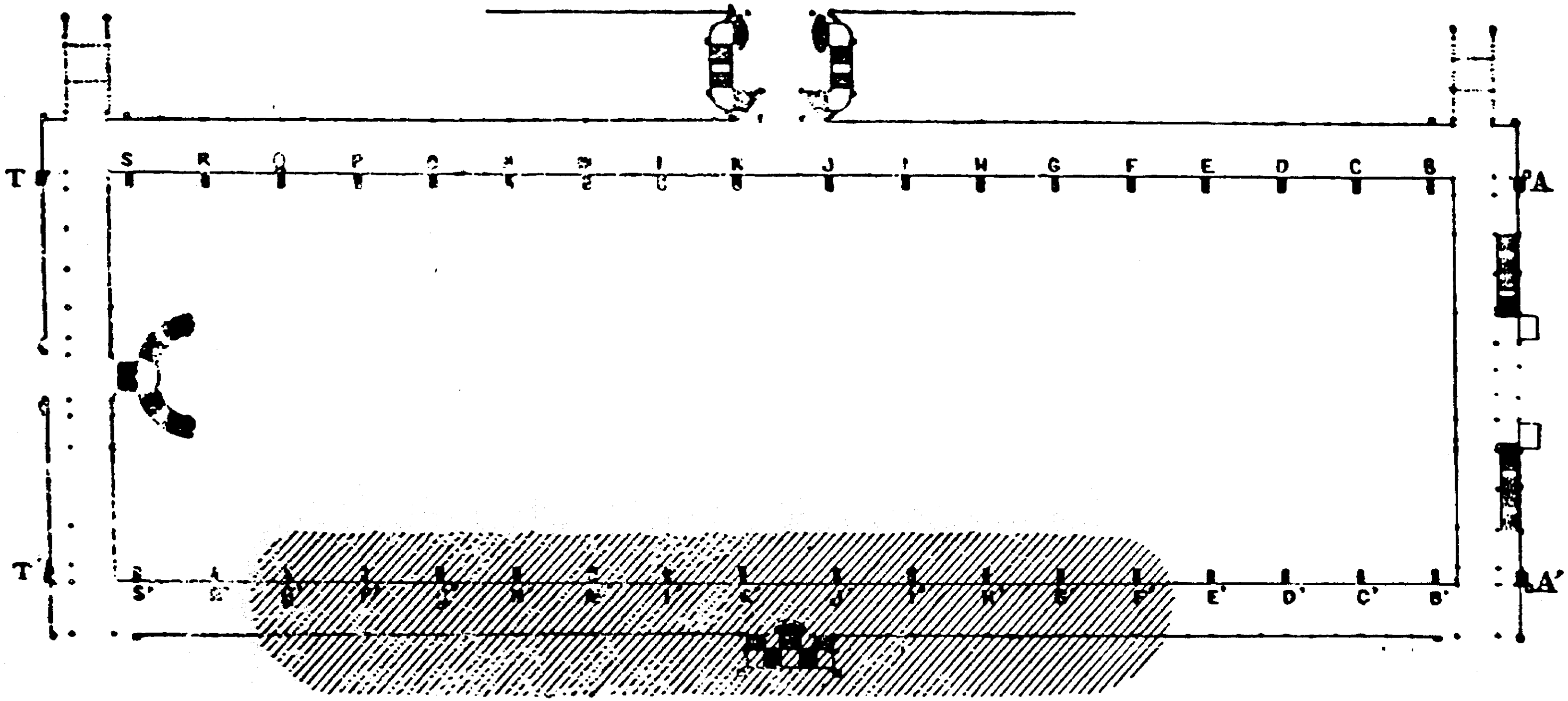


FIG. 243.—General plan of the foundations of machinery hall.

On account of the differences in the strata it was found necessary to adopt three types of piers according to the thickness of the gravel on which they rested. Whenever the thickness of the alluvial deposit exceeded 3 meters, the foundation of the pier consisted of a block of masonry 7 meters long, 3.50 wide, and 3.70 thick, resting on a layer of béton from 0.50 to 0.80 meter thick. (In this first case the resistance of the ground was required to be 3 kilograms per square centimeter). This is the general type of foundation, twenty-five piers out of forty being so constructed. When the bed of gravel was reduced in thickness, without falling below 1.50 meters, the depth and surface of the béton was considerably augmented, the dimensions being 1.35 meters in thickness, with a surface of 11.20 by 6.50 meters in some instances, supporting a mass of masonry which was the same for all the piers; the resistance in this latter case was 1.9 kilograms. Only five piers were constructed on this type, viz, G, M, P, Q, and P′.

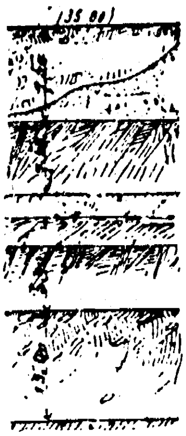


FIG. 244.—Geological section.

Finally, for the piers which had to be constructed on the site of the gravel pit, the bed of béton was the same as in the last case, but, before laying this, a group of piles 0.33 meter in diameter and 9 meters long was driven into the bed of quartz sand, which extends below the layer of clay 7 meters thick.

The foundations on the line A T began on July 5 and presented no difficulty, but in sinking the piers G P portions of the foundations of the exhibitions of 1878 were met and blasted out. Figs. 245 and 246 show a vertical section and plan of one of these piers. Each of these elliptic excavations was 20 by 15 meters at the top, 11.20 by 6.50 meters at the bottom, and from 7 to 7.50 meters deep. The contents varied from 1,100 to 1,200 cubic meters. The piles were sawn off and covered with a layer of béton, 11.20 by 6.50 by 1.80 meters, amounting to 131 cubic meters. The operation of running in and ramming the béton occupied 26 men two days. Upon this the various layers of masonry (Fig. 245) were built—varying from 120 to 130 cubic meters—by six or seven masons and as many helpers, in 8 or 9 days.

The feet of the principal girders were at the reference 35.12 meters.*

The masonry was stopped at 32.96 meters to put in the anchor bolts holding the bearings. These bolts are six in number, united by a network of T irons imbedded in the masonry.

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* Above the level of the sea.

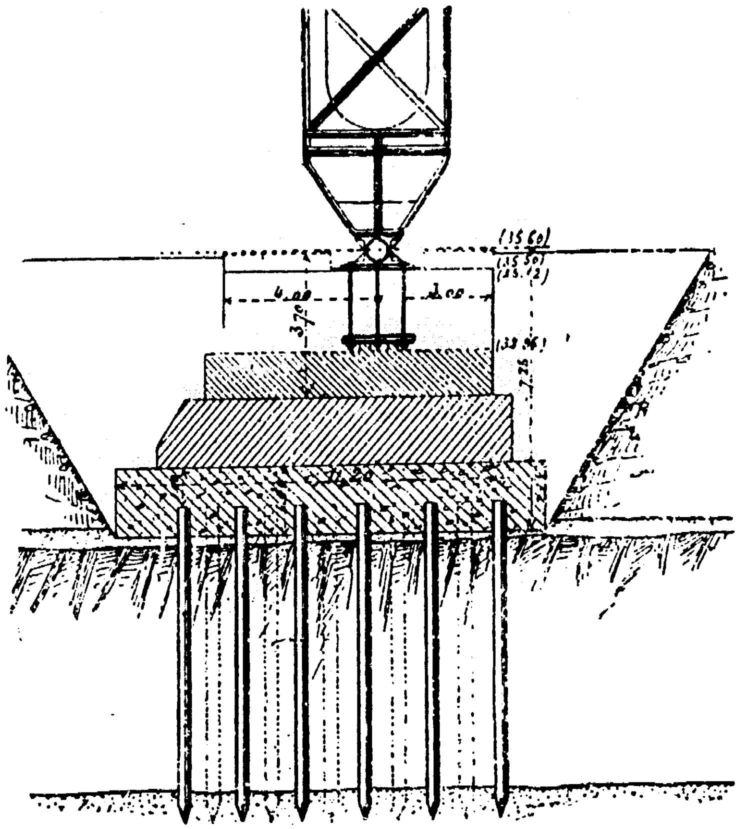


FIG. 245.—Foundation of a truss girder; elevation.

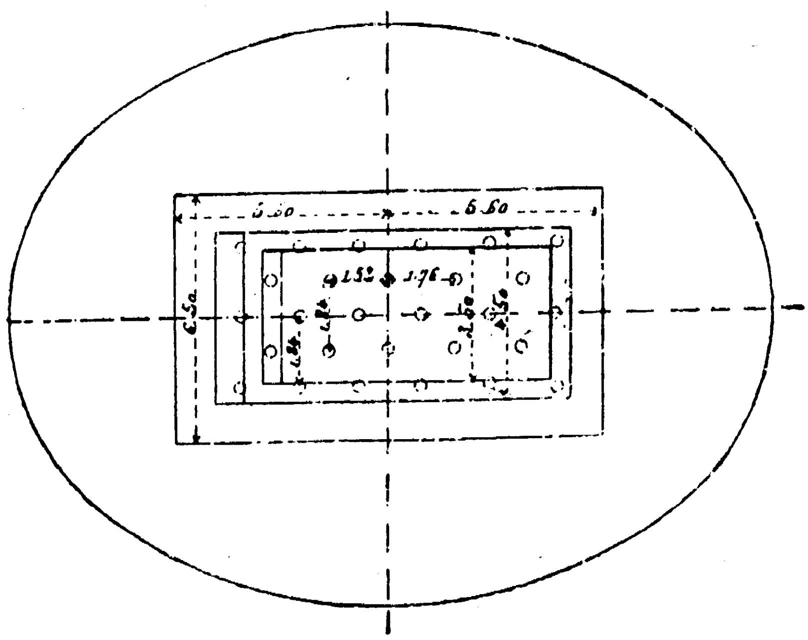


FIG. 246.—Plan.

Each bolt is separated from the masonry by being placed in a cast-iron tube, which allows it 0.03 meter play in every direction. At

0.50 meter above the reference 32.96 meters each cast-iron tube is prolonged by one of sandstone, so that it may be cut to the exact height of the bearing. The bearing rests upon a large cast-iron bed-plate, so that rubblework under it answers very well.

The foundations were completed on December 21 by MM. Manoury, Grousëlle & Co., contractors.

(372) *Principal girders or arched ribs.*—Each principal girder is jointed at three points, *i. e.* at the top, and at the springing lines (Fig. 247). This arrangement simplifies the calculation by determining the exact points of application of the stresses; it also facilitates the movements due to the variations of temperature, which cause the ridge to rise or fall as the girders expand or contract.

We will first consider the arch and afterwards the spandrel, which does not affect its strength, but simply constitutes a filling. The arch is divided into twenty-four panels of different sizes. The distance between the extreme plates of the intrados and extrados at the bottom is 3.70 meters. This distance continues up to purlin No. 5, whence it begins gradually to diminish to nearly 3 meters at the top. This very economical form gives a character of lightness and elegance to the whole girder.

As the Figs. 248–254 indicate, the girder consists of two webs 450 by 9 millimeters for the part between panels Nos. 1 to 16; 450 by 10 for that between panels 16 and 21, and 450 by 23 for that between 21 and 24. (Dimensions given in millimeters).

These webs are united by plates 770 by 8 for the extrados, and 900 by 10 for the intrados, and four angle irons $\frac{100 \text{ by } 100}{9}$.

The uprights and diagonals are fastened to the two webs.

For the part between purlin No. 4 and the joint at the foot of the girder the stresses are considerable, and the sections have been strengthened.

The covering plates for those parts subject to the greatest stress are six in number. A plate of 10 thick extends over the entire girder, a plate of 13 over a shorter length, one plate of 11 over a certain length of the intrados, also two of 12, and one of 13, which makes a total of 71 millimeters. (See Fig. 249).

At the extrados, the last two plates are omitted, and they have been replaced by two angle irons $\frac{110 \text{ by } 110}{9}$, which connect the spandrel with the principal girder. (Fig. 252).

The portion of the arch between two purlins is formed by three small diagonals and two large ones. This division of the diagonals into small and large serves to decorate the arch, and has also the advantage of giving the same distance, 10.72 meters, between the vertical purlins, which is indispensable considering their great height.

SECTIONS OF THE GREAT TRUSS GIRDERS.

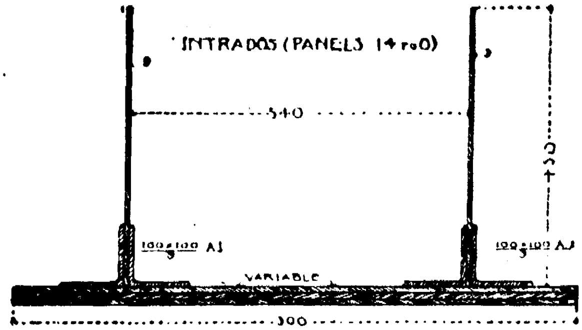


FIG. 248.

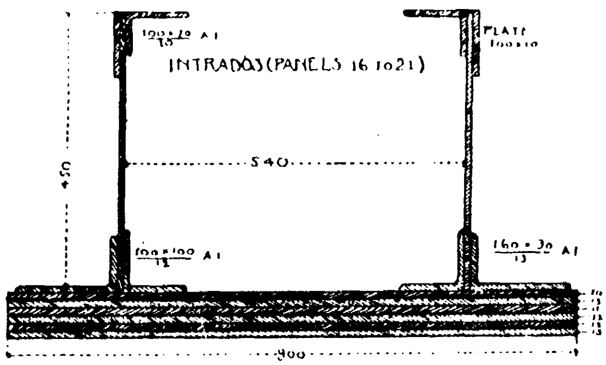


FIG 249

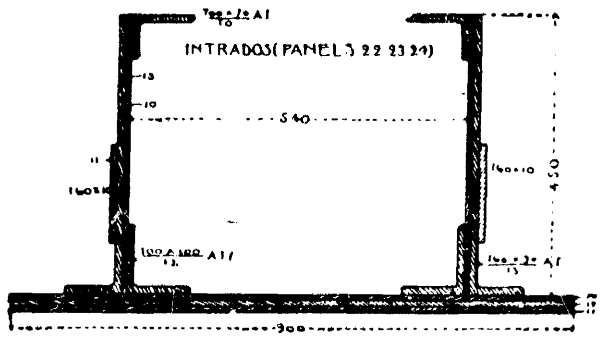


FIG. 250.

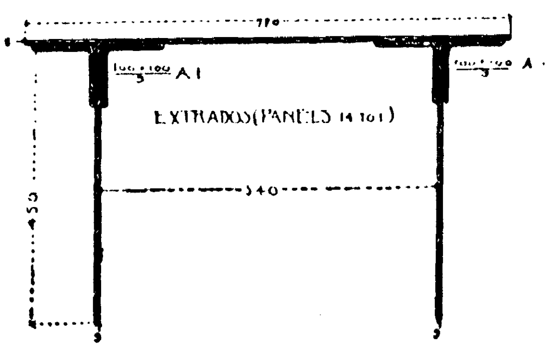


FIG. 251.

SECTIONS OF THE GREAT TRUSS GIRDERS.

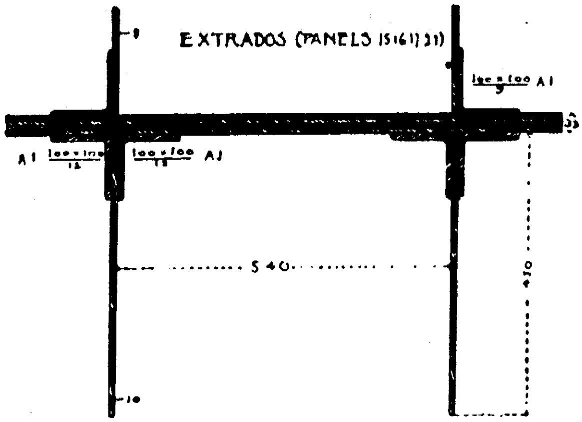


FIG. 252.

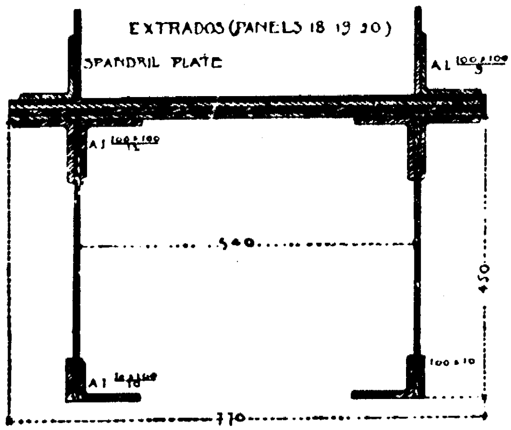


FIG. 253.

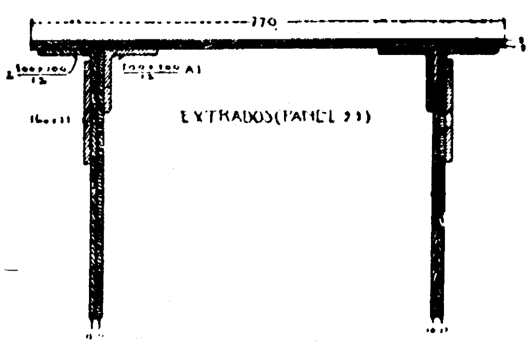


FIG. 254.

(373) The diagonals are formed by T-irons of different dimensions, according to their position in the section with respect to the webs of 450. From the panel 21 to 12 the diagonals are T-irons $\frac{200 \text{ by } 100}{14}$. In the panels 22, 23, 24 they are T-irons $\frac{200 \text{ by } 100}{14}$ strengthened by a plate 200 by 10; in the panels 11 to 1 they are $\frac{170 \text{ by } 90}{13}$.

The panels at the head and foot are of an entirely different construction. In those of the head, which have to resist a horizontal thrust of 74,950 kilograms under ordinary circumstances, of 114,360 when the roof is covered with snow, and of 119,840 in case of a wind having a mean velocity of 40 meters per second, two large diagonal double T-irons are used, which take the thrust, and form, with a series of supplementary webs and strengthening plates, a very stiff frame.

Figs. 264 and 265 show the method of attaching the bearings to the web of the arch.

The bottom panel is entirely plain and has two webs strengthened by several supplementary plates.

The panel rests on the upper bearing by means of an additional plate 20 millimeters thick, to which it is fastened by four bolts. The lower pillow block rests on a cast-iron plate, to which it is attached by long anchor-bolts imbedded in masonry, as has been previously described.

For facility of transportation the different sections were 5 or 6 meters in length, the joints being made in the middle of a panel, and care taken that the angle irons should break joint.

(374) The spandrel has the same construction as the arch itself. It is formed of two webs 400 by 9 united by a plate 770 by 8, and four angle irons $\frac{100 \text{ by } 100}{9}$.

The uprights are in the prolongations of those of the arch, and like them placed beneath the two webs. The vertical part of the spandrel outside of the girder, which carries the arches of the lateral galleries, and the gutter purlins, is strengthened by two webs 150 by 7 and four angle irons $\frac{100 \text{ by } 100}{10}$.

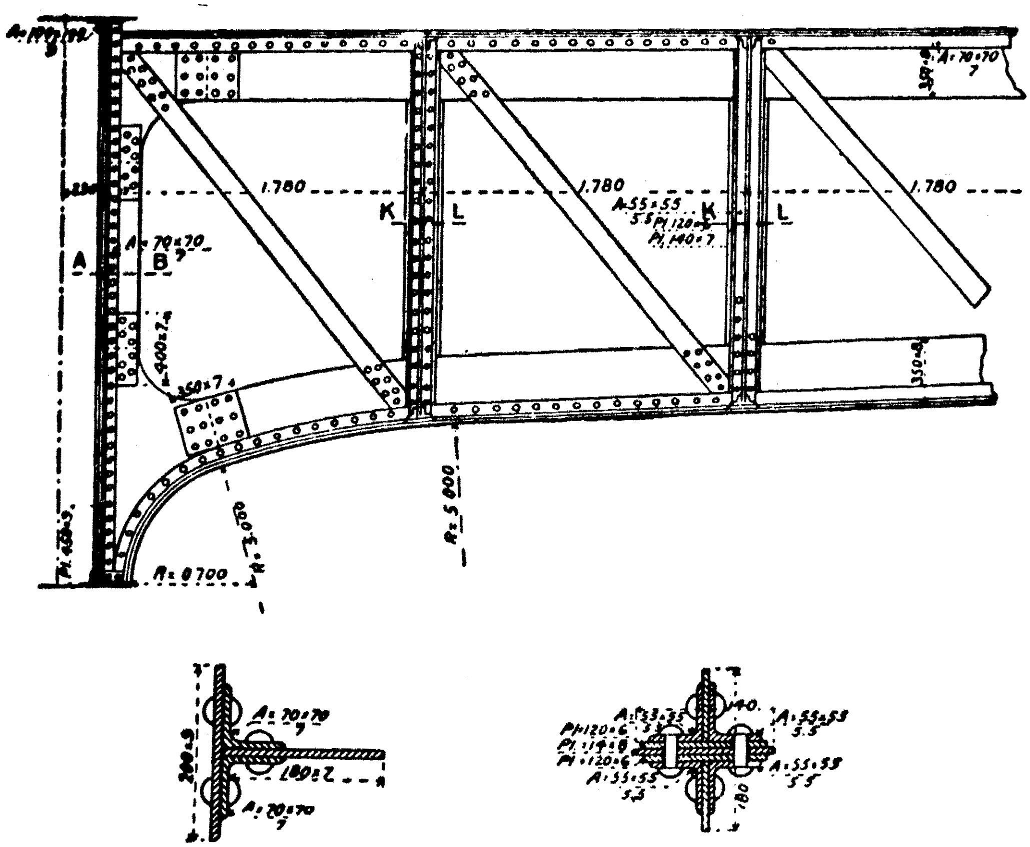
The joints between the gutter purlins and the girder are made by bolts, on account of the difficulty of riveting at this height, and the gutter is secured to the uprights of this purlin by a number of brackets. All the space below this purlin above the arches of the lateral galleries is closed by a plate-iron curtain 4 millimeters thick formed by plates 1.73 meters long and lapping over each other for a distance of 0.150 meter.

(375) *Purlins.*—There are twelve purlins, including those which support the gutters, which are differently constructed from the others. The two latter are formed of a web 1.05 meters high by 8 millimeters thick, and two plates 300 by 9 millimeters with four angle irons $\frac{70 \text{ by } 70}{7}$.

The uprights, consisting of a web and four angle irons, stiffen the beam, and serve at the same time as a support for the rafters on the interior and for the gutter corbels on the exterior.

The other ten purlins (Figs. 255-257) are each formed of an N-shaped lattice girder. The tension bars are two flat irons 120 by 8 joined on each side to the two plate webs of 350 millimeters thick. For the two panels near the trusses where the shearing stress is greatest the thickness of the plates is 9 millimeters.

MACHINERY HALL. PURLIN WITH DETAILS.



Section A B. Section K L.

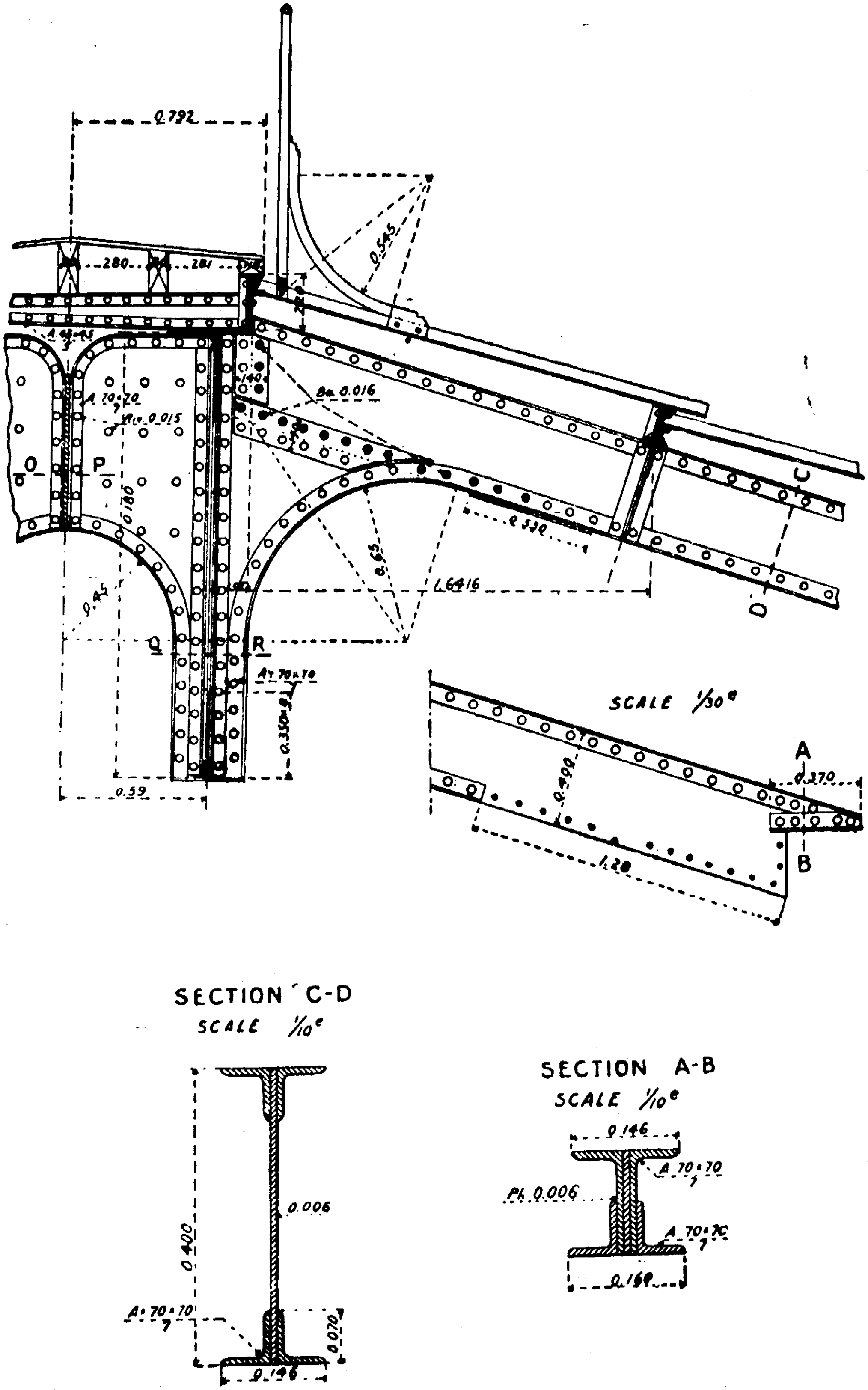
FIGS. 255, 256, 257. Purlin.

The purlins have been calculated by considering them as pieces resting on two supports and carrying three separate loads, viz, the rafters, a portion of sashes and glass, and their own weight. These conditions give a height in the middle of the purlin of 1.80 meters, and this height has been augmented toward each end for architectural effect.

(376) *Rafters.*—The purlins are braced by a series of rafters running from the ridge to the gutters (Figs. 258-262). Upon the rafters rest the minor purlins which support sash bars. Rafters Nos. 1 and 2 have been selected as illustrations on account of the peculiar arrangement at their upper parts due to the joining of the principal girders.

On account of the great length of the purlins it is indispensible that they should be braced at several points; this is accomplished by

MACHINERY HALL. RAFTER.



Figs. 258–261. Rafter, rafter end, and sections A B and C D.

means of the three rafters placed between two principal girders. This bracing is made secure by putting at the right of each rafter and for each purlin a large ear of plate and angle irons. Between the two ears a sheet of lead 15 millimeters thick is placed.

This arrangement does not prevent the movements due to variations of temperature, for when the girder expands the ridge rises. The lead gives at its lower part and allows the motion.

Six bolts are used to unite the two ears, but, in order to leave a slight play, care is taken not to screw up the nuts too tightly.

The two ridge purlins support a walking gallery with an outside parapet. This gallery is fixed to the right gutter purlin only, and is free from the other so as to vary its position as the roof moves.

(377) *Erection.*—The contracts for iron work and the erection of the Machinery Hall were allotted to three companies, viz, the gables and lateral galleries to MM. Baudet, Donon & Co., and the other portions of the great nave were equally divided between the companies Fives-Lille and Caile.

(378) *The method adopted by Fives-Lille Co.* is due to M. Lantrac, chief engineer of the company, and was superintended by M. Balme,

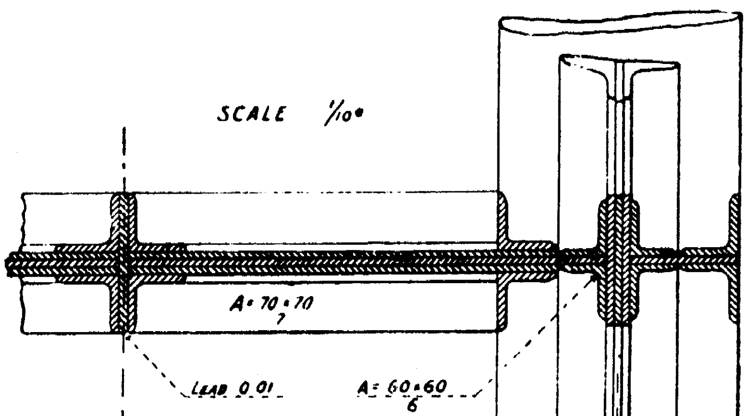


FIG. 262.—Rafter. Section O P Q R.

the resident engineer. This system consisted in putting the parts of the girder together on the ground so as to form four sections, viz, two piers and two arches, then raising these four sections to their proper places, and riveting them together on scaffoldings arranged for the purpose.

The scaffoldings required for the whole operation were three in number, one high central one, and two lateral ones; they are shown in Fig. 263; they are mounted on wheels, and are entirely independent of each other.

DESCRIPTION OF FIG. 263.

Fig. 263 represents the method of raising the girders, with the traveling scaffoldings in use.

MACHINERY HALL. ERECTION OF A GREAT TRUSS GIRDER. METHOD ADOPTED BY THE FVIES-LILLE COMPANY.

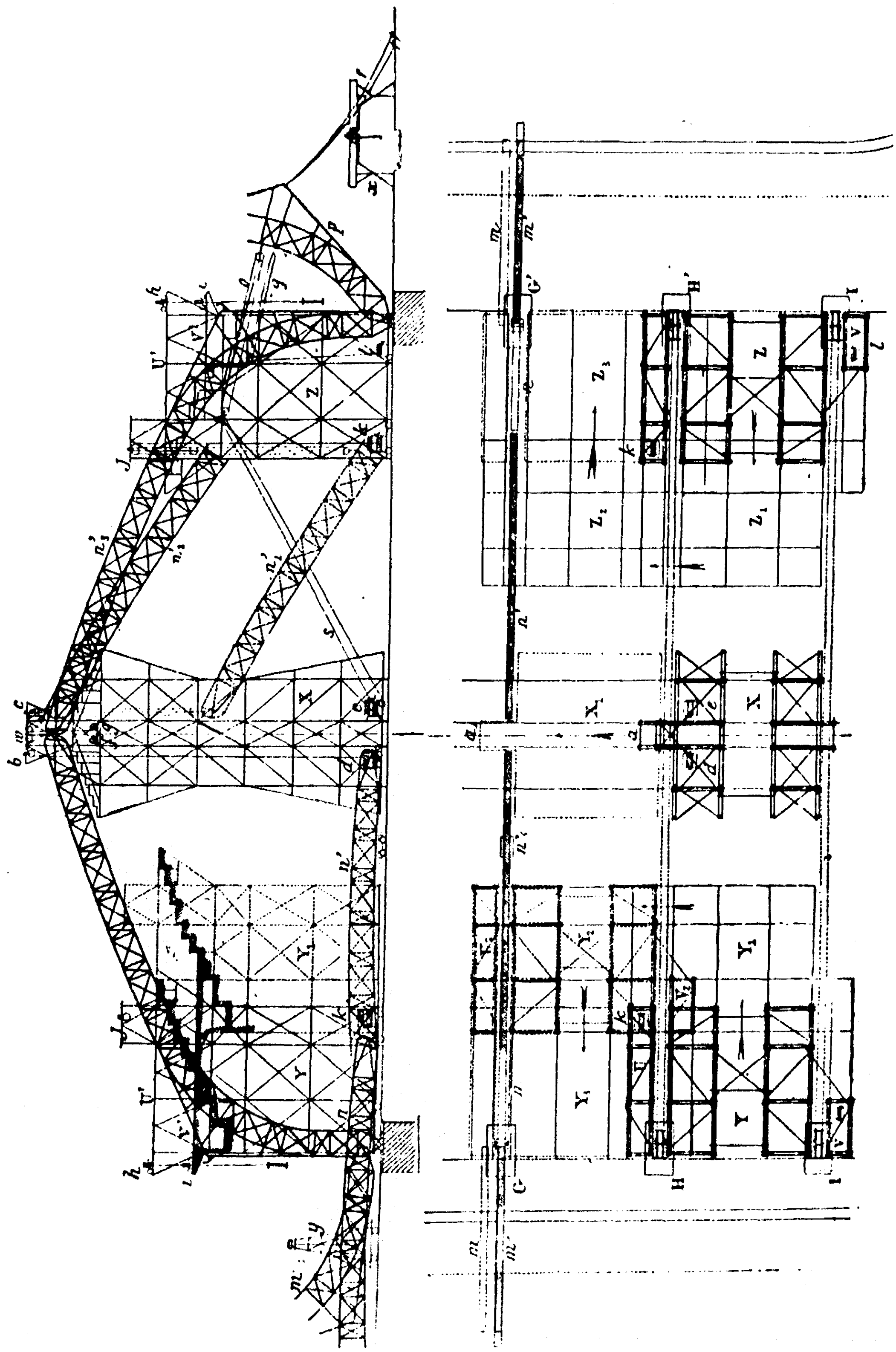


FIG. 263.—Elevation and plan of girders and scaffolding.

I I′, piers; X, high central scaffoldings 22 meters long, 19 meters wide, 44 meters high, running on 18 wheels 0.80 meter in diameter; Y Z, two smaller traveling scaffoldings just alike; U′ U′, secondary scaffoldings fastened to Y and Z; V′ V′, traveling scaffoldings fastened on to Y and Z; *a*, *a*, firmly braced projecting stage; *b*, *c*, hoisting pulleys on *a*; *d*, *e*, winches for *b* and *c*; *f*, *g*, smaller winches below; *h*, *i*, small cranes; *j*, lifting pulley; *k*, *l*, winches; *m*, *p*, foot of girder; *x*, a platform on piles, with a winch; *n*, the rest of the half girder; *r*, guys; *w*, pulleys; *y*, traveling crane.

When it was desired to transfer UZ and V from one bay to another, the following operations were necessary: First, a motion at right angles to the axis of the nave for a distance of 17 meters, so as to clear Z and V and allow them to pass under the arched girder; second, a movement of 21.50 meters parallel to this axis to the following bay; third, a movement at right angles to the axis, so as to bring the whole back into line with its primitive position.

These travelers were carried on three sets of rails, two across and one lengthwise, by means of fifty wheels, twenty-eight for the first and third travelers, and twenty-two for the second.

The height of the axles of the wheels could be raised enough to enable the wheels to clear the rails, by removing a set of cast-iron bearings placed above the axles for this purpose.

In order to pass from one line of rails to another, the travelers were raised by a set of hydraulic jacks, the upper bearings removed, the wheels pushed up and wedged into their frames, and the set of wheels for the other line brought down. The travelers were then moved by cables attached to piles driven into the ground, the cables being wound up on the winches *k* and *l*. The time required to shift X, Y, and Z, was a little less than two days.

(379) *General process of erection.*—The bed plates, cast-iron pillow blocks, were fastened by the anchorage bolts already described. The form is shown in Figs. 264 and 265.

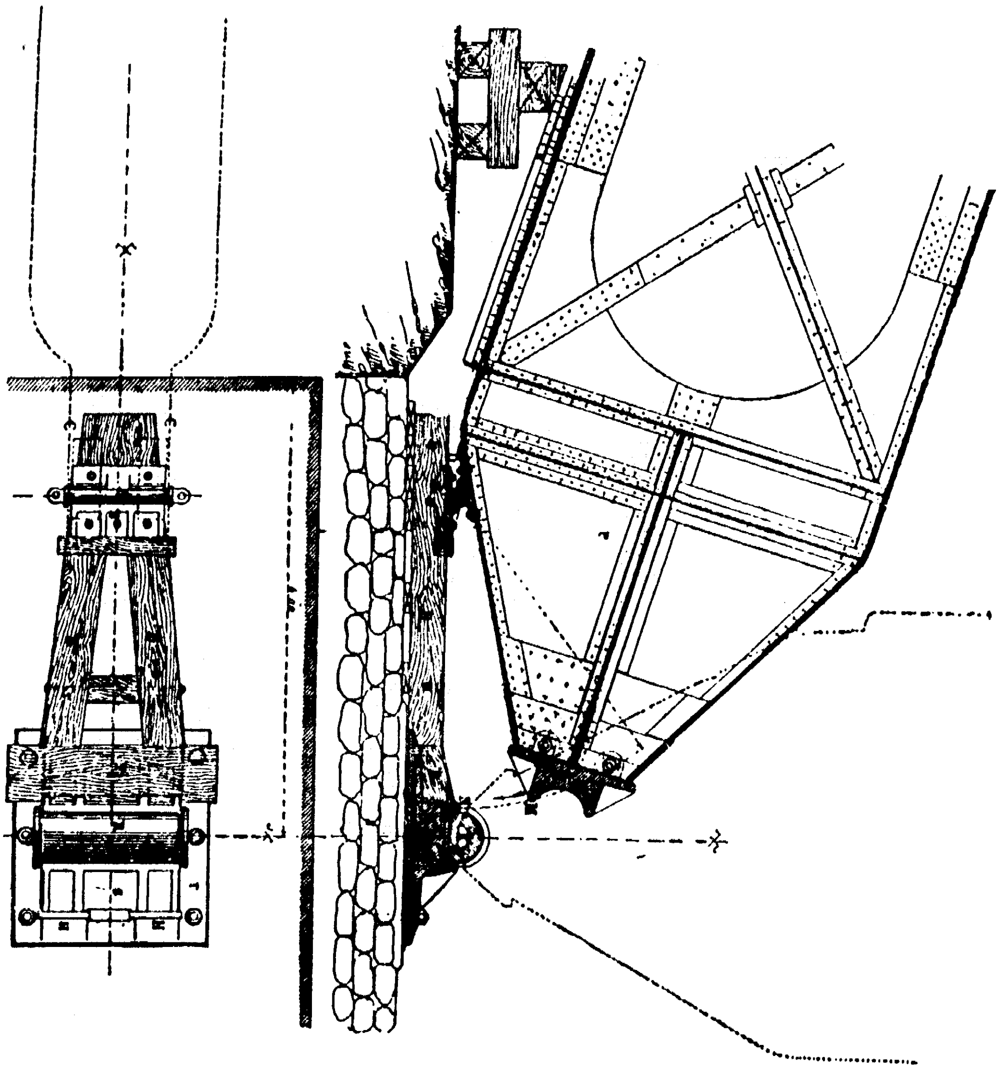
The bed plate rests on a sheet of lead 5 millimeters thick, spread upon a coating of Portland cement laid upon the masonry.

The portions of one-half of the girder, consisting of the foot, the head panel, and the intermediate sections unriveted, were sent from the shop.

The traveling crane *y*, 10 meters high, was used to handle the different pieces, which were put together in two separate portions, *m* and *n*, and laid parallel to each other (Fig. 263).

Suppose now the bay H H′ I I′ to be finished; we pass to the following bay thus: X takes the position X_1; Y, the successive position Y_1 and Y_2; and Z, those of Z_1 and Z_2. Then the portion of the girder *n* placed upon cars running on a cross track is brought to *n*′, directly under the pulleys forming the hoisting apparatus on X, while the foot *m* is dragged to the position *m*′ just in front of its bearings. Y_2 is then pushed into the position Y_3 in line with its first position. The same movements are made with Z. The two pieces *m'* and *n'* are now ready to be raised.

(380) *Erection of the foot of the girder.*—Fig. 264—The first operation is to turn P around an auxiliary axle, A, until the rounded edge, M, of O bears upon N. S is fixed by four steel wedges, H, to the bed plate T, which is made fast by the anchorage bolts. The auxiliary axle A is a steel cylinder 0.12 meter in diameter and 0.80 meter long. It rests on the cast-iron half pillow block B bolted to the oak frame E. The half pillow block, C, of the axle A is fixed upon P by bolts and



Figs. 264 and 265.—Method of raising the foot of a great truss girder.

braced by two iron claws, D, riveted to the girder itself. The pieces C and D are subsequently removed and the holes stopped with rivets.

When the piece P is dragged over so as to stand exactly in front of R, it is lifted by hydraulic jacks, and the supports are gradually removed until C comes in contact with A. The hoisting was done by means of a cable and two pulleys—one fixed to the scaffolding Z, and the other united by an oscillating bar and two connecting rods to a steel axle fixed to the lower flange of the fifth panel (Fig. 266), so that the different pieces could oscillate at right angles to the traction in both directions. The cable was 0.075 meter in diameter and had been tested to 40 tons. The foot weighing 48 tons and bearing partly upon A, its axle of rotation, with three plies of the cable there was no danger of rupture. The cable passed over the winch *e* and was worked by a gang of twelve men. As an extra precaution the first motion of the girder was aided by the auxiliary hoist *q*. Two guys steadied *p* in its motion, and finally the traveler Z was guyed by a steel cable *s*. It took about three hours to raise both feet together.

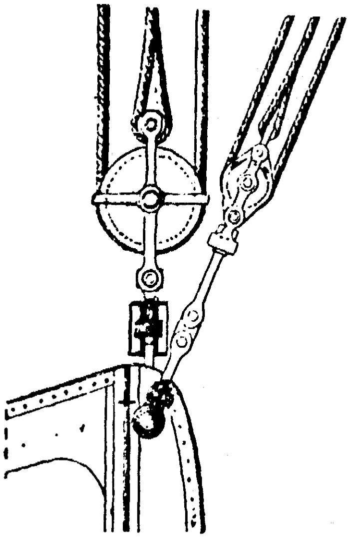


FIG. 266.—Special arrangement of the pulleys for lifting the foot of the girder so that the different pieces may oscillate in directions at right angles to each other, in order that the traction shall always be normal to the axis of rotation.

(381) *Erection of the remainder of the girder.*—When each foot was raised and secured to its traveler the joining pieces were brought into place by the traveling cranes, *h h*, and were riveted on the scaffoldings.

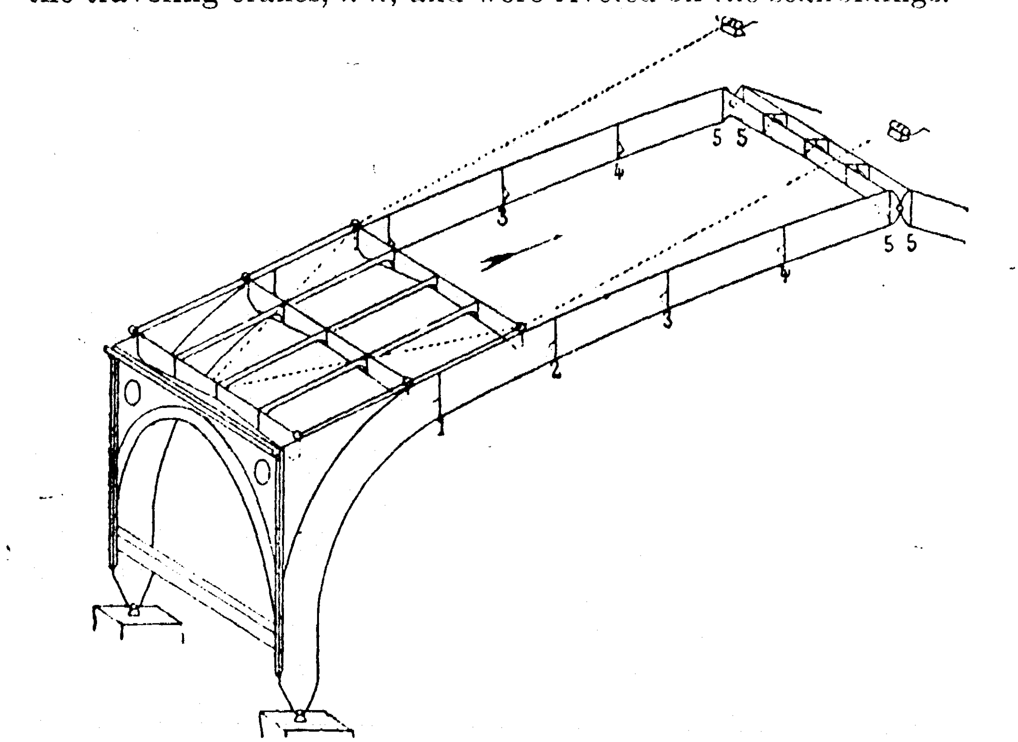
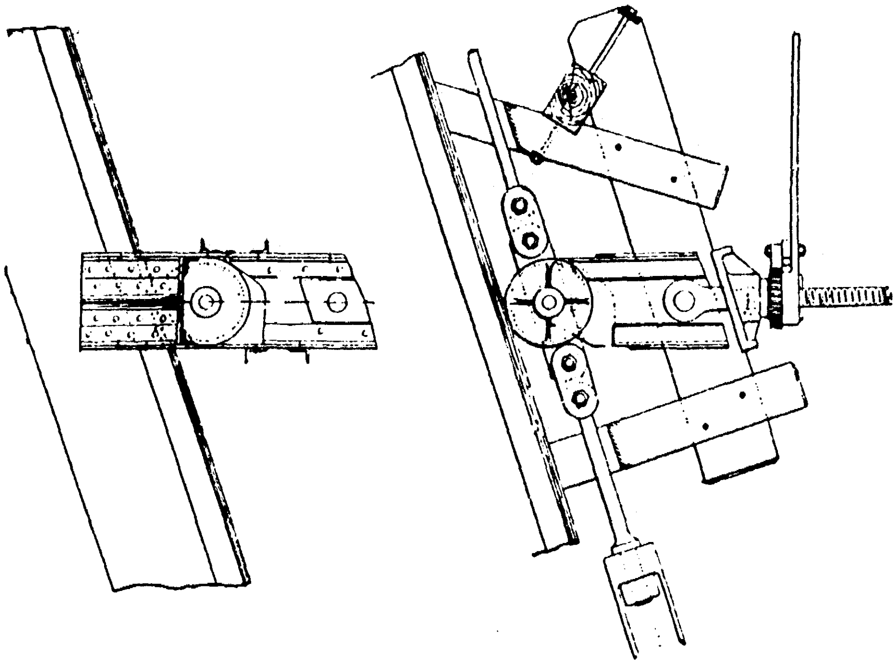


FIG. 267.—Scheme adopted by Fives-Lille Co. for erecting the rafters and purlins.

The other portion *n′* of the girder was slung at its extremities to the pulleys *d* and *k* by three cables each, so that the section, which weighs about 38 tons, was borne with perfect security. The inner end was first raised by the winch d until the section took the position n'_1. It was then raised by means of d and k, to the position n'_2, the head being about 2 meters from its final position n'_3. To bring it to the position n'_3 the winch d was stopped, and a second pulley w worked by the winch f was attached to the end of girder.

MACHINERY HALL. METHOD ADOPTED BY THE FIVES-LILLE CO. FOR ERECTING THE PURLINS.



FIGS. 268 and 269.—Method of holding and rolling the purlins on the girders.

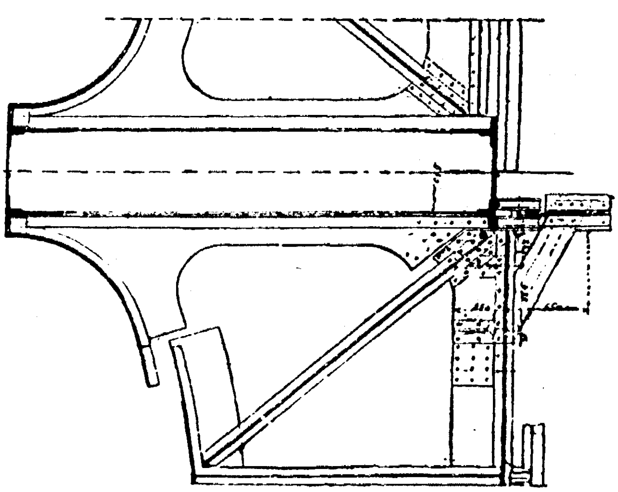


FIG. 270.—Purlin in the act of being lowered into position.

Fig. 263 shows the arrangement of these two pulleys. By hauling and slacking alternately with the pulley d, the bearing of the head was brought to the trunnion of the upper joint. The raising of the other section was carried on at the same time until both bearings closed upon the trunnion. When this was done the collar plates were bolted on, uniting the two bearings together. During this time the two sections of the girder were being riveted together.

The operation of raising the whole girder took five hours and a gang of eighty men in all.

(382) *The raising of the purlins.*—After the gutters had been raised and placed by the cranes *h* and *i*, purlins Nos. 2, 3, 4 (Fig. 267) were raised and placed on U'. The upper extremities were furnished with bushings carrying rollers (Figs. 268 and 269).

Then the three purlins with their six rafters were riveted together upon the floor of the traveler. The whole system was then rolled by two winches placed on the central traveler and hauled to its final place; the rollers were taken off, the cheeks let down by special jacks arranged on wooden frames; the purlins came into their proper places and were bolted to gussets riveted to the girder (Fig. 270).

(383) *Weight.*—

	Tons.
Weight of each gable-end girder	240
Weight of each of the other girders	196
Weight of one-half bay including the purlins, rafters, and sash bars	62
Weight of gutters, arcade, etc., for one-half bay	23

Number of rivets for the ordinary girders, about 32,000, not including those for the purlins. Of these 19,600 were driven in the shops, 10,300 on the ground, and 2,100 on the scaffoldings.

Number of workmen employed on the ground daily, 250.

The first girder was erected April 20, 1888. The first bay was completed in 23 days, the second in 16 days, the third in 12 days, and each of the following bays in about 10 days.

(384) *Method of erection adopted by Cail & Co.*—The system adopted by Cail & Co. was devised by M. Barbet, chief engineer of the company. It consisted in raising the girder in pieces not exceeding 3 tons and riveting them directly from a single scaffolding, the top of which conformed as nearly as possible to the intrados of the arch.

Fig. 271 shows the elevation of this great scaffolding, consisting of five stagings 16, 18, and 20 meters long, by 8 wide, connected at a height of 10 meters by a series of bridle pieces; the stagings are united at their upper parts by plank floorings; one of the floorings, a flight of steps, follows the outline of the girder which it is intended to support; it has a width of 5 meters; the other, 35 meters high, is horizontal.

On this platform, 4 meters wide, two rails, 2.50 meters apart, are laid, which carry a traveling crane, shown in the figure.

The five stagings are mounted on twelve wheels 0.60 meter in diameter. The rails, 0.12 meter high, are fixed to strong cross-ties 1.10 meters by 0.25, by 0.15, 0.70 apart and the whole carefully leveled.

The scaffolding is moved by five winches set up on its lower framing, and the ropes pass through pulleys made fast to piles driven into the ground. Each staging was provided with a plumb line, and,

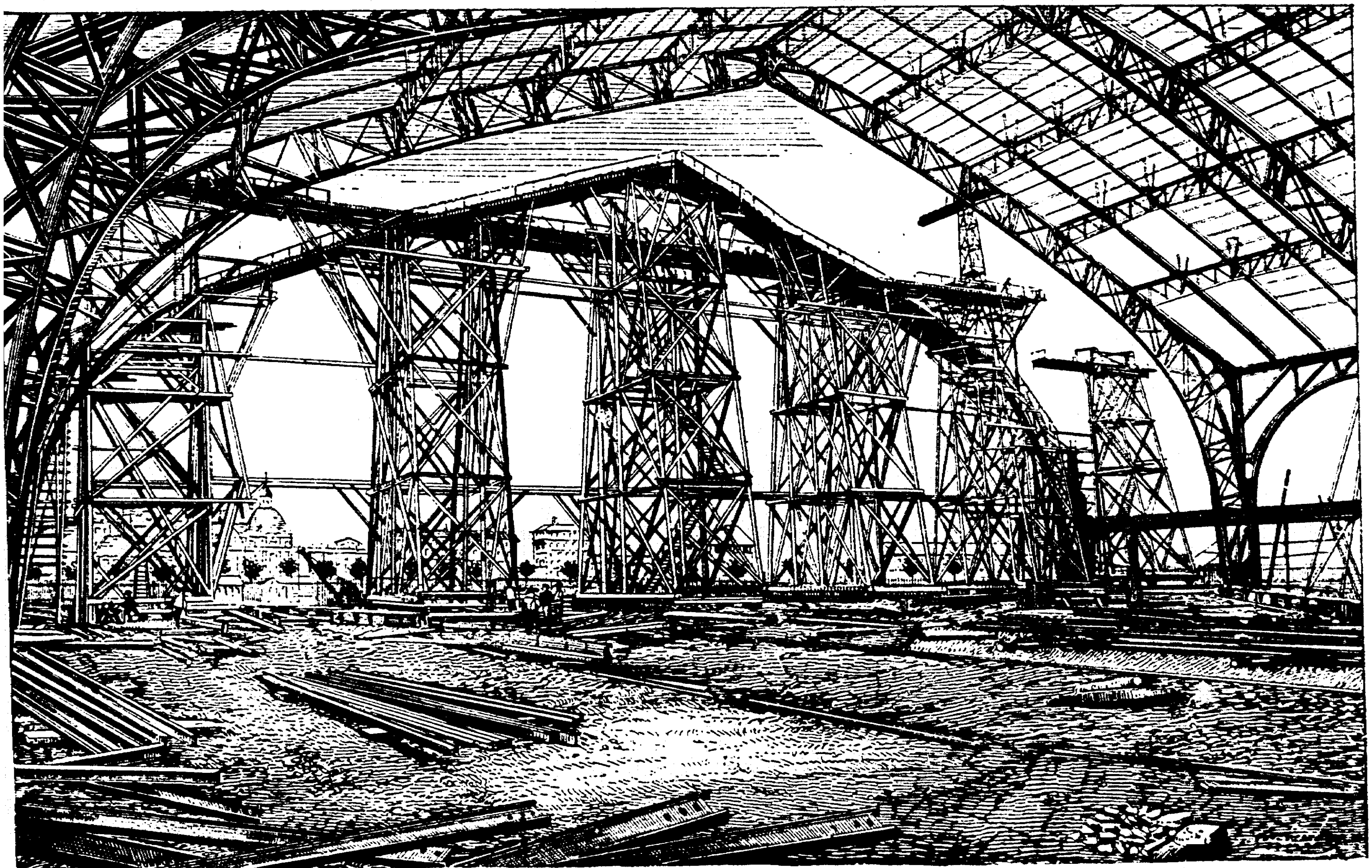


FIG. 271.—Erection of the great truss girders. Method used by Cail & Co. View of the girders and the erecting scaffolding.

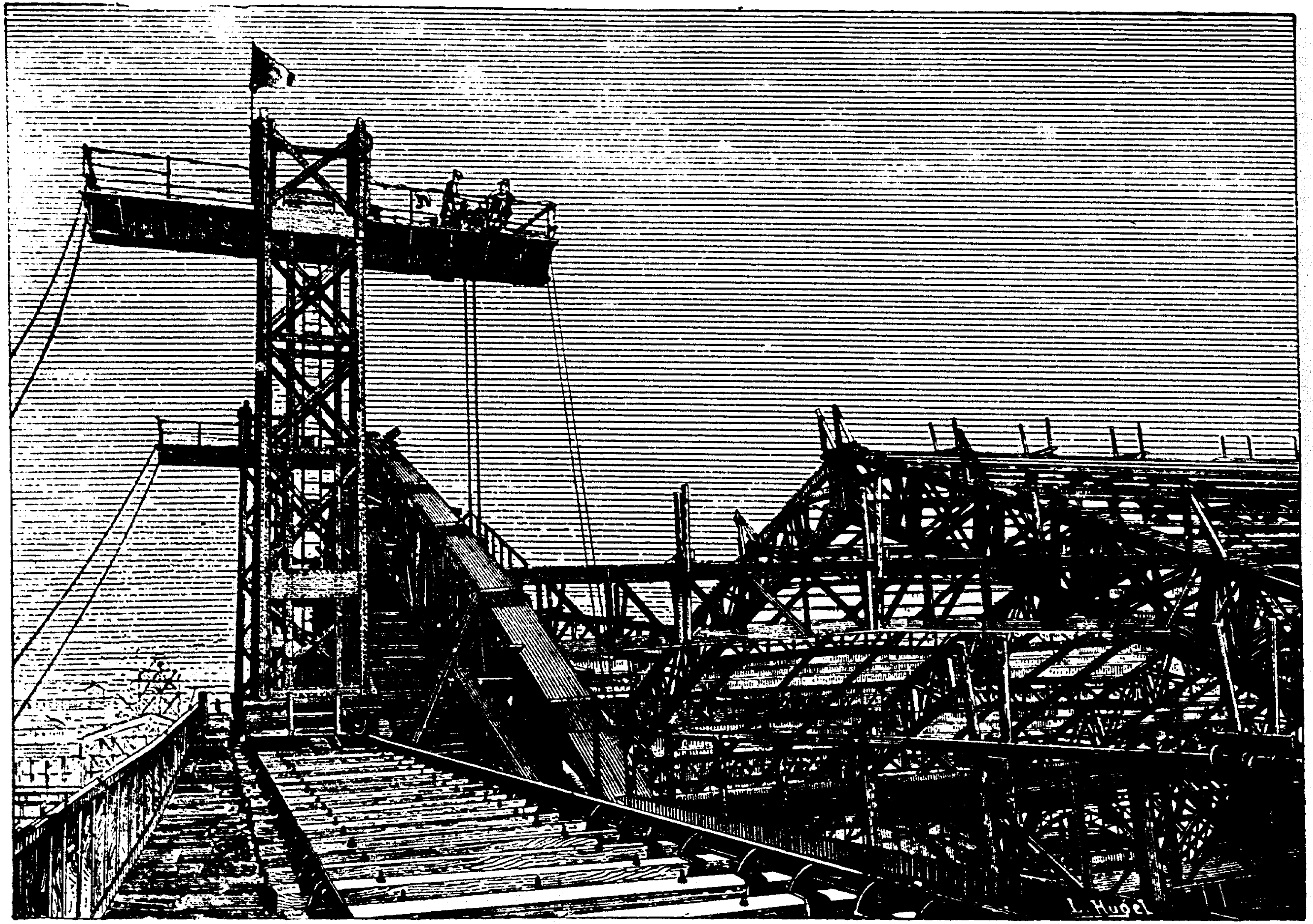


Fig. 272.—Erection of the great truss girders. Method used by Cail & Co. One of the upper platforms of the rolling scaffolding.

as all the rails were marked in divisions, it was possible to correct, from time to time, irregularities in the motions of the different stagings. The shifting of the scaffolding for one bay occupied not more than 1½ hours.

In addition to these scaffoldings there were two large traveling cranes, 8 meters by 6, and 28 high, running on tracks laid outside and parallel to the axis of the nave.

(385) *Process of erection.*—After bolting down and adjusting the bed plate, the bearings, etc., they proceeded to erect the bases of the

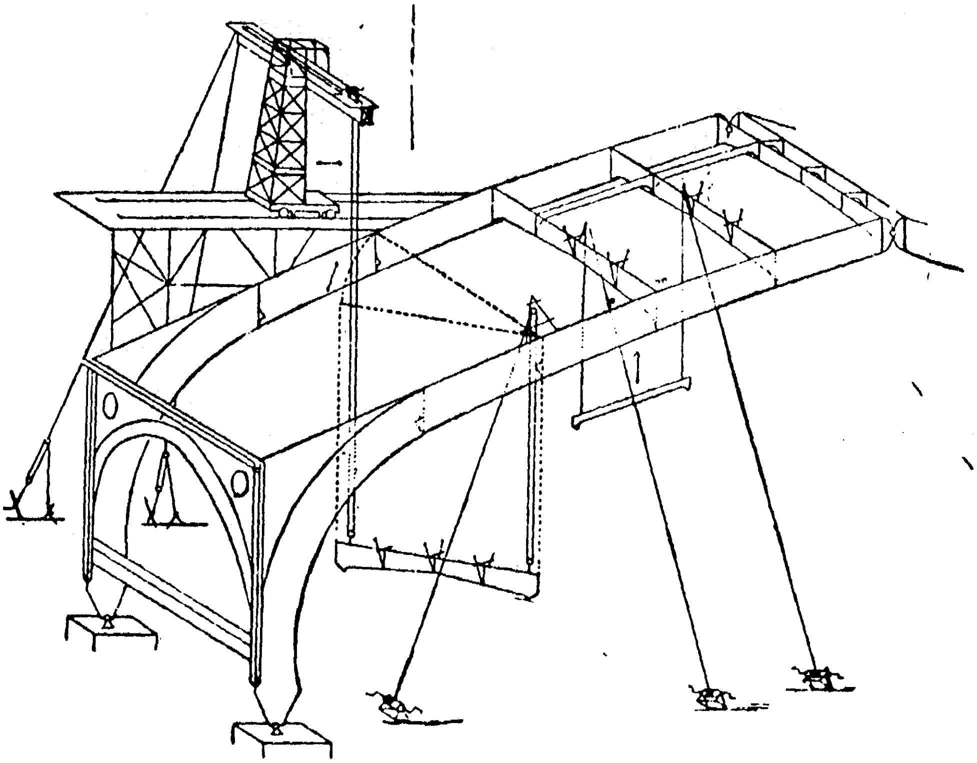


FIG. 273.—Method of erecting the purlins adopted by Cail & Co.

girders by building around the pier a staging which was capable of holding a flooring at any height below the gutters; pieces, brought by cars, were taken by the cranes, carried up, and fitted; a gang of riveters followed the fitters as the work went on, to the level of the gutters. The cranes were then moved on to the next pier and the operation repeated.

During this time the traveling cranes on the great scaffolding (Fig. 272) raised and placed the other pieces of the arch which were first secured, then bolted together. The two half arches rose progressively together to the upper joint; at intervals the intrados plate was supported on pairs of jacks, thirty-two for the whole girder, which was thus held a little above its final position so as to leave a little play at the joint. When the riveting was finished the half girders were dropped into their proper position and the connecting collars bolted on.

(386) *Erection of the purlins and rafters.*—Figure 273 shows the method by which the purlins and rafters were placed. One end of the purlin was made fast to the chains of the travelling crane, the other end to a rope from sheers erected exactly in line with the definite position of the purlin. The crane was moved out of line as the hoisting went on, until the purlin had cleared the flanges of the girders, the crane was then brought back and the purlin lowered into its place. At the time of lowering the purlin, an aperture was made in the scaffold flooring by taking up some of the planks, which were replaced when the operation was finished.

The rafters were raised in a similar manner. To each purlin were fastened six outriggers, coupled at the right of the angle irons fastening the rafters; these outriggers carried pulleys over which ropes passed to winches on the ground. The rafters, like the purlins, were raised by these winches.

As before stated, there were 32,000 rivets; of these 4,000 were driven in the workshop, 8,000 on the ground, and 20,000 upon the scaffoldings.

The average number of workmen was 215.

The first girder and bay were completed on the 24th of May; the second and third girders and bays required 13 days each; the fourth and fifth 12 days each, and the rest 10 days each, on an average.

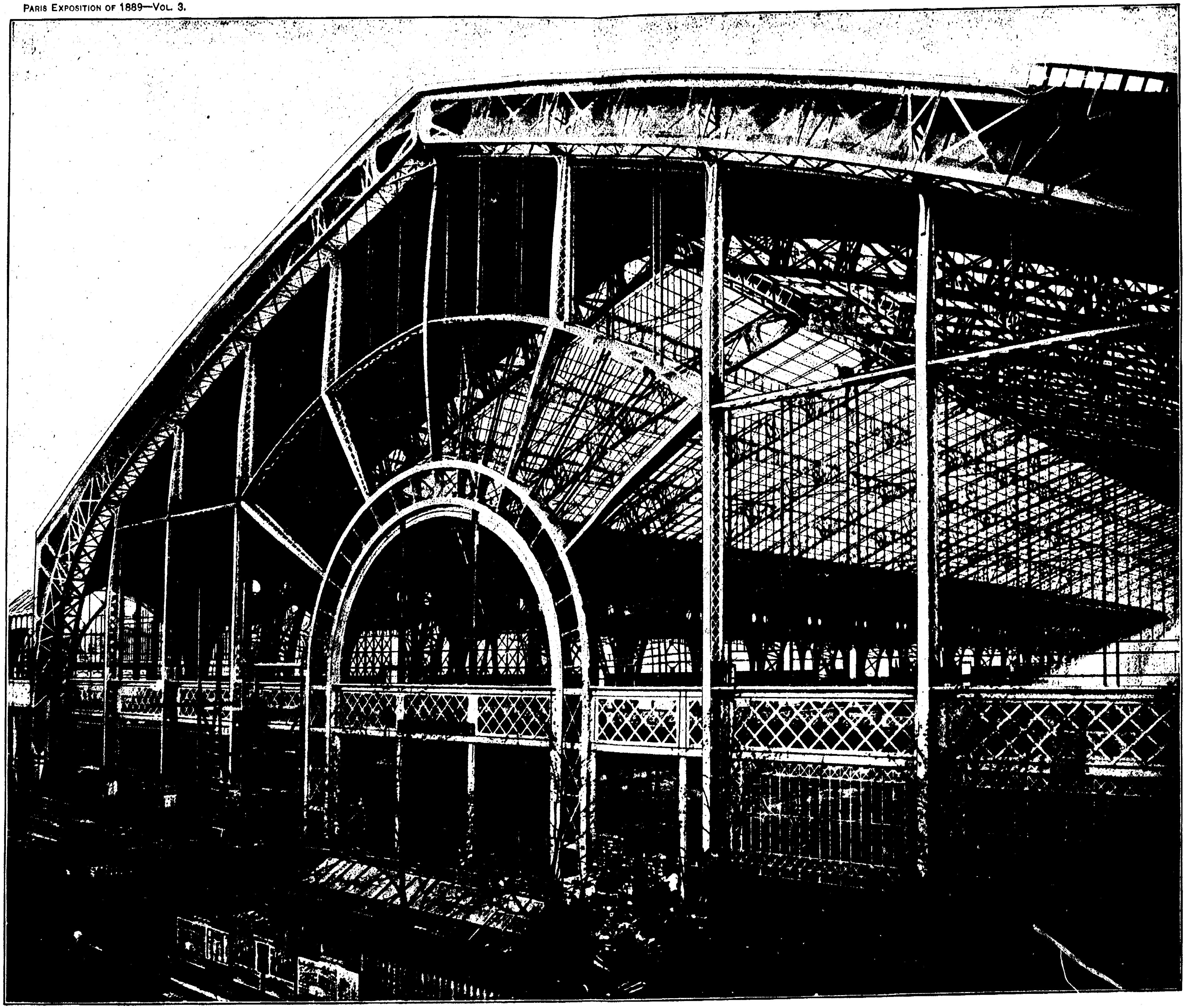
A view of the gable in process of construction is given in Plate XIX, and a view of the interior of one end of the hall in Plate XX.

(387) *The great vestibule.*—The central 30-meter gallery communicates with the Machinery Hall by a vestibule (Fig. 274), which unites it with the lateral galleries of the great nave. This vestibule has two wings covered by hooded arches 4.60 meters wide, each containing a monumental staircase leading to the Machinery Hall gallery.

The iron framework consists of four great pillars 22 meters high, which, by means of four arches, support a belt 25.66 meters in diameter, resting on the middle of each arch. A part of the weight of this belt is borne directly by the pillars by means of struts which form, with the base of the belt, four pendant arches.

The roof is a cupola formed by sixteen curved ribs resting, below, on the belt, and converging to a second belt 10 meters in diameter, which supports the lantern. The latter also consists of sixteen ribs 0.15 meter wide, springing from the upper belt and converging to a third belt 1 meter in diameter. The ribs are braced by circular purlins, which support the sash bars and that part near the gutters which is covered with zinc.

The roof has a double glazed ceiling. A spherical glazed ceiling, hung from the curved ribs by iron rods, extends upward to a perforated circular plate suspended from the lantern ribs, serving as a



VIEW OF MACHINERY HALL, SHOWING THE END TRUSS GIRDER AND THE GABLES.

means of ventilation. This double ceiling is only ornamental; it is entirely glazed except at its lower part, and is divided into sixteen panels made up of a number of pieces of colored glass set in lead frames.

The portions of the interior of the dome and wing not glazed are decorated with paintings and ornamented plaster and ceramic work.

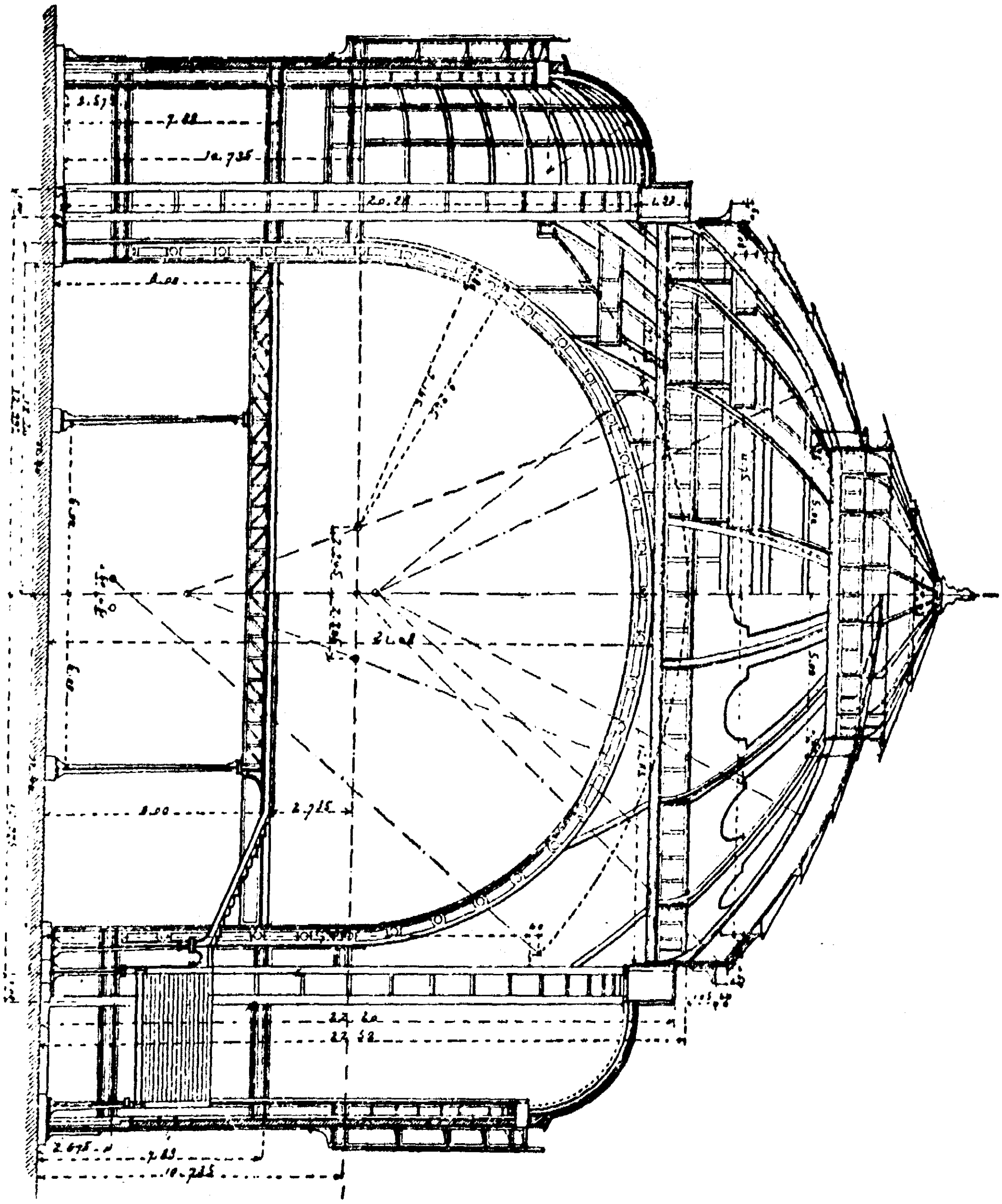


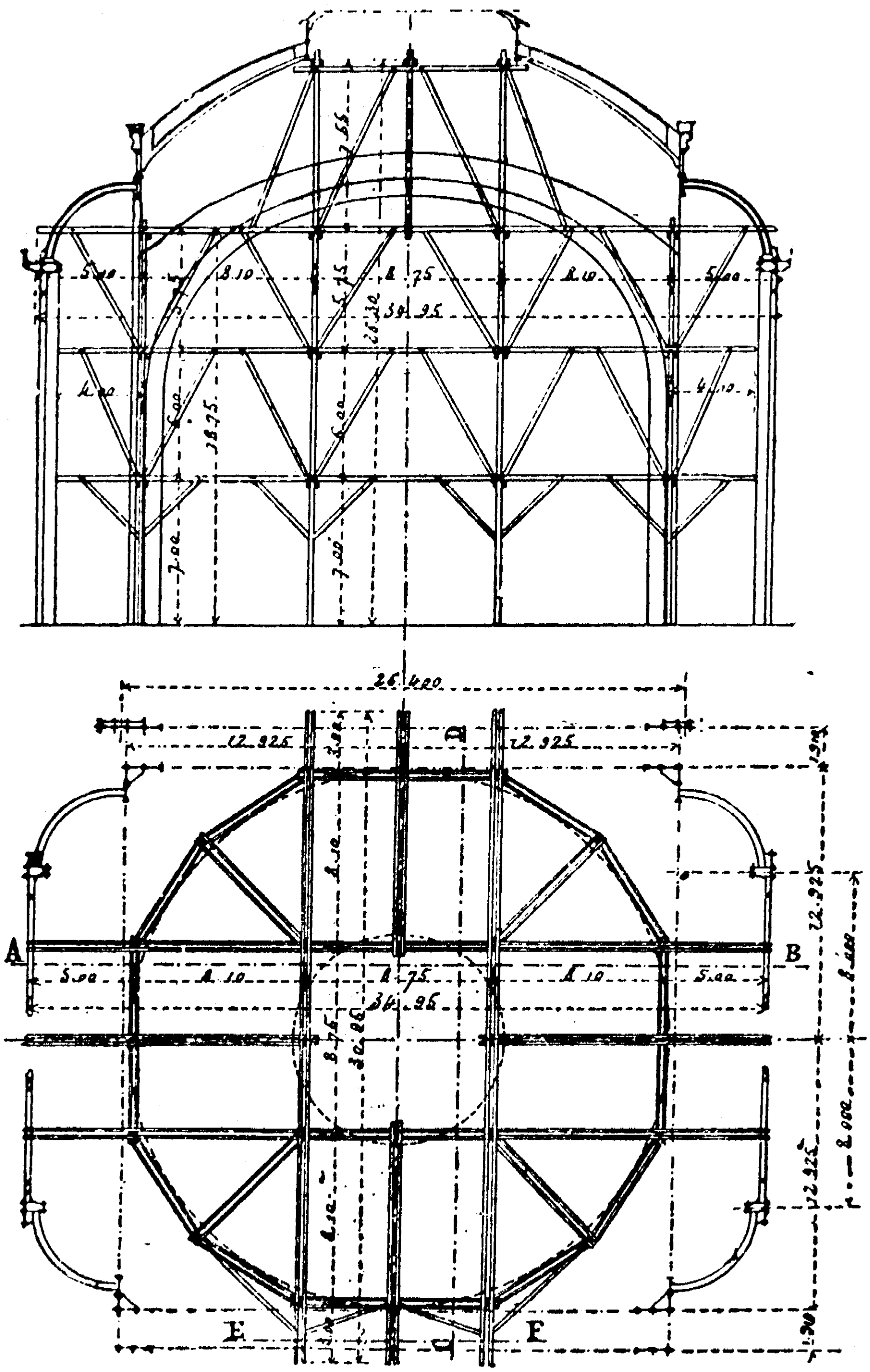
FIG. 274.—Cupola of the vestibule of the Machinery Hall. Transverse section.

The balustrade of wrought iron and bronze is a work of great artistic merit. Two bronze figures at the entrance, by MM. Cordonnier and Barthelemy, carry a group of twenty incandescent lamps.

(388) The erecting scaffolding is shown in Figs. 275 and 276; it is circular, being formed of two framed belts of the same size as those of the cupola. The exterior belt has twelve sides; it is made up of sixteen posts united by four courses of bridle pieces and double

diagonals. The interior belt is square, formed of eight posts united like the preceding ones.

The two belts are connected with each other by sixteen trestles, four of which intersect and form the sides of the interior square.



FIGS. 275 and 276.—Transverse section and plan of the scaffolding used in erecting the vestibule of Machinery Hall.

The dome was erected by means of wooden shears set up on two wooden platforms, the first 18.75 meters, and the second 26.30 meters high.

The constructors of the iron work for this pavillion were MM. Monreau, Frères.

(389) *Decoration.*—The nave is covered with ground glass fur-

MACHINERY HALL. SIDE GALLERIES.

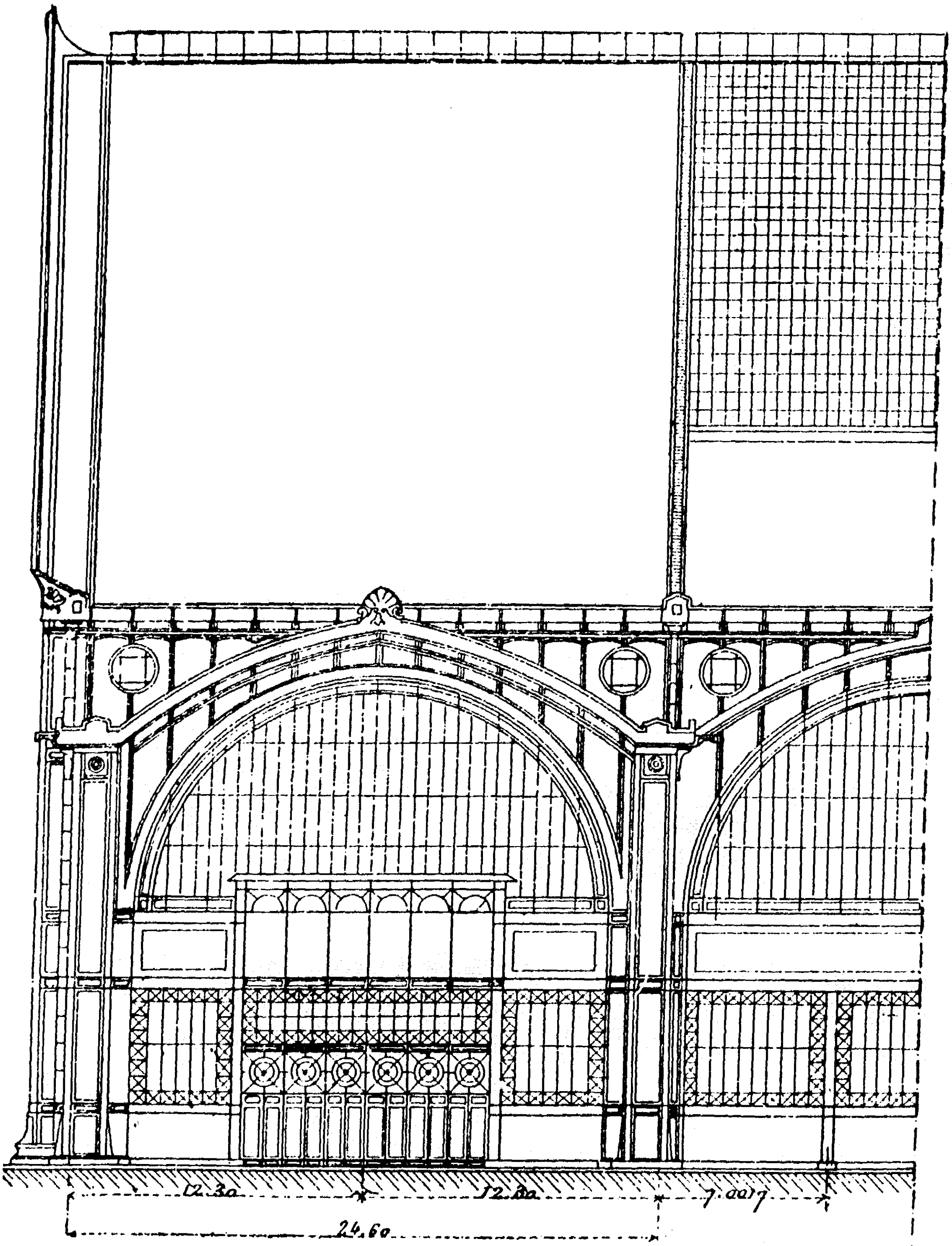
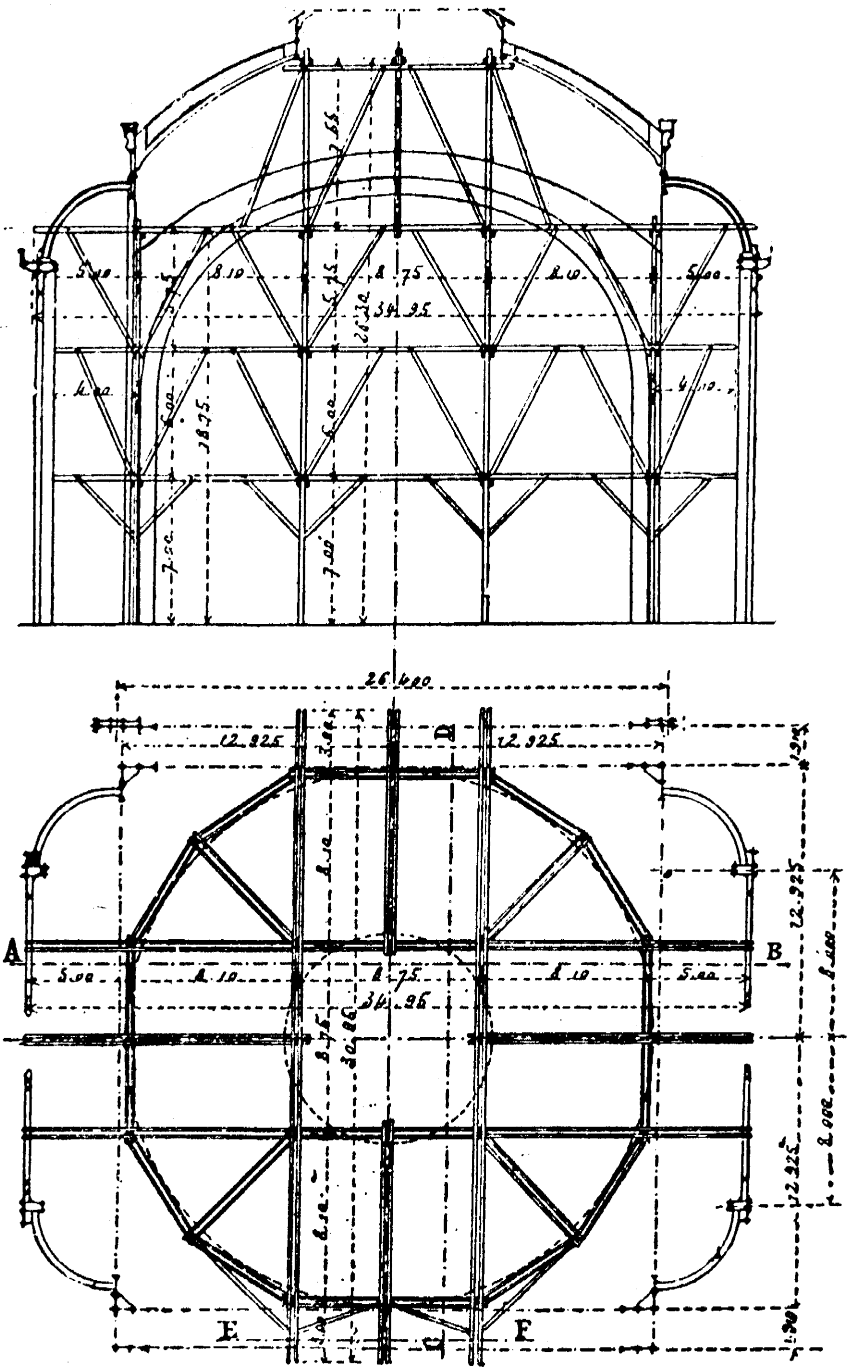


FIG. 277.—Longitudnal façade.

nished by the Saint Goban Manufactory; the lower parts toward the gutters are unglazed, but decorated with the arms of the principal diagonals. The interior belt is square, formed of eight posts united like the preceding ones.

The two belts are connected with each other by sixteen trestles, four of which intersect and form the sides of the interior square.



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MACHINERY HALL. SIDE GALLERIES.

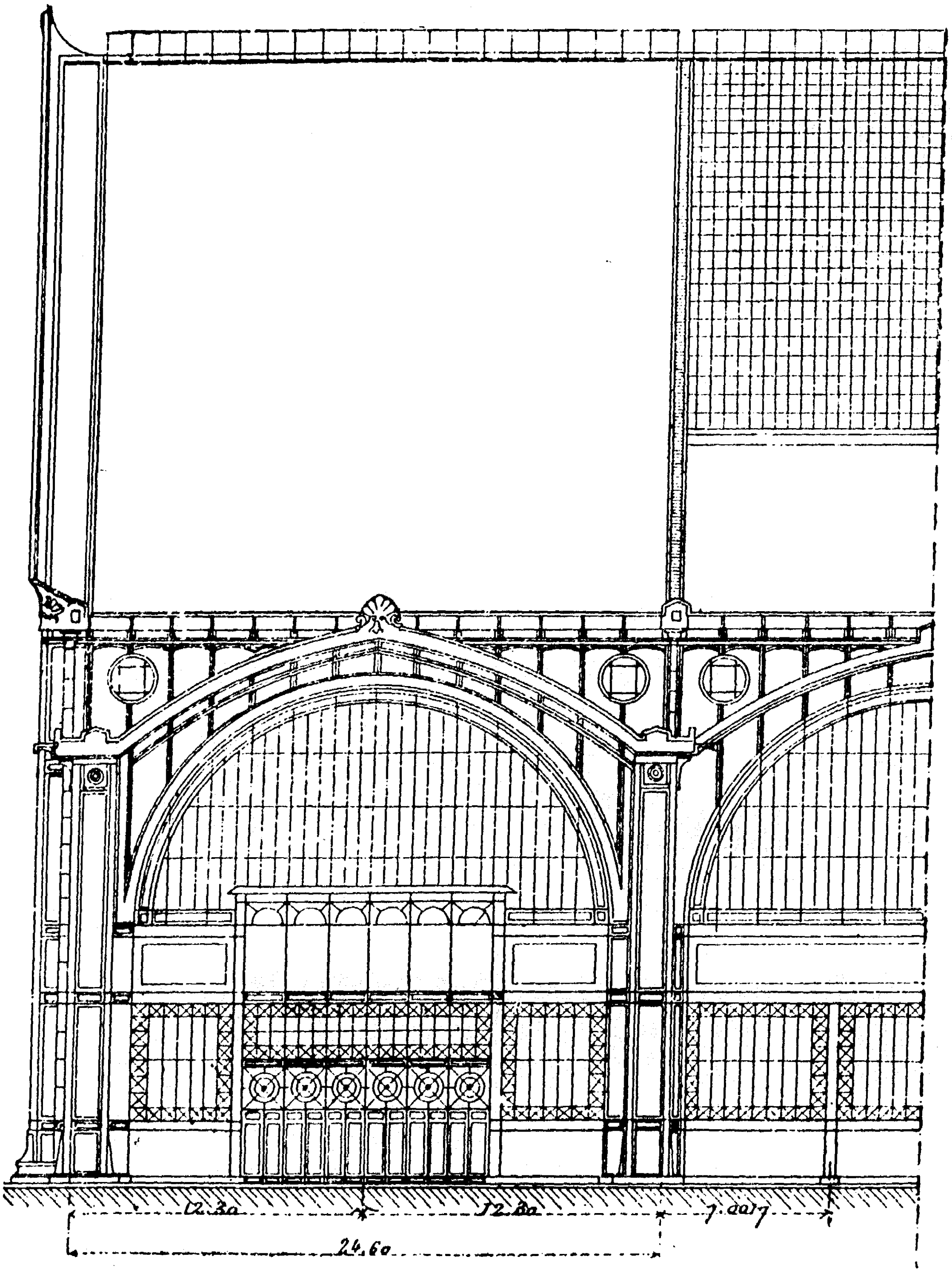


FIG. 277.—Longitudnal façade.

nished by the Saint Goban Manufactory; the lower parts toward the gutters are unglazed, but decorated with the arms of the principal cities of the world and those of the chief towns of France and her colonies.

(390) *Lateral galleries of Machinery Hall.*—Figs. 277–279 show elevations and a section of the lateral galleries annexed to the great nave of Machinery Hall. The galleries are on the two long sides of the great nave only; they are made up of a series of arches.

The first series consists of the arches situated between the great girders and united with the vertical part of the spandrel, in which is fixed the gutter purlin of the great nave. These arches brace the great girders and sustain a flush vertical portion, a sort of curtain which closes the space left between the girders above the arches.

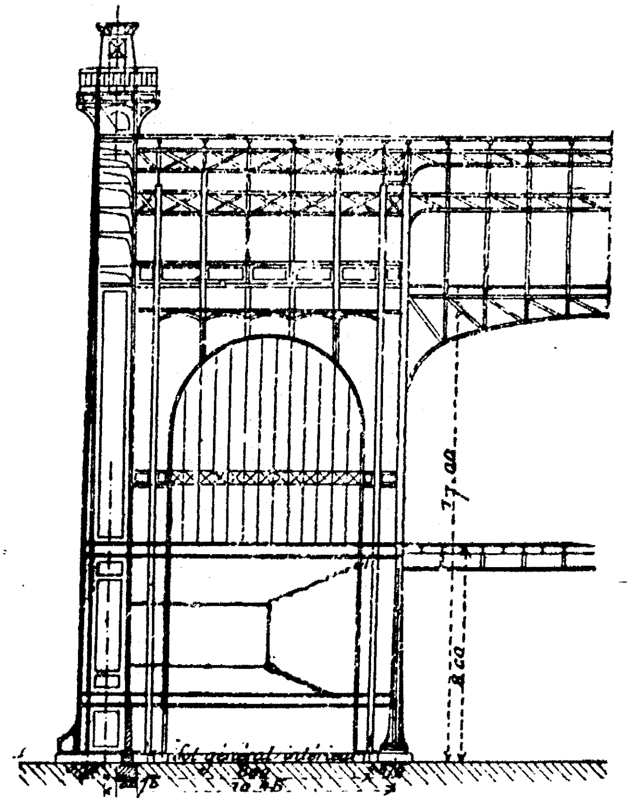


FIG. 278.—Transverse section through the crown of the arch.

The second series of arches, situated 15 meters outside the first, is identical in form with the preceding, but of a slightly different construction. The two series are united by a system of purlins and rafters supporting a zinc roofing.

The lateral galleries are divded into two stories by a flooring 8 meters above the ground; on this flooring the grand stands are placed.

The façade arches are formed of a girder with a full web.

This girder is made up of a plate cut according to the profile of the arch, having its upper and lower members formed by two angle irons $\frac{90 \text{ by } 90}{9}$ and by a plate 300 by 8 millimeters. These mem-

MACHINERY HALL. SIDE GALLERIES.

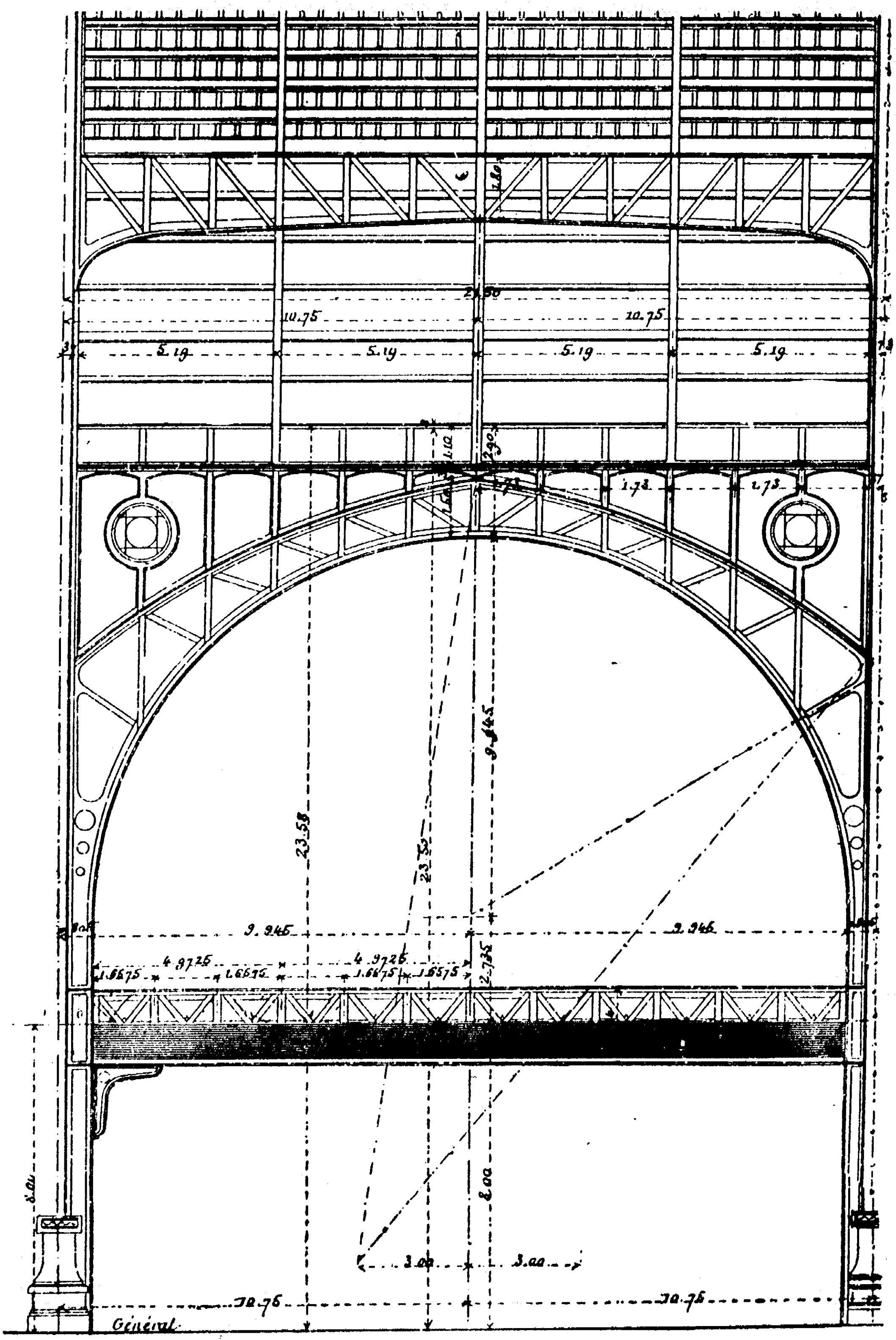


FIG. 279.—Side galleries. Lateral view from the principal nave.

bers are united at intervals by a certain number of uprights which stiffen, and serve as points of attachment for a series of brackets and angle irons supporting the upper crown of the arch.

For all the portions of the façade arches and also for the interior part, where a purlin is fixed to an upright, the uprights are formed by four angle irons.

At the interior portion of the arches of the façade (Fig. 279), and to reproduce the lattice of the arches, plate-iron bars are riveted to the girders. This lattice only serves as a decoration. The piers of the façade arches are the same as those of the interior. These piers support a horizontal girder resting on two intermediate columns. The floor beams are joined to this beam. These beams are attached on the interior side to a girder half flush and half lattice, which spans, without support, the intermediate space of 21.50 meters between the girders. Above, the horizontal façade girder the space is filled with brick, and above that, with glass to light the first story of the galleries.

The ground floor is lighted by a glazed portion situated below the horizontal girder, beginning at a distance of 0.575 meter above the ground.

The decorations of the annexed galleries, like the decorations of the great nave, are very simple, and indicate clearly the utilitarian object of the structure.

(391) The construction of the gable ends and the lateral galleries (Plates XIX and XX) was done by MM. Baudet, Donon & Co., the gable ends and galleries attached requiring over 1,200,000 kilograms of iron. One end is decorated by a great glass window, consisting of 19 panels 9 meters high, representing the battle of Bouvines.

The opposite end is flanked by two towers, and bears in relief the arms and attributes of the city of Paris. The archivolt is decorated with the arms of the principal countries taking part in the exhibition.

Plate XXI and XXII show the two groups of figures, 10 meters high, supporting the lintel of the gable, referred to elsewhere.

(392) *Weight.*

The total weight of iron used	kilograms	12,761,063
Total surface covered	square meters	62,113
Weight per square meter covered	kilograms	205.45

A GROUP OF FIGURES SUPPORTING THE LINTEL OF MACHINERY HALL, AND REPRESENTING ELECTRICITY; BY M. BARRIAS.

A GROUP OF FIGURES SUPPORTING THE LINTEL OF MACHINERY HALL, AND PERSONIFYING STEAM; BY M. CHAPU.

Cost of Machinery Hall.

	Francs.
Earthwork and masonry	592,425.54
Ironwork	5,398,307.25
Woodwork	193,760.51
Covering, lead and zinc	236,682.74
Floorings	78,591.04
Joiner's work	34,345.86
Glazing	182,242.67
Decoration	256,141.50
Painting	158,547.40
Administrative expenses, etc	190,227.66
Engineers, etc.	192,922.52
Total	7,514,094.69

(393) *Acknowledgments.*—In terminating this extended notice, I wish to express my obligations to M. Contamin, chief engineer of the building, for valuable assistance and information.

The original plans and descriptions of Machinery Hall were published by M. Grosclaude, M. Contamin's assistant, but were considerably modified (iron substituted for steel) before the structure was erected. M. Grosclaude was kind enough to correct his plans and descriptions published in Le Genie Civil and also furnish me with new drawings of the main girder and its details. The notice of the foundation and erection are from the description of M. Henard, assistant architect of the building, published in the same journal.

To Cail & Co., and especially to M. Baudet, contractor for the gables, I am indebted for photographs and for much valuable information.

PART V.—LIGHT-HOUSES.

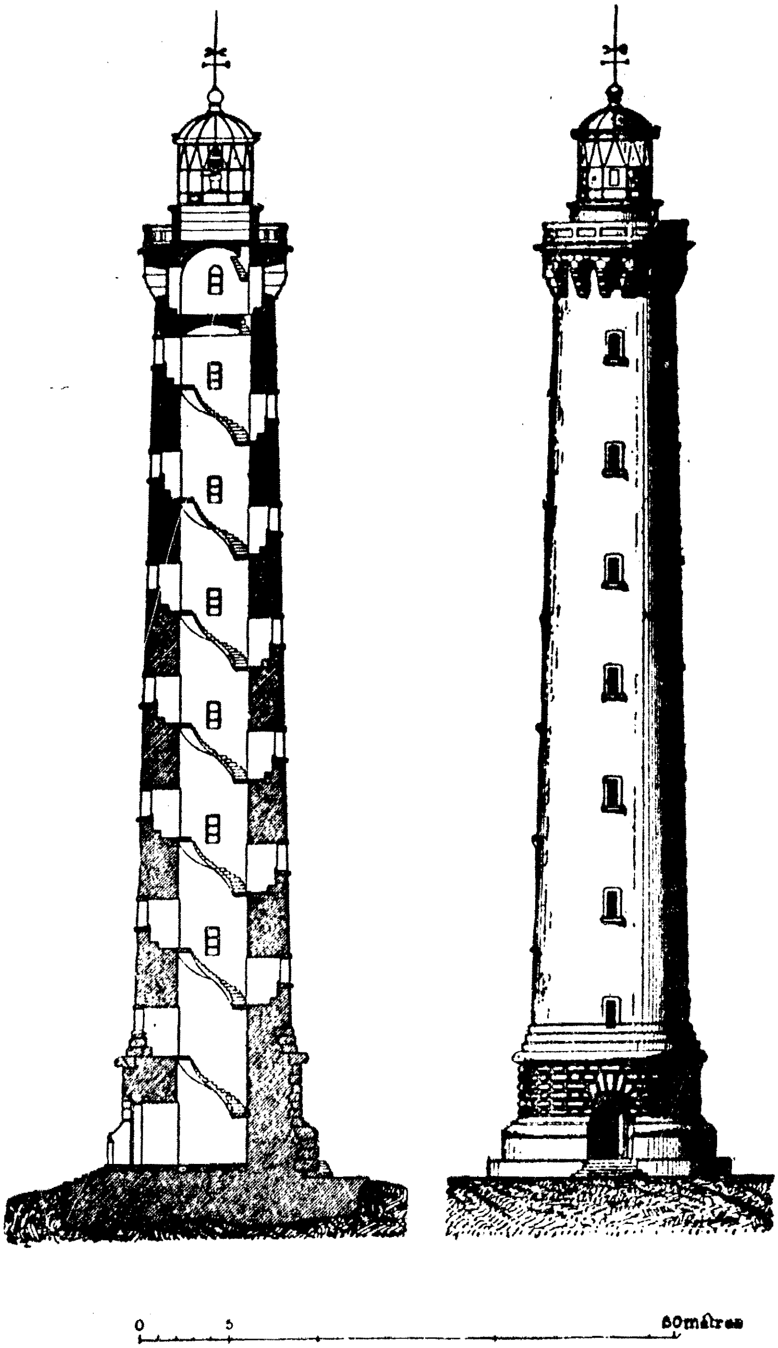
CHAPTER XLVII.—PLANIER LIGHT-HOUSE.

(394) At a distance of 8 miles southeast of the entrance to the port of Marseilles is a vast mass of rocks for the most part under water, and which emerge at one point only, where they form the islet of Planier, which is 200 meters in length from east to west and 100 meters in breadth. It consists only of rocks and has a flat surface, the most elevated point of which is only 4.50 meters above flood tide; in the heavy swells from southeast to south and west, the waves cover the islet to the approaches of the light-house tower.

The sides of the islet are perpendicular, but several little creeks exist where it is possible to land when the weather is favorable, care being taken to select one to leeward. They are, however, very small, and have not more than 1 or 2 meters of water, owing to which circumstance only small boats can enter them.

Being situated at the entrance of the bay of Marseilles, this islet has, from time immemorial, been pointed out to navigators, and an old tower on the eastern side originally served as a beacon. In 1829 it was considered necessary to establish at Planier, for the benefit of vessels making the land, a light-house which would be visible at a great distance, and a tower was constructed on the west side, on which was placed a light of the first order, eclipsed at intervals of 30 seconds, and with its focus 36 meters above the ground and 40 meters above flood tides.

Owing, however, to the immense development of the maritime commerce of Marseilles, and because, since the period of steam navigation, the speed of vessels has been augmented to such a degree, it became imperatively necessary to render the approaches of the port as conspicuous as possible, so that there need be neither error nor hesitation on the part of the commanders of vessels at a long distance from the island. It was, therefore, decided to establish here a flashing electric light, with eclipses at an interval of 5 seconds, a red flash succeeding three white flashes, having a range of about 23.04 nautical miles. To obtain this range, so superior to the old one, which was not more than 15.03 miles, the light had to be increased in intensity, the oil lighting replaced by an electric light, and the tower raised 40 meters, that is, to 63,469 meters above low tide. As the existing tower was not high enough for so extensive a range, and the nature of the construction did not admit of any addition to its height, the erection of a new tower was resolved upon, which is shown in Figs. 280 and 281. It is cylindrical in form, built of rubble masonry with hydraulic mortar. Ashlar is used only for the



Figs. 280 and 281.—Section and elevation of the Planier light-house.

revetment at the base, and for the cornice and parapet at the crown. The facing of the shaft consists of a layer of Portland cement. The staircase is of ashlar. The base rests upon a foundation platform leveled at 4.45 meters above low water. The height of the base above this platform is 8.60 meters, that of the shaft 42.44 meters, and that of the crown 5.45 meters. The focus is 59.019 meters above the platform foundation. The radii of the horizontal sections of the tower are as follows: 3.35 meters for the top of the shaft, 4.40 meters at its base, and 6.90 meters at the bottom of the basement. The interior space forming the staircase is a cylinder 4 meters in diameter. It is lighted by twenty-five windows. The stone stairway, 0.80 meter wide, stops on the two hundred and fifty-fourth step. It is prolonged by an iron staircase of sixteen steps reduced to 0.60 meter. This last goes through the arch upon which the flooring of the service chamber rests, at a height of 49.08 meters above the sill of the entrance. This chamber is lighted by four windows pierced between the brackets of the coping and facing in the direction of the four cardinal points. A second iron staircase of twenty-one steps leads through another arch to the lantern, which is contained in a little stone tower 2 meters high, which forms the base of the lantern and surmounts the coping of the light-house. The iron lantern is 4 meters diameter inside. The light-house is protected by a lightning rod.

(395) *Lighting apparatus.*—In order to avoid confusing the Planier light-house with those in the vicinity, and as the electric light is very appropriate for producing flashes, it was decided to give the new apparatus the character of a flashing light with three white flashes and one red one.

The optical system which has been adopted consists of a dioptric apparatus with a fixed light, 0.60 meter in interior diameter, surrounded with a movable drum of vertical lenses consisting of six groups of four lenses, one red and three white, making a revolution in 90 seconds. The lenses intended to produce the red flashes include a space of 30 degrees; those which give the white flashes extend only over 10 degrees; hence there is an interval of 2½ seconds between the white flashes, and 5 seconds between each red flash and the succeeding white flash. The machine which produces the regular rotation of the drum is lodged in the base of the apparatus.

The driving weight is about 150 kilograms; it descends in a pit arranged in the masonry wall of the tower and its fall is about 0.90 meter per hour.

(396) *Machinery.*—The apparatus for producing the electricity is double. It is formed of two distinct groups set up in a separate house and arranged so that either steam engine can drive either magneto-electric machine. The steam engines are horizontal, with surface condensation; having separate boilers and forming two independent systems. Each boiler is furnished with two steam pipes so that it can feed either engine. The boilers are rated at 5 kilograms per square centimeter; the power of each is 5 horse power, which can be raised to 10.

The electricity is produced at Planier by magneto-electric machines capable of furnishing a light of 85 Carcel lamps per horse power.

The current is transmitted to an electric regulator by a commutator, which allows the machines to be coupled either for intensity or quantity, and for using them successively or separately.

The ordinary light is 400 Carcel burners and can be carried to 800.

The luminous range of the flashes is 48.02 nautical miles for the ordinary atmospheric conditions. The actual geographical range is 22.02 miles for an observer at 4.50 meters above the level of the sea.

The cost was 474,776 francs.

The plans were prepared by MM. Bernard, Chief Engineer, and André, under the direction of M. Leonce Raynaud, Director of the Light-House Service.

CHAPTER XLVIII.—IRON LIGHT-HOUSE AT PORT VENDRES.

(397) To facilitate the entrance and exit of steamers plying regularly between Port Vendres and Algeria a light-house has been constructed upon the pier head erected for the protection of this port against heavy seas.

On account of local circumstances exceptional difficulties were met with in this construction.

On one hand, they were obliged to guard against the consequences of the settling of the foundations of the pier head, which was built on artificial blocks according to the usual process adopted in the Mediterranean. Again, it was necessary to arrange the edifice so as to lodge the keeper, and to resist the great violence of the waves, for the parapet of the pier head was only 4 meters above the level of low tide, entirely insufficient in great tempests to prevent the waves from breaking over it and striking the light-house.

Under these circumstances the idea of constructing a masonry light-house was abandoned, as well as one with an iron frame work, on account of the influence of the waves in causing vibrations, and loosening the screws of the tie rods.

It was finally decided to build this edifice (Figs. 282 and 283) upon six upright hollow iron pillars 14.50 meters long arranged in the form of a regular hexagon 2.20 meters on each side. Each of these uprights is formed of three parts. The lower part, which has an exterior diameter of 0.30 meter, 0.03 meter thick, is built, for a length of 2 meters, into the mass of the masonry and united by a coupling collar to the middle portion, which has the same diameter and a thickness calculated according to the stress. The upper part is screwed to the middle part, and fastened at its upper extremity to the iron floorings of the platform and the service room.

The walls of the latter are formed of plate iron, which completes the bracing. It is cased on the inside with woodwork. The floor and the ceiling are equally of wood. Access to the lantern is obtained by a spiral staircase. The risers are of cast iron, curved, movable around the newel post, and resting on four pieces which allow them to turn easily without the upper risers obstructing the motion. The steps and hand rail are removable; hence in a threatening time they are rapidly taken away, and all the risers are placed according to the direction of the waves so as to avoid almost com-

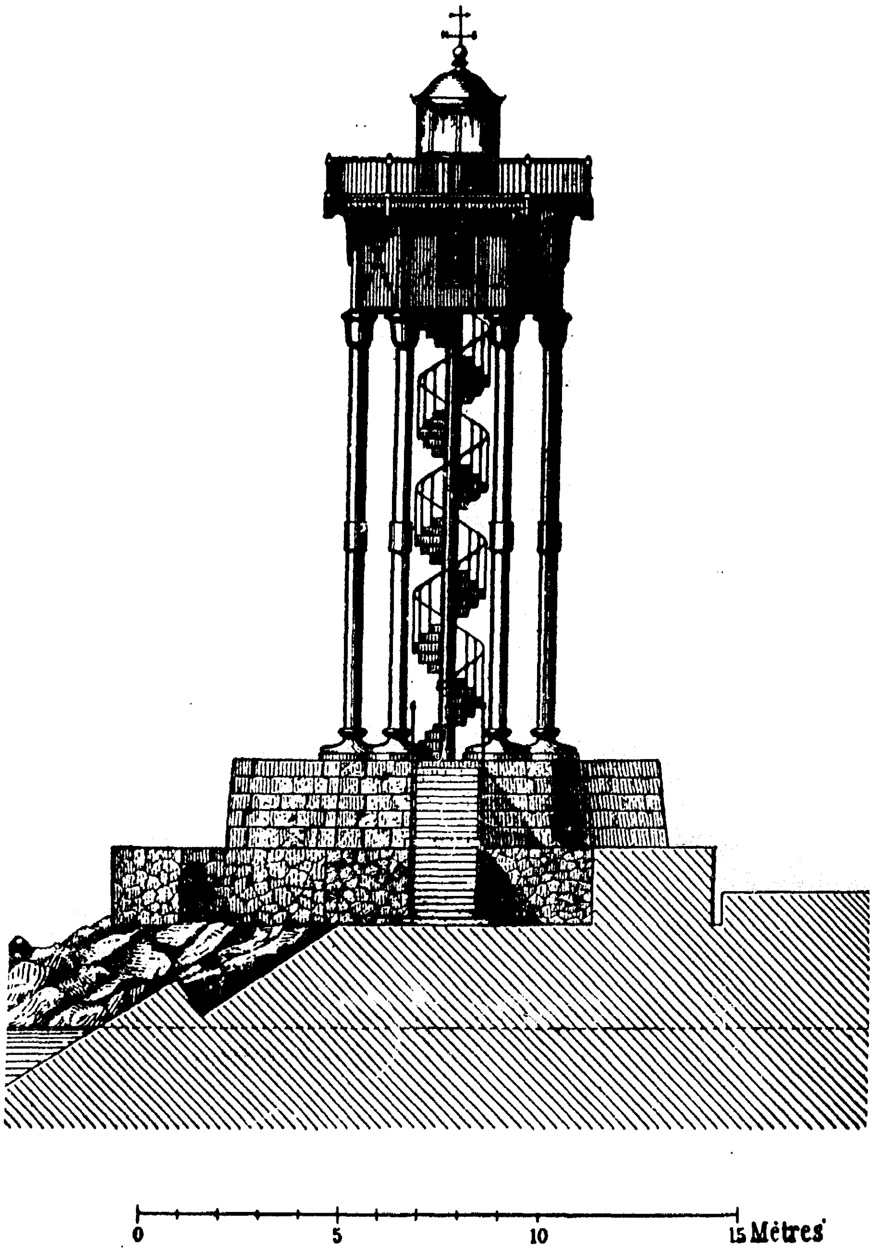


FIG. 282.—Iron light-house at Port Vendres.

pletely being struck by the waves. Under these circumstances the risers form a vertical ladder, which also gives access to the chamber and the lantern.

Arrangements are made so that the keeper may remain without communication with land during heavy weather.

For about four years the light-house has been in regular operation without accident, notwithstanding tempests of exceptional violence during the winter 1887-'88, which destroyed a portion of the jetty

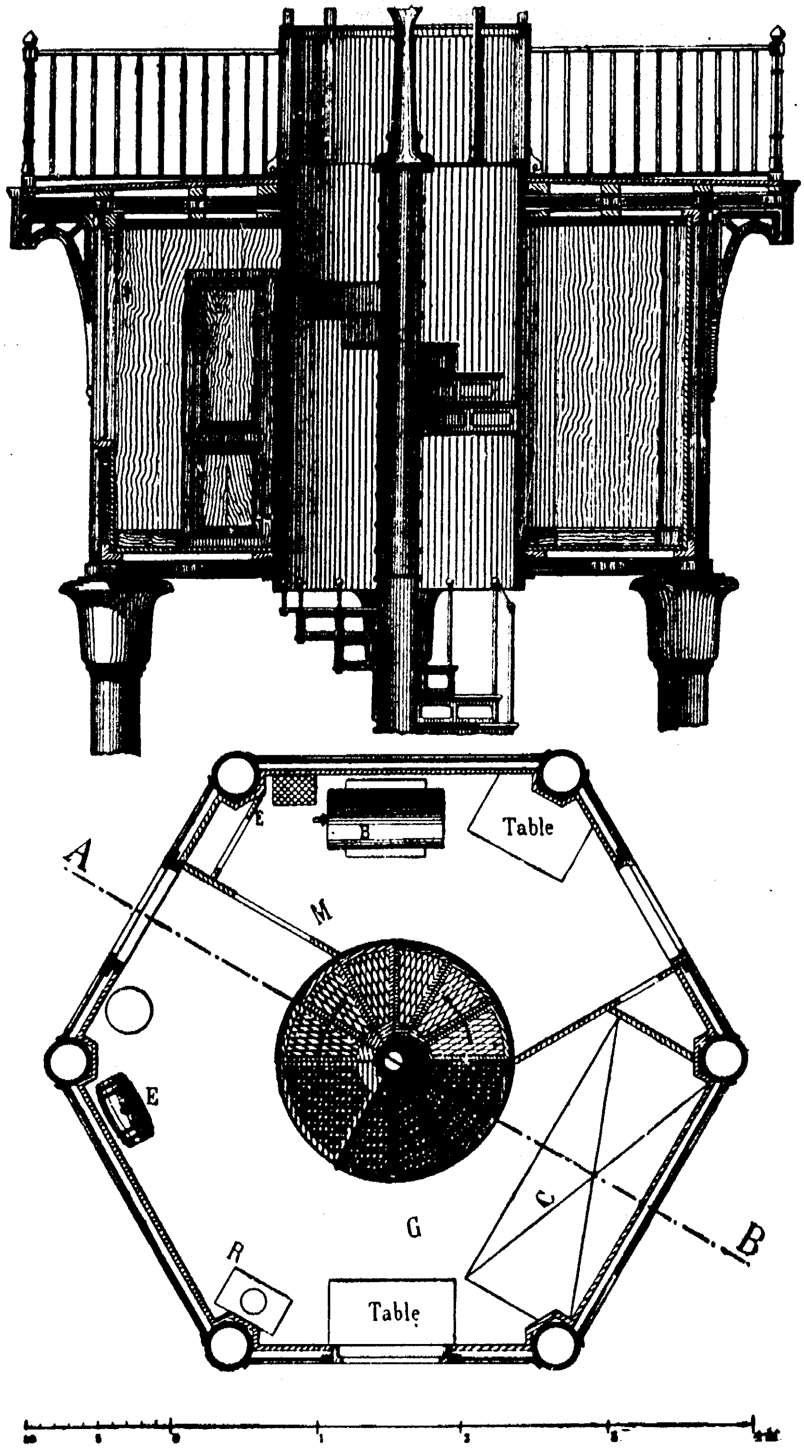


FIG. 283.—Section and plan of the lodging room of Port Vendres Light-house.

and carried away the parapet. Great dashes of spray frequently covered the lantern, put out the fire, and broke the glass in the keeper's room. Nevertheless neither the security of the service nor the stability of the construction has been endangered. The results, therefore, may be considered satisfactory in every respect.

Cost.—The cost was 59,489 francs.

The light-house was planned and erected under the direction of M. Leferme, general inspector, by M. Bourdelles, chief engineer; M. Barbier & Co. built the iron superstructure.

CHAPTER XLIX—APPARATUS, 2.66 METERS IN INTERIOR DIAMETER, CALLED HYPER-RADIANT, FOR LIGHTING CAPE ANTIFER.

(398) The apparatus for a light-house, called hyper-radiant, appears in a universal exhibition for the first time.

It may not be out of place to call to mind that the first lenticular apparatus which Fresnel made for the light-house at Corduan, in 1822, was a first-class light, having a diameter of 1.84 meters, the same as all those hitherto constructed. And although important improvements have been made in the lenses, yet there has never been hitherto an apparatus constructed of greater diameter.

M. Barbier, toward the end of 1885, succeeded in constructing a great annular lens of one-sixth, having a focal length of 1.33 meters and an angular aperture of 65 degrees in the vertical plane. This lens was tried at South Foreland in 1885, and compared with the greatest of the lenses of the first order, and especially with a lens of English construction similar to that of the new Eddystone Light-house, a lens of 0.92 meter focal distance, which occupies equally 60 degrees in the horizontal plane, and subtends an angle of 92 degrees in the vertical plane.

Photometric measurements made by Prof. Harold Dixon, of Balliol College, Oxford, on the 13th of October, 1885, showed that the illuminating power of the lens of 1.33 meters focal length compared to the Eddystone lens (the two lenses illuminated by the same lamp) was, for the first series of experiments, as 62.2 to 31.8, and for the second series, in the ratio of 28.9 to 13.7.

If we consider that the lens of the Eddystone type has an angle of 92 degrees in the vertical plane, while the latter, corresponding to the lens of 1.33 meters, has only 65 degrees, we see that the illuminating power of this last is not simply twice but nearly three times as great.

This apparatus was shown in the pavilion of the minister of public works.

(399) *Apparatus for Cape Antifer.*—The first hyper-radiant apparatus to be placed on the French coast will be for the new light-house on Cape Antifer, near Havre (Fig. 284). The optical apparatus which is 2.66 meters in interior diameter, consists of six annular panels each one occupying a sixth of a circumference and including

twelve lower catadioptric elements, ten upper dioptric intermediate elements, and twenty-six upper catadioptric elements.

The optical apparatus is placed on a cast-iron frame formed of six

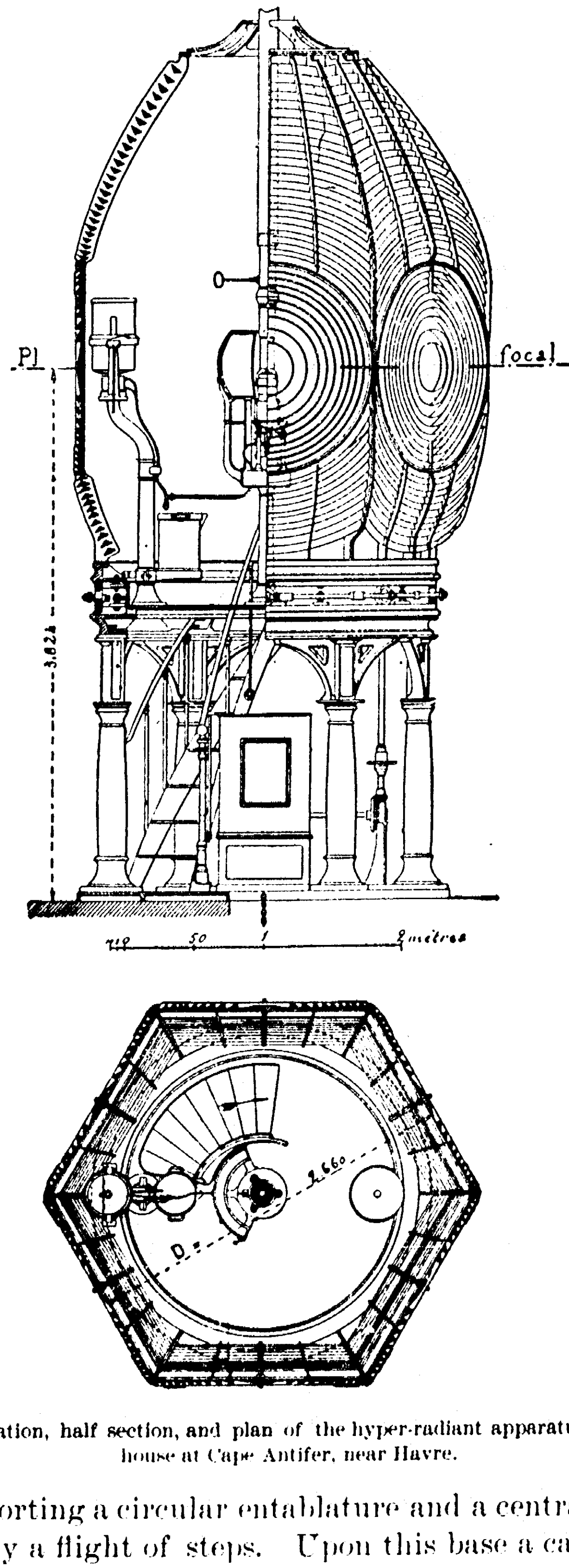


FIG. 284.—Half elevation, half section, and plan of the hyper-radiant apparatus for the new lighthouse at Cape Antifer, near Havre.

columns supporting a circular entablature and a central table which is accessible by a flight of steps. Upon this base a car with conical steel wheels carries the frame of the apparatus, of which the base is formed by a movable plate with its toothed circumference gearing with the pinion of the driving machine. The clockwork of this machine turns the apparatus completely in 120 seconds, so as to produce flashes every 20 seconds, followed by total eclipses of the light.

The machine has an automatic break and an electric alarm for the slowing and stopping, as well as an arrangement for winding up the weight without interrupting the rotation. This apparatus will presently be described.

The cost of the apparatus was 94,000 francs.

CHAPTER L.—IMPROVEMENTS IN THE APPARATUS FOR LIGHT-HOUSES USING MINERAL OIL.

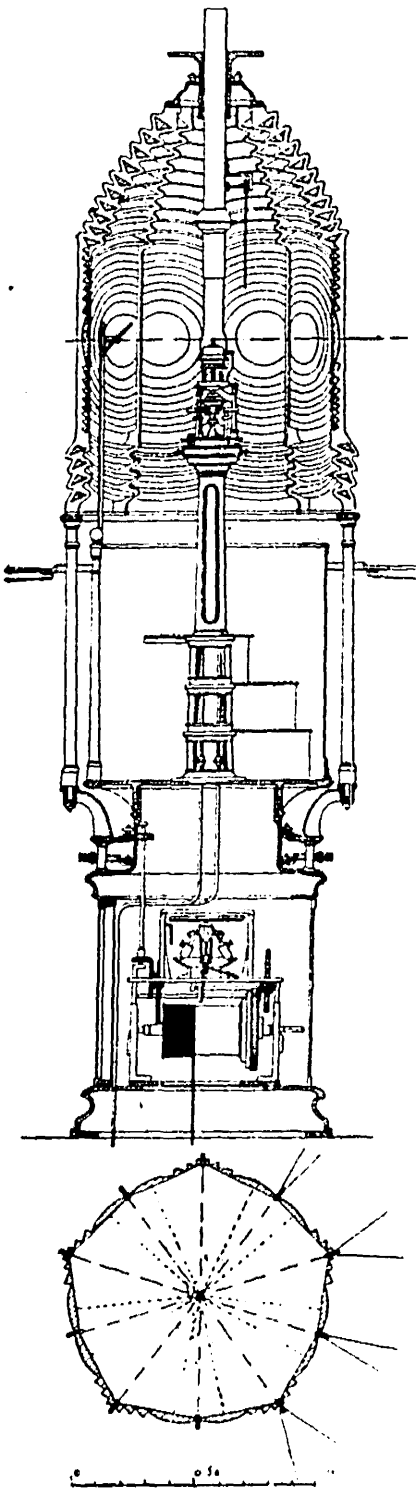
(400) The reconstruction of the Faraman light-house and the introduction into the new edifice of a flashing light of the third class, afforded an opportunity for bringing together the different improvements which have recently been introduced into several French light-houses burning mineral oil. These were shown at the exhibition.

Multifocal optical apparatus.—It is the general custom to construct the dioptric elements of the annular lenses and the cylindrical and vertical elements, employed in the optical apparatus of light-houses, with a common focus. The same rule is applied to the catadioptric rings, and there has been hitherto only one exception.

This manner of proceeding would be required if the lenses were formed of a single piece, but it can not be justified for those in echelons or steps in use in light-houses, and still less for the catadioptric rings; for the elements which compose them must be calculated and constructed separately. It is easy to perceive that it does not realize either the maximum useful effect of the light, nor the best distribution of the light upon the surface of the ocean, and that these results can not be obtained except under the condition of assigning to each element a special focus placed in the most favorable position.

By determining thus the different foci of the elements of a cylindrical lens we find that they should be taken upon the axis of revolution above the focus of the central lens and at a height increasing with the distance of the elements from the focal plane of this lens.

This method of distributing the foci is not adapted to the annular apparatus the elements of which are obtained by revolution around a horizontal axis; but it is easy to recognize that one may realize the desired effects by taking the foci on this axis, as in the preceding case, with this difference: that the elements situated above the central lens have their foci to the left of that of the lens, and the lower elements to the right. In virtue of these arrangements the contiguous edges of two successive rings are formed of two concentric circles of the same radius, which come together and unite perfectly without either space between or superposition. We thus avoid the defects of the ancient annular pieces of apparatus, at the place of contact of the dioptric elements with the catadioptric rings, which have a distinct focus placed outside of the axis of revolution.



FIGS. 285 and 286.—Vertical and horizontal sections of an apparatus lighted with petroleum oil.

Thus multiplicity of foci does not complicate either the calculation or the optical construction, and presents, consequently, advantages without any inconvenience.

The new apparatus of the Faraman light-house is multifocal. It consists of five panels, each formed of two unsymmetric lenses, having their principal axes at an angle of 23 degrees. Its flashes are thus emitted in groups of two. In each group they last a second, and are separated by a little eclipse of two seconds. A great eclipse of six seconds separates each group from that which precedes and follows it. The apparatus revolves once in fifty seconds.

(401) *Spherical reflector.*—As the Faraman light illuminates only half of the horizon, it becomes convenient to utilize the light lost on the land side and to send it toward the sea by means of a spherical reflector. But it has not been judged necessary to give to this reflector a radius sensibly equal to that of the lenses as has been hitherto done. It is easy to see that the result to be obtained is independent of this radius, and that one can reduce without inconvenience its length according to the convenience of the service or of the construction.

Under these conditions it is easy to make the reflectors of molded, or even of blown, glass with great economy; a slight retouch by grinding, suffices to assure the proper regularity of the interior and exterior surface; the latter is then silvered and covered with a protecting varnish. Reflectors are thus made, at little expense, which utilize about a third of the incident light, and are easily placed in all optical apparatus.

(402) *Clockwork.*—The clockwork and the frame have been the object of various improvements, many of which have been introduced in France. Among these we may mention:

First. The substitution of conical wheels for spheres, previously used, for the rolling chariot.

Second. The winding apparatus for the weight, permitting this weight to be raised without stopping the machine.

(403) *Automatic brake and regulator.*—That the rotation shall be uniform, requires the action of the weight to be always equal to the passive resistances which it has to overcome. When these increase

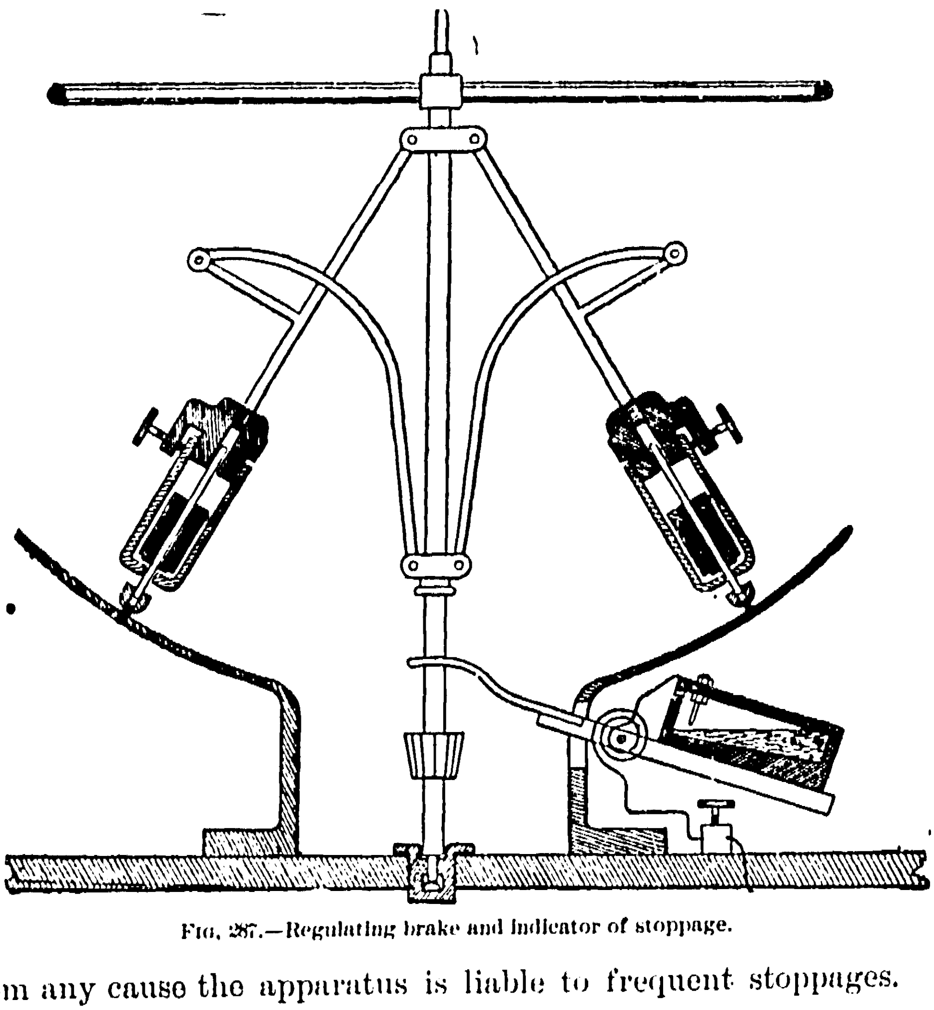


FIG. 287.—Regulating brake and indicator of stoppage.

from any cause the apparatus is liable to frequent stoppages. To obviate these we must:

First. Give the moving weight an extra load which shall render it capable of putting the machine in motion and overcoming the friction of its parts at the beginning.

Second. Counteract, during the motion, the effect of this extra load, which tends to accelerate the velocity.

The combination has been realized by means of a conical pendulum (Fig. 287), each arm of which is furnished with a stirrup pierced with a hole, in which a properly balanced rod can slide. This rod carries at its lower part a wooden or a cork button, which rubs upon the interior surface of a spherical segment when the speed of rotation brings the arms of the pendulum to their normal distance apart. The friction ceases automatically when the arms approach each other in consequence of the rotation becoming slower or stopping. In the latter case a stop prevents the rod from descending and the center of the segment is situated a little above that of the circumference described by the button when the rod rests upon its stop.

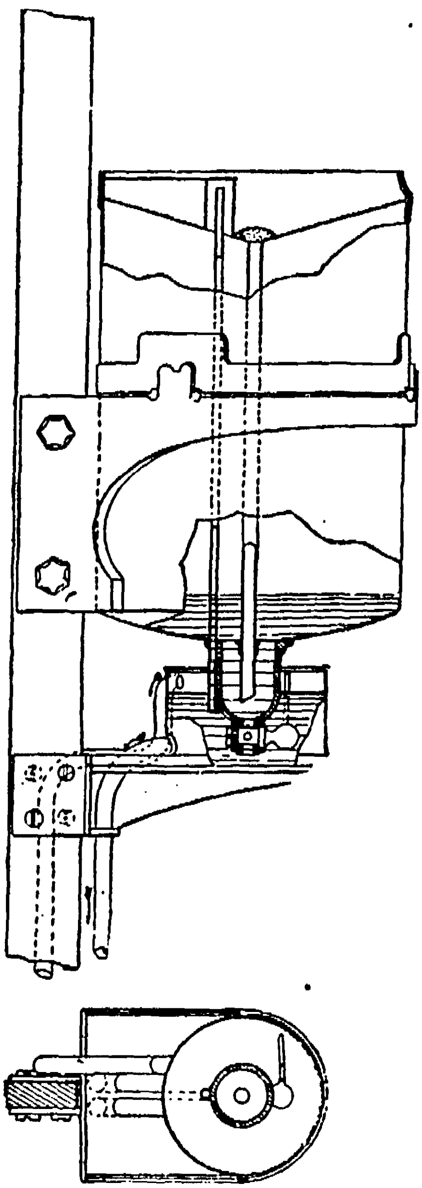
With this arrangement the surcharge is free if the machine is at rest, and its action determines the motion, which accelerates until the branches of the pendulum have taken their normal distance apart. At this moment the work of the load is equalized by that of the friction, on account of the path which the button describes upon the segment and the pressure exerted by the loaded rod on account of the centrifugal force. The movement then becomes uniform, and the rotation is maintained in the required conditions as long as the passive resistances remain constant. If they diminish slightly the rotation is accelerated, the distance apart of the pendulum balls. as well as the work of the friction increases, and the uniform motion is reëstablished. It is the reverse in the case where the resistances increase. The brake works thus as a regulator and has great sensibility.

It is evident that in varying the load and the path of the rods this arrangement will accommodate itself to all the motions of the clockwork.

(404) *Electric indicator of the stoppage of the apparatus.*—These machines, notwithstanding the intervention of the brake, may, notwithstanding, stop, if the keeper is negligent, and especially if he forgets to wind up the weight at the proper time. It has therefore been considered prudent to signalize such an accident by an electric bell. It is put in motion by the arms of the pendulum when they fall on account of the slowing or stopping of the machine. Their weight then overturns an ebonite box containing mercury. This liquid closes the electric circuit having its two poles in the box.

(405) *Constant level lamp.*—The old lamps have been replaced by lamps on a new model with a constant level. They consist of a cylindrical copper reservoir furnished at its lower part with a neck which can be opened or shut at will with a cock. A central tube, open at its extremities, passes through the bottom of an upper compartment of the reservoir. arranged like a tunnel, and descends to the lower part of the neck. Another vertical tube emptying on the exterior of the neck rises to the upper part of the reservoir, with which it communicates. The neck dips into a little tank, from whence starts the feeding tube for the wick and that of the overflow.

To fill the lamp, the cock in the neck is closed and the oil is poured upon the funnel, and runs into the reservoir by means of the central tube, driving the air into the lateral tube, whence it escapes into the atmosphere. When the reservoir is filled the cock is opened, the oil flows into the tank until its level has attained the lower orifice of the central tube, that is to say, a constant level.* From this moment the central tube is empty, the lateral tube is full up to the level of the oil in the reservoir, and the lamp is ready to work. If we open the wick cock it may be lighted. As the oil is consumed its level lowers in the tank and opens the orifice in the central tube by which air escapes, making the requisite quantity of oil flow into the tank so as to reëstablish the constant level.



FIGS. 288 and 289.—Elevation and plan of a constant level lamp.

The lamp is fixed upon one of the uprights of the lantern.

It communicates with the wick by means of tubes which pass under the frame and rise in a central column which supports the burner. This arrangement makes the service easier, especially for apparatus of small dimensions, like those of the third class. It avoids all the inconveniences of moderator lamps and properly feeds the wick.

Cost.—The expense of the apparatus for the Faraman light-house amounts to 23,300 francs.

M. Bourdelles, engineer in chief of the service, made the plan under the direction of M. Emile Bernard, general inspector and director of the light-house service.

CHAPTER LI.—IMPROVEMENTS RECENTLY MADE IN ELECTRIC LIGHT-HOUSES.

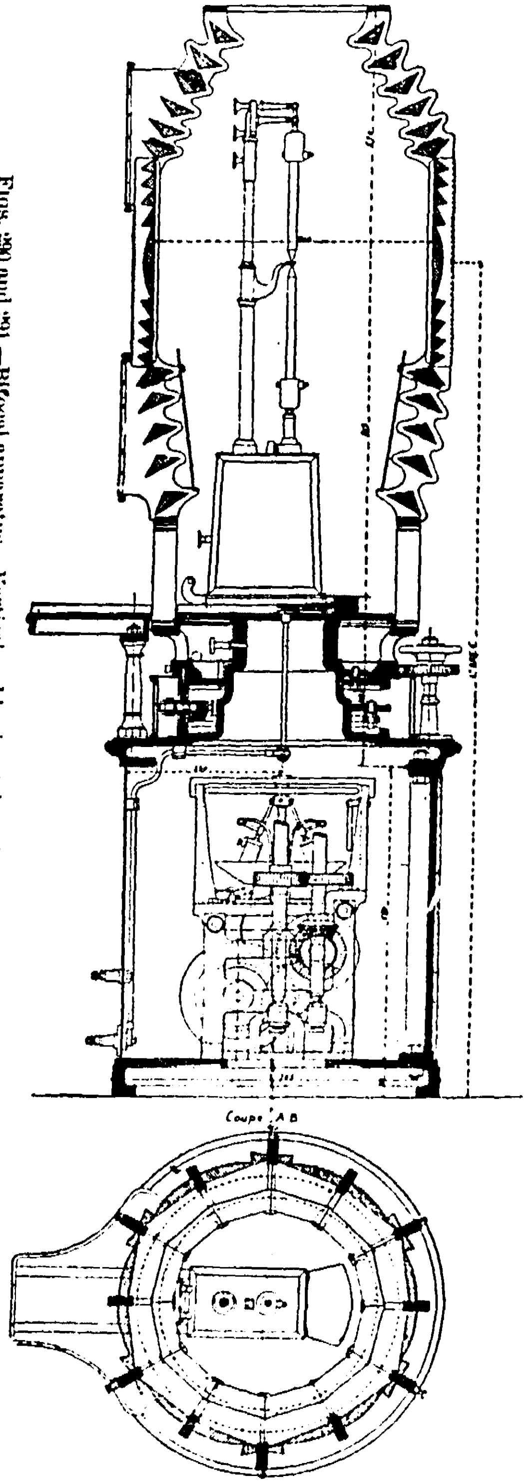
(406) Important improvements have been recently made in the electric illumination of the French coast. This illumination is confined at present to eight important points, viz, Dunkirk, Calais,

* When the lower cock is opened the air in the reservoir is slightly rarified, by the oil passing into the tank. The outer air enters the central tube and clears it, and as the oil rises it is forced up the lateral tube as high as the level of the oil in the reservoir.

Gris-Nez, La Canche, La Hève, Créach, Les Baleines, and Planier. Five others are in process of erection.

Bifocal apparatus.—The small dimensions of the optical apparatus

RECENT IMPROVEMENTS IN ELECTRIC LIGHT-HOUSES.



FIGS. 290 and 291.—Bifocal apparatus. Vertical and horizontal sections of an apparatus for an electric-light house.

(0.60 meter in diameter) have been preserved. The apparatus itself consists of annular unsymmetric lenses, preserving the character of the electric light (flashing with groups of two, three, or four flashes), which is thoroughly appreciated by seamen. This arrangement of the optical apparatus enables the horizontal angle subtended by the lenses to be augmented, consequently the intensity of the light increased. (Figs. 290 and 291).

The latter is still further increased by the suppression of the horizontal divergence artificially given to the lenses in the vertical elements of the old apparatus.

As to the vertical divergence, it has not been thought best to increase it artificially.

This bifocal arrangement is the most advantageous and the most appropriate for electric lighting, and it has accordingly been introduced into the new apparatus.

Caloric engines as motors have been substituted for portable engines, three, of 9-horse power, being placed in each light-house. A single one is sufficient in ordinary times, but two are used in case of fog, or to work the fog horns. The third is used as a reserve.

The magneto electric machines used are those of M. de Méritens, which have been entirely satisfactory in all respects. A number of modifications have been introduced, viz:

The arrangement of the bobbins.—Eight have been coupled for tension, *i. e.*, one-half in each of the five disks making up a magneto-electric machine. The five half disks are coupled quantitively, so as to divide each machine into two half machines having separately five groups of eight bobbins in tension. Finally, by a commutator arranged for the purpose, two, three, or four half machines may be quantitively combined.

On the other hand, it is not necessary to couple two machines when they are in use so as form a single machine. The same result is obtained by leaving them separate and driving them by a single belt. This is accomplished by interposing between the machines a short shaft, the prolongation of those of the machines, carrying two loose pulleys, so that the driving belt can be thrown on or off of either.

(407) *Working of the system.*—The system of magneto-electric machines and their accessories allows the variation of the intensity of light according to the condition of the atmosphere.

The following table shows the different intensities admitted in the service and the means of obtaining them:

Weather	Clear.	Ordinary.	Mist.	Fog.
Diameter of the carbon points, in millimeters	10	16	20	23
Number of magneto-electro machines in use	½	1	1½	2
Mechanical measures:				
Number of revolutions per minute	430	430	430	430
Horse power on shaft (*t*), circuit closed with the lamp	2.24	3.80	5.90	7.50

Weather	Clear.	Ordinary.	Mist.	Fog.
Electrical measurements:				
Intensity (I) in ampères:				
Circuit closed without the lamp	33	78	111	150
Circuit closed with lamp	22	51	74	98
Electro-motive force (E) in volts:				
Open circuit	68	68	68	68
Closed with lamp	41	42	41	44
Energy in watts (E I).:				
Circuit closed with lamp	902	2,142	3,034	4,312
Photometric measurements:				
Horizontal intensity (L) of the electric lamp in Carcel burners	160	360	500	738
Intensity of the beam of light emitted measured at a distance of 460 meters	350,000	....	....	600,000
Efficiency:				
Carcel burner power per horse power	61.3	85.3	77.6	88.5
Number of burners per ampère	6.5	6.4	6.1	6.8
Efficiency $\left(\frac{E I}{75\, g\, i}\right)$	.54	0.77	0.71	0.78

In clear weather, *i. e.*, ten-twelfths of the year, the luminous range of the new electric light exceeds 27 miles, which is amply sufficient. For the other two-twelfths the luminous range is insufficient on account of the fogs, but it is impossible to remedy this defect without an outlay entirely out of proportion to the results to be attained.

(408) *Electric regulator.*—The electric service as previously described could not employ M. Serrin's regulators except by modifying them and adapting them to the new conditions of electric lighting. This has been accomplished as follows:

The current of a demi-magneto before passing to the lower carbon point passes through an electro-magnet acting on a rod of soft iron carrying the detent which serves to separate the star wheel from the regulator. This rod is suspended from a horizontal axle around which it can oscillate. It is placed at the proper distance from the poles of an electro-magnet by means of a bent lever driven by a screw and furnished with two spiral springs acting in opposite directions. (Fig. 292).

With this simple arrangement the variations in the resistance of the voltaic arc and those of the current resulting therefrom determine the oscillation of the soft iron, the escape of the detent, and the proper distance between the two carbon points.

It may be noticed also that the new arrangement of escapement is independent of the lower carbon point. When the electric lighting requires more than one demi-magneto, the circuit of the supplementary machines is connected directly with the carbon points by means of brushes which allow the motion of the carbon-point holders, and the regulator consequently continues to work under these circumstances as if there was only one demi-magneto acting.

ELECTRIC REGULATORS AND INDICATORS.

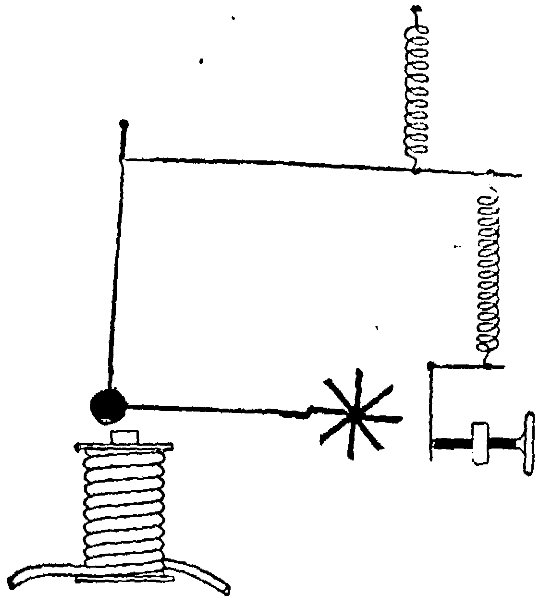


FIG. 292.—Modification of the electric-light regulator.

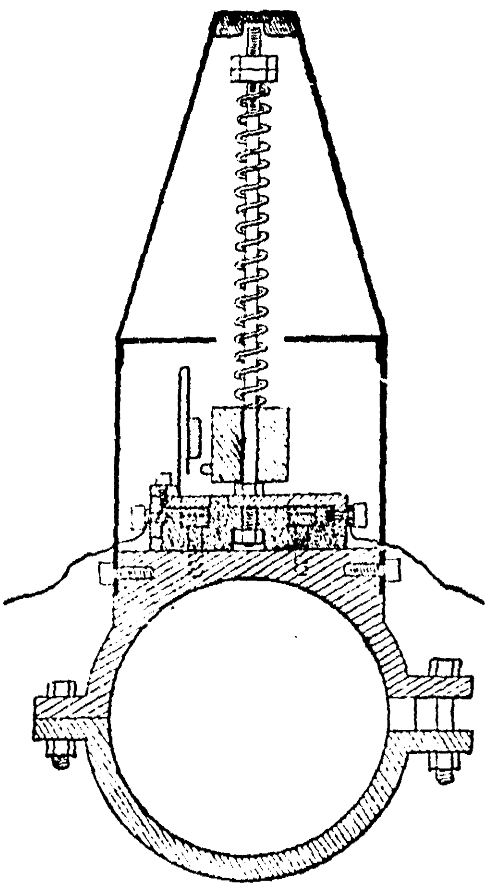


FIG. 293.—Electric indicator of the stoppage or slowing of the machines.

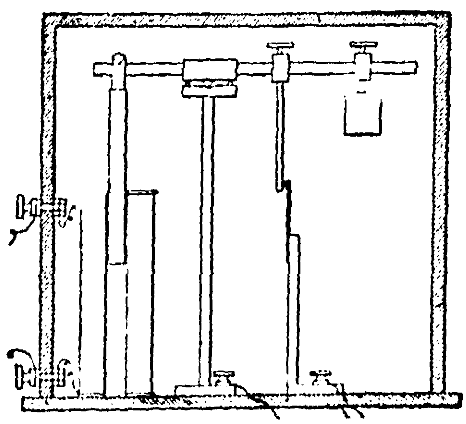


FIG. 294.—Electric indicator of the extinction of the lamp.

As to the lighting, it is done by a hand lever which separates the carbon points the exact distance requisite for the production of the arc light.

(409) *Controlling apparatus.*—The apparatus of an electric light-house is also supplemented by different instruments to indicate the working and make known the defects which may be produced, viz:

First. A Siemens electro-dynamometer to measure the intensity of the currents.

Second. An electric indicator of the stoppages or slowing of the magneto-electric machines, by means of a bell. This apparatus consists of a traveler (Fig. 293) moving by means of centrifugal force along a fixed rod attached at right angles to the axle of the magneto-electric machine, and which compresses a spiral spring in proportion to the velocity of rotation given to the machine.

When the velocity is insufficient the spring brings the moving piece into such a position that it closes the circuit of an electric bell.

Third. An electric signal, showing when the light has been extinguished. This consists of an electro-magnet with its coil in a circuit secondary to that of the regulator. If the light is extinguished the principal current is arrested and the secondary becomes capable of causing, by means of the electro-magnet, the motion of a soft iron rod arranged so as to close the current of an electric bell. (Fig. 294).

Fourth. An alarm serves to awaken the keeper when any stoppage of the machines takes place.

Cost.—The cost of the various pieces of apparatus, including the optical apparatus, the indicating instruments, three caloric engines, two magneto-electric machines, etc., is 80,000 francs.

M. Barbier constructed the optical apparatus; MM. Sautter, Lemonnier & Co., the motors, and M. Méritens, the magneto-electric machines, under the direction of M. Émile Bernard, director of the light-house service.

CHAPTER LII.—ACOUSTIC SIGNALS IN CONNECTION WITH ELECTRIC LIGHT-HOUSES.

(410) *Programme.*—It is proposed to realize in the new establishments the following programme:

First. To utilize as much as possible the personnel and machinery of the electric light-houses for working the acoustic signals.

Second. To arrange all the mechanism so as to produce the sounds when needed.

Third. To emit these sounds at a distance from a light-house under the most favorable conditions to be heard at sea.

Compressed air is used instead of steam, and all the apparatus is united in the same building under one engineer, who takes charge of the electric and the acoustic apparatus, and the three caloric engines used to drive the air-compressor.

The sirens are operated by compressed air, from a reservoir.

THE ESTABLISHMENT OF THE SOUND SIGNALS IN THE ELECTRIC LIGHT-HOUSE OF BELLE ILE AND BARFLEUR.

Fig. 295 shows the arrangement of the machinery in the Belle Ile light-house.

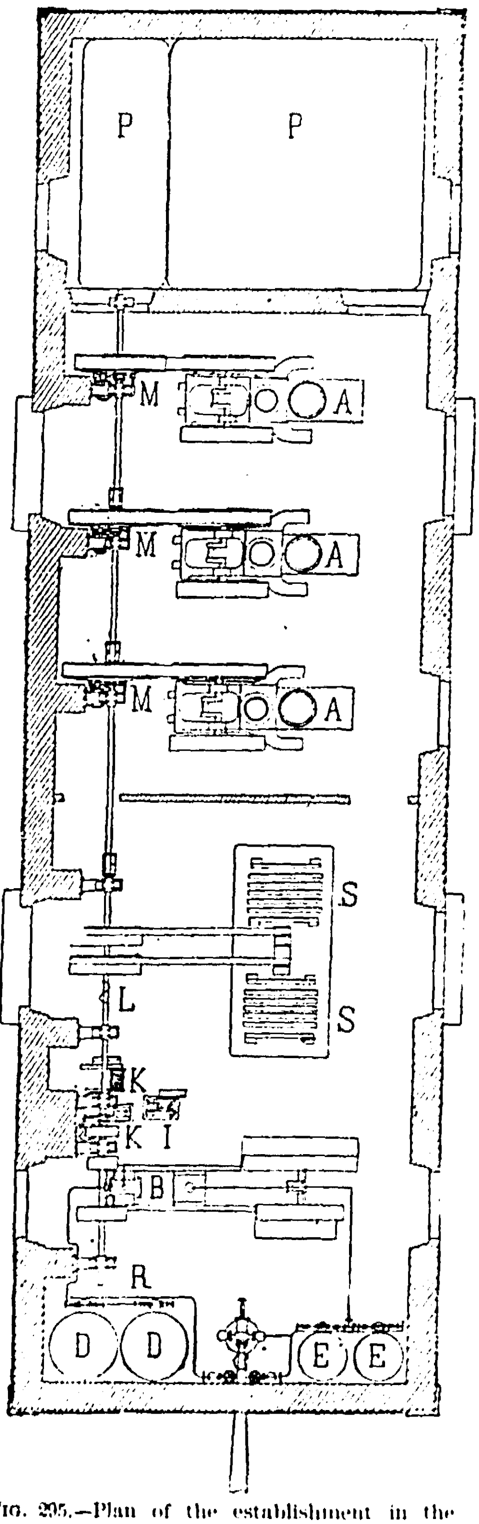


FIG. 295.—Plan of the establishment in the light-house at Belle Ile.

	Francs.
A, A, A, caloric engines, 9 horse power each	24,000
B, air-compressor, 20 horse power, with water circulation to cool it.	8,000
C, Holmes siren, with electric-mechanism for the emission and the rythm of the sounds	8,000
D, D, two reservoirs containing 4.5 cubic meters of compressed air.	6,800
EE, two distributing reservoirs containing 1.5 cubic meters	2,400
I, motor of one-half horse power.	1,100
K, Gramme dynamo to work the sirens	1,600
L, shafts, belts, etc	5,400
M, M, M, M, engaging and disengaging gear	4,100
P, P, plate iron reservoirs	2,500
R, pipes and valves	2,900
Sundries	3,200
Total	70,000

S, S, electro-magnetic machines.

This sum includes much that is required for the light-house itself. The extra expense is about 34,000 francs, without including the cost of erection.

The contractors were MM. Sautter, Lemonnier & Co., under the direction of M. Bourdelles, chief engineer of the light-house service.

CHAPTER LIII.—THE ILLUMINATION OF ISOLATED BUOYS AND BEACONS BY MEANS OF GASOLINE.

(411) It is very important for the security of navigation that there should be some means of lighting economically the beacon towers on isolated reefs. This has been successfully accomplished in the following manner.

The apparatus.—Fig. 296 consists of four burners placed in the center of a dioptic drum with a fixed light and sheltered by a cylindrical lantern. This lantern is glazed below for a height corresponding to the optical apparatus, and furnished with every arrangement requisite for ventilation and for avoiding the effects of squalls. Its upper part is closed with plate iron riveted to uprights built into the masonry of the tower. A door above the glazing allows the optical apparatus to be removed, and the burners replaced or repaired.

(412) The burners communicate with two reservoirs, each holding 225 liters and intended to contain enough gasoline to last for there months. These reservoirs are placed around the iron lantern, leaving two sectors for the service. They are sheltered from the sun, the rain, and the sea, by an iron roof, and a cylindrical cage, supported by a strong steel lattice girder which allows the luminous beams to pass through the openings. The girder is built into the masonry, and the whole construction is sufficiently strong to resist completely the action of the waves. To increase this resistance, the tower is raised as much as possible above the level of the sea, and its diameter at the top exceeds by 1 or 2 meters that of the iron superstructure, which is 2 meters.

(413) *Properties of petroleum products.*—Long experience shows that all petroleum products employed in lighting, produce, by their decomposition by heat, tar deposits, and charcoal, adhering to the orifices of the burners, which, increasing with time, reduce more and more the flow of the fluid, and consequently the intensity of the flame.

The amount of these deposits diminishes, and the duration of the light increases, as the product employed is more volatile and approaches the character of the ethers. Again, the luminous intensity diminishes as the essence employed becomes lighter. For these reasons, a gasoline weighing 670 grams per liter, perfectly pure and rectified, has been selected. As to the burners, the old type has been kept. They are furnished with a capillary tube giving vent to the gasoline vapor which is projected without pressure upon a metallic spatula upon which the flame rises in the form of a butterfly. This spatula serves, besides, to heat still more the gasoline which comes from the burner. The former passes through a tube communicating with the reservoirs, and is tamped with cotton near the burner.

(414) The arrangement of the reservoirs constitutes the most delicate portion of the problem. It is necessary to store nearly half a cubic meter of gasoline, to furnish this combustible as it is used, to maintain a constant pressure at the burner in order to have a constant combustion, and, finally, to avoid all overflow of an extremely volatile liquid capable of producing an explosive mixture, which might give rise to a serious accident. For this purpose a special contrivance was adopted, namely, a pressure regulator between each

reservoir and the burners which are fed by it. This regulator consists of a cylindrical floater which carries, in the direction of its axis, a graduated test-glass containing a calculated quantity of mercury, into which a glass tube plunges; this tube has a stopcock and communicates with the reservoir. The floater rises with a slight play in a receiver united to the burners by means of a tube from the bottom. The reservoir cock being open, the gasoline flows through the tube, fills the test glass, flows into the receiver, and raises the floater. As the latter rises, the reservoir tube sinks gradually into the mercury and thus reduces the flow of the gasoline until it ceases.

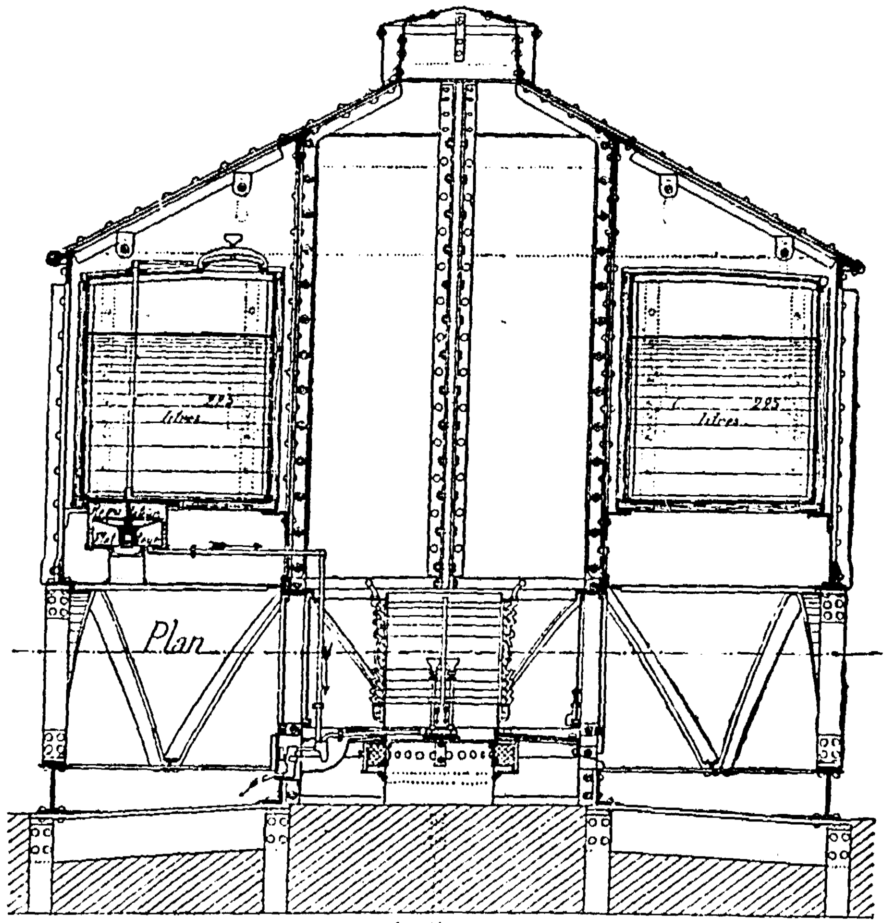


FIG. 286.—Section of the apparatus for lighting beacon towers with gasoline.

At this moment the level of the liquid attains in the reservoir a height of 0.30 meter above the orifice of the burner, *i. e.*, the most favorable height for the working of the light. Then the burner may be lighted by opening the burner cocks. The gasoline runs from the receiver and lowers the floater until the flow of the reservoir equals that consumed by the burners. The permanent flow is then established, and the apparatus works automatically with great sensitiveness, and maintains regularity of flow, notwithstanding the thermometric and barometric variations, whatever may be the height of the gasoline in the reservoirs.

Repeated experiments have shown that the arrangements adopted answer perfectly the purpose for which they were established. The light has been kept burning one hundred and fifty days and nights without changing the burners. The luminous intensity is equal to that of three Carcel burners for a group of four burners. With the optical apparatus a light is obtained nearly equal to that of the fifth order of Fresnel lights.

No accident has thus far occurred, and everything indicates that, with simple precautions, lights may be maintained, at least in the beacon towers.

One of these was set up on the beacon tower near Ré Island opposite the new port of La Pallice, and a number are in process of erection.

(415) *Cost.*—The cost of the metallic superstructure, including the optical apparatus, the reservoirs, and all accessories, was 7,000 francs. As to the cost of maintenance, it cannot be calculated exactly; it varies with circumstances; it may be approximately estimated at 1,000 francs per year, as an average.

This system of lighting proposed by M. Bourdelle, chief engineer of the light-house service, was constructed by MM. Barbier & Co.

Chapter LIV.—Graphic method of quadrature.

By M. Ed. Collignon, *Chief Engineer of Roads and Bridges.*

(416) The following figures, illustrating a new graphical method of quadrature, were exhibited in the pavilion of the ministry of public works.

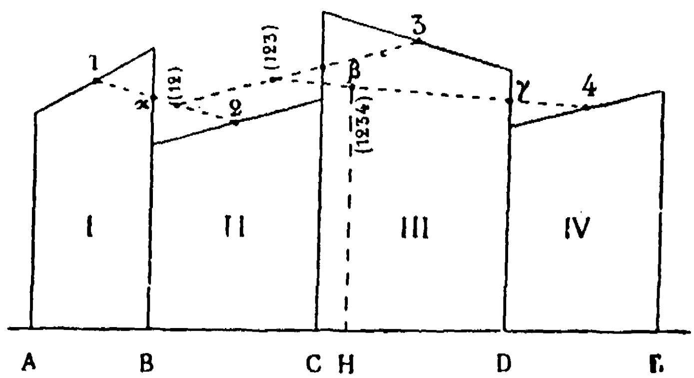


Fig. 297.

The quadrature of a plane area may be reduced to the problem of finding the sum of adjoining trapezoids I, II, III (Fig. 297), the bases of which are situated in a right line. This summation is easily made by the following method :

Take the middle points, 1, 2, 3 of the upper sides of the successive trapezoids. Draw the line 1 2; it cuts in α the ordinate separating the trapezoids I and II. Reverse this line 1 2 end for end. The point α after this reversal takes the position (1 2), defined by its distance 2 (1 2) = 1 α. It is easy to see that the product of the ordinate of the point (1 2) by the sum A C of the bases is the measure of the sum of the areas of the two figures I and II.

We then join (1 2) and 3, which gives a right line cutting in β the ordinate separating the surfaces II and III. On reversing end for end the right line (1 2) 3, and taking the segment (1 2) (1 2 3) = 3 β; the product of the ordinate of the point (1 2 3) by the sum A D of the three bases, will be equal to the sum of the surfaces I, II, III.

Finally joining (1 2 3) and 4 and taking (1 2 3) (1 2 3 4) = 4 γ we obtain a point (1 2 3 4) situated vertically over the middle H of the total base A E, and such that the product

$$H\ (1\ 2\ 3\ 4) \times A\ E$$

is the sum of the surfaces of the four given trapezoids.

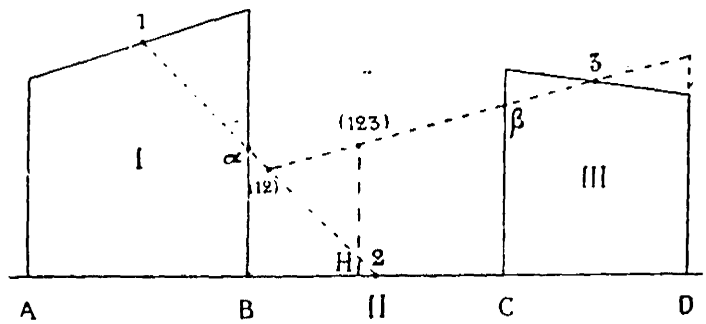


FIG. 298.

The method is general: it applies to the algebraic addition of positive or negative areas, to the evaluation of closed areas, etc.

(417) The consideration of zero areas is useful for adding noncontiguous trapezoids, and for reducing a rectangle to a given base. First. Suppose (Fig. 298) that we had to add the two figures I and III, separated by a free interval, B C, standing on the same line, A D: we will consider the interval B C as a rectangle II with a height zero, which will make a connection between the surfaces I and III. Applying the method to the three trapezoids I, II, III, we arrive at a final point (1 2 3), and the product

$$(1\ 2\ 3)\ H \times A\ D$$

is the required area.

(418) Second. To change a rectangle, A B C D, into an equivalent rectangle, which has for base a given length, A, E. We will consider the required rectangle as the sum of the rectangle A B C D (Fig. 299), and a rectangle having zero for height, and B E for base. We therefore take the middle points, 1 and 2, of the upper sides of these rectangles; we join 1 and 2, the line 1 2 cuts in α the ordinate,

which separates the two surfaces, and taking 1 (1 2) = 2 α, we have at the point (1 2) the middle of the upper side of the rectangle, A E F G, which has for base A E, and which is equivalent to the given rectangle. The construction avoids the last multiplication which would be necessary to compute the total area. We may take the

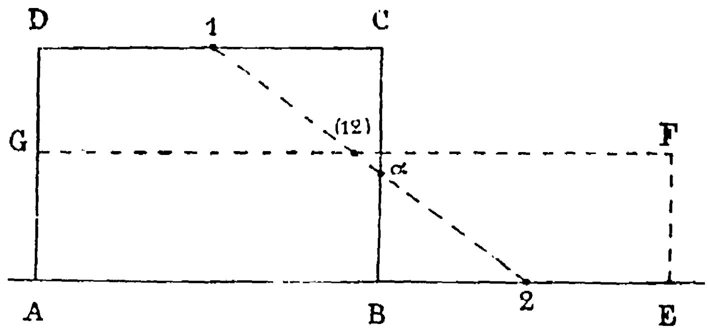


FIG. 299.

base, A E, so as to render this last operation very rapid. It is sufficient to make, for example, A E = 1 meter, or equal 10 meters or 100 meters, etc.

(419) The method applies to the computation of the surfaces of cross sections, to the tracing of longitudinal sections along a line, for balancing excavations and embankments, and for the determination of the mean of given numbers without seeking beforehand the total.

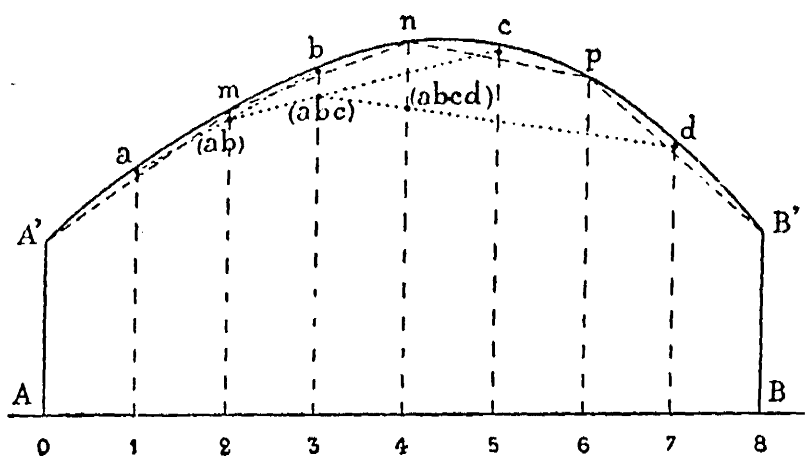


FIG. 300.

Finally, it applies to the quadrature of curves with the same degree of approximation as that given by Simpson's rule.

Divide the base A B of the area to compute into an even number of equal parts, in eight parts, for example (Fig. 300), at the points 1, 2, ... 7; erect ordinates at the points of division, then draw the chords A′ *m*, *n m*, *n p*, *p* B′, by joining the successive points of the curve situated upon the even ordinates. Take the points *a*, *b*, *c*, *d*, on the deflections of the segments comprised between the curve and the chords at two-thirds of these deflections starting from the chord.

It only remains to join a and b, which gives the point $(a\ b)$ upon the ordinate (2), to join $(a\ b)$ and c, which gives the point $(a\ b\ c)$ on the ordinate (3); to join $(a\ b\ c)$ and d, which gives the point $(a\ b\ c\ d)$ upon the central ordinate of the curve. The required area is the product

$$\mathrm{A\ B} \times 4\ (a\ b\ c\ d).$$

The equidistance of the ordinates has avoided the necessity of reversing end for end the successive joining lines, the construction being thus considerably simplified.

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