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J. DREDGE

1899-1900

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J. Eugène Schneider. Memorial Statue at Creusot.

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Sophus Berendsen, Aktiskb.
Kjøbenhavn.

THE WORKS

OF

MESSRS. SCHNEIDER AND CO.

BY

JAMES DREDGE, C.M.G.,

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COMMANDEUR, LEOPOLD; OFFICIER, LEGION D'HONNEUR; OFFICIER, INSTRUCTION PUBLIQUE;
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NOTE.

IN the earlier pages of this volume an attempt is made to differentiate the geographical expression "Creusot" from the name of "Schneider," and to leave no excuse for a preference in employing the former instead of the latter, whenever the famous metallurgical works of France are referred to. In its earliest days it was the location that was celebrated; but with the first generation of Schneiders, this condition was reversed, and it is only by force of habit that the word "Creusot" is incorrectly made to stand for the vast establishments, and their widely-scattered dependencies of mines, and blast furnaces, and constructive works.

It is believed that so complete and detailed a history of a great industry has never before been given to the public; and it is wholly owing to the manner in which Messrs. Schneider and Co. have placed every information at my disposal that such a publication is now possible. That they have done this, to a foreigner, and without reserve, is only in keeping with the spirit of progress which for generations has characterised the methods of the family.

Possibly that section of this book dealing with the gun factories of Messrs. Schneider and Co. will attract special attention. In some measure, these pages may be regarded as supplementary to my earlier volume on "Modern French Artillery," which dealt exclusively with the progress made in ordnance construction by one of the most famous specialists, Monsieur Gustave Canet. Since that book was written, the gun factory at Havre has been purchased by Messrs. Schneider and Co., who secured at the same time the assistance of M. Canet as manager of their Ordnance Department, the products of which are famous throughout the world, in all calibres and for every purpose.

JAMES DREDGE, C.M.G.

35, 36, BEDFORD STREET, STRAND, LONDON,
November, 1900.

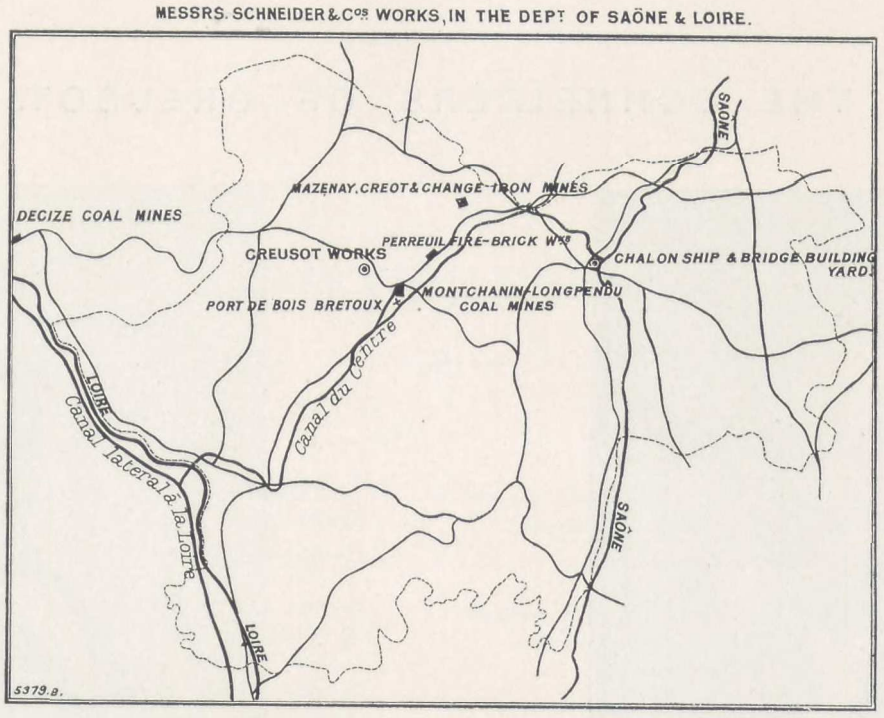
LIST OF MINES AND WORKS OWNED BY

MESSRS. SCHNEIDER AND CO.

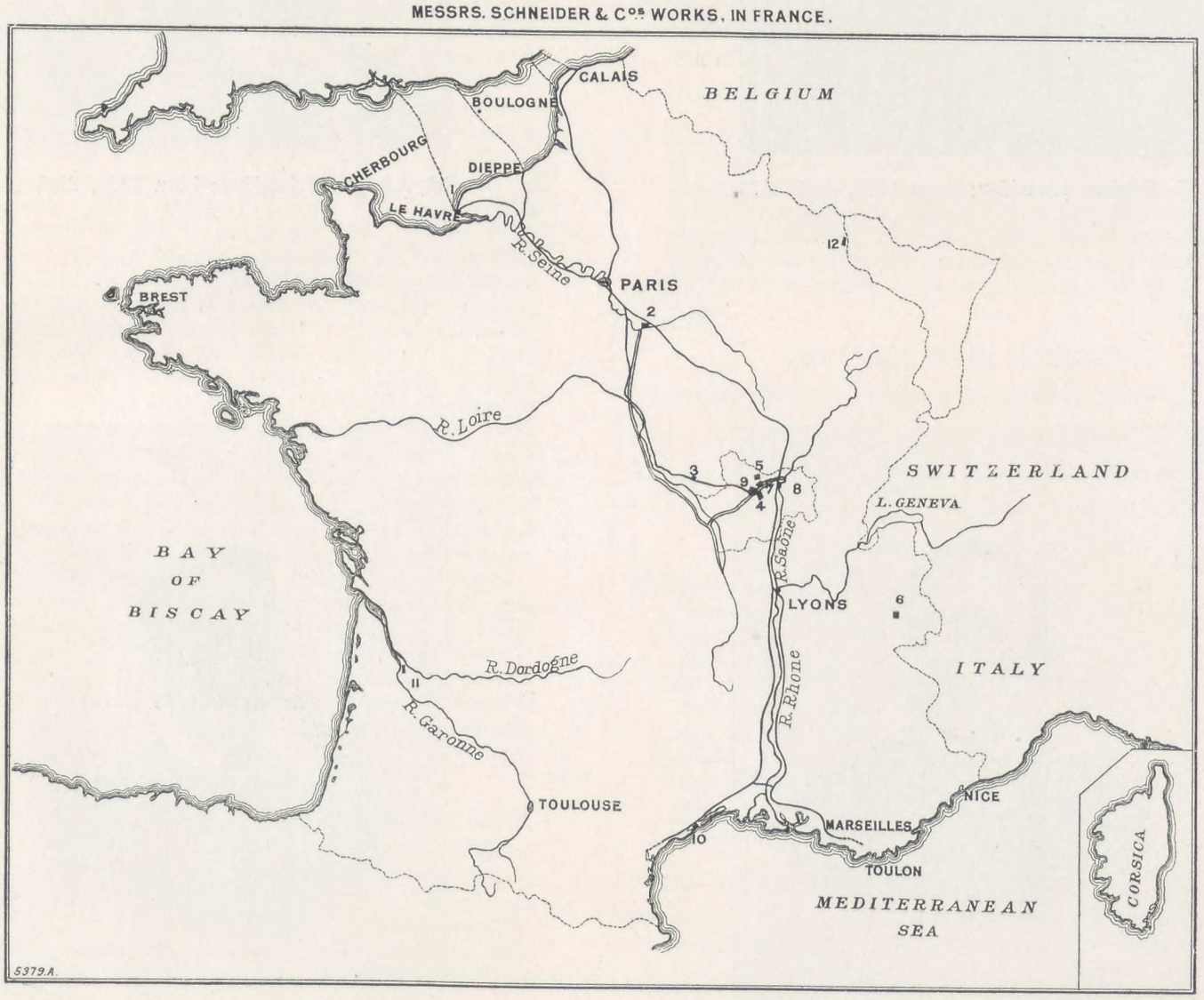
Cette - - - - -	Blast-Furnaces, Steel Works, and Rolling-Mills (now being put down).
Chalon-sur-Saône - - -	Ship and Bridge-Building Yard and Works.
Champagne - - - -	Electric Construction Works (now being put down).
Creusot - - - - -	Coal Mines, Blast-Furnaces, Steel Works, Rolling Mills, Engineering Works, Electric Construction Works, Artillery Works, Villedieu Proving Ground.
Decize - - - - - -	Coal Mines.
Havre - - - - - -	Artillery Works, Hoc Proving Ground, Harfleur Long-Range Proving Ground.
Mazenay, Créot, and Change -	Iron Mines.
Montchanin and Longpendu -	Coal Mines.
Perreuil - - - - -	Fire-Brick Works.
Spain - - - - - -	Iron Mines.

Apart from the above mines and works, which belong to Messrs. Schneider and Co., the firm owns large interests in several French and foreign mineral and industrial concerns.

MESSRS. SCHNEIDER & Cos WORKS, IN THE DEPT OF SAÔNE & LOIRE.



MESSRS. SCHNEIDER & Cos WORKS, IN FRANCE.



1. Havre Artillery Works; Hoc Proving Ground; Harfleur Long-Range Proving Ground.
2. Champagne Electric Construction Works (being put down).
3. Decize Coal Mines.
4. Montchanin-Longpendu Coal Mines.
5. Mazenay, Créot, and Change Iron Mines.
6. Allevard Iron Mines.
7. Perreuil Fire-Brick Works.
8. Chalon Ship and Bridge-Building Yard.
9. Coal Mines; Blast-Furnaces; Steel Works; Rolling Mills; Engineering Works; Electric Construction Works; Ordnance Works; Villedieu Proving Ground, at Creusot.
10. Cette Works. Blast-Furnaces; Steel Works; Rolling Mills (being put down).
11. Société Anonyme des Chantiers et Ateliers de la Gironde, at Bordeaux (see page 13).
12. Jœuf Rail Mills (see page 81).

THE SCHNEIDERS OF CREUSOT.



M. J. Eugène Schneider; born 1805, died 1875.



M. Adolphe Schneider; born 1802, died 1845.



M. Henri Schneider; born 1840, died 1898.



M. C. P. Eugène Schneider; born 1868.

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PART I.

HISTORY, MINES, BLAST-FURNACES, STEEL WORKS, ROLLING-MILLS, ENGINEERING WORKS, ETC.

LE CREUSOT.

I.—INTRODUCTION.

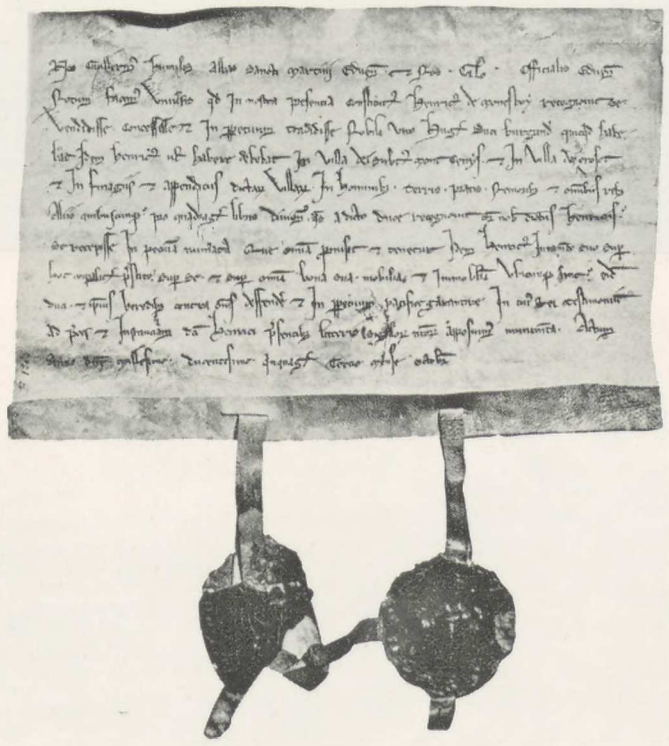
BEFORE developing into the great industrial centre which it is to-day, Creusot has passed through many varying phases, alternating periods of prosperity and difficulties having marked the earlier years of its existence. But when the works—then only on a comparatively small scale—passed into the hands of Messrs. Schneider Brothers, they progressed rapidly, and have steadily advanced until, to-day, they form one of the largest, and most perfectly organised metallurgical establishments, in the world.

The first known document, still in existence, and reproduced in Fig. 1, in which the name of Creusot is mentioned, is a deed of sale, dated 1253, by which Henry de Monestoy ceded the "Villa de Crosot" to Hugues IV., Duke of Burgundy.

At that remote time, Creusot was nothing but a villa or dairy farm, occupied by a few persons; this farm was located on valuable coal deposits, the existence of which was only recognised 250 years later (1502), when the first rude efforts to obtain mineral fuel, were made by the inhabitants of the farm and adjoining village. Nearly three centuries later, in 1782, a company was formed, under the direct patronage of Louis XVI., for the installation and working of the Royal Ironfoundries of Montcenis, a village near Creusot; these works obtained their supplies of raw material from the mines of Creusot, which had then been opened under a concession granted to M. de la Chaise. Fig. 2 is a general view of Creusot, copied from an old print bearing the date of 1782. Four years after, in 1786, this concessionaire disposed of all his rights to the Montcenis Company. It is evident that considerable activity characterised the administration of this company, which, after having acquired the Creusot property, erected four blast-furnaces, and employed the English engineer, William Wilkinson, the inventor of the cupola furnace for re-melting cast iron with coke, to put his system into

TEXTE LATIN

« *Nos Guillermus, humilis abbas Sancti Martini Eduensis, et nos Gilo, officialis Eduensis, notum facimus universis quod in nostra presentia constitutus Henricus de Monestoy recognovit se vendidisse, concessisse et in perpetuum tradidisse nobili viro Hugoni, duci Burgundie, quicquid habebat idem Henricus vel habere debebat in Villa-Dei subtus Montcenys et in villa de Crosot, et in finagiis et appendiciis dictarum villarum, in hominibus, terris, pratis, nemoribus et omnibus rebus aliis quibuscunque, pro quadraginta libris Divionensium, quas a dicto duce recognovit coram nobis dictus Henricus se recepisse in pecunia numerata. Quæ omnia promisit et tenetur idem Henricus juramento suo super hoc corporaliter præstito, super se et super omnia bona sua mobilia et immobilia ubicunque fuerint, eidem duci et ipsius hæredibus contra omnes defendere et in perpetuum garantire. In cujus rei testimonium ad preces et instantiam dicti Henrici, præsentibus litteris sigillorum nostrorum apposuimus munimenta. Actum anno Domini millesimo ducentesimo quinquagesimo tertio mense octobris.* »



TRADUCTION

« *Nous Guillaume, humble abbé de Saint-Martin-d'Autun, et nous Gilo, official d'Autun, à tous savoir faisons que séant en notre présence Henry de Monestoy a reconnu avoir vendu, concédé et livré à perpétuité à noble homme Hugues, duc de Bourgogne, tout ce que ledit Henry avait ou devait avoir dans la Villa-Dei (Ville-Dieu) sous Montcenys et dans la Villa de Crosot (Ville du Creusot), et dans les finages et apparentances desdites villa, en hommes, terres, prés, bois et toutes autres choses quelles qu'elles soient, pour quarante livres dijonnaises, que ledit Henry a reconnu par-devant nous avoir reçues dudit duc en argent compté. Toutes choses que ledit Henry a promises et auxquelles il est tenu par son serment qu'il a prêté étant corporellement présent, s'engageant de sa personne et au risque de tous ses biens meubles et immeubles, à les défendre contre tous au bénéfice dudit duc et de ses héritiers, et à les garantir en paix à toujours. En foi de quoi, à la prière et à la requête dudit Henry, nous avons apposé aux présentes lettres la sanction de nos sceaux respectifs. Acté l'an du Seigneur mil deux cent cinquante-trois au mois d'octobre.*

Fig. 1. Facsimile of Deed of Sale of Creusot (A.D. 1253).

operation at the works. Up to this time water-power had to be almost entirely relied upon where mechanical power was required in industrial operations; and as this source of energy was lacking at Creusot, the company applied to a still more famous Englishman, James Watt, to erect steam engines for them. In 1785 other coal and iron mines were opened, and the foundry had in that year become so largely extended, that it gave employment to more than 1,500 persons, for whom houses had been built by the company. In 1787, the industry known as the "Manufacture de Cristaux de la Reine," which had previously been established at Sèvres, was transferred to Creusot; these glass works were maintained in operation until the year 1832.

In 1793 the great Central Canal was constructed; as it passed near the Creusot works it opened a new and very important means of communication for the latter, thus giving extended facilities for the receipt of raw materials, and the transport of manufactured products. By this time, too, the increase in the population, due to the growing industry, made Creusot, which had hitherto been a dependence of the district of Breuil, of so much importance that it was raised to the dignity of a separate commune. During the period of the Revolution, the foundry was requisitioned by the Provisional Government, and was worked wholly on account of the nation. Restored to its former condition as a private enterprise,



Fig. 2. Le Creusot in 1782.



Fig. 3. The Town of Creusot in 1851.

under the Empire, it still continued to carry out large Government contracts, and manufactured great quantities of cast-iron and bronze guns, as well as projectiles. To such an extent had the military requirements of the Revolutionary Government, and of the Empire, absorbed the productive power of the works, that when the permanent peace of 1815 succeeded the long series of years of war, the occupation of Creusot disappeared; and finding it impossible to create new business, the company had no alternative but to close the works entirely. They passed, in fact, through a period of bankruptcy, after having absorbed a capital of 14 million francs.

In 1818, one of the creditors, M. Chagot, the elder, purchased the whole of the works for 905,000 francs; and five years later (1823) M. Chagot created a new company in association with his children: but this proved a disastrous undertaking, and the works languished until, in 1828, there was founded the "Société Anonyme des Usines, Forges et Fonderies, du Creusot et de Charenton." This company, however, proved itself no better able to achieve success than its predecessor, and it had to go into bankruptcy on June 25th, 1833. On November 25th, 1835, the works were repurchased by MM. Coste frères, Jules Chagot, and some others, and in the following year they were acquired by M. Eugène Schneider, at that time director of the iron works of Bazeilles. This gentleman, the real founder of Creusot, in association with his brother, M. Adolphe Schneider, created a new stock company, under the title of

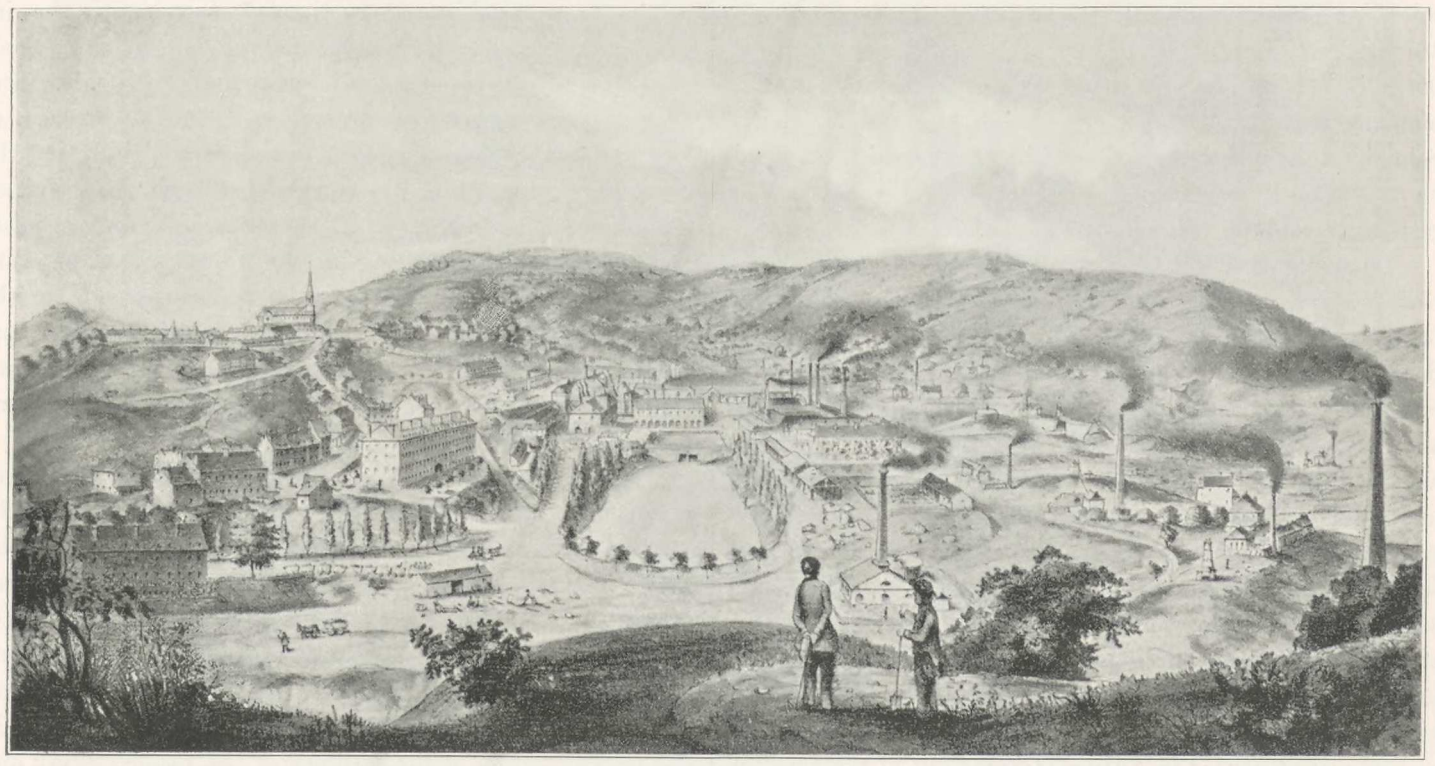


Fig. 4. Le Creusot in 1851.



Fig. 5. "La Verrerie," Creusot, in 1851.

"Schneider frères et Compagnie." After the death of his brother, on August 3rd, 1845, M. Eugène Schneider remained as the sole director of Creusot, and it was at this time that the name of the company was altered to its present title, "Schneider et Cie." M. Eugène Schneider's son Henri, born in 1840, was closely associated with his father in the management of the works; he became the sole director on the death of the latter (November 27th 1875). M. Eugène Schneider, of the third generation, born in 1868, had recently become associated in the management of the business with his father, M. Henri Schneider. Since, the death of his father, which occurred on the 17th May, 1898, M. Eugène Schneider is the sole responsible chief of the whole concern.

Reverting to the period when the foundations for the real prosperity of Creusot were laid after the disastrous failure of June, 1833, it will be observed that MM. Schneider frères acquired Creusot at the time when railway construction and steam navigation were expected to give an immense impulse to metallurgical industries; and the new owners did not fail to recognise that if they were to be able to meet the requirements of a coming industrial era, it was necessary to equip their works with the best and most complete plant that could be obtained. Extensive machine shops were, therefore, erected at Creusot; and at the same time, engine works specially adapted for the construction of marine engines, were built on the banks of the Saône at Chalon. In 1838 the first locomotive manufactured in France steamed out of the Creusot works, and in 1839 the company completed other locomotives, as well as some steamboats for the navigation of the Saône and the Rhône. All of these extensive orders had been completed with relatively imperfect appliances, which it was the special care of the energetic chief of the company to improve, so as to increase the facilities of output. At the same time, Mr. Eugène Schneider, senior, possessed the gift of bringing around him able engineers; amongst others, Mr. Bourdon, who constructed the steam hammer that created an entire revolution in the forge. It was with this first hammer that Messrs. Schneider and Co. were able to make the machinery for vessels of war of 1,350 horse-power, as well as the engines for ocean-going steamers.

In this way Creusot continued to advance from year to year. Figs. 3, 4, and 5 are various views of Creusot, all reproductions of contemporary engravings dated 1851. In 1855, when the Crimean war broke out, Messrs. Schneider and Co. rendered the French Government very notable services by their rapid delivery of considerable orders for warship machinery, and the first armour-plates for floating batteries. During a period of seven months they completed seventeen marine engines, each of 450 horse-power, for gunboats and floating batteries. They also, during the same time, finished four marine engines of 1,950 horse-power for ships of the line, and commenced three of 2,400 horse-power for frigates.

In the year 1860, treaties of commerce were made which brought about great changes by throwing open the gates of France to foreign competition. The industrial situation appeared critical, and for awhile the Creusot works, in common with many other industries, feared extinction. They could not compete with the importations from abroad, as regards price, for they were not equipped to carry on a war of competition. To do this successfully meant a practical reconstruction of the works, the introduction of new machinery, and of improved methods of production: a complete awakening, in short, from the indifference born of protection. The alternative of extinction was not one that commended itself to the energetic managers of the works, who faced the situation with no half measures. The number of blast-furnaces was increased; new rolling mills with an annual capacity of 150,000 tons were erected; the railway system of the works was extended to the iron mines of Mazenay; and plant for the manufacture of fireclay and other refractory products was started on the bank of the Canal du Centre, near the Perreuil forges.

In the year 1867 the steel industry was introduced at Creusot: at first, Messrs. Schneider and Co. employed the Martin-Siemens process, and this, a little later, was supplemented by the Bessemer process. It is from this time that dates the manufacture, at Creusot, of steel rails; plates and bars of soft steel for shipbuilding; and steel ingots and forgings for gun construction. By this development, Messrs. Schneider and Co. were very largely instrumental in the reconstruction of the artillery of the French Army and Navy. In 1875 a large department was created, especially for producing heavy steel forgings, and steel tyres for locomotives and rolling stock. The 100-ton steam hammer, an enormous machine, was completed the following year; it was used almost entirely for forging marine-engine steel shafting, and steel gun tubes of large size. Up to this time the plates used for armoured ships had been made wholly of iron. Messrs. Schneider and Co. saw the benefits to be derived from their special qualities of steel, and they sent to Spezia, in 1876, for comparative firing tests, the first steel armour-plate that had ever been made. The results obtained were remarkable, and the Italian Government was so convinced of Messrs. Schneider and Co.'s claims, that they gave to Creusot the order for steel armour-plates for the two great war-vessels Duilio and Dandolo. The value of steel for armour was hotly disputed, and the full degree of credit due to Messrs. Schneider and Co. for this bold departure in armour-plate construction, was not accorded them till many years later.

The improvements constantly introduced into means of defence since the first practical tests of armour-plates—those placed by Messrs. Schneider and Co. on the floating batteries used during the Crimean War—naturally resulted in equally active developments in methods of attack. Cast-iron guns gave place to bronze, and afterwards to breech-loading steel, guns; and in this connection it may be mentioned that the tests of the steel plates of Creusot were contemporary with the completion of the Armstrong

MR. SCHNEIDER'S CREUSOT RESIDENCE.



Fig. 6. "La Verrerie" in 1898.

WITHDRAWN FROM OBERLIN COLLEGE

100-ton guns—those costly follies built for the Italian ironclads, and uselessly repeated subsequently to some extent in the British Navy. As the natural consequence of the great facilities they possessed in the production and manufacture of steel, Messrs. Schneider and Co. took, and have maintained since 1870, the leading position in France as makers of steel ordnance. For a number of years this department of the works was included as a part of the general machine shops; but in 1888 the company, in order to extend the manufacture of war material, erected a very extensive gun factory, where all the final operations are completed, and the mountings and war material for fortifications, etc., are made. Adjoining the gun shops of Creusot is a polygon, where the firing trials of guns and mountings are conducted, as well as tests of armour-plates, etc.

Shortly after the establishment of the gun factory, an electrical department on a very large scale was established. The chief addition in 1892 was that of a steel foundry, in which castings of the largest size are produced.

On account of the constantly increasing orders for armour-plates from the French and other Governments, it had become necessary to increase and modify the machine tools and other appliances, for the completion of such orders. These additions include extensive installations for forging, cementation, tempering, and finishing the steel plates, especially of the most modern types, such as those with hardened surfaces, or Harveyised; the first of these were manufactured in 1893, by a process patented and owned solely by the company. These constant changes and extensions of the steel departments involved the removal of the old railway tyre shops, which have now been shifted to a new position; the change was made in 1895.

At the commencement of 1897, Messrs. Schneider and Co. acquired the Ordnance Department of the Société des Forges et Chantiers de la Mediterranée, and they have combined this department with that of Creusot, and the polygon of Hoc with that of the Villedieu, under the general name of "Services de l'Artillerie." This huge department has been placed under the direction of Mr. Canet, whose reputation as a gun designer and constructor is known throughout the world. This combination has placed at the disposal of Messrs. Schneider and Co. extraordinary means of producing war material, which are still further being extended.

It will readily be understood that by this combination there has been formed a great and very powerful establishment in France, for the manufacture of ordnance and its accessories for all nations. This material is now known as "Schneider-Canet," and Messrs. Schneider and Co. are the only French manufacturers of war material who construct largely for foreign countries.

It is almost unnecessary to say that during this rapid and constant development, the town of Creusot has grown also. In 1836 the population was 2,700; to-day it is 32,000.

We have endeavoured in the foregoing pages to sketch in mere outline the history and development and the work accomplished by the succeeding generations of Schneiders, and which prepared the way to the gigantic industry of Creusot as it exists to-day.

II.—THE SOCIAL ECONOMY OF CREUSOT.

Extent and Capacity of Messrs. Schneider and Co.'s Works.—The establishments of Messrs. Schneider and Co., including workshops, open courts, railway tracks, &c., occupy an area of about 800 acres; the Creusot workshops themselves extend uninterruptedly for a distance of 2½ miles; an idea of them is given by the general view, see Fig. 7, Plate II. The different services are connected with each other, and to the auxiliary establishments of Mazenay, Montchanin, and Bois-Bretoux, by a system of railways 190 miles in length, furnished with a rolling stock of 30 locomotives and 1,500 wagons. The port of Bois-Bretoux, situated on the bank of the Canal du Centre, is equipped with a very perfect system of machinery for the rapid and cheap transshipment of material. The railway system of the company has a service of from 50 to 60 regular trains per day, and transports daily a load of 7,000 tons for a mean distance of 6.3 miles, representing 13 million mile-tons per annum. The various offices, workshops, and courts, as well as the port of Montchanin, are lighted by electricity, and the dynamos employed for this purpose, and for the transmission of electrical energy, which is very extensively employed, represent a total of more than 1,800 horse-power. The subjoined list gives some idea of the importance and varied character of Messrs. Schneider and Co.'s works :—

Annual Consumption of Material.

	Tons.
Coal and coke	515,000
Cast iron	110,000

Annual Amount of Finished Products.

Iron and steel plates	130,000
Armour-plates	6,000
Ship construction, bridges, and ironwork ...	10,000
(The foregoing figures do not include the output of the various engineering and artillery departments).	

Extent of Creusot and its Dependencies.

	Acres.
Area of the various departments	800
Land occupied by employés' houses and gardens; churches and schools	600
Farm lands	4,500
Total	5,900

Employés.—The number of persons of all classes employed by Messrs. Schneider and Co. varies from 14,000 to 15,000. The permanence of this vast *personnel* is one of the very interesting features of the great establishment, and speaks eloquently for the good relations existing between employers and employed. The diagrams, Figs. 8 and 9, page 7, show, on a total of 13,000, the number of workmen who have been from one to thirty years, and from thirty to sixty-nine years, in the service of the company. One-third of the *personnel* has had more than twenty years of continual service, one-fourth, more than twenty-five years, and one-eighth has a record of more than thirty years. These long terms of employment have been without interruption, except for military service, and it is not rare to find families of two or three generations, and numbering six or seven members, or even more, among the staff of Messrs. Schneider and Co. As a natural result, there are many families who, by steady work, have gradually improved their positions, and have become persons of importance in the works.

In view of the serious difficulties between employers and employed, unfortunately so common at the present time in all countries, especial interest attaches itself to the relations that exist, and have existed for many years, between Messrs. Schneider and Co. and the great army of workmen in their employ; and a description of the conditions under which a gigantic industry can be carried on to the mutual satisfaction of employers and employed, will be read with interest. Piece-work is the general rule at Creusot; the workman is therefore paid according to his ability, at a minimum daily wage, to which is added the profit of the piece-work. Diagram, Fig. 10, shows the advances which have been made in wages from 1837 to 1895. In addition to the daily pay, the workman profits from various subventions, either in kind or in money, which for the most part form an actual increase, direct or indirect, on the wages paid. The following Table gives the statement of these various subventions paid during the year 1895-96 :—

Amounts Paid in Subventions by Messrs. Schneider and Co., 1895-96.

	£
Churches; schools; municipal taxes; music; various societies (clubs, natural history, cycling, gymnastics, sports, &c.); miscellaneous subscriptions	13,018
Contributions to the French National Pensions Department; supplementary pensions to insure a minimum benefit of £12 to superannuated workmen	28,713
Ambulance department of Messrs. Schneider and Co.; medical and pharmaceutical department and hospital; special assistance to sick and injured workmen	14,558
Allowances to men absent on military service; allowances to fathers of families of over five children less than fifteen years old; losses arising from letting houses and gardens below their value; fuel allowances; coffee allowed to workmen during the summer months	30,280
Total	£86,569

Workmen's Savings.—Messrs. Schneider and Co. have always received in trust the savings of their workmen, on which is paid a varying rate of interest. Thus on the first £40 invested, 5 per cent. interest is paid; on the second £40, the rate is reduced to 4 per cent.; and for further sums the interest is 3 per cent. The diagram Fig. 11, shows the increase of economies effected by the workmen from 1837 to 1895, and gives also the number of depositors, and the amount of deposits.

Workmen's Dwellings.—Messrs. Schneider and Co. for many years have encouraged their workmen to become proprietors of their own houses; and they have aided this object by selling them, at reduced prices, ground suitable for building, and also by making money advances. Even in those cases where the entire capital is lent for the purchase of the ground, as well as for building, the workman becomes at once proprietor of the house, instead of being only a tenant, with the remote and doubtful prospect of gradually becoming the owner of a dwelling built by the employer, as in most other industrial centres. Diagram, Fig. 12, shows the development and the importance of the advances made to their employés by Messrs. Schneider and Co. on account of land and buildings, and also the monthly repayments made by the workmen on this account. In many cases workmen and employés have constructed their own dwellings without borrowing capital, making use for this purpose of their own savings that had been deposited with the company. No restrictions are imposed as to the style and arrangement of the houses, so that a special inducement is offered to the workmen to construct dwellings adapted to their own individual tastes. The general types, however, which prevail are those of houses suitable for families, containing from two to five rooms, and standing detached in the midst of some garden ground. Some such dwellings are illustrated in Figs. 13 and 14, and give a good idea of the general type; although as a matter of fact these particular houses exist at Montchanin and Decize, some of the outlying works of Messrs. Schneider and Co., to be referred to later.

There are, of course, many exceptions to this rule. For example, Messrs. Schneider and Co. have, from time to time, erected dwellings which are let to workman tenants; there are 1,334 of these buildings, most of them having a garden ground of from 800 to 1,000 square yards, a poultry yard, pig-styes, &c. The type universally adopted for these houses is semi-detached with a walled garden. Such dwellings are naturally in much request, and are let as a special privilege to the higher class of workmen, depending upon the length and importance of their service, the size of their families, and so forth. The rent charged for these houses varies from 1s. to 7s. per

Fig. 9.

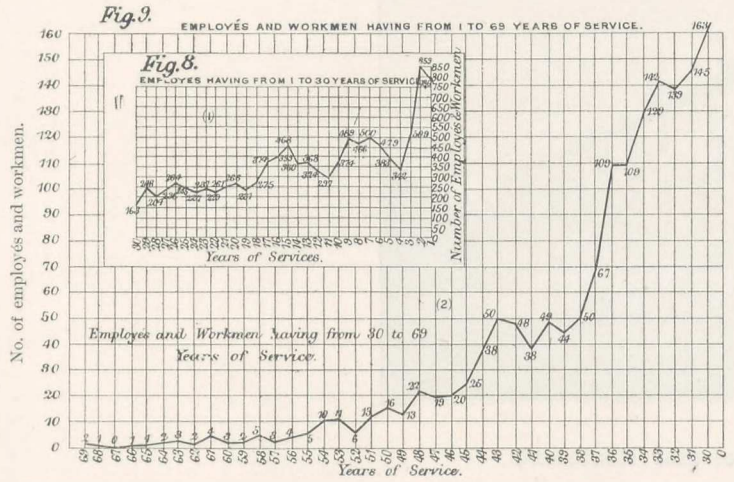


Fig. 8.

Fig. 10.

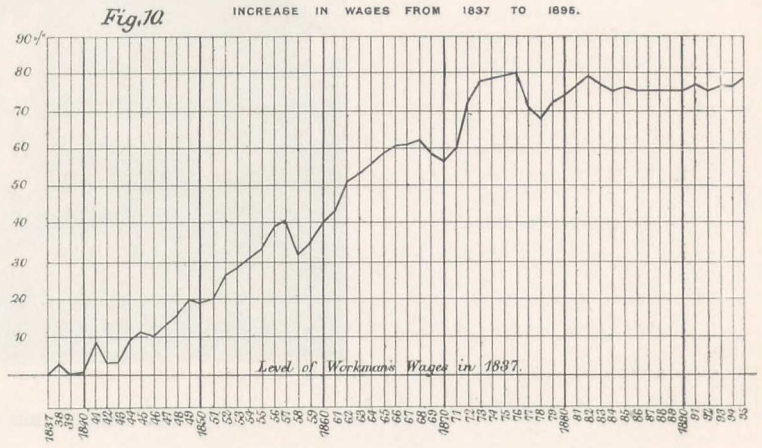


Fig. 11.

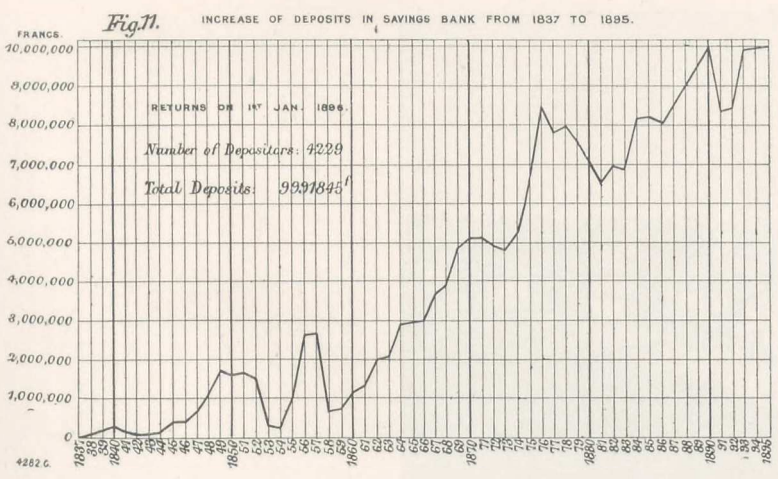
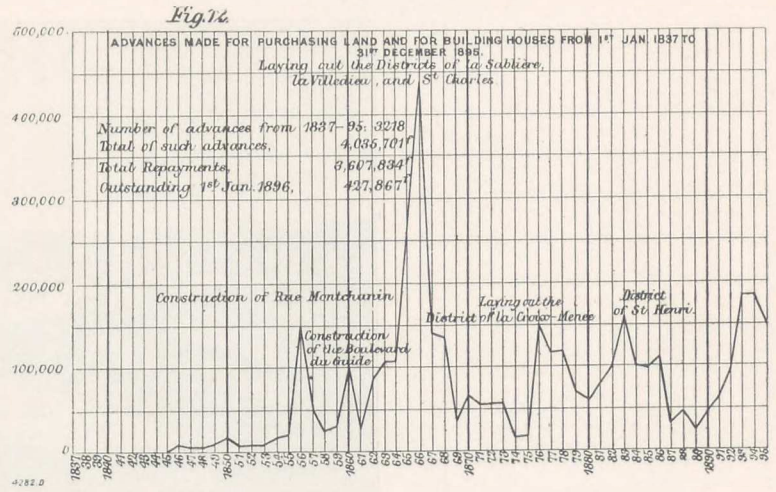


Fig. 12.



n onth, but it often happens that even this nominal rate is reduced, and the houses are sometimes let gratuitously to superannuated workmen, or to widows with families. All repairs are made, and good sanitary conditions are maintained, at the cost of Messrs. Schneider and Co.; for this purpose a special staff of inspectors and workmen is constantly engaged to keep the buildings in good condition. In addition to the gardens attached to the houses, and which cover an area of 60 acres, there are 2,363 additional gardens, having a total area of more than 200 acres.



Fig. 13. Workmen's Houses near Montchanin.

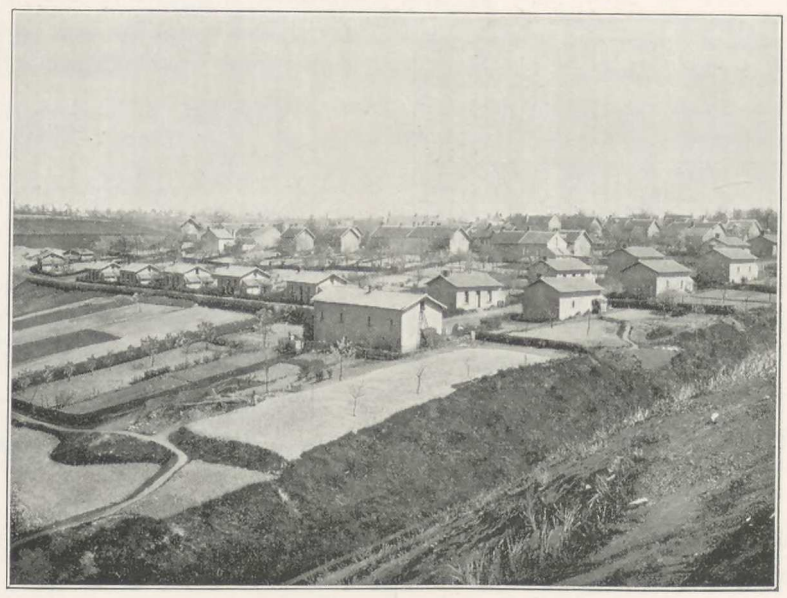


Fig. 14. Workmen's Houses, Cité Ste. Marie, Decize.

Pensions.—It is the custom of Messrs. Schneider and Co. to pay quarterly to the National Pension Fund of France, such an amount of voluntary subscription, as shall assure to their workmen, for the future, the advantage of a retiring pension proportional to the duration of service and to the amount earned. Every employé or workman of French nationality, twenty-three years of age, employed by Messrs. Schneider and Co., and having three years of steady service, is taken into consideration in making up these voluntary subscriptions, and participates in the privilege without any deduction being made in his wages. When this admirable system was inaugurated, the contributions were calculated on the basis of 3 per cent. on the salary paid, 2 per cent. of which was settled on the husband, and 1 per cent. on the wife. On several occasions, in order to increase the amount of retiring pensions, Messrs. Schneider and Co. have doubled, and then trebled the amount of this percentage; indeed, these acts of liberality have been repeated no less than twelve times during the last twenty years. At the present time the percentage of the subvention is actually 3 per cent. for the husband and 2 per cent. for the wife;

MESSRS. SCHNEIDER AND CO.'S WORKS AT CREUSOT, 1897.

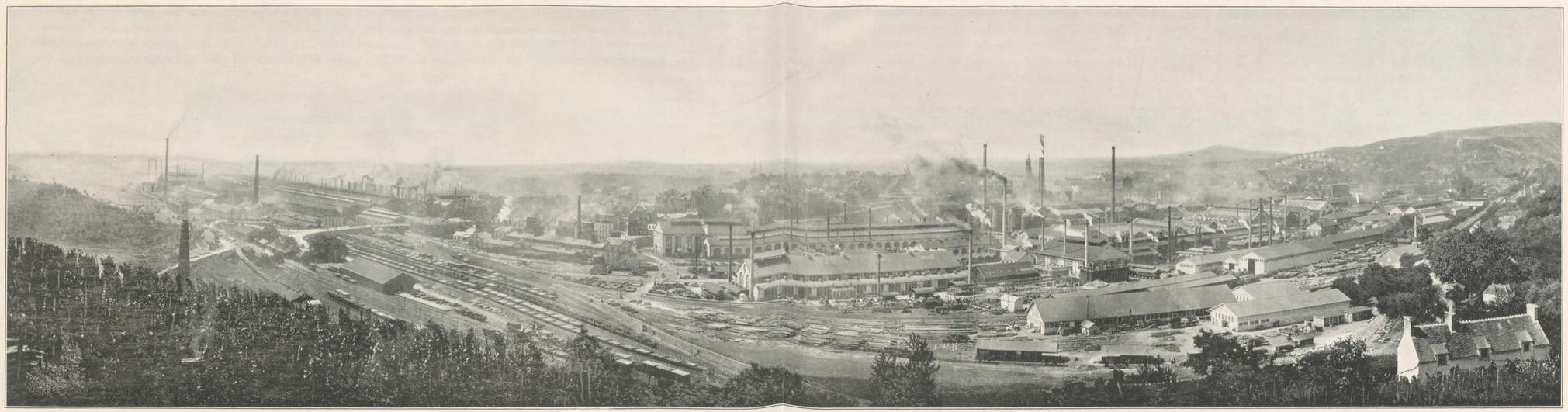


Fig. 7. General View of the Creusot Works.



Fig. 15. Boys' School, Decize.

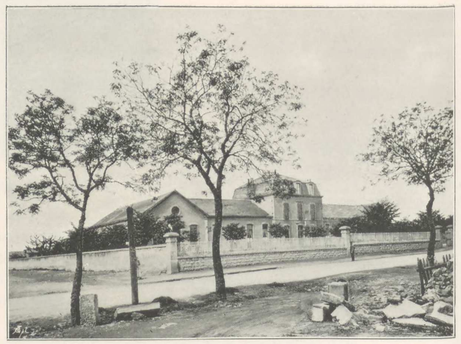


Fig. 16. The Montchanin Schools.



Fig. 17. Girls' School, Decize.



Fig. 18. Girls' School, Decize.

but if the husband is more than sixty years of age, the proportion is raised to 6 per cent. for himself and 4 per cent. for the wife. These payments are made with the object of an ultimate annuity which ceases totally on the death of the pensioner; but on the demand of the pensioner, and subject to approval, the capital to be accumulated may be reserved. In this latter case the annuity is less, but the accumulated capital is paid over to the heirs of the pensioner on his decease, whatever be his age. Individual accounts are opened for the employé or workman and his wife, from the date of the first payment being made, and the investment becomes an absolute and definite personal property, so that the workman or the employé, on leaving his employment, or on being dismissed, still retains for himself and for his wife, pension rights, the amount of which is in proportion to the subscriptions that have been made on his behalf by Messrs. Schneider and Co. In order to enjoy the pension, the workman or employé must be of the age prescribed by the laws and regulations of the National Pensions Department (Caisse Nationale des Retraites).

In consequence of various reductions in the rate of interest paid by the French Government on the securities in which the pension funds are deposited, the revenues arising from the subscriptions are now considerably smaller than they were at the time this benefit system was established. To make good this serious loss to the superannuated workman, Messrs. Schneider decided that from January 1st, 1893, they would insure a minimum pension of 300 francs (£12) a year to every workman who had been thirty years in their employ. The wife's pension, derived from the sums invested on her account as above described, is in addition to this minimum allowance. Mr. Eugène Schneider, the present chief of these works, decided to raise this minimum to 365 francs (£14 12s. 0d.) on and from the 17th May 1898, the date of his father's death, Mr. Henri Schneider; this minimum of 365 francs is equal to one franc (10d.) per day. No workman's pension can be hypothecated or seized for debt.

Charitable Funds.—In such an establishment as that of Creusot, where the industrials form quite a large town, dependent wholly upon the special industries carried on at the works, sickness must be more or less prevalent, and accidents of frequent occurrence. To provide against these inevitable conditions, Messrs. Schneider and Co. have made important and very successful organisations. Large subsidies are paid by them to the local charity boards in the various districts where their works are situated, while at Creusot itself there is a special aid organisation. The district boards distribute, in the name of Messrs. Schneider and Co., monthly payments to old workmen who are in want, and who cannot profit by the supplementary pension of 365 francs a year, because they have not completed their thirty years' service; the number of these cases is, however, very small. These charitable subsidies benefit all the suffering poor of the surrounding districts, but they are especially intended to assist the widows and orphans left by the workmen of Messrs. Schneider and Co.

Schools (see Figs. 15 to 18, Plate II.).—The administration of the French law of March 28th, 1882, dealing with compulsory primary education, has had the result of greatly reducing the importance of the schools supported by Messrs. Schneider and Co. at Creusot, and in the various districts where their supplementary works are situated. Until 1882, they had entirely supported all the primary schools of Creusot. At that date the boys' schools comprised a special group for superior primary teaching, and four other groups—central, western, southern, and eastern—for primary elementary teaching. These four groups have been of necessity abandoned, but the special group has been preserved and converted into a free school. Admission to this school is by way of competitive examinations, which take place every year, and to which all the pupils from the other schools in Creusot can be admitted.

In 1891 a primary elementary school was established at Creusot by Messrs. Schneider and Co.; two chaplains are always attached to the special, and the elementary group. There is also a free school for girls, and kindergartens, at Creusot; these are managed by the Sisters of St. Joseph de Cluny, assisted by lay teachers. Similar schools and kindergartens are maintained in the various supplementary works. The schools altogether comprise 28 classes for boys, 34 classes for girls, and 10 kindergartens; more than 100 teachers are employed in this work.

Home for Old Men and Women.—A home for the aged poor was founded by Madame Veuve Eugène Schneider and by Mr. and Mme. Henri Schneider. It was opened on January 4th, 1887, and the buildings, which cost £14,000, were contributed by Messrs. Schneider and Co. as their part of this admirable work. The establishment can accommodate seventy old people of both sexes, selected, in the first place, from the helpless workmen of the company, their wives and widows; in the second place, from among the other poor of Creusot; and thirdly, from among the poor of the canton of Creusot. The establishment is controlled by the Sisters of St. Joseph de Cluny.

Medical and Pharmaceutical Service.—Messrs. Schneider and Co. maintain, at their own cost and without any charge upon the wages of their employés, a very complete medical and pharmaceutical service. This service is for the special benefit of:

1. The whole of the active staff.
2. Workmen specially pensioned by reason of accident.
3. Widows pensioned on account of the death of their husbands, caused by accident during work.
4. The wives of employés and workmen.
5. Their children under the age of fifteen.
6. Eldest daughters, unmarried, who keep the house for widowed fathers.
7. Widowed mothers keeping house for unmarried sons.

The privilege of medical and pharmaceutical attendance is usually accorded to the father and mother of the

employé or workman, provided that he takes charge of his parents in his house.

Sick workmen who have been three months and upwards in service, and who are not able to work for three days or more, receive a daily allowance for a maximum period of six months; workmen injured in service receive a similar allowance from the day of the accident until they are able to resume work, or until the amount of the pension granted for this purpose is exhausted; the daily allowance varies from 1 to 2 francs.

The Creusot Hospital.—This establishment, opened on September 15th, 1894, was founded by Mme. Veuve Eugène Schneider and Mr. and Mme. Henri Schneider. The company assisted in this work by an important subsidy towards the construction of the building and by the gift of the land on which it stands, as well as of the grounds surrounding it, which occupy more than 150 acres. The original funds of the hospital have been increased by subsequent donations. The establishment was built to replace an infirmary and hospital which was inadequate for the requirements of the district, and which had been maintained entirely at the expense of the works. The new hospital contains 127 beds, but it is arranged so as to receive double that number in case of necessity; the cost has been £66,000. It insures medical and pharmaceutical attention to the employés and workmen, and to their families, and the usual hospital service in case of injury or sickness to the following:

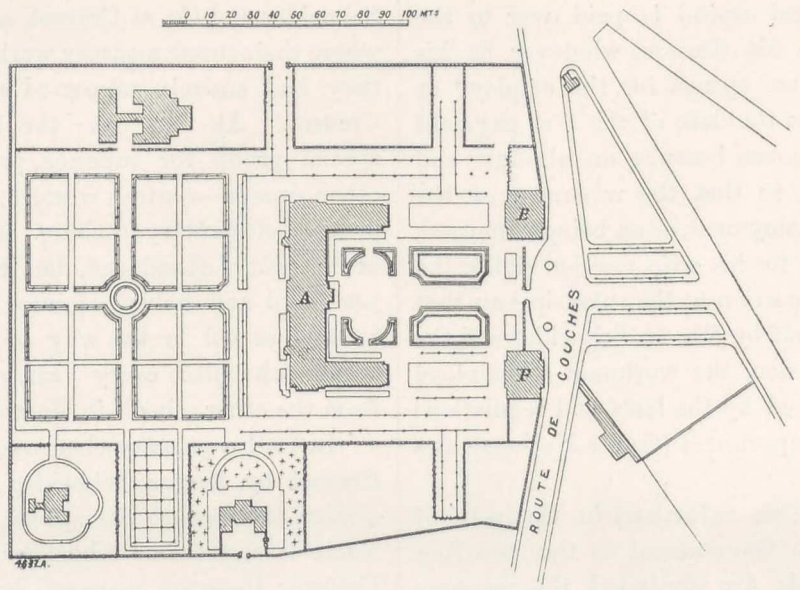


Fig. 21. General Plan of the Creusot Hospital and Enclosed Grounds.

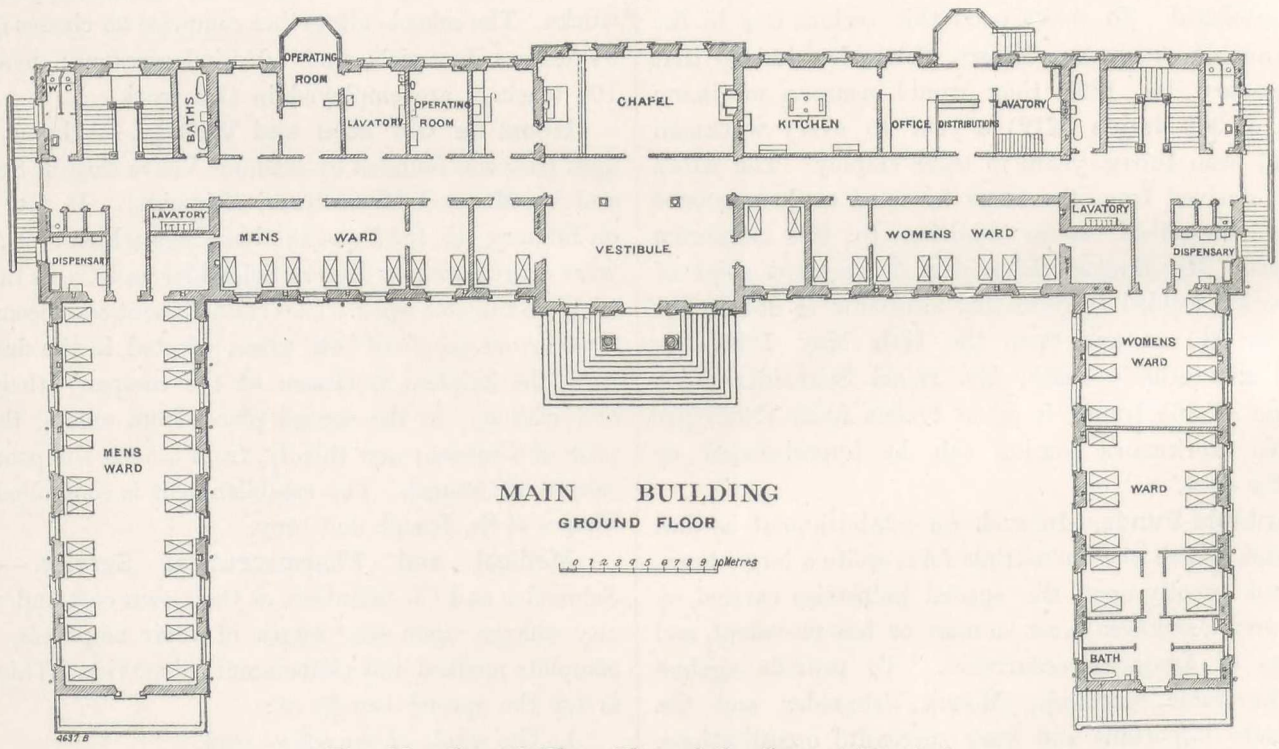


Fig. 22. Ground Floor Plan of the Creusot Hospital.

THE HÔTEL DIEU OF CREUSOT.

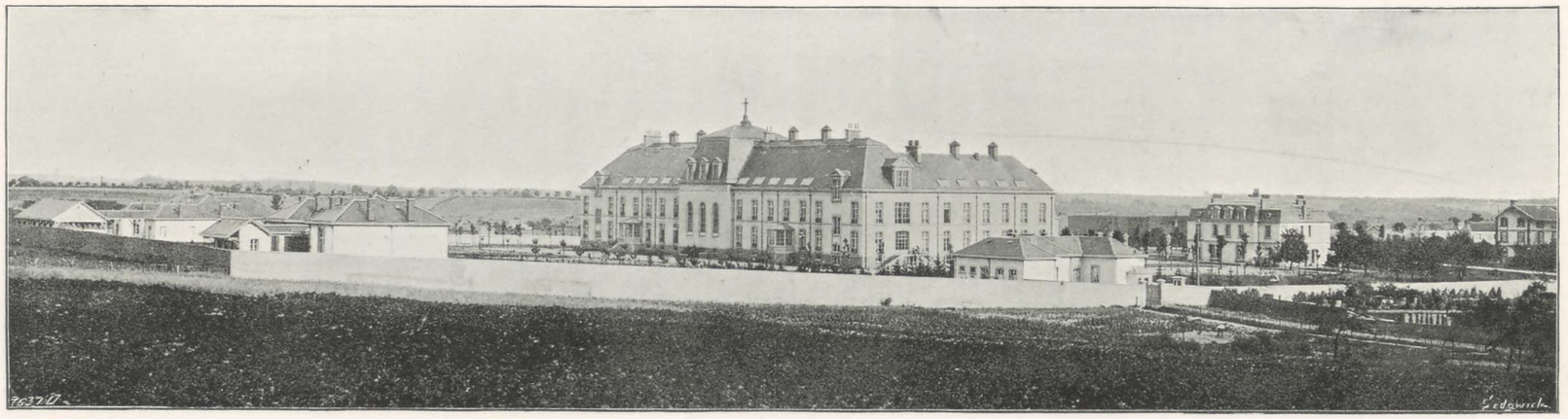


Fig. 19. View of Hospital, North Front.

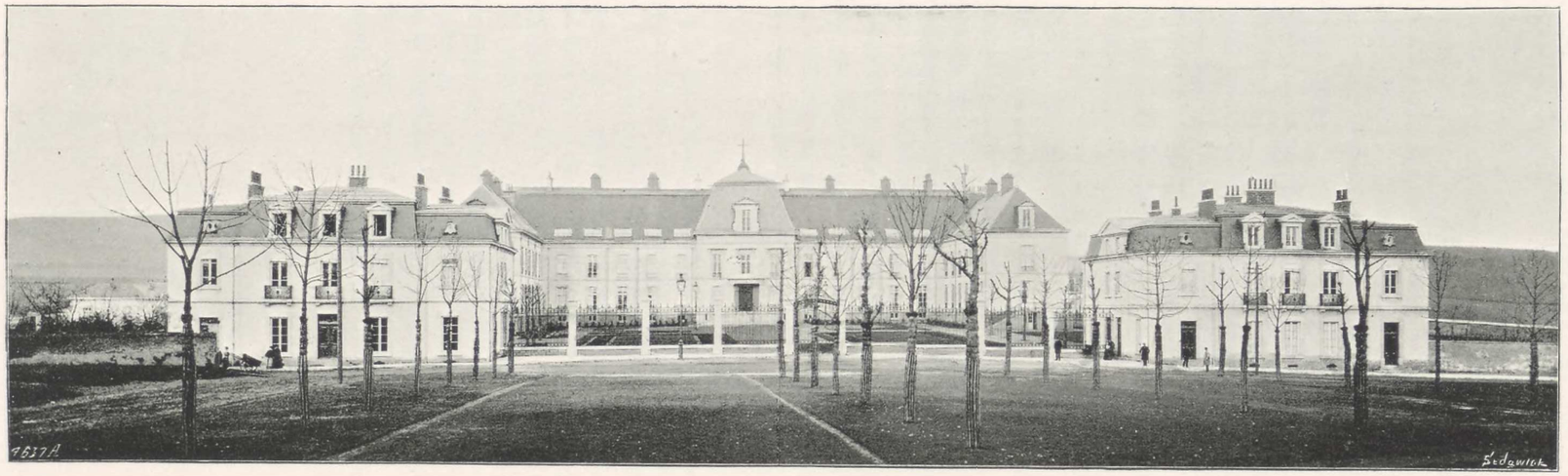


Fig. 20. View of Hospital, South Front.

1. To the *personnel* of Messrs. Schneider and Co.

2. To the inhabitants of the town and canton of Creusot.

3. To the troops in garrison at Creusot.

4. To strangers living temporarily at Creusot.

The service of the hospital is in the hands of the Sisters of Notre Dame des Sept Douleurs, the mother-house of which is the Hospital of St. Jacques, at Besançon.

Figs. 19 and 20, Plate III., are engravings of the north and south façades respectively, of the Creusot hospital, and some more detailed particulars may be added here to the general facts given above. The hospital was commenced in 1889, and opened to patients in the autumn of 1894. The buildings and gardens, enclosed within a wall, cover an area of 5½ hectares, but the surrounding property which belongs to it has a total extent of 57 hectares. Within the enclosed space, the plan of which is illustrated by Fig. 21, besides the main building, A, are two large pavilions on the road front, E, F; an isolated building—for contagious diseases; a bathing, laundry, and disinfecting building; and a mortuary.

The main building is 86 m. (282 ft.) in length, besides the wings, which are 27.75 m. (91 ft.) long; it is built with a ground and first floor, and one storey in the roof. The ground floor is raised 2.50 m. (8 ft. 2 in.) above the normal level, access to it being gained by a broad central staircase, beneath a porch. Within is a vestibule, from which a central gallery passes right and left, dividing the building into two parts, one facing north and the other south. The galleries terminate at the wings, and lead to two broad end staircases. In the northern side of the building, on the ground floor are, the chapel in the centre; on the east side, the kitchen and offices; on the west, the operating and dispensing rooms. On the south side are sick wards, and some small rooms for separately-treated cases. The wings are occupied with more sick wards, and in the east wing is a space set apart especially for military patients. Bath rooms, elevators, linen hoists, &c., are placed at each end of the main central passage. The plan of the ground floor, Fig. 22, clearly illustrates the arrangement just described. The first floor is arranged in a very similar manner, except, of course, that the kitchen space is otherwise utilised. The chapel rises above the first floor, and the area over the vestibule is occupied by a council chamber. The vast space on the top floor, within the roof, is utilised for stores, water-supply tanks, &c.; but, in the event of epidemics, many beds could be made up there. There is a basement, which contains the heating apparatus, the kitchen cellar, some rooms for mad patients, a gas-lighting plant, and a staff refectory. The wards are all spacious and airy, and of varying dimensions, to contain two, six, eight, or twenty-four beds.

Nursing Sisters.—Since April 1st, 1897, Messrs. Schneider and Co. have made arrangements with the Community of Franciscan Sisters from Montfaucon-du-Velay to organise a house service of nursing sick or injured persons. This service comprises:

1. Visiting and nursing sick and injured persons by day and by night.

2. Absolute execution of doctors' orders and the proper administration of medicine.

3. Taking necessary steps to insure medical attendance and distributing the medicine prescribed.

4. Taking care of the children and the houses of sick or injured persons, whether the latter are tended in their own homes or nursed in the hospital.

This service is for the gratuitous benefit of Messrs. Schneider and Co.'s employés, workmen, and their families; of the inhabitants of the town and canton of Creusot; and of foreigners in temporary residence.

There is little room for wonder why workmen remain from generation to generation in a service which does so much for their comfort and benefit. The establishment is, indeed, almost patriarchal in its habits and customs, and workmen who from love of change seek employment elsewhere, usually return to Creusot under the influence of irresistible nostalgia. It does not matter that the hours of work are long, and the wages paid are light; the workman is contented, and seeks no better than to pass an active life and a comfortable old age in honourable service. Needless to say that Creusot is wholly free from the curse of trades unionism, and from all the evils that follow in its train.

III.—GENERAL CLASSIFICATION OF MESSRS. SCHNEIDER AND CO.'S WORKS.

WE may now proceed to a consideration of the principal installations that go to make up the actual establishment of Creusot and its many dependencies. This may be most conveniently done, in the first place, by a summarised list as follows:

I. Mineral Section.

1. Coal mines:
   - *a.* Creusot.
   - *b.* Montchanin (Saône et Loire).
   - *c.* Decize (Nièvre).
2. Iron mines:
   - *a.* Mazenay, Créot and Change (Saône et Loire).
   - *b.* Allevard (Isére).
3. Brickyards.

The brickmaking plant of Perreuil, where refractory bricks of all shapes and sizes are manufactured for the metallurgical departments.

II. Metallurgical Section.

4. Blast-furnaces.
5. Coke ovens.
6. Steel works:
   - *a.* Bessemer and Martin plants.
   - *b.* Forging shops for the treatment of heavy steel pieces, thick armour-plates, gun parts, marine engine shafting, &c.
   - *c.* Steel cementation and tempering shops, especially for tempering and re-heating armour-plates.
   - *d.* Armour-plate finishing shops.
   - *e.* Tyre shops devoted to the manufacture of steel tyres for locomotives and rolling stock.
   - *f.* Steel foundry.
7. Rolling mill department:
   - *a.* Puddling for the manufacture of puddled iron.
   - *b.* Rolling mills for all classes of sectional steel; steel plates; light steel armour-plates for the Navy; armour-plates for protected land turrets, &c.

The rolling shops and steel works are provided with thoroughly equipped laboratories for making all kinds of physical and chemical tests. It is in these laboratories where all materials employed, as well as manufactured products, are submitted to analysis.

III. Construction Department.

8. Mechanical shops for the construction of machines, and parts of machines; marine and stationary engines; locomotives; boilers; &c.
9. Electrical shops, for the construction of dynamos and other electrical apparatus.
10. Laboratory for mechanical tests.
11. Laboratory for electrical tests.
12. The artillery shops at Creusot.
13. The artillery shops at Hâvre.

Both of these latter are equipped for fitting, finishing, and mounting guns of all calibres; carriages; cupolas; and, in general, all kinds of war material.

14. The polygon at Creusot (Villedieu), for testing guns and armour-plates, powders and projectiles.
15. The polygon at Hâvre (Hoc), arranged especially for ballistic experiments with guns of all calibres.
16. Miscellaneous shops for the construction and maintenance of the buildings in the works; the maintenance and renewal of the fixed plant and rolling stock of the railways belonging to Messrs. Schneider and Co.; the direction of traffic on these lines, and that of a port belonging to the company on the Canal du Centre, at Bois Bretoux.
17. The workshops at Chalon-sur-Saône, which contain the shipbuilding and bridge-construction departments.

IV. The Direction.

18. The administrative services, comprising:
   - *a.* The central direction.
   - *b.* General control.
   - *c.* General inspection.
   - *d.* Régie du Domaine.
   - *e.* An arbitration office.
   - *f.* Cashier's office.
19. The commercial services are divided into nine sections:
   - *a.* General stores.
   - *b.* Coal mines.
   - *c.* Transports.
   - *d.* Steel works and rolling mills.
   - *e.* Artillery.
   - *f.* Engineering department.
   - *g.* Electricity.
   - *h.* Finance.
   - *i.* Archives.
20. There is also an extensive printing office and a photographic studio.

MESSRS. SCHNEIDER AND CO.'S WORKS AT CREUSOT.

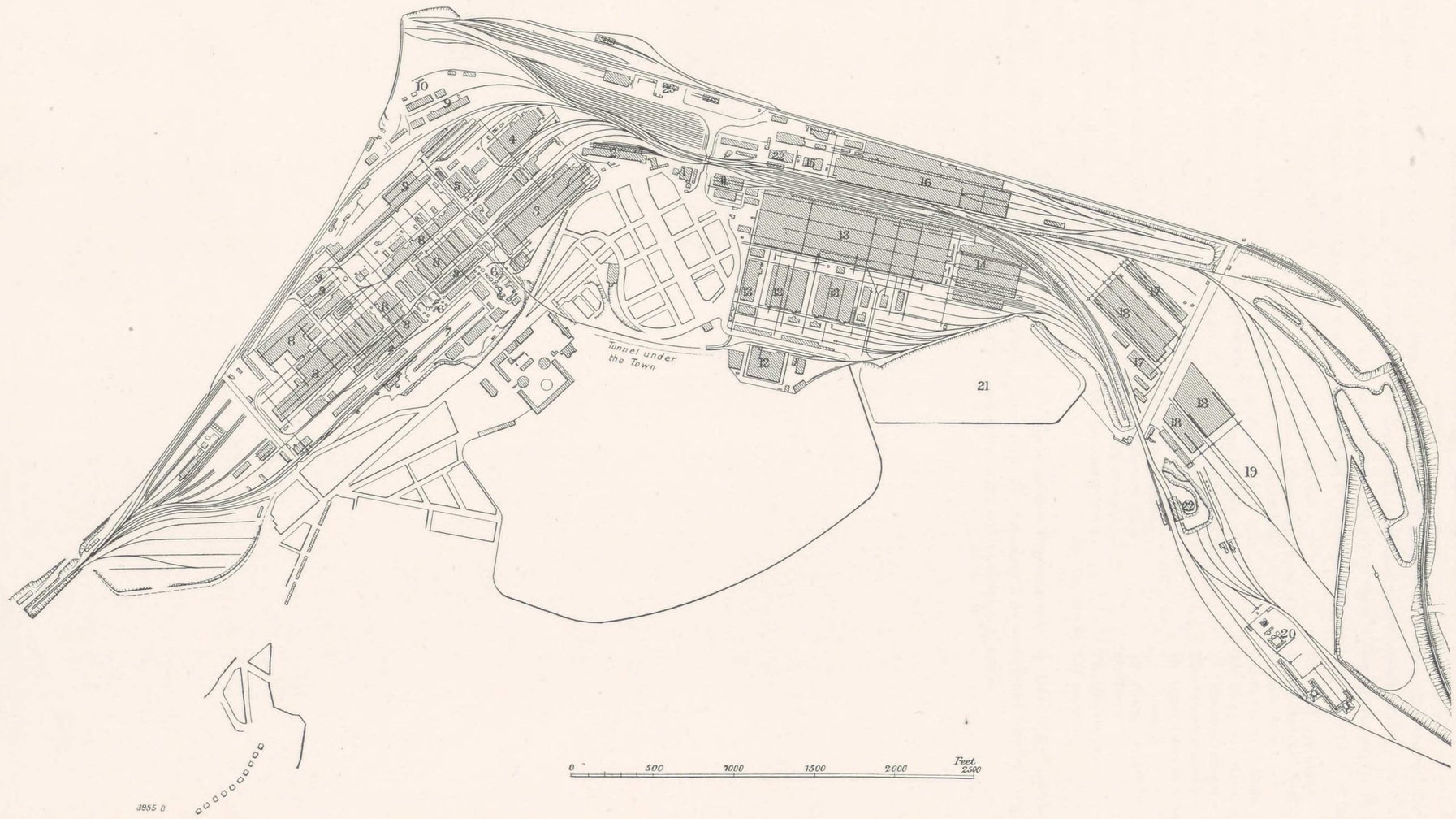


Fig. 23. General Plan.

Besides the foregoing, Messrs. Schneider and Co. own important interests in numerous French and foreign industrial establishments, and in the Société Anonyme des Chantiers et Ateliers de la Gironde, at Bordeaux, where vessels of all sizes for the Navy, as well as for the merchant service, are constructed.

General Plan of the Works.—This may be found a convenient place to say a few words about the general arrangement of the Creusot works, with the assistance of the plan Fig. 23, Plate IV. As may be seen, the works may be roughly divided into three sections: the first comprising the blast-furnace and steel plant, with the machine and construction shops; the second, the rolling mills, steam hammers, &c.; and the third, the electrical works, the gun-making shops, and the firing grounds of Villedieu. Included in this vast area are the coal mines to be presently described, worked by the St. Pierre and St. Paul shafts, as well as the St. Laurent shaft, not far distant. It will be seen that railway lines run around three sides of the works, and that branches and sidings are laid down to accommodate every shop. The figures given on the plan correspond to the different parts of the works as follows:

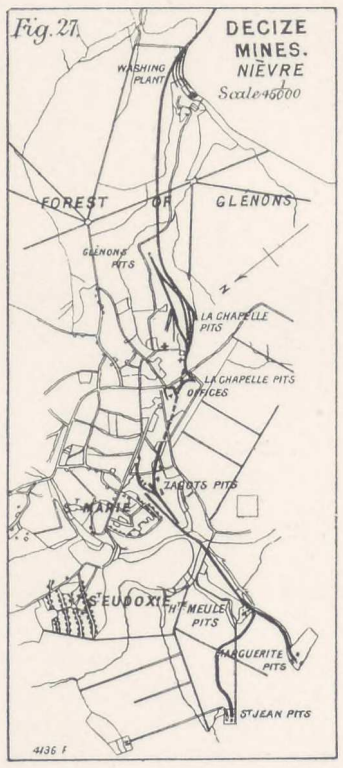
1. General offices.
2. Coal mines (St. Pierre and St. Paul shafts).
3. Steel works.
4. Steel foundry.
5. Rotary puddling furnaces.
6. Blast furnaces.
7. Coke ovens.
8. Machine shops.
9. Carpenters' shop.
10. Auxiliary shop.
11. Locomotive shed.
12. Steel tyre works.
13. Rolling mills and forge.
14. Iron stores.
15. St. Laurent shaft.
16. Steam hammer shop.
17. Electrical shops.
18. Ordnance works.
19. Open space attached to gun shops.
20. Firing ground.
21. Pond.
22. Gas works.
23. Creusot railway station.

The various departments of this huge establishment may now be considered in somewhat careful detail, commencing with the various coal mines.

IV.—COAL MINES.

The Coal Mines of Creusot.—Coal is raised from the Creusot mines by several pits, varying in depth from 1,100 ft. to 1,350 ft. All the installations of these mines, the surface as well as the underground plant, are of modern types, and the hoisting machinery is arranged for rapid and safe working. Sorting, screening, and washing the coal, are done immediately after extraction. One shaft, called the St. Laurent Pit, is devoted to draining the mine; it has a steam pump that discharges on an average 3,000 tons of water per twenty-four hours.

The bed of coal at Creusot consists of a main seam 50 ft. to 65 ft. in thickness, from the walls of which run smaller seams; the thickness of these often reaches 12 ft.



to 14 ft. The coal is extracted from three pits, the Chaptal, the St. Pierre, and the St. Paul.

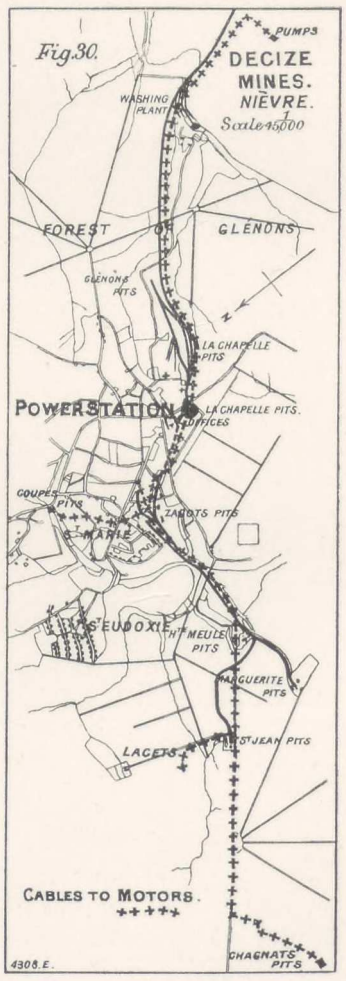
The headworks of the Chaptal pit are illustrated by Fig. 24, Plate V., and those of St. Pierre and St. Paul, by Fig. 25 on the same Plate.

From the Chaptal pit, the highest part of the bed is worked; it yields semi-bituminous coal, giving 22 per cent. of volatile matter. The lower parts of the bed are worked by the St. Pierre and St. Paul shafts; they yield anthracite only, containing 12½ per cent. of volatile matter.

Both the classes of coal mined are of high quality, and well adapted for metallurgical purposes. The coal in the Creusot mine is worked by horizontal stalls, the spaces being completely filled up afterwards. This method of working was tried for the first time at these pits as long ago as 1840, and since then it has been generally followed.

A new pit, the St. Antoine, is now being sunk at the Creusot group, with a view to facilitate the opening of those parts of the bed that had been only partially mined by the ancient workings, where fires were of frequent occurrence, owing to the methods of extraction followed in former times.

The Decize Mines.—These mines, the working centre of which is at La Machine (Nièvre) are among the oldest



in France; they were commenced under the protection of a decree, dated July 16th, 1689. On August 16th, 1806, they were conceded definitely to M. de Mallevault, and in 1869 they became the property of Messrs. Schneider and Co. The mines are placed in communication with Creusot, 55 miles distant, by a branch of the Paris, Lyons, and Mediterranean Railway—the line from Chagny to Nevers. A private railway of five miles connects these mines (1) to the Nivernais Canal, at the Port du Rio; and (2) to the Paris, Lyons, and Mediterranean Railway, by a branch running to the Decize (Nièvre) station. Very important

THE COAL MINES OF CREUSOT.

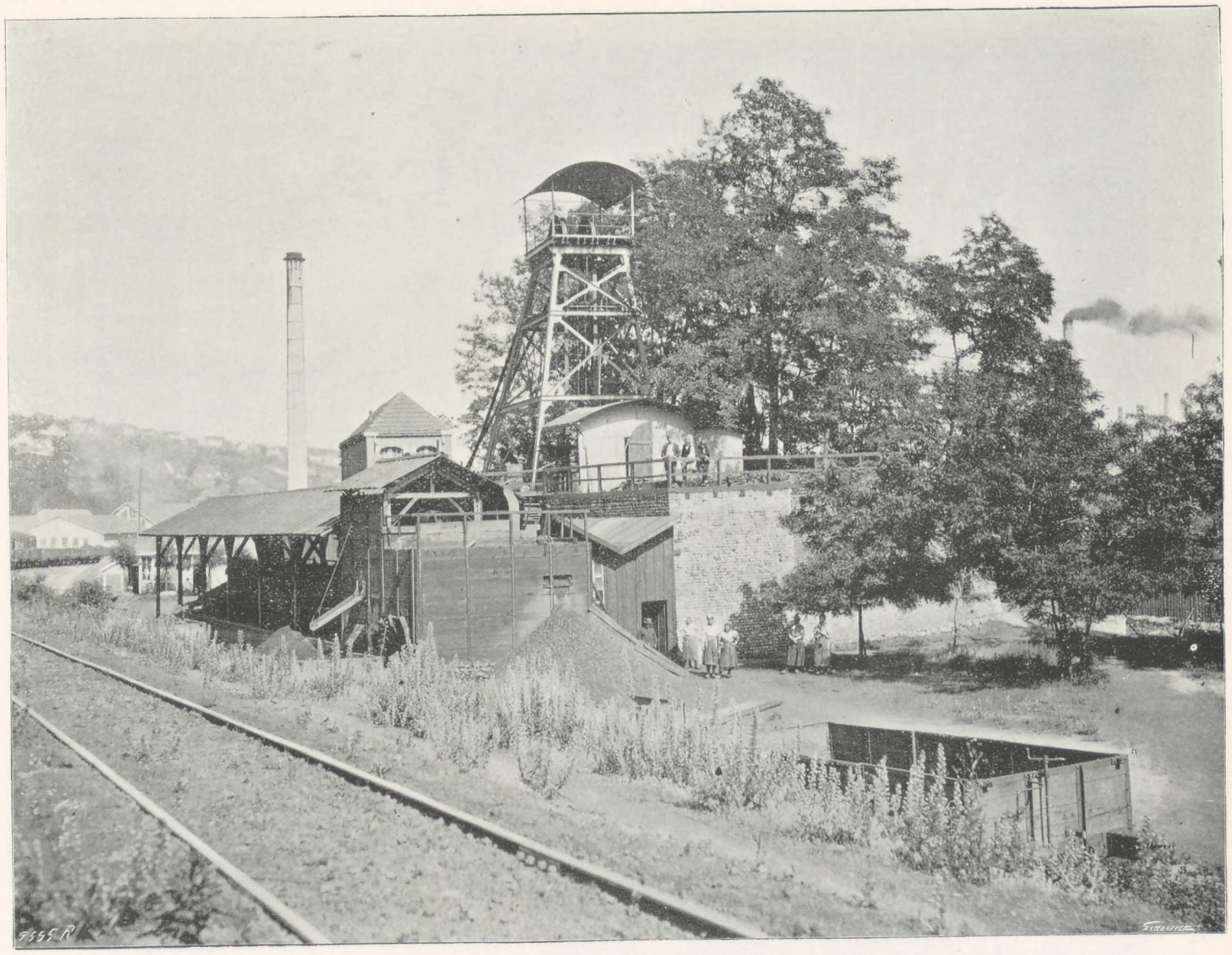


Fig. 24. Head Works of the Chaptal Pit.

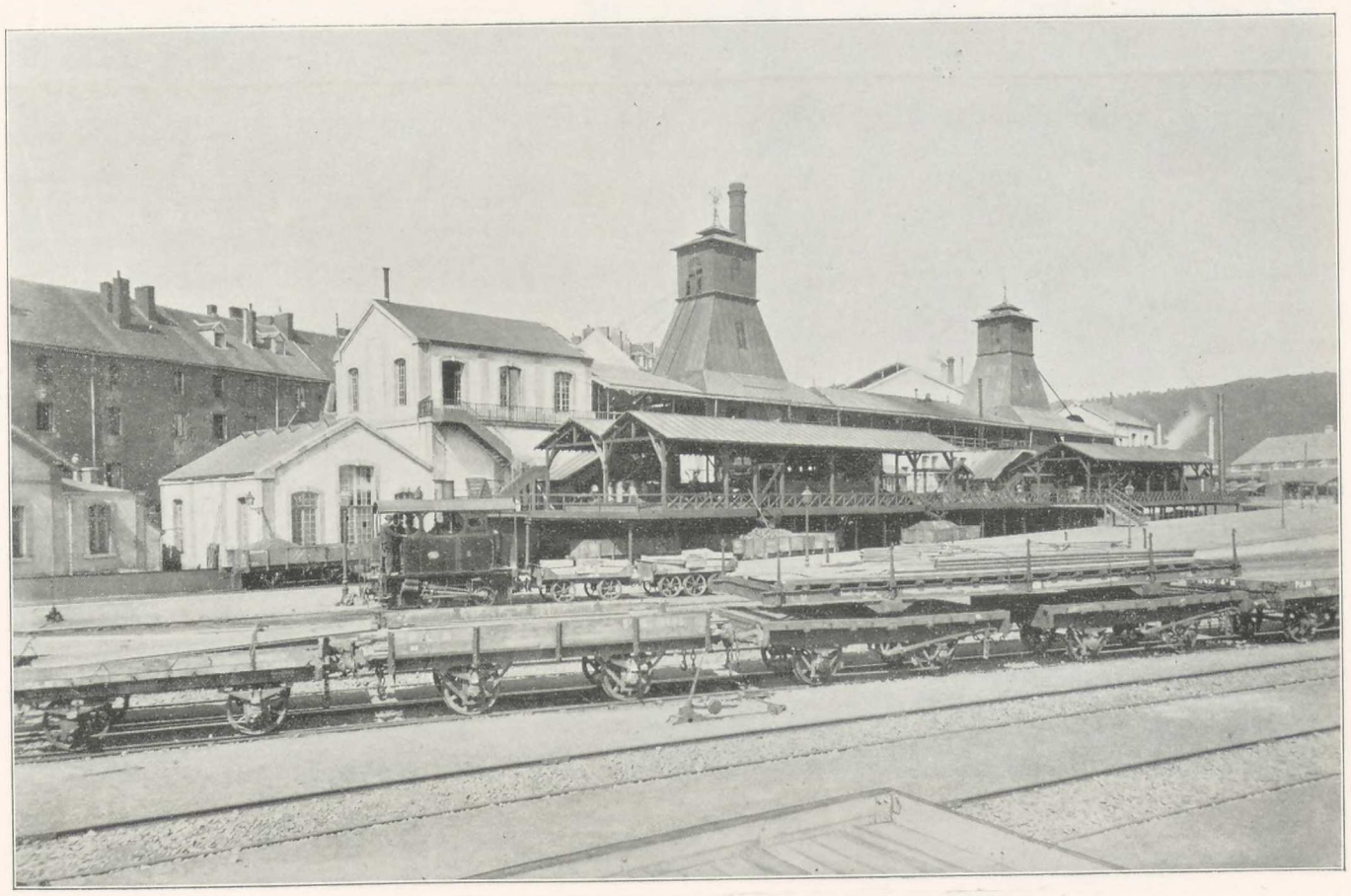


Fig. 25. Head Works of the St. Pierre and St. Paul Pits.

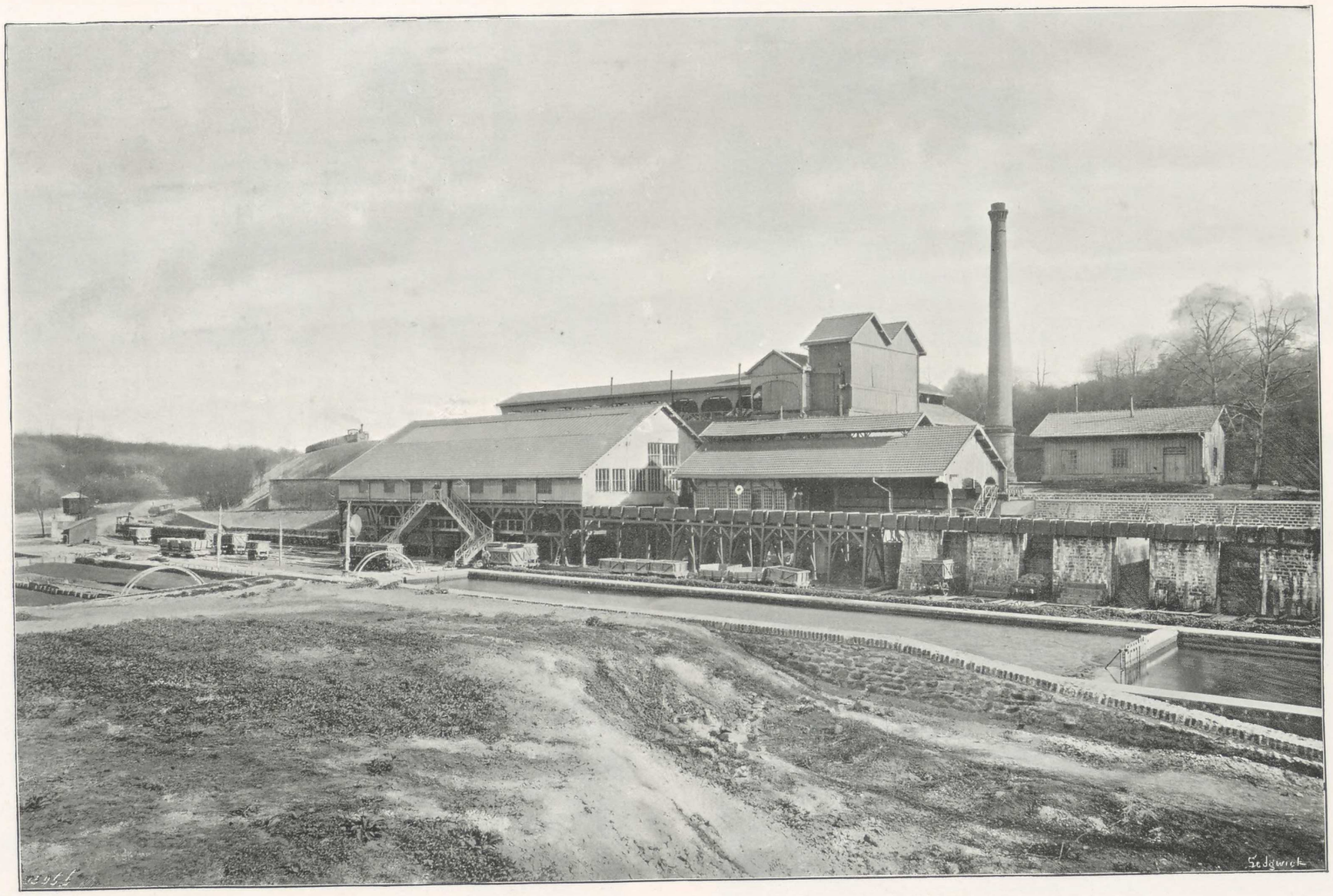


Fig. 26. Coal Washing and Screening Plant at Pré Charpin, Decize Mines.

THE JOINT WIRE

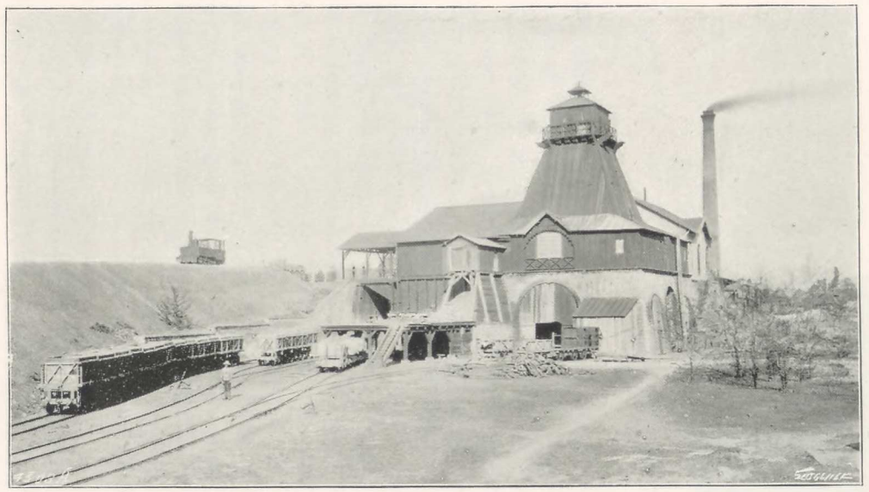


Fig. 28. Head Works of the Zagot Shaft, No. 2, Decize.



Fig. 29. Head Works and Air-Compressing Plant, La Chapelle Pit, Decize.

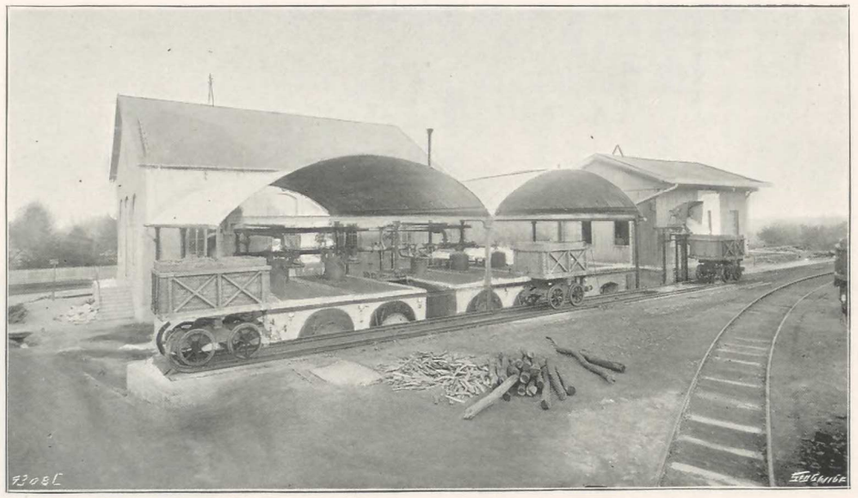


Fig. 31. Boilers of Electrical Power Station, Decize.

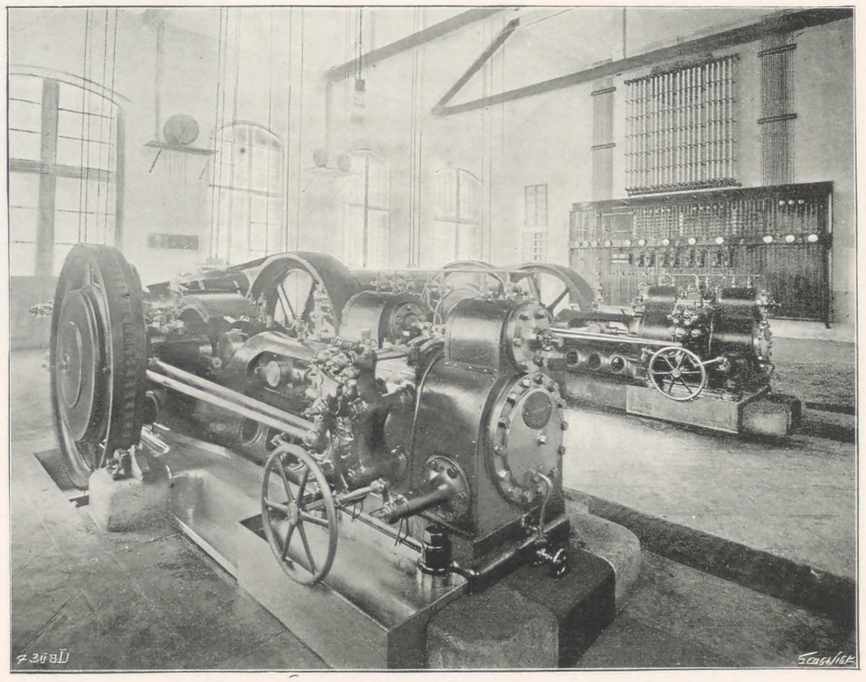


Fig. 32. Interior of Electrical Power Station, Decize.

PLATE VII.

THE GETTY RESEARCH INSTITUTE

coal washing and separation works are established at Pré Charpin on the line of railway belonging to Messrs. Schneider and Co. Fig. 26, Plate VI., is an illustration of this extensive plant. The district of La Machine, which forms the centre of the working, is 5 miles from the small town of Decize. It contains 5,000 inhabitants, and is situated about 300 ft. above the level of the Loire, on the ridge which separates the two valleys where the coal pits are sunk.

The beds are nine in number, forming three separate systems; their thickness varies from 3 ft. to 9 ft. The method of working is by stopes, the coal in the lode being taken away direct without filling up. Three main pits (Fig. 27) serve for extracting the coal: the Glénons pit on the west, the Zagots pit in the centre, and the Marguerite pit to the east. Fig. 28, Plate VII., shows the head of the Zagots pit, whilst Fig. 29, on the same Plate, illustrates the headworks and air-compressing plant of one of the smaller pits, that of La Chapelle. The Marguerite pit is in communication with the two others by means of a system of inclined planes, and by a narrow-gauge railway on which run small locomotives. In 1890 investigations were commenced beyond the dip of the coal bed, and compressed air was used in connection with these new workings. One gallery starts from the 1,200 ft. level of the Glénons pit, and has been carried to a depth of 2,100 ft. In the case of this working, the exploration carried out at the level of 1,500 ft., in the seam itself, has proved the latter to extend for a length of 4,200 ft. Since 1890 the use of compressed air has been greatly increased, not only for exploration works, but also for hoisting the coal up the inclined planes by means of winches, thus saving the excessive cost of cutting fresh levels through rock.

In 1893 an important electric plant was put down for the lighting of various shops, and also for the transport of power over long distances. The development of the workings made it necessary to establish a certain number of ventilators, at long distances apart and in unfrequented spots difficult of access. Each ventilator would have involved the installation of a separate power station, which it would have been difficult to keep regularly supplied with fuel and water, and the services of two men would have been required at each station. Moreover, the fuel it was intended to use, was of such an inferior quality that it would not have paid to transport it.

Under these conditions, the only practical plan that suggested itself was to burn this inferior fuel at a central station near the pits, and to transmit the power thus produced, electrically. This installation was completed in 1893, and a plan of the district is given in Fig. 30, on which the lines of cables to the distributing stations are marked. The electric plant was designed and manufactured



Fig. 33. Electrical Receiving Station, Decize Mines.

by Messrs. Schneider and Co., at their Creusot Works. The distance between the extreme points is 5 miles; current is supplied to six electric motors, of 15 to 30 horse-power; to 30 arc lamps; and to 600 incandescent lamps. The generating station, placed approximately in the centre of the distribution area, consists of three complete groups of 100 kilowatts each, one of them being kept in reserve. Each group is complete in itself, with boiler, engine, and dynamos. The illustrations, Figs. 31 and 32, Plate VII., and Fig. 33, show the central station and one of the isolated receiving stations.

The Montchanin and Longpendu Mines.—These collieries include two distinct concessions:

1. The Montchanin Mine, once forming a part of the Creusot concession, but made independent of it by a Royal decree dated October 24th, 1838. In the same year Messrs. Schneider and Co. organised a company to work this separated portion, under the title of the "Société des Houillères de Montchanin."

2. The Longpendu Mine, which was conceded to the Marquis de Montaigu, by a Royal decree dated October 6th, 1832. Both properties were acquired at a later date by Messrs. Schneider and Co. They are served by the Montchanin station on the Nevers and Chagny branch of the

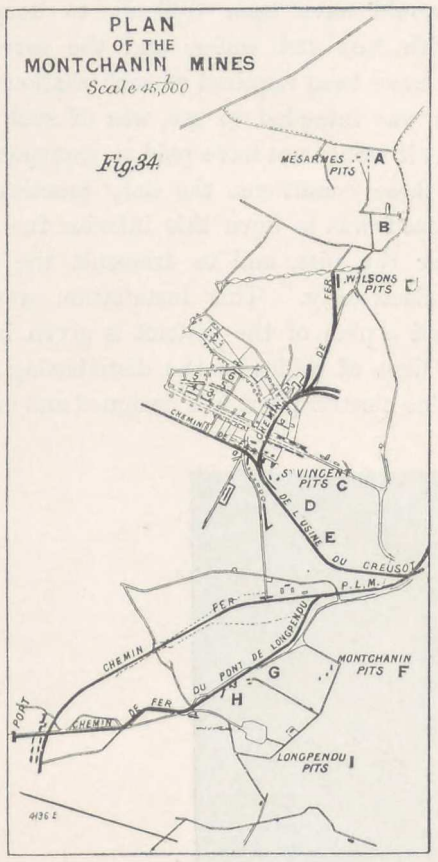


Fig. 34.

Paris, Lyons, and Mediterranean Railway, and are connected with Creusot and with the Canal du Centre (Bois Bretoux and Longpendu ports) by a railway, one of the first constructed in France.

The concession of Montchanin consists of 4,240 acres. and that of Longpendu of 1,754 acres. The coal formation rests, southwards, on granite, and northwards it is covered by the Permian system. Three pits, the depth of which does not exceed 600 ft., serve for extracting the coal; they are, as will be seen from the plan, Fig. 34, the Wilson pit to the west, the Quètel pit in the centre, and the Grand Puits de Longpendu on the east. The length of the seams extends east and west. In the places where the beds show a sufficient thickness, the method of working is horizontal, in the same way as in the Creusot mine, and with complete filling up after extraction. Most of the output consists of a long-flamed bituminous coal, containing 35 per cent. of volatile matter. The bed at Montchanin is interrupted by longitudinal and transverse faults, which divide it in masses of various forms. One of these masses, measuring 200 ft. in thickness and 2,000 ft. in length, has formed the output of the Quétel pit for many years. The numbers on Fig. 34 refer to the following buildings, &c., connected with the concession:

1. Stores.
2. Offices.
3. Girls' school.
4. Boys' school.
5. Workmen's dwellings.
6. ,, ,,
7. Stores.
8. Workmens' town of Longpendu.

The various shafts in this district are marked on the plan as follows:

A. Puits des Mèsarmes.
B. Puits Sorot.
B¹. Puits Wilson.
C. Puits St. Vincent.
D. Puits Quétel No. 2.
E. Puits de Ségur No. 2.
F. Puits Ste. Barbe de Montchanin.
G. Puits Louise.
H. Grands Puits.
I. Puits Ste Barbe de Longpendu.

At Longpendu five beds of 3 ft. to 9 ft. in thickness are worked; these also are irregular owing to faults, but it has been possible, notwithstanding, to work the seams very regularly and on an important scale.

V.—IRON MINES.

The Mazenay and Change Mines.—These form two distinct concessions: (1) that of Mazenay, and (2) that of Change. As will be seen from Fig. 35, both concessions are very near together; and they are about 19 miles from Creusot, to which they are connected by the Paris, Lyons, and Mediterranean Railway, and by a line belonging to Messrs. Schneider and Co. The ore actually worked is in a deposit 5 miles long and $\frac{3}{4}$ mile wide, the thickness varying from 20 in. to 8 ft. 6 in. The depth of the working shafts does not exceed 130 ft. The concession of Mazenay comprises 2,700 acres; that of Change 2,630 acres. The product of these mines is an oolitic calcareous

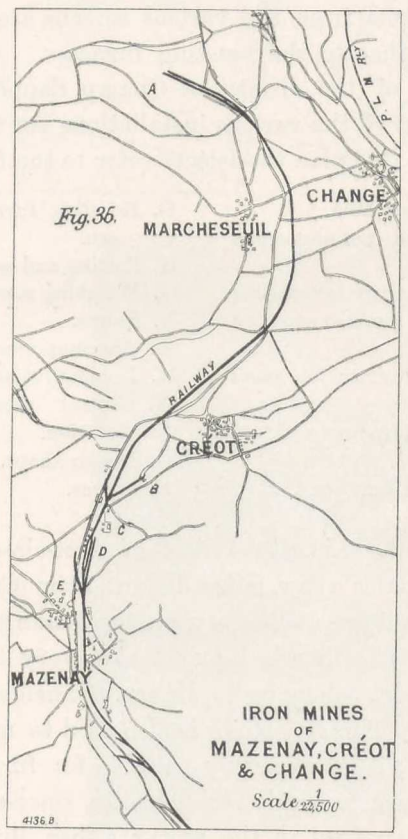


Fig. 36.

ironstone. The beds are interrupted by dislocations, but the general direction has not been shifted. The St. Eugène pit at Mazenay has an annual output of 50,000 tons of ore; that of St. Charles at Change, is 60,000 tons.

At St. Charles, where the bed is of the greatest thickness, the analysis of dry ore shows a percentage of 30.90 of metallic iron, which is equivalent to 28.5 per cent. in the blast furnace. The various iron ores mined in France contain widely variable percentages of phosphorus, and a remarkable feature of the Mazenay ore is that phosphorus is in constant proportion to the percentage of iron; so that as samples become poorer in iron, and, therefore, richer in calcareous matter, the percentage of phosphorus decreases regularly, notwithstanding the increasing number of fossil shells. The phosphorus, therefore, is not combined with the lime, but with the iron itself, forming a phospho-carbonate. A few years ago the ore was worked on the long-pitch system; now the long-wall method is adopted, some of the faces of workings being 1,000 ft. in length. This is found to be much more economical, especially where the bed is not very deep.

On leaving the mine, the trucks are tipped direct into 10-ton wagons, and the ore is brought to the Creusot blast furnaces by the railway belonging to the company.

The references on Fig. 35, a plan of the Mazenay and Change mines, are as follows:

A. St. Charles shaft. B. St. Francois incline.
C. St. Eugène shaft. D. Railway station.
E. Incline.

The Allevard Mines.—These consist of a group of seventeen concessions, which were acquired by Messrs. Schneider and Co. in 1874 from MM. Charrière et Cie., and from the Marquis de Marcieu. They have been worked at a great number of points since the beginning of the century, but it is only of late years that their development has been carried on in a satisfactory manner. They are connected with the Paris, Lyons, and Mediterranean Railway by a local line conceded to Messrs. Schneider and Co. in 1875. This line ends with four inclined planes. It leaves the concession at Taillat, at an elevation of 3,650 ft., and runs to the Cheylas station on the Paris, Lyons, and Mediterranean Railway at an altitude of 813 ft. The first three inclines are, together, 4,920 ft. long and the fourth is 1,640 ft. long. These planes account for a difference in level of 2,840 ft. between the mines and Cheylas station. The ore brought from Taillat by the first inclines is for the most part roasted, six furnaces being installed for this purpose at Champ Sappey, at the foot of the incline.

The concessions collectively cover 6,330 acres. The ore is a carbonate of iron contained in numerous veins on the west side of the Belledone chain of mountains, and especially in the vicinity of Allevard. These veins are, as a rule, contained in crystalline slate, and in triassic quartz rock, which covers the slate. The furnaces in which the ore raised from these mines was melted at the beginning of the century, have long since disappeared, and when Messrs. Schneider and Co. purchased the concessions in 1874, they put down entirely new plant.

The average annual output is now 50,000 tons. The most important part of the mine is that known as Taillat, in which two principal veins are worked; these are cut by

the Ste. Madeleine heading, at a height of 3,340 ft. In 1893, a new heading called St. Henri, at a height of 2,700 ft., one mile in length, was driven by means of drills worked by compressed air. This gallery also cuts the two veins, and will facilitate the work of extraction for many years to come. The first vein intersected is 18 ft. to 25 ft. deep; it yields a foliated ore, largely crystallised, and known as "maillat" ore. This quality gives the finest samples from a mineralogical point of view, but it is not the best for practical purposes, as it is not sufficiently rich in manganese, does not roast easily, and yields a certain

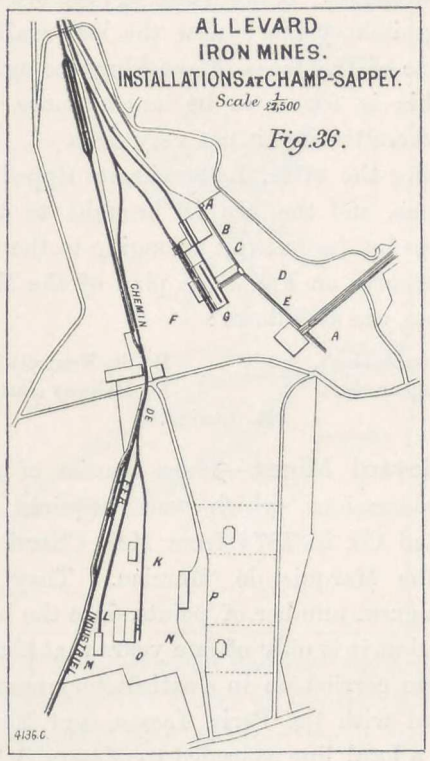


Fig. 36.

quantity of dust. The second vein, the finest of the whole region, is equal in depth to the "maillat" vein. The ore it yields shows smaller scales, and is richer in manganese. The gangue is chiefly quartz; in some cases it is found to be dolomite, and multiple carbonates of iron, of manganese, and of lime. The mode of working is by galleries, which divide the veins into a series of levels, one above the other. These levels are reached by shafts, and the veins are worked by inclined cuttings, the excavation being filled up as the ore is taken out.

On leaving the mine, the trucks are carried, four at a time, on frames which descend the inclined planes as far as Champ Sappey, near St. Pierre d'Allevard. There the ore is thrown on screens and washed by means of jets of water; it is then sorted, the largest pieces being broken with the hammer. After washing, the ore is roasted. Three furnaces of an ordinary type serve for this purpose, and three others built specially are used for roasting the fine ore. The furnaces are heated by gas, which is produced in separate generators. The ore loses 25 per cent. of its weight in roasting, and after this operation, it contains from 46 to 48 per cent. of metallic iron and manganese The proportion of crude fine ore being rather large, a special plant has been put down for mechanical preparation and washing. The largest pieces are crushed between rolls, and the whole is then screened. The product is divided into five classes, and is carried to continuous washing machines provided with lateral pistons and sieves. The ore gradually falls to the bottom of the tank, and the waste stone is carried away by the stream from the washers. The finer portion is treated in another type of washing machine. Classification into different sizes is carried on only to facilitate the washing process, and the washed products from the various screens are afterwards brought together to the roasting furnaces. Fig. 36 is a general plan of the district of Champ Sappey, and subjoined is a list of the various installations for treatment of the ores. In this plan the letters refer to the following:

A. Weighing machine.
B. Sorting and washing small ore.
C. Magnetic screens for treating refuse of the heavy roasted ore.
D. Roasting furnace for small ore.
E. Roasting furnace for heavy ore.
F. Screens for heavy ore.
G. Roasting furnace for small ore.
H. Sorting and screening ore.
I. Weighing machine.
K. Stores.
L. Air compressors.
M. Locomotive shed.
N. Central electric lighting station.
O. Repair shops.
P. Offices.

Limestone.—Limestone flux of first-class quality is found in quarries a few miles distant from Creusot. The most important are at Chagny, on the banks of the Canal du Centre. The flux is brought at a very low cost by boat to the port belonging to Messrs. Schneider and Co., at Montchanin. This limestone is also used to make lime of great purity; it is extremely suitable for furnace linings. The same remark applies to dolomite, fluor-spar, various sands and clay used in the works, either direct, or after treatment at Messrs. Schneider and Co.'s brick works at Perreuil.

VI.—THE PERREUIL BRICK WORKS.

General Arrangement.—These brick works (see plan, Fig. 37), belonging to Messrs. Schneider and Co., are situated in the vicinity of Creusot, on the line from Chagny to Nevers, at 200 yards from the Canal du Centre. Besides this means of transport a private railway

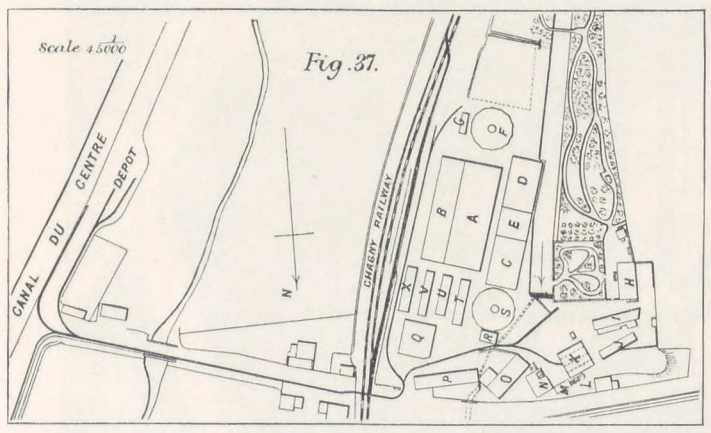


Fig. 37.

line unites the brick works to Creusot, and a narrow-gauge railway runs from the Briqueterie to the Canal. Messrs. Schneider and Co. purchased the ground on which to build these works in 1842. Previously it was occupied by a blast-furnace and a small forge, both of which have been pulled down. In 1844, a plant was put down for the manufacture of earthenware pottery; this ceased in 1846, when the present industry was created. Since that date the importance of the brick works has increased year by year, following the development of Creusot in the manufacture of Bessemer and Siemens-Martin steel.

The plan, Fig. 37, shows the general arrangement, and the railway connection with the Chagny line, as well as the private railway to the Canal du Centre; the letters on the plan refer to the following parts of the installation:

A. Main shop with drying floors.
B. Depôt and shipping department.
C. Shop for making silica bricks.
D. Depôt for finished articles.
E. Shop for making special pieces for the steel works.
F. Brick kiln No. 2.
G. Gas producer.
H. Manager's house.
I Offices.
J. Wood store.
L, N. Ovens.
M. Gas producers.
O. Tuyere-making shops.
P. Shop for mechanical preparation by machinery.
Q. Store.
R. Gas producers.
S. Brick kiln No. 1.
T, U, V, X. Brick sheds for summer working.

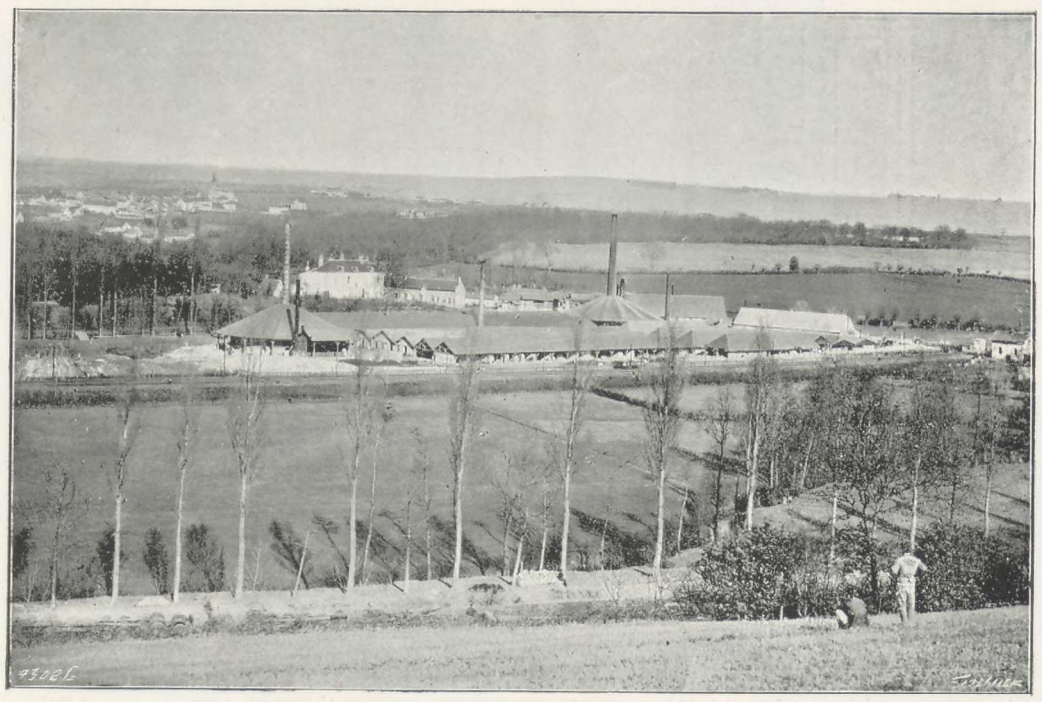


Fig. 38. General View of the Perreuil Brick Works.

A general view of the brick works is given in Fig. 38.

The motive power is furnished by a two-cylinder compound vertical engine, of the steam-hammer type, of 50 nominal horse-power. This drives the various clay mills, &c. Steam is produced in a multitubular boiler.

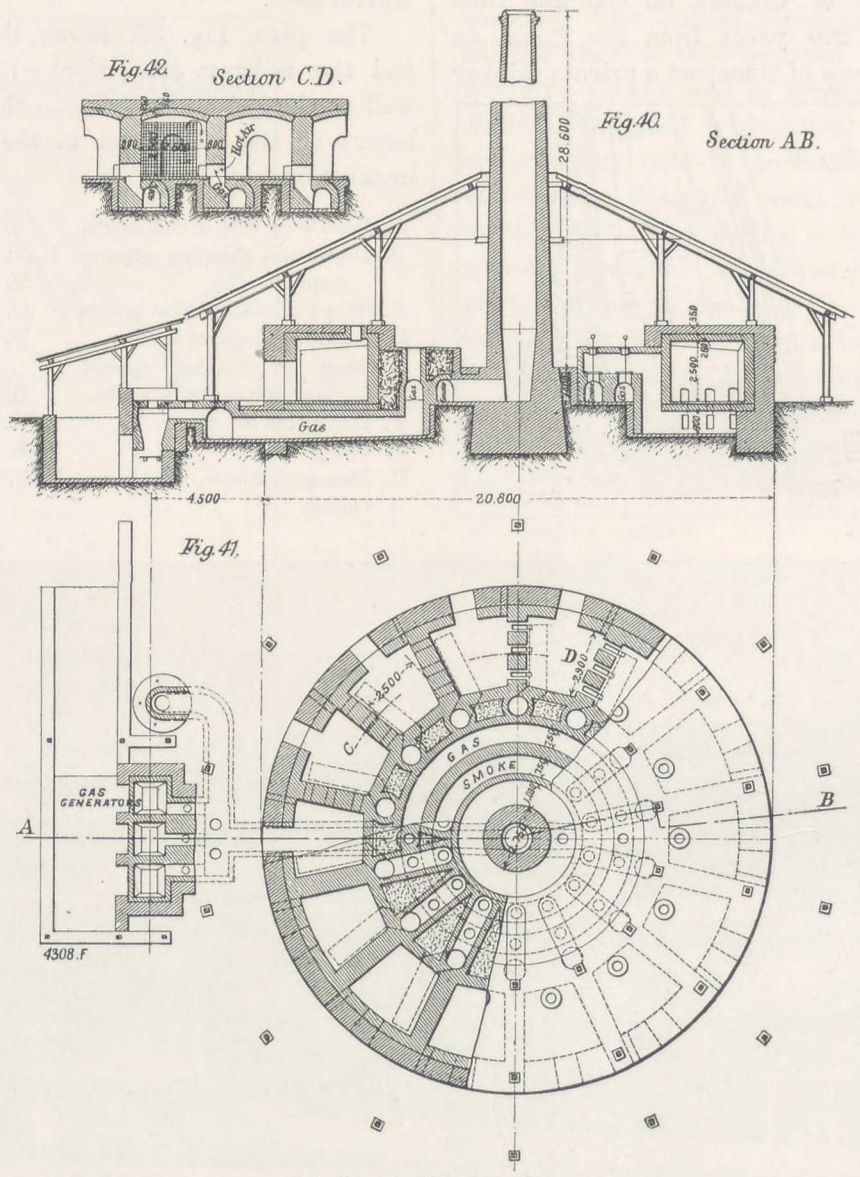
Clay Mills.—These are in a building 100 ft. long by 85 ft. wide; the principal machines it contains are as follows: A clay pug mill, with bucket elevator; a pug mill for treating various clay and other mixtures; a table

elevator for the lifting and distributing, on the first floor, of the clay prepared in the pug mills; an automatic bridge with trucks to carry down the goods manufactured on the first floor; three large crushing machines fitted with automatic feed and central screening arrangement. Fig. 39, Plate VIII., gives an excellent idea of the crushing mill plant. Each of the crushing machines is fitted with a bucket elevator, which distributes the crushed, mixed, and sifted products into separate bins. The plant also includes a crushing machine with revolving trough; a complete series of other machines for crushing, mixing, and preparing clay; and machines for pressing bricks, tuyeres, plugs, &c., of the various sizes and shapes used in the manufacture of iron and steel.

Kilns.—There are two circular continuous gas kilns, illustrated by Figs. 40 to 42, each divided into fourteen compartments; there are also two ordinary kilns, one burning coal, the other gas; one reverberatory kiln and a series of eight Perret kilns in three stories, which burn coke dust. These last serve, with numerous other kilns, to heat the drying rooms and closed shops, thus enabling the work to be carried on in the winter.

The circular kilns are used for baking the bricks of special form; the other kilns are used for preliminary roasting of the raw material. The total area occupied by the works is 35,000 square yards.

Circular Kiln.—The circular kiln (Figs. 40 to 42) is 65 ft. in diameter. The chimney is in the centre, and is 98 ft. high. The compartments are fourteen in number; they are 9 ft. 6 in. deep, 8 ft. 6 in. high, and their average width is 8 ft. 3 in. They communicate with each other by means of three openings in the walls, and at the bottom



Details of Circular Kiln.

the gases arrive below the floor through three vertical openings. Combustion begins near the separating walls, and spreads through the flues, which are arranged by placing the bricks in the compartments. The baked bricks in course of cooling serve to heat the air necessary for the combustion of the gases. The air passes through five or six compartments, each hotter than the other, before arriving in contact with the gases, in the compartment where the kilning is in progress.

The products of combustion (gases and smoke) flow through the compartments following the one in which the kilning goes on, and heat them before escaping through



Fig. 39. Crushing Mills.

the chimney in such a manner that the cell adjoining the one in operation, is already red-hot when the gases are introduced.

The temperature in the kiln can be raised to 2,732 deg. Fahr.; notwithstanding this it requires but very little repair. It is built of sand bricks outside, and fire bricks inside. The gas generators, hoppers, valves, and general mechanism, are of the simplest kind.

Raw Material and Products.—The raw material used consists of aluminous, silicious, and porcelain clay, quartz, bauxite, ores, carbonate of lime, &c. Nearly all this material comes from the Department of Saône et Loire, or from other departments bordering upon it. The silicious and porcelain clay is either stored in the open or under cover, where it remains as long as possible in order to increase its plasticity. The aluminous clay is kept in blocks under cover, so as to dry before being roasted, in order to drive out the remaining water. It is afterwards used as a mixture with softer clay.

At these works are manufactured refractory products of all kinds and shapes for metallurgical purposes; foundries; gas works; stove manufacture, &c. The chief products may be classified as follows, according to the various uses to which they are put:

A. *Quality.*—For puddling furnaces; re-heating furnaces, coke ovens; boiler bricks.

B. *Quality.* — For tuyeres; valve seats; ladles for Bessemer and Siemens-Martin steel.

C. *Quality.*—Cupola bricks, which have to withstand sudden and great variations in temperature.

D. *Quality.*—For the various parts of blast-furnaces; pieces for steel casting moulds; various parts of foundry cupolas; supports inside re-heating furnaces; coke ovens, heating stoves.

Silicious Quality.—For the construction of Siemens-Martin furnaces.

Bauxite Quality.—Aluminous isolating bricks for basic Siemens-Martin furnaces; flame bridges for puddling and re-heating furnaces.

Ore Quality.—For inside lining of rotary puddling furnaces.

The annual output of the Perreuil brick works is about as follows:

	Tons.
Bricks of all kinds	14,700
Tuyeres and special pieces for the steel works...	800
Fire-clay mortar	2,500
	18,000

VII.—THE BLAST-FURNACE DEPARTMENT.

General Arrangement.—The arrangement of the blast-furnace department at Creusot is shown on the general plan, Fig. 43 ; at the present time it consists of :

Five furnaces in blast.

Twenty Cowper stoves.

Thirty tubular gas-fired boilers.

Six horizontal blowing engines, Corliss type.

One battery of 168 horizontal coke ovens.

Eight tubular boilers fired by the waste gases from the coke ovens.

One shop for cleaning and grinding coal ; this shop is placed at one end of the long line of coke ovens.

Two Briquette-making installations containing three double-action presses, Couffinhall system.

The references to the letters on the plan, Fig. 43, are as follows :

A, A. Blast-furnaces.
B, B. Briquette shops, Nos. 1 and 2.
C, C. Hydraulic presses.
D. Lime stores.
E, E, E. Raised platforms.
F. Battery of 18 gas-fired (furnace) boilers.
G. Blowing engine-house.
H. Three coal-fired boilers.
I. Coal-handling yard.
K. 168 Horizontal coke ovens.
L. Battery of six gas-fired (coke oven) boilers.
M. Old vertical blowing engines.
N. Battery of ten gas-fired (furnace) boilers.
O. Repair shops.
P. Stores.
Q. Offices.
R. Water reservoir.
S. Steel works.
T. Pumps and accumulators.

Blast Furnaces.—Figs. 44 and 45, Plates IX. and X., illustrate the furnaces with their Cowper apparatus and

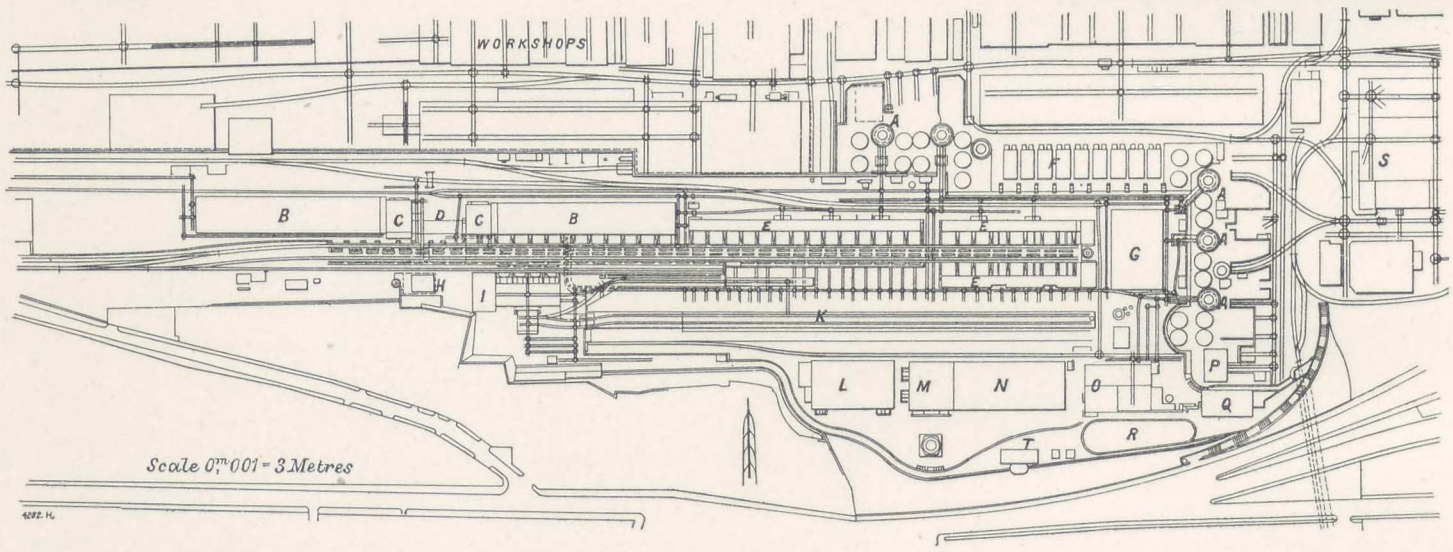


Fig. 43. Plan of Blast-Furnace Plant and Coke Ovens.

One repairing shop for the maintenance and current repairs of blast-furnace plant, and auxiliary material.

Offices and stores.

All the blast-furnaces, which are served each by a separate hydraulic charging lift, are built in front of a platform half the height of the furnaces ; this platform is used for stacking ore, and for the various installations connected with the work, excepting the Cowper stoves, and a battery of 18 gas-fired boilers which are mounted on the ground level.

In the compressing shops, briquettes are manufactured from pyrites refuse, obtained from outside sources, and from the refuse of roasted spathic carbonaceous iron ore obtained from the mines of Allevard (Isère), which have already been described.

hoists, the chimneys for the escape of the products of combustion, and the pig beds. The furnace on the right (Fig. 45), has been lately remodelled in its outer shell. The blast-furnace plant at Creusot was originally insignificant in size, and of imperfect construction, but changes have been made from time to time which have kept the plant well up to modern practice; in the following pages only the latest appliances will be dealt with, especially those which have relation to the blowing engines and the utilisation of waste gases.

The type of blast-furnaces in use has not been modified for some years, the form established by experience being well adapted for the production of the special qualities of iron required by the works. The height in all cases is 20 metres (65 ft. 7 in.) ; it has been found that this height

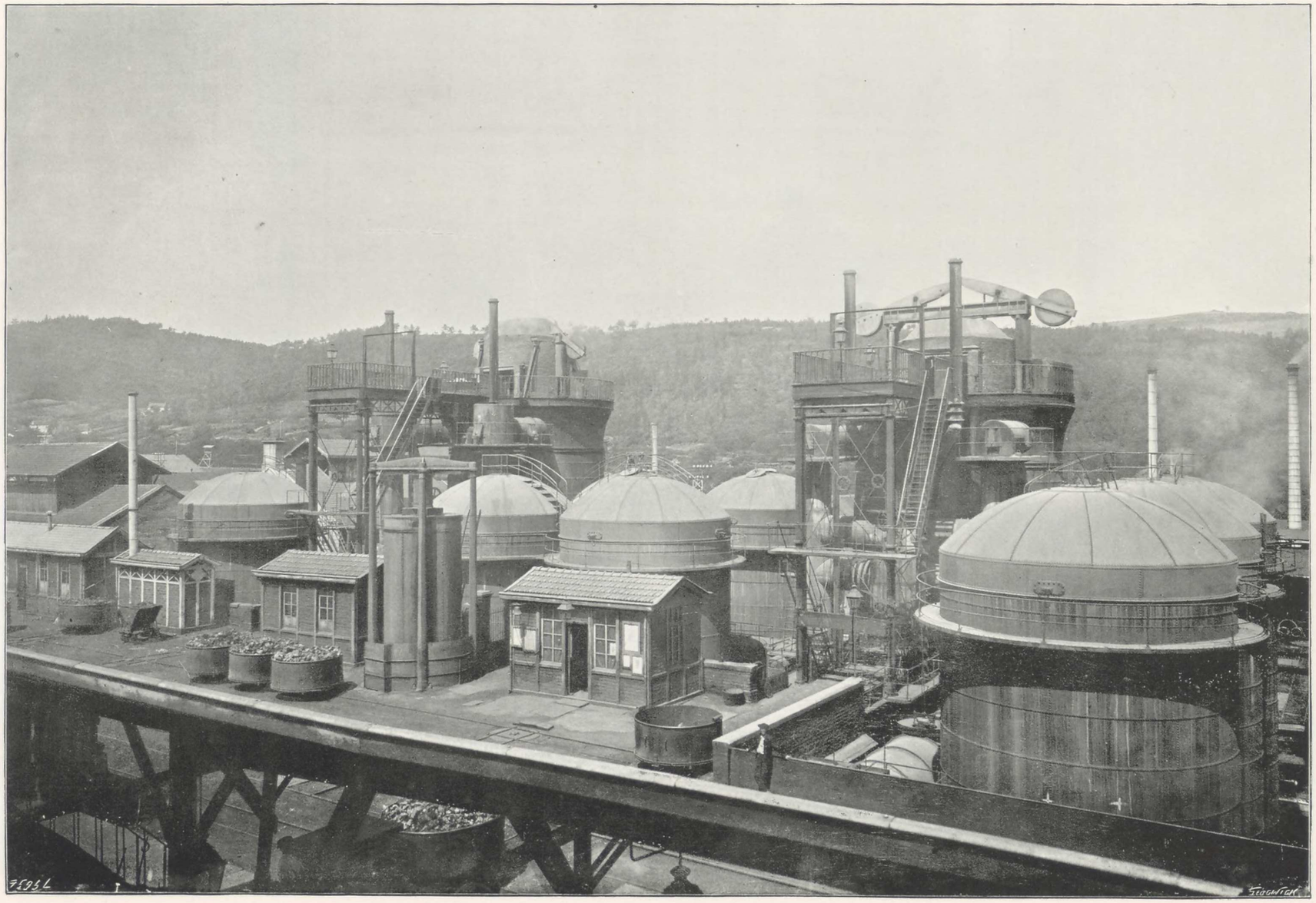


Fig. 44. Blast Furnaces Nos. 7 and 8, and Hydraulic Hoists.



Fig. 45. General View of Blast Furnace Plant.

is the most convenient for working and for reducing the ores which are employed. One of the furnaces above mentioned was put into blast on September 8th, 1897; the construction of this furnace is shown in section and plan, Fig. 46; such modifications as have been introduced refer almost entirely to matters of detail. The mouth of the apparatus, a frame consisting of heavy cast-iron girders that shift the weight (or bearing points) of the apparatus nearer to the edge of the furnace, and to those points where the masonry incurs no risk of being injured. Within the gas chamber, a cast-iron lining 2 in. thick has been placed, with the object of protecting

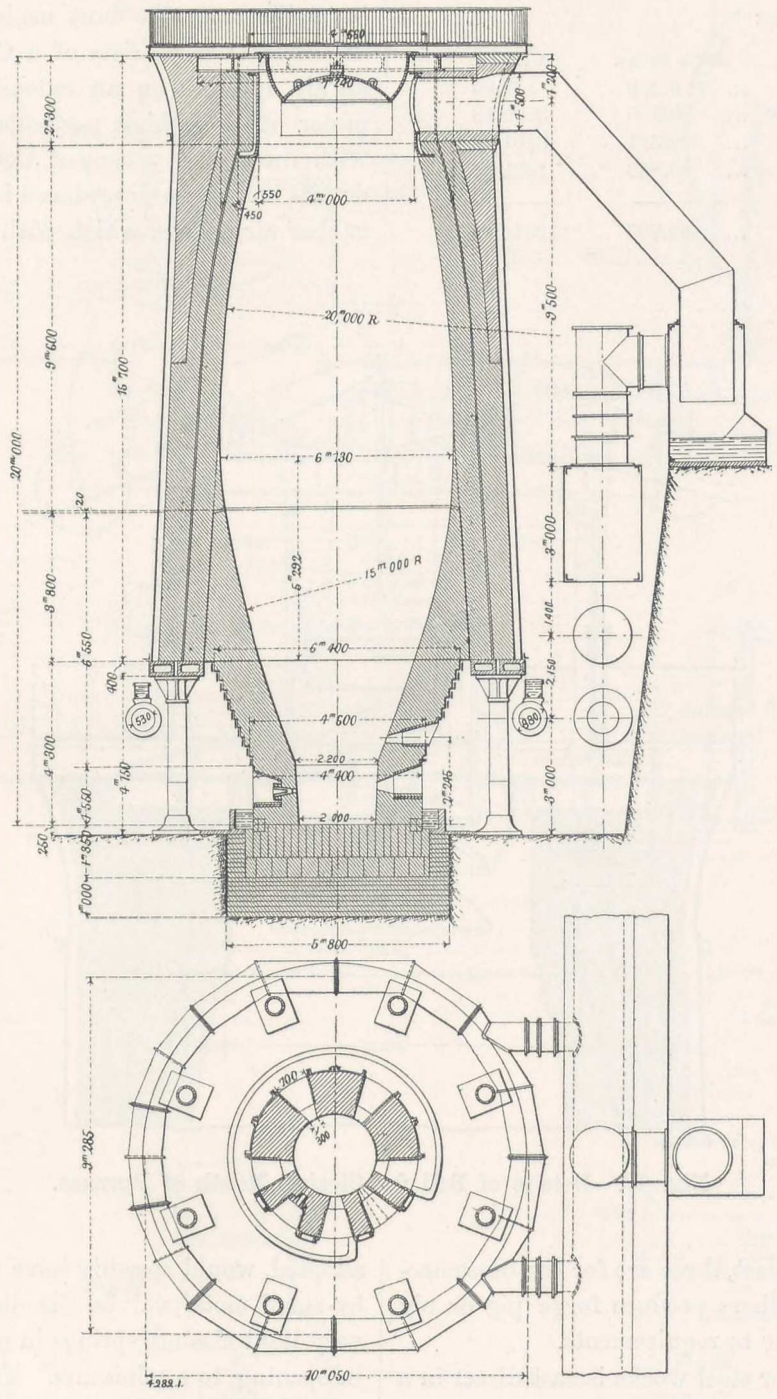


Fig. 46. Sections of Standard Type of Blast-Furnace.

the furnace is closed by a bell operated by hydraulic presses; the arrangement is peculiar to Creusot, and is clearly illustrated by Fig. 47. The closing apparatus in the earlier types was placed on the refractory lining at the top of the furnace. This arrangement was found wanting in stability when the lining became worn in the vicinity of the falling charge. The defect has been remedied by placing underneath the columns carrying the inner shell from breaking down on account of the fall of the charges. The air mains have been lightened, in such a way as to facilitate moving and replacing them. It is always desirable, as far as possible, to shift the mains by hand, without the use of cranes, which are inconvenient and less rapid than manual working. The tuyere arches have been reduced to a minimum of opening, and are made of steel castings; the strength of the hearth

and boshes is much increased by the construction adopted. All the blast-furnaces are of the closed breast type, and have five tuyeres placed normally, the mouth being 140 millimetres (5.51 in.) in diameter. The body is protected outside by a wrought-iron shell, but the hearth is only strengthened by iron rings. The volume of this new furnace, which is practically the same as that of others, is divided as follows:

	Cubic Metres.	Cubic Feet.
Crucible and hearth	5.370	189.66
Boshes	99.156	3500.18
Shaft	229.381	8101.73
Gas chamber	28.888	1021.32
Total	362.795	12812.89

stopped, excepting on one occasion, when the crucible and part of the hearth were renewed.

Blowing Engines.—Blowing engines of from 10 to 15 revolutions have been abandoned for horizontal machines running at a much higher speed. By this change a considerable economy in steam production has been made, as well as a saving in the first cost of installation. Figs. 48 to 52 illustrate the most modern type of blowing engines at Creusot; it consists of a Corliss horizontal motor and an air cylinder on an extension of the same line. The motor offers nothing particular for notice, as it is fitted with the ordinary type of Corliss valve gear. Some new details have been introduced in the blowing cylinder; the rubber air valves, which with the high speed of running

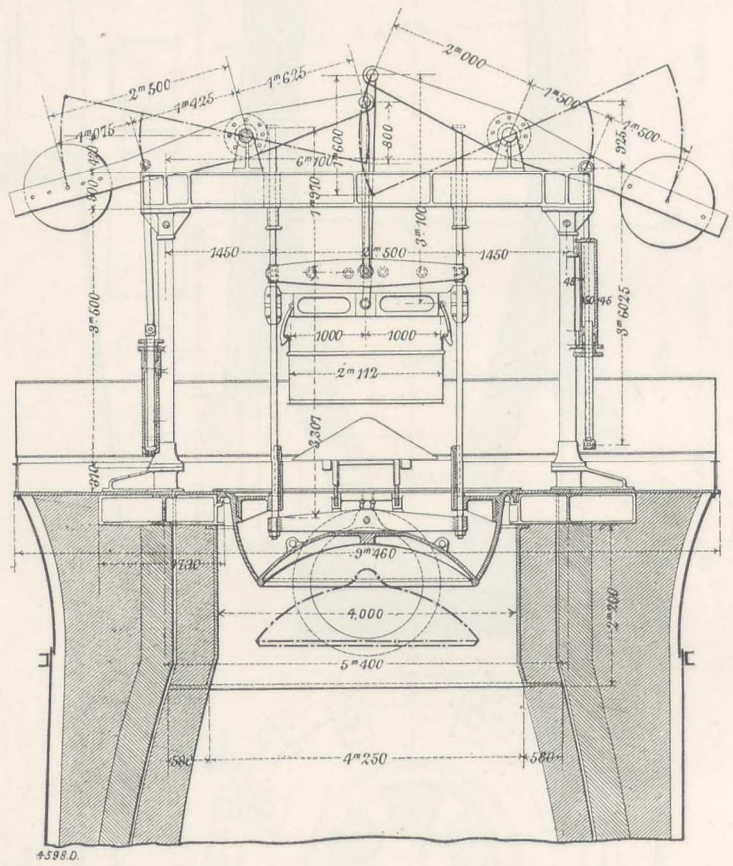


Fig. 47. Details of Bell for Closing Mouth of Furnace.

Of the five furnaces in blast, three are for the Bessemer-Thomas process; the two others produce forge pig or pig for ordinary work, according to requirements.

The pig for the Bessemer steel works is cast direct in a travelling ladle hauled by a small locomotive that conveys it to the steel department close by; when the Bessemer plant is not working, the pig iron is cast into ingot moulds. The daily production of pig from each furnace averages about 80 tons. The duration of the blast-furnaces is very considerable, the minimum being from eight to nine years. The furnace recently re-modelled had had the longest existence; it was lighted on August 9, 1879, by M. Ferdinand de Lesseps, and it remained in constant service until March, 1897. This showed a life of nearly 18 years, during which time, but for small accidents, the blast was never

adopted, would speedily have worn out, have been replaced by small metal valves, the discs of which are fitted with very light closing springs in order to reduce the resistance in opening to a minimum. The discs are of special steel made at Creusot; they have very considerable durability, and can be replaced with great facility. The inlet valves are arranged on the lower half of the air cylinder, and the outlet valves on the upper half, in the manner usual with horizontal blowing engines. The general arrangement of the engines is shown in the illustrations, Figs. 48 and 49, Plate XI., being longitudinal and horizontal sections respectively, whilst Figs. 50 and 51 are a cross-section and an end view of the air-compressing cylinder. Figs. 52 and 53 are reproductions of indicator diagrams taken from both the steam and air cylinders. The blowing

THE BLAST-FURNACE DEPARTMENT.

Fig. 48.

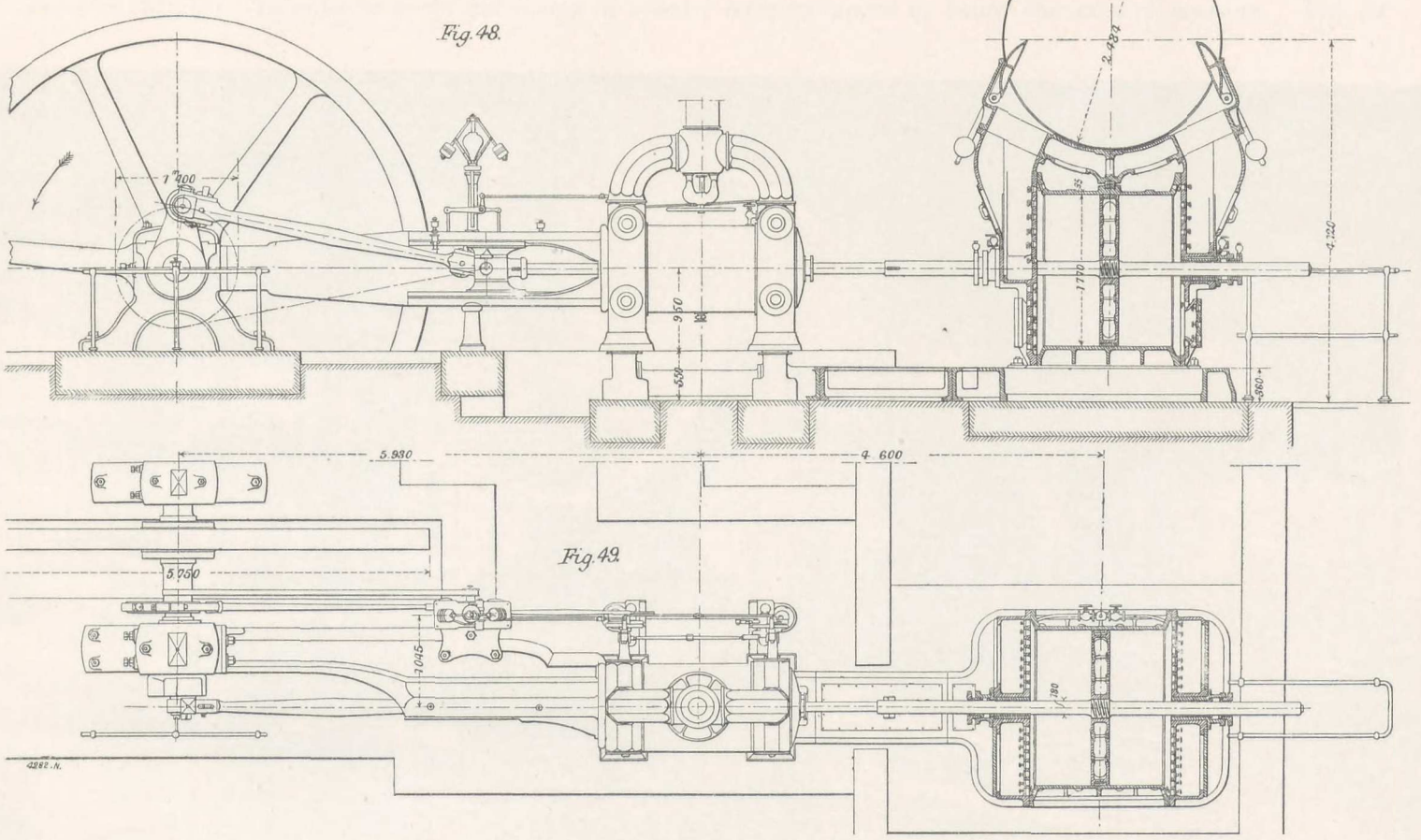


Fig. 49.

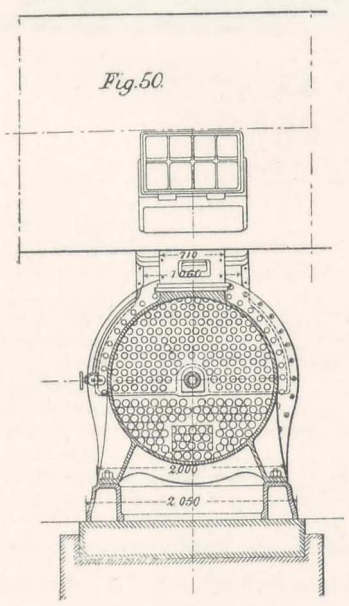


Fig. 50.

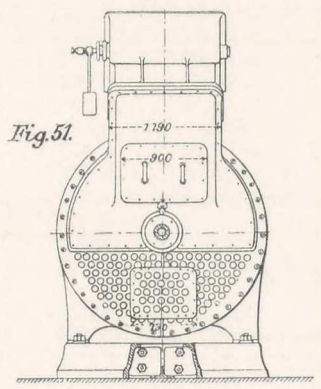
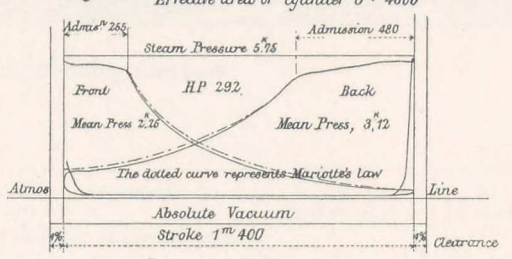


Fig. 51.

Diagrams from Steam Cylinder

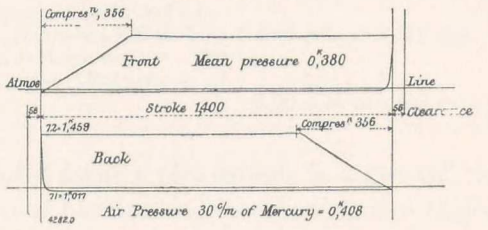
Fig. 52. *Scale 10 %m = 3 k°*
Effective area of Cylinder 0sq.m4300



Revs. per min 50.

Diagrams from Air Cylinder

Fig. 53. *Scale 5 %m = 3 k°*
Area of Cylinder 2sq.m4360



Details of Blowing Engines.

cylinders are connected by two mains forming pressure chambers, to a general reservoir above, common to the six machines, and from which are taken the service mains that distribute the cold air to the Cowper heating stoves. Each engine can, in case of necessity, be isolated from the reservoir by means of valves placed on the upper side of the pressure chamber. In order to avoid differences of speed and of pressure which are liable to occur in an installation where all the furnaces are in communication, each machine is provided with a double regulator of speed and of pressure. This regulator is a combination of the ordinary centrifugal governor, with an air cylinder containing a piston that receives, on one side only, the air pressure from the reservoir. These two regulators are connected to the valve gear, and act simultaneously and independently of each other, without interfering with their proper action on the expansion. Thanks to this arrangement, the engine speed never exceeds the maximum of 54 revolutions per minute and the variation of the air pressure does not amount to 1 centimetre (.39 in.) of mercury above or below the normal pressure. Fig. 54 which is reproduced from a photograph, is a general view of the installation of blowing engines, showing five engines, the sixth being in course of erection. A large number of machines of this type, as well as vertical blowing engines, have been constructed at Creusot for different metallurgical works in France.

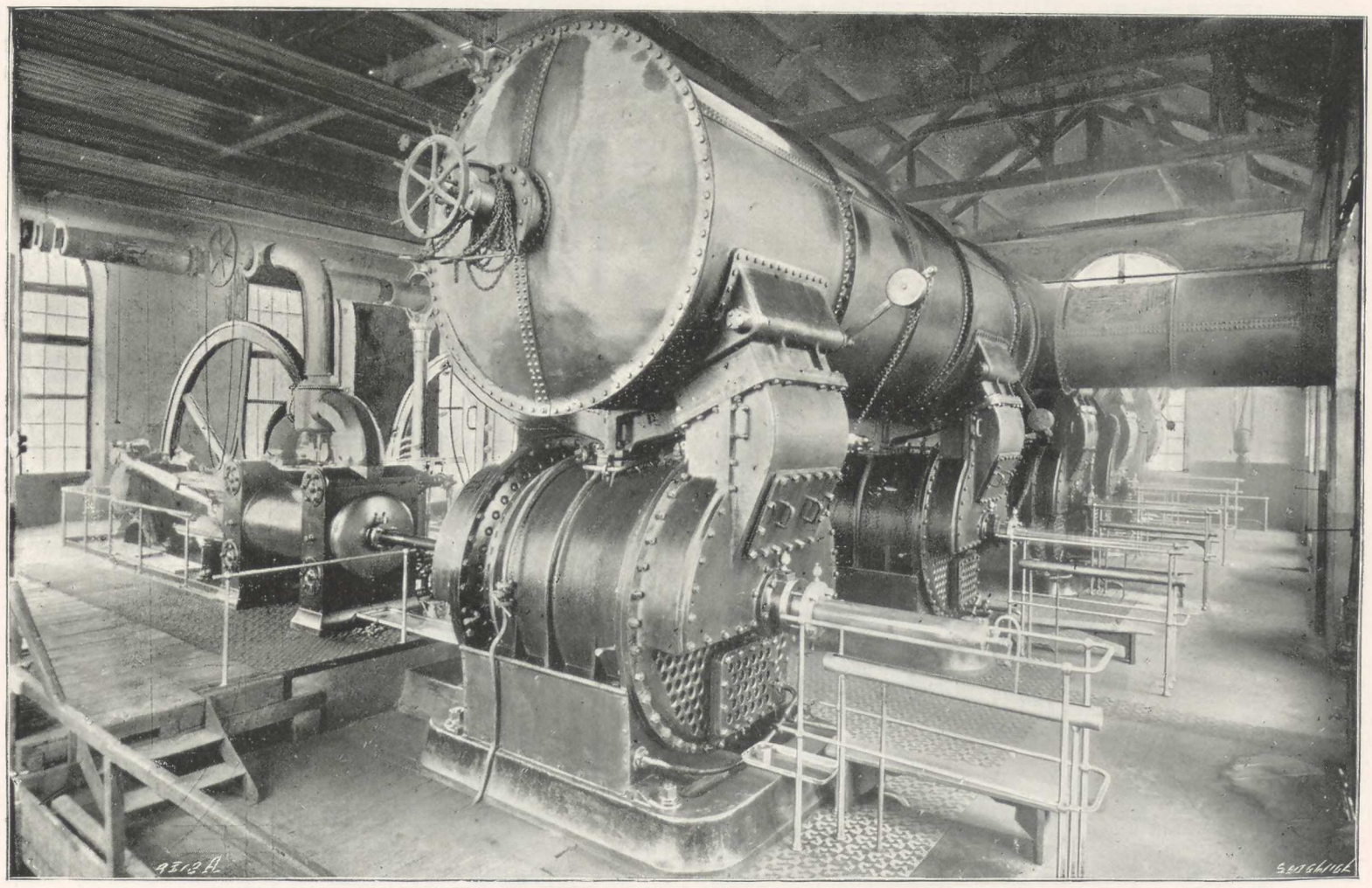


Fig. 54. Blast-Furnace Department; Installation of Blowing Engines.

PARTICULARS OF BLOWING ENGINES.

Diameter of steam cylinder	.750 m.	29.53 in.		Number of revolutions per minute ...	50	50
Length of stroke	1.400 m.	55.12 in.		Weight of flywheel	11,000 kgs.	11 tons
Mean steam admission	.300 m.	11.81 in.		Air pressure in reservoir (in centimetres of mercury)	30	11.81 in.
Effective steam pressure at cylinder ...	6 kg.	85 lb.		Maximum depression at inlet (in centimetres of water)	17	6.69 in.
Diameter of air cylinder	1.770 m.	69.69 in.		Work absorbed by air cylinders	288 h.-p.	288 h.-p.
Effective section of cylinder	2.436 sq. m.	26.39 sq. ft.		,, developed in steam cylinder ...	378 h.-p.	378 h.-p.
Volume of dead space	4 per cent.	4 per cent.		Volume of air compressed per revolution at 0 deg., and at .760 metre (29.92 in.)	6.06 cub. m.	212 cub. ft.
Number of inlet valves at each end of air cylinder	150	150		Air compressed at 0 deg. and at .760 metre (29.92 in.) per kilogramme of steam used	4.50 cub. m.	158 cub. ft.
Maximum inlet area	.276 sq. m.	2.969 sq. ft.				
Number of outlet valves at each end of cylinder	180	180				
Maximum area of outlet valves	.331 sq. m.	3.56 sq. ft.				

Granulating Slag.—Up to the present time, the slag

was allowed to run over a space paved with cast-iron slabs, whence, after being cooled by jets of water, it was shovelled in iron trucks and carried to the slag-heap. An installation, shown in Figs. 55 to 57, is now being built in front of two of the blast-furnaces. It consists of two circular masonry heap, and part to a shop now being built, where it will be used for the manufacture of bricks, slabs, drain-pipes, &c. The granulating plant is being built on the site on which the slag was previously made to run; this necessitated the carrying out of a special arrangement for the removal of

Fig. 55.

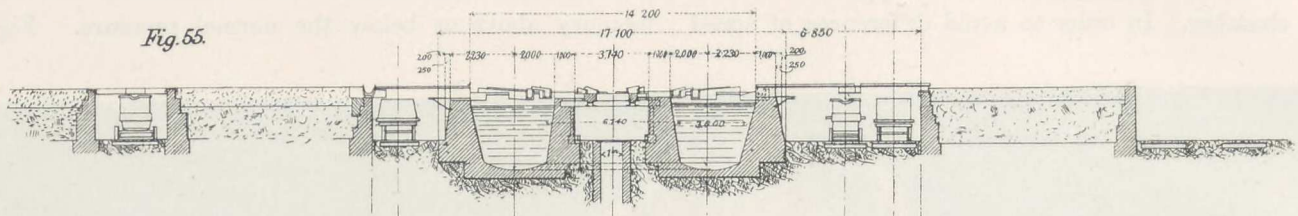


Fig. 56.

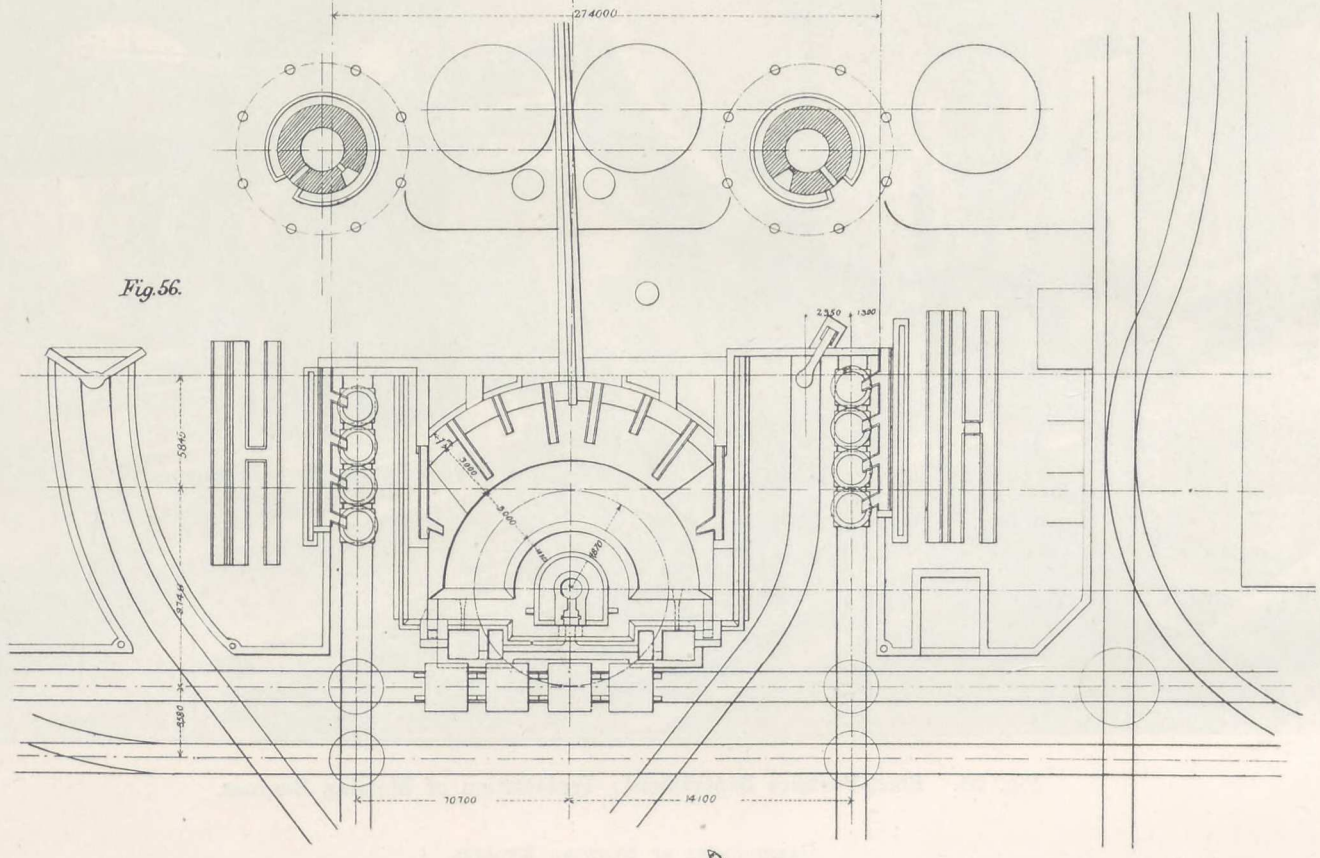
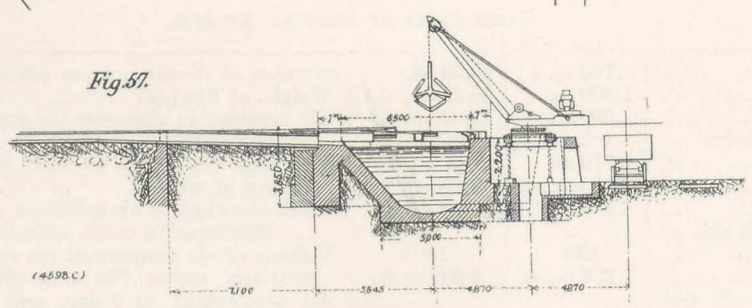


Fig. 57.



Installation for Granulating Slag direct from the Blast-Furnaces.

cisterns, in which the water used in connection with the blast-furnaces is collected. The liquid slag will be made to run into the cisterns by a series of radiating gutters, and become granulated; it will then be removed from the cisterns by a grab suspended from an electric revolving crane, which will deposit it direct in the trucks. Part of the granulated slag will be taken as heretofore to the slag-the slag, during the construction of this new installation. It is provisionally made to flow into ladles carried on trucks; these are hauled to an adjacent iron-paved space, over which the slag is poured, cooled, and removed as mentioned above. This arrangement will be maintained, and used when it will be necessary to repair the cisterns, or when the slag, owing to various circumstances in the work-

THE BLAST-FURNACE DEPARTMENT.

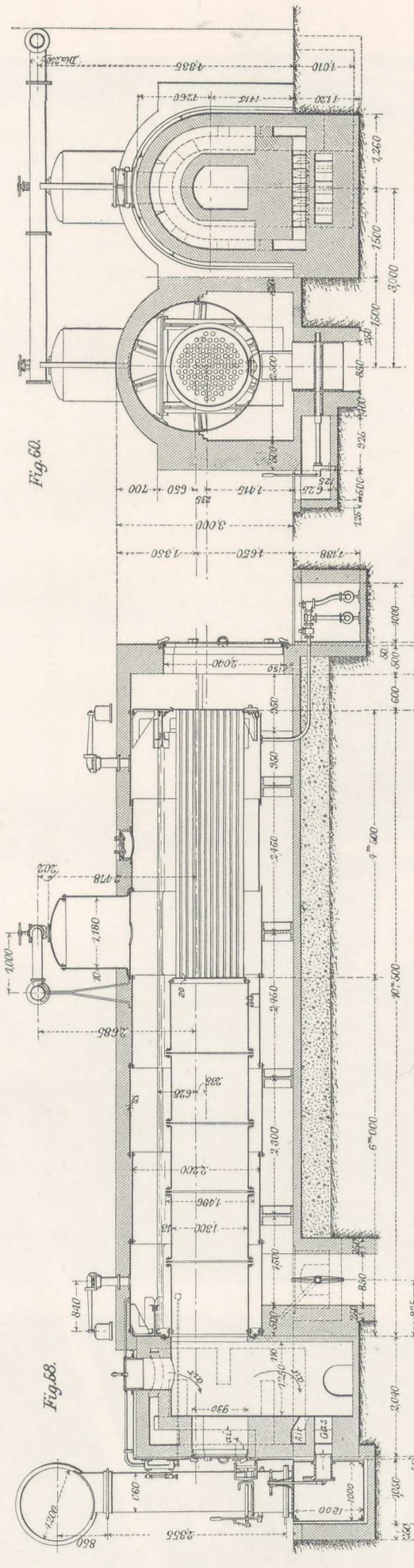


Fig. 60.

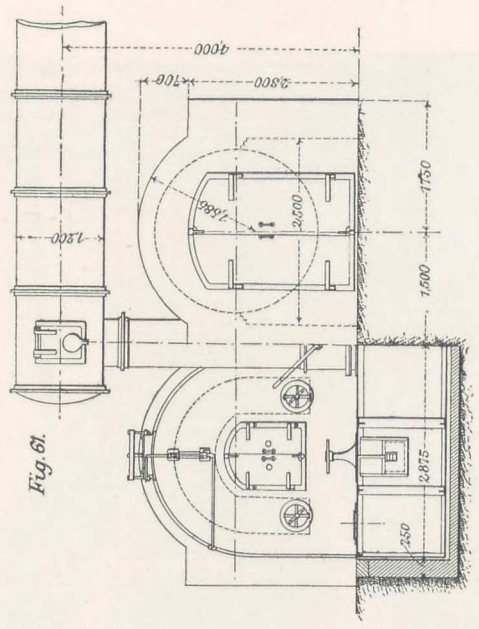


Fig. 61.

Fig. 58.

Details of Boilers Heated by Waste Gases from the Blast Furnace.



Fig. 62. Boilers Heated by Waste Gases from Blast Furnaces.

ing of the blast-furnaces, will not be suitable for granulating.

Gas Fired Tubular Boilers.—All the coal-fired boilers at one time in use, have been replaced by tubular generators, which are illustrated in Figs. 58 to 61, Plate XII.; they are heated entirely by the waste gases from the blast-furnaces. In order, however, that a sufficient supply of steam might be obtained, in the event of the furnaces being stopped four of these boilers are fitted with auxiliary coal-burning grates. These four generators, combined with those heated by means of the waste gases from the coke ovens, the production of which is always constant, would be sufficient to meet all demands consequent upon even a prolonged stoppage of the blast-furnaces. As will be seen from the illustration (Plate XII.), the boilers are of the tubular internal firebox type. In front there is a combustion chamber of refractory brick, which can be maintained at a red heat for a sufficient length of time to light the gases in the event of any moderate interruption to their admission. If it should happen that a prolonged delay occurs, the gases are ignited by means of lighted grease fuses that are thrown into the combustion chamber. The air necessary for combustion is admitted into the bottom of the chamber, above the gas inlet, after it has been raised to a sufficiently high temperature by circulating round the sides of the chamber. The adoption of this boiler was decided on experimentally, and with considerable doubt as to its successful working; fears being entertained that the tubes would become rapidly obstructed with the dust deposited by the circulating gases, but experience has shown that no difficulty arises from this cause. The tubes require cleaning only twice every twenty-four hours, and the operation can be completed in twenty minutes as a maximum. They are swept by means of an ordinary long flue brush, and the dust thrown down on the internal fire-grate by the brush, is collected with a rake, and drawn into the combustion chamber, from the bottom of which it can be removed from time to time through a side door. Some interesting experiments have lately been made, having for their object the employment of compressed air instead of brushes for cleaning the tubes. These experiments have given excellent results, both as regards efficiency in cleaning and saving of time. In addition, the dust is so effectually dispersed that there is no necessity for collecting it in the combustion chamber. This method of cleaning is about to be universally adopted at Creusot. Experiments having the same object were also made with steam jets instead of compressed air, but the results obtained were not satisfactory. The steam caused the dust to become damp, and it then formed a paste that adhered to the inner sides of the tubes, with the result that the transmission of heat was considerably checked, and the safety of the tubes themselves was endangered.

All the boilers in this department are fed by pumps which deliver water at 90 deg. to 95 deg. Cent. (194 deg. to 203 deg. Fahr.), the temperature being obtained by feed heaters, through which the exhaust steam is discharged from the blower engines. The steam which is cleansed by going through a special separator, circulates through the feed heaters in a direction opposite to that of the feed water. Fig. 62, Plate XIII., gives an admirable idea of a battery of these boilers heated by the waste gases of the blast-furnaces.

The following are some of the principal particulars of these boilers:

Heating surface of firebox ...	25 m².	269.10 sq. ft.
,, ,, tubes ...	108 m².	1162.54 sq. ft.
,, ,, return flue	30 m².	322.95 sq. ft.
Total heating surface... ...	163 m².	1754.59 sq. ft.
Volume of water space ...	23.150 m³.	817.57 cub. ft.
,, steam space ...	7.700 m³.	271.94 cub. ft.
Registered working pressure	7 kg.	99.56 lb. per sq. in.
Number of tubes	100	100
Interior diameter of tubes ...	73.5 mm.	2.88 in.
Thickness of tubes	3.5 mm.	.138 in.

The efficiency of the boilers, ascertained from a long series of experiments, may be summarised as follows:

Water evaporated per hour ...	1800 kilos.	36 cwt.
Consumption of gas per minute	30 m³.	1059 cub. ft.
Temperature of escaping gases	250 deg. Cent.	482 deg. Fahr.
,, feed water ...	90 deg. Cent.	194 deg. Fahr.

Coke Ovens.—For many years, vertical coke ovens, of the Appolt and Bauer types, were used at Creusot, together with a large number of horizontal ovens; but, taking into consideration the quality of the coal employed, it was found that the vertical ovens gave results far inferior to those obtained with the horizontal type, and the former have been definitely abandoned. Until a comparatively recent date, the horizontal ovens, of the so-called Belgian type, were constructed after the original designs, in which each oven was provided with a separate chimney for the discharge of heated gases. In order, however, to utilise the waste heat, which was sufficient to maintain a constant steam supply, important changes were made in the arrangements, with the view of economising this heat; these changes were adopted only after a long series of careful experiments, which gave very satisfactory results. Messrs. Schneider and Co. had no inducement to seek for the utilisation of by-products from the coke ovens, because the mixtures of coal employed are very poor in volatile residues, on account of a large proportion of Creusot anthracite being introduced. On the other hand, an economy of the waste heat for generating steam, was an important object to be attained. The transformation of the ovens was carried out under very special conditions and considerable difficulties; all of them being in good condition, it was desirable that the change to be effected should interfere as little as possible with their construction. Moreover, it was not possible to reduce the volume of coke production beyond a very limited extent; and for this reason it was necessary to proceed with the various alterations gradually, by changing a few ovens at a time. Under the special conditions that existed, it was found more convenient to construct a waste-heat collector above the ovens, instead

of below, as is the usual practice. The ovens were divided into groups of twenty-four (see Fig. 63), and between them a mass of brickwork was built, in which was formed an inclined passage joining the upper collector, with a general underground gas main constructed along the whole length of the battery of ovens in front of the discharging platform. As it was not possible to place the steam generators in the same line as the ovens without reducing the number of the latter, which would have meant a reduced production of coke, it was necessary to instal them in an independent building, opposite to, and almost in the centre, of the battery. This arrangement involved the construction of a second underground collector. The generators, which are grouped in pairs, are arranged so as to receive the heat from the collector by short branch mains, which are independent for each group. Figs. 64 to 69, Plate XIV., show the details of construction of the ovens and the arrangement of the inclined collectors. This system of double collectors, one above and the other below, is probably somewhat disadvantageous as regards economy of heat; but as the draught of the chimney common to all the boilers, is energetic, the gases are dragged through the collectors to the boilers with but little loss. Experiments have shown that between leaving the furthest oven and arriving at the boilers, the fall in temperature is less than 212 deg. Fahr., which is insignificant in comparison with the temperatures of 1,832 deg. or 2,012 deg. Fahr. at which the gases leave the ovens.

Regulating chambers are placed at intervals upon the upper collector; one chimney is common to twelve ovens, and is furnished with stop-valves at the base, so that any group, or number of groups, can be cut out at pleasure, and all the waste heat can be diverted from the boilers if it is desired to stop them for repairs, or for any other reason. This arrangement was, moreover, necessary during the period of construction in order to avoid stopping the production of coke. Advantage was taken of this extensive alteration to strengthen the ovens. Previously the construction left something to be desired, and the ovens frequently broke down, necessitating costly repairs, either of the brickwork or of the doors, the frames of which needed constant inspection.

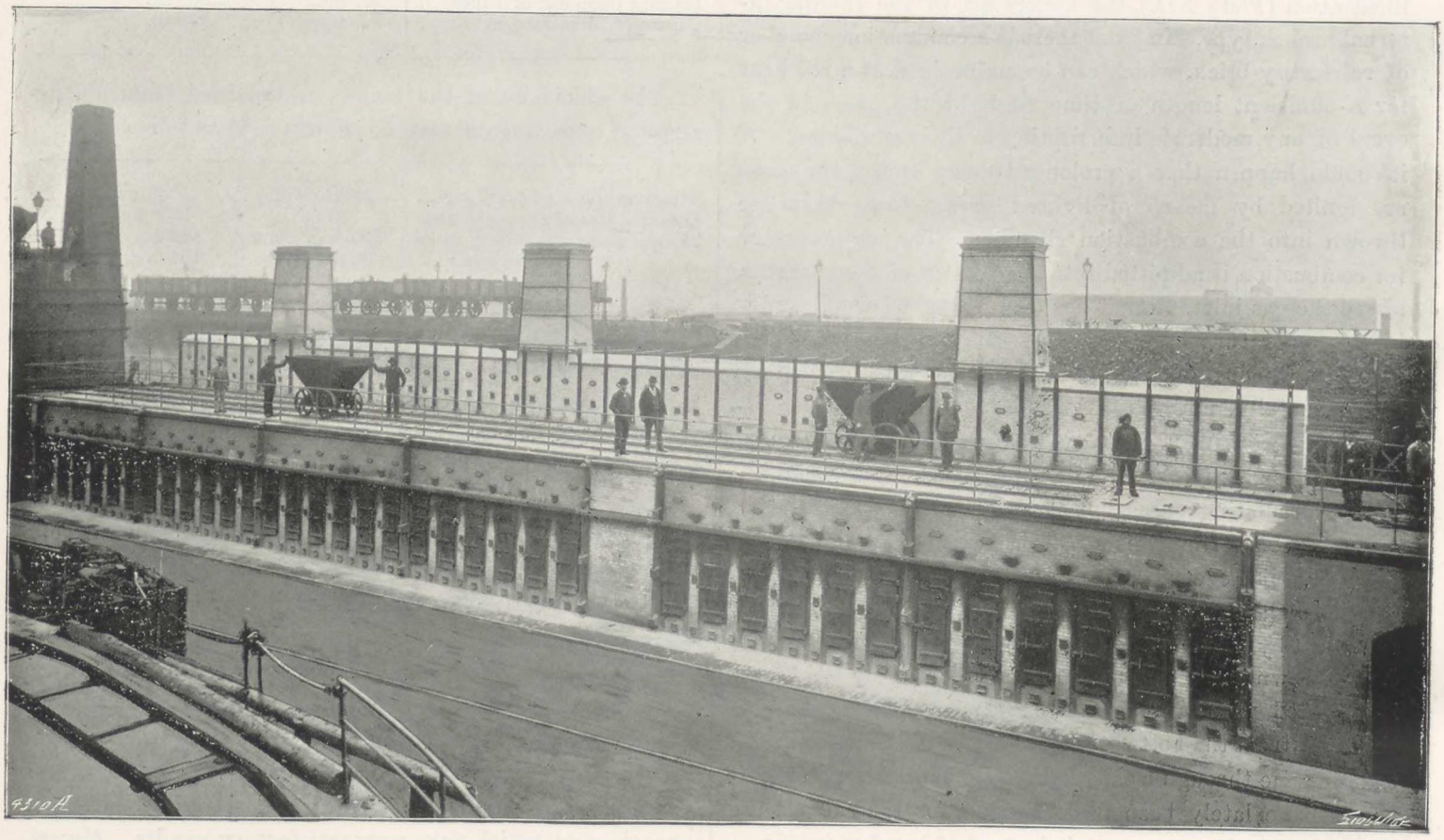
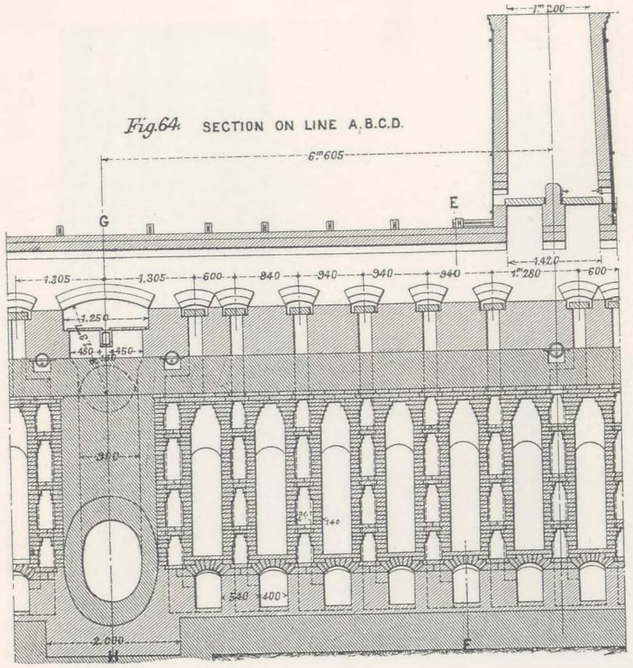
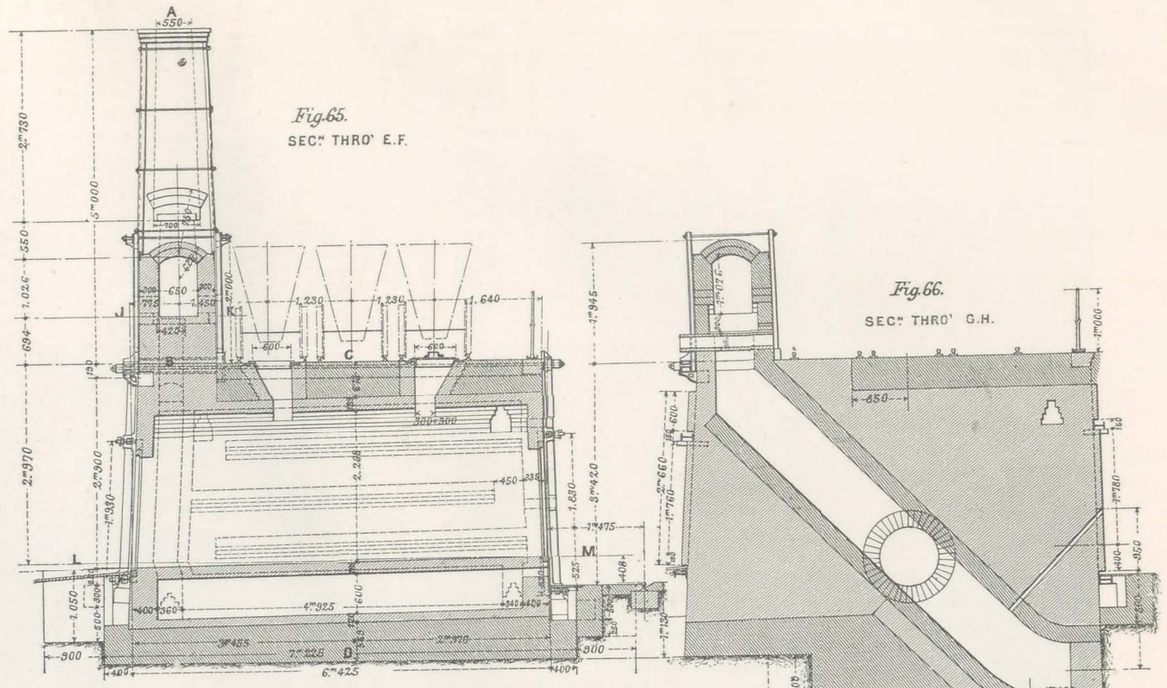


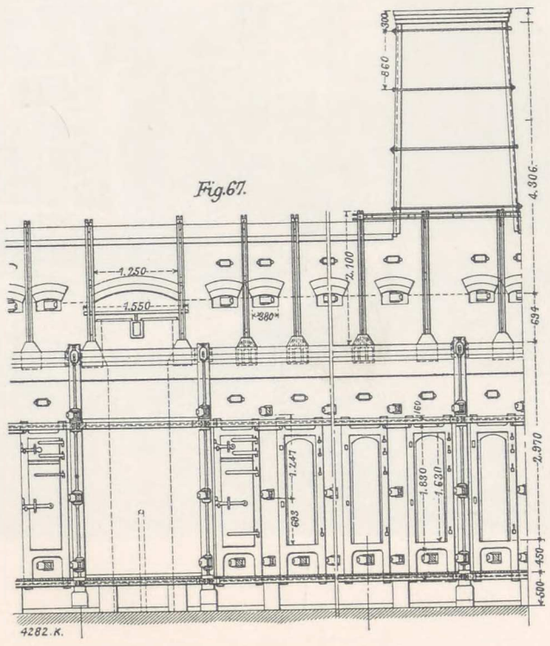
Fig. 63. Battery of Coke Ovens.

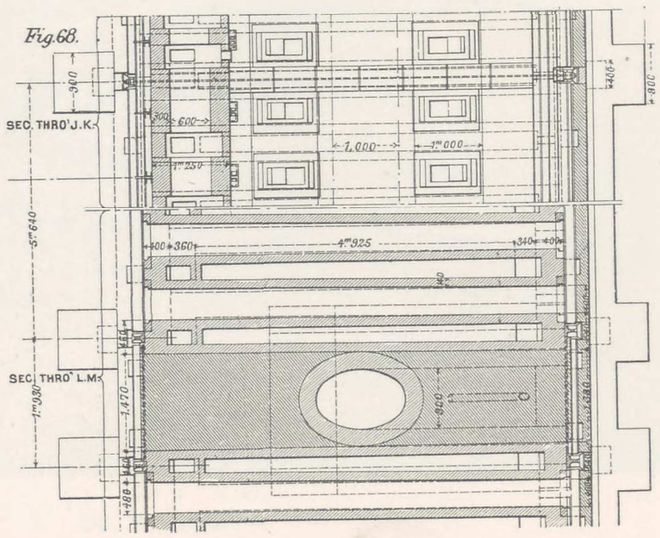
The actual form of construction is shown clearly in the illustrations.

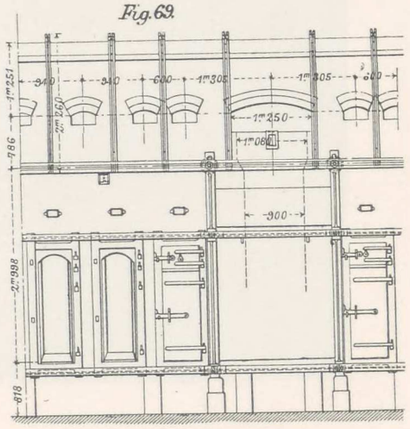
Each oven is large enough to receive a charge of from 2.7 to 3 tons, and the period of carbonisation is twenty-four hours; the amount of serviceable coke obtained is 73 per cent. Charging the ovens is carried on at present day and night, but the grinding and mixing shop is only kept in operation during the day, a sufficient quantity for the night service of the ovens being always in store. After a prolonged series of experiments, Messrs. Schneider and Co., have come to the conclusion that but little economy can be effected by doubling the shifts at the ovens, with the object of obtaining a more regular distribution of heat to the boilers. When charging the furnaces during the day only, the pro-











Details of Coke Ovens.

PLATE XIV.



Fig. 70. Emptying Coke Ovens.

Fig. 71

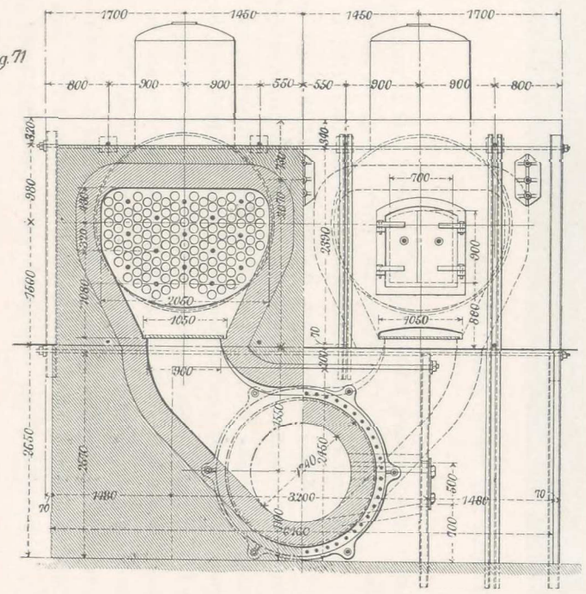


Fig. 72.

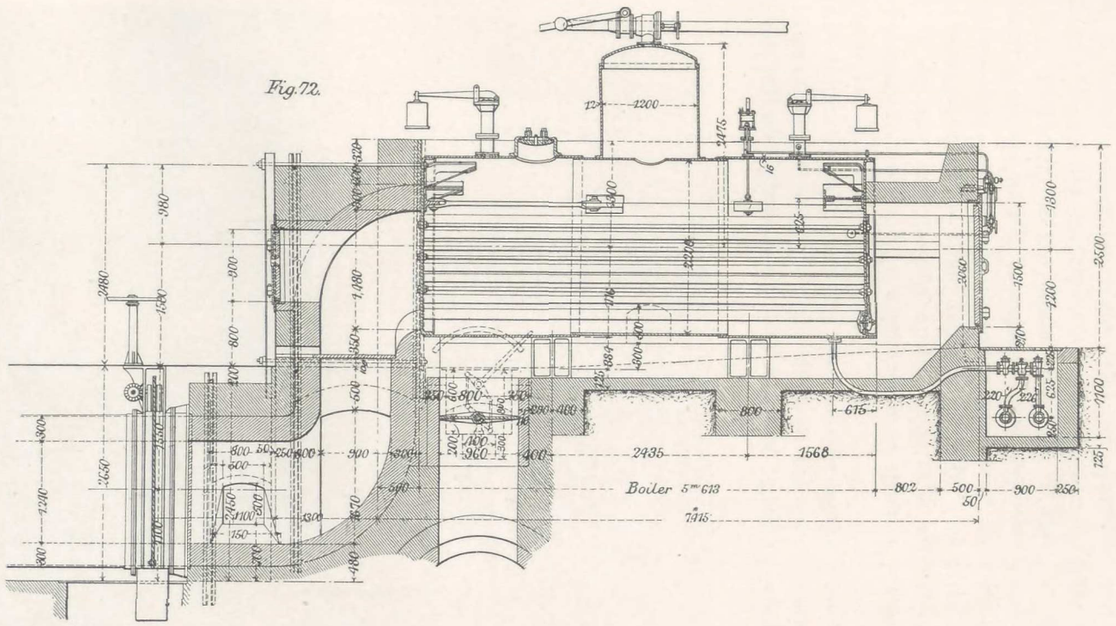


Fig. 73.

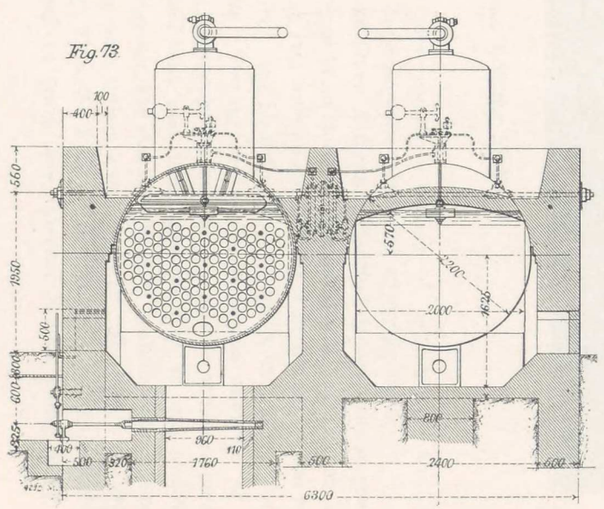
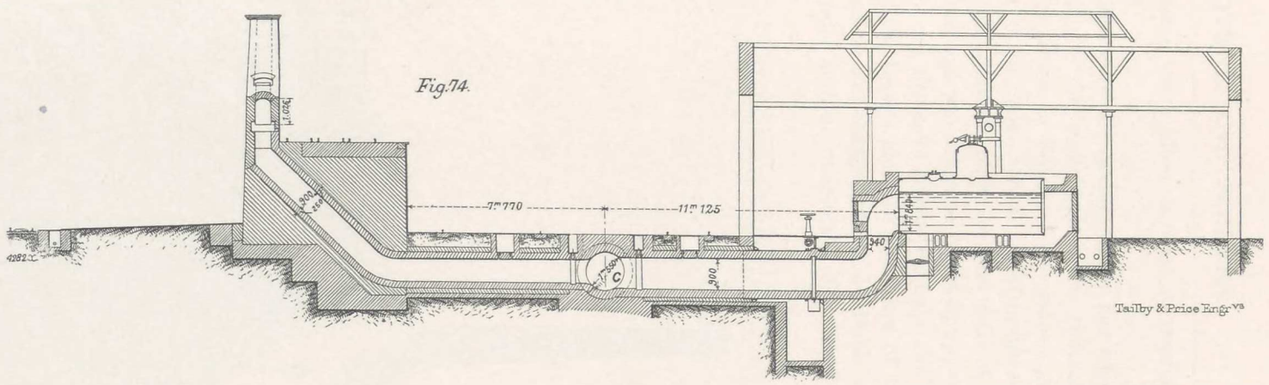


Fig. 74.



Tailby & Price Engrs

Details of Boilers Heated by the Waste Gases from the Coke Ovens.

PLATE XVI.

duction of steam during the night does not decrease materially, while the day production is slightly higher.

A large proportion of the steam generated in this department is utilised, as will be explained later, by other departments of the works. As a certain number of the engines belonging to these other departments, only work during the day, and, exceptionally, up till 8 P.M., it is not at all necessary to have so high a production of steam in the night as during the day service.

Messrs. Schneider and Co. are therefore considering the advisability of discontinuing the night shifts at the coke ovens; this will save labour as well as the cost of lighting and carbonisation takes place, at least as regularly as in the old ovens.

Besides the important saving which has been effected by the utilising of the waste gases from the coke ovens, the sanitary condition of the town has gained greatly, as the dust and thick smoke which used to spread over it from the chimney, 230 ft. high, are now evils of the past. This is an advantage which has been greatly appreciated by the inhabitants, as the coke ovens are near the centre of the town, and the houses close to this part of the works were, previous to the change, hardly habitable when the wind blew from certain quarters. Fig. 70, Plate XV.,

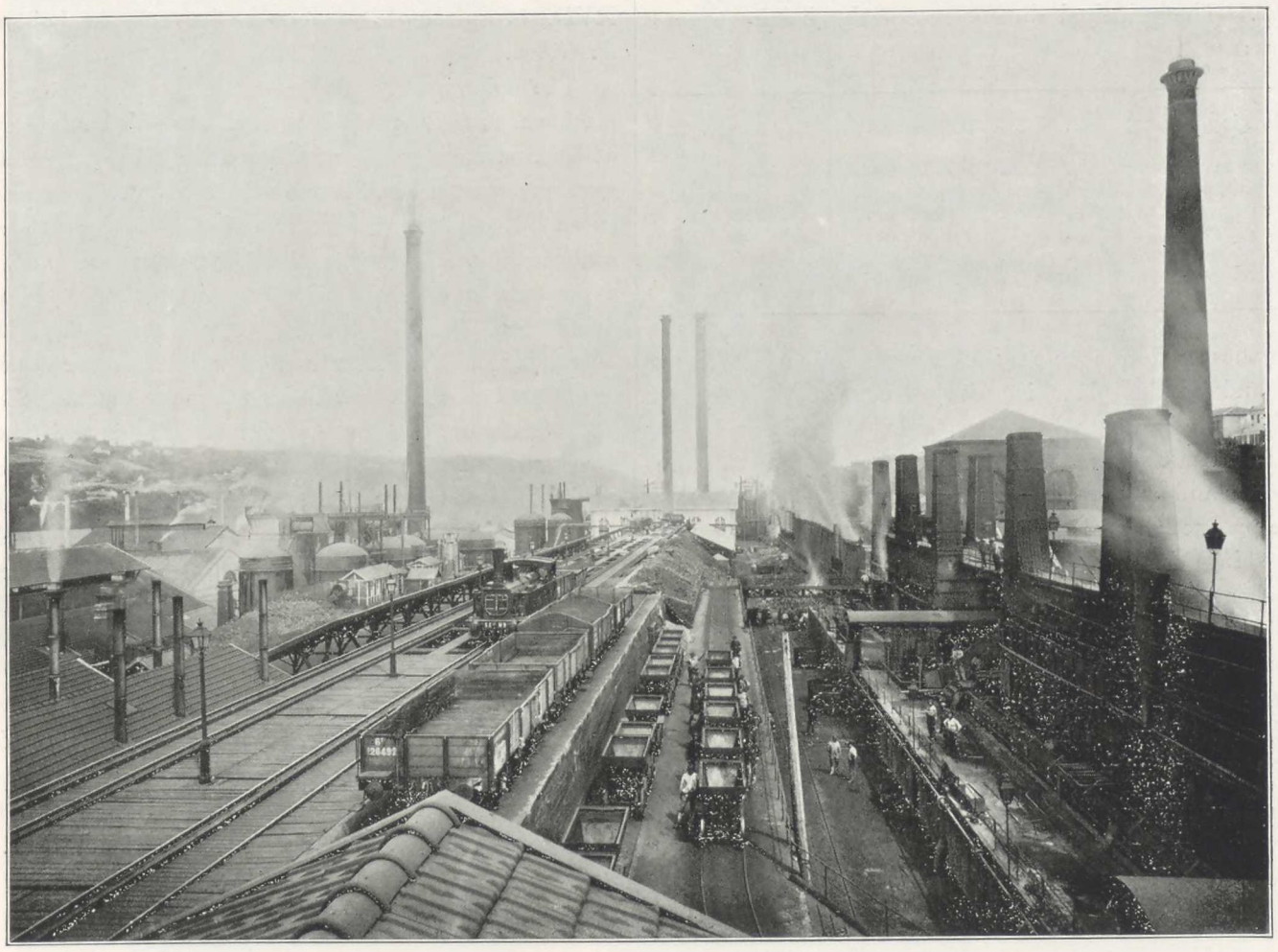


Fig. 76. Coke Ovens and Blast-Furnace Loading Platform.

up this section of the works. Fig. 76 gives a general view of a portion of these ovens, as described. Recently a battery of fifty-four new ovens has been built on precisely the same lines as those described, in order to make the whole system uniform. As the chimney of the coke-oven boilers also serves for a set of boilers fired by the waste gases from the blast-furnaces, there might have been cause to fear, considering its energetic action—equivalent to $1\frac{3}{16}$ in. of water—that the working of the coke ovens would be difficult of control. Owing, however, to the dampers placed at the top of the vertical conduits of the ovens, and which establish communication with the top receiver, the regulation of the draught is easily effected, shows very clearly a battery of coke ovens; the view taken illustrates the method of emptying them.

Coke-Oven Boilers.—The first experiments in generating steam from the waste gases of the coke ovens, were made on two tubular boilers that were heated by the waste gases from the blast-furnaces, which were adapted for the purpose. During the trials, numerous analyses of the flames having shown that there was little or no combustible gas available, and that, consequently, it was useless to introduce air, the standard type of installation for mounting the coke boilers was arrived at; the details are shown in Figs. 71 to 74, Plate XVI. In these boilers, which are mounted in pairs, the internal firebox being quite un-

necessary, has been suppressed, and the flames pass direct into the tubes. In order to facilitate cleaning, these, and the tube-plates, are so arranged as to be easily removed. The gas conduit connected with the principal underground collector, is branched so as to meet each of the boilers of a group, but before the point of division, a valve is introduced by which the gases can be entirely shut off; by this arrangement the boilers can be stopped at will for cleaning and repairs. The tubes require cleaning but seldom, because very little residue is deposited on them. At the present time, the installation consists of six boilers only, but four more will be shortly set up; of these boilers, eight will be kept in steam, and two will be held in reserve. The principal dimensions of the boilers are as follows:

Tube-heating surface	200.00 m^2.	2152.86 sq. ft.
Number of tubes	125	125
Thickness of tubes...	4.25 mm.	.165 in.
Internal diameter of tubes ...	90.00 mm.	3.54 in.
Total cross-section of tubes .	.79 m^2.	8.5 sq. ft.
Volume of water	12.00 m^3.	423.8 cub. ft.
,, steam	5.00 m^3.	176.58 ,,
Registered working pressure ...	7 kilos.	99.56 lb. per sq. in.

As these boilers have only been in operation for a short time, and as the plant is not yet completed, it is not possible to give data based on prolonged results, but it would appear that the evaporation is not less than 2.5 tons per boiler and per hour, which corresponds approximately to the production of 1 lb. of steam for each pound of coal charged into the ovens. In any case, the addition of these waste-heat boilers to the gas-fired tubular boilers of the blast-furnaces, has effected a very considerable economy. When the boilers were started it was thought it would be necessary to clean the tubes at least once every twenty-four hours. It was soon found, however, that the flames deposit hardly any soot, and tube-cleaning once a week is more than sufficient to maintain the boilers in perfect condition. In order more fully to illustrate the system of collecting the gases, and the arrangement of the boilers, a cross-section of the plant, Fig. 74, Plate XVI., is added. The steam now generated is sufficient, not only for the service of the blast-furnace plant, but also for the steel works department, and for a large part of the construction shops; these departments are situated not far from the blast-furnaces. When the boiler plant is completed, the steam-generating plant will consist of thirty gas-fired tubular boilers burning the waste gases from the blast-furnaces, and ten coke-oven boilers. This plant will enable the Blast-Furnace Department to supply to the other departments of the works, 36 tons of steam per hour equal to about 2,000 horse-power. Fig. 75, Plate XVII., is a front view of a battery of the boilers just described.

The boilers being placed on the blast-furnace loading platform, as well as on the ground level, a complete system of distribution was required to convey the steam to the various departments. As the distances involved are very extensive, efficient means had to be devised to reduce condensation. Various protecting coverings tried, such as silicate cotton, plastic compositions, &c., not having given good results, besides being very costly, Messrs. Schneider and Co. experimented with a mortar formed of granulated slag mixed with soot taken from the boilers or Cowper stoves. This compound is laid on easily with a trowel, in thicknesses varying from $1\frac{1}{4}$ in. to $2\frac{1}{4}$ in., according to the size of the pipes. It is then wound round with felt, and a sheet-steel covering is fitted over the felt for such pipes as are in the open, this casing being replaced by a cloth wrapping where the pipes are sheltered by buildings or shops. This inexpensive method is found to answer admirably, the temperature of the outside of the pipes thus protected being little higher than that of the surrounding air, so that condensation is reduced to a minimum. The whole of the blast-furnace and coke-oven plants, machinery, boilers, engines, &c., were designed and constructed by Messrs. Schneider and Co. in their works.

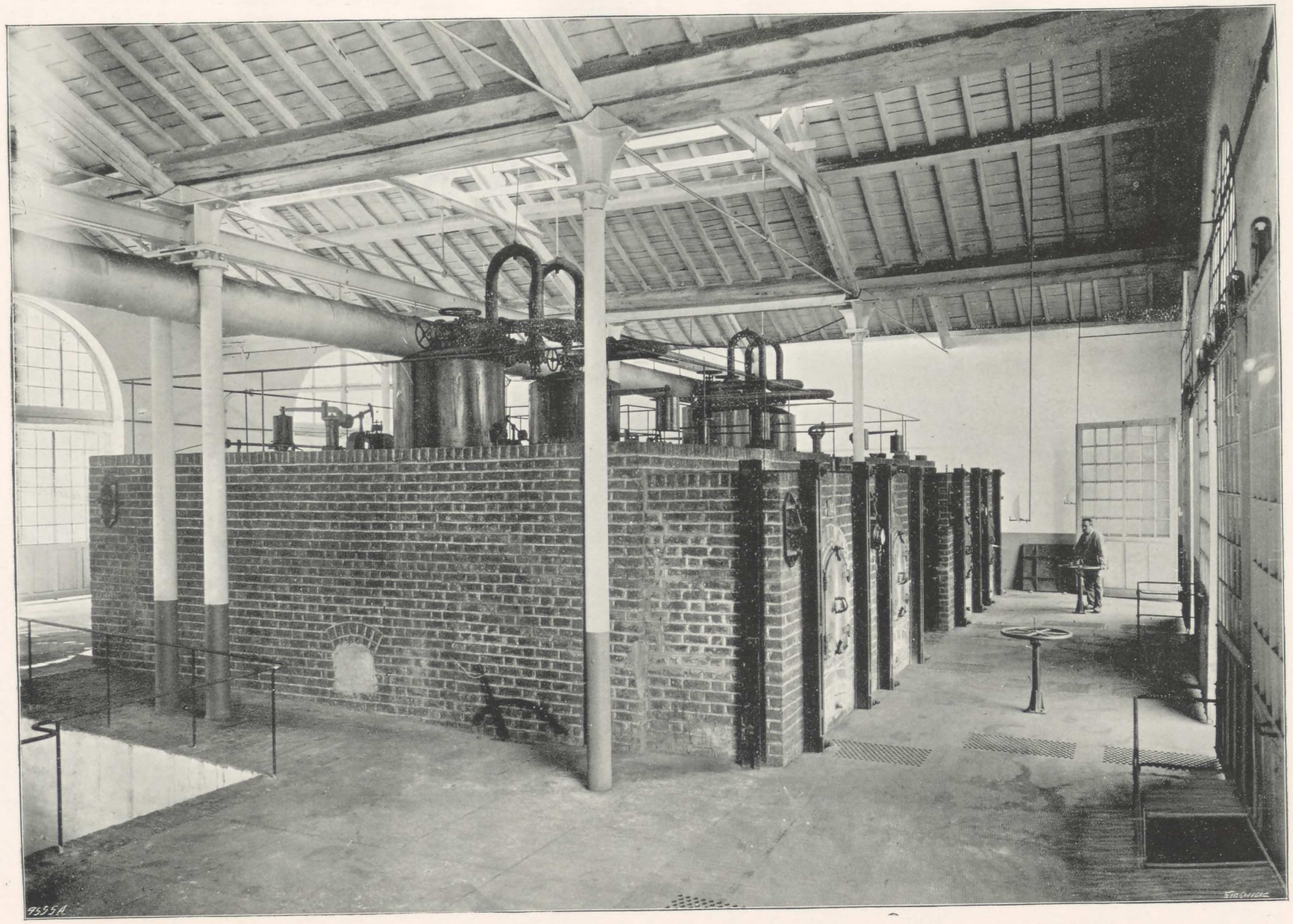


Fig. 75. Boilers Heated by Waste Gases from Coke Ovens.

THE STEEL WORKS.

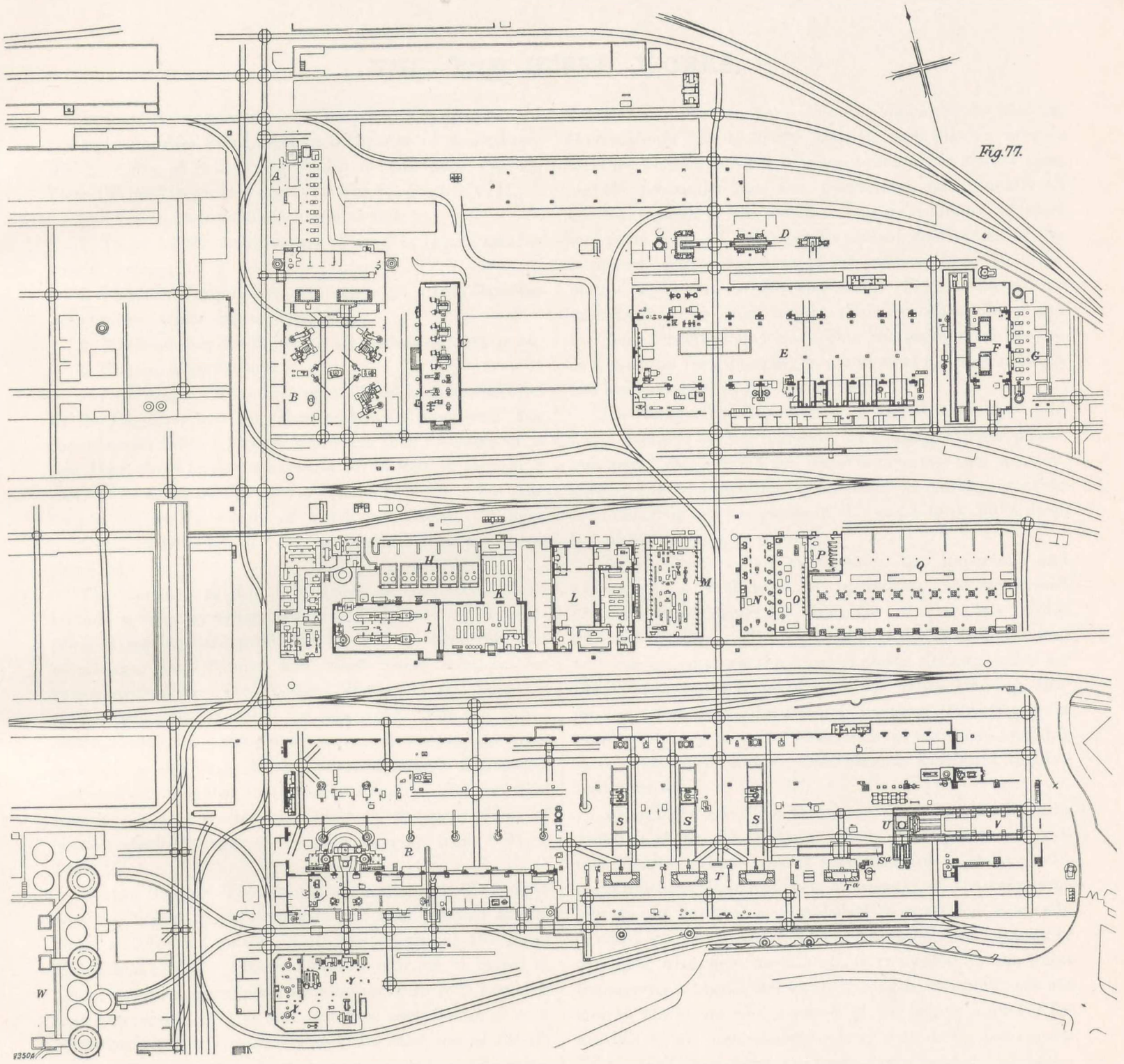


Fig. 77.

General Plan.

A. Battery of gas generators for rotary puddling surfaces.
B. Mechanical puddling furnaces.
C. Central electric lighting and power station.
D. Annealing furnaces for steel castings.
E. The steel foundry.
F. 10-ton furnaces of steel foundry.
G. Gas generators for 10-ton steel foundry furnaces.
H. Boilers.
I. Blowing engines.
K. Stores.
L. Laboratory.
M. Machine shop, for maintenance and repairs.
N. Forge, for maintenance and repairs.
O. Boiler shop, for maintenance and repairs.
P. Woodwork shop, for maintenance and repairs.
Q. Gas generators for main steel works.
R. The Bessemer department.
S, S, S. Ingot pits of the 35-ton furnaces.
T. 35-ton Siemens-Martin furnaces.
T*a*. 25-ton Siemens-Martin furnace.
S*a*. Ingot pit of 25-ton furnace.
U. Steel-compressing plant.
V. Main casting pit.
W. Blast-furnace plant.
X. Dolomite furnace.
Y. Phosphate-grinding mills.

VIII.—THE STEEL WORKS.

General Arrangement. — The steel department of Creusot comprises four independent groups of workshops, the positions of which are shown on the plan, Fig. 23, Plate IV., and in greater detail on Fig. 77, Plate XVIII.

The four groups referred to are as follows:

1. Those for the manufacture of steel in ingots and for special castings.

2. Those for forging heavy pieces, with a full plant for cementation, tempering, and reheating.

3. Machine-shop for finishing all classes of steel work.

4. The wheel-tyre shops.

First Group.—In the first group, steel is manufactured by the Bessemer and the Siemens-Martin processes. For the Siemens-Martin process there are four furnaces of a new type, three having a capacity of 35 tons of steel at a cast, with a moulding pit for each of them. For the largest ingots, the weight of which may exceed 120 tons, a special casting pit of very large dimensions has been provided.

The annexes to the first group of the steel works include a foundry where machine parts and other complicated castings are produced, as well as those for gun mountings, stern frames, and other pieces required for ship construction. Two 10-ton Siemens-Martin furnaces produce the steel required for this work. For the larger castings, such, for example, as armoured turrets, the steel is made in the large Martin furnaces above mentioned, and carried in ladles to the steel foundry. In the steel foundry is a converter employed in the production of smaller steel castings, of weights varying from 2 lb. to 1,000 lb.

Second Group.—The 100-ton steam-hammer of Creusot was the largest of its kind that had been erected at the time; a full-sized model of it was shown at the Paris Exhibition of 1878. Its maximum power can be raised to 120 tons, and the complete installation, with four furnaces and four cranes of 100 and 160 tons each, forms a very remarkable plant. Armour-plates of a thickness of 23½ in. and weighing 65 tons, have been produced in the steel-forging works. The equipment is sufficiently extensive to produce annually, in addition to marine shafting and gun parts, more than 6,000 tons of armour-plates. Messrs. Schneider and Co. have already delivered to various Governments about 60,000 tons of such plates; of this total the French Government has taken about 26,000 tons, and the remainder has been distributed among nearly all the Navy yards of the world. The manufacture of steel gun parts is one of the most important specialities of the company. Pieces for guns of all calibres, from 40 millimetres (1½ in.) up to 45 centimetres (17¾ in.), have been manufactured in great numbers for French artillery and for most foreign countries. The Schneider steel has, as as a material for gun-making, a universal reputation which has been established for many years.

The tempering-shop, which is placed near the main forge, contains special furnaces for heating armour-plates, gun parts, &c.; tanks for water-tempering thin armour-plates; a second installation for water-tempering; another for tempering armour-plates in oil; and a tank, 66 ft. deep, for oil-tempering gun tubes, &c.

Third Group.—The fitting-shops are important and extensive; a multitude of operations are performed here, the most important being for armour-plate work, gun-making, &c. The work done includes straightening and bending, planing the edges of plates, drilling holes for the bolts that attach the plates to the ship's framing, &c.; for these and other miscellaneous purposes, there is a great number of very powerful tools, such as disc metal-cutting saws, horizontal and vertical planing machines, drilling machines, &c.

Fourth Group.—The fourth group of the steel works contains shops for making tyres. The plant for this manufacture, which was at first installed in the armour-plate finishing shop, has been, on account of the very large increase in business, re-established in a section especially devoted to the work. The shop, which is thoroughly equipped with new machinery, is connected to the ingot foundry by a tunnel 400 yards in length, in which rails are laid, to allow the rapid transit of the ingots intended for making tyres, immediately after they have been cast. Tyres of all dimensions for locomotives, tenders, carriages, wagons, and tramways, are made in this department. The total annual output amounts to between 12,000 and 15,000 tons.

IX.—THE BESSEMER PLANT.

MESSRS. SCHNEIDER AND CO. began working two 6-ton converters in 1870, for the manufacture of Bessemer steel. The rapid development in the use of this steel obliged them to put down, in 1872, two more converters of 8 tons each; and in 1874 two others of the same capacity were constructed.

When, in 1879, the Thomas Gilchrist process was introduced, Messrs. Schneider and Co. were the first manufacturers in France to adopt it; they were, in fact, the pioneers who led the way for other metallurgical works in the east of France, towards the utilisation of the phosphorous iron-stone which is so largely found in their vicinity.

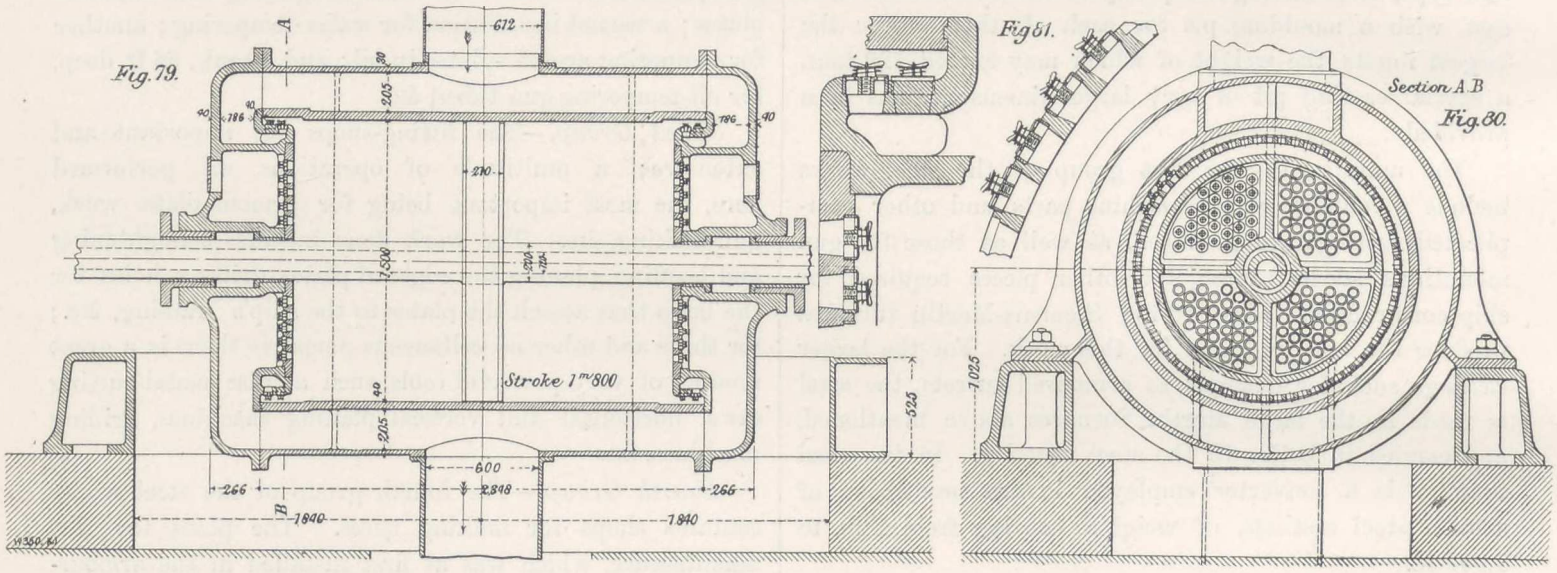
The Basic Process.—The Mazenay iron mines (see page 17) have always supplied to the Creusot Works the phosporous ore for the manufacture of the pig iron used in their Bessemer steel plant. The nature of the converter lining, which formed a special feature of the basic process, was minutely described by the inventors; but when the process came into the hands of Messrs. Schneider and Co. much remained to be done before it could be regarded as continuous and wholly satisfactory.

A long and careful series of investigations were made, and as a result Messrs. Schneider and Co. decided to form the converter lining of a mortar formed of roasted and crushed dolomite, mixed with coal tar. This gave excellent efficiency, and all the other steel works using the basic process subsequently adopted this method.

Of the three groups above mentioned, each consisting of two converters, only one is in use at the present time. It consists of two converters of 7.5 tons each, placed over a casting pit common to the two vessel. Fig. 78, Plate XIX., gives a good idea of the interior of the Bessemer converter house.

The diameter at the belt is 2.8 metres (9 ft. 2 in.) and the total internal capacity is 9 cubic metres (318 cubic feet), equivalent to 1.2 cubic metres (42.4 cubic feet) per ton of pig iron under treatment. Each converter is in two parts, and the joint is formed a little below the belt, the upper half being fixed in the bearings, and the lower part made moveable.

A hydraulic revolving lift placed in the centre of the casting pit, brings the ladle under the mouth of the converters; the steel is poured into this ladle, and thence into ingot moulds placed around on a circular platform. All the labour is performed by two 20-ton quick-action hydraulic cranes. Owing to the way in which each converter is dismantled for repairs, cranes of this power were necessary.



Details of Air Cylinders, for Bessemer Blowing Engine.

The converter is fitted with magnesia tuyeres, around which dolomite mortar is rammed. These tuyeres are manufactured at the Perreuil Brick Works (see page 19). The dolomite employed is found in abundance at short distances from Creusot. The lower half of the converter thus prepared, lasts, on an average, for 60 heats; some have withstood as many as 90 heats. The lining of the upper, or fixed part, of the converter lasts, as a rule, 140 heats.

Blowing Engines.—The blowing engines which supply air to the converters are of a horizontal non-condensing

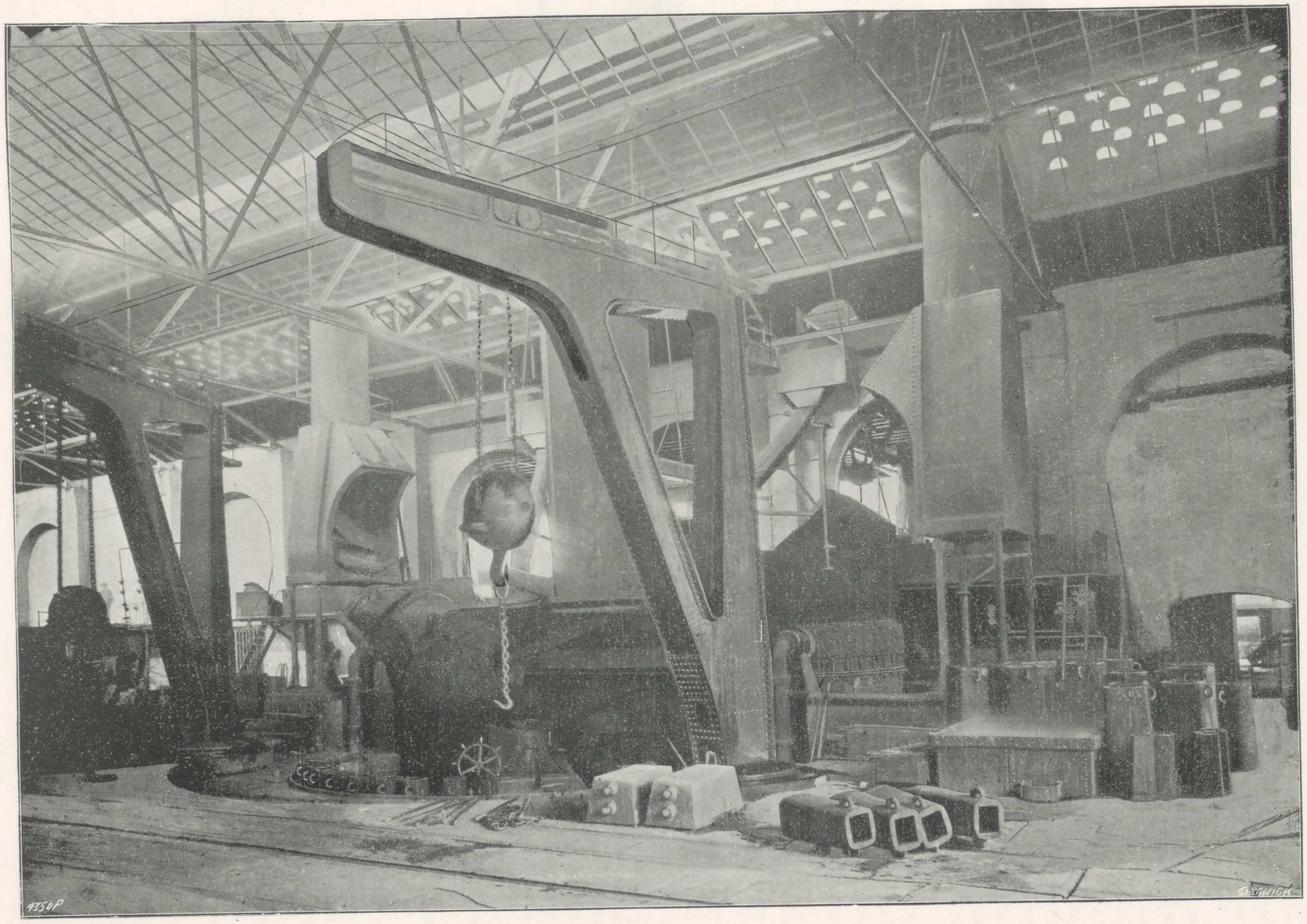


Fig. 78. View of the Bessemer Converter House.

type, with two connecting cylinders. The following are some of the dimensions:

Diameter of air cylinders	1.5 m.	4 ft. 11 in.
,, steam cylinders ...	1.2 m.	3 ft. 11 in.
Stroke	1.8 m.	5 ft. 11 in.
Air pressure, mercury	150 cm.	4 ft. 11 in.
Volume of blast supplied per ton of pig under operation and per minute	45 c. m.	1,589 cub. ft.

The inlet and outlet valves of the air cylinders are of the Corliss type (see Figs. 79 to 81). An air receiver of 225 cubic metres (7,943 cubic feet) capacity, is situated between the engines and the converters. The steam for the engines is produced in the boilers fired by the waste gases from the blast-furnaces and the coke ovens. These boilers have been already described (see pages 27 and 29). The various improvements made since the plant was first put down have enabled Messrs. Schneider and Co. to obtain an output which is large as compared to the size of the installation. As a rule, the ingots weigh about 1,350 kilogrammes (26 cwt. to 27 cwt.), but smaller ones are also cast, weighing from 300 to 500 kilogrammes (6 cwt. to 10 cwt.); these latter are chiefly used for rolling into plates, and for light rails. There are usually 17 heats per twelve hours, and the yearly output is 62,000 tons. The molten pig iron is taken direct from the blast-furnaces, which are only 82 yards distant. A small locomotive hauls the truck carrying the ladle on to an elevator, which lifts it on a platform at the height of the converter mouth. The steel ingots are taken out of the moulds, and carried hot, in special trucks, to the rolling mills.

The carburising agent varies according to the degrees of hardness required. For mild steel of less than 48 kilogrammes per square millimetre (30.48 tons per square inch) breaking strain, 75 per cent., ferro-manganese in a red-hot state is used. For steel of 48 kilogrammes to 60 kilogrammes per square millimetre (30.48 to 38.09 tons per square inch) breaking strain, a small proportion of anthracite is added to the ferro-manganese. A mixture of manganeseous pig iron and hematite pig, melted in a cupola, is used for obtaining steel which is to give a higher breaking strain than 60 kilogrammes per square millimetre (38.09 tons per square inch.) The heated ferro-manganese is thrown into the converter previous to the pouring of the metal in the casting ladle. The carburising by anthracite, and by the mixture melted down in a cupola, is effected by putting the carburising agent first into the ladle; the metal from the converter is then poured into the ladle, care being taken that no slag runs in with it.

Qualities of Bessemer Steel.—Messrs. Schneider and Co. have classified their Bessemer steel, according to its breaking strain, under eleven numbers, each one representing a different quality; there is a difference of 5 kilogrammes per square millimetre (3.17 tons per square inch) breaking strain between every two consecutive numbers. The hardest, styled No. 1, has a breaking strain of 90 kilogrammes per square millimetre (57.14 tons per square inch), and the softest, styled No. 11, 35 kilogrammes per square millimetre (22.22 tons per square inch) only.

A small sample ingot is taken from each heat, and from this there are made, first, a test-piece forged to a diameter of 16 millimetres ($\frac{5}{8}$ in.) and annealed in the open, previous to undergoing tensile test; secondly, a test-piece for analysis; and, thirdly, a test-piece forged to a diameter of $\frac{5}{8}$ in. for testing the quality when hot. For this last test, the piece is brought to a white heat, and bent at right angles with a hand-hammer; it is then straightened out again and bent over at right angles the other way. This is carried on until the piece breaks. The quality of the steel is defined by the number of times the test-bar withstands bending.

Bessemer steel is also classified in three qualities, namely: Mild (ordinary and extra-mild), semi-hard, and hard. The ordinary mild quality serves for current products, such as rolled bars, sections, plates for tanks, receivers, &c.

The extra-mild quality is more especially used for the manufacture of nails, wheel tyres, thin sheets for dynamos, buckled plates, sheets for galvanising, tinplate bars, &c. The semi-hard steel is used for base-plates, fish-plates, light rails, sleepers, shafts, shovels, spades, &c. The hard quality serves exclusively for the manufacture of heavy rails. Notwithstanding the classification from results of tests as above described, Messrs. Schneider and Co. take into account, when fixing the quality of their steel, and consequently in deciding the use to which it has to be put, the class of pig iron employed, the manner in which the metal behaved in the converter, and also the way in which the steel flows in the ingot mould. Minute inspection at all stages of the process explains the high reputation acquired by the sheets, dynamo steel, welding steel for wheel tyres, &c., manufactured at Creusot with the basic plant.

All the hydraulic machinery is worked under a pressure of 30 kilogrammes per square centimetre (426.69 lb. per square inch). Water is supplied by two vertical pumps of 50 horse-power each, which serve not only the Bessemer plant, but also the other installations, namely, the Siemens-Martin plant, the steel foundry, and the rotary puddling furnaces. All the accessory plant, cupola fans; crushing mills for preparing dolomite, lifts for ladles, slag receivers &c., are operated by electric motors.

Slag.—The slag, after being poured in special receivers, is removed, and after cooling is crushed and screened in a special shop near the Bessemer plant, and is sold to agriculturalists as manure. This by-product is highly appreciated in the district, as it contains a high percentage of phosphoric acid. Messrs. Schneider and Co. sell 15,000 tons of this every year.

X.—THE SIEMENS-MARTIN PLANT.

Furnaces and Casting Pits.—The Siemens-Martin plant was commenced in 1873, with six 8-ton furnaces; these were placed in a building 94 metres (308 ft.) long; 54 metres (177 ft.) wide; and 9 metres (29 ft.) high. In 1874 the furnaces were enlarged to a capacity of 12 tons. They were again increased to 15 tons capacity in 1876, and to 20 tons in 1888. These furnaces were constructed on two parallel lines, and in two groups of four and two, level with the ground. Each furnace was supplemented by an adjacent gas-heating furnace, in which the metal to be melted down, was previously brought to a red heat. They were also provided in every case with a revolving platform 8 metres (26 ft.) in diameter, mounted on a hydraulic ram. The ingot moulds were arranged around the outer edge of this platform, and were brought successively under the casting channel. The removal of the ingots was effected by means of 2-ton hydraulic cranes.

In 1877 a rectangular casting pit was made in the axis of the building, beyond the space occupied by the two lines of furnaces already described. The special purpose of this pit was to facilitate the casting of large ingots required in the manufacture of heavy forgings. It was served by a revolving steam crane of 80 tons, which has lifted on several occasions pieces weighing more than 100 tons.

The dimensions of the casting pit were as follow:

	m.	ft.	in.
Length	16.000	52	0
Width...	3.700	12	2
Depth	5.500	18	0

The depth of 18 ft. was, however, increased to 9.500 metres (31 ft. 2 in.) over a part of the length, to facilitate the production of very heavy ingots. In 1878 such an ingot, weighing 120 tons, was cast in this pit; a full-sized model of it was exhibited at the Paris Exhibition of that year (Fig 82).

When casting ingots in the pit, the ladles carried on bogie trucks, were brought under the casting runner of each furnace by means of the turning platform above referred to. Two main tracks, one on each side of the casting pit, parallel to the furnaces and in communication with the revolving platforms, served by means of turntables, for conveying the ladle to the casting pit. Movable tracks were laid over the pit, in such a way as to be easily adjusted with the turntables of the main tracks. By this arrangement it became easy to bring the ladles direct over the ingot moulds. The tracks on the pit permitted, by means of suitable runners, the discharge of four ladles simultaneously into one mould. Notwithstanding the comparatively small dimensions of this pit, it sufficed for a period of seventeen years, during which time no less than 170,210 tons of large ingots for armour-plates, guns, and shafts, were produced.

A seventh Siemens-Martin furnace, of 20 tons capacity, was built in 1878. In 1892 Messrs. Schneider and Co., finding it an urgent necessity to increase the size of their steel plant, built an eighth furnace, the capacity of which was 25 tons. A new casting pit was also made parallel to this furnace. Since 1892 considerable developments have taken place. The increasing demand for steel, due to the growing manufacture of armour-plates, guns, special

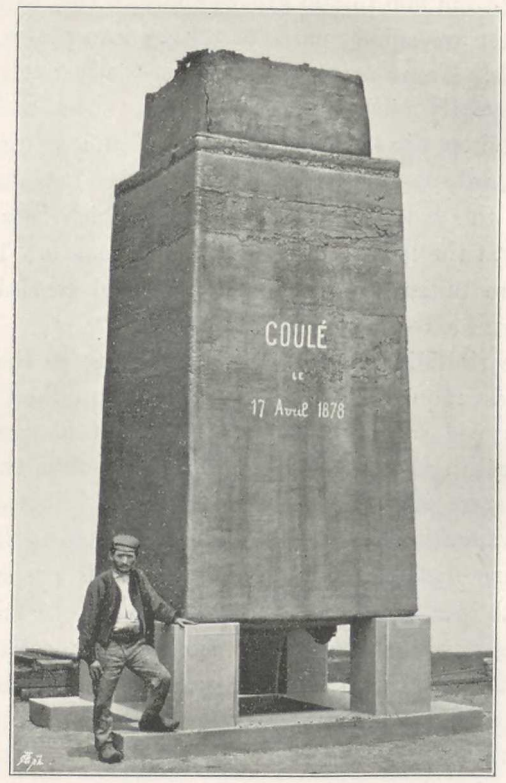


Fig. 82. 120-ton Steel Ingot cast in 1878.

forgings, &c., made it a necessity in 1893 to construct a casting pit much larger than the one already described for the production of still heavier ingots. Figs. 83 and 84 are views of this pit, which is made in a building 25 metres (82 ft.) wide; 54 metres (177 ft.) long; and 14 metres (46 ft.) high, to the springing of the roof; it is placed in a line with that containing the Siemens-Martin furnaces. The plan, Fig. 77, Plate XVIII., clearly shows the position of the different Siemens-Martin furnaces and casting pits. An electrically-driven overhead travelling crane, built by Messrs. Schneider and Co., with a capacity of 150 tons lifting power (to be described later), and

running on overhead tracks, serves for handling all the heavy loads. It is supplemented by a 10-ton portable quick-acting steam crane for lifting the lighter loads. This latter crane travels on all the lines that surround the pit.

In the year 1894, Messrs. Schneider and Co., finding that their latest 25-ton furnace gave excellent results for casting small ingots by means of ladles, decided to do away with the disadvantages that attended direct casting into the small ingot moulds. This change involved the putting down of a new and costly plant, and meant a work of considerable difficulty; the change had to be accomplished

The increase in the size of the new furnaces makes it possible to obtain more homogeneity in the steel of heavy ingots, as these can be cast, according to their size, either from one furnace or from two, with the help of a collecting ladle.

The new furnaces are raised on a platform 4 metres (13 ft.) above the level of the works. Each is provided with a special casting pit, perpendicular to the wall of the furnace, and adapted for casting ingots that weigh from 2 cwt. to 8 tons. The platform is in communication with the ground level, by means of a track, the maximum incline of which is 1 in 40. The raw material is brought up to

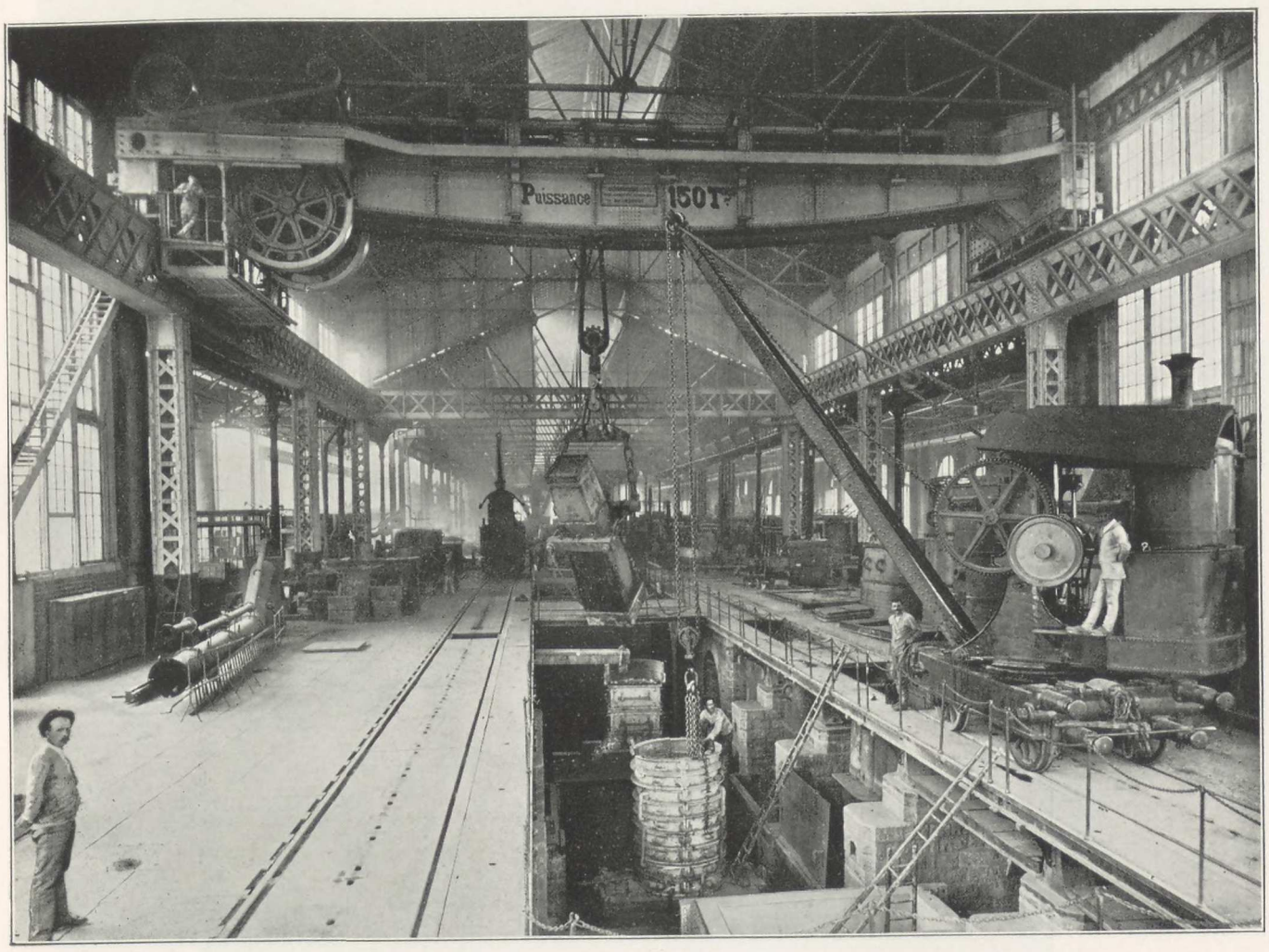


Fig. 83. Main Casting Pit (also showing 150-ton Electric Crane).

without suspending, or in any way checking, the daily steel production. These difficulties were, however, successfully surmounted. A certain number of the old furnaces were kept in work at high pressure, and the alterations were carried out without any diminution of the output. The actual arrangement is indicated in the plan Fig. 77, Plate XVIII. The transformation took less than ten months to complete, and the new plant, when entirely finished, will consist of four furnaces, three of which are of 35 tons capacity, while the fourth will have a capacity of 45 tons, and will be constructed in the place now occupied by the 25-ton furnace which is still at work.

the furnace doors in small trucks, hauled up the incline by a light locomotive.

Charging Furnaces.—A special system is followed which insures a rapid charging of the furnaces. Notwithstanding the diversity of weights and shapes of material and scrap of which the charge consists, a 35-ton furnace is easily charged in less than one hour. For this work a 20-ton overhead electric travelling crane is used, there being one of these for each furnace, and to this is suspended a special **C**-shaped carrier, patented by Messrs. Schneider and Co.

On the lower branch of this carrier is placed the material; this branch is free to move in its bearings on the

upper or fixed part of the top branch, and it is also free to swing to the right or left. The charges, prepared in advance and carried up to the furnace in the trucks, are taken by the carrier, and brought to the furnace by means of the travelling crane. The great facility with which the device is manipulated, enables the charges to be well distributed over the hearth of the furnace, and thus rapid and uniform melting action is secured. Pieces weighing as much as 8 tons can be charged without any manual labour; the operation of guiding the carrier is performed by two men and a boy.

The following are the dimensions of the 35-ton furnaces, which are illustrated by Figs. 86 and 87:

Length between uprights ...	10.600 m.	34 ft. 9 in.
Breadth ,, ,, ...	3.800 m.	12 ft. 6 in.
Inside length between firebridges	6.700 m.	22 ft. 0 in.
Inside breadth in the middle ...	3.100 m.	10 ft. 2 in.
Surface of hearth per ton of steel	0.70 sq. m.	7½ sq. ft.

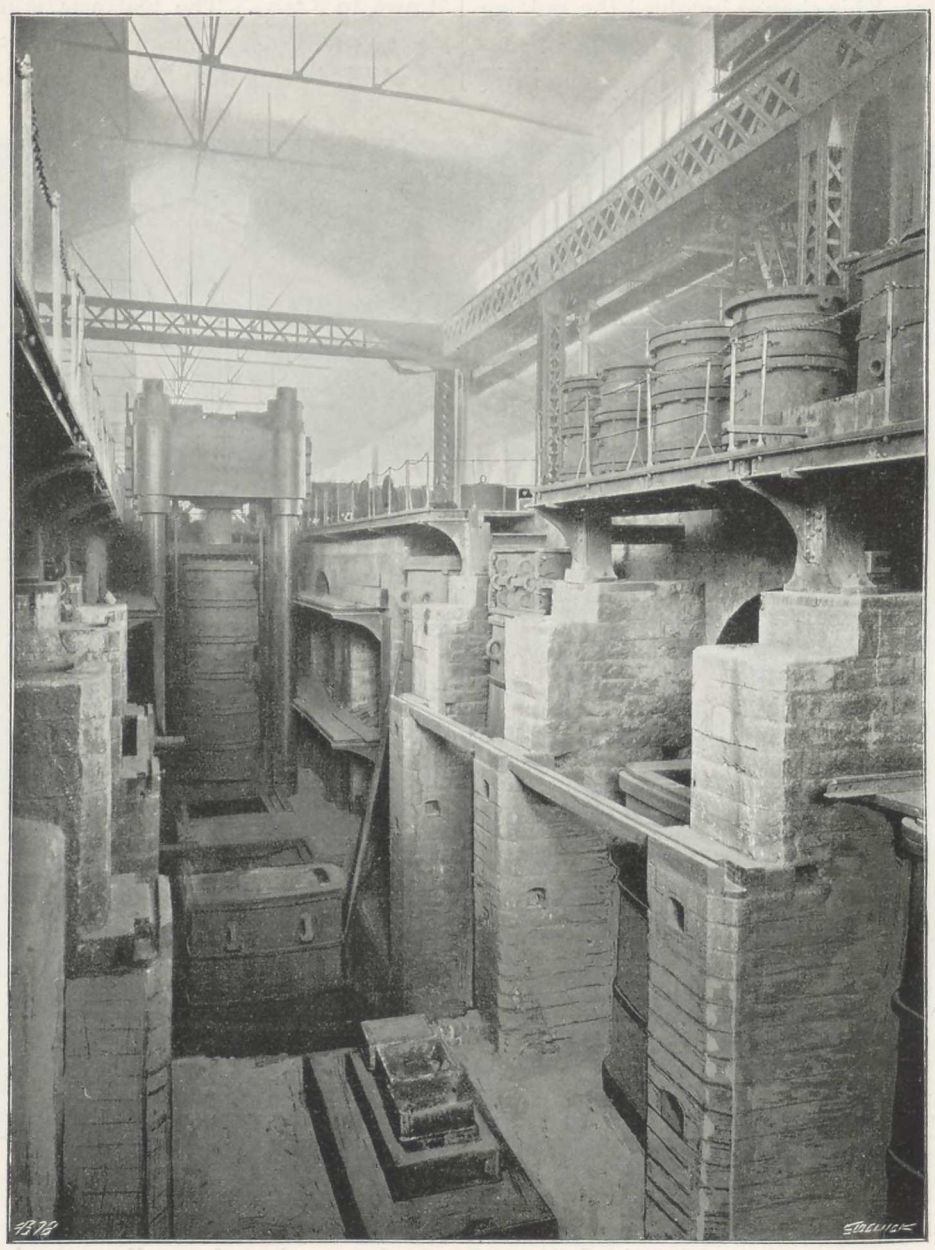


Fig. 84. Main Casting Pit.

Travelling Cranes.—The travelling cranes that serve the Siemens-Martin furnaces, have a span of 13.7 metres (44 ft. 11½ in.), and traverse the whole width of the building. Besides being used for charging, they prove very useful in repairing the furnaces when these have to be taken to pieces, as, for instance, in lifting out the hearth.

There are three charging doors, .80 metre (31½ in.) wide, which can be opened out to 1.1 metre (43 in.) for the larger pieces of a charge. The distance allowed between the furnaces is 20 metres (65 ft.) from centre to centre.

Regenerators.—The capacity of the two air and gas regenerators is 4.6 cubic metres (162.46 cubic feet) per ton of steel, including only that part which contains the brick filling; or 6 cubic metres (211.90 cubic feet), if the total

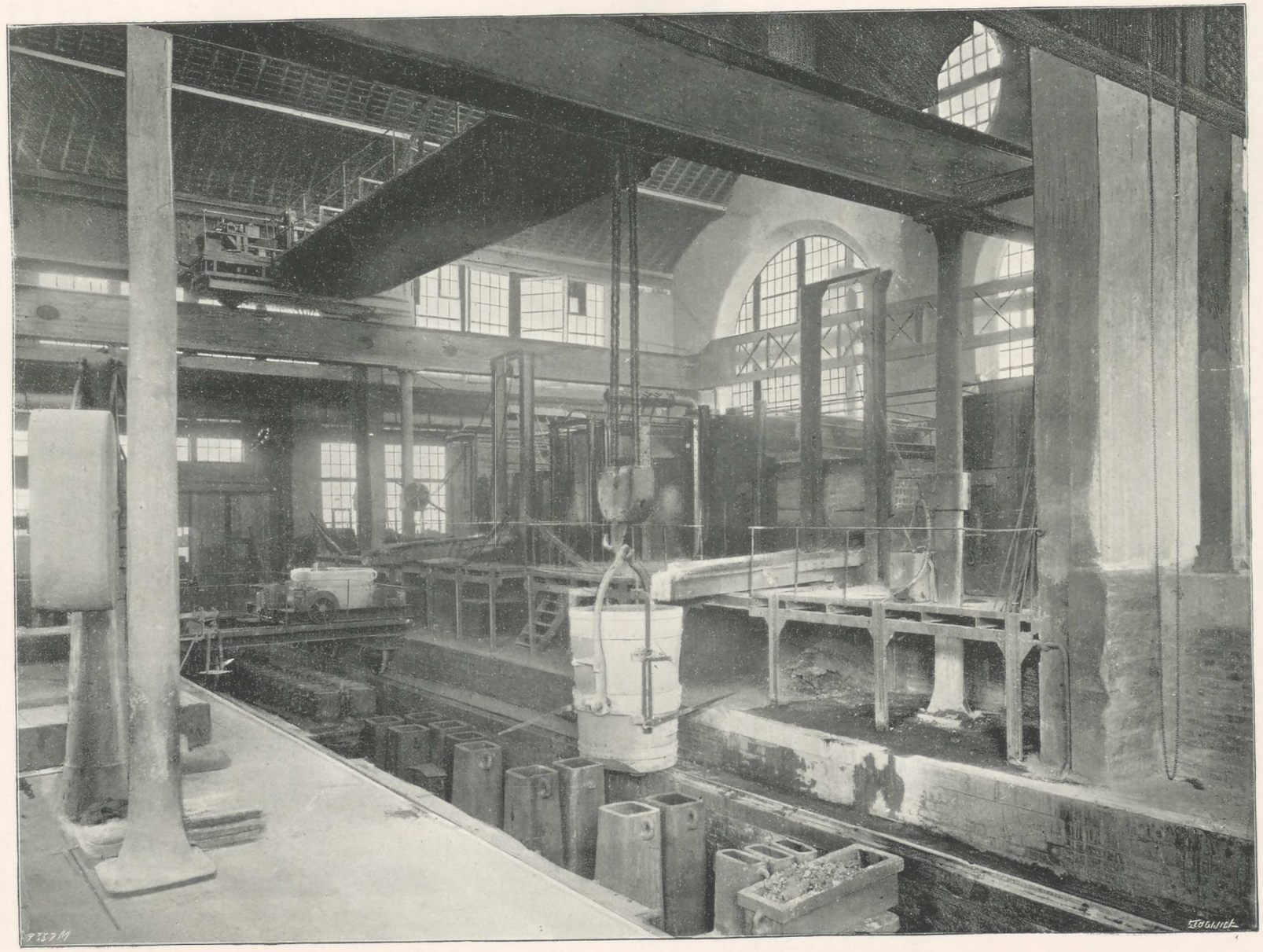


Fig. 85. View of 10-Ton Siemens-Martin Steel Furnaces and Casting Pit.

capacity of the regenerators be counted. A wrought-iron chimney, lined with firebricks, is provided for each furnace; its height is 40 metres (131 ft.), and the inside diameter at the top 1 metre (39½ in.).

It may be mentioned that the chimney belonging to the 25-ton furnace, which happened to be in the way of the overhead line of the travelling cranes, was shifted, just as it stood (see Fig. 88) for a distance of 10 metres (33 ft.) outside the shop, and that advantage was taken of this opportunity to increase its height by 4 metres (13 ft.).

controlling mechanism. The following are the dimensions of the casting pits (see Fig. 86) perpendicular to the wall of each furnace:

Length of pit	18.400 m.	60 ft. 3 in.
Width ,, ...	4.200 m.	13 ft. 9 in.
Depth ,, ...	2 m. and 2.500 m.	6 ft. 7 in. and 8 ft. 3 in.
Diameter of ladle	2.200 m.	7 ft. 3 in.
Height	2 m.	6 ft. 7 in.

Fig. 86.

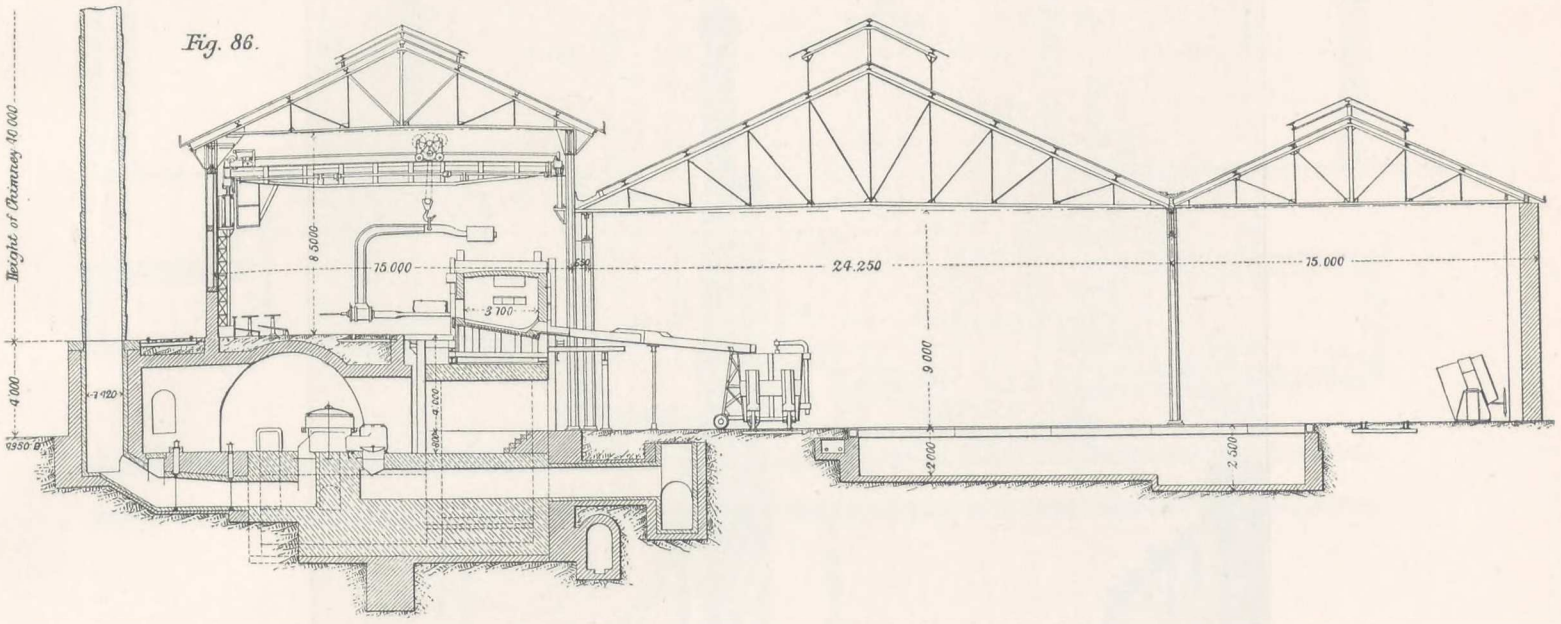
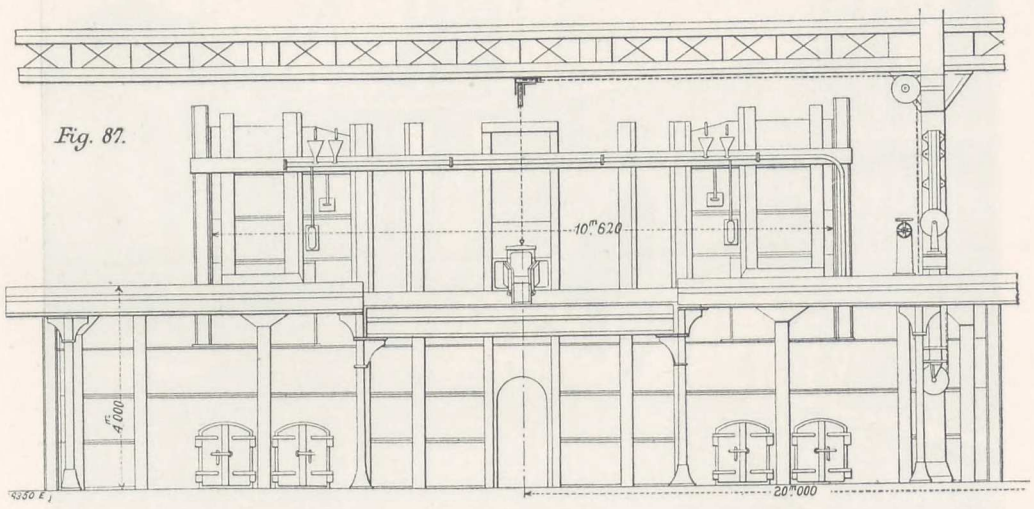


Fig. 87.



35-Ton Siemens-Martin Steel Furnaces.

Casting Small Ingots. — The distribution of gas and air is effected by means of wrought-iron mains with hydraulic joints. Small ingots are cast from a ladle carried on a double-sided bogie truck; this runs on tracks laid the whole length of the casting pit. Each furnace is provided with its own ladle and casting appliances. A 10-ton portable steam crane which runs on a track parallel to the pit, hauls the ladle truck, and shifts it longitudinally or transversely, with the help of a special

The travelling steam crane, above referred to, serves also to lift and load the ingots into trucks, and to raise the ladle which is heated before casting, by being turned upside down over a coke fire, through which a blast of air is directed.

Production of Gas.—Gas for the furnaces is produced by a range of generators placed outside the steel works, and at a distance of about 100 metres (330 ft.) from the furnaces (see Fig. 77, Plate XVIII.).

The coal used is a mixture of three qualities, supplied by neighbouring mines, and containing less than 15 per cent. of ash. The grates are arranged in groups of four, united by collecting flues placed above them, and in which the greater part of the soot is deposited. Their sizes are:

Length of grate	1.700 m.	5 ft. 7 in.
Width ,, ...	1.000 m.	3 ft. 3 in.
Area ,, ...	1.70 sq. m.	18.3 sq. ft.

The average composition of the smoke, taken at the foot of the chimneys, is as follows:

Carbonic acid	16.90
Oxygen	1.40
Carbon oxyde	0.10
Free hydrogen	—
Carburet of hydrogen	—
Nitrogen	81.60
	100.00

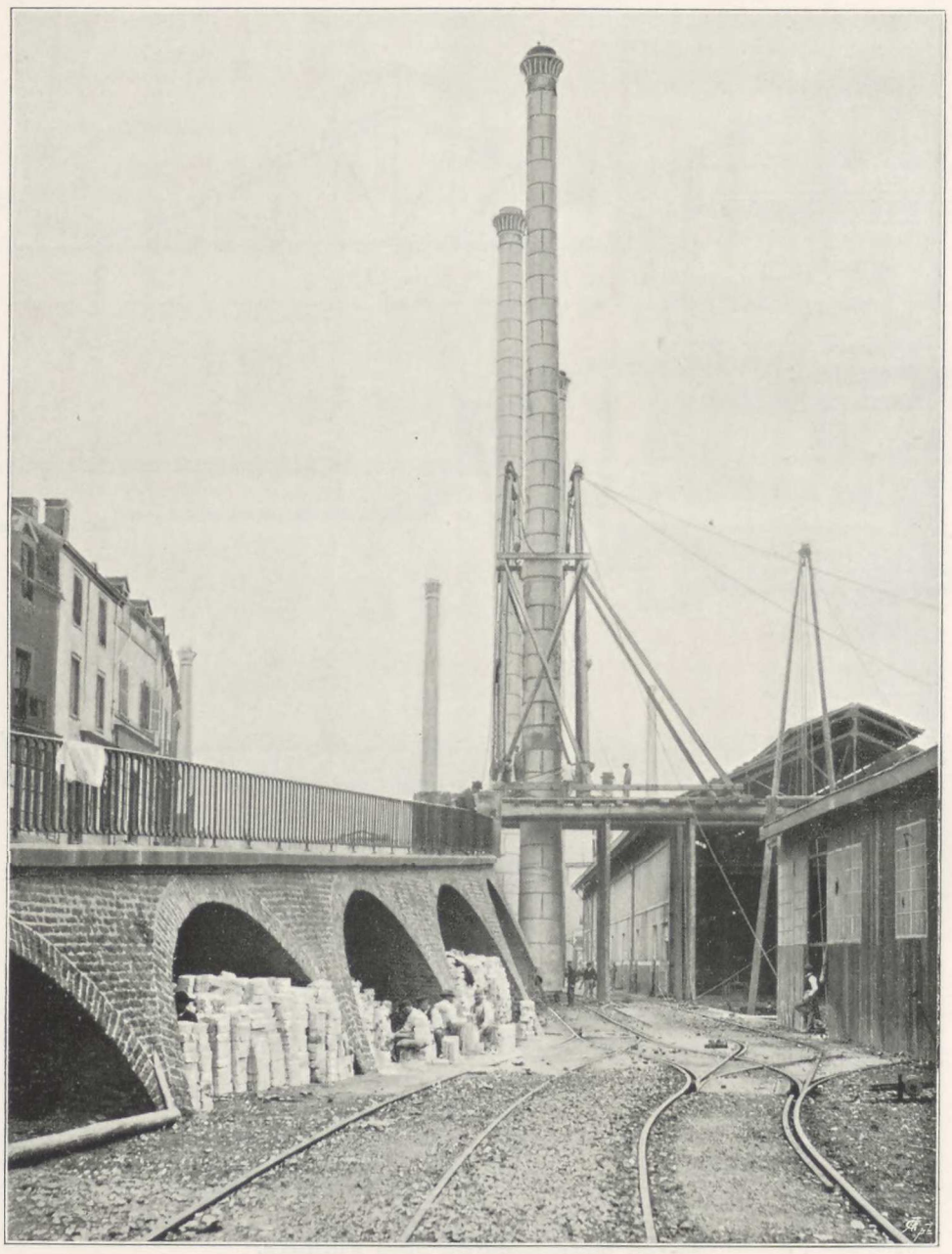


Fig. 88. Wrought-iron Chimney of the Siemens-Martin Steel Foundry.

The average composition of the gas, in volume, is as follows:

Carbonic acid	3.60
Oxygen	0.60
Carbon oxyde	26.60
Free hydrogen	8.80
Carburet of hydrogen	2.60
Nitrogen	57.80
	100.00

A series of underground passages leads the gas to the steel furnaces. In flowing through these, the gas loses a part of its heat, and reaches the furnaces under a relatively high pressure. The condensed tar which collects in the generator chimneys, and the flues, is removed only about once in twenty months.

Main Casting Pit.—The main casting pit to which reference has already been made, is provided with two

THE STEEL WORKS.

Fig. 89.

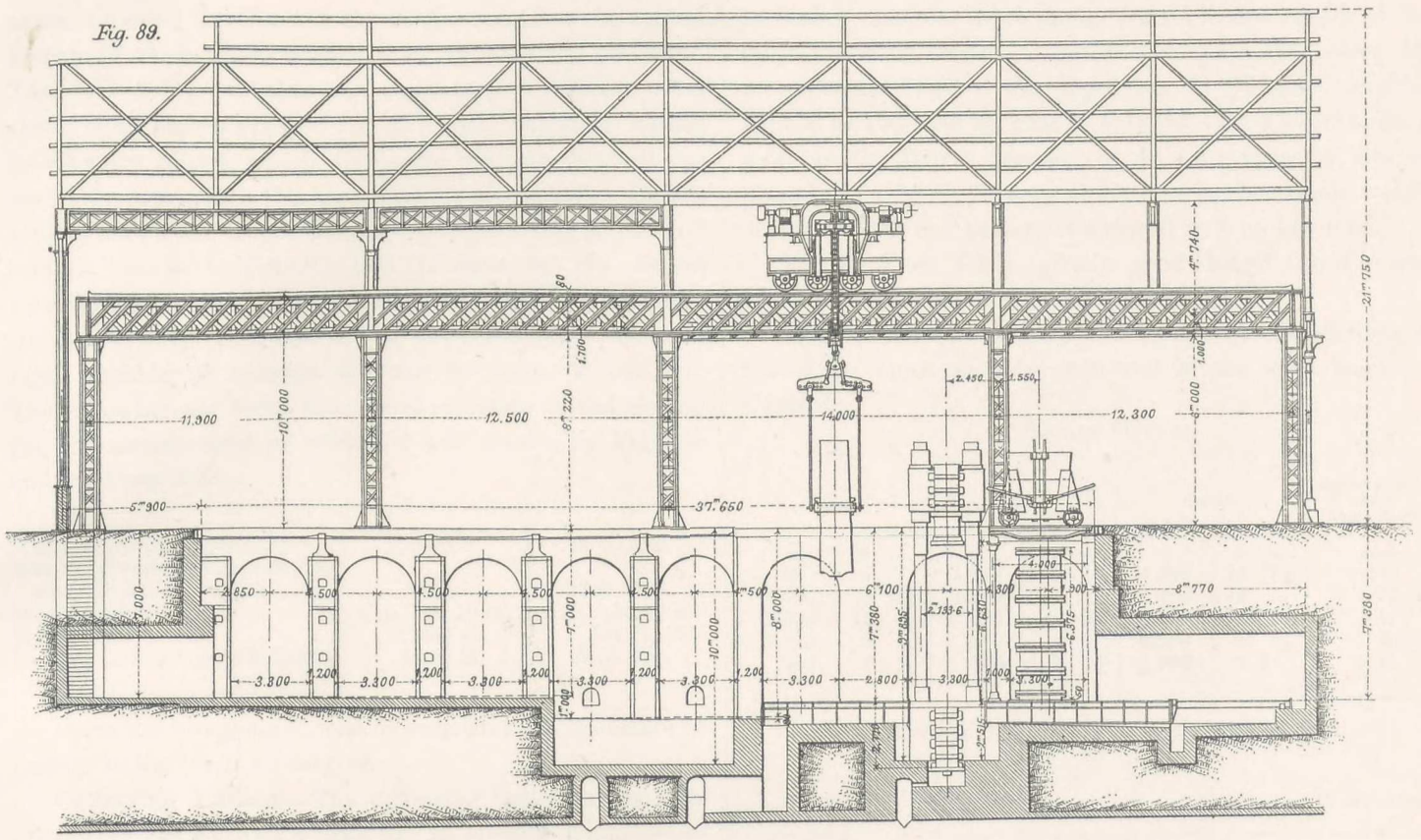
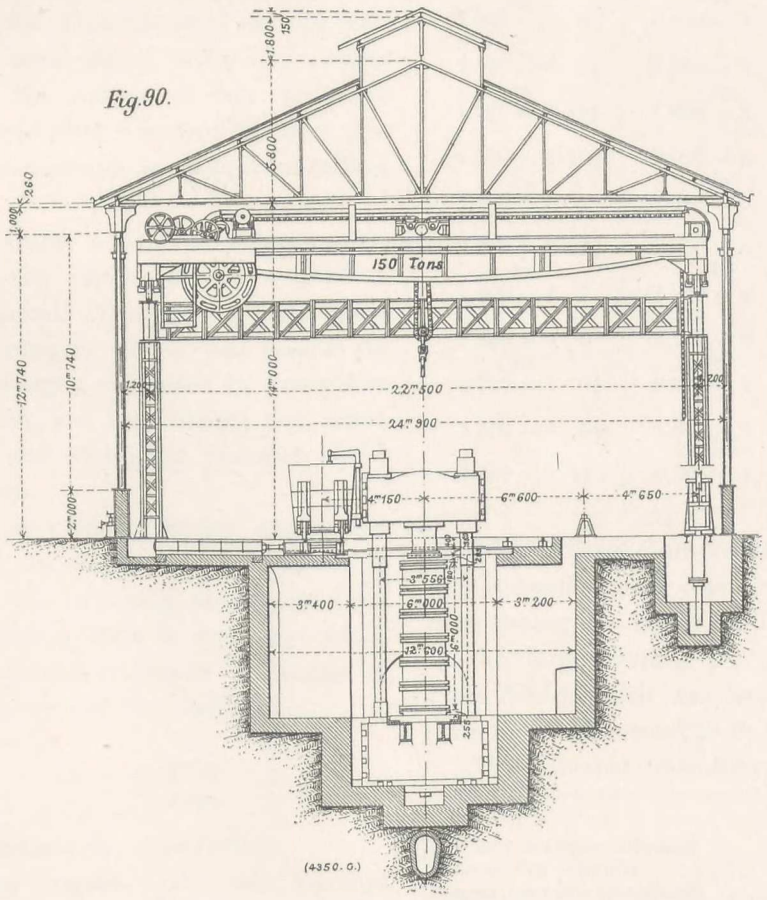


Fig. 90.



Main Casting Pit, Fluid Steel Compressing Plant, and 150-ton Electric Crane.

parallel tracks, one on each side. One of these tracks is extended along the front of the 35-ton furnaces. A special feature of these tracks is that they run over the pit itself. The inside rail is movable, and consists of a series of steel castings 4.5 metres (14 ft. 9 in.) in length, the ends resting on masonry pillars, which divide the pit into five cells on each side, into which the ingot moulds are placed. Before setting the mould in position, or raising the ingot, the rail casting has to be lifted: this is done by the 10-ton travelling crane. The pit contains fifteen casting compartments, ten in the cells and five on the centre line. Several ingot moulds of average size can be placed in one cell. The following are some dimensions relating to the casting pit, the arrangement of which is well shown by Figs. 89 and 90, Plate XXI.:

Width of the pit at the cells ...	12.600 m.	41 ft. 4 in.
Width between pillars carrying movable rail	4 m.	13 ft. 2 in.
Depth of pit	7 m. and 10 m.	23 ft. and 33 ft.
Total length	37.650 m.	124 ft.
Distance between parallel tracks	8.300 m.	27 ft. 3 in.

From the foregoing it will be seen that the operation of casting in the pit is an easy one.

Collecting Ladles.—The collecting ladle, having been previously heated over a coke fire as already described, or over a gas generator provided with air blast, is hauled on the main track in front of the furnace, in order to receive the charge. The runner is made in two parts; that nearest the furnace is free to move vertically, and is lifted by means of a hydraulic hoist when the steel has run out; the slag then falls into a tank placed under the runner joint; the other part of the runner is free to move laterally, and is turned round after the steel has been discharged. This arrangement prevents any slag from falling into the ladle.

The travelling steam crane, acting as a locomotive, hauls the filled ladle to the casting pit, to a position exactly above the ingot mould. The casting takes place direct, without the use of runners. If several moulds are to be filled, the ladle is brought over each in succession. All these manœuvres, which are very simple and rapid, are carried out noiselessly and with great precision under the supervision of a foreman.

65-Ton Ladle.—The heavy ingots which require the charge of several furnaces are cast in the middle part of the pit. For ingots of a size requiring the charge from two furnaces, a 65-ton collecting ladle is used, into which the steel from the two furnaces is tapped by means of special runners. The dimensions of this ladle are:

	m.	ft.	in.
Diameter of ladle	2.700	8	10
Height ,, ...	2.800	9	2

Figs. 91, 92, and 93, illustrate the construction.

Casting the Heaviest Ingots.—For the heaviest ingots that require the steel from more than two furnaces, the quantity is made up by two other ladles filled from the other furnaces; these supplementary ladles are hauled on to the track opposite that on which the 65-ton ladle stands. In such a case, the ingot mould placed in the centre of the pit, is filled by means of inclined runners that carry the metal to the top of the ingot mould. Ingots weighing from 8 to 130 tons are cast in this pit. In a short time, as soon as the fourth furnace, of 45 tons capacity, has replaced the existing furnace of 25 tons, the maximum weight of ingots that can be cast at Creusot will be 145 tons.

Fig. 94, Plate XXII., gives a good idea of the Siemens-Martin 35-ton furnaces and accessory plant.

Ingot Moulds.—The following are the dimensions of the large ingot moulds employed in the steel works at Creusot:

1. Square Moulds.

Base.			Top.			Height.			Weight of Ingot with Dead Head.
m.	ft.	in.	m.	ft.	in.	m.	ft.	in.	tons
1.900	6	3	1.570	5	$1\frac{3}{4}$	4.400	14	$5\frac{1}{4}$	110
1.580	5	$2\frac{1}{4}$	1.250	4	1	4.400	14	$5\frac{1}{4}$	71
1.225	4	$0\frac{1}{4}$	.975	3	$2\frac{3}{8}$	3.200	10	6	47
1.170	3	10	.970	3	2	2.600	8	$6\frac{1}{4}$	23
.940	3	1	.850	2	$9\frac{1}{2}$	1.800	5	11	11

2. Rectangular Moulds for Armour-Plates.

Base.	Top.	Height.	Weight of Ingot.
m. ft. in.	m. ft. in.	m. ft. in.	tons
2.500 = 8 $2\frac{1}{2}$ by 1.300 = 4 3	2.450 = 8 $0\frac{1}{2}$ by 1.150 = 3 $9\frac{1}{4}$	3.000 = 9 10	70
2.300 = 7 $6\frac{1}{2}$ by 1.000 = 3 $3\frac{1}{2}$	2.240 = 7 $4\frac{1}{4}$ by 0.850 = 2 $9\frac{1}{2}$	3.000 = 9 10	51
2.570 = 8 $5\frac{1}{4}$ by 1.175 = 3 $10\frac{1}{4}$	2.500 = 8 $2\frac{1}{2}$ by 1.000 = 3 $3\frac{1}{2}$	3.400 = 11 2	76
2.100 = 6 $10\frac{3}{4}$ by 1.250 = 4 1	2.030 = 6 8 by 1.080 = 3 $6\frac{1}{2}$	3.400 = 11 2	66
2.050 = 6 $8\frac{3}{4}$ by 1.400 = 4 7	2.000 = 6 7 by 1.250 = 4 1	3.000 = 9 10	65
1.830 = 6 0 by 0.770 = 2 $6\frac{1}{4}$	1.770 = 5 $9\frac{1}{2}$ by 0.630 = 2 $0\frac{3}{4}$	2.200 = 7 $2\frac{3}{4}$	20
1.670 = 5 $5\frac{3}{4}$ by 0.580 = 1 11	1.630 = 5 $4\frac{1}{4}$ by 0.505 = 1 8	2.000 = 6 7	12

Liquid-Steel Compressing Plant.—In 1896, a 10,000-ton hydraulic press was erected in the steel works, for compressing the liquid steel in the ingots. It was placed in the large casting pit (see Fig. 84 and Figs. 89, 90, Plate XXI.), which was lengthened for this purpose for a distance of 9 metres (29 ft. 6 in.).

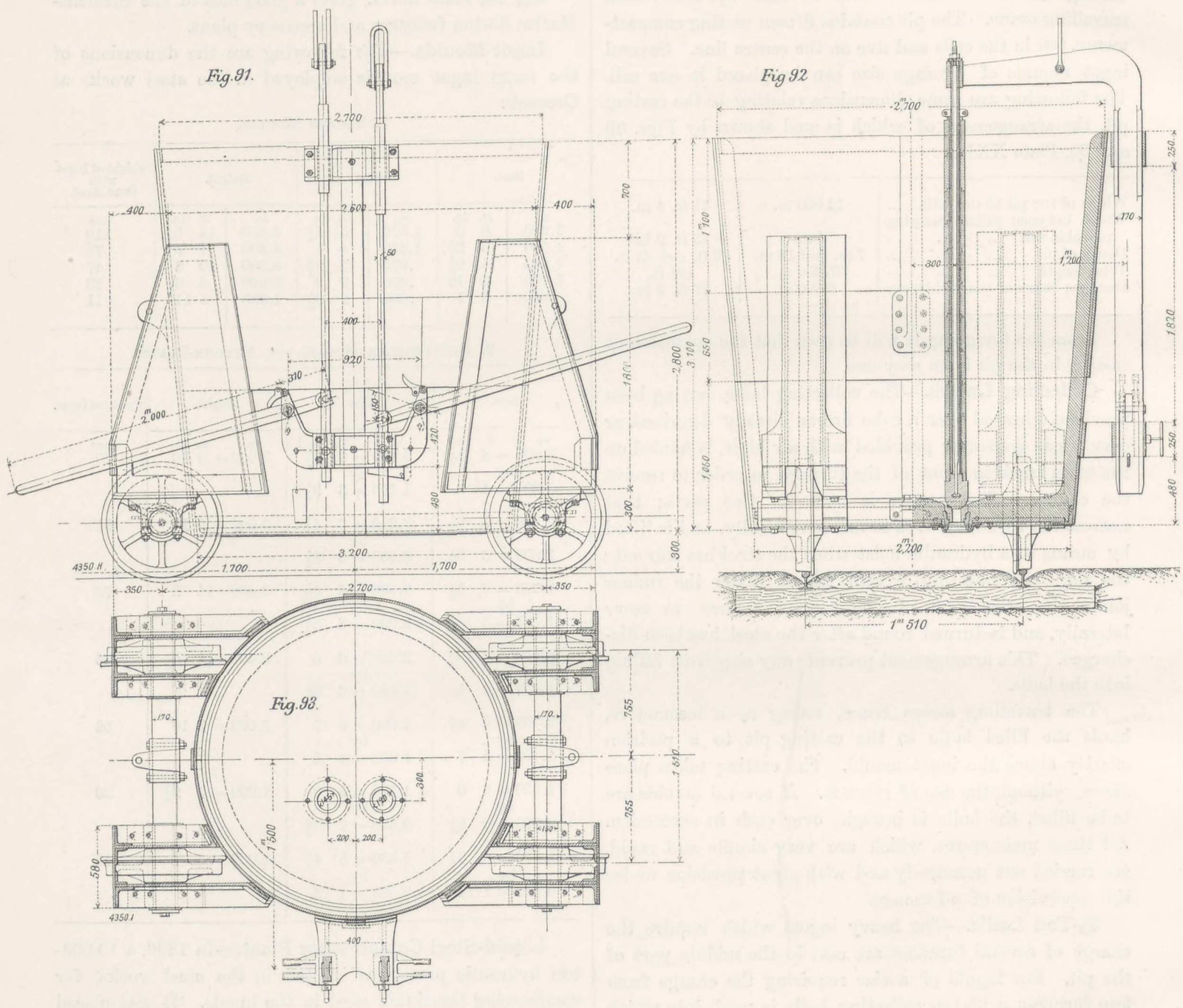
The principal dimensions of the press are the following:

	m.	ft.	in.
Distance between columns	3.040	10	0
Diameter of columns	0.500	1	8
Height between crossheads	8.200	26	11
Maximum height of ingot moulds ...	6.000	19	$8\frac{1}{4}$
Diameter of piston	1.676	5	6
Travel	1.000	3	$3\frac{1}{2}$

The maximum water pressure employed is 430 kilogrammes per square centimetre (6115.9 lb. = $2\frac{3}{4}$ tons per square inch); the pressure used varies with the size of the ingot to be compressed. The depth of the pit where the press stands is 7.400 metres (24 ft. 3 in.).

The ingot moulds employed in this process have to withstand a very heavy pressure, and are specially designed for that purpose. They are formed of a series of consecutive size being 50 millimetres (say 2 in.). There are, therefore, seventeen sizes of ingots. The weights are as follows:

	Tons.
Smallest ingot .670 metres ($26\frac{3}{8}$ in.), weight of mould	38
Weight of ingot	$16\frac{1}{2}$
Largest ingot 1.470 metres (4 ft. 10 in.), weight of mould	108
Weight of ingot	75



65-Ton Collecting Ladle.

cast-steel rings 1 metre (3 ft. $3\frac{1}{2}$ in.) high, joined together by means of strong bolts. The inside of each mould is covered with cast-iron staves, lined with highly-refractory sand 20 millimetres ($\frac{3}{4}$-in.) thick.

Compressed-Steel Ingots.—The smallest compressed-steel ingot made has a diameter of .670 metres ($26\frac{3}{8}$ in.), and at the present time, the largest is 1.470 metres (4 ft. 10 in.) in diameter, the difference between each

Casting is done by means of the 35-ton and 65-ton collecting ladles (see Figs. 91 to 93,) as already described, according to the weight of ingot. Hydraulic lifts placed overhead are used to bring the ladle above the ingot mould, and others placed underneath, push the mould when it has been filled, under the press. Lifting ingot moulds and ingots after the operation, is done by the 150-ton electric travelling crane. The advantages of com-

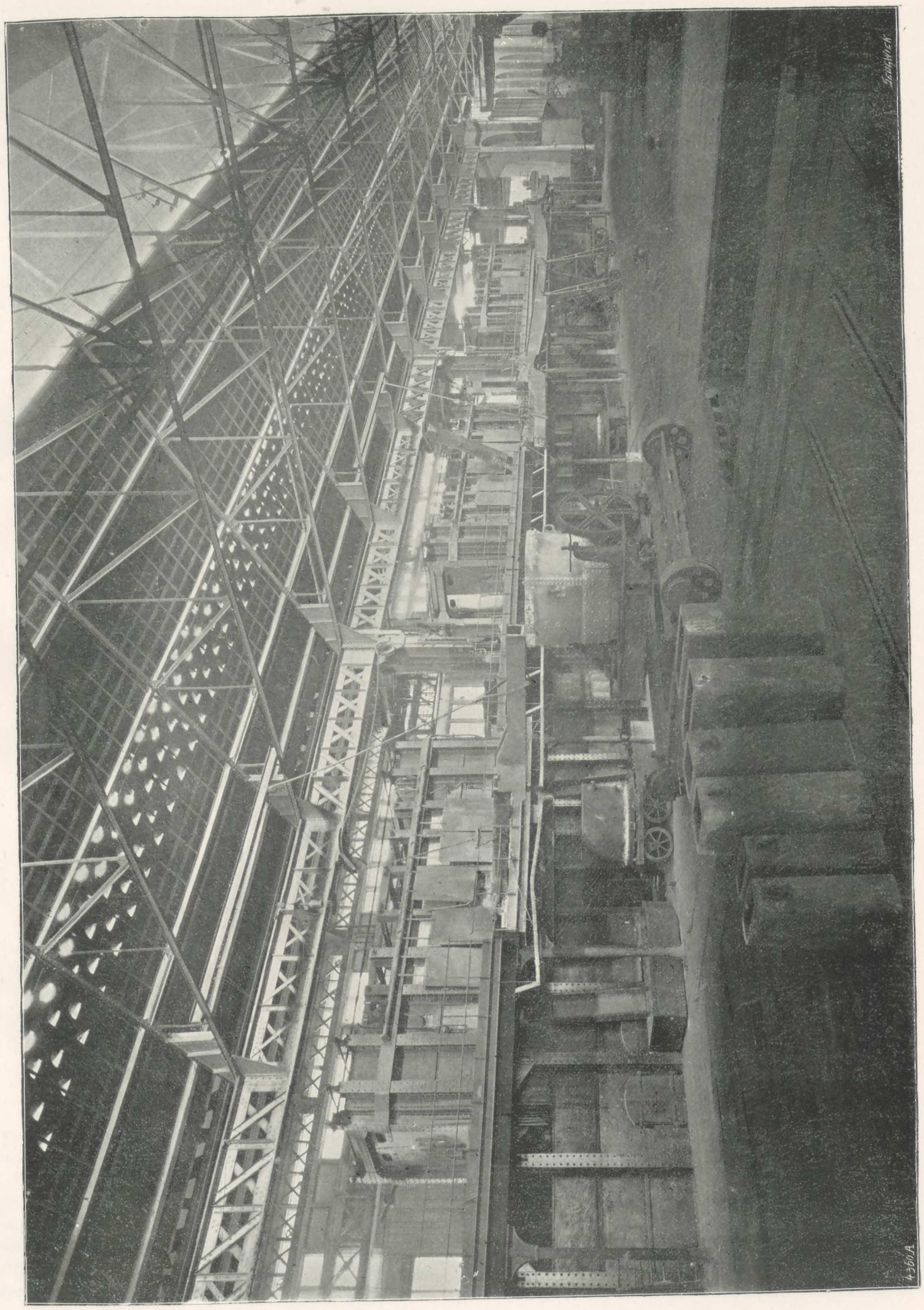


Fig. 94. Range of Siemens-Martin Furnaces.

pressed steel are almost too well known to require enumeration; among them are included total elimination of gases and consequent absence of blow holes; the possibility of manufacturing round ingots, which cannot be obtained sound, if cast in the ordinary way in ingot moulds; this is a great advantage for forging gun tubes and shafts. There is a greater homogeneity of the various parts of the accompanying Table, which contains the chemical analyses made of it; the results show clearly the great homogeneity of the steel.

The French Navy, after various comparative trials made with pieces taken from ordinary ingots and from compressed ingots, have authorised the use of the latter for the manufacture of guns and marine forgings. Since

TABLE OF ANALYSES OF THE FIRST FLUID COMPRESSED STEEL INGOT CAST BY MESSRS. SCHNEIDER AND CO.

The Proportions are given in One Hundred Thousandths.

Index No.	Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Index No.	Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
1	250	82	27	24	620	57	250	82	30	24	630
2	270	116	35	23	640	58	250	82	28	25	630
3	280	152	33	22	620	59	260	82	32	29	620
4	550	222	50	28	540	60	290	116	35	33	630
5	280	128	32	25	620	61	320	116	46	33	640
6	250	93	35	23	610	62	300	116	34	33	630
7	250	82	35	23	620	63	250	82	34	28	650
8	260	82	27	24	620	64	250	82	30	25	630
9	260	105	35	21	640	65	240	82	26	23	660
10	310	128	28	20	630	66	270	82	29	26	640
11	350	210	28	28	600	67	320	93	43	33	650
12	420	303	46	33	540	68	330	105	50	37	630
13	380	210	35	32	540	69	310	93	40	35	640
14	270	93	35	23	620	70	270	82	35	32	630
15	260	82	30	25	630	71	240	82	28	25	640
16	260	82	35	25	620	73	350	93	48	42	650
17	250	116	26	20	630	76	340	116	46	41	650
18	370	128	66	39	560	78	270	82	35	32	630
19	350	233	46	33	600	79	240	82	28	26	630
20	360	128	55	33	600	81	290	93	38	33	620
21	260	105	30	24	630	82	270	82	34	31	630
22	260	82	32	24	640	83	240	82	26	28	630
23	260	82	28	23	630	84	300	105	45	33	640
24	270	93	26	23	630	85	270	82	28	32	620
25	310	93	42	26	630	86	240	82	27	32	630
26	320	163	46	33	630	87	270	93	40	33	620
27	310	93	36	26	640	88	260	82	34	32	620
28	260	105	35	25	630	89	240	82	30	32	640
29	250	82	32	18	630	90	260	82	34	37	630
30	270	82	26	23	640	91	270	82	30	32	640
31	270	116	28	20	640	92	240	82	28	32	640
32	280	116	27	30	640	93	250	82	35	39	610
33	280	163	46	26	640	94	270	82	30	32	620
34	290	105	35	26	650	95	240	82	33	30	620
35	260	105	30	20	640	96	260	82	35	28	630
36	260	82	30	20	650	97	240	70	30	32	630
37	260	82	34	21	640	98	240	82	35	32	640
38	250	116	26	25	640	99	240	82	28	25	630
39	280	105	33	26	620	100	240	82	28	28	650
40	280	128	46	26	640	101	270	82	35	26	640
41	280	116	35	26	650	102	250	82	34	29	650
42	250	105	32	25	640	103	240	105	32	23	620
43	250	82	30	25	620	104	230	116	20	23	640
44	250	82	34	20	640	105	230	93	26	25	650
45	250	82	26	24	640	106	250	82	30	28	640
46	280	93	35	26	650	107	250	93	25	23	640
47	300	105	46	26	650	108	220	93	24	20	650
48	280	93	29	26	640	109	230	105	22	25	630
49	250	82	26	25	640	110	230	105	22	25	630
50	250	87	29	25	630	111	250	93	21	25	640
51	260	82	35	25	640	112	250	93	19	25	630
52	260	82	30	26	630	113	240	93	22	25	640
53	300	93	35	32	620	114	240	93	23	25	640
54	280	93	46	29	630	115	240	93	23	25	640
55	280	93	30	31	640	116	250	93	25	25	630
56	260	82	30	31	630						

the ingot, and less liquidation in the head, owing to the quicker and more uniform solidification of the whole mass.

Fig. 95 shows the first compressed steel ingot manufactured by Messrs. Schneider and Co. at Creusot, for testing the plant. The size of the central pipe at the head of ingot is very much reduced in actual manufacture by increasing the pressure. Fig. 96 is a set of diagrams referring to this ingot, particulars of which are given in

May 13th, 1896, when the press was first set to work, there have been cast 144 ingots for the manufacture of guns, shafts, and various forgings, weighing in all 4,742 tons. Messrs. Schneider and Co. have supplied a great many compressed ingots to various manufacturers who do not cast their own steel. We may add here that the Creusot Works are the only ones in France where this process has been applied to the treatment of steel; though

it necessitates a very important and costly plant, the results obtained repay the outlay and trouble involved.

Uses of Siemens-Martin Steel.—Until 1880 Messrs. Schneider and Co. manufactured only acid steel by the scrap process, with material obtained from pure pig iron made in the Creusot blast-furnaces, with Mokta, Bilbao or Allevard ore. To arrive at a greater degree of purity they tried the same material in a basic hearth, in a small experimental Siemens-Martin furnace, during the months of November and December, 1879. It was found from these experiments that they could obtain steel practically free from sulphur and phosphorus, and of a milder quality than the softest steel made by the acid process. On January 20, 1880, one of the 20-ton furnaces was transformed and fitted with a dolomite hearth; it produced steel equal in quality and purity to the best Swedish iron. Other furnaces were transformed later on, and gave extra mild steel, preferable to that obtained by the acid process, for the construction of marine boiler furnaces.

The actual plant consists of three furnaces with a basic hearth, and one with an acid hearth; the latter is used exclusively for the manufacture of steel for guns. For large guns that require an ingot heavier than the charge of this furnace, those adjacent are temporarily modified for the acid process. However, by the present methods of gun construction, such heavy ingots for this purpose are rarely necessary. Ingots for making shells, for locomotive tyres, for springs, &c., are made from acid steel, while basic steel is cast for armour-plates, engine shafts, plates, sections, various tyres &c.

Messrs. Schneider and Co., only manufacture in their Siemens-Martin plant, steel of strengths from 35 to 100 kilogrammes per square millimetre (22.22 to 63.50 tons per square inch). The lower-grade steel, such as that for rails, joists, &c., is made in the Bessemer plant. There are, as a rule, two heats per twenty-four hours. With certain grades, three heats can be obtained. For gun steel, however, the heat lasts about fourteen to sixteen hours. The shape of ingot moulds varies according to the purpose for which the ingots are intended. Thus, ingots for axles and tyres are cast in octagonal moulds; rolled plates and bars are made from ingots cast in square or rectangular moulds.

The scrap process is still employed. The material used consists of superior quality hematite pig, puddled iron obtained with this same pig iron, and steel scrap. For the manufacture of gun steel, Swedish and South of France (Landes) charcoal pig is used, together with hematite pig, the charge being entirely made up with puddled iron.

The total output of the Siemens-Martin plant is now

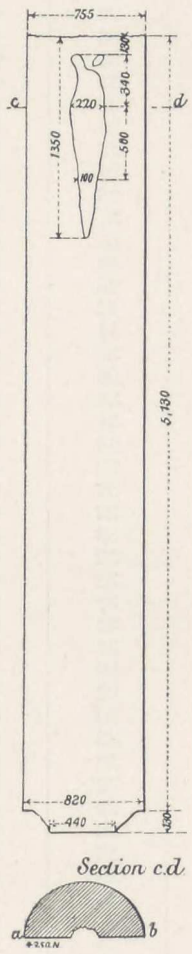


Fig. 95. First Compressed-Steel Ingot Made by Messrs. Schneider and Co.

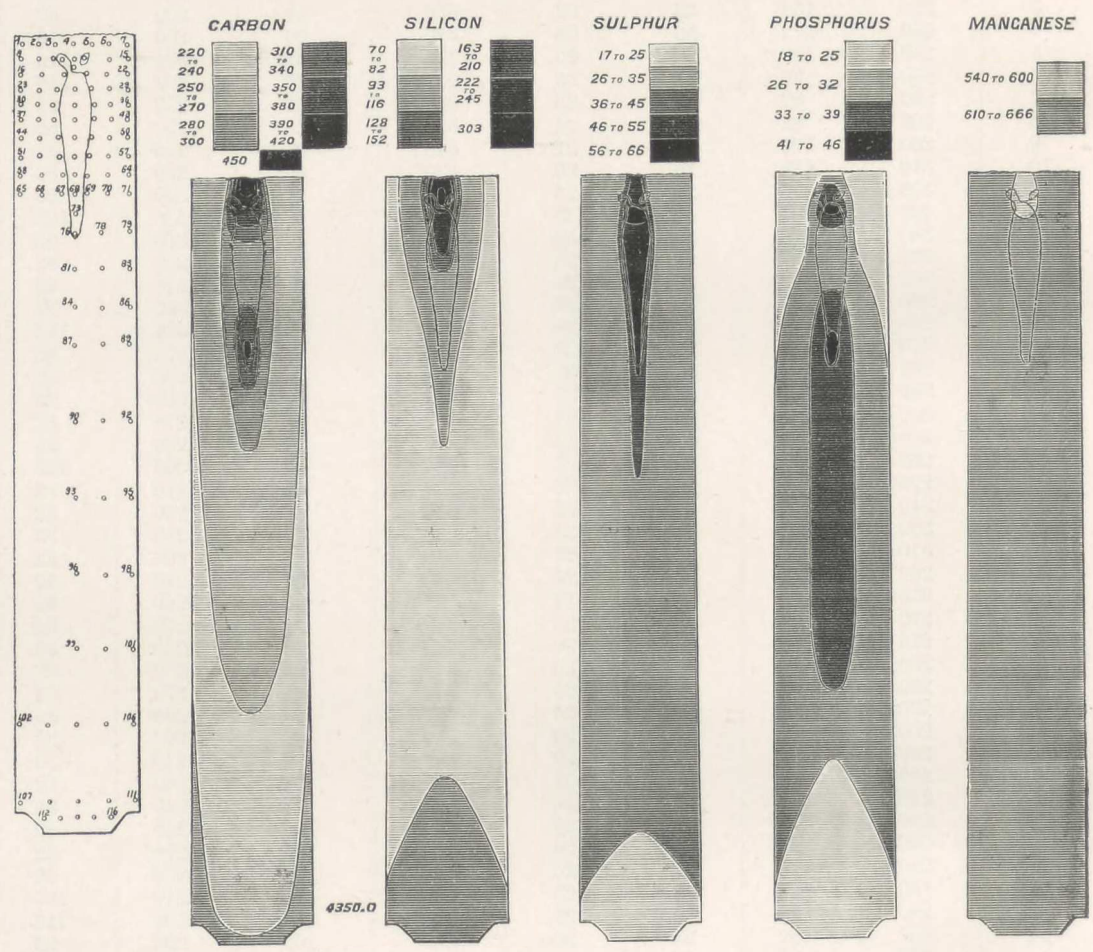


Fig. 96. Diagrams Showing Results of Analyses of the First Compressed-Steel Ingot Made by Messrs. Schneider and Co.

THE STEEL WORKS.

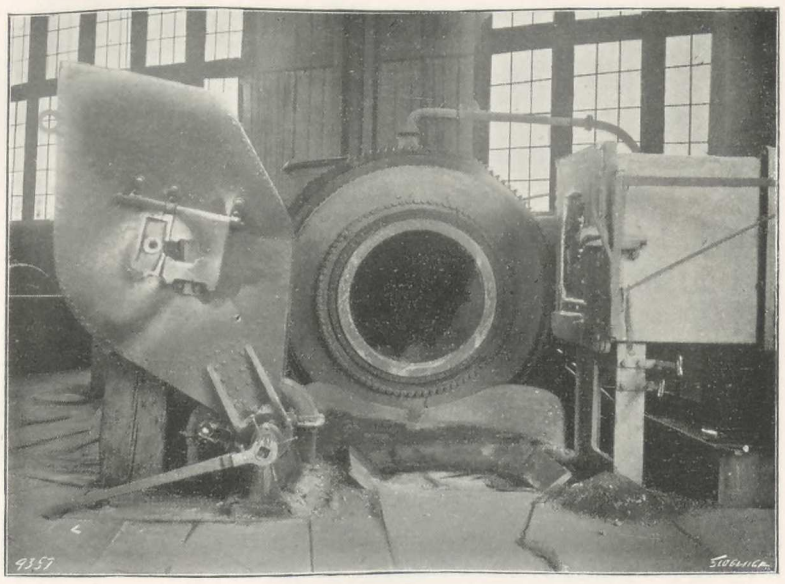


Fig. 97.



Fig. 98.

Rotary Puddling Furnace.

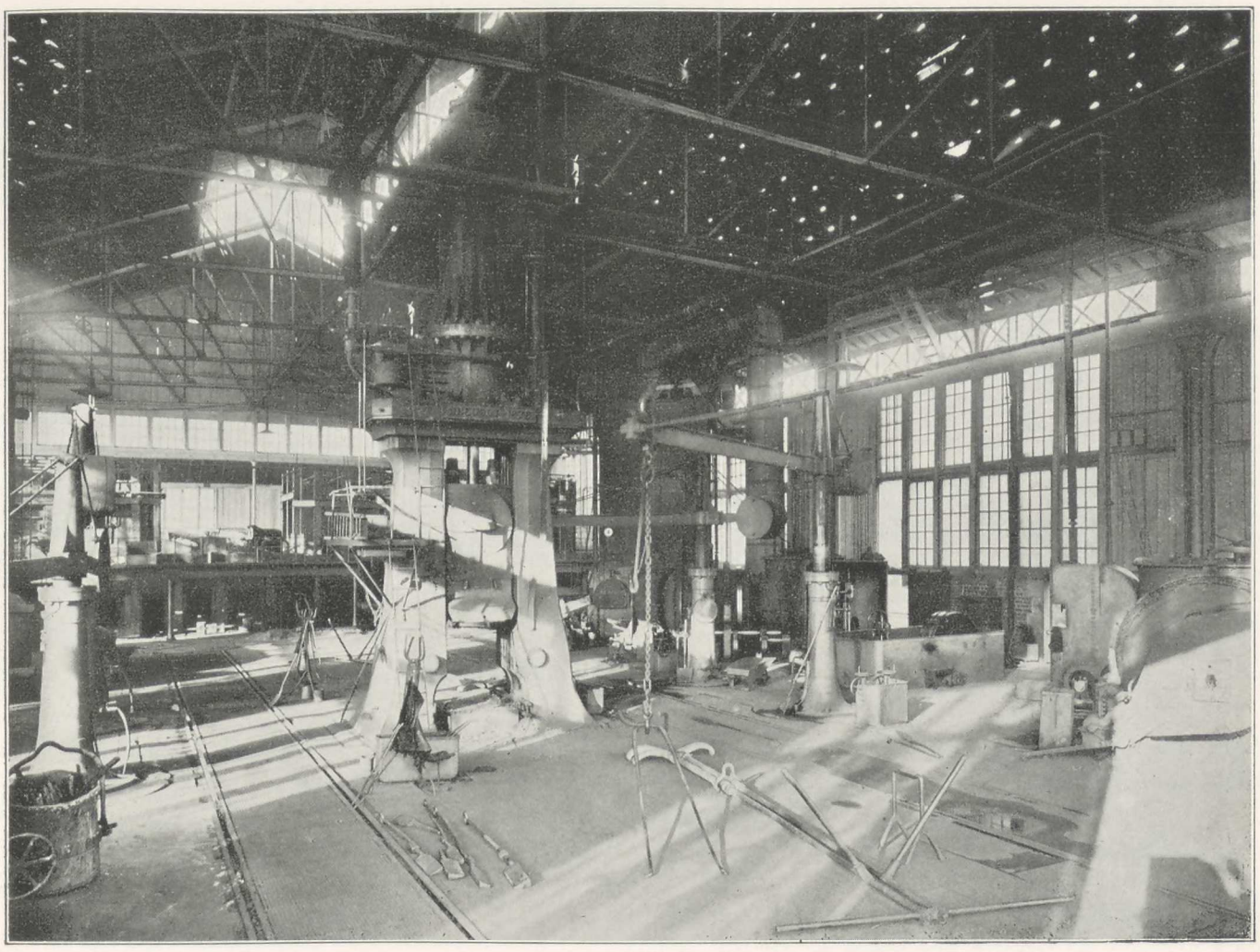
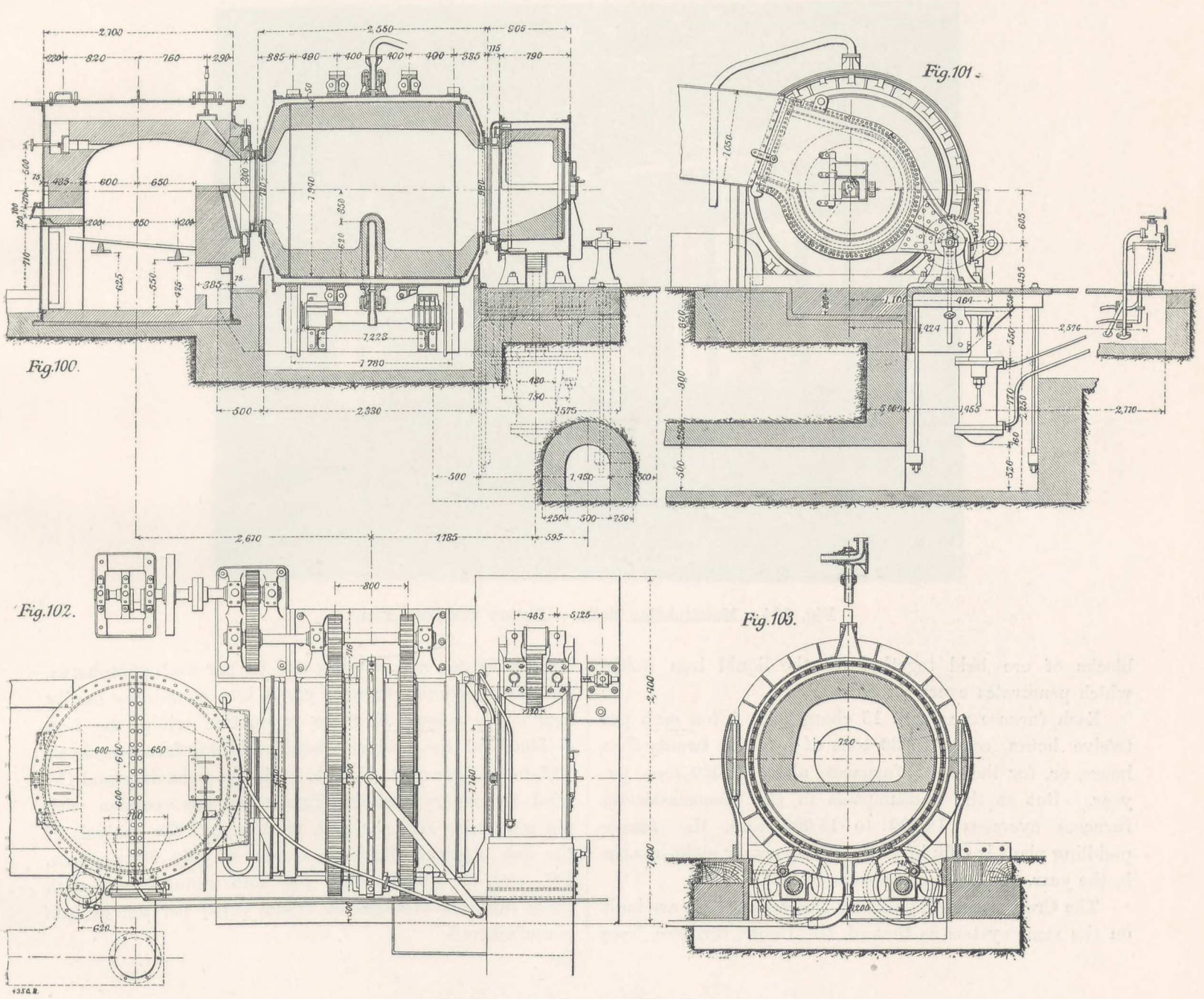


Fig. 99. Rotary Puddling Furnace Shop.

60,000 tons annually; this output will, it is estimated, reach 80,000 tons in 1900.

Rotary Puddling Furnaces.—These are contained in an annex of the Siemens-Martin plant (see Figs. 97 to 99, Plate XXIII., and Figs. 100 to 103). The building is 51 metres (167 ft.) long; 30 metres (98 ft.) wide; and 9 metres (29 ft.) high to the springing of roof. The plant consists of:



Details of Rotary Puddling Furnace.

One 30-ton Siemens furnace for melting down high-class hematite pig, which is charged in its molten state, into the rotary puddling furnaces.

One 8-ton Siemens furnace, solely used for melting iron oxides used with blocks of pure ore for the inside lining of the rotary puddling furnaces.

Three rotary puddling furnaces.

One 18-ton steam hammer for shingling the iron balls.

One 8-ton steam hammer used specially for breaking the iron blooms when cold, in order to classify them according to their quality.

One range of eight gas generators for the Siemens furnaces.

Each rotary puddling furnace is fitted with a multi-tubular boiler, heated by the waste gases (see Fig. 104).

The present plant was put down in 1892; it dates originally, however, from 1876. At that time there were only two rotary puddling furnaces placed near the original Siemens-Martin furnaces. Each rotary puddling furnace consists of three main parts:

1. The revolving chamber, worked by a motor.
2. The hearth.
3. The smokebox, which leads the waste gases to the boiler; this can be raised and lowered by means of a rack worked by hydraulic pressure.

The revolving chamber is fitted with a double iron

covering, cooled by a continuous stream of cold water. The inside is divided into two equal parts by a separator, which is also cooled by a stream of water. This separator divides the charge, which is worked into two parts, the charge being made into balls weighing each 10 cwt. The inside lining of the chamber consists of a layer of thin bricks, on which are placed in a red hot state, blocks of ore held together by the liquid iron oxide, which penetrates every joint.

Each furnace produces 15 charges of 1 ton each per twelve hours, equal to 30 tons of iron per twenty-four hours, or, for the three furnaces, about 25,000 tons per year. But as the consumption in the Siemens-Martin furnaces averages 12,000 to 15,000 tons, the rotary puddling plant is only in work during six or eight months in the year, and two furnaces are used at a time.

The Creusot rotary puddling furnaces, which are built on the same system as that of the Danks furnaces, have for their object the production of chemically pure iron, *i.e.*, iron containing no sulphur and no phosphorus, to be used instead of Swedish iron in the manufacture of steel for guns and armour-plates, for which purity of metal is necessary to a very high degree. The results obtained have always given complete satisfaction. The numerous analyses made every day show that with pig iron containing .04 per cent. sulphur and .06 per cent. phosphorus, the rotary puddling furnace yields iron containing hardly appreciable traces of these impurities, while the iron obtained in the ordinary hand-puddling furnaces shows .015 to .020 per cent. of both. Messrs. Schneider and Co. tried the rotary puddling furnace on one occasion with pig containing .815 per cent. phosphorus; the analysis of the iron obtained, showed a residue of only .082 per cent. The cost of transforming pig into refined iron with these furnaces averages 30 francs (24s.) per ton of iron manufactured.

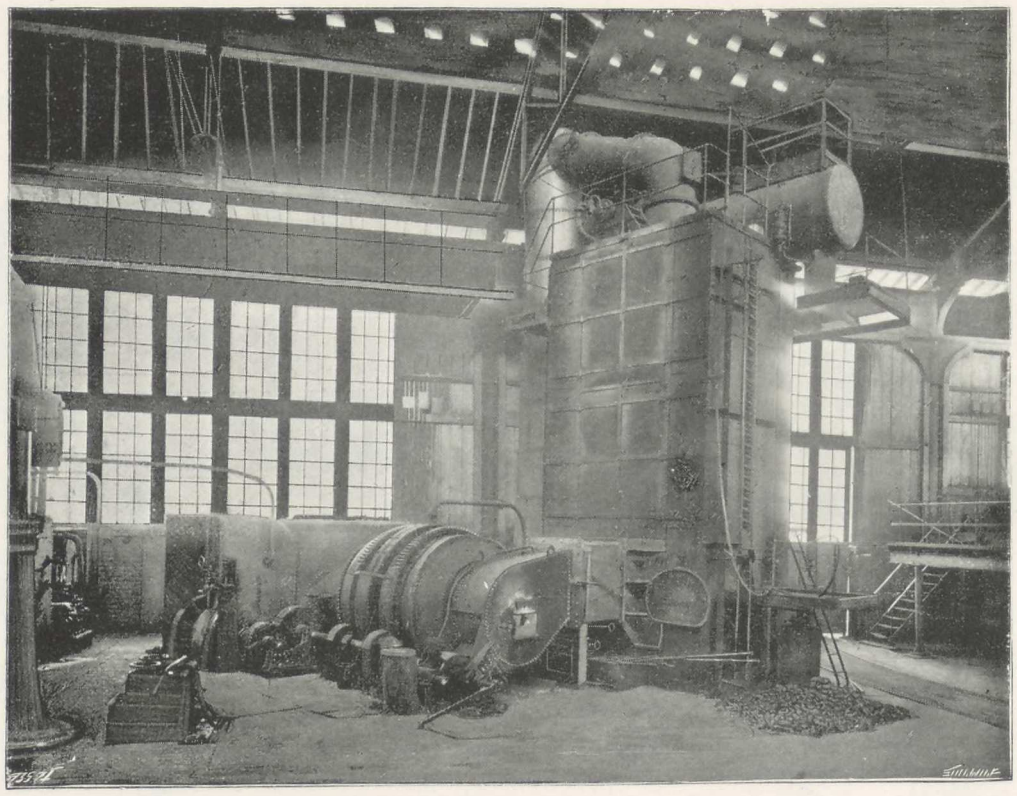


Fig. 104. Multitubular Boiler; Rotary Puddling Plant.

THE STEEL WORKS: 150-TON ELECTRIC TRAVELLING CRANE.

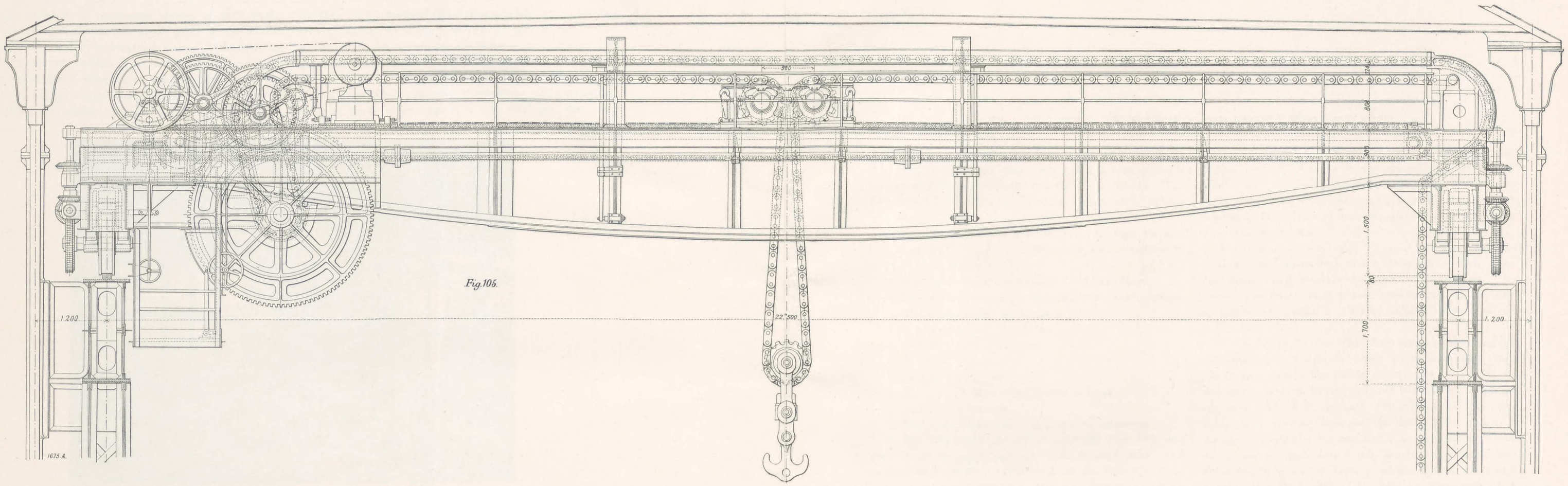


Fig.106.

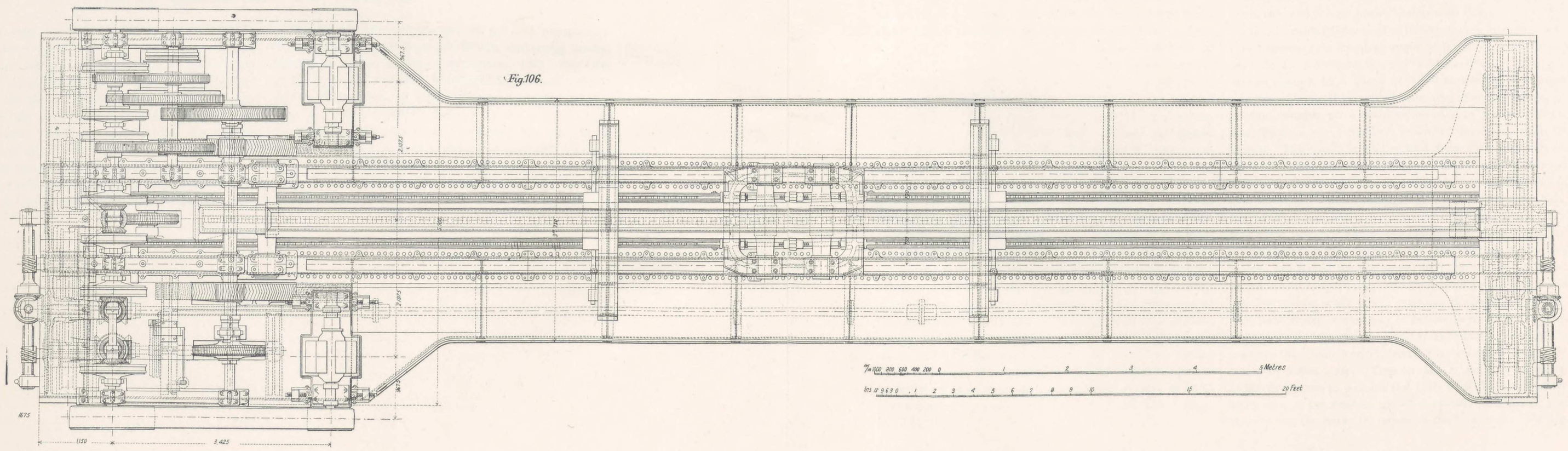


Fig.106.

XI.—150-TON ELECTRIC TRAVELLING CRANE.

FREQUENT reference has been made to the 150-ton electric travelling crane that forms so conspicuous a feature of Messrs. Schneider and Co.'s steel works. The following is a detailed and illustrated description of this very fine machine.

The 150-ton crane, which is illustrated by Figs. 105 and 106, Plate XXIV., and Figs. 107 to 110, was completed in 1893. It is is composed of:

1. Two girders, each 23.4 metres (76.75 ft.) long.
2. Two short cross-girders, supporting the main girders.
3. The wheels carrying the crane.
4. A truck carrying the lifting hook.
5. A three-speed lifting gear.
6. A lowering gear.
7. The traversing gear.
8. The gear for traversing the chain truck.
9. Two electric motors.
10. Two footbridges and a cabin for the attendant.

1. *The Main Girders.*—These are (see Figs. 105 and 106) of the box type, and are built of steel plates and angles. Each girder is constructed of the following component parts: Two webplates each 15 millimetres (.59 in.) thick, .800 metre (2.62 ft.) deep at the ends, and 1.700 metres (5.57 ft.) deep at the middle, the lower edges being parabolic. Both upper and lower flanges have a total thickness of 50 millimetres (1.97 in.), and are each built up of five 10 millimetre (.39 in.) plates. The angles between the flanges and webs are 100 millimetres by 100 millimetres by 15 millimetres (3.94 in. by 3.94 in. by .59 in.). The webplates are firmly braced together by internal stiffeners of steel plates and angles, which are spaced about 2 metres (6.56 ft.) apart, and insure the transverse rigidity of the girders. The upper flanges carry the slides on which the chain truck runs (see Fig. 110). The two girders are braced together at the ends by cast-iron stiffeners, in addition to the short cross-girders on which they rest. At one end of the crane there are two of these cast-iron cross-girders, of which one serves as an abutment for the chain used for traversing the chain truck, and the other is utilised similarly for the support of the lowering gear and the crane traversing gear. At the other end of the crane there is only one of these cast-iron cross-girders, which carries another chain-wheel for the car-traversing chain, and also has attached to it one end of the lifting chain. The two main girders are further braced together by stiffeners built up of plates and angles, arched so as to give room for the passage of the chain truck below them (see Fig. 109).

2. *The End Supporting Girders.* — The two main girders rest on, and are firmly connected by means of gussets to, two stout cross-girders (Fig. 107) built up of plates and angles, which thoroughly brace the main girders together. These cross-girders are carried by the wheels on which the crane runs.

3. *The Wheels Carrying the Crane.*—The crane rests on eight wheels, four at each end. These wheels have cast-steel centres and wrought-steel tyres of U-section. To insure a fair distribution of load between the wheels, they are connected together in pairs by balance levers as shown in Fig. 108.

4. *The Chain Truck.*—The chain truck is of cast steel, and supports the shafts on which are mounted two chain wheels, over which the lifting chain passes. It rests on four cast-iron shoes, having strips of anti-friction metal let into them, and which are each .600 metre (1.97 ft.) long. These shoes have oil cups cast in them, which insure a thorough lubrication of the slides at any point. These slides are of cast iron, and are covered for their whole length by cotton belting, which rests on them and protects them from dust. The belts are kept taut by a compensating device, and pass over guide pulleys on the chain car, which thus passes underneath them.

5. *The Lifting Gear.*—The lifting gear is arranged with three speeds—viz., a slow speed of 0.930 metre (3.05 ft.) per minute; a medium speed of 2.510 metres (8.23 ft.) per minute; and a high speed of 3.610 metres (11.84 ft.) per minute. These three speeds are obtained by means of friction clutches on a countershaft driven by the motors. The clutches are controlled by forked levers operated by screws. The power is transmitted from these clutches by means of gearing to the first motion shaft (see Fig. 106) of the crab On this first motion shaft is a gun-metal pinion, gearing with a wheel running loose on the main crab shaft, but which it can drive by means of a friction clutch. On this shaft are two gun-metal pinions .390 metre (15.3 in.) in diameter, driving two wheels 3.01 metres (9.875 ft.), which are keyed on the same shaft as the chain wheel which operates the lifting chain. A band brake is fitted to the first motion shaft, which supports the load when lifted. This band brake is normally in action, being provided with a counterweight to this end, and is sufficiently powerful to prevent the crane working until the weight is raised by means of a foot lever. Thus to raise a load it is necessary in the first place to connect the crab with the motor shaft by means of the friction clutches already mentioned, and then to free the brake by means of the foot lever. To stop

lifting, the operation is reversed. As will be seen from the illustrations, helical teeth have been used nearly everywhere. The larger wheels have cast-steel centres, the teeth being of cast iron.

The lifting hook is fixed on a swivel frame, which is hung from the pin on which the lower chain wheel (Fig. 105) is fixed. Great care was taken in the design and manufacture of this detail. The total lift is 13½ metres (44.34 ft.). The lifting chain is constructed of two rows of links of steel plate 12.5 millimetres (½ in.) thick, there being four of these links on each side of the pins. Great care has also been taken to insure the perfect flexibility of the chain, as the wheels over which it runs are small in diameter, and were the chain at all stiff, the stresses on it might be seriously increased. One end of the chain is fixed to one of the cast-iron braces at the end of the girder, and its path will be best seen from Fig. 105. After passing over the hook wheel and back over the car wheel, it is led round the driving wheel on the crab, and then through a guide back to the other end of the crane, where, after passing through a second curved guide, it hangs down freely. The guide supporting the chain is held up by movable supports, which are displaced by the chain car as it passes by them, and afterwards return automatically to their places. The chain weighs 206 kilogrammes per metre run (138 lb. per foot), and as its total length is 57.34 metres (188.07 ft.), its total weight is 11,800 kilogrammes (11.61 tons).

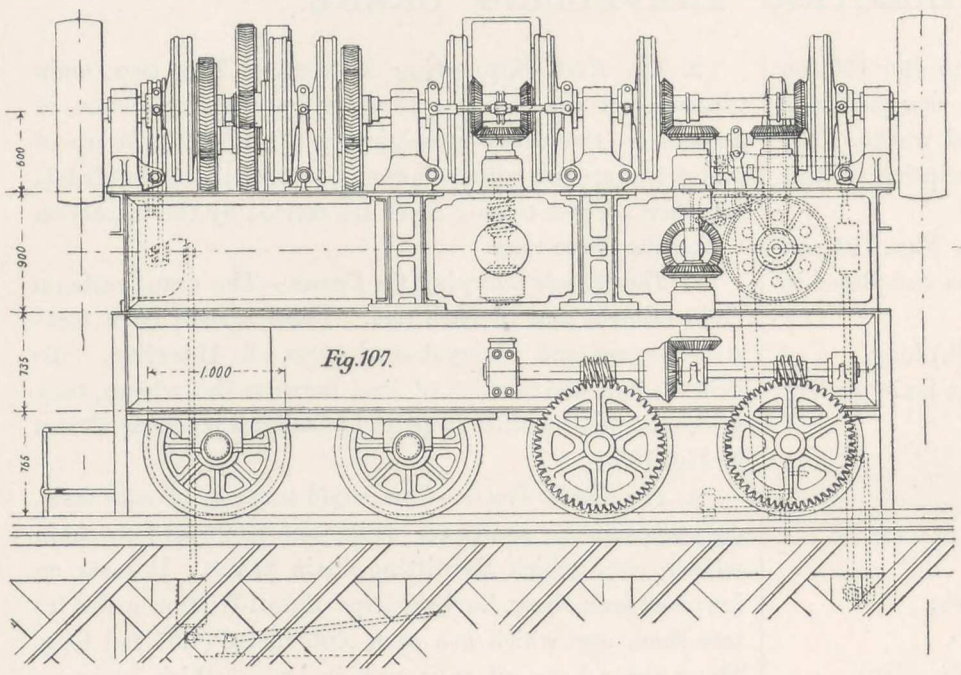


Fig.107.

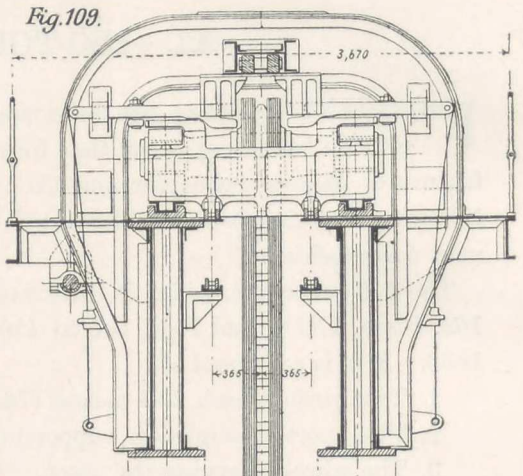


Fig.109.

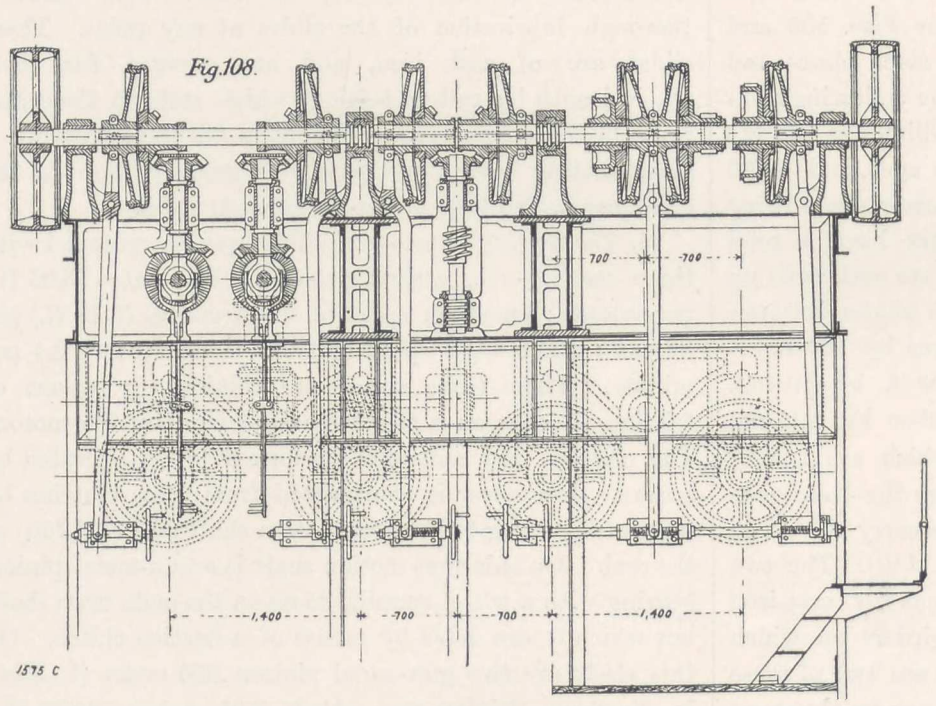


Fig.108.

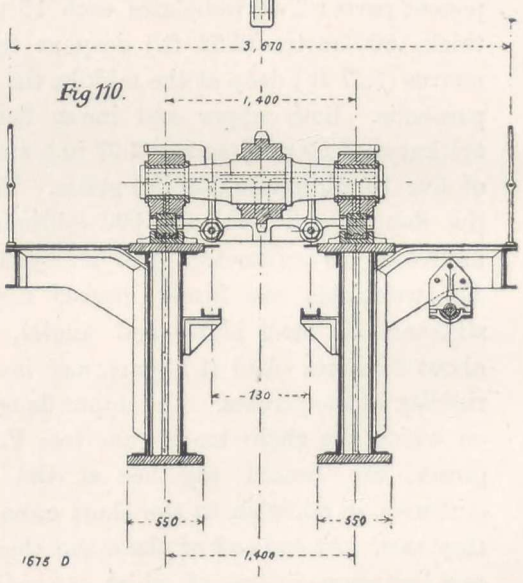


Fig.110.

Details of 150-Ton Electric Travelling Crane.

6. *Lowering Gear.*—To lower the load a special gear has been provided, worked by a friction clutch from the

main countershaft. This friction clutch carries a bevel wheel of phosphor-bronze, gearing with a similar wheel keyed to a vertical shaft (see Fig. 108), at the other end of which is a second bevel wheel gearing with a couple of similar wheels running loose on a horizontal shaft. Either of these wheels, however, can be temporarily keyed to this shaft by a clutch, and the arrangement accordingly acts as a reversing gear. By means of this gear, light loads can be lifted at a high speed, as the horizontal shaft above mentioned, drives, by a worm, a wheel running loose on the intermediate shaft of the crab, but which can be keyed to it by another clutch engaging at will either with this wheel or with the wheel controlling the main lifting gear. In order to lower a load, the clutches are set so that the wormwheel turns in the proper direction, and then this wheel is keyed to its shaft by its clutch, and the wheel driving the main gear is released. The worm shaft, we should add, is also provided with a band break and counterweight, which must be released before it can turn.

7. *The Crane Traversing Gear.*—The traversing gear is also controlled by a friction clutch on the main countershaft. This clutch drives a vertical shaft by bevel gearing, and at the bottom of this shaft is a bevel reversing gear of the usual type, by means of which a long horizontal shaft extending from end to end of the crane is driven. On this shaft are bevel wheels gearing with others mounted on vertical shafts, by means of which motion is finally communicated to the worm shaft which drives the wormwheels keyed to the wheels carrying the crane, as shown in Fig. 107. The speed of traverse is 10.75 metres (35.26 ft.) per minute.

8. *The Chain Car Traversing Gear.*—For this also, a friction clutch on the main countershaft is used for driving this gear, the arrangement for reversing being similar in principle to that on the main traversing gear. In this way motion in one direction or another is transmitted to a vertical shaft carrying a worm at its end. This worm gears with a wormwheel mounted on a horizontal shaft, to which also is keyed a pair of chain wheels over which pass the chains, the ends of which are attached to the chain truck, as shown in Fig. 105. Throughout their lengths these chains are supported by guides, those for the upper portion resting on the upper flange of the main girders, whilst special channel-iron guides are provided for the lower ends. The speed of traverse in this case is 8 metres (25.84 ft.) per minute.

9. *The Motors.*—The two motors are of the Ganz continuous current type, and were built by Messrs. Schneider and Co., who are sole licensees for the system in France and its colonies. Each motor is designed to take 45,000 watts. Two uninsulated cables, supported on porcelain wheels, are used to convey the current to the crane. Carbon brushes are used on the crane for picking up the current from these cables. These brushes are hollow, the cable passing through them, and they raise it from its supporting pulleys as the crane passes over them. Belts are used to connect the motors with the clutch shaft. When the load to be lifted does not exceed 75 to 80 tons, only one of the motors is used. All the fittings required for the working of the motors are grouped together in the attendant's cabin. Amongst these may be noted a sulphate of copper rheostat, which enables the motors to be started without shock. To do this the main switch is closed, and the electrodes of the rheostat brought gradually into contact. A second metallic rheostat is also provided, which enables the strength of the magnetic field and the speed of the motors to be varied, beside which the work done by the two motors can be equalised by its means. A special safety device is also provided in case of the attendant allowing the chain to drop too far. This consists of a switch on the armature circuit of the motors, which is opened when the chain passes a certain point. As the field magnets still remain excited, the load is brought up almost immediately by the resistance developed to the motion of the armatures. The voltage at which the motors are designed to work is 220 volts. The dynamo providing the current has an output of 100,000 watts, and is a four-pole Ganz machine. Both dynamos and motors are compound wound.

10. *The Foot Bridges and Cabin for the Crane Attendant.*—Footways are provided on both sides of the crane, and run from end to end, giving access to all bearings and other parts requiring attention. They are supported by brackets fixed to the main girders. The attendant's cabin is built of iron plates and angles, but has a wooden floor. It is fixed below the main girders of the crane, and from it the attendant can easily follow all motions of the hook. All the handwheels, foot levers, &c., are grouped together as close as possible, so as to be within easy reach of the attendant, thus enabling him to do his work most efficiently. The total weight of the crane is 200 tons.

XII.—THE STEEL FOUNDRY.

General Arrangement of Foundry.—Messrs. Schneider and Co. commenced the production of steel castings in 1885; at first only Bessemer steel was used for this purpose, but afterwards Siemens-Martin steel was substituted.

In 1887, a plant for making steel castings was put down on the site which had been occupied by the second and third groups of Bessemer plant. The steel was melted in a 4-ton petroleum furnace; a type adopted because the heat could be regulated in accordance with the progress of the work. When, however, the use of steel castings became more general, Messrs. Schneider and Co. constructed a Siemens-Martin furnace of the usual form, but of small dimensions; it was found that a considerable economy in working was secured by this, as compared with the petroleum furnace. This plant, though quite of a provisional character, produced much important work, such as stern-shaft brackets, stern tubes, stern, and stem-posts, castings, traversing platforms for gun carriages, &c. In casting these large pieces, the steel is taken from the large Siemens-Martin furnaces already described.

This temporary plant became, as might have been expected, entirely inadequate to meet the increasing demands for steel castings, and Messrs. Schneider and Co. decided in 1891 to create a special department for this industry on a large scale. Accordingly they erected for this purpose a building 112 metres (367 ft.) long by 37 metres (121 ft.) wide, a general view of which is shown in Fig. 111, Plate XXV., whilst Fig. 112 is an interior view.



Fig. 112. Steel Foundry, Interior of Main Building.

Two 10-ton steel furnaces are erected at one end of the building; they are 1.500 metres (4 ft. 11 in.) above the level of the works.

The necessary gas is produced by a range of eight



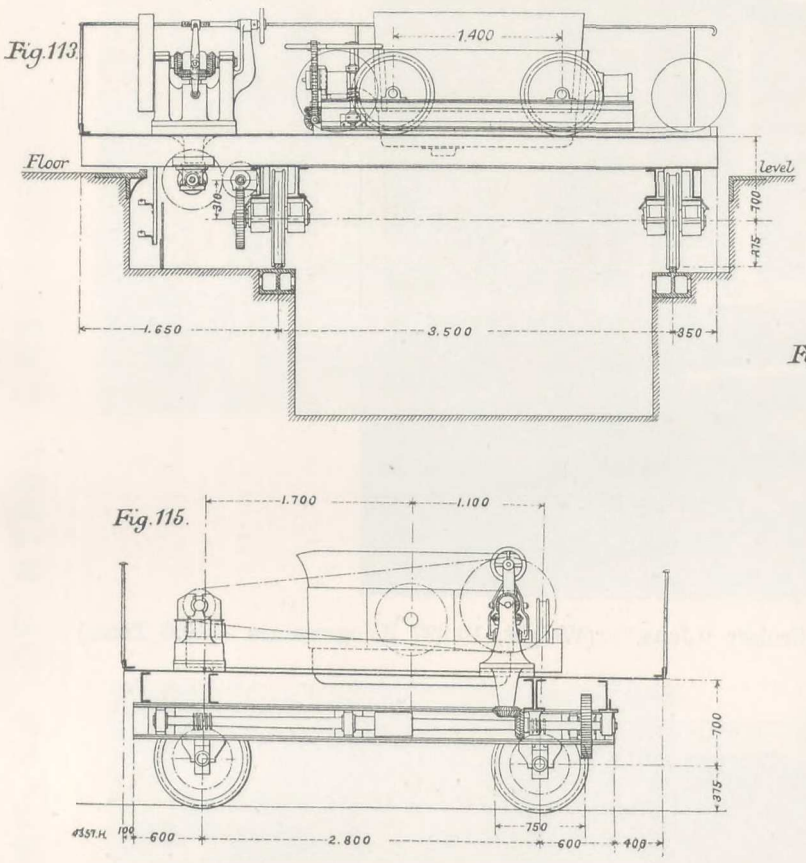
Fig. 111. Exterior of Steel Foundry.

generators, placed in a pit at a short distance in the rear of the furnaces. They are not provided with a syphon, the gas going direct to an underground main, in which the furnace gas valves are placed.

As four heats are made every day, only part of the steel is used for castings, the remainder being poured into ingot moulds in a pit in front of the furnaces (see Fig. 85, Plate XX.). This pit is 3 metres (10 ft.) wide by 32 metres (105 ft.) long, and is served by a double-sided truck carrying the ladle, and moved by an electric motor mounted on the truck itself (see Figs. 113 to 116). The working of this motor is highly satisfactory, as it has never given any trouble.

the steel being taken from the 35-ton furnaces. When it is not convenient to put large-sized moulds—such as those for turret face plates—in the Siemens-Martin principal casting pit, the metal taken from the large furnaces is carried on trucks to the steel foundry.

	m.	ft. in.
Distance from centre to centre of rails forming overhead track	16	52 6
Height of rails above foundry floor level	7	23 0
Speed of travel (longitudinally) per minute	26.2	86 0
Speed of travel (transversely) per minute	14.4	47 3
Lifting speeds of loads	3.15 and 1.28 per minute.	10 4 and 4 2½ per minute.



Electric Motor Truck and Ladle for Steel Foundry.

The comparatively small size of the furnaces renders them quite suitable for the manufacture of special steel, such as nickel steel, the use of which is rapidly increasing. The ingots cast in this shop are used for the rolling of plates, sheets, and special sections, as well as for the manufacture of tyres.

The central bay of the building, which is 20 metres (65 ft.) wide, is utilised for the manufacture of large moulds; it is served by three overhead travelling cranes, two of 15 tons and one of 30 tons.

The moulds are filled with a ladle carried by the cranes. When the weight of the casting to be made, is more than 20 tons, the metal is poured in the large ingot-casting pit,

The above are some dimensions of the cranes in this shop.

On the left of the foundry are four drying-rooms for the moulds: these rooms are of the following dimensions:

	m.	ft. in.
Length	7.5	24 7
Width of three	4.5	14 9
,, the fourth	5.5	18 1
Height	3.5	11 6

On the same side as these, and near the stoves, is a small yard, served by a 6-ton electrically-driven travelling crane, where the ladles are lined and heated previous to casting operations. Beyond is the loam and sand preparing

shop, in which are two sand mills and a screening machine worked by a dynamo. The right-hand bay of the foundry is used for moulding small and averaged-sized pieces. Here the lifting work is done by three 6-ton electric travelling cranes. The end of the foundry opposite to that occupied by the furnace, is set apart for the storage of the pieces, while the neighbouring shops are provided with machine tools for cutting off runners, and roughing and finishing, &c., a certain number of the castings. All these tools are driven electrically. In fact, no steam or gas is used in the steel foundry, the lighting and transmission of power being provided from an electrical station.



Fig. 125. Cast-Steel Stern-Post for the Armoured Cruiser "Jena." (Weight, 10,897 Kilogrammes = 10.6 Tons.)

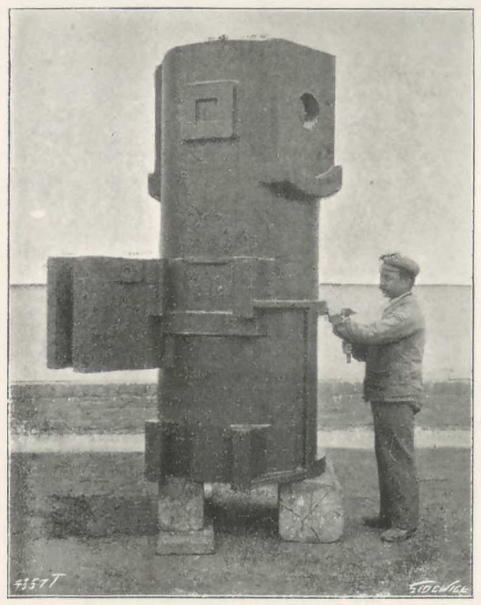


Fig. 126. 24 Centimetre (9,449 in.) Gun Housing.

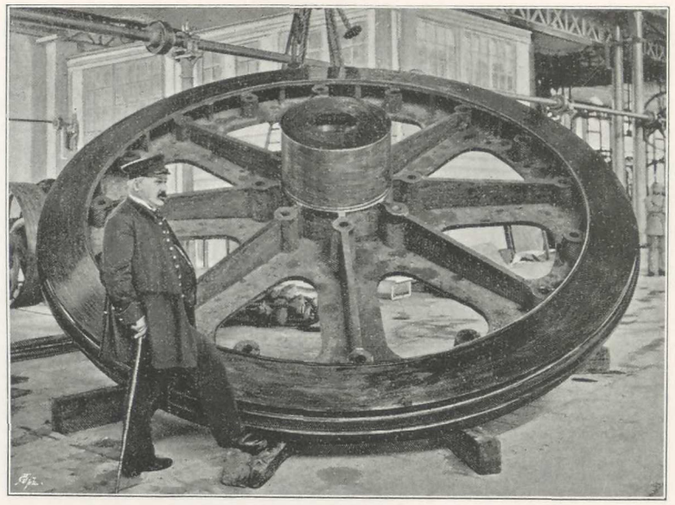


Fig. 117. Bolster for 12 in. Gun.

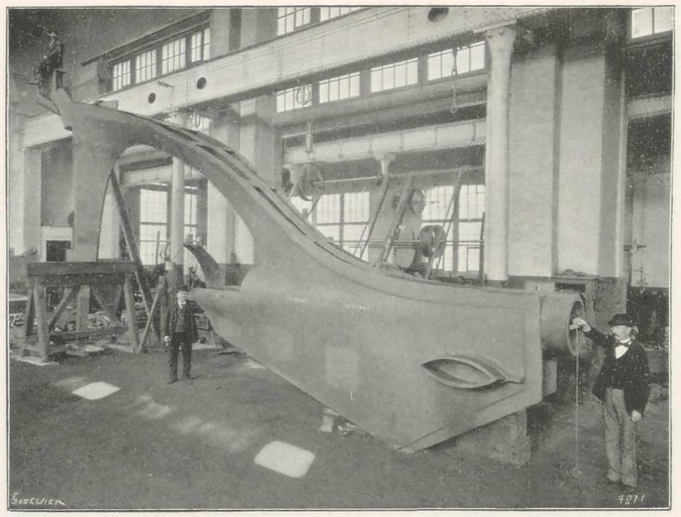


Fig. 118. Sternpost for the Armoured Cruiser "Gueydon" (Weight, 20 Tons).

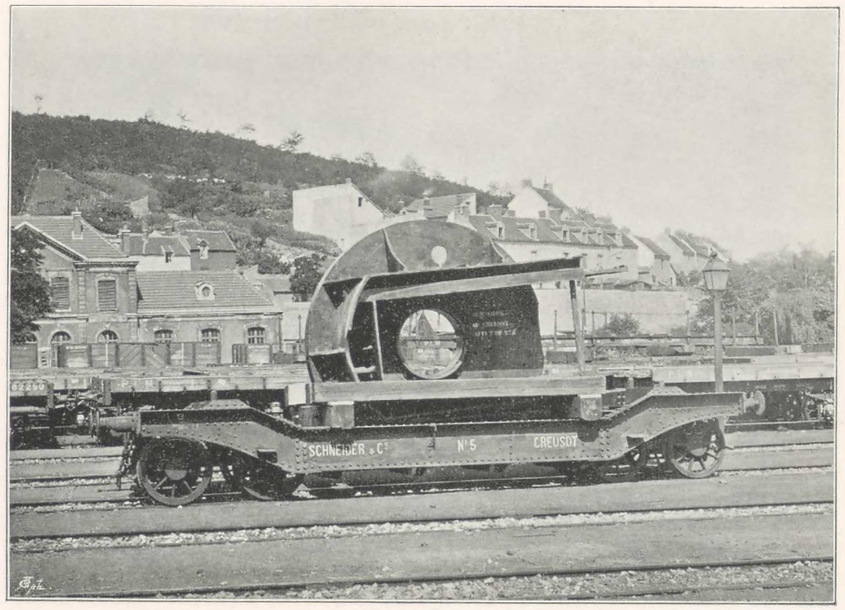


Fig. 119. Slide for 27 cm. Gun Mounting.

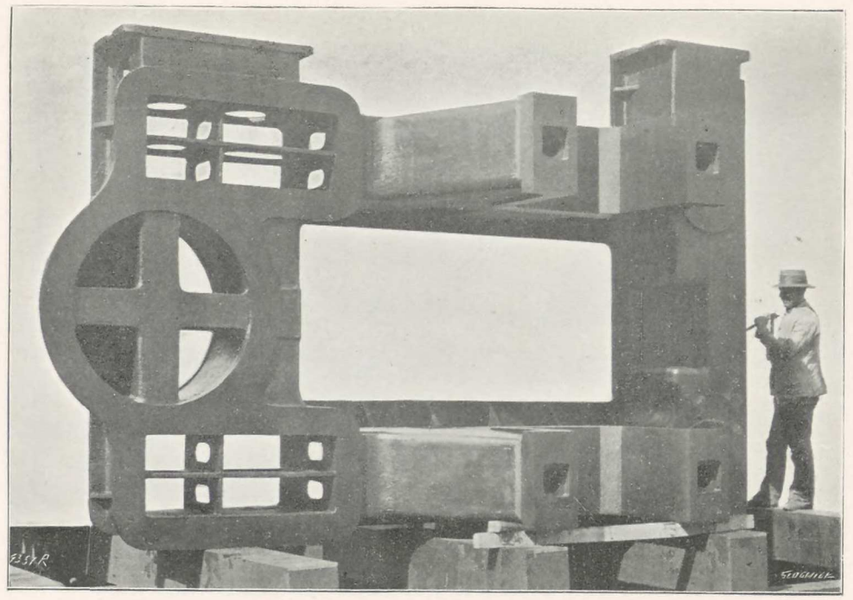


Fig. 120. Foundation for Marine Engine.

EXAMPLES OF STEEL CASTINGS.

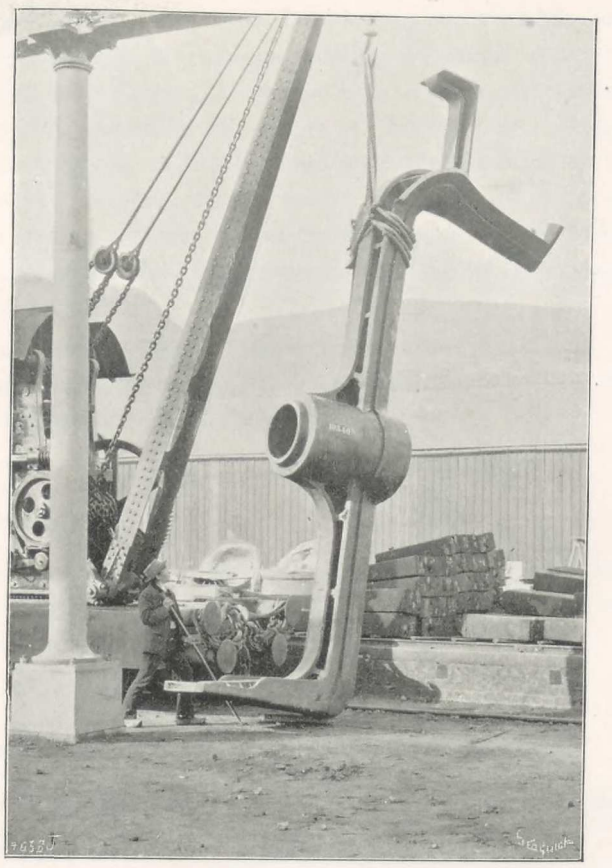


Fig. 121. Sternpost for the French Navy.

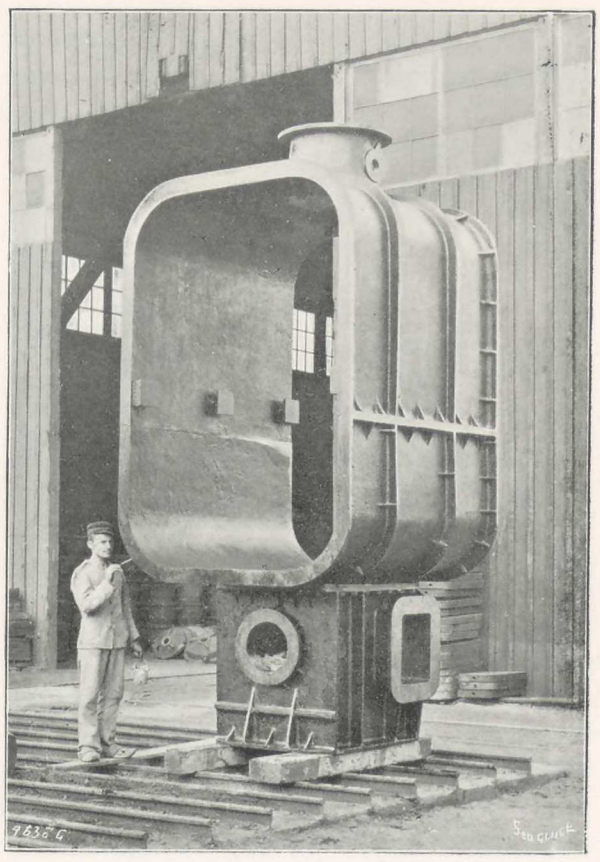


Fig. 122. Condenser for a French Liner.

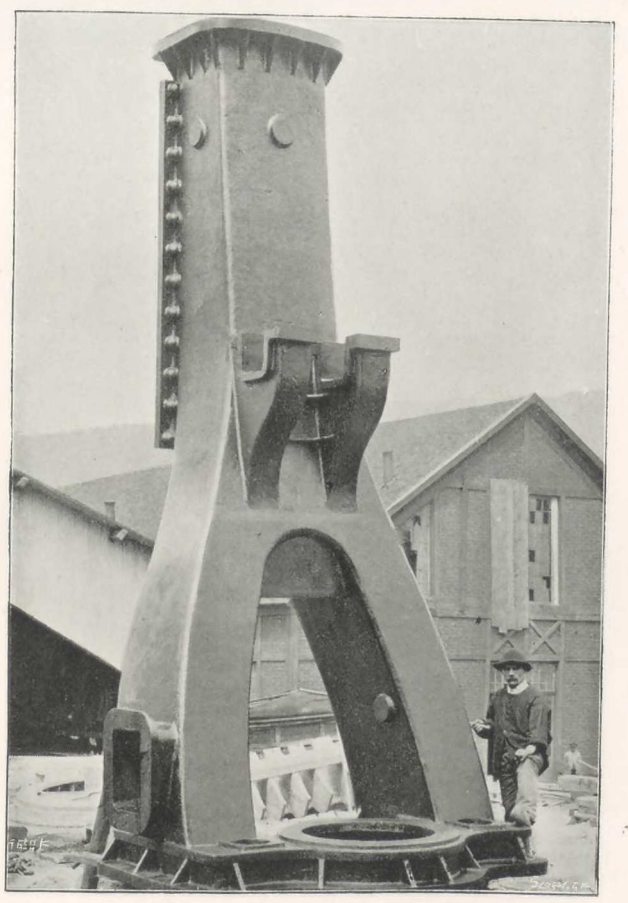


Fig. 123. Framing for Marine Engines.

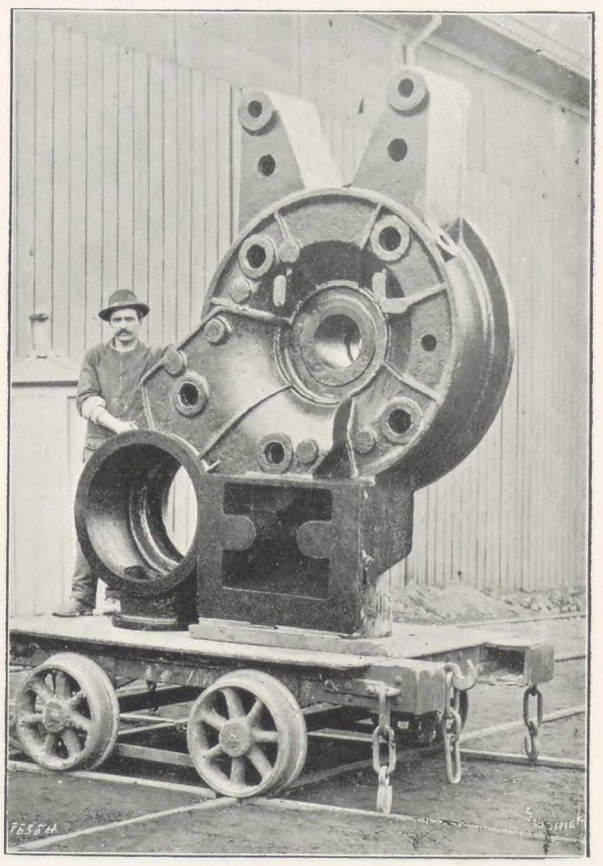


Fig. 124. Cylinder Cover for a French Battleship.

Pneumatic hammers have only recently been used in this department; they are found very serviceable for chipping the ribs on castings, cutting off small runners, surfacing, &c. Three coal stoves, with a movable hearth, are used for annealing the whole of the castings. Great attention is given to this treatment of the castings, as it modifies the texture of the metal, and largely reduces internal strains. When the annealing operation has been carefully carried out, the physical qualities of the steel are much improved.

Composition, Tests, and Uses of Steel Castings.—The standard composition of the steel made for parts of gun-carriages and engine frames, is as follows:

Carbon	0.40 to 0.45 per cent.
Silicon	0.30 ,, 0.40 ,,
Manganese	0.50 ,, 0.70 ,,

Physical tests of pieces 13.8 by 100 millimetres ($\frac{1}{2}$ in. full by $3\frac{1}{16}$ in.) which had been previously forged and annealed, have shown the following results:

Breaking strain ...	65 kilos. to 75 kilos. per sq. mm.	41.27 to 45.71 tons per sq. in.
Elongation ...	15 per cent.	

Results on similar test-pieces simply cut out from the castings have given:

Breaking strain ...	52 kilos. to 57 kilos. per sq. mm.	33.01 to 36.19 tons tons per sq. in.
Elongation ...	12 to 18 per cent.	

Pieces 30 by 30 millimetres ($1\frac{3}{16}$ in. square) tested with a falling weight of 18 kilogrammes (39.67 lb.) have to withstand thirteen blows, the height of fall varying from 1 metre ($39\frac{3}{8}$ in.) to 1.6 metre (63 in.) by 50 millimetres (2 in.) at every drop.

The following is a list of some of the more important examples of steel castings recently manufactured by Messrs. Schneider and Co.:

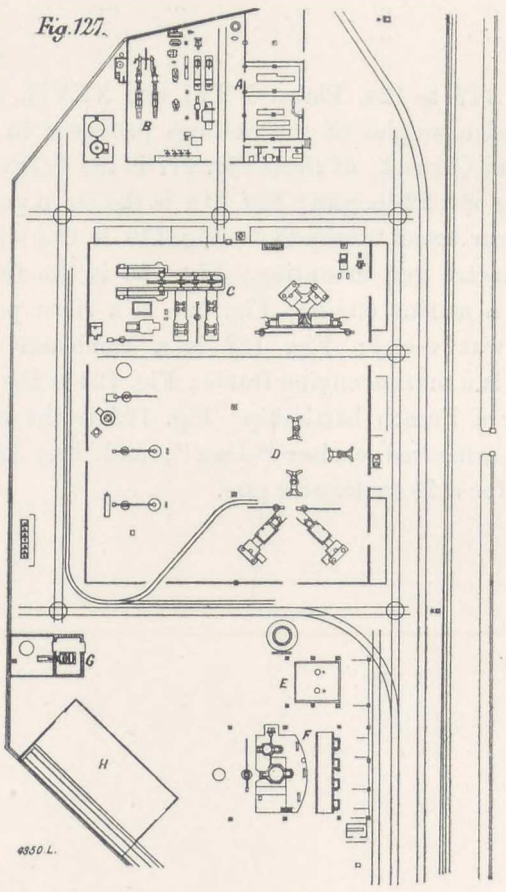
	Tons.
Roller path for coast gun-carriage, 12-in. gun, United States	10.3
The gun-carriage body	9.9
27-centimetre gun-carriage body	4.0
,, ,, slide	15.0
,, gun-roller path	11.8
32 ,, ,, pivot transom	8.7
Observatory roof for the Dutch Government Corps of Engineers	26.0
Screw boss, Messageries Maritimes	7.6
Sternpost	12.4
Cylinder covers, framework, and foundation plates for the mail steamer Touraine, total	63.0
Sternpost for the French Navy	10.0
,, ,, ,, ...	15.7
,, ,, ,, ...	3.2
,, ,, ,, ...	6.2
,, ,, ,, ...	20.0

Figs. 117 to 124, Plates XXVI. and XXVII., illustrate some good examples of the castings produced in the steel foundry at Creusot; of these Fig. 117 is the bolster for the mounting of a 12-in. gun; Fig. 118 is the stern post of the French war vessel "Gueydon"; Fig. 119 is the slide for a 27 centimetre gun mounting; Fig. 120 is the foundation plate of a marine engine; Fig. 121 is a stern post for a French war vessel; Fig. 122 is a condenser casting; Fig. 123 is a marine engine frame; Fig. 124 is the cylinder cover for a French battleship; Fig. 125 is the stern post for the armoured cruiser "Jena"; and Fig. 126 is the housing for a 24 centimetre gun.

XIII.—TYRE SHOPS.

History.—Messrs. Schneider and Co. commenced to roll steel tyres for locomotives and wagons twenty-three years ago. During a number of years the industry was carried on in the armour-plate finishing shop (see plan, Fig. 22, Plate IV.). In 1892, however, as more space was required for armour-plate work, it was decided to remove the tyre-rolling plant and steam hammers, and to suspend the manufacture of railway tyres until a special building

Fig. 127.



A. Machine shop.
B. Pumps.
C. Tyre mill.
D. Hammer shop.
E. Boilers.
F. Annealing furnace.
G. Tower for tests of tyres.
H. Delivery shed.

could be erected. The machinery was, therefore, taken to pieces, and stored for a time.

In 1894 the new works were ready, and the tyre machinery was reinstalled in a building 550 yards distant from the Bessemer and Siemens-Martin steel works. As a hill separates the new tyre shops from the steel works, a tunnel 440 yards long was cut through it, to establish an easy and rapid means of communication by railways between them. Fig. 127 is a plan of the tyre works; Fig. 128, Plate XXVIII., and Fig. 129, are external views of the shops, the latter showing the testing tower; and Fig. 130, Plate XXIX. is an interior view of the tyre mill.

The new tyre shop covers an area of 15,800 square metres (19,000 square yards), and consists of one main building 56 metres (183 ft.) wide, 68 metres (223 ft.) long, and 9 metres (29 ft. 6 in.) high to the springing of the roof.

Arrangement. — 1. A building A, Fig. 127, for the hydraulic machinery and machine tools; the offices and store-rooms are in this building.

2. A shed covering the boilers and annealing furnaces F.

3. A delivery shed H.

4. A tower for the fall tests of tyres G.

The main building contains all the necessary machinery for the special manufacture, and is divided into two principal parts; in one are placed two steam hammers. The larger of these (10 tons) is used to forge the ingot, to flatten it, and to punch the central hole. With the smaller hammer (8 tons) the hole is enlarged, and the disc is finally prepared for the rolling mill. These various operations are completed at one heat.

Furnaces and Hammers. — Two coal-fired furnaces, provided with steam boilers, serve for heating the ingots. A 2-ton hydraulic crane is attached to each furnace and is used for charging the ingots by means of special tongs, and for shifting them when heated, to the steam hammer.

The capacity of the furnaces is sufficient to contain from twelve to eighteen ingots, according to their size; they are cast in the shape of a truncated cone with an octagonal base. Three charges are made per day (of twelve hours) with each furnace, which corresponds to an average output of 27 tons per twelve hours of rough tyre forgings.

The furnaces are so arranged as to leave ample room for the free handling of the ingots and their transport from the furnaces to the hammers.

The following are some data relating to the hammers and furnaces:

Height of fall of 10-ton hammer ...	2.200 m.	7 ft. $2\frac{3}{4}$ in.
Diameter of cylinder	.760 m.	2 ft. 6 in.
Height of fall of 8-ton hammer ...	1.900 m.	6 ft. $2\frac{3}{4}$ in.
Diameter of cylinder	.660 m.	2 ft. 2 in.
Length of furnace hearth	3.400 m.	11 ft. 2 in.
Width	1.690 m.	5 ft. $6\frac{5}{8}$ in.
Grate area	1.22 sq. m.	13 sq. ft.

Furnace Boilers. — The furnace boilers are of the multitubular type, with short tubes. The flames go

THE TYRE SHOPS.



Fig. 128. General View of Tyre Shops.

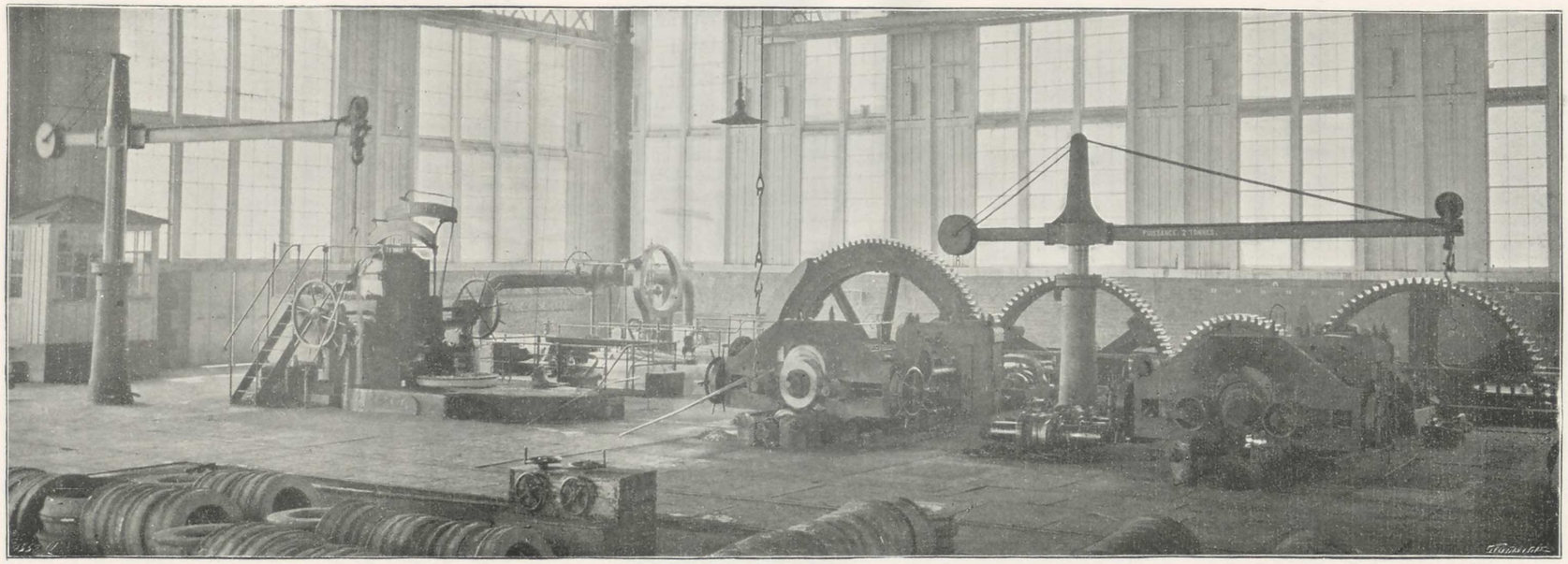


Fig. 130. Interior of Tyre Mill.

through the group of tubes upwards, the draught being provided by a chimney placed directly over the boiler.

Height of chimney above level of works	30 m.	98 ft. 6 in.
Diameter at top	.700 m.	2 ft. 3½ in.
Heating surface of one boiler ...	126 sq. m.	1356.29 sq. ft.
Production of steam per pound of coal burnt on the grate	4 lb.	4 lb.

Reheating Furnaces. — The other part of the plant consists of the tyre-rolling mill and two reheating furnaces, with boilers of the same type as those above mentioned.

The following are some particulars of the engine :

Diameter of cylinder	0.800 m.	31½ in.
Length of stroke	1.750 m.	5.9 in.
Revolutions per minute	45	45
Pressure of steam	6 kilogs.	85.338 lb. per sq. in.

The rough-forged tyre is fed vertically into the roughing rolls ; each friction roll is made with a groove which takes half the thickness of the tyre. The lower roll is fitted with two spindles, and is mounted on a block that can be shifted vertically by means of an hydraulic cylinder; this arrangement maintains an efficient grip during the operation of rolling. The pressure on the hydraulic piston is 78 tons. The top roll is fitted in the end of the shaft, and is without any outside support. The two rolls are driven by toothed wheel gearing ; the number of revolutions is 60 per minute.

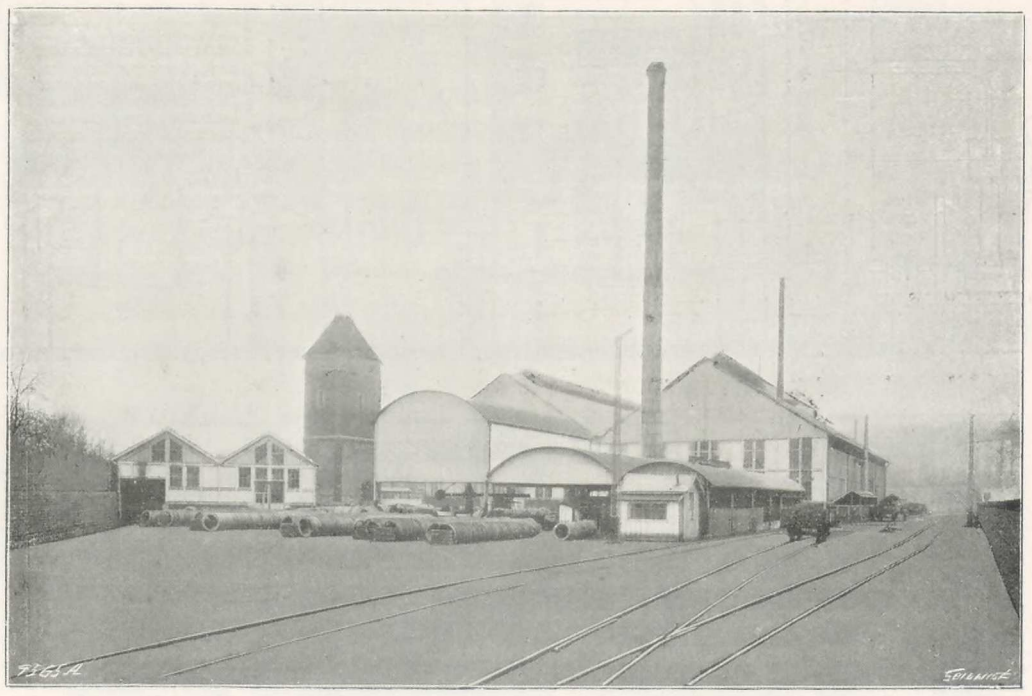


Fig. 129. Tyre Shops and Testing Tower.

The dimensions of the reheating furnaces are :

Length of hearth	4.200 m.	13 ft. 9⅜ in.
Width	1.900 m.	6 ft. 3 in.
Grate area	1.22 sq. m.	13 sq. ft.

Crane.—A 2-ton hydraulic crane serves each furnace, which is large enough to hold from fifteen to twenty rings for wagon tyres, and can treat three charges per twelve hours, equal, for the two furnaces to 30 tons of tyres per day. The rough-forged ring taken from the furnace by the crane, is carried to the mill by a hook suspended from a trolley that travels on an overhead track.

Rolling Mills.—The rolling-mill plant consists of a series of roughing rolls, of finishing, and of special rolls, the latter being used only for the manufacture of gun hoops and some other kinds of rings.

A non-condensing 300 horse-power engine, with two cylinders, drives the three mills by means of toothed-wheel gearing.

In finishing the tyres the table is horizontal and the rolls vertical. Unlike the roughing rolls, those for finishing have cheeks sufficiently high to fit the total thickness of the tyre. The central roll carries the lower cheek and the outside one the top cheek. The outside roll is fitted with two spindles, and is mounted on a block movable horizontally by means of a hydraulic cylinder, in the same way as the roughing rolls. The pressure on the piston is 100 tons. The centre roll is fixed on the end of the shaft. The two rolls are worked by toothed gearing, and the speed is 60 revolutions per minute.

The third mill, which is used for gun hoops, is similar to the rough-rolling tyre mill, excepting that the roll grooves are of the same type as those of the tyre-finishing rolls.

The plant is sufficiently extensive, and is fully adapted for the manufacture of all kinds of tyres, from those of field-gun carriages weighing 25 kilogrammes (55 lb.) to the largest locomotive tyres 2.200 metres (7 ft. $2\frac{3}{4}$ in.) in diameter, weighing 650 kilogrammes (13 cwt.). The gun hoops vary in weight from 25 kilogrammes (55 lb.) to 1 ton, and in width from 50 millimetres (2 in.) to 280 millimetres (11 in.).

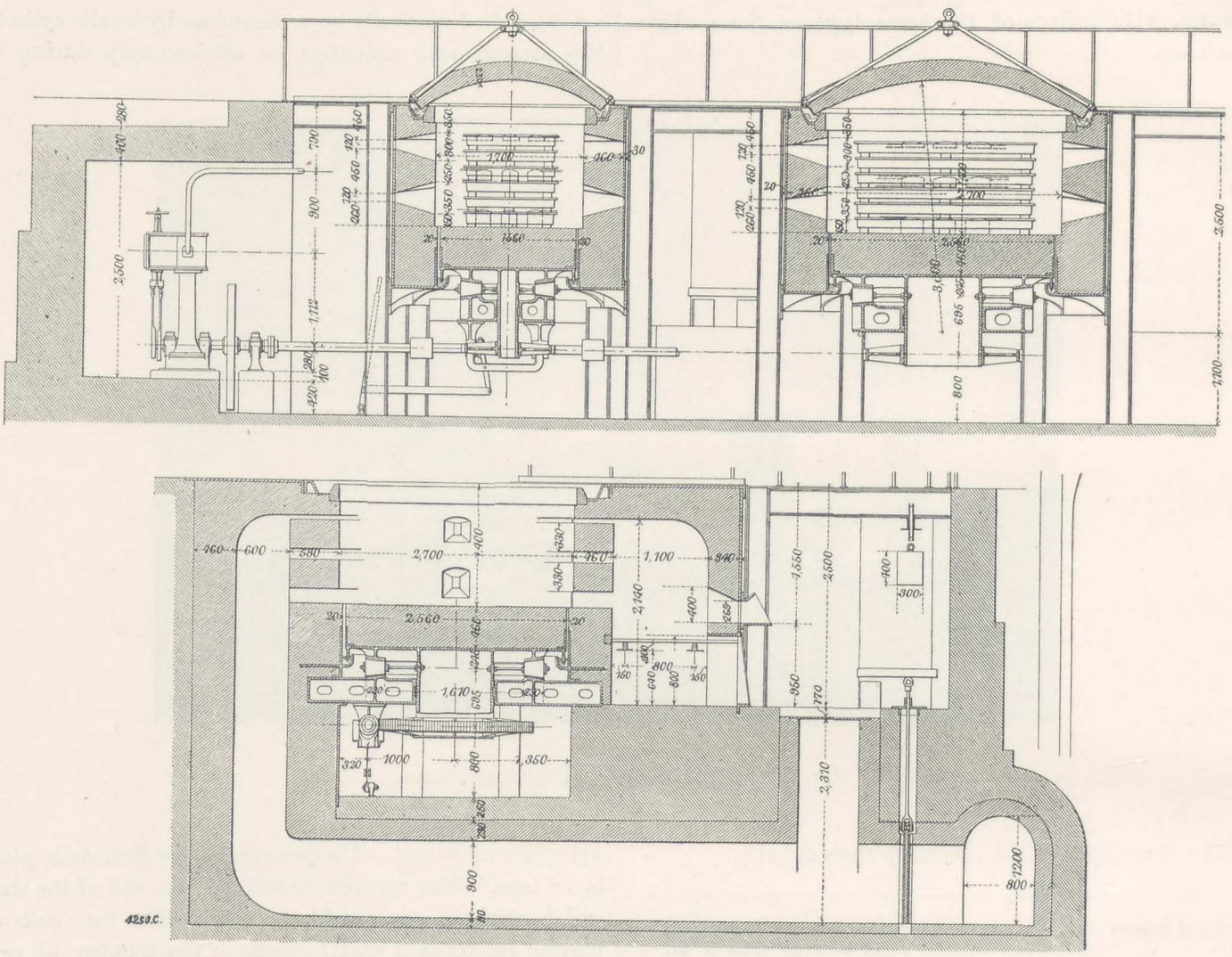
On leaving the finishing rolls, the tyres are transferred by a hydraulic crane to a slab, where they are stamped hot, and thence they go to two 95-ton hydraulic presses, which finally shape them and give the finished diameter.

Annealing.—Most of the tyres and hoops are afterwards annealed. For this work two types of furnaces are used: The first is a horizontal furnace 2.600 metres (8 ft. 6 in.) wide and 16 metres (52 ft. 6 in.) long with four grates in one of the sides; this will contain 140 wheel tyres, weighing from 35 to 38 tons. The time occupied is as follow:

Heating	14	hours.
Cooling	48	,,
Total	62	,,

The second type is vertical, and there are two of these with revolving hearths, Figs. 131 and 132, one for tyres up to 1.500 metres (4 ft. 11 in.) in diameter; and the other for tyres up to 2.500 metres (8 ft. $2\frac{7}{16}$ in.) in diameter. A 3-ton hydraulic crane serves for lifting the furnace top and for shifting the tyres in and out of the furnace.

As soon as the proper temperature for annealing is reached, the tyres are taken out and placed in the open on cast-iron slabs, where they are allowed to cool. Sixty tyres can be annealed in these two furnaces every twelve hours, equal to an output of about 20 tons. Near the annealing furnaces, and under the same shed, are two horizontal tubular boilers, with inside fireboxes; these are required, as the steam generated in the boilers attached to the re-heating furnaces is not sufficient for supplying the whole of the power. The dimensions of these boilers are the following:



Figs. 131 and 132. Tyre Annealing Furnaces.

Diameter	2.800 m.	9 ft. $2\frac{1}{4}$ in.
Length	8.000 m.	26 ft. 3 in.
Diameter of fireboxes	1.100 m.	3 ft. $7\frac{5}{16}$ in.
Length of tubes	4.500 m.	14 ft. 9 in.
Grate area	4 sq. m.	43 sq. ft.
Heating surface	215 sq. m.	2314.32 sq. ft.

Hydraulic Plant.—The pumps that supply water to

the various hydraulic machines are driven by a horizontal Corliss engine with two cylinders, non-condensing; the pumps are in the same line as the steam cylinders. Some of the leading dimensions are as follows:

Diameter of steam cylinders ...	.550 m.	$21\frac{5}{8}$ in.
,, pump plunger ...	.070 m.	$2\frac{3}{4}$ in.
Length of stroke	1.100 m.	3 ft. $7\frac{5}{16}$ in.
Water pressure	65 kilogs.	924 lb. per sq. in.

All the piping is laid down in passages easy of access thus giving facility for inspection.

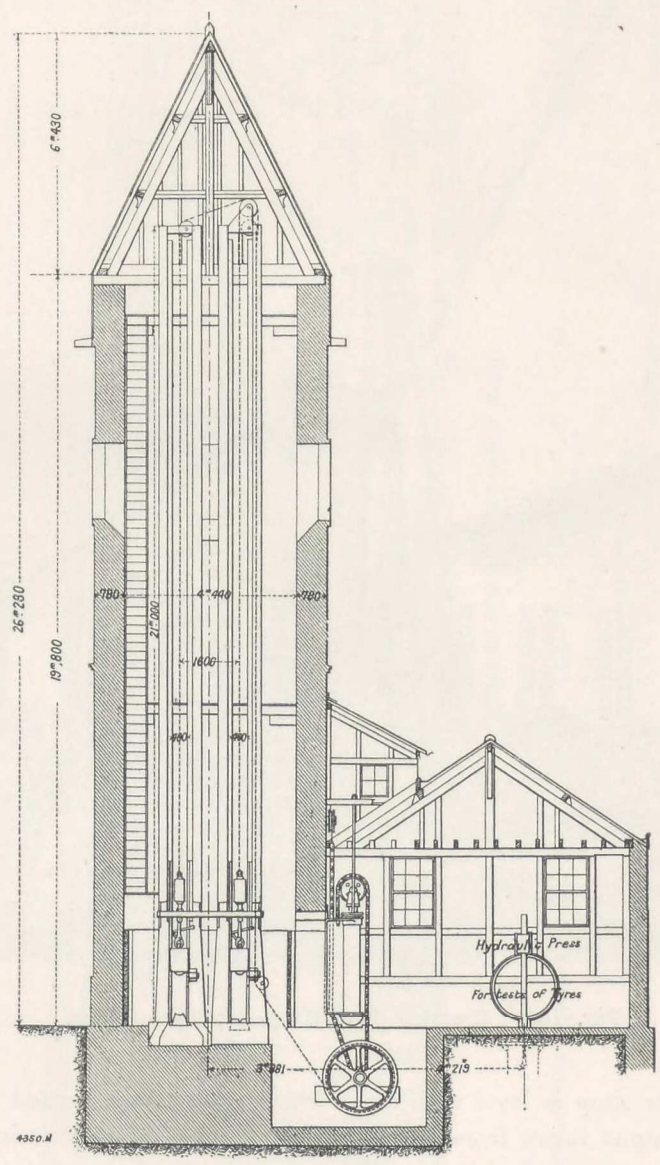


Fig. 133. Falling Weight Tests for Tyres.

Testing Tyres.—The falling tests of the tyres are made in a tower 20 metres (65 ft.) high (see Fig. 133). There are in this tower two dropweights weighing each one ton, and having a maximum fall of 16.700 metres (54 ft. $9\frac{1}{2}$ in.). The anvil block beneath weighs 10 tons, and is fixed on three cubic metres (106 cubic feet) of masonry foundations. A hydraulic press is erected in an adjacent part of this building for special tests. As a rule, tyres undergo two kinds of tests—drop and tensile tests.

The chief object of the former is to ascertain the degree of brittleness of the metal, and each railway company has its own conditions for tests. For good quality tyres the height of fall varies from 2.700 to 5 metres (8 ft. 10 in. to 16 ft. 5 in.), and the number of blows from two to four. The total deflection produced varies from 10 to 25 per cent. of the original inside diameter. For a superior quality of tyre the conditions are much more strict; the number of blows varies from four to six, and the height of fall from 8 to 12 metres (26 ft. to 39 ft.).

For the second class of test, a piece is cut out from the part which has suffered the least from the effects of the fall tests. These pieces must show an ultimate tensile strength which varies, according to conditions imposed by the railway companies, from 40 to 75 kilogrammes (25.40 to 47.62 tons per square inch), the elongation being 12 to 20 per cent. Tests are made on one tyre for each cast; one cast represents from thirty to ninety tyres.

The Southern of France Railway, instead of tensile tests, insist upon compression tests; these are effected on a tyre which has been bored to its exact thickness. The deflection must be 17 per cent. under a determined load, which varies according to diameter and section. The tyre

is then put under the 1-ton falling weight, the largest diameter being placed vertically; it must show a deflection of 17 per cent. of the original diameter after two or three blows, the height of fall being 10 metres (32 ft. 9 in.).

Chimney.—A wrought-iron chimney 50 metres (164 ft.) high, and 1.800 metres (5 ft. 11 in.) in diameter at top, is common to the boilers and to the annealing furnaces. This chimney was brought on the spot in three pieces, which were then riveted together; and lifted into place whole. The chimney weighs 36 tons, and is fixed to its foundation by means of sixteen bolts 46 millimetres ($1\frac{13}{16}$ in.) diameter. This type of chimney is largely used at Creusot; the method of its erection is illustrated by Fig. 134.



Fig. 134. Erecting Iron Chimney, Tyre Shops.

The delivery wharf of the tyre shop is level with the wagon platforms. The annual output varies from 12,000 to 15,000 tons according to the types manufactured. All the material and plant have been designed and built at Creusot.

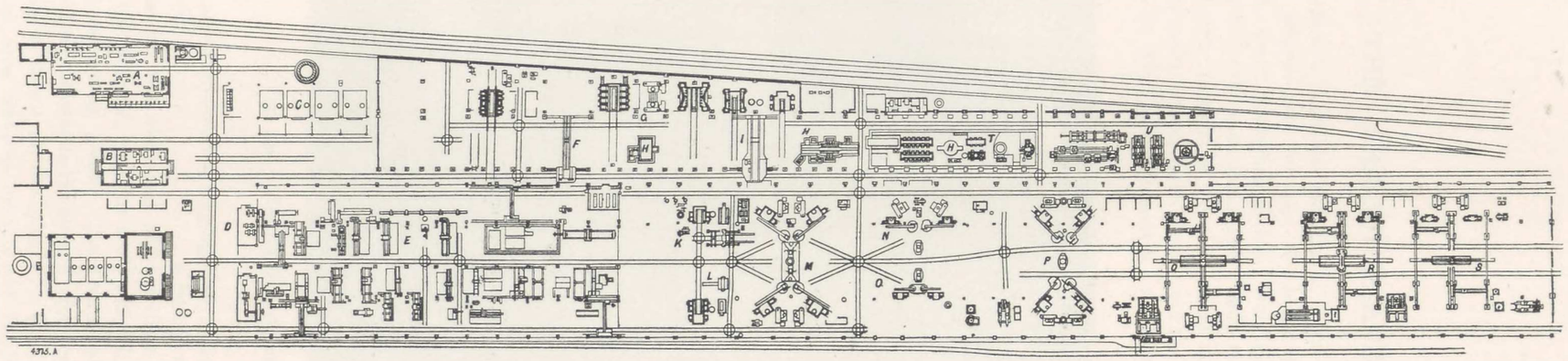


Fig. 135. Plan of the Armour-plate Shops.

A. Shop for maintenance and repairs.
B. Offices.
C. Boilers.
D. Dynamos.
E. Finishing shop for armour plates.
F. 40-ton travelling crane.
G. Cementing furnaces.
H. H. H. Tempering pits.
I. 80-ton travelling crane.
K. 6,000-ton armour-plate bending press.
L. 1,200-ton armour-plate bending press.
M. 100-ton steam hammer.
N. 20-ton steam hammer.
O. 15-ton ,, ,,
P. 40-ton ,, ,,
Q. 3,000-ton forging press.
R. 2,000-ton ,, ,,
S. 1,200-ton ,, ,,
U. Shop for cutting and boring ingots.

XIV.—THE ARMOUR-PLATE DEPARTMENT.

FROM the year 1876, when Messrs. Schneider and Co. submitted the first steel armour-plate for trial at Spezia, this special branch of their manufacture has steadily increased, and to day it forms the most important department, except, perhaps, the gun factory, of the vast establishment at Creusot. The main armour-plate shop is a building 50 metres (164 ft.) wide and 430 metres (1,410 ft.) long; in this all the various processes of forging, pressing, and machining, are carried on.

Another building, 25 metres (82 ft.) wide, and 277 metres (908 ft.) long, joined to the first one, contains the two heating furnaces and the tempering plant. The cementing furnaces are placed in annexes outside the main shop. The general arrangement is shown on the plan, Fig. 135. Plate XXX. The total area occupied by this department is 65,000 square metres (78,000 square yards).

100-Ton Steam Hammer. — The most conspicuous object in the main shop is the 100-ton steam hammer, the working of which has impressed visitors to Creusot for more than twenty years. It was constructed at a time when nothing approaching its power had been attempted, and the complete success which attended the bold experiment gave the works at Creusot a distinct advantage over all other large metallurgical works. The model which formed so conspicuous an object in front of the company's pavilion at the Paris International Exhibition of 1878, will still be remembered as dividing the honours of that remarkable exhibit with the 120-ton steel ingot to which reference has already been made (see Fig. 82, page 34 *ante*).

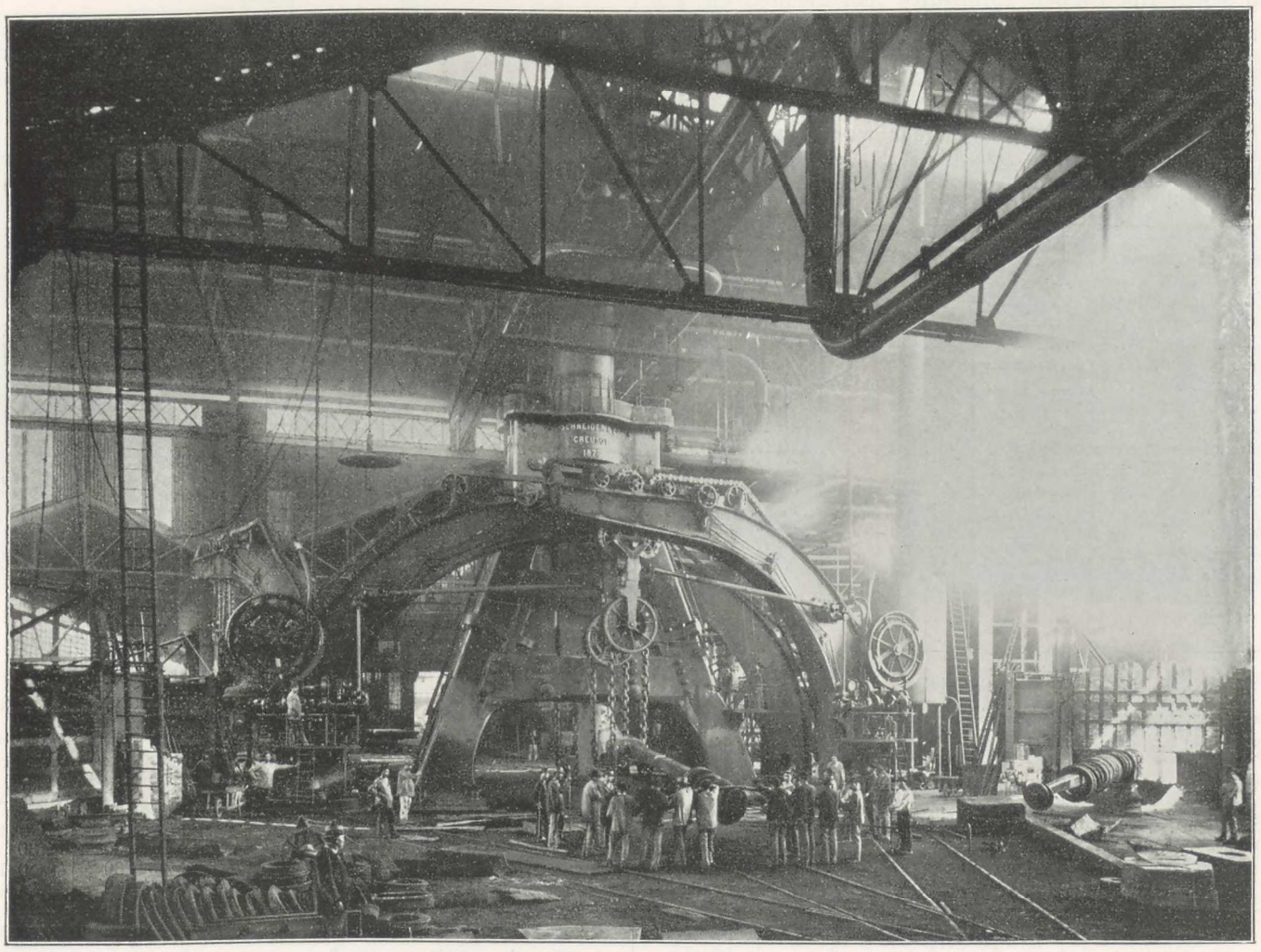


Fig. 136. The 100-Ton Steam Hammer.

Fig. 136 gives a good general idea of the appearance of the hammer, which can be heard in operation for a distance of 7 miles. The two diagrams, Figs. 137 and 138,

are given as an interesting means of comparing the advance made by Messrs. Schneider and Co. in the construction of steam hammers; Fig. 137 illustrates the first steam hammer built at Creusot in the year 1840, by M. Bourdon, and Fig. 138, drawn to the same scale, the great 100-ton hammer.

To Messrs. Schneider and Co. is due the credit of having conceived and carried into execution the construction of this hammer, the only one of its size at the time it was built, and for several years after. Since that time, however, other French and foreign works have followed the example thus set. But as will be seen later on, the real usefulness of the machine has been supplemented by other appliances. The productive value of this gigantic hammer at the time it was constructed, and for many years after, cannot be over-estimated. It was built at a period when the French Admiralty had decided on the construction of powerful cruisers, the armament and equipment of which involved the manufacture of heavy masses for which at that date no mechanical appliances existed.

The construction of the hammer was commenced in 1875, and it was started on September 23rd, 1877. Its principal dimensions are as follows:

Diameter of cylinder	1.900 m.	6 ft. 3 in.
Stroke	5.000 m.	16 ft. 5 in.
Weight of falling mass	100 tons	100 tons
Height of frame in the clear above anvil block	3.430 m.	11 ft. 3 in.
Distance between feet of frame in the clear	7.520 m.	24 ft. 8 in.
Width of hammer block	1.900 m.	6 ft. 3 in.
Diameter of steam inlet valve ...	.345 m.	0 ft. $13\frac{9}{16}$ in.
Diameter of steam exhaust valve...	.470 m.	0 ft. $18\frac{1}{2}$ in.
Height of entablature above floor level	12.060 m.	39 ft. 7 in.
Height of cylinder cover	21.000 m.	69 ft. 0 in.
Depth of foundations below floor	8.500 m.	27 ft. 11 in.
Total height...	29.500 m.	96 ft. 11 in.
Weight of anvil block	750 tons	750 tons
,, steam hammer ...	550 tons	550 tons
Total weight	1300 tons	1300 tons

The anvil block consists of seven tiers of planed cast-iron slabs fitted together by means of ties fixed hot.

Reheating Furnaces.—Four reheating coal-fired furnaces, fitted with boilers, are placed round the hammer. These furnaces are served by four steam cranes, three of which are of 100 tons and the fourth of 150 tons. The dimensions of the furnaces are:

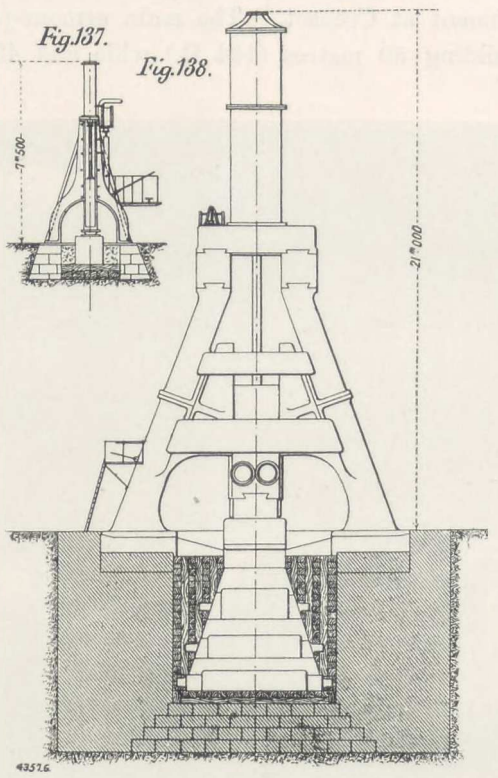
	m.	ft.	in.
Width of heating space between fire-bridges	4	13	$1\frac{1}{2}$
Depth of heating space...	3.500	11	6
Doors (worked by hydraulic power) width ...	3.500	11	6

The clear height of one of the furnaces is sufficient to receive an ingot two metres (6 ft. 6 in.) square. Two grates provided with air blast are placed in front of the furnaces, one each side, with a grate area of 3.40 square metres (36.60 square feet).

The outlet for the flames is through the centre of the sole at the back. The boilers economising the waste heat are of the multitubular type, but with short tubes, in order to take up less room. The heating surface of these boilers is 252 square metres (2712 square feet) and the production of steam per boiler and per twelve hours, is 22 tons.

Owing to the energetic action of a chimney .815 metre (32 in.) in diameter at top and 30 metres (98 ft.) high above ground level, the flow of the hot gases does not in any way interfere with the efficient working of the furnaces.

Cranes.—Each of the four cranes that forms an accessory to the furnaces, turns on a single pivot, placed in a pit. The jibs are so shaped as to be but little effected by shock from the blows of the hammer. Each crane is provided with a two-cylinder steam engine, which lifts the load, shifts the carrying truck, revolves the crane, and



Steam Hammers at Creusot, 1840 and 1877.

turns the ingot under the hammer. The chains are made up of plate links. The following are some dimensions of these cranes:

	m.	ft.	in.
Maximum radius of jib	9.250	30	4
Diameter of engine cylinders	.260	0	$10\frac{3}{16}$
Stroke of piston	.300	0	$11\frac{13}{16}$

The size and power of the 100-ton hammer has rendered it possible to produce forgings of exceptional dimensions and weight; an example is shown in the conning tower of the Lepanto, measuring 3.050 metres (10 ft.) in outside diameter, 1.500 metres (4 ft. 11 in.) high, and 320 millimetres ($12\frac{5}{8}$ in.) thick. The work was done on a mandril 1.700 metres (5 ft. 7 in.) in diameter. No less powerful tool could have produced such a forging, which is illustrated by Fig. 139. Fig. 140 is another example of a similar kind, being the conning tower for a torpedo-boat destroyer.

Since 1877, when the 100-ton hammer was set to work,

it has forged 52,000 tons of armour-plates and 9,600 tons of gun forgings, and various pieces.

Hydraulic Armour-plate Shaping Presses.—Until the year 1886, the 100-ton steam hammer served to forge and bend armour-plates, even when these were of the most complicated shapes. Thus all the plates for the bows of ironclads forming the ram, were, during nine years, entirely manufactured under the steam hammer. Until recently, the steam hammer was chiefly used for the forging and shaping of armour-plates; these, however, are now shaped under hydraulic presses.

Shaping Presses.—Two presses are used for this work, namely one of 6,000 tons, and one of 1,200 tons for relatively thin plates, and a description of these, with auxiliary plant will be found of interest. These two armour-plate shaping hydraulic presses are placed on the right and left of the great hammer.

The principal dimensions of the 6,000-ton press are as follow:

Diameter of cylinders	.875 m.	2 ft. $10\frac{7}{16}$ in.
Travel of plunger pistons	1.200 m.	3 ft. $11\frac{1}{4}$ in.
Maximum water pressure	500 kilogs.	3.15 tons per sq. in.
Distance between columns	4 m.	13 ft. $1\frac{1}{2}$ in.
Diameter of columns	.400 m.	1 ft. 4 in.
Available height from movable table to moulding block	1.470 m.	4 ft. 10 in.
Travel of table	2 m.	6 ft. $6\frac{3}{4}$ in.

The dimensions of the 1,200-ton press are:

Diameter of cylinders ...	.550 m.	1 ft. $9\frac{5}{8}$ in.
Travel of plunger pistons ...	1.100 m.	3 ft. $7\frac{5}{16}$ in.
Maximum water pressure ...	250 kilogs.	1.58 tons per sq. in.
Distance between columns ...	4 m.	13 ft. $1\frac{1}{2}$ in.
Size of square columns ...	.250 m. sq.	0 ft. $9\frac{7}{8}$ in.
Available height from movable table to moulding block ...	1.430 m.	4 ft. $8\frac{5}{16}$ in.
Travel of table	2 m.	6 ft. $6\frac{3}{4}$ in.

The 1,200-ton armour-plate shaping press is of the same type as the 6,000 ton press.

Both presses are provided with two cylinders acting on a crosshead suspended to two hydraulic hoists, and the moving tables are worked by hydraulic cylinders. Two furnaces heated by coal, and fitted with a movable hearth, serve for heating the heavy armour-plates, while the lighter plates are generally bent cold. A set of pumps is attached to each press, and there are no accumulators, the water passing direct to the cylinders, so that the energy put into the pump is always in accord with the work to be done in bending the plates.

The 6,000-ton press is provided with two 50-ton hydraulic jacks mounted on a travelling carriage, one of which is fitted with mechanism for turning over the plate when necessary. This press is illustrated by Figs. 141 and 142.

The movable hearths of the furnaces are brought under the presses to receive the plates that require to be reheated. A steam winch is used for removing and replacing the hearth by means of return pulleys placed along the tracks.

Small Steam Hammers and Furnaces.—In the forging shop, and beyond the 100-ton hammer, are two other hammers, of 15 and 20 tons respectively, each with two furnaces fitted with boilers. These hammers are provided with two cranes of the same type as those of the 100-ton hammer. They are used specially for forging medium-sized pieces. Further on stands a 40-ton hammer, with four furnaces and boilers, and four 50-ton cranes. The arrangement of this hammer and plant is a reproduction of that of the 100-ton hammer. It was installed in order to relieve the great hammer, which very frequently cannot do all the heavy work required, and cannot, of course, do economically such work as can be completed



Fig. 139. Conning Tower of Italian Battleship "Lepanto."



Fig. 140. Conning Tower for Torpedo-Boat Destroyer.

with a less powerful tool. Armour-plates weighing as much as 25 tons, and measuring 2.200 metres in width (7 ft. 2⅝ in.), are forged by the 40-ton hammer, besides a great variety of other pieces. The furnaces, however, have been designed especially for heating armour-plates. The principal dimensions of the 40-ton hammer and furnaces are as follow:

the hot gases reaching the boiler through an underground passage. In these furnaces the area of the two grates is 2 square metres (21.53 square feet), and the heating surface of the boiler, is 125 square metres (1345.52 square feet).

The cranes are of the same type as those which serve the 100-ton steam hammer; the height of the jib above the

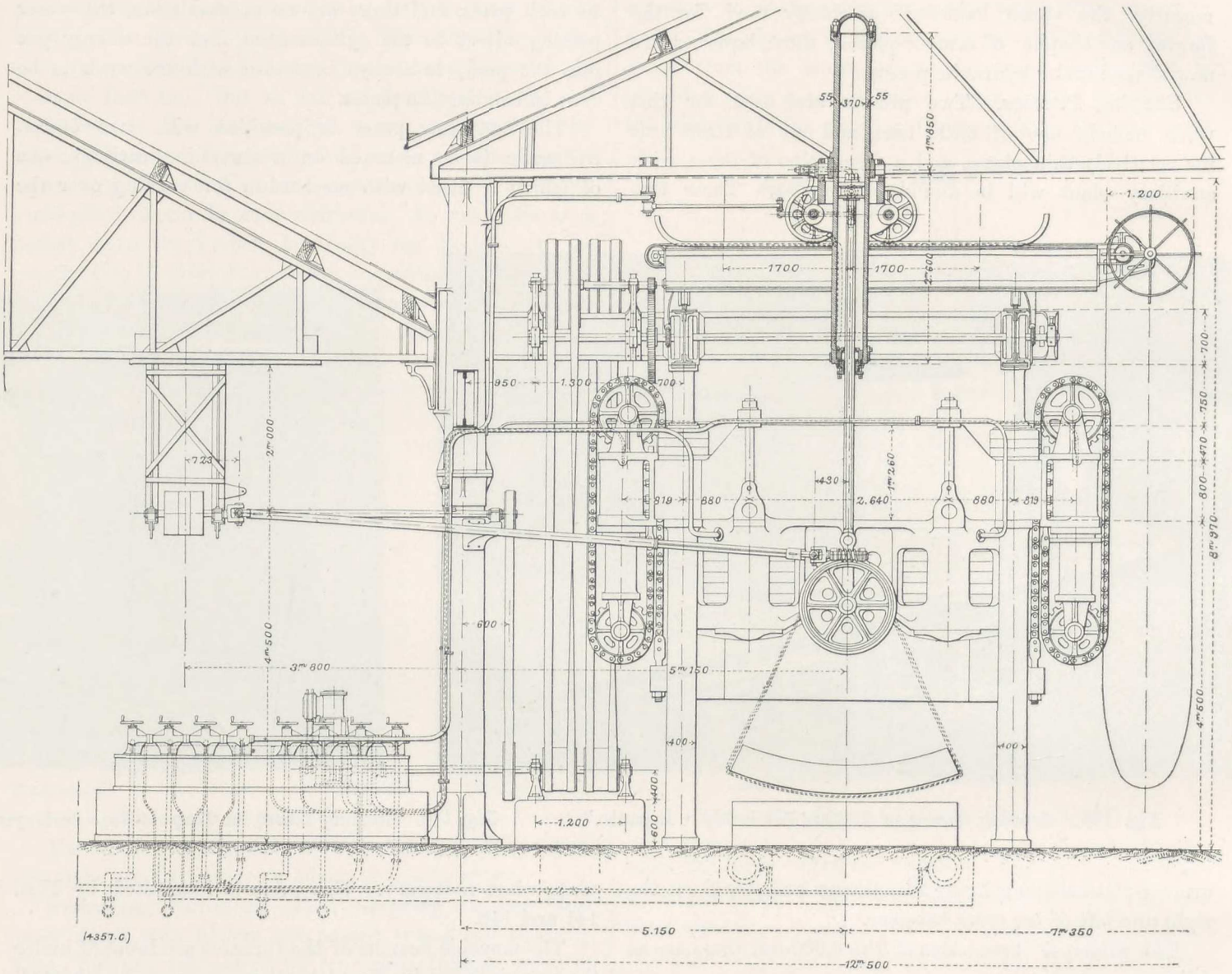


Fig. 141. 6,000-Ton Hydraulic Plate-Shaping Press.

Diameter of cylinder	1.200 m.	3 ft. 11 in.
Height of fall (stroke)	3.250 m.	10 ft. 8 in.
Width of hammer	1.900 m.	6 ft. 3 in.
Distance between feet of frame arcade	2.800 m.	9 ft. 2 in.
Weight of anvil block	210 tons	210 tons
Total weight of hammer, including anvil block	390 tons	390 tons
Dimensions of Furnaces.		
Width between fire bridges	3.000 m.	9 ft. 10 in.
Depth	2.800 m.	9 ft. 2 in.
Height of furnace roof	1.700 m.	5 ft. 7 in.

Two grates provided with air-blast are fitted to each of the four furnaces, one each side and one in front; the flame outlet is at the back, through an opening in the hearth, floor level is 8.050 metres (26 ft. 5 in.), and the maximum radius is 9 metres (29 ft. 6 in.).

2,000-ton Forging Presses.—Further on in the same building are three forging presses; one with a capacity of 3,000 tons, one of 2,000 tons, and one of 1,200 tons. The oldest of these is the 2,000-ton press (Fig. 143), which was put down in 1889. The upper crosshead, carrying the cylinder, is movable vertically to the extent of 2.150 metres (7 ft. 1 in.), the height being regulated according to the size of the forgings. The distance between the columns is 4.255 metres (13 ft. 11½ in.) and 1.700 metres (5 ft. 7 in.); the greatest distance from the lower crosshead to the hammer, is 4.300 metres (14 ft. 1¼ in.). It will

THE ARMOUR PLATE DEPARTMENT.

Fig.144.

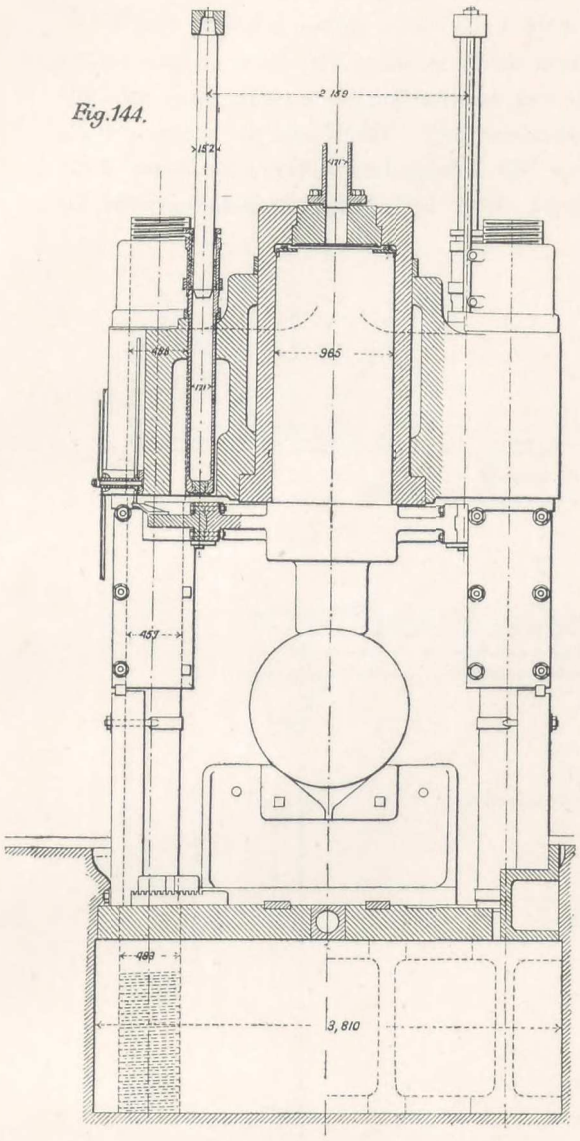


Fig.145.

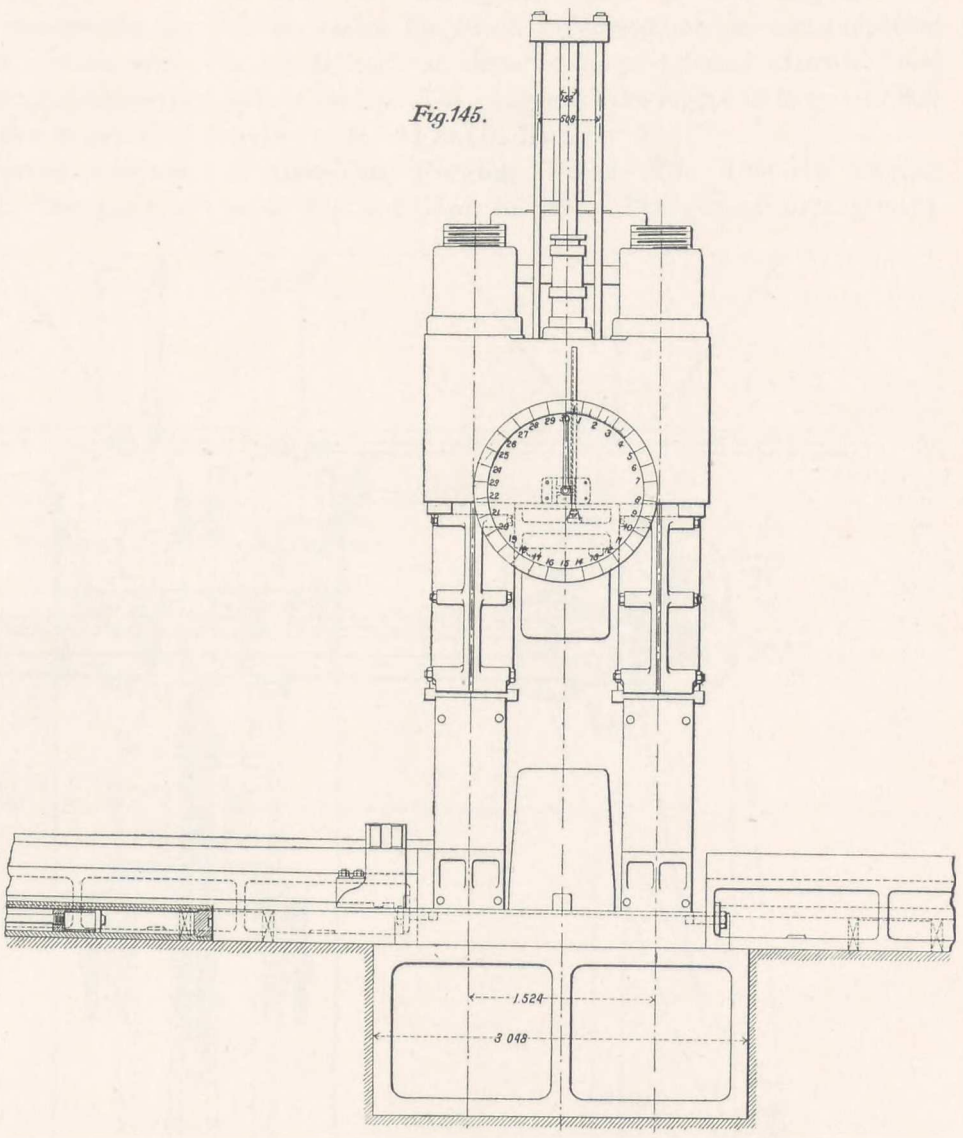


Fig.146.

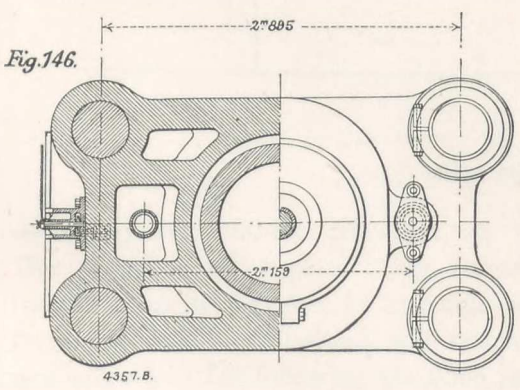
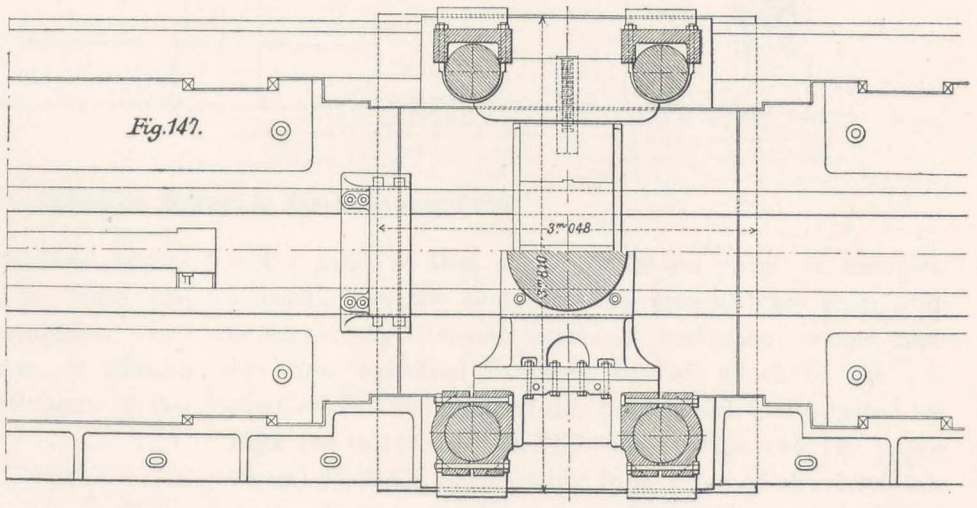


Fig.147.



3,000-Ton Hydraulic Forging Press.

be seen, therefore, that exceptionally large pieces can be treated in this press. Thus, quite recently, rings measuring 3.400 metres (11 ft. 2 in.) in diameter, 0.500 metres (1 ft. 8 in.) high, and 0.110 metre ($4\frac{3}{8}$ in.) thick, were forged on mandrils in the machine.

Water under pressure is supplied by a non-condensing steam engine with two cylinders, combined with an accumulator charged to 400 kilogrammes per square centimetre (2.54 tons per square inch). The accumulator is provided with three cylinders, which enable the working pressures to be regulated to 1,200 and 2,000 tons. The press is served by two 100-ton travellers on overhead tracks. The ingot or other piece being forged, is lifted and turned when in the press, by hydraulic mechanism, while travelling, both longitudinal and transverse, is effected mechanically. The following are some particulars of this installation:

	m.	ft. in.
Span of travelling cranes	11.125	36 6
Length of travel longitudinally ...	25	82 0
,, ,, transversely ...	10	32 9
Height of rails above floor level ...	11	36 0

Three coal-fired furnaces, provided with air-blast and fitted with boilers are used to heat the ingots; one of the furnaces is of specially large capacity for taking pieces of exceptional dimensions. Owing to the great height of the 2,000-ton press, it was necessary to raise the building to 14 metres (46 ft.) above the ground level. This machine is used for making all classes of solid forgings, and hollow pieces forged on supported, or on non-supported mandrils, such as rings of large internal diameter, and hollow shafts. The press can take ingots as large as 1.200 metres (3 ft. $11\frac{1}{4}$ in.) in diameter.

3,000-Ton Forging Press.—The 3,000-ton forging press was put down in 1895. The general arrangement

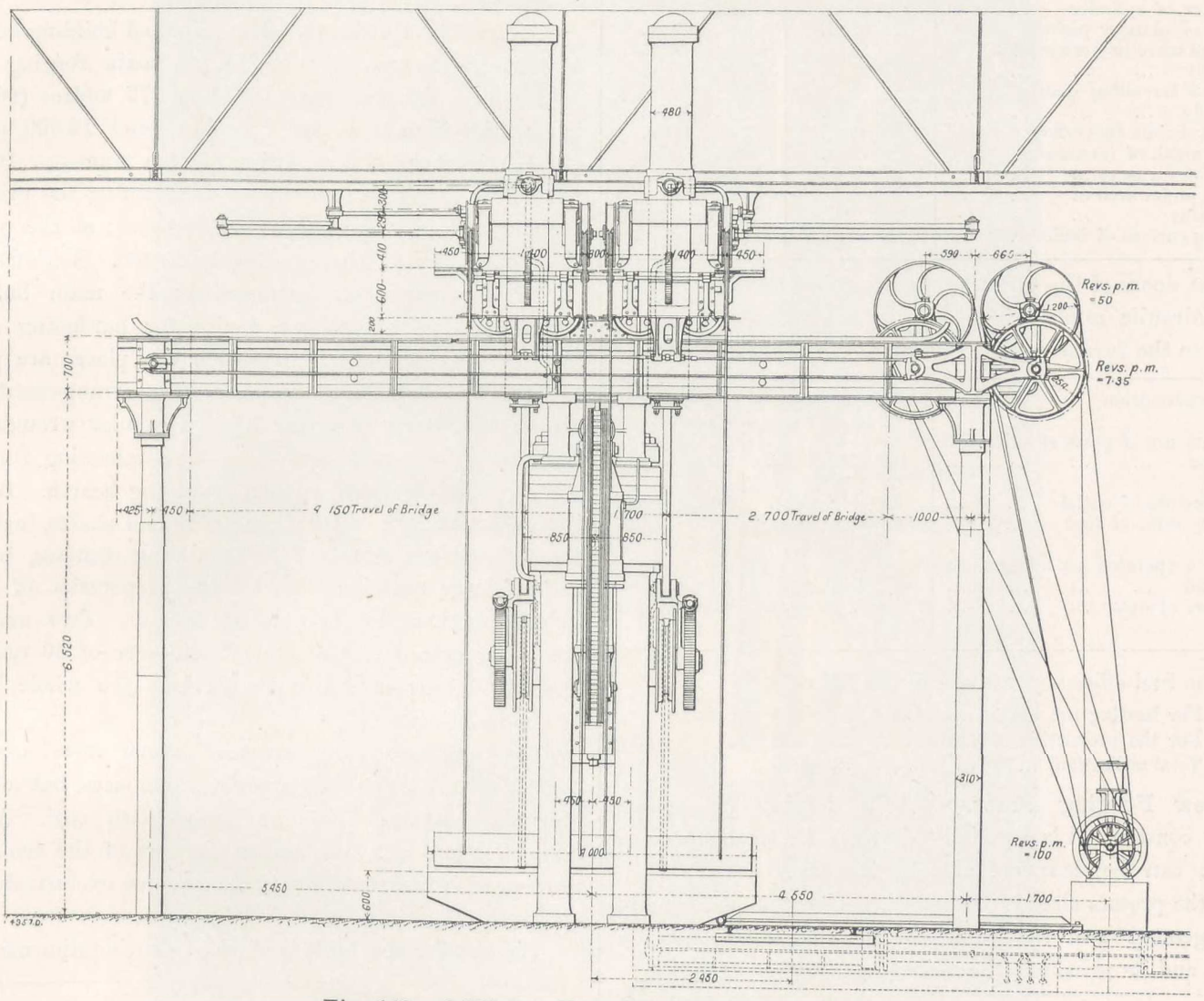


Fig. 142. 6,000-Ton Hydraulic Plate-Shaping Press.

is the same as that of the 2,000-ton press; it occupies a position in the centre of the armour-plate shop, and is served by 100-ton overhead travelling cranes, and by three coal-fired furnaces, one of which is not yet completed. The details of this press, which is illustrated by Figs. 144 to 147, Plate XXXI., and by Figs. 148, 149, pages 64 and 65, differ considerably from those of the 2,000-ton press; the top cross-head is fixed, the columns are placed nearer to each other, and the press, as a whole, is built more compactly. The pumps deliver direct into the forging cylinder, so that no accumulator is employed, the work done by the pumps being, therefore, in proportion to the energy required, as with the 6,000-ton armour-plate bending press

already described. This machine is specially used in the production of simple forgings, such as solid and hollow shafts, gun rings, &c. Crankshafts, however, are often made with it. Its dimensions are such that it can forge ingots measuring 1.500 metres (4 ft. 11 in.) in diameter. The pit containing the anvil and the mandril supports is 15 metres (49 ft.) in length, 4 metres (13 ft.) in width, and .600 metre (1 ft. 11$\frac{5}{8}$ in.) deep. The principal dimensions of the press and its furnaces are as follow:

Distance between columns ...	2.460 m.	8 ft. 1 in.
Diameter of columns	·440 m.	1 ft. 5$\frac{5}{16}$ in.
Height between crossheads ...	3.630 m.	11 ft. 11 in.
Diameter of cylinder	.965 m.	3 ft. 2 in.
Stroke of plunger piston ...	2.100 m.	6 ft. 10$\frac{5}{8}$ in.
Speed of travelling cranes, longitudinally	25.000 m.	82 ft. 0 in.
Speed of travelling cranes, transversely	10.000 m.	32 ft. 9 in.
Height of rails above floor level ...	8.250 m.	27 ft. 1 in.
Inside width of furnaces	2.600 m.	8 ft. 6$\frac{3}{8}$ in.
Depth of furnaces	3.200 m.	10 ft. 6 in.
Height under arch	2.100 m.	6 ft. 11 in.
Grate area	2 sq. m.	21.53 sq. ft.
Heating surface of boiler	135 sq. m.	1453.18 sq. ft.

The doors of the furnaces serving this press are worked by hydraulic rams. Evaporation trials with the boilers fitted to the furnaces, have given the following results:

Coal consumption	140 kilogs. per sq. m. of grate area.	28.6 lb. per sq. ft.
Temperature of gases entering the boiler	1080 deg. Cent.	1976 deg. Fahr.
Temperature of outlet	180 deg. Cent.	356 deg. Fahr.
Heating value of fuel	6585 calories per kilog.	2988 per lb.
Water evaporated per kilogramme of coal	4 kilogs.	4 lb. per lb.
Pressure of steam	6 kilogs. per sq. cm.	85.34 lb. per sq. in.

The fuel efficiency values are the following:

For heating the ingots	9.5 per cent.
For the production of steam	38.5 ,,
Total utilisation	48.0 ,,

New Forging Press.—A third forging press now being constructed is especially destined for small forgings which can be manufactured by it more cheaply than with the presses already described. The type and general arrangement are the same as those of the 3,000-ton press, and its principal dimensions are:

Diameter of forging cylinder ...	0.620 m.	2 ft. 0$\frac{3}{8}$ in.
Stroke of plunger piston	1.100 m.	3 ft. 7$\frac{5}{16}$ in.
Height available between lower crosshead and hammer	2.200 m.	7 ft. 2$\frac{1}{4}$ in.
Height between crossheads ...	3.000 m.	9 ft. 10$\frac{1}{8}$ in.
Distance between columns ...	2.200 m.	7 ft. 2$\frac{1}{4}$ in.
Diameter of columns	0.300 m.	0 ft. 11$\frac{7}{8}$ in.
Maximum pressure on plunger piston	400 kilogs.	2.54 tons per sq. in.
Maximum diameter of ingot ...	1.000 m.	3 ft. 3$\frac{3}{8}$ in.
Travel of mandril supports ...	6.000 m.	19 ft. 8 in.
Length of pit	15.000 m.	49 ft. 2 in.
Width ,, ...	3.000 m.	9 ft. 10 in.
Depth ,, ...	0 500 m.	1 ft. 8 in.
Power of travelling cranes ...	75 tons.	75 tons
Longitudinal travel of ,, ...	25.000 m.	82 ft. 0 in.
Transverse ,, ,, ...	10.000 m	32 ft. 9 in.
Height of rails above floor level ...	8.250 m.	27 ft. 1 in.
Inside width of furnace	2.000 m.	6 ft. 6 in.
,, depth of furnace	2.200 m.	7 ft. 3 in.
Height of arch	1.500 m.	4 ft. 11 in.
Heating surface of boiler	88 sq. m.	947.25 sq. ft.

Depôt and Annealing Furnace.—A depôt for storing ingots, and for large tools, has been erected outside the main armour-plate shop; it is supplied with a 100-ton steam crane, travelling on rails laid on the floor level. The length of the depôt is 120 metres (393 ft.), and the width, 11 metres (36 ft.).

A furnace 20 metres (65 ft. 7 in.) long has been built in this depôt for annealing shafts, large gun parts, &c.

Five portable 10-ton steam cranes are used for carrying the various tools and manufactured material, and a small locomotive is also attached exclusively to the armour-plate department.

Cementing Furnaces.—The principal building devoted to this plant runs parallel to the main forging shop, with which it is connected. It is 277 metres (909 ft.) long; 24.350 metres (80 ft.) wide; and 12.500 metres (40 ft.) in height. A series of ten annexes, 10 and 15 metres (33 ft. and 49 ft.) wide, adjoining the principal building, contains the cementing furnaces; at the present time only five of these are constructed. Various tempering appliances are arranged in the main building. There is a jet tempering device for hardening plates horizontally; a second, in which the plates are placed vertically. There is a dip hardening arrangement, consisting of a water reservoir, a large circular wrought-iron tank, with a smaller tank and four reheating furnaces, one of which is fitted with a revolving hearth. Beyond is the hardening plant for gun parts and shafts, including two reheating furnaces. This building contains, besides, several large machine tools for the preparation of round ingots previous to their being forged. Two overhead travelling cranes on the same track—one of 40 tons and one of 80 tons—are able to traverse the whole length of the building.

The five cementing furnaces above mentioned (see Figs. 150 to 152, page 66) are of various sizes, but all have movable hearths. They are heated with coal. Messrs. Schneider and Co. were the originators of the cementing process with hydrocarbon gas, a process exclusively used at Creusot.

The last furnace built is of the following dimensions:

	m.	ft.	in.
Length of chamber	9.000	29	6
Width ,, ...	5.000	16	4
,, of hearth	3.500	11	6
Height of arch above hearth ...	2.300	7	6$\frac{1}{2}$

There are four fires on each side. The flames escape in the middle of the length of the furnace through two openings which communicate with an underground passage; this leads the waste gases to a multitubular boiler. The fires are level with the ground and are provided with air-blast; the grates are .900 metre (35$\frac{1}{2}$ in.) long and .800 metre (31$\frac{1}{2}$ in.) wide. The movable hearth consists of an iron frame mounted on wheels and carrying a cast-iron casing thickly lined with refractory material to prevent all loss of heat by radiation. This hearth can

carry plates 8 metres (26 ft. 3 in.) long and 3.500 metres (11 ft. 6 in.) wide, or several plates of smaller dimensions.

When plates are subjected to the cementing process, after having been moulded to template, they are placed one above the other with spaces between them, which constitute gas chambers. A cast-steel frame is put between each pair of plates; this frame completely encloses the gas chamber; and to prevent any gas escape, an asbestos strand is fitted between the plates and the frame. The sides of the frame, which correspond with the length of the furnace, are drilled and fitted with gas pipes; these are placed about 20 in. apart. On the hearth are placed steel blocks, which carry the plates to be treated. The outside surfaces of the plates are covered with sheet iron, in order to prevent oxidation.

When the furnace has been prepared, the plates are put in and the openings are closed with firebricks. the gas pipes are then fixed, openings being provided for this purpose in the furnace walls. These pipes, or tuyeres, are of copper, and are kept cool by a stream of water. Each one is fitted with four passages—one for the gas inlet, one for the water inlet, the third for the water outlet and the fourth for the outlet of the gas when it has remained some time in the gas chamber. Three branches are connected to the collecting pipes by means of india-rubber tubes. This arrangement suits for all the thicknesses of plates, as the flexibility of the connecting tubes allows of advancing the tuyeres more or less deeply into the furnace, according to the size of the plates. The part of the tuyere which penetrates the furnace has a fireproof

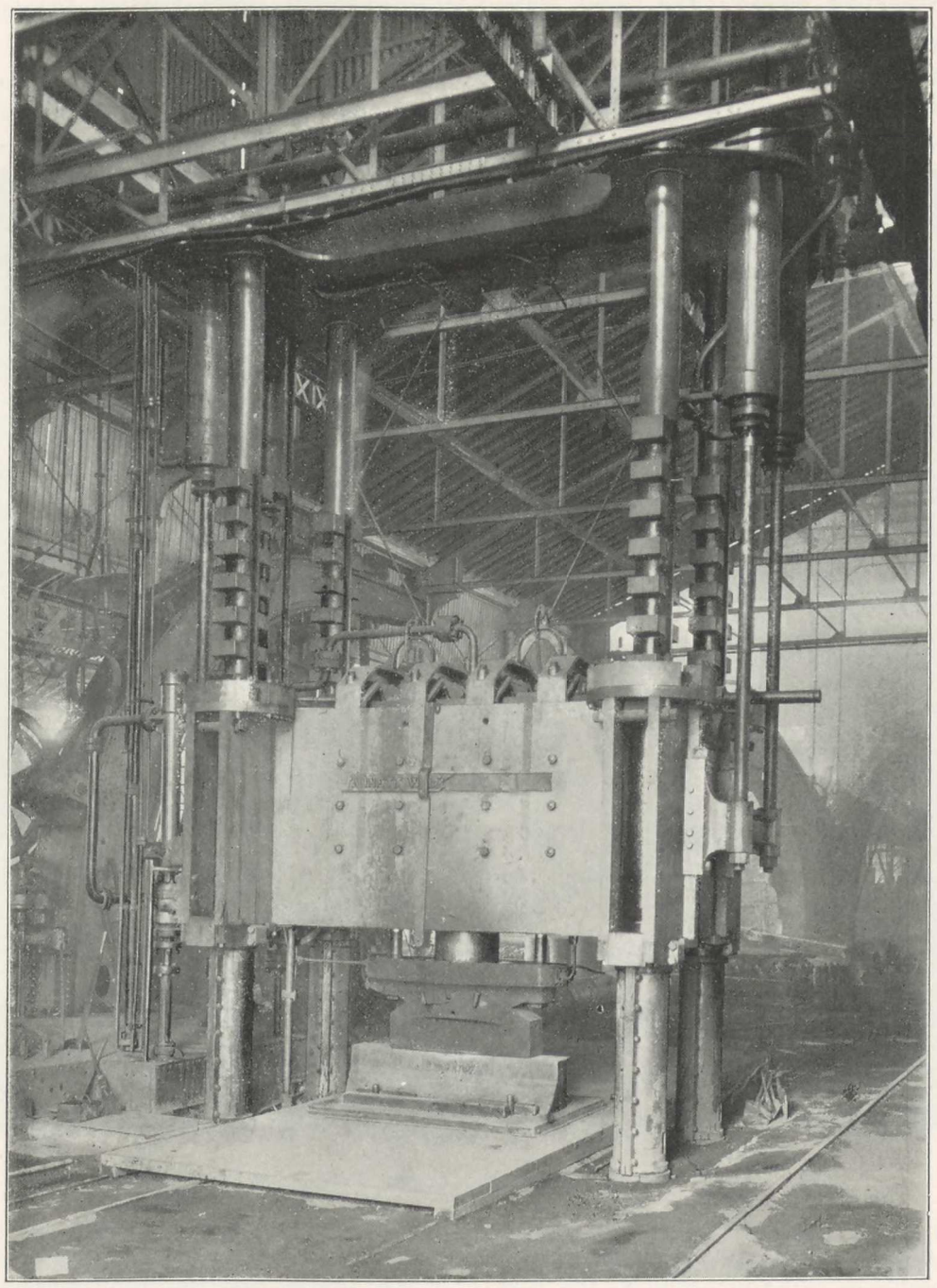


Fig. 143. 2,000-Ton Hydraulic Forging Press. (See page 60.)

covering which extends from the furnace wall to the plates. Thus protected they withstand the high temperature, and require but slight repair. Since 1894, when Messrs. Schneider and Co. began to work this process on a large scale, none of the nozzles have worn out. Each furnace is fitted with a gas meter and pressure regulator.

Cementing Process.—The following are the leading particulars of the cementing process: The plates, when arranged as above described, are raised as uniformly as possible to a dark red heat. When this has been done, gas is admitted through the tuyeres on one side for half an hour. The gas is distributed in the space between the plates; the hydro-carburets separate owing to the heat; and a powerful cementing action sets in owing to the carbon which is liberated. Part of the carbon penetrates the steel of the plates in a combined state, the remainder being deposited mechanically on the surfaces of the casing, or escaping with hydrogen through the series of pipes on the opposite side. In these pipes a certain re-formation of hydro-carburets, less rich in carbon, takes place, and this gas escapes through the fourth branch mentioned above. The escaping gas is ignited and the progress of the cementing operation is ascertained by the appearance of the flame.

Gas admission is stopped when the operation has been continued long enough, for a certain time, during which cementation gains in depth, the lower surfaces taking carbon from the top ones which become saturated under the action of the gas. Gas is then admitted for another half-hour, through the pipes by which the waste gas has escaped during the first part of the operation. The poor hydro-carburets escape through the opposite pipes, and are burnt outside the furnace. Another stoppage, of equal duration to the first one, now takes place. Thus the process goes on, gas being admitted first on one side, then on the other, the alternation insuring an even depth of cementation over the whole surface of the plates.

The quantity of gas used is in proportion to the area of the plates; the amount passed each time is regulated by meters, and the pressure is maintained uniform by means of special regulators.

The thickness of the plates, and the conditions stipuated for the firing tests, determine the time the operation is to last, and the maximum temperature which has to be maintained. The temperature is kept under complete control. This is secured by the following arrangement: Each cementing furnace is connected by an electric wire, the total resistance of which is constant, to a switchboard

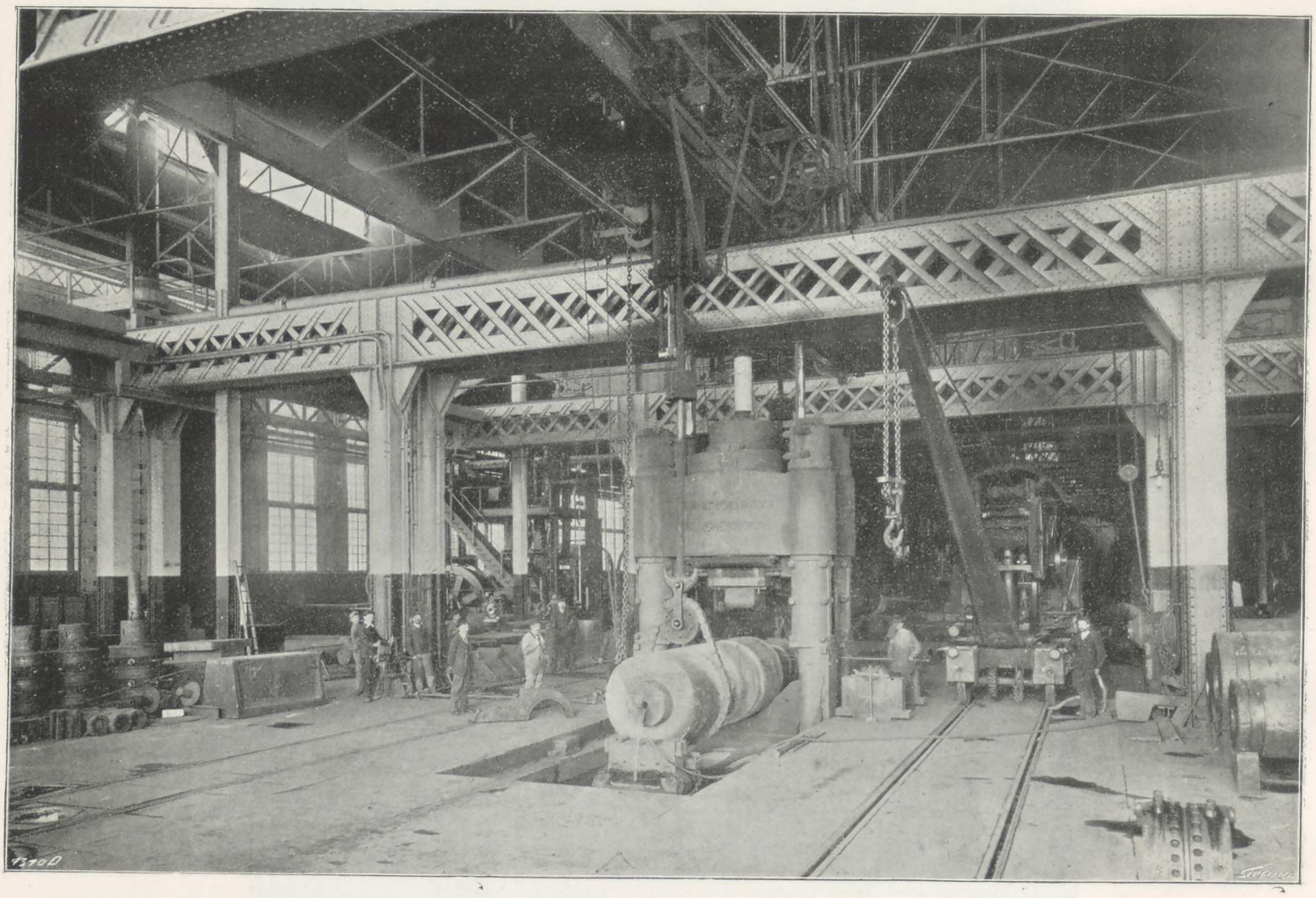


Fig. 148. 3,000-Ton Hydraulic Forging Press. (See page 61.)

placed in the works' engineer's office. This line receives, for each furnace, the current from a thermo-electric element (platinum, platinum rhodiumised), the hot soldering of which is in the inside of the floor of the cementing casing. The current to the switchboard is transferred, by the working of a commutator, to a mirror galvanometer, which indicates a simple relation between the electromotive force of the current and the heat of the furnace. The heat is thus regulated in such a way as to cause it to effect the maximum of cementation, there being no cause to fear surface melting of the plates.

During the operation, the tuyeres become obstructed with carbon deposits, and they have to be cleaned every hour with a wire. The plates are cooled gradually while remaining in the furnace.

Hardening Plant.—The horizontal hardening plant is placed approximately in the centre of the group of cementing furnaces just described, and in which the plates are heated. The pit containing the sprinkling jet apparatus is 8 metres (26 ft. 3 in.) long; 3.900 metres (12 ft. 10 in.) wide; and 4.300 metres (14 ft. 1 in.) deep. The series of tubes through which the lower surface of the plate is sprinkled, is mounted on a movable frame, placed higher or lower in the pit, according to the shape of the plate. Those tubes that sprinkle the upper surface are mounted on wheels. When the plate is laid on the bottom frame, the top series of tubes is brought over it, and connected to the water main leading from a reservoir, at such a level as to maintain a pressure of 3 kilogrammes per square centimetre (42.67 lb. per square inch.) Controlling valves are placed on the mains, in order to regulate the quantity of sprinkling water delivered.

The second water-hardening device consists of two wrought-iron tanks 6 metres (19 ft. 9 in.) long; and 3 metres (9 ft. 10 in.) high, placed in a pit. These tanks are 1.500 metres (4 ft. 11 in.) apart. The two inside walls of the tanks are drilled with holes 37½ millimetres (1½ in.) apart over the whole of their surface, and the tanks are divided horizontally into five water-tight compartments, each of which can be isolated by means of valves. By this arrangement it is possible to use only the exact number of holes required for sprinkling any particular plate. Further regulation is obtained by closing any excess number of holes with wooden plugs. The plates are heated vertically in furnaces to be described further on. They are carried by a special frame suspended to the travelling crane.

The method of vertical hardening by means of water jets has many advantages. The plate being suspended during the operation, it can be brought nearer one or the other of the perforated walls, in order to vary the rate of cooling on the adjacent surface, or it can be shifted to-and-fro in such a manner as to place a part of the surface outside the action of the jets.

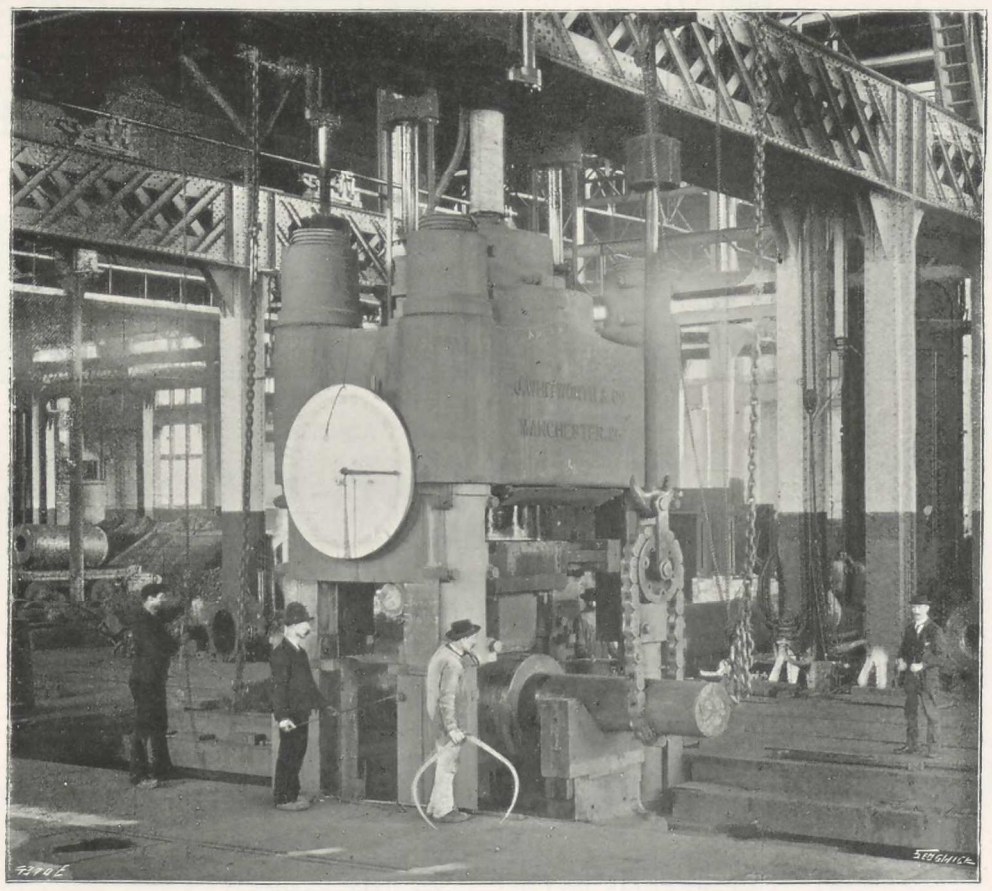


Fig. 149. 3,000-Ton Hydraulic Forging Press. (See page 61.)

Hardening by immersion is effected in a wrought-iron tank 5.500 metres (18 ft.) in diameter; and 7.300 metres (24 ft.) deep; this tank is filled, according to circumstances, either with oil or water. This plant is only now used for hardening special pieces, as armour-plates are always water-hardened by one or the other of the sprinkling processes above described. When a piece has to be hardened in water, a pump is used to empty the tank and transfer the oil to another reservoir; this pump also serves to agitate the oil or the water during the hardening operation. The oil can be afterwards admitted to the tank through a series of valves.

Two furnaces placed near the tank serve to heat large armour-plates vertically. One is 10 metres (32 ft. 9 in.) long; 3.500 metres (11 ft. 6 in.) high; and 1.500 metre (4 ft. 11 in.) wide. The top is closed by a movable arch, which is lifted off by a travelling crane when a plate is to be put in or taken out. The other furnace is 6 metres (19 ft. 8 in.) long, with three fires on each side. These furnaces are used for heating large armour-plates previous to their being hardened, either by immersion or by sprinkling. Thin plates are heated vertically in a similar furnace, and are hardened by immersion in a water tank placed in the same line as the furnace. This furnace can be opened at one end, and the plate dipped rapidly, without having lost any appreciable amount of heat. A fourth furnace, with a revolving hearth, is used for heating gun parts, such as hoops, trunnion rings, &c. Near this is a round wrought-iron tank filled with water, in which the pieces are dipped.

	m.	ft.	in.
Diameter of tank	2.450	8	$0\frac{1}{2}$
Depth	4.000	13	$1\frac{1}{2}$

Fig.150.

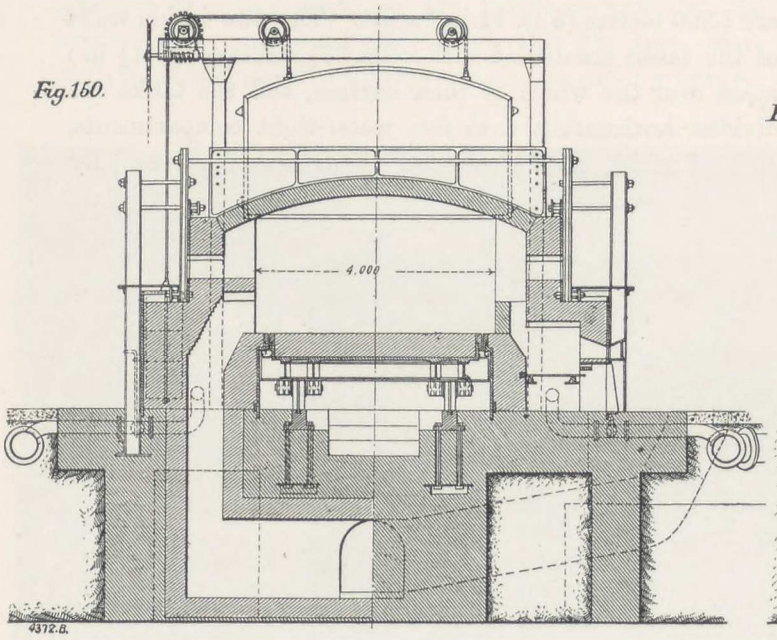


Fig.151.

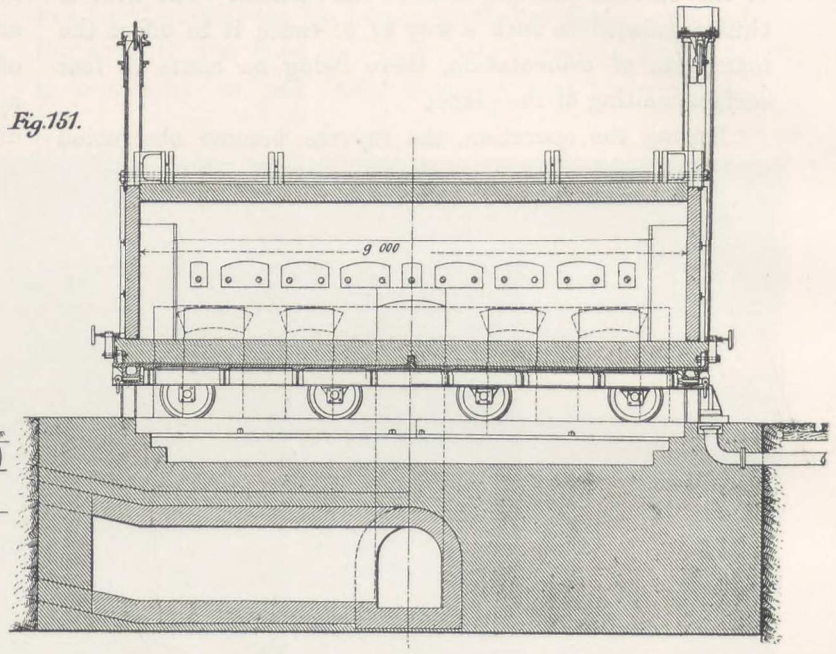
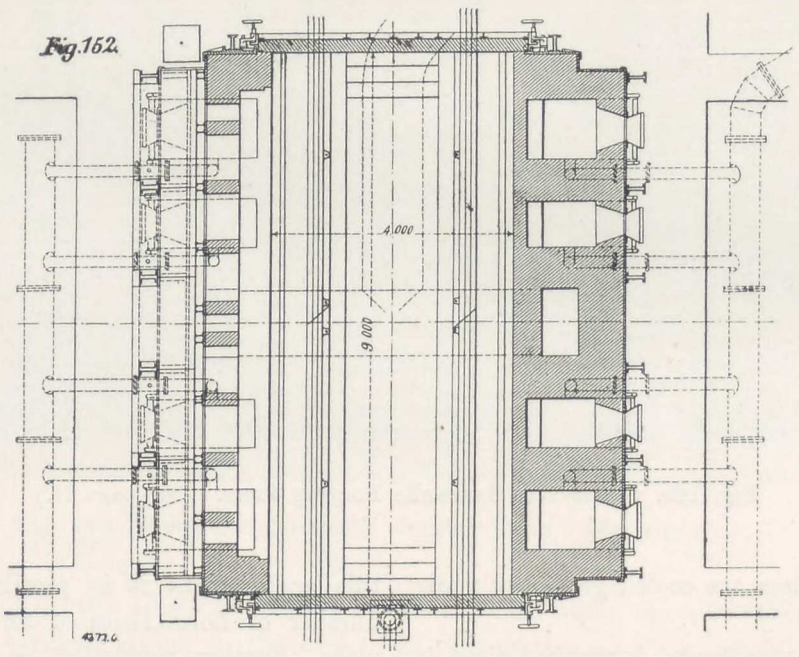


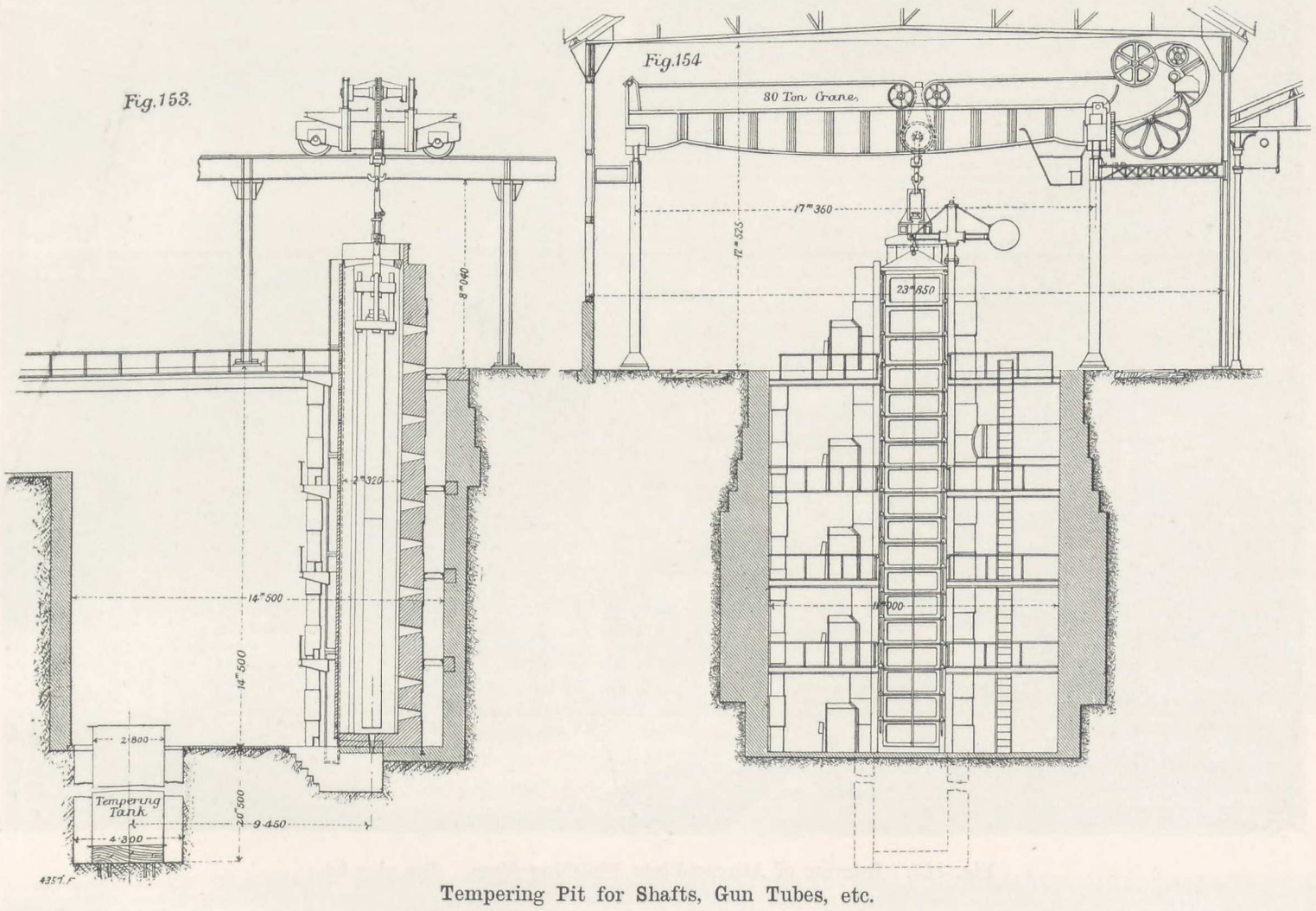
Fig.152.



Details of Cementing Furnace; Armour-Plate Department. (See page 62.)

The plant for gun tempering consists of two vertical furnaces and a tank, placed in a large pit 14.500 metres (47 ft. 7 in.) long; 11 metres (36 ft.) wide; and 14.500 metres (47 ft. 7 in.) deep. The large furnace is 18.300 metres (60 ft.) high; it is provided with five tiers of fires, one above the other. The gases escape on the opposite side, through a series of openings with outlets in a flue built up the whole height of the furnace. The side of the furnace which is nearest to the pit opens out in one piece for admitting and removing the pieces. The tempering tank can therefore be reached with little delay, as the piece has not to be lifted out of the furnace. The opening is closed by a kind of casing consisting of a series of iron frames lined with firebricks and connected together, the whole being suspended on a traverse beam that turns on a pivot. During the heating operation, the piece being treated is caused to revolve slowly (one revolution per minute) in order to obtain an equal distribution of heat on all points. The apparatus to which the piece is suspended, rests on a roller path, carried by a beam which is supported from the top of the furnace. The rotary motion is given by an electric motor. The tempering tank is placed opposite the furnace opening, 9.450 metres (31 ft.) distant from it; it is 2.800 metres (9 ft. 2 in.) in diameter, and 20.500 metres (67 ft. 3 in.) deep; its capacity is 125 cubic metres (4,415 cubic feet). The greatest length the present furnace can take is 16 metres (52 ft. 6 in.), but the tank can take a piece 18 metres (59 ft.) long. The tank is filled with water or oil, according to requirements; by means of a pump and special piping, oil or water can be delivered, during the period of tempering, inside hollow pieces under treatment. Figs. 153, 154 illustrate the arrangement of this tempering pit.

The armour-plate hardening tank, the oil reservoir, and the gun-tempering tank, are in communication with each other by means of pipes; this arrangement enables the oil to be circulated from one tank to another, according to the nature of work in progress.



Tempering Pit for Shafts, Gun Tubes, etc.

A second vertical furnace, but of reduced dimensions, is used for heating small and medium-sized pieces; its capacity is sufficient to take forgings 10 metres (32 ft. 9 in.) long. The piece is caused to revolve in this furnace during the heat; but instead of being suspended, it rests on the hearth which is set out on a centre. The furnace is on one side of the pit, in the same line as the tempering tank; it is opened in the same way as the larger one, and, as in the case of the other furnace, only a single movement is required to place the piece in the tank. To avoid loss of heat, it is absolutely necessary that the piece should be transferred quickly from the furnace to the tanks.

Electric Travellers.—All the appliances described above are served by two electric travellers, of 40 and

80 tons capacity, respectively. Both are fitted with powerful brakes, enabling the pieces to be lowered rapidly into the tanks. Owing to the great depth of the gun-tempering tank, both travellers are provided with a considerable length of chain. The vertical travel of the hook is 22 metres (75 ft.); the chains are plate chains; that for the 80-ton traveller is 74 metres (243 ft.) long and



Fig. 157. Interior of Armour-Plate Finishing Shop. (See page 69.)

weighs 11 tons. The following are some of the principal dimensions:

Distance from centre to centre of overhead tracks	17.350 m.	56 ft. 11 in.
Width served by the hook ...	15.550 m.	51 ft. 0 in.
Speed of travel (longitudinal) per minute	35 m.	114 ft. 10 in.
Travel of hook (transversely) per minute	20 m.	65 ft. 8 in.
Lifting speeds	3 m.	9 ft. 10 in. for heavy loads.
,, ...	6 m.	19 ft. 8 in. per minute for medium loads.

The 40-ton traveller is provided with a 75,000 watt dynamo, and the 80-ton traveller with a 100,000 watt dynamo. The electrical energy is supplied by two 220 volts direct-current generators, which give the power necessary for this department of the steel works. The current is taken for each traveller, on a main that extends the whole length of the works.

Ingot Preparing Shop.—The shop in which ingots undergo preparation, occupies the south-east end of the armour-plate building. It contains special machine tools, which cut and bore compressed steel ingots previous to their being distributed in the forging shop. The following tools may be mentioned among others: Two lathes 9.800 metres (32 ft. 2 in.), length of bed; 1.100 metres (3 ft. $7\frac{3}{8}$ in.), height of centres; to cut the ingots according to requirements. They are fitted with four tool-slides, that can work together and cut in two places at once. They are moreover, provided with the necessary tools to bore ingots 1.500 metres (4 ft. 11 in.) long. These lathes can take ingots up to 1.400 metres (4 ft. 7 in.) in diameter; 5.500 metres (18 ft. $0\frac{1}{2}$ in.) long; and weighing 60 tons. One roughing lathe, 1.525 metres (5 ft.) height of centres, and 16 metres (52 ft. 6 in.) length of bed; total length 22.500 metres (73 ft. 10 in.). This lathe can take pieces weighing as much as 100 tons. It can also bore pieces 10 metres (32 ft. 10 in.) in length. It is fitted with four

INGOT PREPARING SHOP.

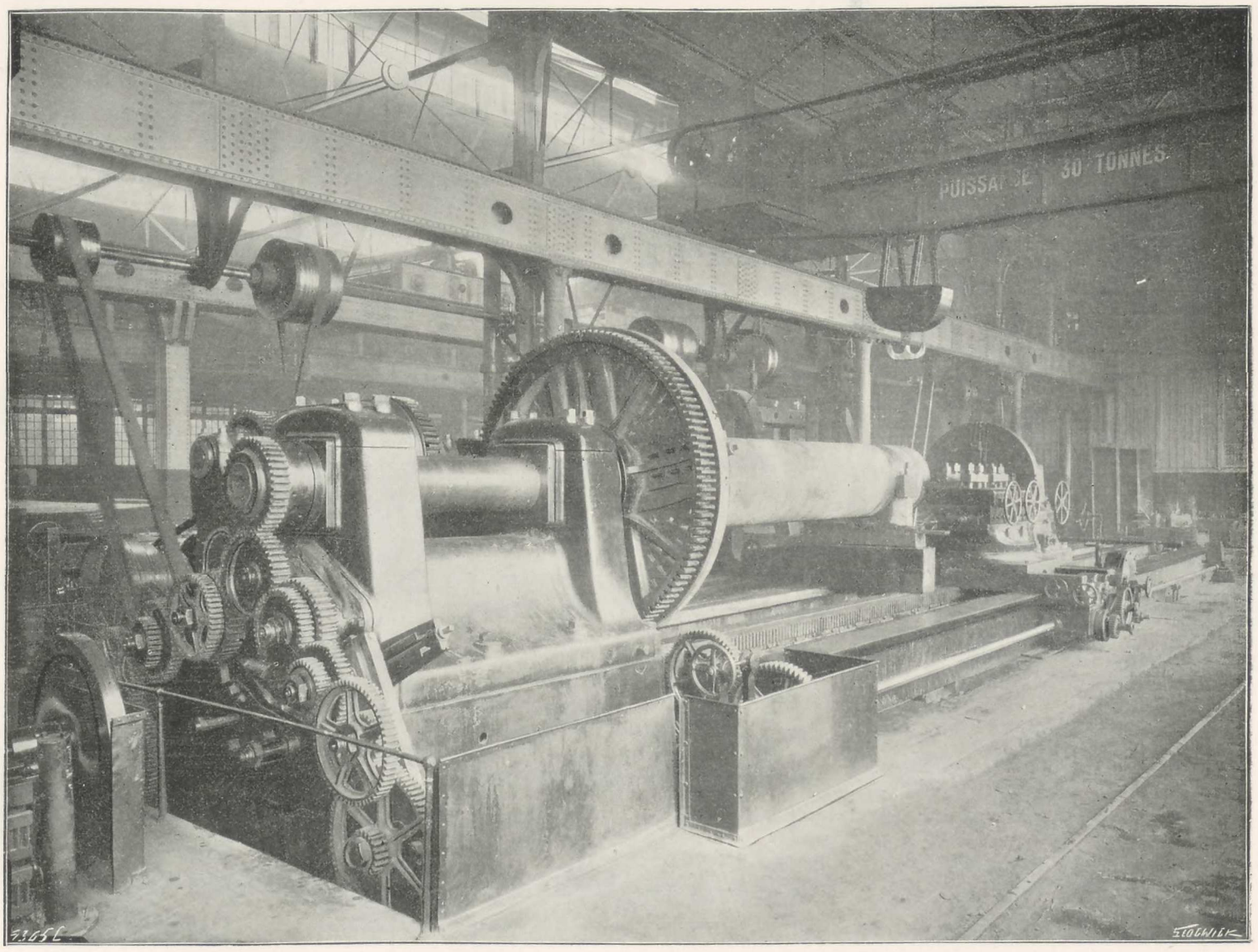


Fig. 155. Ingot and Gun Lathe.

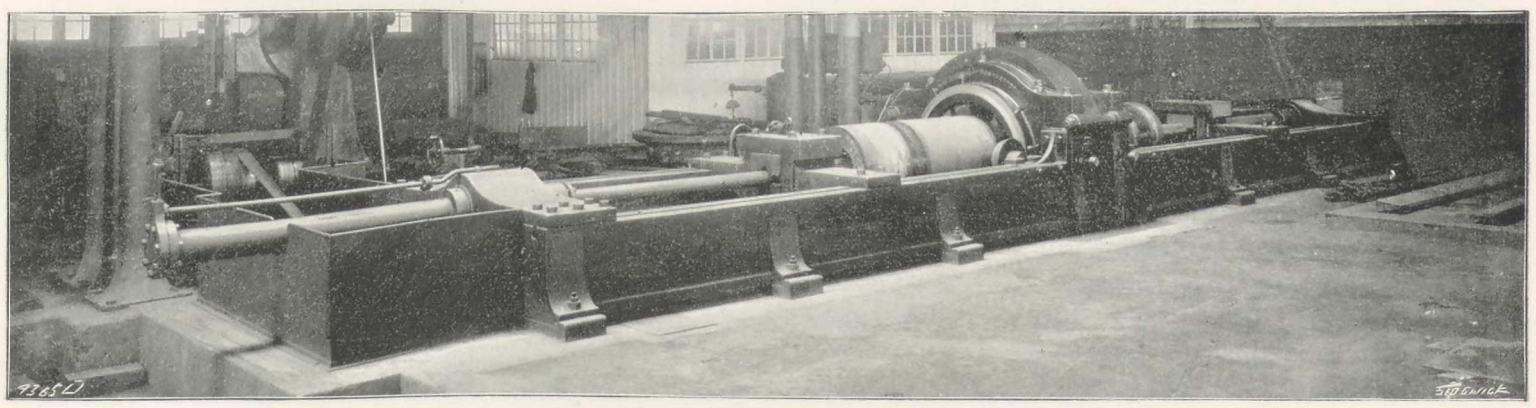


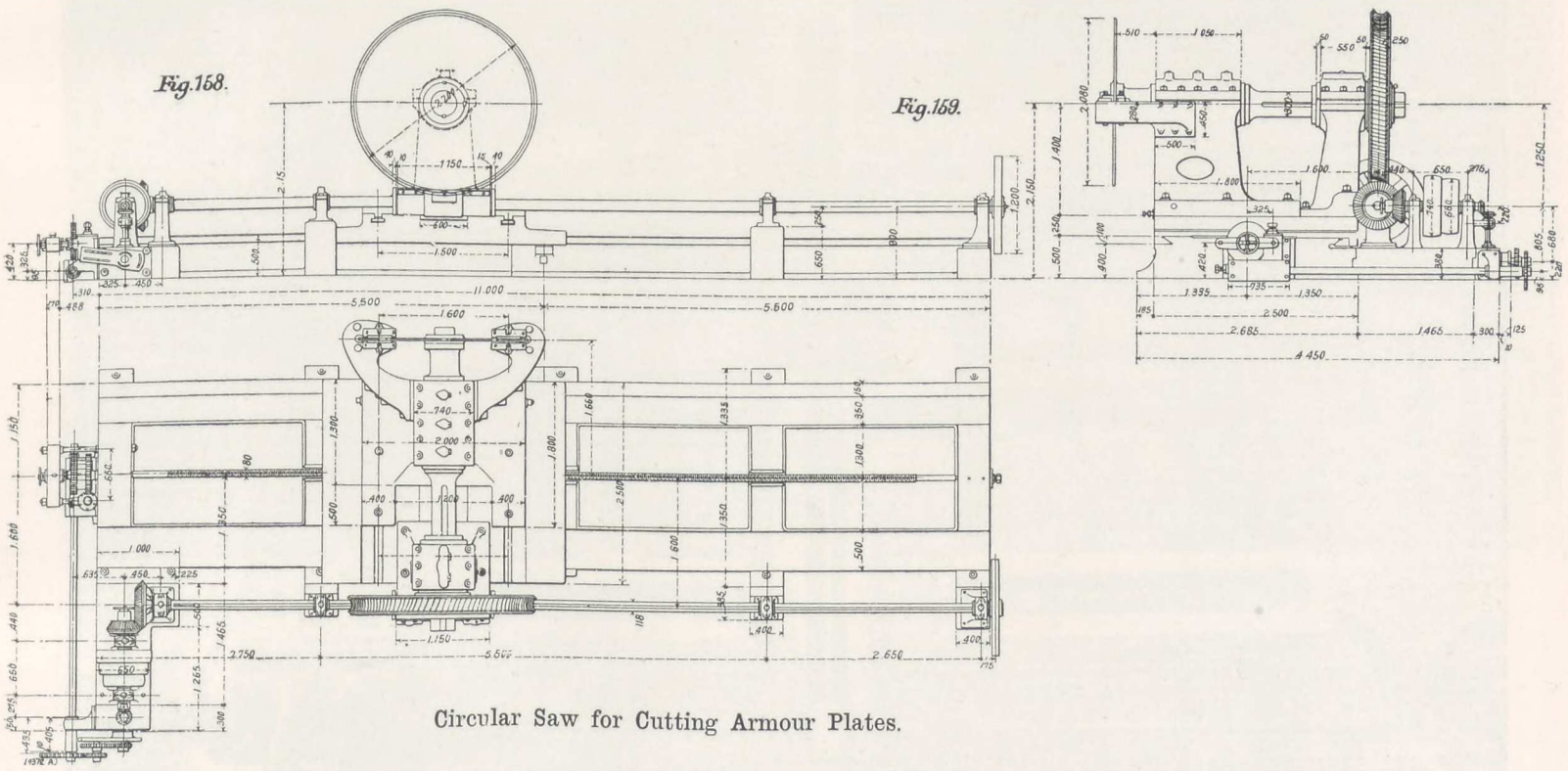
Fig. 156. Boring Machine for Compressed-Steel Ingots.

tool carrying slides. Total weight of the lathe 250 tons (see Fig. 155, Plate XXXII.). There is one boring machine, with an hydraulic feed device, to bore out ingots for the manufacture of hollow forgings. The ingot is fixed in a revolving jacket, placed on the middle of the length of the frame. Boring is carried on at both ends simultaneously by means of two boring bars, which are kept at a regular feed by two hydraulic rams. These bars are of two kinds, one boring out a central core, the other clearing out the central part (Fig. 156, Plate XXXII.). Some specifications require that the core be inspected, in order to ascertain that the ingot does not contain any internal flaws.

	m.	ft. in.
Diameter of largest ingots bored...	1.400	4 7
Length	6.000	19 8
Diameter of usual bore	0.400	1 4

Fig. 158.

Fig. 159.



Circular Saw for Cutting Armour Plates.

Ingots can be finish-bored up to .800 metre diameter (2 ft. 7½ in.).

Another powerful lathe is used for cutting up very large ingots, and to rough-turn heavy forgings. It can work pieces weighing up to 100 tons.

	m.	ft. in.
Length of bed	17.500	57 5
Height of centres	1.500	4 11
Length between centres	16.700	54 9
Diameter of faceplate	3.000	9 10

There are four tool-holders, two on each side. The total weight of this lathe is 312 tons.

Near these lathes is a powerful vertical finish-boring machine, placed in a pit, and which is used for finishing the inside surfaces of turret armour. It can treat cylindrical or conical turrets 5 metres (16 ft. 6 in.) in diameter and 6.600 metres (21 ft. 8 in.) high.

Each one of these machine tools is driven by a separate dynamo. The pieces are lifted in and out of place by the two travellers of 40 and 80 tons already described.

Armour-Plate Finishing Shop (Fig. 157).—As a rule, the armour-plates on leaving the steam hammer or the rolling mill, are moulded to shape and then cut to size. The cutting is done by circular saws of a special type designed and manufactured by Messrs. Schneider and Co. The plate is fixed, while the saw travels forward. These machines are of two sizes.

The largest-sized machine (Figs. 158, 159) for finishing thick plates, consists of a low frame 11 metres (36 ft.) long; 2.300 metres (7 ft. 6½ in.) wide; and of a slide on which are mounted two headstocks, one carrying a shaft, at one end of which is fixed the circular saw, a large toothed wheel gearing in a screw being fixed at the other end. A shaft runs the whole length of the machine, and is set in motion by a transmission fitted on the end of the frame. The driving screw which sets the toothed wheel in motion is placed in a casing that forms one piece with the headstock on that side, and travels forward with it. The shaft is formed with a groove on its whole length, in which slides a screw key. The headstock on the side of the saw is made to slide crosswise, to facilitate the regulation of the cut. When the plate has been put in place and strongly bolted down, the line of cut being parallel to the machine frame, the saw is made to advance in place exactly opposite the line of cut. This is easily determined, as the shaft on which the saw is fixed, can move to-and-fro in the toothed wheel on the opposite side.

The saw is a hard-steel disc 22 millimetres (⅞ in.) thick, with 76 tool-sockets 24 millimetres (1 5/16 in.) wide, and 70 millimetres (2¾ in.) deep around its periphery; these sockets contain an equal number of cutters, half of which are 25 millimetres (1 in. bare) wide, the other half being

12 millimetres ($\frac{1}{2}$ in. bare) wide, the latter tools jutting out 2 millimetres ($\frac{1}{16}$ in.) over the wider ones, in order to divide the steel cuttings in two. These cutting tools are held in place, each by two screws, one at the back which acts as a thrust and serves to place them all at the same distance from the centre; the other holding the tool firm in its socket. The tools are manufactured entirely by a shaping machine; each one requires 14 operations to give it the necessary form. A special process enables them, however, to be manufactured in quantity at the cost of 2d. each. The proper feed of the saw in the plate is insured by a screw which draws forward the saw-carrying frame. The speed varies according to the hardness and thickness of the plates; for nickel-steel plates .300 metre ($11\frac{13}{16}$ in.) thick, the travel is .120 metre ($4\frac{3}{4}$ in.). These machines can cut plates 8 metres (26 ft. 3 in.) long and .600 metre ($23\frac{5}{8}$ in.) thick as a maximum.

	m.	ft.	in.
Diameter of saw	2.050	6	$8\frac{11}{16}$
Speed at circumference per minute	4.200	13	$9\frac{3}{8}$

The shop contains five large sawing machines and three smaller ones for thin plates. The latter are of the same type as the heavier ones, but the saw is .964 metre (38 in.) in diameter, and carries only 38 tools, 19 being 15 millimetres ($\frac{5}{8}$ in.) wide at the cutting part, and the remainder 8 millimetres ($\frac{5}{16}$ in.).

Planing and Finishing Armour Plates.—The plates on leaving the saws are cemented and water-hardened; they are then carried back to the finishing shop to be given their final shape. This operation is completed by a series of planing machines of various types, adapted to different natures of work. The edges of the plates are usually surfaced with side-planing machines. The plate is fixed flat on a table, and the edge is brought under a travelling tool (Fig. 160). Several of these machines are fitted with special appliances for planing rabbets on curved plates. Figs. 161 and 162 show the arrangement for planing turret-plates. Those for side armour, with a strong curve, are laid down on the slab, and a template, giving exactly the shape of the rabbet, is placed on them and serves as a guide. The tool-holder is free to move vertically, and carries a roller which travels on the template and controls the cut. Motion is given to the

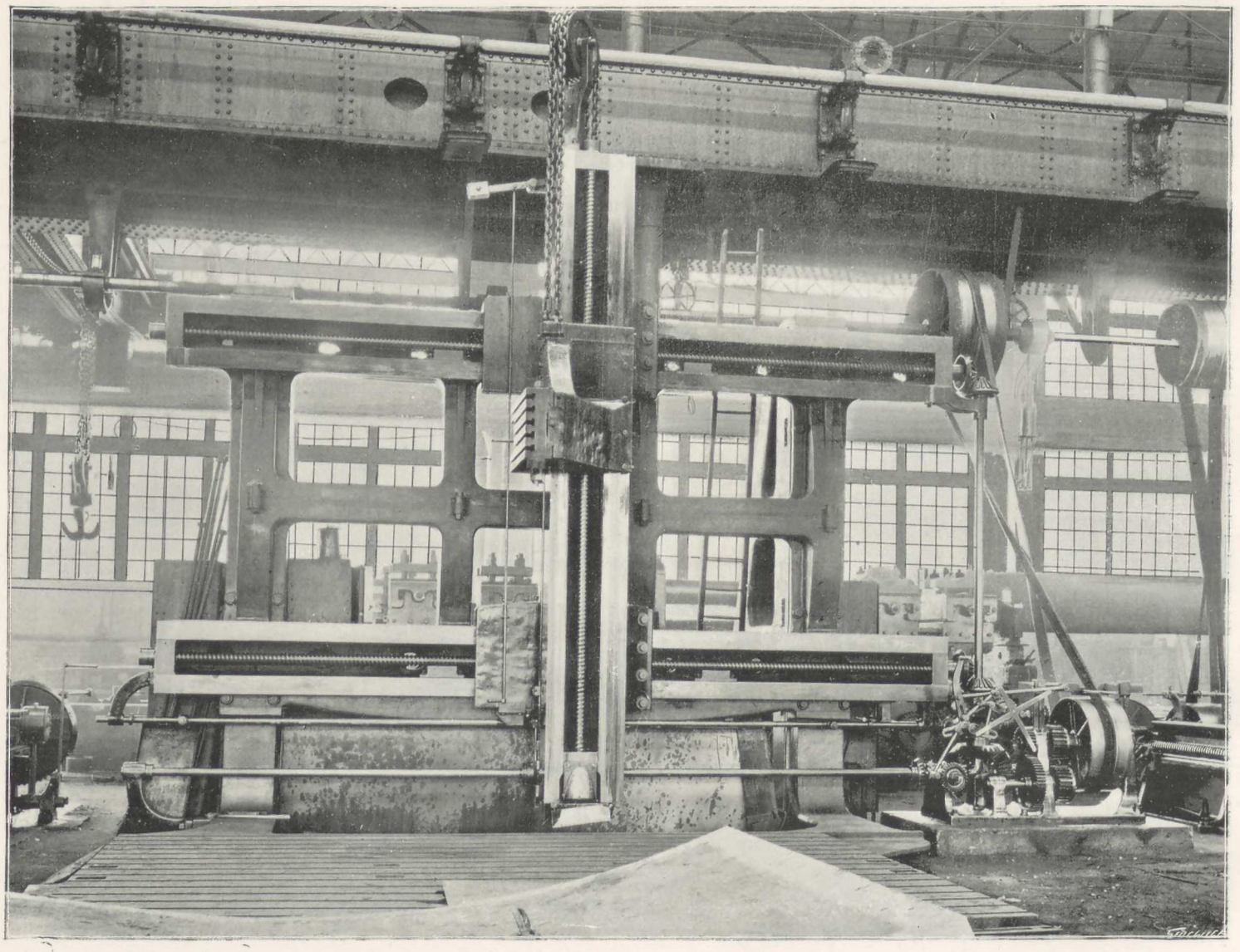


Fig. 160. Vertical and Horizontal Planing Machine for Armour Plates.

THE ARMOUR PLATE DEPARTMENT.

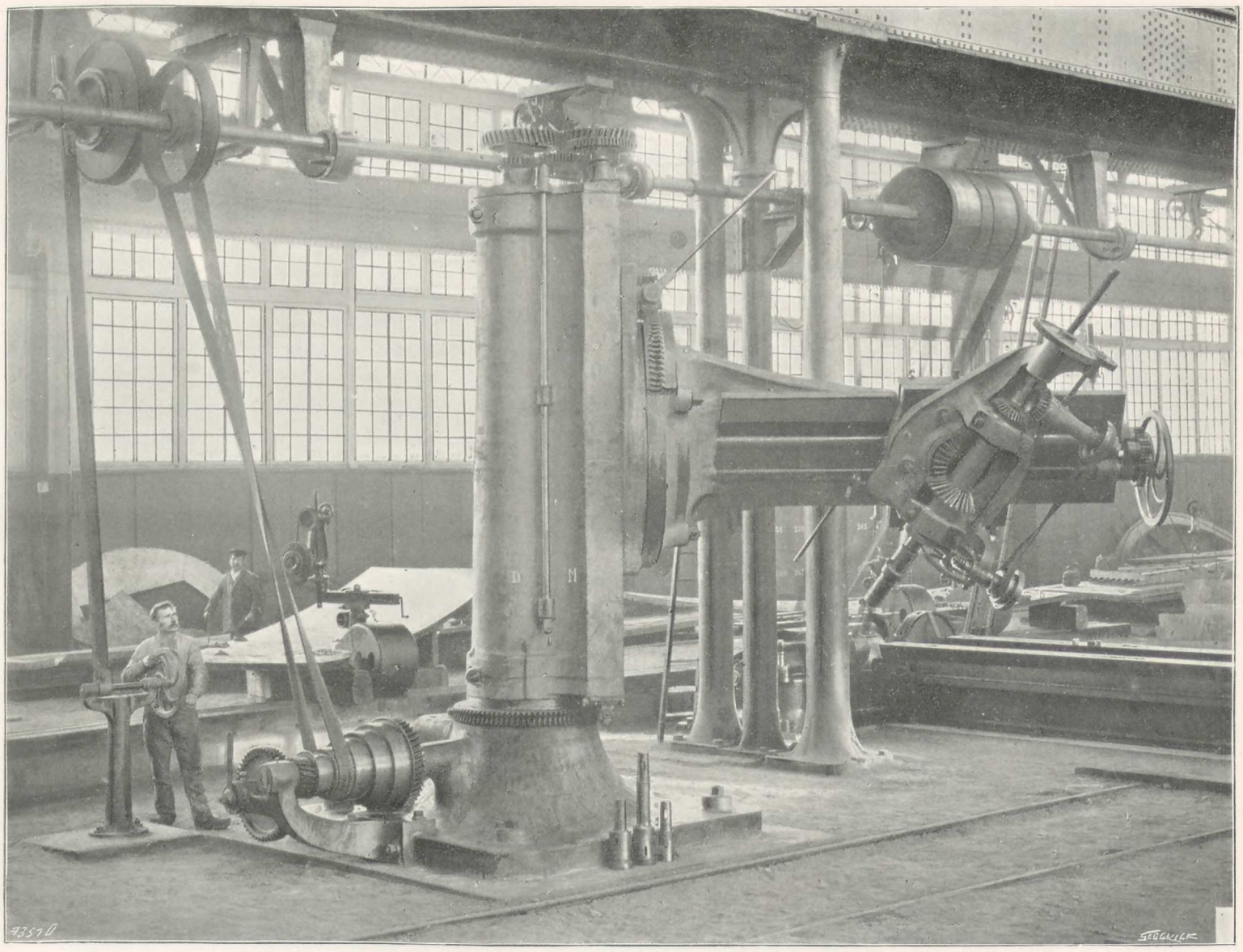


Fig. 163. Drilling and Tapping Machine for Armour Plate.

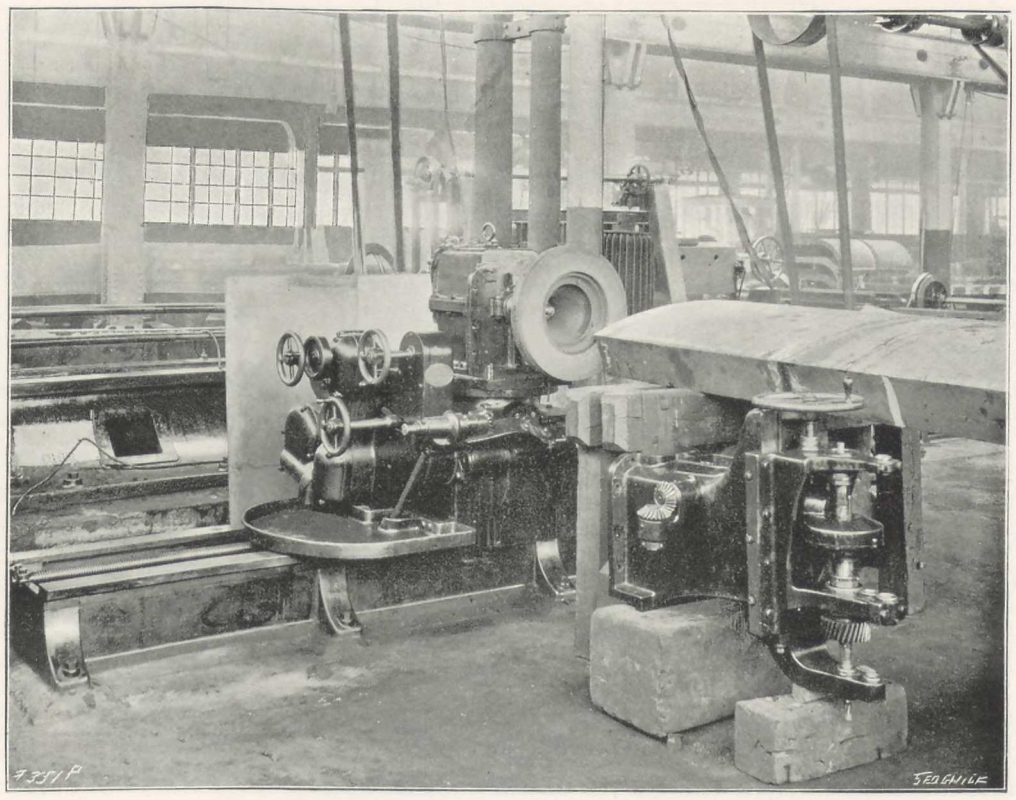


Fig. 164. Machine for Finishing Edges of Armour Plates.

slide by a double-screwed shaft .122 metre ($4\frac{3}{4}$ in.) in diameter.

	m.	ft. in.
Length of frame	11.000	36 1
Travel of slide	9.000	29 6
Vertical travel of tool	1.200	3 $11\frac{1}{4}$
Speed of cutting per minute ...	4.200	13 $9\frac{3}{8}$

There are six such planing machines in the works, all of them having been designed and built by Messrs. Schneider and Co.

When the edge has a winding surface, as is often the case for side armour-plates, it is finished by a special tool called the winding-surface planing machine. It consists of two cast-iron frames 3.600 metres (11 ft. 10 in.) apart from centre to centre. On these is a clear space between two uprights, which slide on the frames and carry a cross-piece on which is fixed the tool-holder. The cross-piece

Fig. 161.

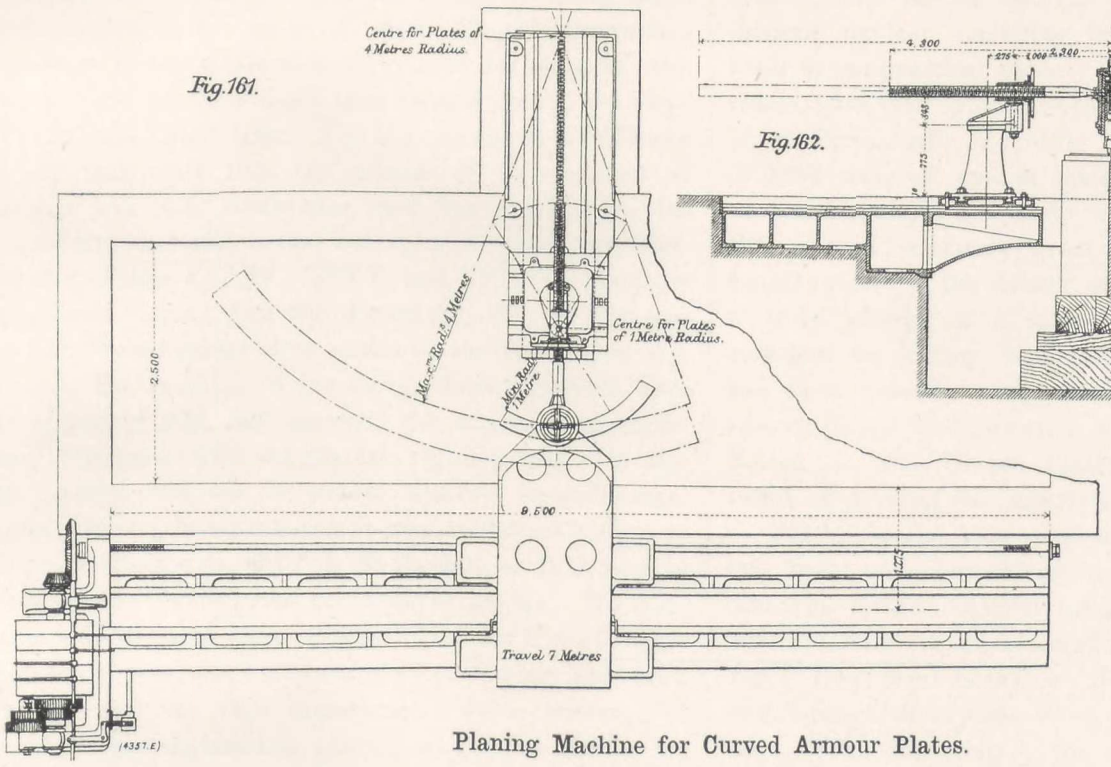


Fig. 162.

Planing Machine for Curved Armour Plates.

can be raised or lowered at will, in order to bring the tool to the height of the edge which requires planing. The tool-holder is mounted on a vertical sector which allows it to cant to any desired angle. The plate is fixed in a pit between the two frames; the workman holds the levers which control the incline of the tool and cause the crosshead to travel up and down. He can thus vary the position of the tool after each cut, and follow exactly the two lines marked out, and which indicate the winding surface to be given to the plate. The following are the principal dimensions of this machine.

Length of frames	8.000 m.	26 ft. 3 in.
Width of pit	2.500 m.	8 ft. $2\frac{7}{16}$ in.
Length ,, ...	7.850 m.	25 ft. 9 in.
Depth ,, ...	2.600 m.	8 ft. $6\frac{3}{8}$ in.
Travel of tool carrying slide lengthwise	6.000 m.	19 ft. 8 in.
Travel of tool crosswise	.900 m.	$35\frac{7}{16}$ in.
Incline of tool holding slide ...	15 deg. on either side of horizontal.	15 deg. on either side of horizontal.

The horizontal motion is obtained by two screwed shafts, one on each frame, which pass through nuts fixed in the foot of the movable crosshead uprights.

Near this tool is a shaping machine, the cutters of which can be inclined at will; this can also be employed in finishing winding surfaces.

There are, besides, two large planing machines for flat surfaces, and two vertical and horizontal planing machines, which are used specially for planing port-holes and other openings in armour; this work is done vertically.

Drilling and Tapping. — Holes in armour-plate are drilled and tapped after the plates have been hardened; this work is not attended by many difficulties, as the holes are made in the surface which has not been hardened. When — which seldom happens — a hardened surface has to be drilled, the metal at the particular spot is previously softened.

There are three large radial drilling machines (see Fig. 163, Plate XXXIII.) for thick plates and six smaller ones for deck plates. There are also a milling machine, driven electrically for finishing the edges of the hardened surfaces; a large milling machine (Fig. 164, Plate XXXIII.), 32 ft. 10 in. length of bed, and .900 metre ($35\frac{1}{2}$ in.) cross travel; a trimming machine .900 metre ($35\frac{1}{2}$ in.) vertical travel; a face-plate planing machine; a horizontal drilling machine; a lathe for sectioning ingots and gun hoops; and a boring machine. There are in all fifty-seven machine tools, with which the manufacture of all the varied shapes of armour-plates are completed.

The shop is divided into three bays on its width; the centre one, which contains all the principal tools, is 25 metres (82 in.) wide, and the two side bays are 12.500 metres (41 ft.). The total length is 120 metres (393 ft.

8 in.). Each bay has one or two electric travellers of 30 to 50 tons capacity. Two main transmission shafts, each 393 ft. 8 in. in length, driven at 120 revolutions per minute, give the motion to the various machines. The main engine is of the Corliss condensing type of 450 horse-power.

Diameter of cylinder	0.750 m.	2 ft. $5\frac{1}{2}$ in.
Stroke	1.400 m.	4 ft. $7\frac{1}{8}$ in.
Revolutions per minute	60	60

This engine also works two direct-current dynamos, of 220 volts, which supply power to all the electric apparatus, travellers, tools, &c.; and it drives the dynamo of the electric welding apparatus.

The steam required for the steam engines and hammers is supplied by a range of eight tubular boilers, with two inside fire-boxes, and by the boilers which are heated by the waste gases from the furnaces. Three of the cementing furnaces are also provided with boilers.

The plant is completed by a repairing and maintenance shop.

Summary.—Below is given a recapitulation of the principal machines and tools contained in this important department.

4 Steam hammers.	12 Pivoting cranes.
3 Forging presses.	15 Travelling ,,
2 Moulding ,,	5 Portable steam cranes.
27 Reheating furnaces.	57 Machine tools.
5 Cementing ,,	6 Pumping machines.
6 Hardening tanks.	31 Steam boilers.

XV.—ARMOUR-PLATES.

UNTIL 1876 the calibre of guns used for firing against armour was progressively increased, culminating in the production of the 100-ton, and heavier guns; as a necessary consequence, the thickness of armour-plates was also increased, and unceasing efforts were made to improve the quality of material, and the methods of manufacture.

To Messrs. Schneider and Co. belongs the credit of being the first to manufacture, and submit for firing trials, thick armour-plates made of steel. To this interesting departure in the production of armour for ships of war, dating back now for more than twenty years, we shall refer in more detail later. For the present it is sufficient to say that since 1876 the process of development at Creusot has been continuous, and has resulted in the magnificent material, a few examples of which are illustrated on Plates XXXIV., XXXV., and XXXVI. For more than sixty years before the Armstrong 100-ton gun was fired at the Schneider steel plates in the Italian proving-grounds, the question of protecting ships and forts from the effects of shot, had occupied the attention of engineers. Compared with the gigantic requirements of to-day, the problem was one of almost absolute insignificance; but everything being relative, it was as desirable then to keep out the round 32-lb. or 64-lb. shot, as it is now to break up the heaviest steel projectile of to-day. We must go back to the time when England and the United States had been at war, and the question of protecting New York Harbour was of vital importance. John Stevens, of Hoboken, an engineering genius, who lived before his proper time, had conceived — and for more than fifty years his idea was laboured at by himself and his sons— the plan of a steam-propelled and rotating floating battery, the guns of which should be sheltered behind the iron-plated walls of a turret. The experiments made at that early date were very limited, and are of historical interest only.

Passing by Colonel Paixhan's recommendation in 1821 for protecting shore batteries with iron armour, we come to the actual trials made in 1827 by Major-General Ford at Woolwich. The structure consisted of a granite wall 7 ft. thick, faced with two layers of iron bars, the inner one attached horizontally, and $1\frac{1}{4}$ in. square; the outer row, fixed vertically, consisted of bars $1\frac{1}{2}$ in. square. After twenty rounds from a 24-pounder gun, at 634 yards' range, the defence was practically destroyed. In this, the first-recorded, of the not-yet-ended, struggle between gun and armour, victory lay with the former, as it has continued to do for the most part ever since. Messrs. Stevens, of Hoboken, appear to have carried out long and costly, though quite futile, experiments, on the subject of armour and projectiles. In 1841 they were in a position to form the conclusion that 4-in. wrought-iron plates would suffice to keep out 9-in. shell fired at short range. It was on this deduction that the Stevens battery was finally completed about 1853, at an enormous cost, embodying many modern devices, including breechloading guns, but of little or no practical value. From 1846 to 1856 experiments with iron armour were almost continuously carried on at Portsmouth and other British dockyards. Those of 1854 were of special interest. The target consisted of $4\frac{1}{2}$-in. wrought-iron plate on a heavy timber backing; this showed relatively great power of defence, but it could not resist the attack of a 68-pounder fired with a 16-lb. charge, at a range of 400 yards. This was sufficient to destroy both target and backing. During the same period, many interesting experiments with armour-plated land batteries were carried out by General Totten in the United States, and always with the result of proving the superiority of the gun.

But by far the most important work done during the ten years under consideration, was that of Dupuy de Lôme, in France. Under his auspices, floating batteries had been built for service in the Baltic during the Crimean War; they were heavy wooden-framed vessels covered with wrought-iron plates $4\frac{1}{2}$ in. thick, 3 ft. long, and 20 in. wide. The following is an extract from a report by Commander Dahlgren, on their performance in action: "The French floating batteries, 'Devastation,' 'Lave,' and 'Tonnante,' steamed in to make their first essay, anchoring some 600 or 700 yards off the south-east bastion of Fort Kinburn. . . . The Russians could only reply with eighty-one cannon and mortars, and no gun of heavier calibre than 32-pounders, while many were lower . . . This was the sole occasion in which the floating batteries had an opportunity of proving their endurance. . . . They were hulled repeatedly by shot; one of them (the 'Devastation'), it is said, sixty-seven times, without any other effect on the stout iron plates than to dent them, at the most $1\frac{1}{2}$ in. Still there were ten men killed and wounded in this battery by shot and shell which entered the ports." The armour-plates scored an easy victory over the guns, at this, the first and last engagement (if we except some of the naval fights during the American Civil War), fought under conditions that were soon to become obsolete. The end of the Crimean War witnessed the end

also of the old order of artillery, and the creation in 1855 of the first Armstrong breechloading gun. From that time, in this country and abroad, dates the revolution in the construction of artillery which culminated, as regards weight and calibre, with the 100-ton Armstrong gun of 1876, and the far more formidable weapons of to-day, produced by the same firm, by Schneider and Co., Krupp, and a few others, at the present time. The great and rapid changes in gun construction since 1855 have given problems more and more difficult of solution to the manufacturer of armour, for the power of the attack advanced always more rapidly than that of the defence. The first record of a steel plate being tested is one that was tried at Woolwich in 1857; it was but 2 in. thick, and failed rapidly, as did also the 4-in. wrought-iron plate, with 2 ft. of oak backing, that was broken up the same year, also at Woolwich, by wrought-iron shot. It is of interest to note that a steel plate, at a little later date, was fired at in Russia, with somewhat better results. The next six years brought remarkable developments, both in guns and armour; manufacturers still famous in their specialty, such as Brown and Cammell, had succeeded in the commercial production of iron armour-plates up to 6 in. in thickness, while gun-makers like Armstrong and Whitworth were making artillery of such calibre and energy as to still maintain the balance in favour of the guns. Round shot had given place to pointed projectiles, either of chilled cast iron, like the Palliser; of wrought iron case-hardened; or of Bessemer steel. The following list of armour-plates that were tested at Portsmouth in February, 1864, will give an idea of the condition of the industry at that time in Great Britain.

Names of Makers.	Ship for which Plates were made.	Thickness of Wrought Iron.
John Brown and Co....	"Lord Warden"	$5\frac{1}{2}$ in.
,, ,, ...	,, ,,	$4\frac{1}{2}$,,
,, ,, ...	"Royal Alfred"	$4\frac{1}{2}$,,
,, ,, ...	"Prince Albert"	$4\frac{1}{2}$,,
Mersey Company ...	"Agincourt"	$5\frac{1}{2}$,,
Cammell and Co. ...	"Lord Clyde"	$5\frac{1}{2}$,,
Millwall Company ...	"Bellerophon"	6 ,,
Beale and Co.	"Pallas"	$4\frac{1}{2}$,,

As we have seen, it is to the French engineer Dupuy de Lôme, in 1854, that is due the credit of being the first to design and have constructed, floating batteries for actual warfare, protected with iron armour. The plates for the "Lave," "Tonnante," and "Devastation" were manufactured by Messrs. Schneider and Co. The first armoured frigates, "Gloire" and "Heroine," were built immediately afterwards; their iron armour-plates were 12 centimetres ($4\frac{3}{4}$ in.) thick, and resisted fairly well the fire from all the guns of the time.

The building of the "Gloire" may be regarded as the real starting-point of the armour-plate industry; from that time dates also the serious beginning of the struggle between projectile and armour Since then armour-plate makers have been constantly engaged in devising means to produce plates that shall be successful in warding off every blow; and on their side the gun-makers have been equally energetic in making guns of increased resistance, higher velocities, and flatter trajectories; whilst improvements in the manufacture of projectiles and explosives have been equally progressive.

In the foregoing paragraphs some general idea has been given of the early development of the armour-plate industry, and we may now pass on to consider the great part taken by Messrs. Schneider and Co. in the more recent and important developments, commencing with the year 1876, when the Italian Government was building the two great battleships "Duilio" and "Dandolo." It was at this time that Messrs. Schneider and Co. decided upon the series of now historic trials, with the view of proving the superior value of steel over iron for armour-plates. These trials were conducted at the proving-yard of Muggiano, near Spezia; they took place in September and October, 1876, and demonstrated the superiority of Messrs. Schneider and Co.'s steel plate over the others tested at the same time. The order for the "Duilio" and "Dandolo" steel armour was immediately after given to Creusot. Imperfect as were these early plates, compared with those they now manufacture, the advantages to be derived by the use of all-steel plates became apparent to the naval advisers of many Governments; and the conclusion was very widely arrived at, that iron had become inadequate for ship protection, and had to be abandoned.

Thus in July, 1879, the Danish Navy, instituted competitive trials at the Amager proving-yard, near Copenhagen. At these trials the Creusot plate was not the only steel plate tested; other makers, whose interest had been aroused by the result of the Muggiano trials, also sent steel plates for test. The trials at Amager, however, established the superiority of "Schneider-metal" and the "Tordenskjold" deck-armour and turrets were ordered from Creusot. After the value of steel plates had been established, the manufacture of compound armour was commenced in Great Britain. This type was invented by Mr., now Sir Alexander, Wilson; it gave from the beginning satisfactory results in many cases, and was adopted by various navies. Meantime Messrs. Schneider and Co. were steadily working out improvements in the manufacture of homogeneous steel armour, with the result that the resisting power of their plates was constantly increasing; they obtained at this period, from the French Government, the order for the "Terrible's" armour. Other important trials took place at the Muggiano proving-yard, in November, 1882, and in October and November, 1884, which resulted in Messrs. Schneider and Co. obtaining the order for the "Lepanto's" armour-plates. These trials were so conclusive that the Terni Company decided to put down a powerful plant for the manufacture of plates on the Schneider process. The 1882 trials resulted also in deciding the Italian and the French Navy, and subsequently other navies also, to adopt the Schneider patent armour-plate bolt.



Fig. 165. "Terrible," 19.69 in. and 15.83 in.



Fig. 166. "Cataluña," 9.84 in.

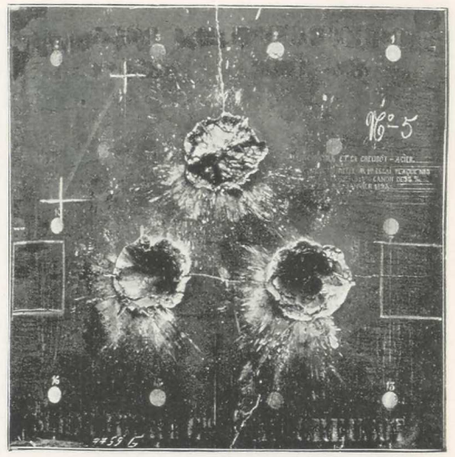


Fig. 167. "Tréhouart," 12.60 in.

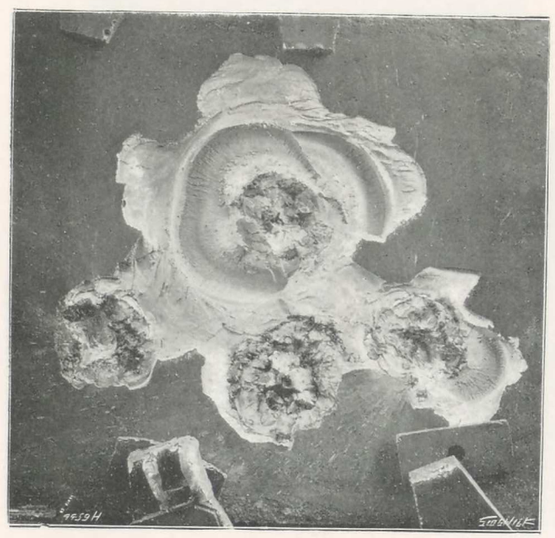


Fig. 168. Experimental Plate 6.14 in.

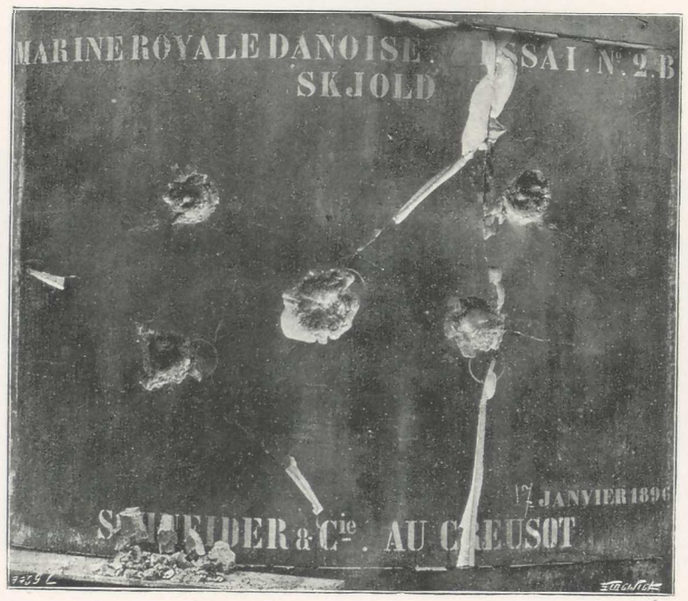


Fig. 169. "Skjold," 7.87 in.

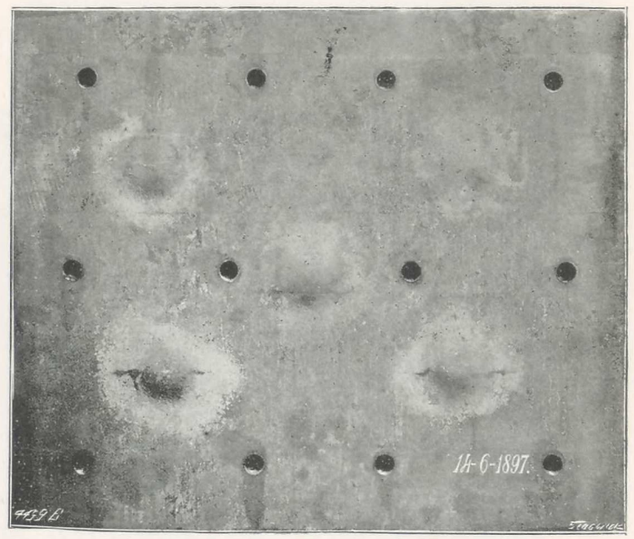


Fig. 170. "Cataluña," 9.84 in. (Back).

TESTED ARMOUR PLATES.

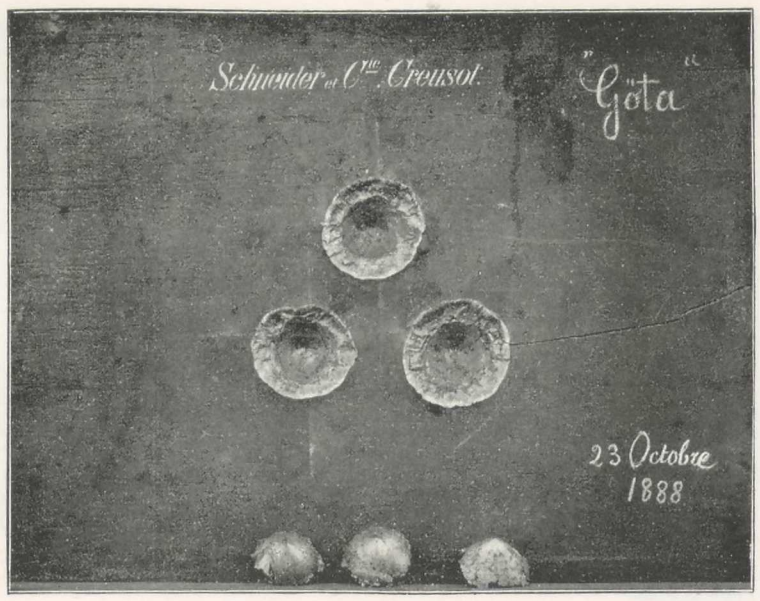


Fig. 171. "Gota," 9.56 in.



Fig. 175. "Massena," 3.94 in.

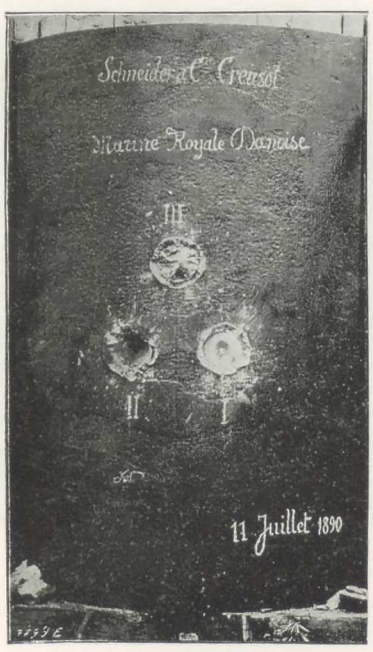


Fig. 172 (Front).

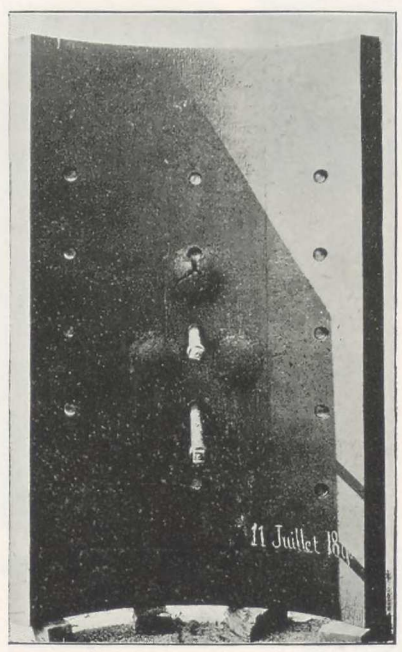


Fig. 173 (Back).

"Tordenskjold," 4.52 in.

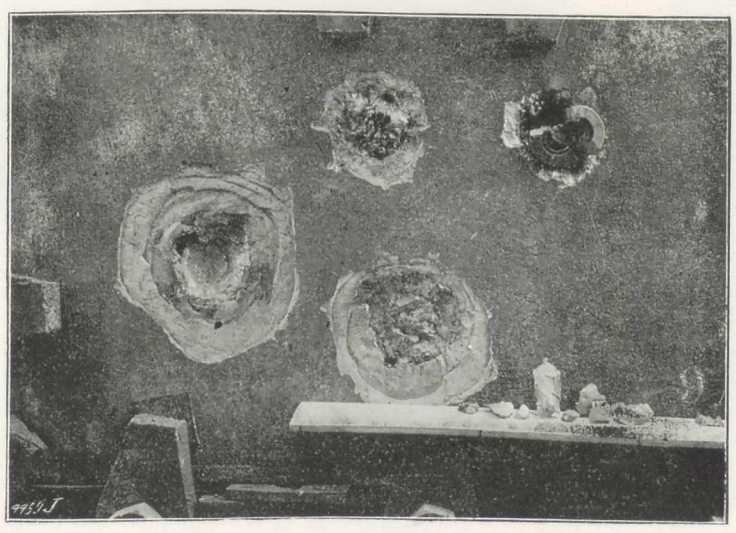


Fig. 174. Experimental Plate, 6.14 in.



Fig. 176. "Gaulois," 10.63 in.

TESTED ARMOUR PLATES.

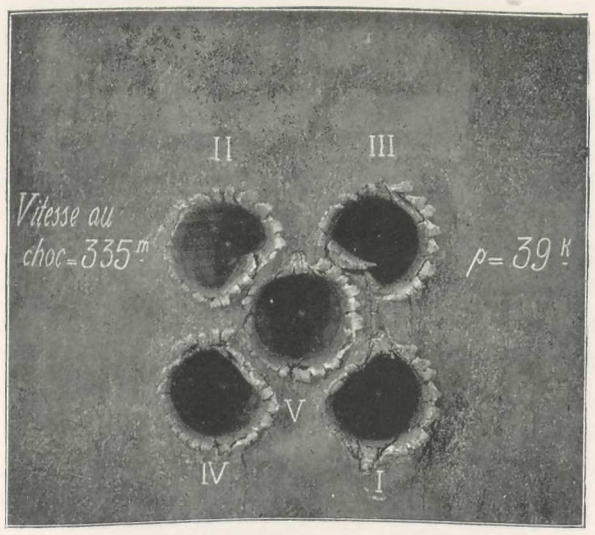


Fig. 177. 4.72 in.

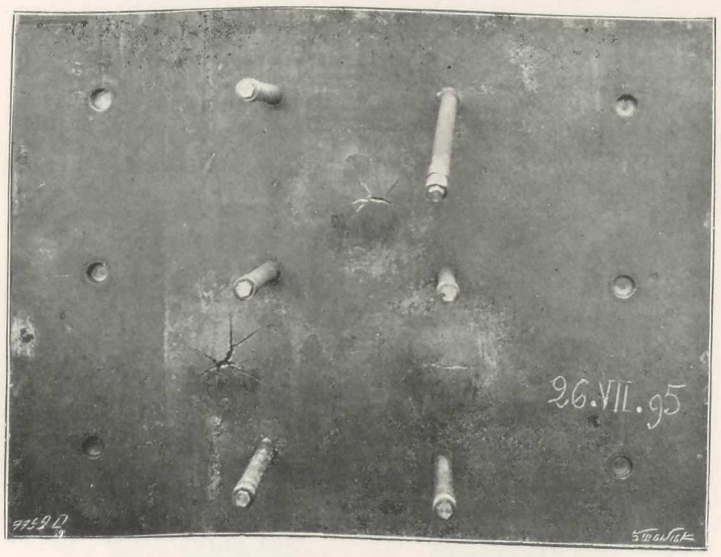


Fig. 178. "Oden," 9.84 in. (Back).

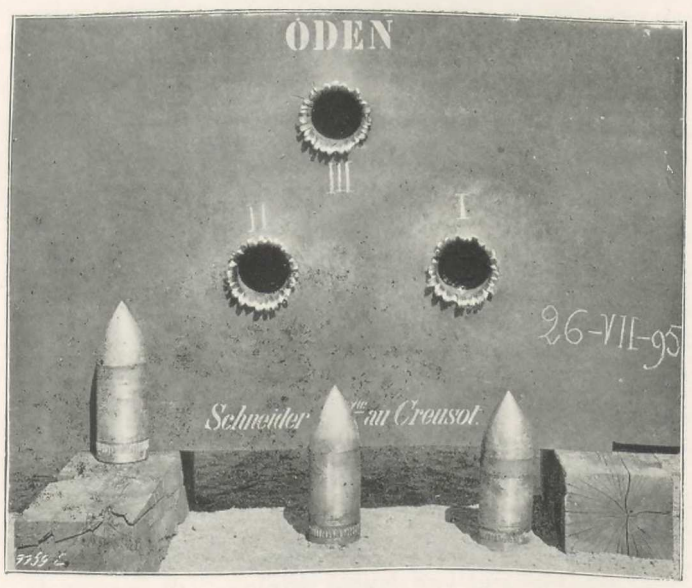


Fig. 179. "Oden," 9.84 in. (Front).

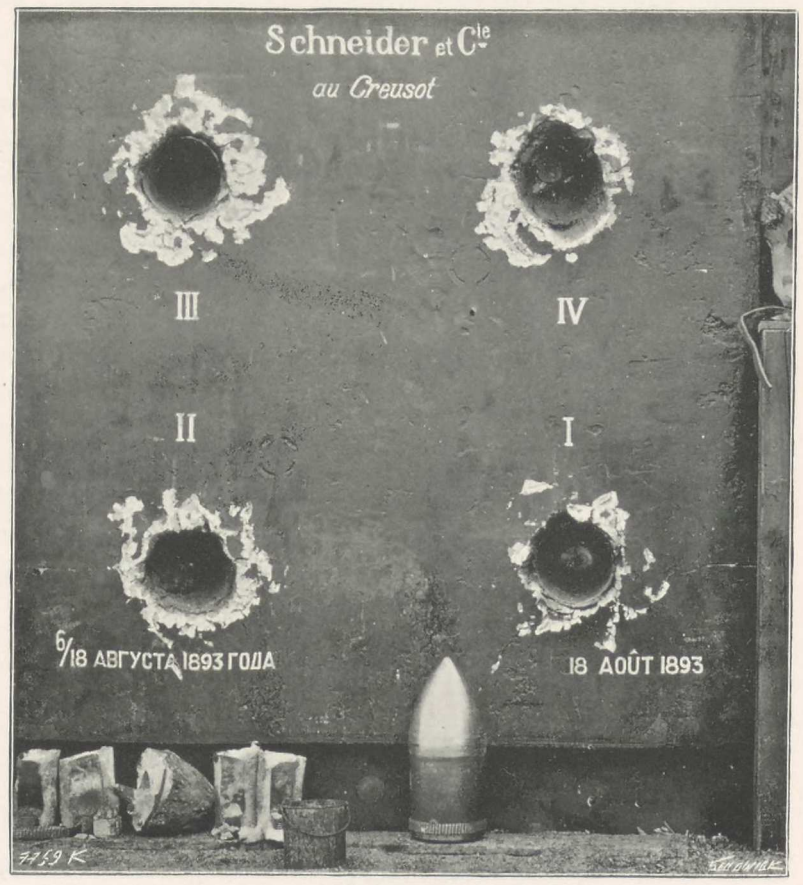


Fig. 180. "Trois Saints," 15.99 in.

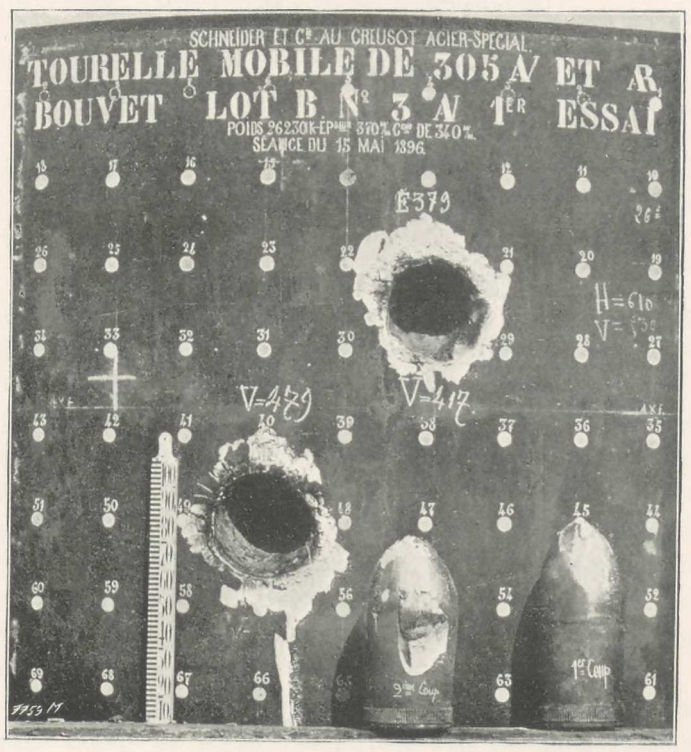


Fig. 181. "Bouvet," 14.57 in.

About this time the United States of America took serious steps towards creating a navy. An important part of their new naval programme was a decision as to the type of plate to be accepted, and the encouragement of private companies to develop the manufacture of that special type. They chose, in 1887, the all-steel Schneider plate. The Bethlehem Iron Company, who were appointed by the United States Government for the supply of armour, contracted with Messrs. Schneider and Co. for the designing of the necessary plant, and sent engineers and officers to Creusot to follow the manufacture in every detail. From the outset this branch of industry acquired in the United States a very great development, which is justified by the high quality of the American armour-plates manufactured. Notwithstanding the progress they had already made in the production of armour, by their experience in the manufacture and in the handling of various grades of steel of soft grade is now used with the best results, instead of extra-mild ordinary steel, for the manufacture of deck plates.

We now arrive at the period when Harvey was perfecting, in the United States, his process for hardening plates with a powdered cementing material, and at the same time Messrs. Schneider and Co. were endeavouring to increase still more the resistance to penetration. They were the first in France to design, put in practice, and regulate cementing by gas, as already described (see page 62, *ante*); this treatment, with water-hardening, gives plates, the front surface of which is of such hardness that the heaviest projectiles are broken on impact. Having demonstrated the value of this method, Messrs. Schneider and Co. lost no time in constructing a new and costly plant for the purpose, and were then enabled to produce cemented plates, and to deliver them to the Russian Navy

TESTS OF STEEL ARMOUR-PLATES MADE BY MESSRS. SCHNEIDER AND CO., CREUSOT.

——	Date of Trial.	Country for which Plate was Tested.	Name of Ship.	Thickness of Plate.		Calibre of Gun.		Remarks.
				mm.	in.	cent.	in.	
Fig. 165 ...	Dec., 1881 ...	France... ...	"Terrible" ...	500 and 402	19.69 and 15.83	32.0	12.60	Homogeneous steel, "Schneider Metal."
Fig. 171 ...	Oct., 1888 ...	Sweden ...	"Gota"	243	9.56	15.0	5.90	Homogeneous steel, "Schneider Metal."
Fig. 172 } Fig. 173 }	July, 1890 ...	Denmark ...	"Tordenskjöld"	115	4.52	15.0	5.90	{ Homogeneous steel, "Schneider Metal." { Rear view.
Fig. 177 ...	Jan., 1892 ...	Roumania ...	"Turrets" ...	120	4.72	15.0	5.90	Cast steel.
Fig. 167 ...	,, 1893 ...	France... ...	"Tréhouart" ...	320	12.60	32.0	12.60	Homogeneous steel.
Fig. 180 ...	Aug., 1893 ...	Russia	"Trois Saints" ...	406	15.99	24.0	9.45	Cemented steel.
Fig. 179 } Fig. 178 }	July, 1895 ...	Sweden ...	"Oden"	250	9.84	15.0	5.90	{ Homogeneous steel. { Rear view.
Fig. 169 ...	Jan., 1896 ...	Denmark ...	"Skjöld" ...	200	7.87	15.0	5.90	Cemented steel.
Fig. 175 ...	,, 1896 ...	France... ...	"Massena" ...	100	3.94	13.68	5.36	Homogeneous steel.
Fig. 181 ...	May, 1896 ...	,, ...	"Bouvet" ...	370	14.57	34.0	13.39	Cemented steel.
Fig. 166 } Fig. 170 }	Jan., 1897 ...	Spain	"Catuluña" ...	250	9.84	15.0	5.90	{ Homogeneous steel. { Rear view.
Fig. 168 ...	June, 1897 ...	Experimental plate.		156	6.14	15.0	5.90	Special cemented steel.
Fig. 176 ...	Oct., 1897 ...	France... ...	"Gaulois" ...	270	10.63	27.44	10.80	Cemented steel.
Fig. 174 ...	April, 1898 ...	Experimental plate.		156	6.14	15.0	5.90	Special cemented steel.

steel, which enabled them to control at will the degrees of hardness then required, Messrs. Schneider and Co. made a considerable improvement by placing upon the market, nickel-steel plates. They were the first to discover that nickel in steel gives great tenacity to the metal. The trials carried out on September 18 and 19, 1890, at the Navy proving-yard of Annapolis (U.S.), were quite a revelation. Messrs. Schneider and Co.'s nickel-steel plate, manufactured at Creusot, carried the day, the one second in value being a steel Schneider plate, sent over from Creusot at the same time. The presence of nickel in steel not only increases in a remarkable way the toughness of a plate, but also its power of resisting penetration; this is especially the case with plates of medium thickness. At the present time, though improvements have been realised in the manufacture of plates by hardening the surface, the steel used still contains nickel, and this fact demonstrates the value of Messrs. Schneider and Co.'s discovery. Nickel for the "Three Saints;" and to the Danish Navy for the "Skjold;" they were the first to supply the French Navy with large quantities.

While Messrs. Schneider and Co. were continuing to improve their process of cementation, the first Krupp plates appeared, the remarkable feature of these being that they do not crack under fire, a quality due to a particular treatment to which the metal is submitted; this characteristic increases in a marked degree their resistance to penetration. Messrs. Schneider and Co. have acquired the process of manufacture of these new armour-plates, so as to be able to meet the demands of the governments which would require armour-plates showing this remarkable resistance to cracking after a certain number of rounds.

As a supplement to this sketch of the all-important part taken by Messrs. Schneider and Co. in developing and improving the manufacture of armour, the repro-

ductions of some photographs of tested plates are given in Figs. 165 to 181, Plates XXXIV., XXXV., and XXXVI. Apart from two (Figs. 168 and 174) which have undergone experimental trials, carried out by Messrs. Schneider and Co. at their Villedieu proving-yard, all these plates were tested officially, and for this purpose had been chosen by inspecting officers, from the lots they represented and after the completion of each lot. It is to be noted that inspecting officers choose generally, for firing tests, those plates which show surface imperfections, or those concerning which doubts may have arisen during manufacture, either owing to some accident, or from the results shown by some of the testing operations of the materials, during the various processes of fabrication. Some particulars of the plates illustrated are given in the Table on previous page.

Appended is a list of the tonnage of steel armour-plates manufactured by Messrs. Schneider and Co. from 1876 till May 1, 1898.

	Tons.	Tons.
French Navy	—	26,193
Italy	8,040	
Spain	3,298	
Russia	2,805	
Sweden and Norway	2,582	
Chili	1,387	
Denmark	1,027	
Greece	777	
Japan	633	
China	342	
United States	132	
Holland	98	
Belgium	15	
Austria	4	
	——	21,140
		47,333

XVI.—THE ROLLING-MILL DEPARTMENT.

Historical.—This important department of the Creusot Works was founded by M. Eugène Schneider at the time when the French Commercial Treaty of 1860 came into operation. The effect of this treaty was largely to reduce the tariff on all imports, which had up to that date protected French metallurgy, among other industries. The immediate result was, of course, inevitable; competition with foreign iron works became impossible, owing mainly to the ancient and imperfect plant in use at the old Creusot forge, which had been put down in 1827, and which, under the fostering aid of Protection, continued to serve the purpose.

Rising promptly to the necessities of the situation, M. Eugène Schneider, assisted by his son, M. Henri Schneider, prepared the plans for the new rolling mills, and their execution was at once put in hand. The levelling of 16 hectares (40 acres) of very uneven ground, involved earthworks of considerable magnitude. This was begun in 1861; the erection of the buildings was then carried on rapidly, as well as the construction and erection of the engines and new plant. In 1865 the puddling furnaces and iron rail mills were set to work; the installation of other mills followed without interruption, and in 1867, the year of the second great Paris Exhibition, the undertaking was completed.

These rolling mills were methodically laid out as a whole and in every detail, in order to meet all requirements as to dimensions and quality of output. They were justly considered as a model of their kind, and were visited by a great number of foreigners who were in France at the time they were started, especially by Americans, who, later on, built the gigantic establishments now at work in the United States.

A reference may be quoted here to these early rolling mills taken from ENGINEERING, vol. iv., 1867, page 476: "By far the most imposing structure at Creusot, and one which, in its way, has no rival in the world, is the new rolling mill, which is covered by a roof in five spans, and 1,250 ft. long, supported on cast-iron columns, but inclosed at the sides by continuous glass windows. The first span of the roof covers the portion devoted to forming the piles of puddle bars as they come from the puddle mill at the side of the new building. The next portion contains the heating furnaces, in the chimney of each of which is placed a vertical cylindrical boiler without flues, 3 ft. 6 in. in diameter, and extending a short distance above the roof, the heat passing around the outside of the boiler, and issuing from the brickwork casing by means of iron chimneys by the side of the steam-room. This form of boiler is very common at the French iron works, and gives great satisfaction. Next, under the centre roof, which has the widest span, are the trains of rolls of all sizes, from such as are suitable for rails or girders down to the rapid guide-roll for $\frac{1}{4}$ in. squares. Following this is the straightening shed, and, lastly, the despatching shed, into which the lines of railway enter to receive the finished product. The appearance of symmetry presented by this mill, with its long row of vertical boilers and its succession of train of rolls, is very striking, and makes even the largest of our English mills seem diminutive by comparison."

Besides completing a first-class plant from the commencement, Messrs. Schneider and Co. organised a special system as regards control of the work, account-keeping, and regular inspection of the raw material and of finished products, thus enabling the central office to ascertain exactly at any time the state of affairs in this particular department.

The outside appearance of the rolling-mill department has been altered but little since the early time, notwithstanding the constant improvements which have been made, in order to keep the plant up to the highest standard of efficiency and modern practice, and especially in the substitution of mechanical for hand labour. Thus, mechanical puddling has taken the place of hand puddling for common qualities of iron; two high roll mills have been superseded by three-high and reversing mills; the furnaces are charged mechanically by processes which, while they are less tedious for the men, reduce the cost of labour; all the old cylindrical boilers have been replaced by multitubular boilers; the accessory machines—shears, flattening machines, &c.—are being transformed for working by electricity, &c., &c.

Present Rolling-Mill Shops.—At the present time the Creusot rolling-mill department, a plan of which is shown in Fig. 182, Plate XXXVII., occupies a space of 16 hectares (40 acres) of which 7.5 hectares (19 acres) are occupied by buildings. The rolling-mill building (Figs. 183 and 184) alone covers 4.30 hectares (10.65 acres); it consists of six connected bays, of varied height and span. Its length is 380 metres (1,250 ft.). The iron framing is of a light and elegant construction, giving a fine appearance to the building. Fig. 185, Plate XXXVIII., gives a good idea of the interior of the main bay.

The other principal shops are the two containing the puddling furnaces, each one 74 metres (243 ft.) long by 80 metres (263 ft.) wide, and the bar stores which are in

the same line with the rolling-mill building. The space covered by these stores was formerly occupied by the heavy rail-finishing machines. The shops of secondary importance are those containing the machine tools for maintaining the plant in repair; the testing shop and buildings covering the circulating pumps; the electric station, &c. About 14 kilometres (9 miles) of normal gauge railway are laid in the shops and yards, the lines being united to the blast-furnaces and steel works through the tunnel which runs under the town; they are besides

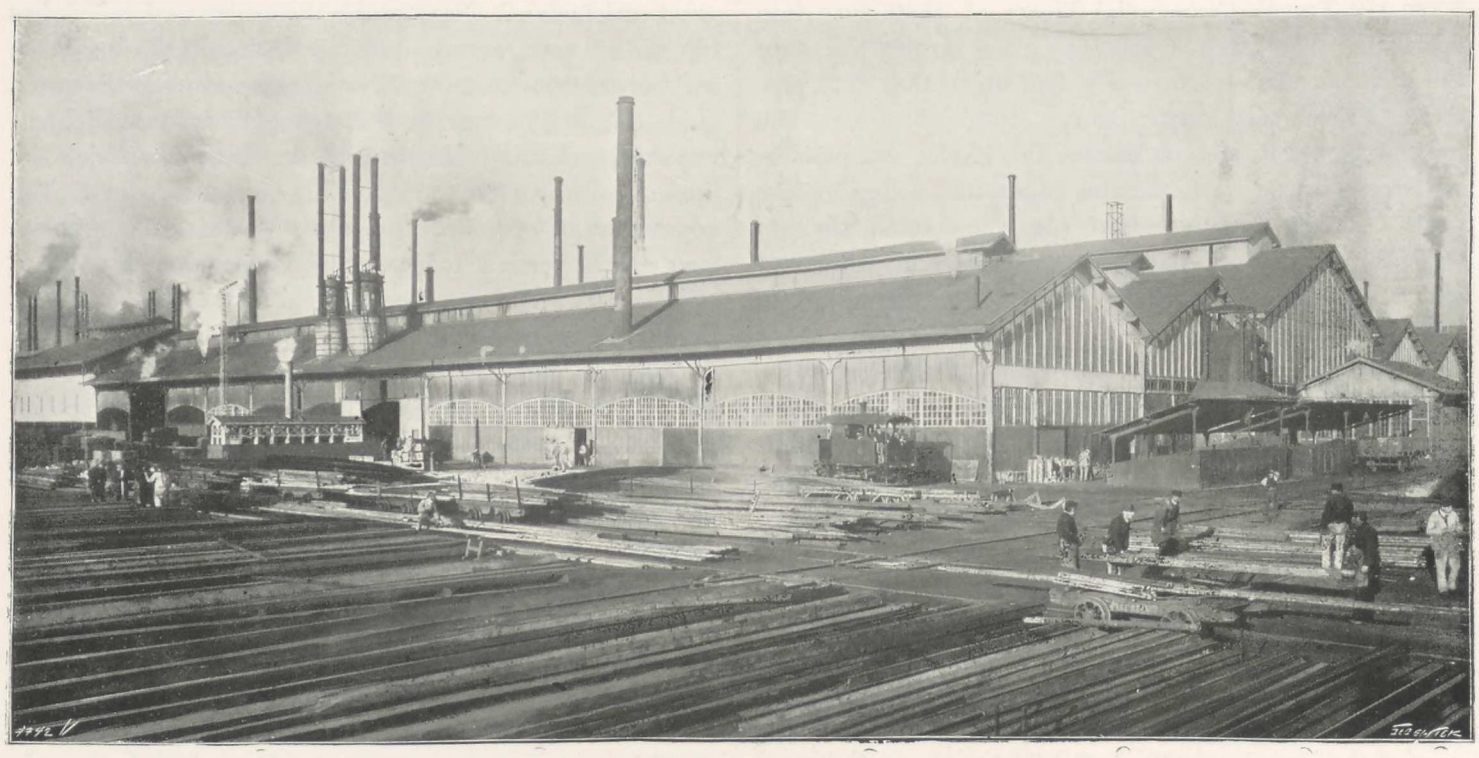


Fig. 183. South Side of Rolling-Mill Buildings.

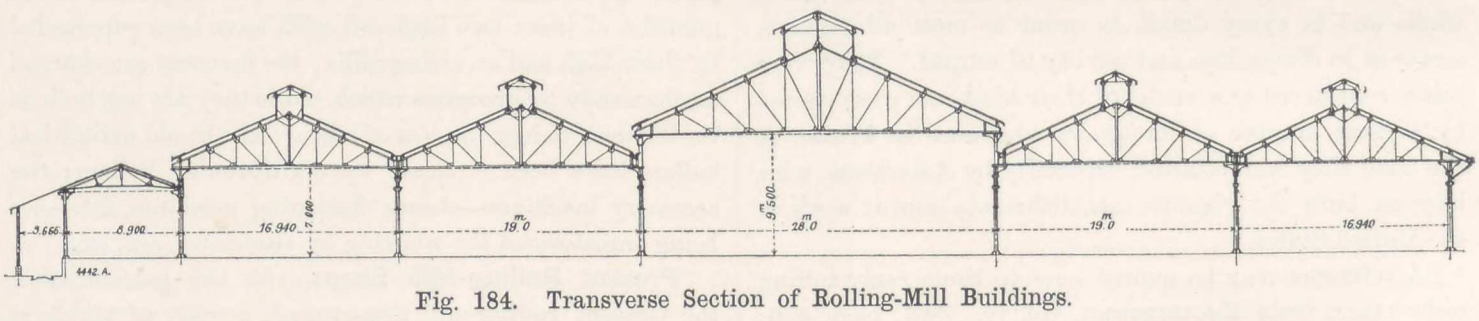


Fig. 184. Transverse Section of Rolling-Mill Buildings.

connected with the other departments of the works, and also to the Paris-Lyon and Mediterranean Railway.

The quantity of crude material worked, averages about 150,000 tons per annum; the coal consumption is about the same quantity, while 120,000 to 140,000 tons of finished products are turned out annually. Four light locomotives and thirteen portable steam cranes serve the various shops. The plant has been arranged so as to obtain systematic and continuous working, and to prevent the carrying backwards and forwards of the material under treatment; the cost of manufacture has been thus reduced considerably. For instance, as regards the manufacture of iron (the sole object for which the plant had originally been established), from the point of arrival of the pig, until the rolled material reaches the delivery wharf, a straight line is followed forward through the puddling furnaces, the shingling hammers, the roughing rolls, the shears, the piling, the reheating furnaces, the finishing rolls, the inspection platform, and the delivery on the railway trucks.

Since 1869 steel has gradually superseded iron, and at the present time more than half of the products manufactured at Messrs. Schneider and Co.'s rolling mills are of steel. The ingots, as a rule, are received hot from the steel works, and are distributed among the various mills for direct rolling; in several cases, however, the ingots are first turned into blooms. The rolling mills occupy 3,000 workmen in day and night shifts, no work being done on Sunday. The necessary motive power is produced by 140 steam engines of various sizes, their total energy being 11,000 nominal horse-power. There are besides fourteen steam hammers. The necessary steam for the whole of the plant is produced by boilers placed near the puddling and reheating furnaces; they are connected with each other, and produce 800 tons of steam every

THE ROLLING-MILL DEPARTMENT.

Fig. 182.

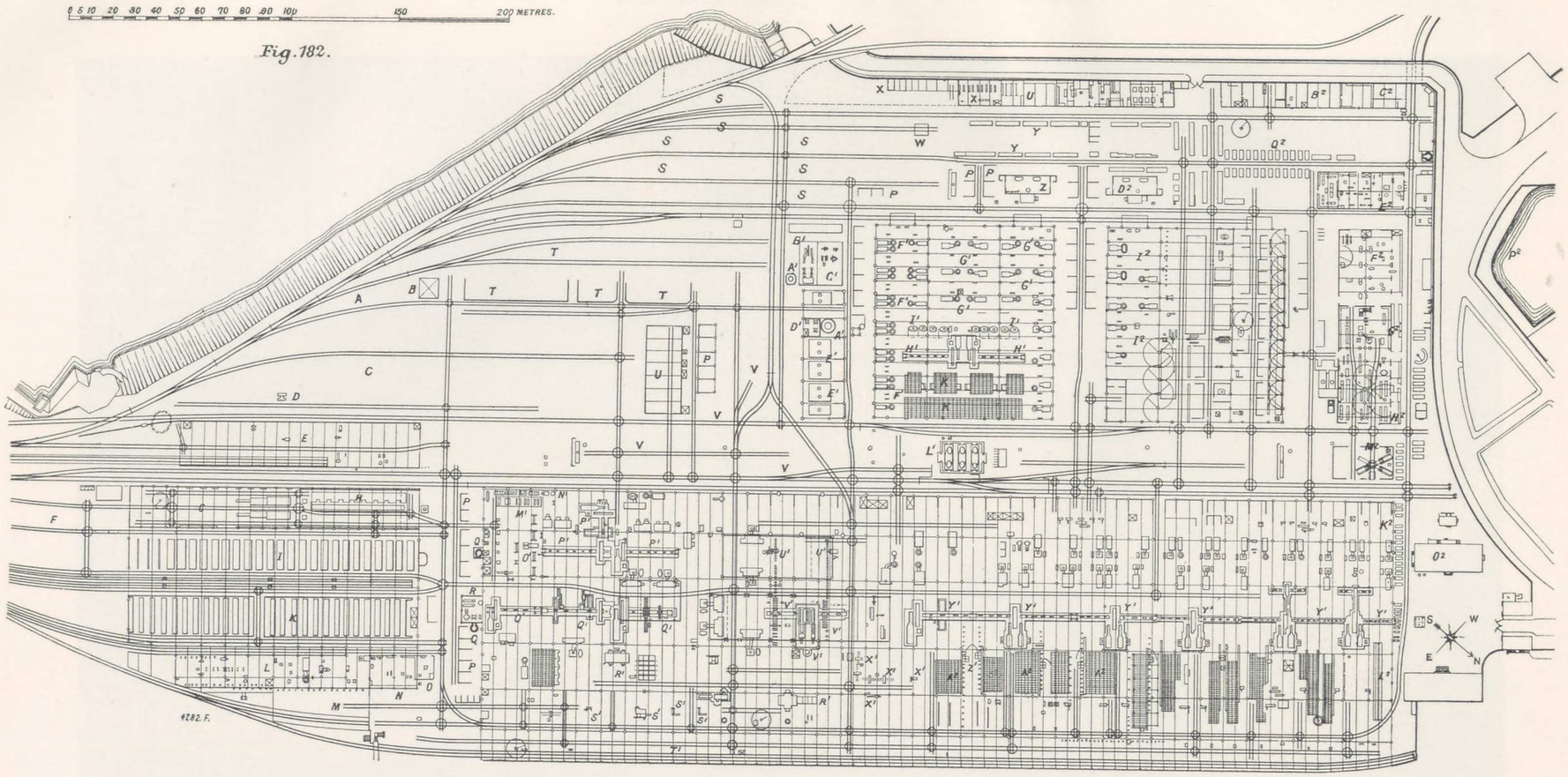


Fig. 182. Plan of the Rolling Mill Department.

A. Railway sidings.
B. Drop hammer.
C. Iron depôt.
D. Hand-cutting machine.
E. Iron finishing shop.
F. Store for section bars.
G. Store for thin plates.
H. Annealing furnaces for thin plates.
I. Store for merchant iron.
K. Store for iron and steel beams.
L. Finishing shop for rails, fishplates, &c.
M. Sidings for receiving and despatching rails.
N. Repairing shop.
O. Hydraulic testing apparatus for rails.
P, P. Coal stores.
Q, Q. Accumulators
R. Hydraulic pumps.
S, S. Cast-iron stores.
T, T. Scrap-iron stores.
U, U. Stores for spare parts.
V. Ingot depôt.
W. Engine house.
X, X. Carpenters' shops.
Y. Roll depot.
Z. Small repairing forge.
A^1. Accumulators.
B^1. Pumps.
C^1. Dynamo room.
D^1. Chimney.
E^1. Battery of boilers.
F^1. Ordinary puddling furnaces.
G^1, G^1. Mechanical puddling furnaces.
H^1, H^1. Rolling trains Nos. 3 and 4.
I^1, I^1. Steam hammers.
K^1, K^1. Cooling beds.
L^1. Pumps.
M^1. Pickling tanks.
N^1. Drying stove.
O^1. Guillotine shears.
P^1, P^1, P^1. Rolling trains Nos. 7 to 11.
Q^1, Q^1, Q^1. Rolling trains Nos. 3, 4, and 5, for heavy, medium, and thin plates respectively.
R^1. Annealing furnace.
S^1, S^1. Shears.
T^1. Sidings for despatching plates.
U^1, U. Hot-shearing machine.
Y^1, Y^1. Blooming and plate mills and engine.
X^1, X^1, X^1. Planing and straightening machines.
Y^1, Y^1, Y^1. Trains Nos. 2 to 12.
Z^2, Z^1. Saws.
A^2. Cooling beds.
B^2. Store.
C^2. Stores.
D^2. Small repairing shop.
E^2. Testing shop.
F^2. Smiths' shop.
G^2. Repairing shop.
H^2. Roll turning shop.
I^2, I^2. Mechanical puddling furnaces.
K^2. Roll store.
L^2. Straightening table.
M^2. Locomotive house.
O^2. Offices.
P^2. Water reservoir.
Q^2. Roll stores.
Total area of rolling mill department, 16.0185 hectares.
Length railway track in mill department, 14,140 metres.

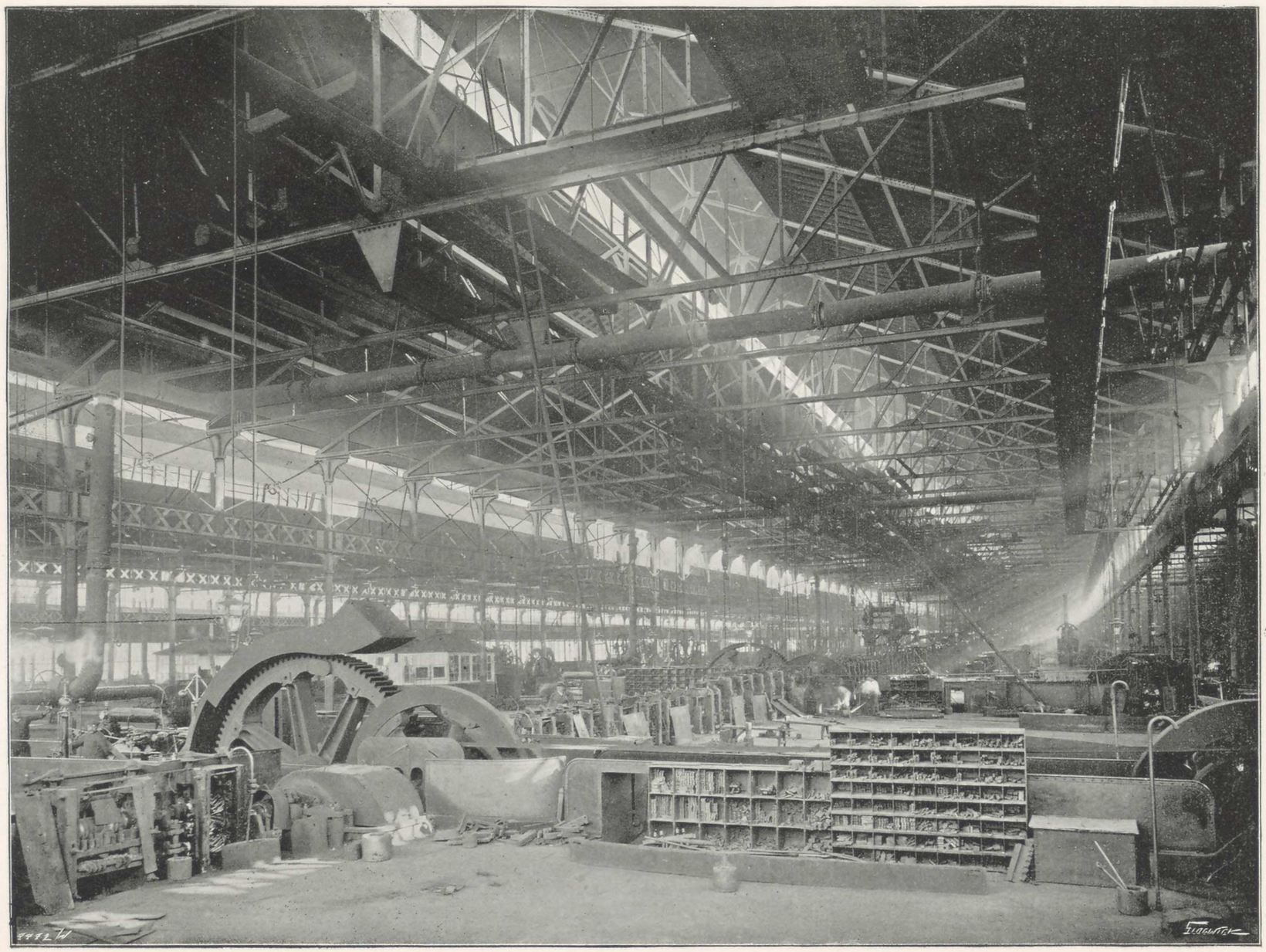
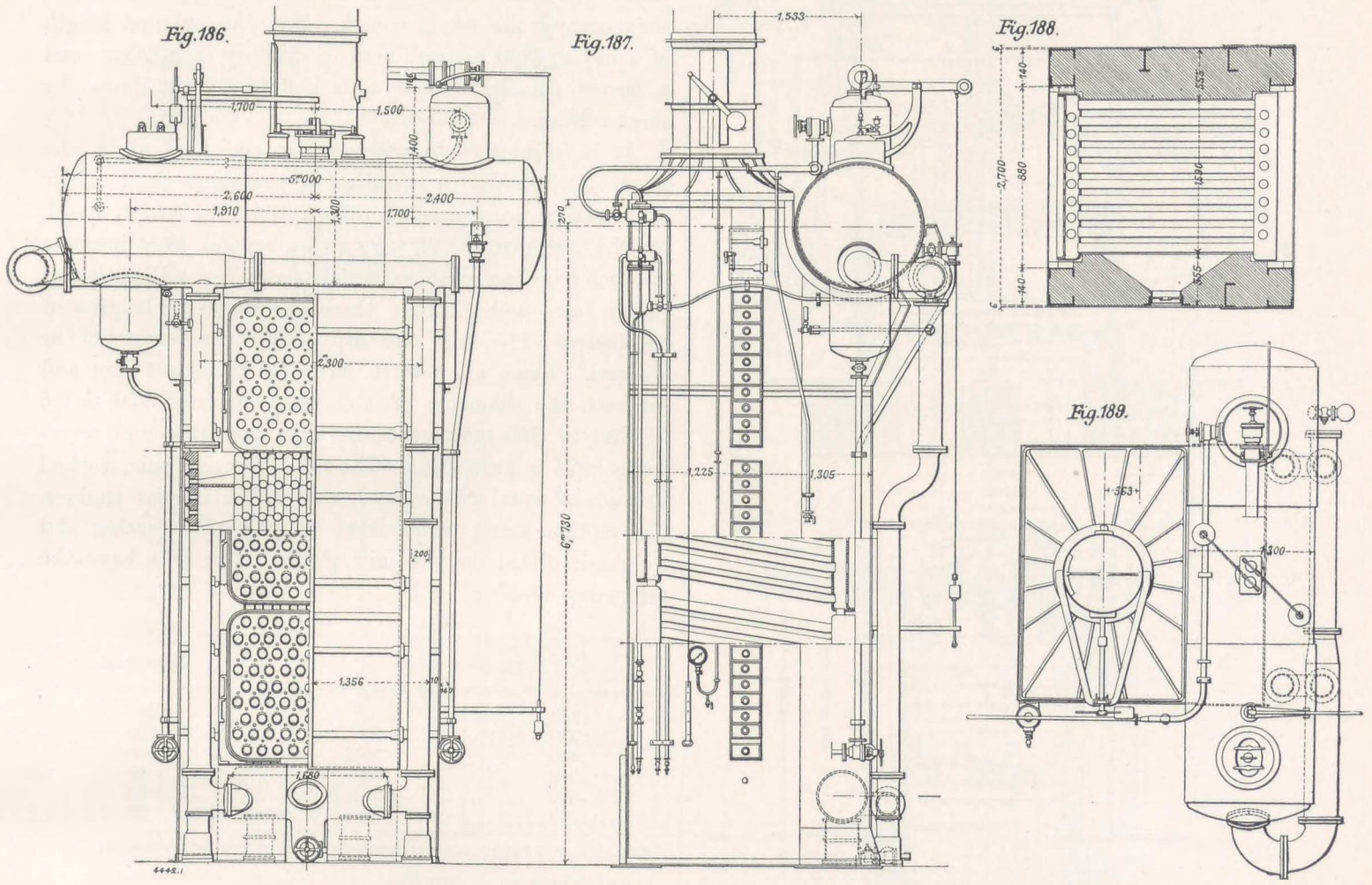


Fig. 185. Interior of Main Rolling-Mill Building.

twelve hours. As the total quantity of steam required may exceed 800 tons, the difference is made up by eight auxiliary boilers, which act as regulators, and maintain the pressure at 5 kilogrammes (71.115 lb. per square inch); the number of these boilers in use varies according to the work in progress.

Steel, though requiring a lesser degree of reheating, demands greater power for rolling, than iron; therefore, through the increase in the proportion of steel manufactured, Messrs. Schneider and Co. were obliged to replace most of the old vertical boilers heated by the furnaces with special multitubular boilers, which produce 4½ lb. to 5 lb. of steam per pound of coal burnt on the grate of the reheating furnaces. This type of boiler, which is illustrated by Figs. 186 to 189, does not take up more room than the vertical boilers, and does not interfere in any way with the draught of the furnaces.



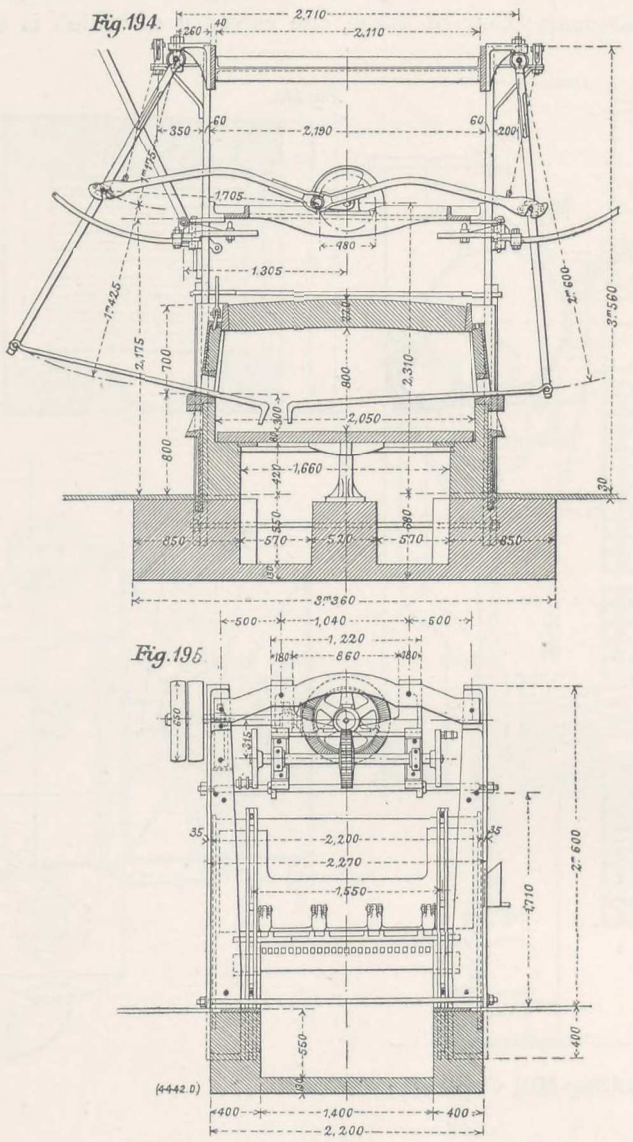
Gas-Fired Water-Tube Boilers; Rolling-Mill Department.

An electric station has been put down for the production of energy, which is distributed to the various shops, and is employed to work a large number of machines. Another, but older, means of transmitting the power necessary for this department is by water pressure; there are at work a number of pumps and accumulators which transmit to the various machines a pressure of 35 kilogrammes per square centimetre (498 lb. per square inch).

As there are no rivers in the vicinity of Creusot, water, and more especially that coming from the condensers, has had to be stored in a large lake which contains 380,000 cubic metres (13½ million cubic feet). The rolling mill department alone requires 1,100 to 1,200 cubic metres (40,620 cubic feet) per hour. The water is pumped up from this lake, and returns to it afterwards, to be again pumped up. The lake is fed by the water from a small stream 18 kilometres (11 miles) distant. This is diverted and brought down to Creusot through pipes; the rain water is also collected. Six pumps of 75 horse-power each are placed in a special building of the rolling-mill department; four of these, the capacity of which is 600 cubic metres (21,190 cubic feet per hour), serve this department. They deliver into a small reservoir marked P^2 on the general plan, Fig. 182, Plate XXXVII., the water running down from there to the various parts of the department. The two other pumps have each a capacity of 300 cubic metres (10,595 cubic feet) per hour; they deliver into higher reservoirs than the one above mentioned, the water from these being distributed in other parts of the works.

The rolling-mill department may be conveniently divided for description into two principal parts. 1. The puddling section, which decreases in importance every day. 2. The rolling section, which, on the other hand, is constantly developing.

Puddling Section.—At the commencement there were, in the two buildings devoted to the special purpose, as many as 100 single puddling furnaces. To-day there are only 40 of these; 21 serve for the manufacture of high-grade iron, and the remaining 19 have been transformed into double-ended mechanical furnaces, devoted to the treatment of lower grades. The average charges are 550 kilogrammes (say 11 cwt.). These furnaces are fully illustrated by Figs. 190 to 193, Plate XXXIX., and by Figs. 194, 195. The mechanical puddling arrangement adopted



Mechanical Puddling Furnaces.

has done away with a great deal of hand labour, and has brought the efficiency of the furnaces to 10 or 11 heats per 12 hours.

Pig iron coming from the blast-furnaces is either used direct or stacked; there is always a large quantity on hand ready for immediate working. The puddling furnaces are placed near each other, and form together approximately a semicircle, in the centre of which are nine 3-ton steam hammers for shingling the balls. These are then rolled direct in two roughing trains with three high rolls, worked by a 200 horse-power engine. All the bars are weighed, and then broken, in order to judge of the quality; the men are paid according to weight and quality produced.

The brands vary from the common quality, styled No. 2, to the high-grade quality, styled No. 7, which is equal to the best brand manufactured at any other works. The bars are distributed among the various rolling mills in the next building, to be sheared and piled for the manufacture of merchant bars and sections. The space originally occupied by the puddling furnaces, which have been pulled down, serves for storing and classifying scrap.

Rolling-Mill Section.—All the mills for finished products, bars, sheets, and plates, are placed in the large bay of the main building mentioned above, and of which they occupy the whole length. But the original length of building (380 metres) became entirely insufficient, and a second parallel line of mills had to be put down for sheet rolling.

It is impressive to witness, especially at night, the whole of the mills in operation at the same time. Near the entrance are the small rolls, running at a high speed, for the manufacture of wire rods; beyond, they increase gradually in size to those which serve for rolling heavy round bars, and girders; these are rolled in lengths of 35 metres (115 ft.), and are afterwards sawn hot or sheared. There are twelve mills for merchant iron and sections, the diameter of rolls varying from .250 metre ($9\frac{7}{8}$ in.) to .760 metre (30 in.), with housings and accessories built in proportion. The trains are, as a rule, worked in pairs of equal power, by two-cylinder Corliss engines, the motion being transmitted by powerful gearing and flywheels fitted on the mill shafts. The rolls have the following speeds:

Diameter of Rolls.		Revolutions.
m.	in.	
.250	$9\frac{7}{8}$	260
.330	13	150
.475	$18\frac{11}{16}$	100
.600	$23\frac{5}{8}$	80
.640	$25\frac{3}{16}$	70 to 80
.760	30	60

All these mills are fitted with three-high rolls. The two-cylinder Corliss engines vary in power from 400 horse-power for the smaller mills, to 600 horse-power for the larger ones. The mill for large sections and long lengths is the only one worked direct by a special compound engine, at 65 revolutions, the power of which averages 1,500 horse-power; motion is transmitted direct from it to the central roll.

Reheating furnaces, varying in size according to the material to be rolled, are placed in a lateral bay opposite each mill. The grates of these furnaces are of the usual type, and air is driven from underneath by means of fans. Washed small coal is used as fuel, and the waste gases serve to heat the multitubular boilers, as mentioned above; the temperature of the smoke escaping from the chimneys is under 300 deg. cent. The same furnaces serve for

Fig.190.

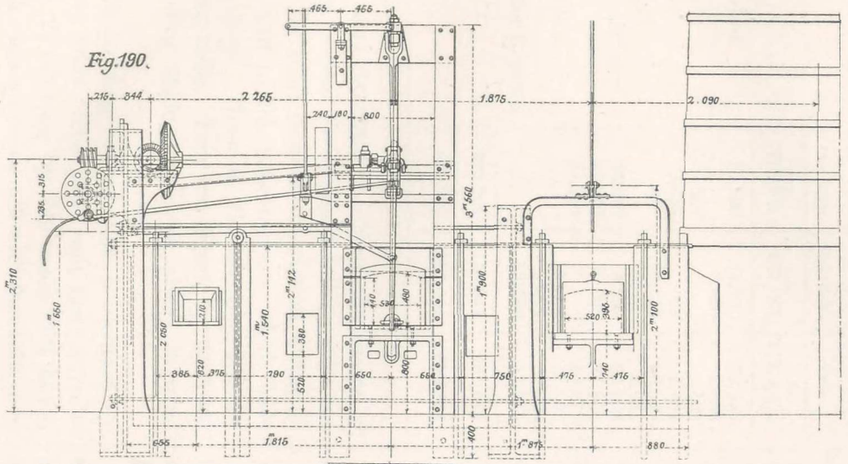


Fig.191.

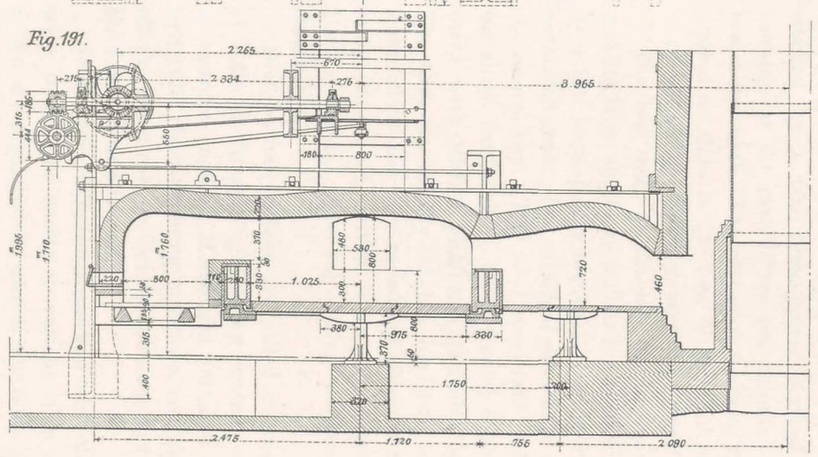


Fig.192.

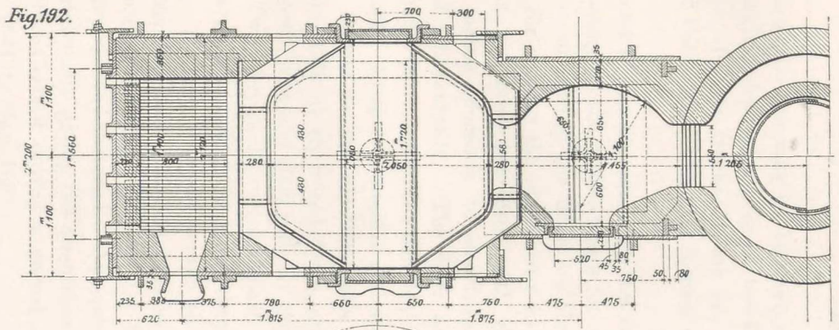
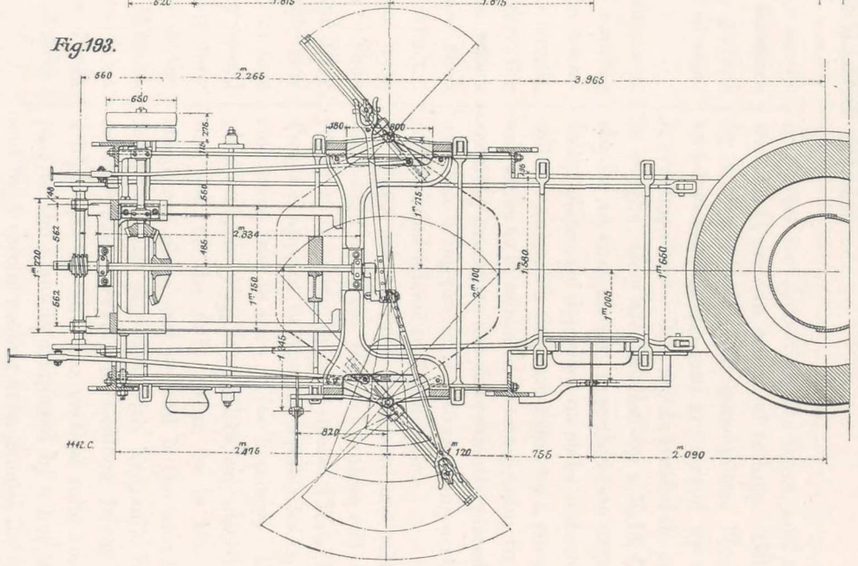


Fig.193.



Mechanical Puddling Furnace.

heating iron or steel, as the case may be, but never simultaneously. The charging and discharging of the furnaces is effected by means of long trucks; these are pushed over the flooring of the works, which is formed of cast-iron slabs.

Under the bay, next to the one covering the furnaces, are the shears for cutting up the puddled bars for making the piles. In the rear of each of the mills are the necessary machine tools for cutting the rolled bars to length, either hot by means of saws provided with carrying rollers, or cold by means of shears, to and from which the bars are carried mechanically. The bars are then straightened, and carried on rollers to the delivery wharf.

Rail Manufacture.—Messrs. Schneider and Co. were among the first in France to manufacture rails. They began rolling them in 1832 at their old forge, and they continued making both iron and steel rails in their new works up to 1880. Two large mills were set apart for this manufacture on a large scale until 1885, when they ceased to roll heavy rails. In their Creusot works they now only roll light sections, but they have established in the east of France, in conjunction with Messrs. De Wendel, rolling mills for heavy railway material. Appended is an interesting tabular statement giving the quantities of iron and steel rails rolled at Creusot during a period of fifty-six years, from May, 1841, to May, 1897:

—	Iron Rails.	Steel Rails.	Total.
	tons	tons.	tons.
For France	706,611	667,061	1,373,672
For export to Switzerland ...	20,596	11,950	32,546
,, Germany	...	2,458	2,458
,, Denmark	500	...	500
,, Sweden	6,669	522	7,191
,, Russia	307	66,242	66,549
,, Turkey	...	8,021	8,021
,, Austria-Hungary ...	35,985	3,253	39,238
,, Italy	42,970	35,008	77,978
,, Spain	18,278	...	18,278
,, United States ...	...	11,500	11,500
,, Brazil	...	3,829	3,829
,, Argentine Republic	...	13,558	13,558
Total export	125,305	156,341	281,646
Grand total	831,916	823,402	1,655,318

Rolling Mills and Accessories.—Near the centre of the main building, beyond the sectional rolling mills, are others which call for some detailed description, owing to their importance, and to the improvements which have been embodied in them. These are the blooming and the armour-plate rolling mills. They are driven by one 3,000 horse-power reversing engine, which is placed between them.

The space in the building beyond these is occupied by the plate and sheet mills. The plate mill has two rolls 2.200 metres (7 ft. $2\frac{5}{8}$ in.) long, by .740 metre ($29\frac{1}{8}$ in.) in diameter. Near this is a universal mill with four rolls (two horizontal and two vertical), and a hot shearing machine. Hydraulic lifting platforms are placed front and back; they are fitted with feed-rollers, driven mechanically, with a receiver for depositing the ingot, and an apparatus for turning it over in course of rolling. This mill is worked by a two-cylinder 600 horse-power Woolf engine. The two furnaces for the mill are served by a 12-ton electric travelling crane. The ingots treated do not exceed 2 tons in weight; they are handled by a light **C**-shaped carrier, similar to that already described (see page 35, *ante*). The rolled plates are deposited on slabs in the rear of the rolling mills, from which they are lifted by a portable steam crane, and taken to be annealed in an adjoining furnace. Powerful shearing machines are conveniently placed near the mills, each one being provided with carrying arrangements which reduce hand labour to a minimum.

Plates of medium thickness are rolled in a Lauth three-high mill; the top and bottom rolls are 1.850 metres (6 ft. $0\frac{7}{8}$ in.) long by .700 metre ($27\frac{9}{16}$ in.) in diameter. Power is applied to these two rolls, the smaller and middle roll being free to turn in its bearings. Hydraulic lifting platforms, carrying feed-rollers, are placed in front and at the rear of the mill. Near by is the mill for rolling chequered plate, and beyond is the universal rolling mill for wide flats, provided with hydraulic lifting platforms on each side, carrying feed-rollers driven mechanically at a high speed. The two vertical rolls are in front. This part of the plant is completed by a hot shearing machine and by a special cooling arrangement for wide flats, with a rectifying machine driven hydraulically. These mills are worked by a 600 horse-power vertical Corliss engine, running at 60 revolutions per minute, and carrying a heavy flywheel. The plates of medium thickness are deposited on slabs in the rear of the mill, and are annealed in the same furnace which serves for the thick plates.

The last train at the end of the building is used for making large sheets, as well as for planishing. It is driven by a 250 horse-power horizontal engine fitted with Meyer expansion gear. The principal sheet mills are placed under the lateral bay. The most important is a three-high mill for sheet bars, driven by a special engine. The mill is fitted with lifting platforms, provided with feed-rollers. The bars are rapidly cut hot into two, four, six or eight slabs, which are then rolled out direct in the five adjacent mills; these are driven by a 600 horse-power vertical Corliss engine. The roll-setting wedges are moved mechanically.

Doubles and lattens are rolled in twelve other pairs of rolls of three neighbouring trains, each worked by a separate engine. Horizontal furnaces face the mills; hydraulic sheet-doubling machines, and shears for cutting off the sheet corners before doubling, are placed between the furnaces and the mills.

Four large guillotine shears and other shearing machines serve to cut the sheets to various sizes and shapes; the sheets are planished in several machines provided with a series of rolls. They are afterwards annealed in a large closed oven 40 metres (131 ft.) long, heated by eight fires, and served by a 15-ton electric travelling crane of 16 metres (55 ft. 6 in.) span. The bar depôt, already referred to, is

120 metres (393 ft.) long by 48 metres (157 ft.) wide; it is formed of two bays, and is placed in the same line as the main building. On one side are stacked all the various sections of merchant bars; on the other are rolled beams in lengths up to 9.500 metres (31 ft. 2 in.); a railway track runs down the middle of the building. The bars are placed upright by means of winches carried on overhead tracks. In this depôt 12,000 tons of bars can be stored. Further on is the light railway material finishing shop, and opposite is the finishing shop for large rolled sections. The shop for maintaining the plant in repair is fully equipped with all the necessary machine tools, and occupies workmen of every trade. Among other tools there are fourteen lathes of various sizes, for turning new rolls and repairing those in service. The yard is absolutely covered with rolls, which are classified two and three high, in special frames, so as to be easily selected. They are handled by portable steam cranes. According to the last inventory there were 2,400 rolls of all sizes, having a total weight of 6,000 tons.

Testing Laboratory.—The testing laboratory is near the machine shop. The various tests carried out are the following:

a. Daily tests of puddled iron, steel ingots, blooms, &c., and investigations of all new material.

b. Tests of merchant iron and steel, before delivery of each order.

c. Tests of products inspected and passed at the mills by the Inspectors of Railway Companies, by the officers of various Navy Departments, Artillery officers, officers of the Corps of Engineers, agents of Veritas, Lloyd's, &c.; all these tests are conducted under the same conditions as those stipulated in the numerous specifications.

The testing office staff elaborate, in conjunction with that of the laboratory for chemical tests, the means of obtaining new products and carrying out new processes; as, for instance, dynamo steel sheets, the rolling of iron and steel alloys, &c. A complete set of machines and apparatus is provided for all kinds of tests by breaking, cold and hot bending, bending after tempering, punching, chasing, welding; for drop tests, tensile tests, &c. Tensile tests, which are by far the most frequently demanded at the present time, are effected with a powerful and improved machine worked hydraulically and fitted with a system of combined levers, which records strains up to 60 tons. The operation of this machine is very simple, and it is so arranged that the time taken for each test may be varied within large limits. Special clutches serve for testing, without previous preparation, bars in the rough up to 40 millimetres ($1\frac{9}{16}$ in.) in diameter, or thickness, and 60 millimetres ($2\frac{3}{8}$ in.) wide, the section, however, being limited by the power of the machine. A large number of interesting test-pieces are kept and form a museum. The tests made annually in the Rolling-Mill Department alone are as follows:

Tensile tests of all kinds	30 to 35,000
Cold bending tests before and after tempering	60 ,, 70,000
Various breaking tests, more than ...	100,000

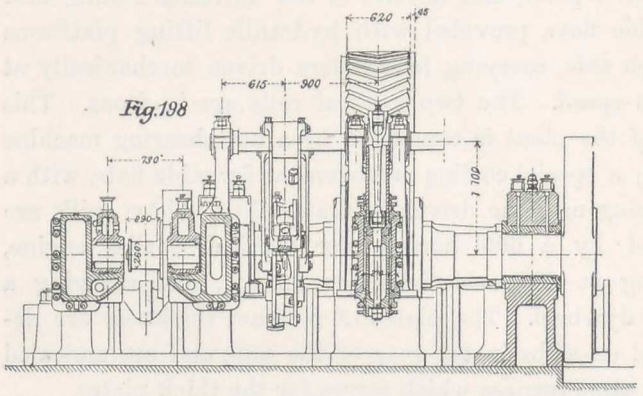


Fig. 198

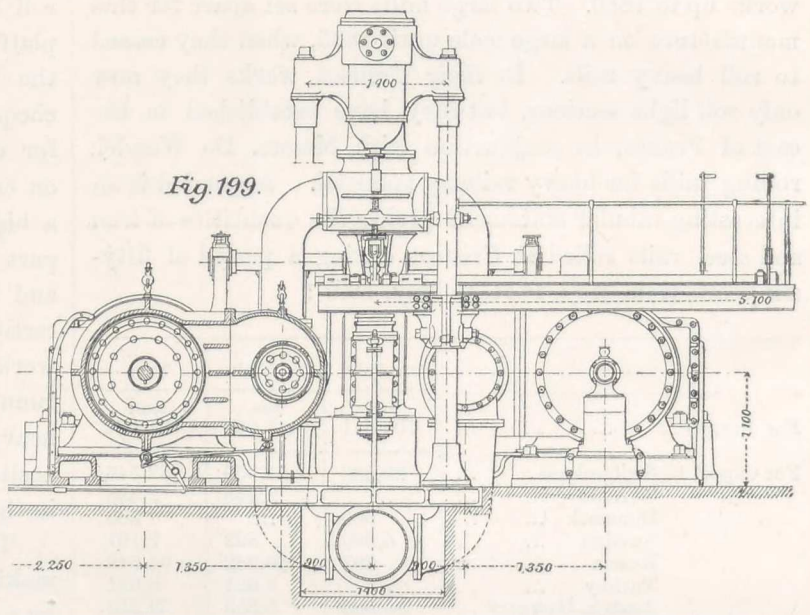


Fig. 199.

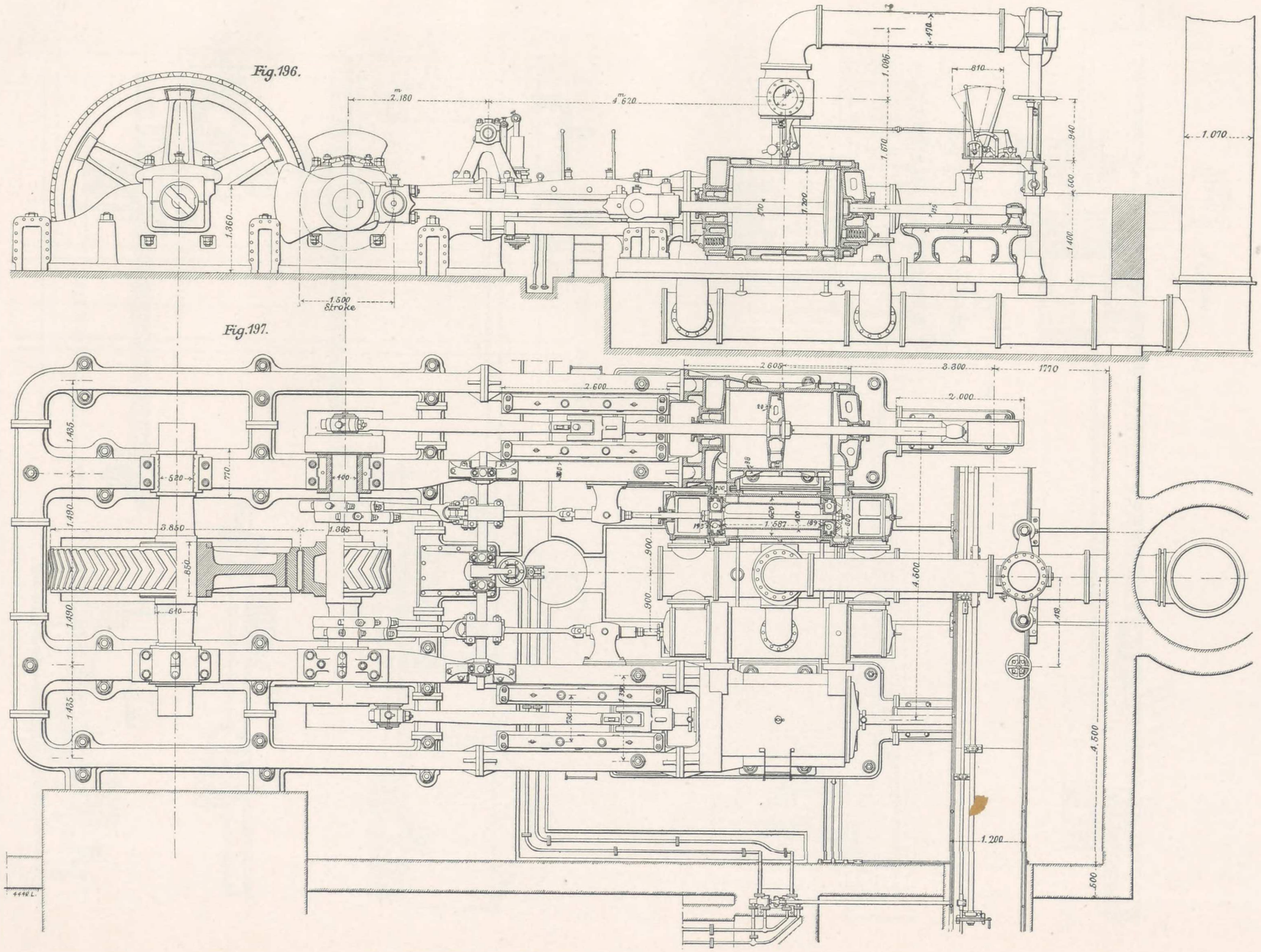
Transverse Section of 3,000 Horse-Power Rolling-Mill Engine.

The shops and yards are illuminated by arc lamps. Near the centre of the department in the rolling-mill building is an accident station, containing all the necessary appliances and medicaments for a rapid preliminary tending of workmen injured at any time of the day or night. All the buildings and most of the plant of this department, have been constructed by Messrs. Schneider and Co., at their Creusot and Chalon Works.

3,000 Horse-Power Rolling Mill Engine.—Passing now to a detailed notice of the more important machines of the rolling mill department, there is first the blooming mill, already referred to. This mill is placed on one side of a 3,000 horse-power reversing engine, shown in Figs. 196, 197, Plate XL.; and in Figs. 198, 199. The engine

Fig.196.

Fig.197.



3,000 Horse-Power Rolling Mill Engine.

PLATE XL.

THE ROLLING MILL DEPARTMENT.

Fig. 200.

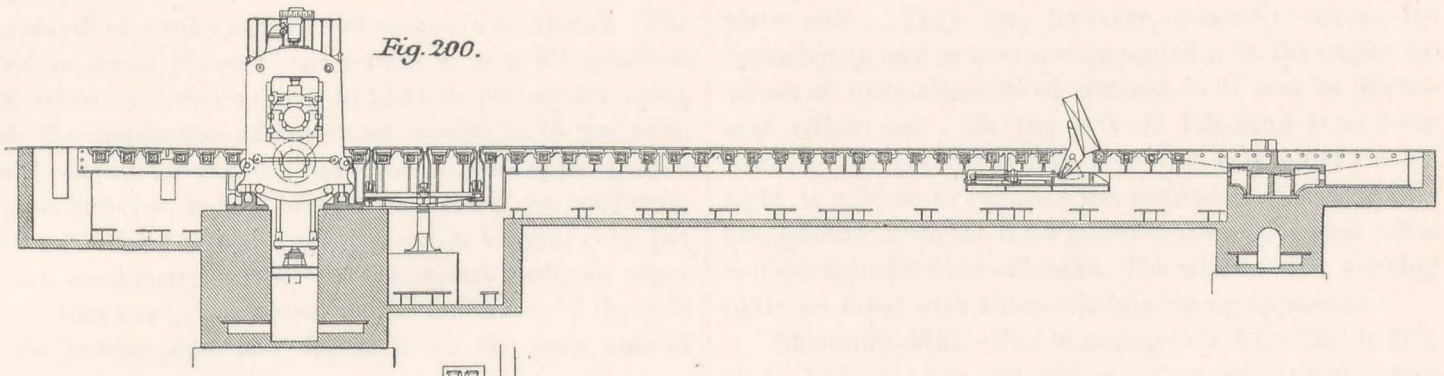


Fig 201

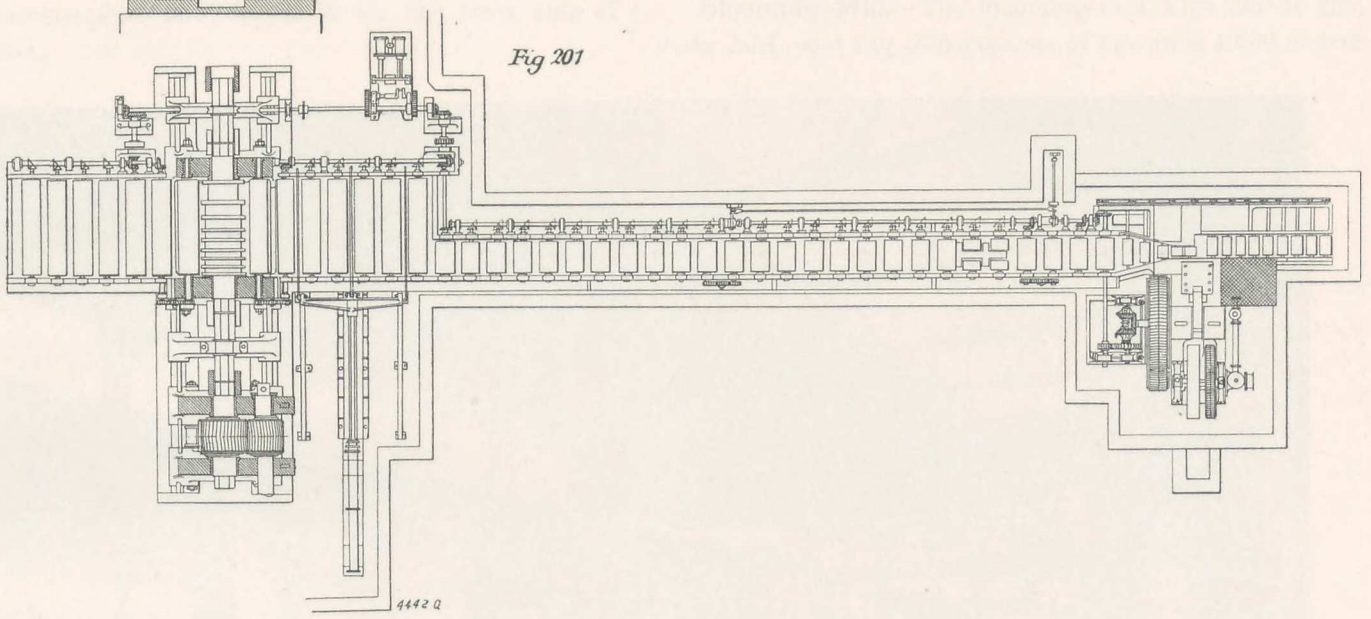


Fig. 202.

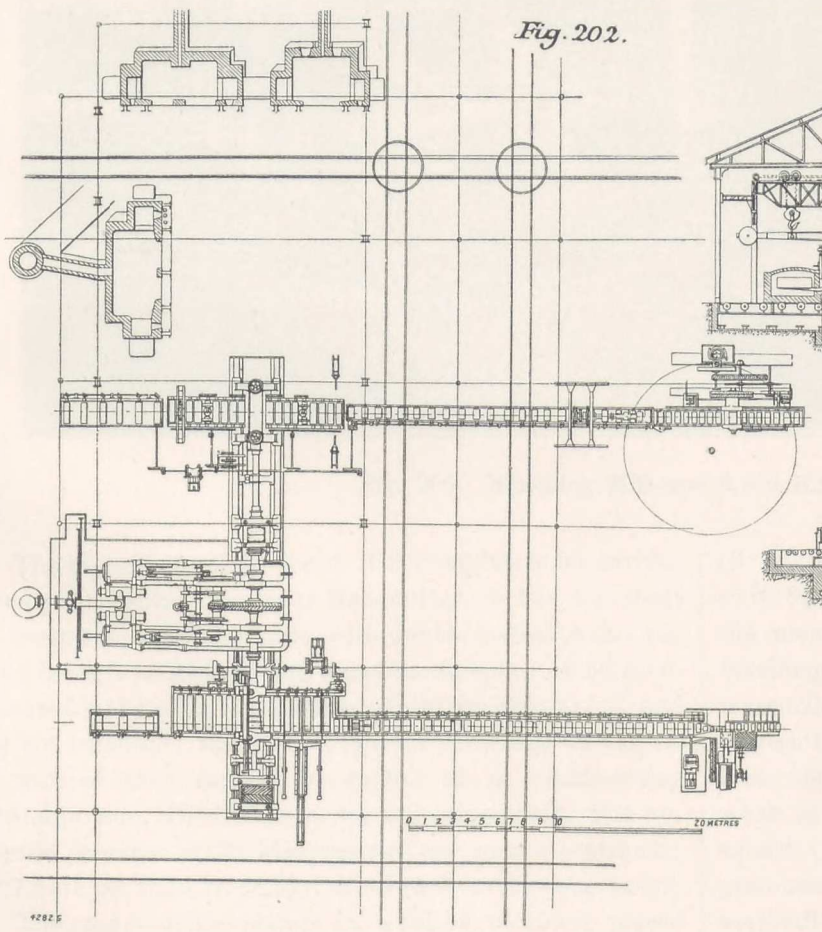


Fig. 203.

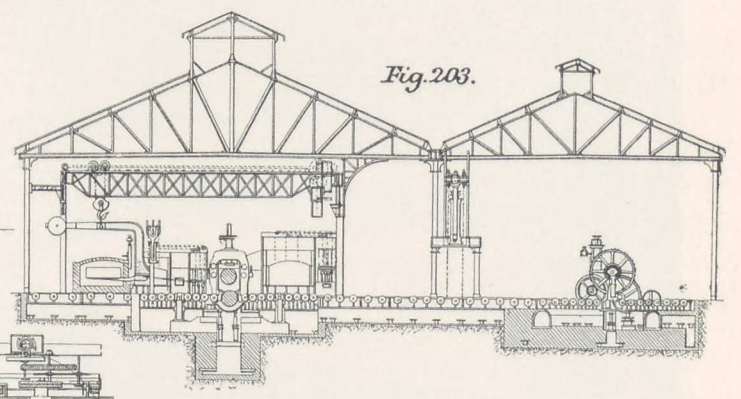


Fig. 204

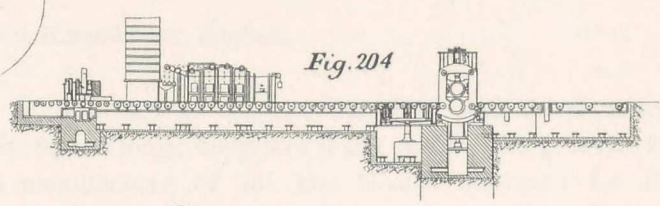
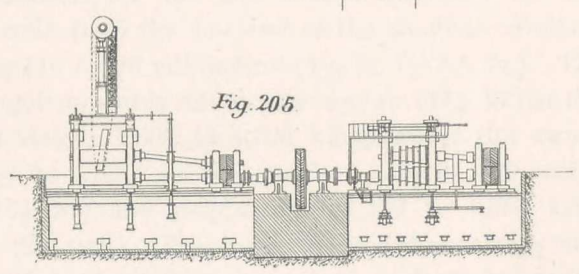


Fig. 205



Details of Blooming Mill.

has two cylinders, 1.200 metres (3 ft. 11¼ in.) in diameter, the length of stroke being 1.500 metres (4 ft. 11 in.). The effective steam pressure varies from 4 to 5 kilogrammes per square centimetre (56.89 to 71.11 lb. per square inch), and the maximum admission of steam is 75 per cent. Until recently the exhaust steam was allowed to escape; the engine, however, is now being fitted with a jet condenser. With an effective steam pressure of 4 kilogrammes per square centimetre (56.89 lb. per square inch), an effort of 150 tons can be exerted on the circumference of the rolls of the armour-plate mill, which is on the other side of the engine.

can operate, simultaneously, the blooming, and the armour-plate, mills. They are, however, generally driven independently, and as they are connected with the engine by means of hydraulic-worked clutches, it is easy to disconnect either one. On the driver's left-hand is a lever working the reversing gear four-way valve, and on his right is a lever to regulate the admission of steam. He also operates from the same platform the steam stop-valve, and the cylinder blow-off cocks. The whole of the working parts are fitted with automatic lubricating apparatus.

Blooming Mill.—The blooming mill, Figs. 200 to 205, Plate XLI., and Fig. 206, consists of two rolls 1.200 metres

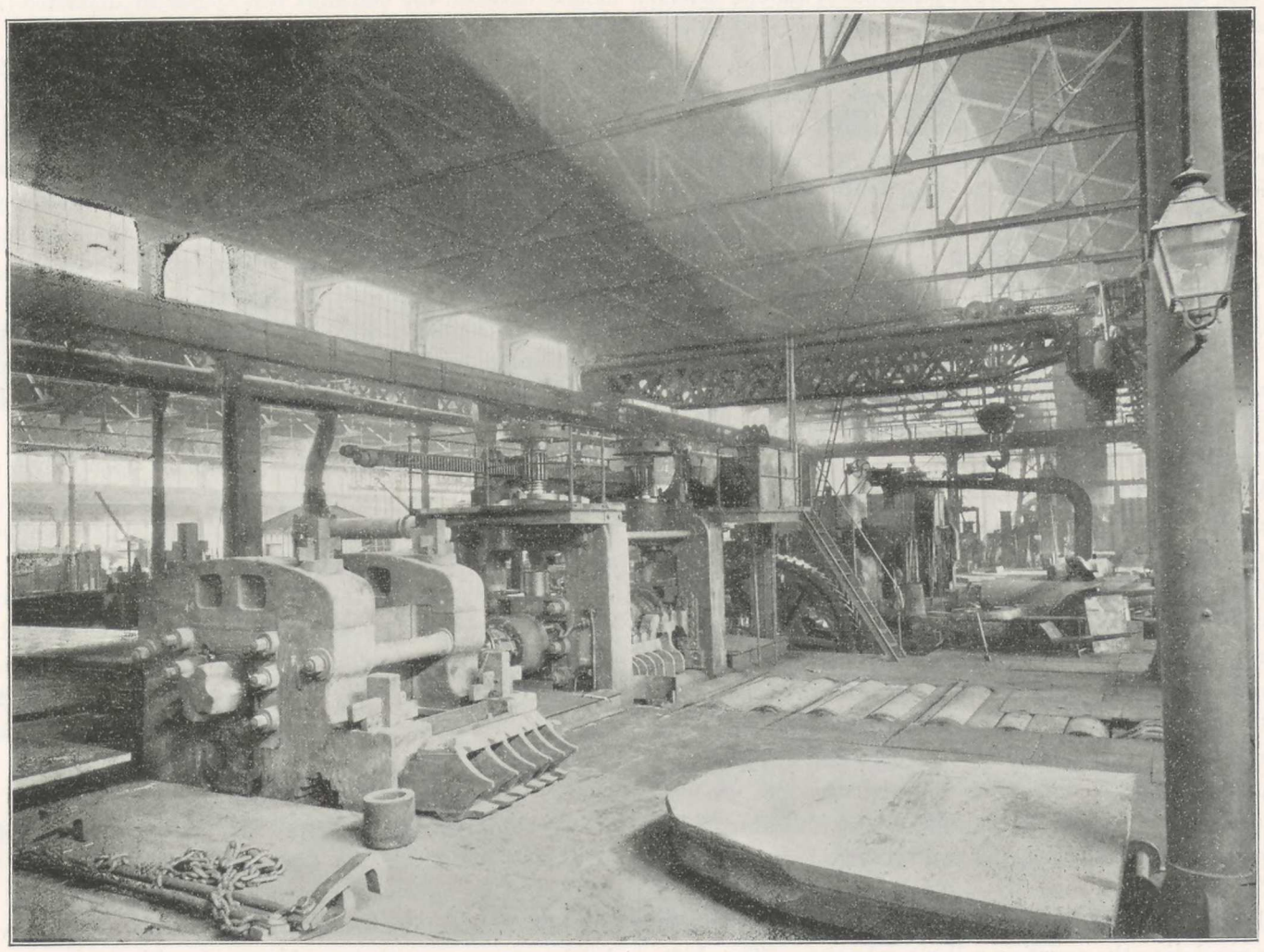


Fig. 206. Blooming Mill and 3,000 Horse-Power Engines.

The highest working speed of the engine is 90 revolutions per minute. Power is transmitted to the roll shaft by means of toothed wheels with double helical teeth, the ratio being 1 to 2.82, giving a maximum speed of 32 revolutions for the rolls. The slide valves are cylindrical, and are not balanced; the link-motion for reversing the engine is worked very rapidly by means of a double-acting hydraulic ram, which acts on the reversing shaft. The hydraulic pressure of 35 kilogrammes per square centimetre (497.81 lb. per sq. in.) is employed throughout the department.

The engine-driver stands on a raised platform placed at the rear of the steam cylinders. He can watch from there all the work being done, and an experienced driver

(3 ft. 11¼ in.) in original diameter, and 2.600 metres (8 ft. 6⅜ in.) long; they are made with eight grooves for the manufacture of all the blooms necessary for the finishing rolls, from the heaviest to the smallest sections, measuring 110 by 90 millimetres (4 $\frac{5}{16}$ in. by 3 $\frac{9}{16}$ in.). The largest ingot measures .450 metre square (17¾ in.) at the base, and weighs 1,600 to 1,700 kilogrammes (33 cwt.); what may be taken as the standard size is .420 metre square (16½ in.), and weighs from 1,250 to 1,350 kilogrammes (26 cwt.). The ingot is guided sideways and vertically through all the grooves, both in front and at the rear of the mill, by a special-shaped cast-steel guard-frame, a spare frame of the same type can be seen near the pinion

housing. With this arrangement but few bars deviate in the course of rolling, and they engage direct in the grooves without it being necessary to guide them with tongs.

The rolls are driven by two pinions set in a special-shaped housing, placed at the end of the train, with a view to serve for a rolling mill for large sections now being designed. These pinions are of cast steel; their original diameter is 1.220 metres (4 ft.); they have double-helical teeth of 191.637 millimetres (7½ in.) pitch; length between bearings 1.050 metres (3 ft. 5⅜ in.); diameter of coupling ends .500 metre (19 11/16 in.). The section is made tapering for the movable roll and its coupling-bar. The top roll is balanced by two hydraulic cylinders, which cause it to rest always on the two setting screws; these are slacked or tightened after every pass of the ingot, and they allow a total vertical travel for this movable roll of 100 millimetres (3 15/16 in.). Its coupling-shaft is also balanced hydraulically. The roll-setting screws are put in motion by a two-cylinder hydraulic device, the two plunger-pistons of which are united by a rack which operates direct the toothed pinions keyed on the roll-setting screws. The travel of the rack is 2.360 metres (7 ft. 9 in.); the two plunger pistons are respectively .165 and .105 metre (6½ in. and 4⅛ in.) in diameter; the smaller one is in constant communication with the accumulator, the pressure in which is 35 kilometres per square centimetre (497.81 lb. per square inch).

Above the right-hand housing frame is a platform, from which both the front and the rear of the mill can be seen. At one time this platform was fitted with levers for working the roll-setting screws, the carrying rollers, the shifting apparatus, and the shifting lift. Now, however, the roll-setting screws and the carrying rollers only, are operated from the platform. The man in charge of the rolls has in sight a special table which shows him how the top roll has to be set for each groove. The ingot, after being turned over, is often passed four times through the first grooves. The positions are given on the table by an indicator which works in conjunction with the two roll-setting screws.

The two levers may be worked by one man, but in regular work it is preferable to put a boy in charge of the lever regulating the carrying roller mechanism. The shifting of the bar opposite each groove is effected with great facility by means of a tilter worked by a hydraulic piston having a long travel; this piston acts on three double-branched forks which slide between the carrying rollers. These forks are hinged on a cross-piece; they roll on the rails of a hydraulic lifting platform, and disappear entirely when the ingot or bar is being rolled. In combining the two actions of these forks, the driver causes the ingot to make a quarter of a revolution, and places it opposite the next groove. The total travel of the forks is 2.800 metres (9 ft. 2¼ in.). The hydraulic piston of the shifting apparatus is .170 metre (6 1/16 in.) in diameter. The piston-rod is .120 metre (4¾ in.) in diameter. One side of the piston is in constant communication with the accumulator, while the larger area of the other side is only put intermittently under pressure by means of a distributor. The driver who works the distributor formerly stood on the platform above the mill; but as he could not ascertain exactly the position of the bars with regard to the grooves, his station has been altered to the ground level, opposite the larger grooves, from where he can readily work the apparatus. When a bar stops in the guides owing to burrs, the shifting forks are used to disengage it.

Two groups of seven large feed-rollers .590 metre (23¼ in.) in diameter, of hard cast iron, are placed in front and at the rear of the mill. These rollers are of the same length as the body of the rolls; the first ones, which are lodged between the housings, are larger in diameter (.640 and .740 metre (25 3/16 and 29⅛ in.), in order to raise the bar and assist in guiding it between the small grooves. Cast-steel pieces placed level with the works fill up the interval between each roller. The two groups of feed-rollers are operated simultaneously by a small reversing engine placed beneath. The diameter of the two cylinders is .240 metre (9 7/16 in.), and the stroke .300 metre (11 13/16 in.). The engine runs at a speed of 100 revolutions per minute. This engine also works part of the series of rollers 1 metre (3 ft. 3⅜ in.) long and .520 metre (20½ in.) in diameter, which connect the rolling mill to the hot-bloom shearing machine. Rollers turning free in their bearings have been added at the rear opposite the smaller grooves.

Shearing Machines.—Rolled bars of all sections and lengths, when they are to be used for making smaller blooms, are carried by the conveying apparatus opposite the line of small rollers to the hot-shearing machine. As a rule, the blooms are rolled out direct in the other mills. When, however, it is not convenient that they should be used immediately, they are covered with a layer of ashes until the time when they can be put in a reheating furnace. By this means a large economy in fuel consumption is effected, and the output of the furnaces serving the finishing rolls is increased.

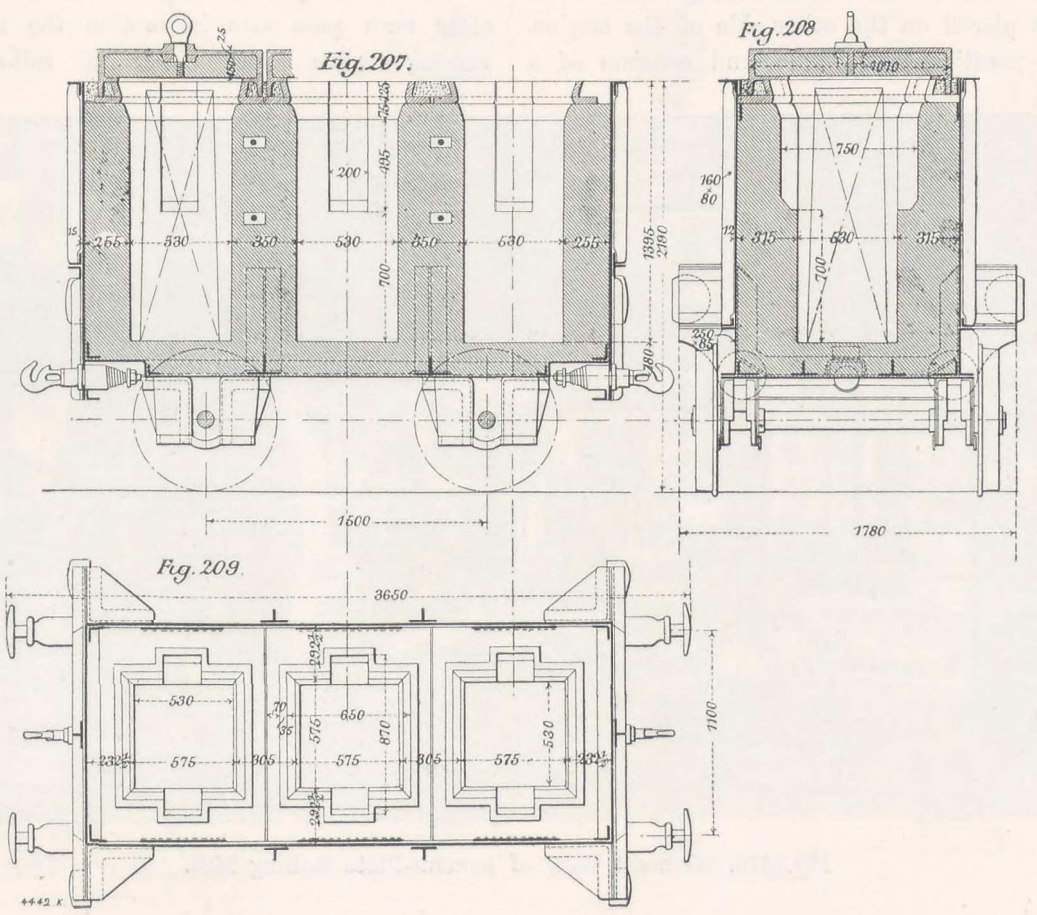
The hot-shearing machine for blooms is 26 metres (85 ft.) distant from the blooming mill. A part of the line of rollers between the two was formerly worked by the shearing machine itself, through toothed gearing with clutches to reverse their motion. As this device did not give full satisfaction, a small two-cylinder reversing engine has been erected on a suitable spot; the cylinders are .165 metre (6½ in.) in diameter, the stroke being .300 metre (11 13/16 in.). This engine works the rollers by friction, the speed varying according to the needs of each case. The small rollers which serve to free the blades from the cut blooms, are alone worked by the shearing machine. The maximum section which can be cut is 300 by 200 millimetres (11 13/16 in.) by 7⅞ in.). The tool-holder moves horizontally, its length of travel being .250 metre (9⅞ in.); it is engaged and thrown out of gear hydraulically. The shearing machine is driven by a vertical engine with a single cylinder .350 metre (13¾ in.) in diameter, and .400 metre (15¾ in.) length of stroke; the normal speed is 160 revolutions per minute. It is fitted with a regulator.

Its energy is transmitted by two sets of toothed wheels, gearing at 20 to 1, corresponding to eight cuts per minute. To prevent any serious fractures, the flywheel only drives through a safety bolt, which would be sheared off if a piece of unusual resistance came between the blades.

The movable catch which regulates the length of the blooms to be cut off, slides on a square shaft, on which it is made to hold at all the distances required. Each bloom, on leaving the shears, is stamped with the number of the cast, and the quality mark.

Reheating Furnaces.—Formerly the ingots were reheated in a gas-fired soaking pit, and were carried hot by a crane to a tilting frame placed between two rollers of the series which run from the mill to the shearing machine. As, however, this method was surrounded by various disadvantages, amongst others the difficulty of getting rid of the slag which accumulated in the air and gas chambers, it was abandoned, and the present furnaces above the ground level were substituted. There are two of the latter, placed as shown on the general plan of the rolling-mill department, Plate XXXVII.; they are served by an electric travelling crane. Each furnace has two fires of the usual type, provided with air blast, one at each end, the flame outlet being at the back in the middle of the furnace length. The hearth is 6 metres (19 ft. 9 in.) long and 2.40 metres (7 ft. 10½ in.) deep; the height under arch is 1.30 metre (4 ft. $3\frac{3}{16}$ in.). At the front there are two large openings 2.200 metres (7 ft. 2¼ in.) wide, each one being closed by a door in three parts, all of which are operated independently by a hydraulic ram connected to the doors by chains. The arrangement is similar to that of the armour-plate reheating furnace.

Each furnace can hold fourteen ingots of 1300 kilogrammes each (26 cwt.); these, when charged cold, are rolled less than five hours after. This shows an output of 45 tons per twelve hours, the average coal consumption being 125 kilogrammes (2½ cwt.) per ton of cold ingots. In current work, however, the ingots are charged hot when each furnace can receive easily up to 150 tons of ingots, which are charged at a temperature varying from 900 deg. to 950 deg. Cent. (1697 deg. Fahr.); this reduces the coal consumption to 35 kilogrammes (77 lb.) per ton of ingots. The flames on leaving the furnace serve to heat a multitubular boiler of approximately 163 square metres (1754.58 sq. ft.) heating surface of the same type as that shown in Figs. 186 to 189 (page 79 *ante*); each of these boilers produces about 20 tons of steam per twelve hours.



12-Ton Hot Ingot Wagon.

The ingots are placed in the furnace on brick supports .300 metre ($11\frac{3}{16}$ in.) high above the hearth, in two rows of four ingots at the fire bridges, and two rows of three ingots in the middle of the furnace — fourteen ingots in all. They are laid lengthwise in the furnace, with sufficient space between them for the circulation of the flame. This is easily done with the ⊂-shaped charging device suspended from an electric travelling crane; three-

and even four, ingots may be charged simultaneously. When hot, the same apparatus carries them rapidly, at a speed of 48 metres (157 ft.) per minute, on brackets from which they are lowered to the feed-rollers which convey them to the mill. The ingots are received hot from the steel works in special trucks divided in three compartments, each closed with a cover (Figs. 207 to 209). The ingots are taken out of the trucks with tongs suspended from a steam crane; they are laid horizontally on a slab. From this the charging device takes them, three at a time, to the furnace.

Armour-Plate Mill.—This rolling mill, of which a general view is given in Fig. 210, is worked by the same reversing engine that drives the blooming mill above described, and is placed on the other side of the engine. It has been in operation since 1886, and consists of a pair of horizontal rolls of cast iron. The following are some particulars:

	m.	ft.	in.
Length of rolls	3.000	9	$10\frac{1}{16}$
Diameter of rolls	.950	0	$37\frac{3}{8}$
Normal distance between rolls ...	.600	0	$23\frac{5}{8}$
Extreme distance between rolls ...	.750	0	$29\frac{1}{2}$

The two main pinions are placed near the engine, the lower pinion being keyed on the engine shaft. The cast-steel shafts connecting the pinions to the rolls, are 5 metres (16 ft. 5 in.) in length, the top one being balanced by a hydraulic ram. The original diameter of the cast-steel pinions is 1.050 metre (3 ft. $5\frac{3}{8}$ in.) and their length between bearings is 1 metre (3 ft. $3\frac{3}{8}$ in.); each pinion is in two parts with double-helical teeth of .183 metre ($7\frac{3}{16}$ in.) pitch. The coupling ends of the pinions and rolls are .500 metre ($19\frac{11}{16}$ in.) in diameter. This mill is illustrated in more detail by Figs. 211 to 214, which also show the foundations. The average speed of the rolls varies between 26 and 34 revolutions per minute. The rapidity with which the rolling and the reversing actions are effected, enables plates 23 metres (75 ft. 6 in.) long, 1.150 metres (3 ft. $9\frac{1}{4}$ in.) wide, and under 5 millimetres ($\frac{3}{16}$ in.) in thickness, to be produced. The following sizes have often been rolled in this mill:

8 metres × 2.200 metres × 6 millimetres (26 ft. 3 in. × 7 ft. $2\frac{5}{8}$ in. × $\frac{3}{16}$ in. full).

18 metres × 2.770 metres × 30 millimetres (59 ft. 0 in. × 9 ft. 1 in. × $1\frac{3}{16}$ in.)

The chief operator is placed in front of the train, and after each pass sets in motion the small vertical reversing engine which works the roll-setting screws by means of a belt. The dimensions of this engine are the following:

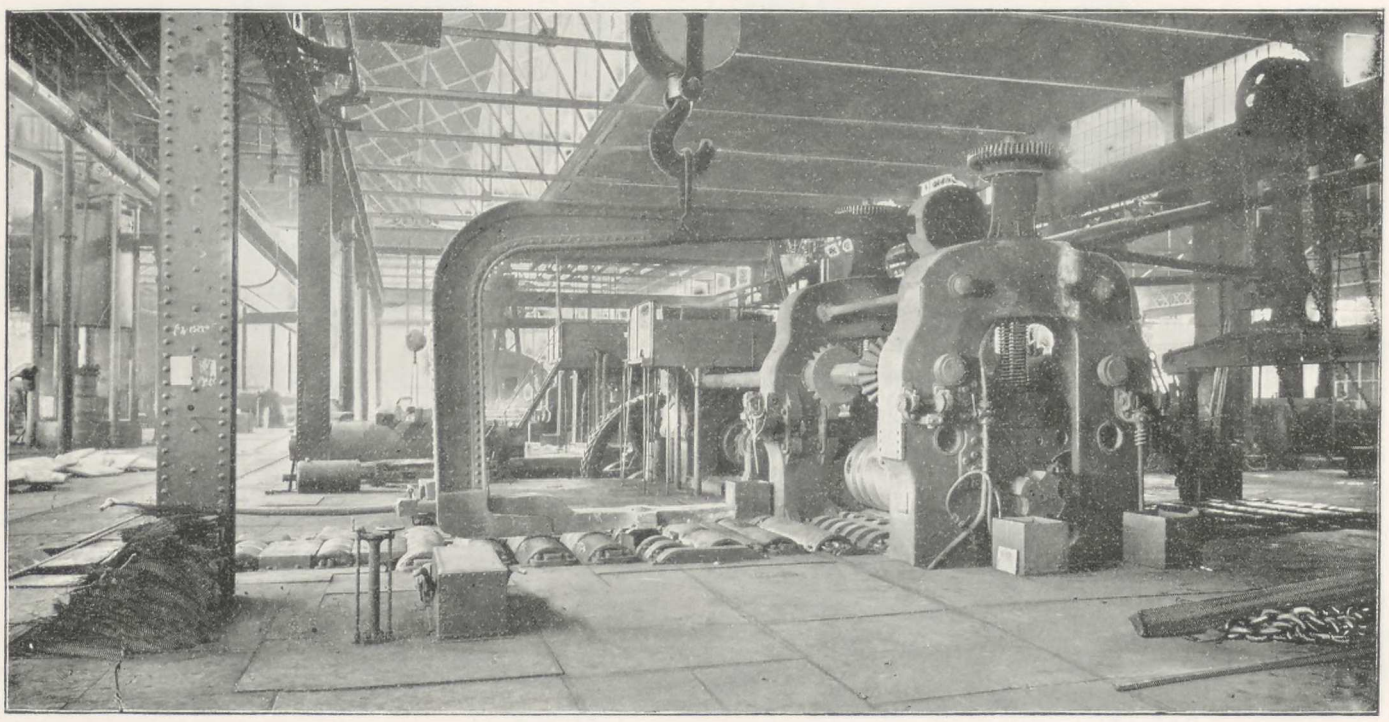
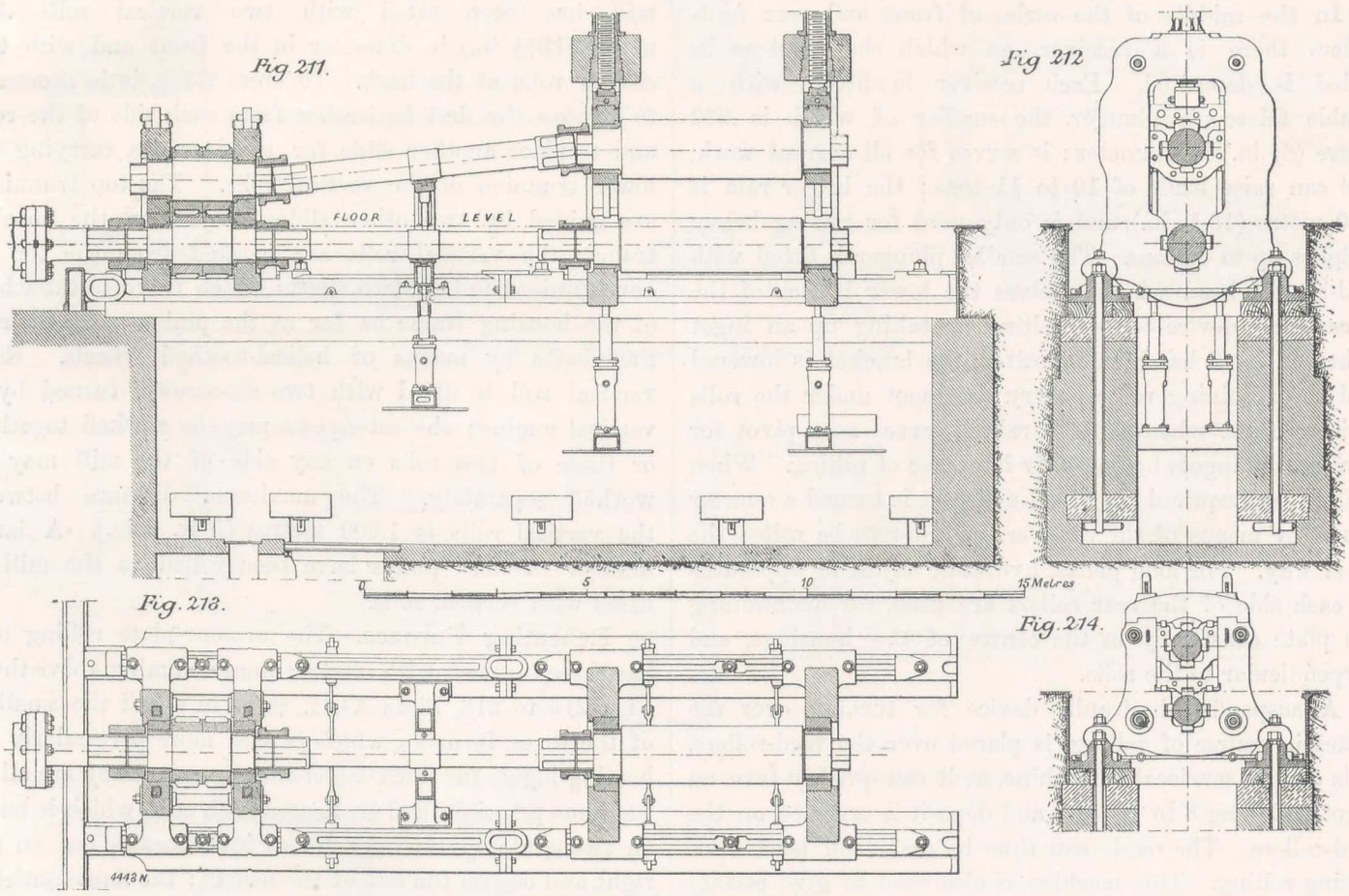


Fig. 210. General View of Armour-Plate Rolling Mill.

Diameter of steam cylinders ...	.165 m.	$6\frac{1}{2}$ in.
Stroke of pistons	.300 m.	$11\frac{13}{16}$ in.
Maximum speed	180 revolutions per minute.	180 revolutions per minute.

This engine is fitted with toothed-wheel gearing of two different ratios, which are thrown in gear alternately. A quick motion is given when the rolling is commenced, and for slacking back the roll-setting screws; this gives a travel of 11 millimetres ($\frac{7}{16}$ in.) for five revolutions of the engine; the slower motion, given when rolling is nearly at an end, produces a travel of 1 millimetre (.039 in.) only, for five revolutions of the engine. For the last passes, pressure can also be given by hand, with a small wheel placed on the second shaft of the engine; one and a half turns of this wheel give a travel of 1 millimetre

(.039 in.). The roll-setting screws are of hard-forged steel, and the nuts are of phosphor-bronze. The outside diameter on threads, is .300 metre ($11\frac{3}{16}$ in.); the threads are single, with 36 millimetres ($1\frac{3}{5}$ in. full) pitch. The screws end in a cylindrical length provided with a groove which slides in the boss of the endless screw-wheels that work them. Under each roll-setting screw is placed a special safety device, with double-ended wedge, and the bolts that hold it together are designed to break under any unusual strain. When, owing to any accident to the rolls or to the engine, a plate remains lodged in the mill, these safety appliances are quickly taken to pieces; this enables the plate to be removed rapidly, thus preventing all damage to the rolls by their remaining in contact with bearings is used; in this case the position of the farther bearing is given by a second index, on the same scale, the first index still showing the position of the lower trunnion. This double indication is readily observed by the attendant; he holds a lever which enables him to throw out of gear, through a clutch, the two endless screws which work the roll-setting screws, and to set only one working when necessary. Regulation is obtained by screwing down the two roll-setting screws to the maximum; then by working on the lever and reversing the engine, the one setting screw which can work is unscrewed and brought up to the required height. With this arrangement it is easy to roll all taper armour-plates. Hard-steel plates of the following dimensions have been



The Armour-Plate Mill.

the rolled material. Under these appliances is a wedge worked by a screw, which serves to maintain the rolls parallel. The top roll, which is movable as well as its fittings, brasses, wedges, &c., is balanced and maintained constantly pressed against the roll-setting screws by four plunger pistons .180 metre ($7\frac{1}{8}$ in.) in diameter, working under the hydraulic pressure of 35 kilogrammes per square centimetre (497.81 lb. per square inch).

The position of the top roll with relation to that of the fixed lower roll, is continuously shown by an index which slides up and down a scale fixed on the housing. A displacement of the roll of 10 millimetres ($\frac{3}{8}$ in.) corresponds to a travel of 25 millimetres (1 in.) of the index. When taper plates have to be rolled, for which it is necessary to incline the top roll more or less, a roll with spherical

rolled in this way: 7.610 metres by 2.360 metres by 80 millimetres by 39 millimetres (24 ft. $11\frac{9}{16}$ in. by 7 ft. 9 in. by $3\frac{3}{16}$ in. by $1\frac{9}{16}$ in.), and though the operation is a delicate one, the plates were turned out perfectly flat, the exact ratio of effort exerted on each side being well maintained. The first taper armour-plates rolled in this mill were of iron, and subsequent operations never revealed imperfect welding.

Feeding rollers are required in front and in the rear of the mill when armour-plates weighing up to 40 tons are being rolled. Each series consists of nine rollers .540 metre ($21\frac{1}{4}$ in.) in diameter and 1.800 metres (5 ft. 11 in.) long, the rollers rising .140 metre ($5\frac{1}{2}$ in.) above ground level. The feed-rollers are worked by a small reversing two-cylinder engine placed below

the ground level. Its principal dimensions are the following:

Diameter of cylinders	.260 m.	0 ft. $10\frac{1}{4}$ in.
Stroke	.300 m.	0 ft. $11\frac{13}{16}$ in.
Maximum speed	150 revolutions per minute.	150 revolutions per minute.

The ratio between the speed of the engine and that of the rolls, is 10 to 1, which corresponds to a speed of the rollers of .424 metre ($16\frac{11}{16}$ in.) per second. In order to prevent fractures, the engine drives the cast-steel toothed wheels, which work the rolls, by friction. The series of rollers which lead from the mill to the shears can be driven by the same engine by means of a clutch.

In the middle of the series of front and rear feed-rollers there is a receiver, on which the ingot to be rolled is deposited. Each receiver is fitted with a double telescopic plunger, the smaller of which is .220 metre ($8\frac{5}{8}$ in.) in diameter; it serves for all current work, and can raise loads of 10 to 11 tons; the larger ram is .390 metre ($15\frac{5}{16}$ in.), and is only used for raising heavy weights up to 40 tons. The smaller plunger is fitted with a U-shaped head which receives the lower branch of the C-carrying device for depositing or taking up an ingot When an ingot has been deposited, the bracket is lowered and the adjoining rollers carry the ingot under the rolls This receiver, when slightly raised, serves as a pivot for turning the ingots horizontally in course of rolling. When a plate has acquired the given width, it is turned a quarter round by means of the receiver, in order to be rolled the other way. For long plates, hydraulic adjusting apparatus on each side of the rear rollers are used, for maintaining the plate constantly in the centre of the housings, and perpendicular to the rolls.

A suspended hydraulic device for turning over the plates in course of rolling, is placed over the feed-rollers. It is a most serviceable machine, as it can quickly turn an ingot weighing 8 to 10 tons, and deposit it reversed on the feed-rollers. The oxide can thus be scaled off both sides during rolling. This machine is also used to give certain ingots a quarter turn, in order to roll them alternately flat or on edge under the horizontal rolls; this gives a much greater pressure than can be obtained in a universal mill, in which lateral pressures are kept necessarily low, to avoid fractures in the gearing.

Another of these machines, but much more powerful, is placed between the mill and the hot shears; it is used only for turning over deck-plates or heavy armour-plates. The hydraulic cylinder is suspended to an iron frame, leaving a free space of 3.500 metres (11 ft. 6 in.) above the feed-rollers. The hydraulic ram is made telescopic; the smaller one of forged steel, .315 metre ($12\frac{3}{8}$ in.) in diameter, serves to lift and turn over plates weighing up to 12 tons. It slides in the larger one, which is .460 metre ($18\frac{1}{8}$ in.) in diameter, and is used to turn over plates weighing from 13 to 40 tons. The travel is 2 metres (6 ft. $6\frac{11}{16}$ in.), and the head is guided in two powerful slides.

The centre of the plate is brought between two endless chains of special manufacture, with forged links: these chains, which are placed 1 metre ($39\frac{3}{8}$ in.) apart, run on two pulleys, that are driven by two ratchet wheels set in motion by a central loose wheel, actuated by a plate chain which encircles it, and one end of which is fixed to the foot of the cylinder. The turning over of a 35 to 40-ton plate is effected with smoothness and efficiency.

All the machines described above, and the accessory apparatus, are controlled from a high platform placed above the coupling shafts, from which the driver can witness all the work on both sides of the mill. The adjusting apparatus, which is not so frequently used, is worked from the floor level. On several occasions this mill has been fitted with two vertical rolls .500 metre ($19\frac{11}{16}$ in.) in diameter in the front and with two similar rolls at the back. To erect these, it is necessary to remove the first feed-roller from each side of the rolls and to place another slide for the bearings carrying the lower trunnion of the vertical rolls. The top trunnions are guided by two other slides, stayed on the housing frame; the vertical rolls are worked from the top by bevel pinions and by two shafts which traverse the whole of the housing frame as far as the pinions; these drive the shafts by means of helical-toothed wheels. Each vertical roll is fitted with two set-screws, turned by a vertical engine; the set-screws may be worked together, or those of two rolls on any side of the mill may be worked separately. The maximum distance between the vertical rolls is 1.600 metres (5 ft. 3 in.). A large number of deck plates have been rolled in the mill so fitted with vertical rolls.

Reheating Furnace.—The armour-plate rolling mill has three furnaces with electric cranes running above them. Figs. 215 to 218, Plate XLII., show in detail the smallest of the three furnaces, which is used more particularly for heating ingots for thick merchant plates. They are all on the same principle, and are heated with coal, which is burnt on two grates provided with air blast nozzles, one on the right and one on the left of the hearth; the flame outlet is in the centre at the back. The flames on leaving the furnace are employed to heat three multitubular boilers, one of 188 square metres (2023.68 square feet), and two others of 250 square metres (2691 square feet) heating surface. The reheating furnace nearest the mill, is similar in construction to that illustrated, but is of the following dimensions:

	m.	ft. in.
Length of hearth	5.960	19 $6\frac{5}{8}$
Depth ,, ...	3.000	9 $10\frac{1}{8}$
Height under arch	1.500	4 11
Width of doors	2.200 and 2.400	7 $2\frac{5}{8}$ and 7 $10\frac{1}{8}$
Two grates	1.400 by 1.100	4 $7\frac{7}{8}$ by 3 $7\frac{5}{16}$

The third furnace serves specially for heavy armour-plates. It was formerly used for heating iron plates

THE ROLLING MILL DEPARTMENT.

Fig. 216.

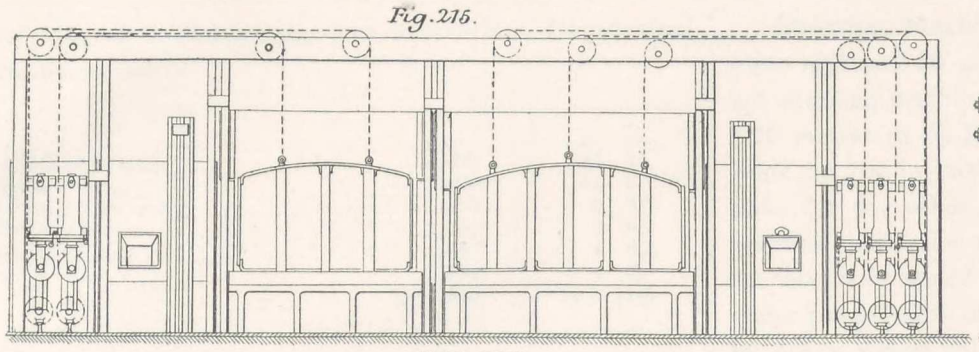


Fig. 216.

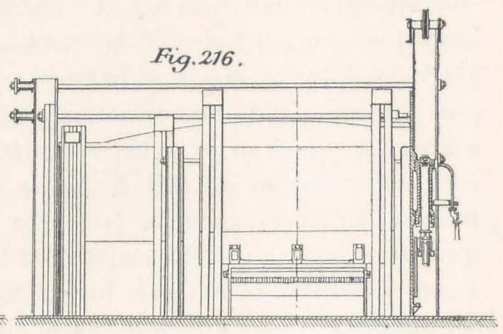


Fig. 217.

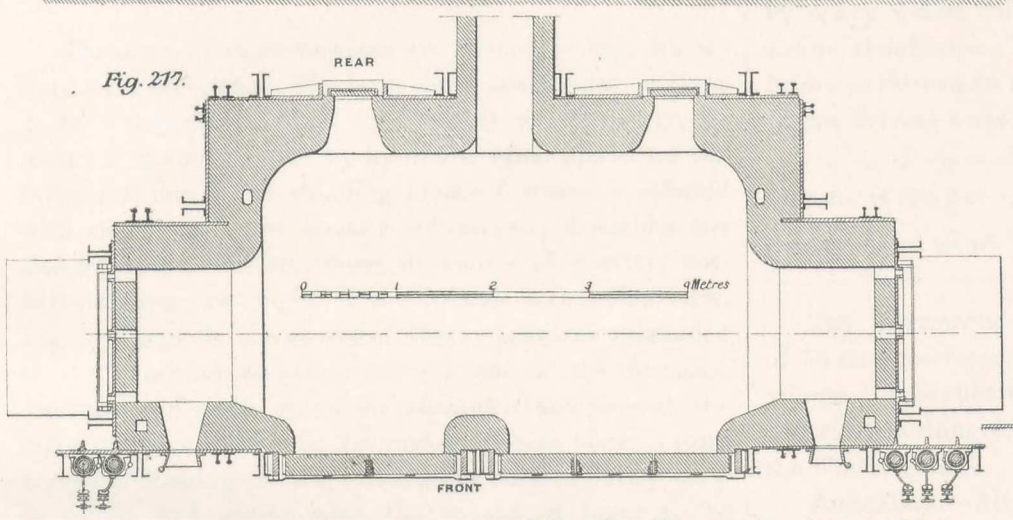
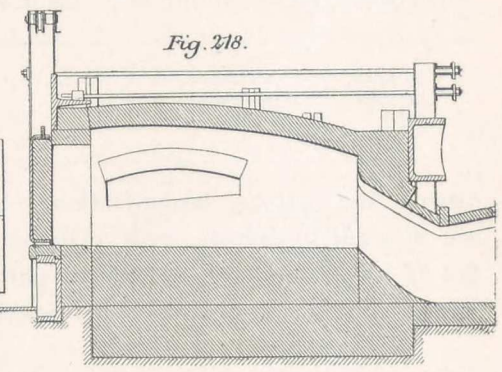


Fig. 218.



Reheating Furnace for Armour Plates.

Fig. 219.

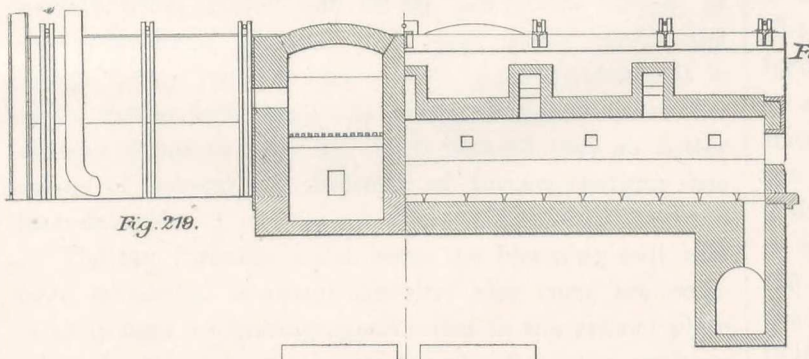
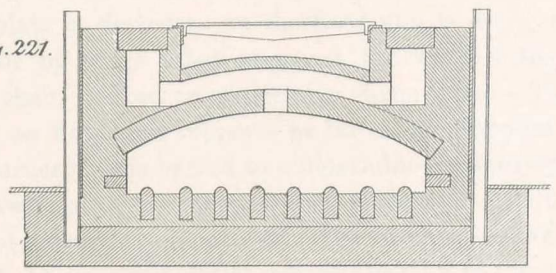


Fig. 221.



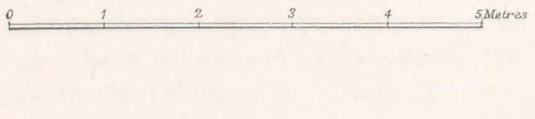


Fig. 220.

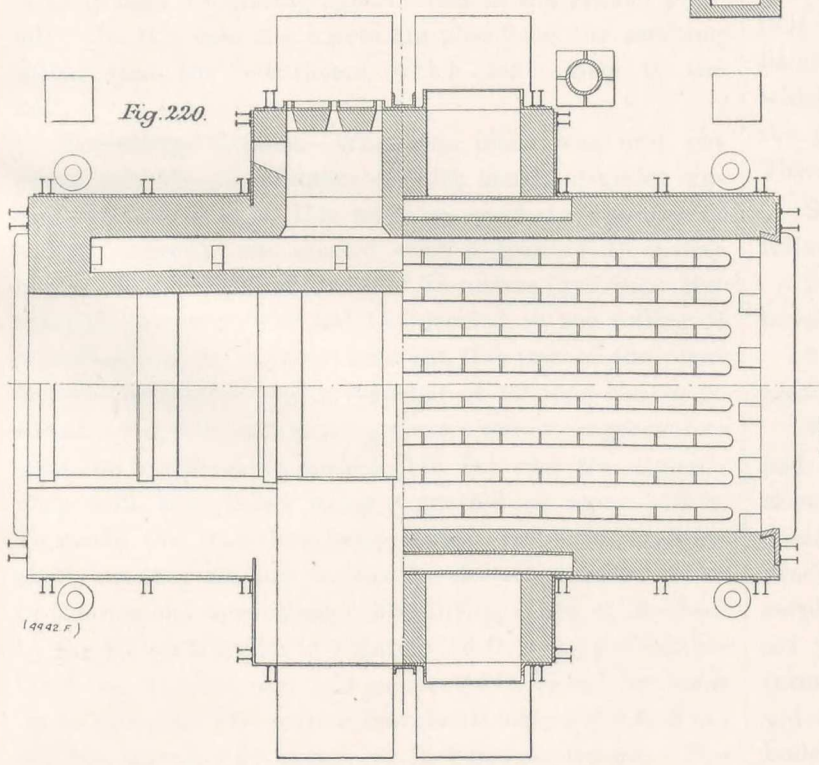
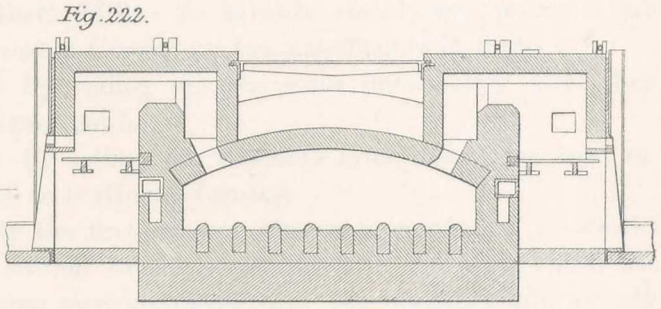


Fig. 222.



Annealing Furnace for Merchant Plates.

weighing 35 to 38 tons, previous to welding. Its principal dimensions are:

	m.	ft.	in.
Length of hearth	4.000	13	$1\frac{1}{2}$
Depth ,, ...	3.400	11	2
Height under arch	1.950	6	$4\frac{3}{4}$
Width of door	2.900	9	$6\frac{1}{8}$
Height of door	1.450	4	$9\frac{1}{16}$
Two grates	1.400	4	$7\frac{1}{8}$
	by .900	by 2	$11\frac{7}{16}$

The doors of these furnaces are formed of iron frames lined with firebricks. The large doors are divided in three parts, which can be lifted up together or separately, by means of chains, worked by hydraulic rams placed on the furnace fronts. The charging of the furnaces is effected with the **C**-apparatus already referred to; it enables the charge to be taken up under its centre of gravity, notwithstanding the height of the furnace arch. The view, Fig. 210, page 86, shows one of these apparatus suspended to the overhead travellers serving one of the furnaces. The men can easily guide the apparatus and deposit the ingot on brick blocks in the furnace; these blocks insure a regular heating of the whole ingot surface; they vary in height and section with the weight of ingot to be carried. There are three sizes of these **C** transporters, namely, 5-ton, 15-ton, and 40-ton power, the weight of the latter being 20 tons. The part which carries the charge being liable to wear, it is made movable; it is either flat or fork-shaped, according to the nature of the charges it has to take up. It is claimed that no better means of solving the difficulty of furnace-charging has been devised.

The two furnaces which serve the blooming mill, and over which an overhead traveller also runs, are occasionally used for heating ingots rolled in the armour-plate mill. In this case the ingots are placed on the carrying rollers near the hot shears, which take them to the mill.

Travelling Cranes.—When the plant was first put down, only the manufacture of thick merchant-plates was contemplated, and for this work an overhead traveller of 20 tons capacity was erected with a span of 19 metres (62 ft.), and a length of travel of 75 metres (246 ft.). But after Messrs. Schneider and Co. decided on the rolling of armour-plates up to 40-tons weight, this part of the plant became insufficient, and a traveller of 60 tons had to be added. For this, the carrying girders were strengthened to span the length of 35 metres (115 ft.) over the armour-plate mill, the girders being supported on extra pillars. Formerly the travellers were driven by a transmission shaft, but they are now worked by electric motors coupled to the original mechanism. The lifting speed of the load by the 20-ton traveller is 5 metres (16 ft. 4 in.) per minute for 8-ton weights, and 1.25 metres (4 ft. $1\frac{1}{4}$ in.) for loads up to 20 tons. The carrier travels 10 metres (32 ft. 9 in.) and the traveller 20 metres (65 ft. 7 in.) per minute. The speeds of the 60-ton traveller are about the same.

Shearing Machines.—In the same axis as the armour-plate mill and 26 metres (85 ft. 4 in.) distant, is a large hot shearing machine, worked by steam, to cut steel plates 1.20 metres (3 ft. 11 $\frac{1}{4}$ in.) wide and .120 metre ($4\frac{3}{4}$ in.) thick, or .700 by .200 metre ($27\frac{9}{16}$ in. by $7\frac{7}{8}$ in.), to prepare slabs for the other mills. A line of rollers unites this machine with the mill, and a series of rollers beyond the blades is added in a jointed frame which gives way under the pressure of the cut piece. The flywheel is fitted by a key which will break in case a piece unusually resistant should come between the two jaws. The top blade holder is thrown in gear by a hydraulic ram. The steam engine driving these shears is of the following dimensions:

Diameter of cylinder	0.550 m.	$21\frac{11}{16}$ in.
Stroke	0.500 m.	$19\frac{11}{16}$ in.
Revolutions per minute	168	168

The intermediate toothed-wheel gearing has a ratio of 56 to 1, corresponding to three strokes of the tool per minute. This shearing machine is placed under the 15-ton electric travelling crane referred to in the description of the blooming mill.

Annealing.—All the steel merchant-plates are annealed separately before shearing; the furnaces in which this work is done is illustrated by Figs. 219 to 222, Plate XLII. The plate is deposited on the floor, and is brought to the furnace by tongs fitted on a rod, the whole being drawn by a chain hooked on a portable steam crane. The plate slides on fire-brick supports as far as the opposite side of the furnace; it is heated to a determined temperature, and is drawn out of the furnace from the rear. It is then left to cool down on cooling beds. The furnace is 7.900 metres (25 ft. 11 in.) long, 3.100 metres (10 ft. 2 in.) wide; it is fired by four grates of the usual type, 1 metre by .7 metre ($39\frac{3}{8}$ in. by $27\frac{9}{16}$ in.), provided with a steam jet. The flames divide through openings, the position and size of which have been determined by experience, the outlet of the gases to the chimney, being near the furnace doors. There are two furnaces of this type.

Sheet Mills.—As already stated, two processes are followed at Creusot for the manufacture of sheets.

1. By rolling out the slabs immediately after they have been cut hot.

2. By rolling out the slabs after these have been reheated in horizontal furnaces.

By the first process, blooms proportionate in weight and section to the slabs required, are taken from the shearing machine placed near the blooming mill already described. When a greater number of blooms are produced than can be dealt with in the sheet mill, the surplus is kept hot under a layer of ashes. The blooms are placed by means of trucks in two small reheating furnaces, fitted with one grate of the usual type, provided with air blast; the waste gases heat multitubular boilers of 135 square metres (1453.18 square feet) heating surface, of the same type as those already described. After

a few minutes' reheating, the blooms are carried on a truck, and placed on the lifting platform feed-rollers.

The slab mill has three-high rolls; it is shown in the general plan of the sheet and plate mills, Fig. 223, Plate XLIII., and in detail by Figs. 224 and 225, Plate XLIII. The engine drives the middle roll pinion; the roll revolves in bearings which rest on shoulders carried by the housing frames; its height is fixed and the position of the top and bottom rolls is determined by adjustable wedges in order to obtain the required thickness for the bar. Only two types of slab bars are rolled in the same set of rolls; the largest size is .235 metre ($9\frac{1}{4}$ in.) wide and the smaller .175 metre ($6\frac{7}{8}$ in.) wide, the minimum thickness of the former being 13 millimetres ($\frac{1}{2}$ in.) and of the latter 8 millimetres ($\frac{5}{16}$ in.). The rolls now in use have eight grooves, alternated for the two sizes of slab bars. The speed of the mill is 54 revolutions per minute; the mean diameter of the rolls is .700 metre ($27\frac{9}{16}$ in.); and their length 2.400 metres (7 ft. 10 in.) The bloom is rapidly transformed into a flat bar, and is afterwards carried to a quick-working shearing machine, which cuts it in two, four, six or eight slabs in a few seconds; the temperature is still maintained to 1,000 deg. or 1,050 deg. (1,877 deg. Fahr.) when they are taken to the sheet mills. The train in which the slabs are rolled out into sheets consists of five pairs of housings, each with two rolls; four of these are for direct rolling, the fifth being used for the sheets that require reheating. The shearing machine is placed opposite the middle mill so as to reduce to a minimum the travel of the slabs; these are taken by boys from the shearing machine to the mills, generally in pairs, following the lines shown in dotted lines in Fig. 223, Plate XLIII.

Figs. 224 and 225, Plate XLIII., show the general arrangement of this train; the roll-setting gear is operated mechanically by means of a transmission, worked by the train itself, which acts by belting and friction cones upon the screws of the roll-adjusting wedges and upon a pressure indicator; this is in sight of the workmen and of the boy in charge of the adjustable gear. The top roll is worked by connecting shafts, and balanced by hydraulic rams. In the fifth mill the top roll is free, and the screws which act upon the adjusting wedges are independent, and worked by a handwheel. The rolls were formerly .620 metre ($24\frac{3}{8}$ in.) in diameter; they are now .650 metre ($25\frac{5}{8}$ in.) diameter, and 1.200 metres (3 ft. $11\frac{1}{4}$ in.) long; the bearings are .480 metre ($18\frac{7}{8}$ in.) in diameter, and the ends .400 metre ($15\frac{3}{4}$ in.).

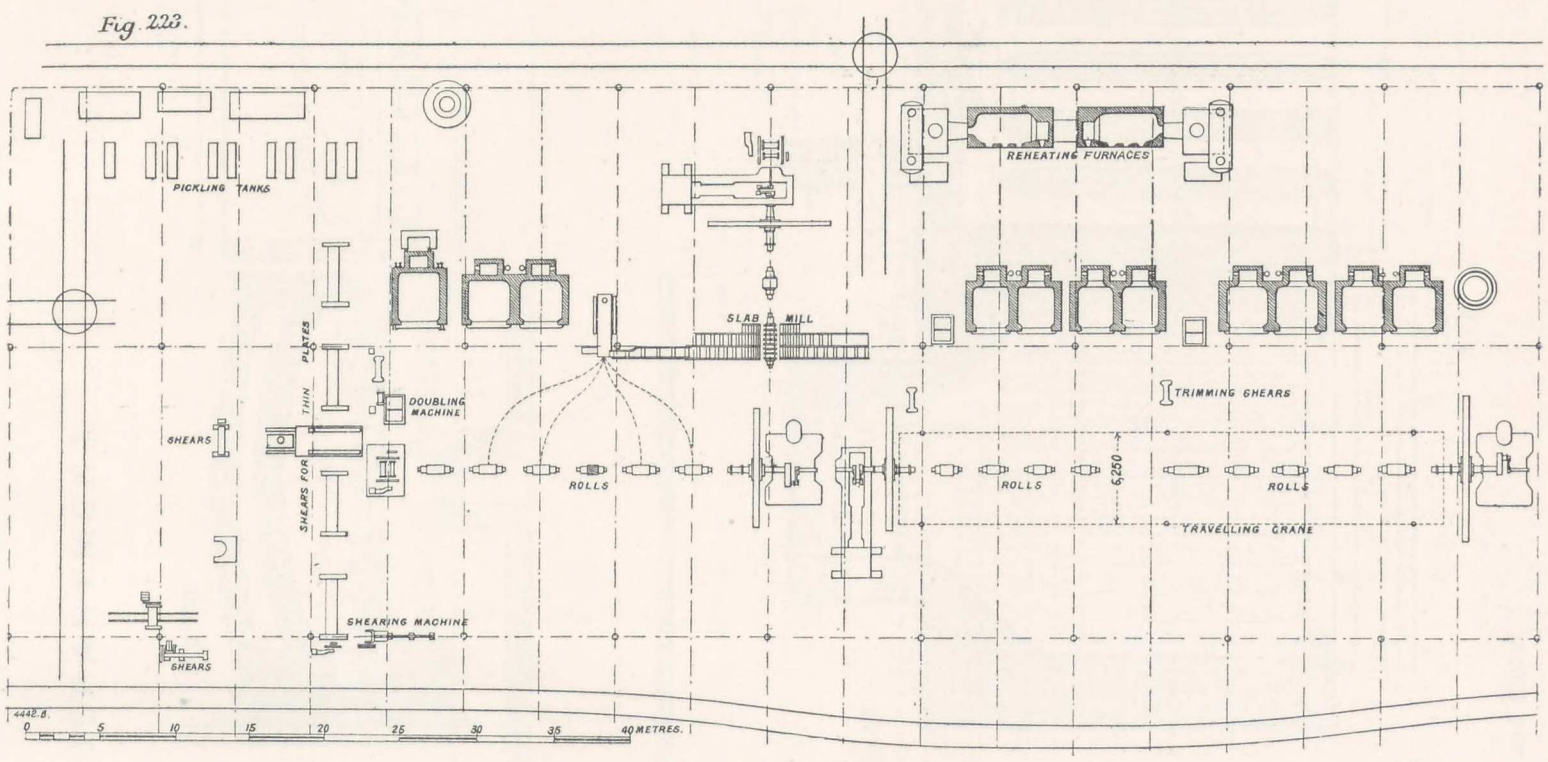
The rolls, which are of hard cast iron, are cooled by a stream of water after each operation. The bearings are lubricated with tallow. The rolls used for finishing thin sheets are not watered, and their bearings are lubricated with hot-neck grease. The thicknesses rolled in this train vary from .6 millimetre (.024 in.) in sheets weighing 9 kilogrammes (20 lb.), to 4 and 5 millimetres (.16 in. and .20 in.) in sheets weighing 63 and 78 kilogrammes (139 lb. and 172 lb.). The thinnest sheets are obtained by rolling them in series of two, three, and four sheets, one over the other, after reheating horizontally. The apparatus for doubling the sheets is illustrated by Figs. 226, 227, and 228, Plate XLIV.; it is placed level with the floor, and consists of two jointed flaps, worked by hydraulic pressure, which come together vertically. The sheets, placed on these flaps, opened out horizontally, are held down by a flat bar placed over the joint, and which is pulled out just before the doubling operation is completed. The dimensions of the hydraulic ram are suitable, with the available pressure of 35 kilogrammes per square centimetre (497.81 lb. per square inch), to double the thickest sheets rolled in this way, even when they are almost cold. When the sheets are doubled, the bundle is brought under a small hydraulic shearing machine to cut off the edges. The bundle is then heated in horizontal furnaces, for the final rolling.

The train manufactures all kinds of merchant sheets. Its output being high, it is often difficult to keep it constantly at work. Thus, 20 to 24 tons of sheets 1 by 2 metres (3 ft. $3\frac{3}{8}$ in. by 6 ft. $6\frac{3}{4}$ in.) weighing 11 to 25 kilogrammes (24 lb. to 55 lb.); or 40 tons of the same-sized sheets, but weighing 27 to 49 kilogrammes (59 lb. to 108 lb.) each, can be produced in 12 hours. Sheets measuring .800 by 1.650 metres ($31\frac{1}{2}$ in. by 5 ft. 5 in.), weighing each as above, can be turned out in equal quantities. A large number of these sheets are annealed in horizontal furnaces near the train, immediately after rolling and before shearing. The special-quality sheets—those for which a perfectly smooth surface is required—are manufactured by the second process, with slabs rolled in advance. The slab bars are rolled in a three-high roll mill and sheared cold; they are then scaled as completely as possible, and are reheated in horizontal furnaces. These furnaces, which are illustrated by Figs. 229 to 231, Plate XLIV., are fitted with one grate of the usual type provided with steam blast. The hearth is covered with brick supports, on which the slabs are placed flat, both sides getting heated simultaneously; the flames are made to return underneath the hearth. There are several furnaces of this type of various sizes; they serve both to heat the slabs and the bundles of doubled-up sheets. The width of the slabs used is .200 metre ($7\frac{7}{8}$ in.), the thickness varying from 7 to 15 millimetres ($\frac{5}{16}$ in. bare to $\frac{9}{16}$ in. full). The slabs are heated to 850 deg. or 900 deg. (1287 deg. Fahr.) maximum; therefore, they leave the furnace without any trace of oxide on their surface. At such low temperatures, however, the rolling requires a high power, and the plant must have a large margin of strength, as the least mistake in the setting of the rolls would result in fractures of the rolls or of the housings.

Figs. 232 to 236, Plate XLV., are illustrations of the latest types adopted by Messrs. Schneider and Co. for these housings; the first rolls used were .620 metre ($24\frac{3}{8}$ in.) in diameter, but as they broke occasionally, their diameter was increased to .650 metre ($25\frac{5}{8}$ in.). The necks are also made exceptionally strong; they are .480 metre ($18\frac{7}{8}$ in.) in diameter, and are united to the body of the roll by large

THE ROLLING MILL DEPARTMENT.

Fig. 223.



Plan of Sheet Mills.

Fig. 224.

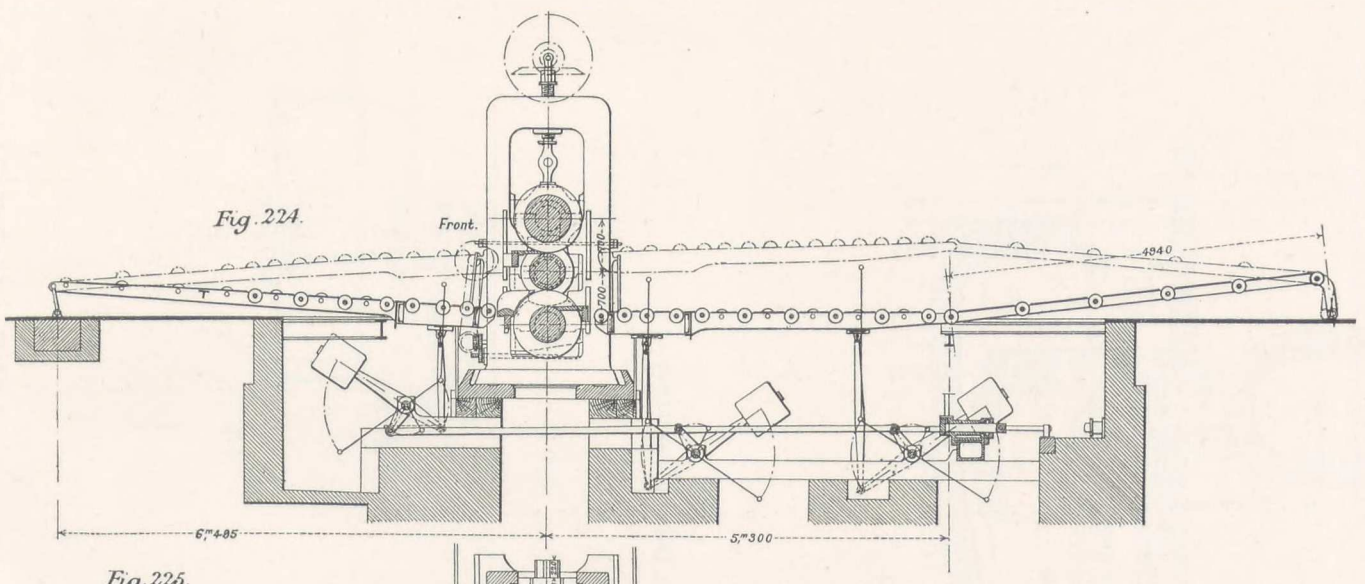
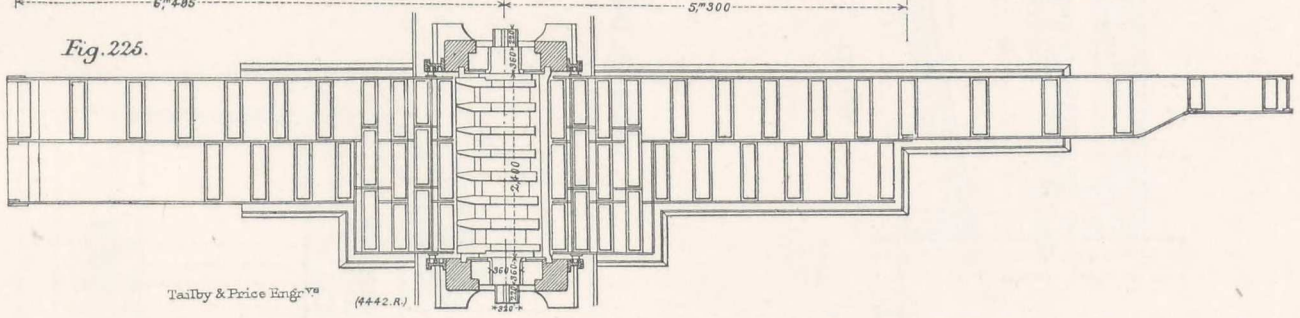
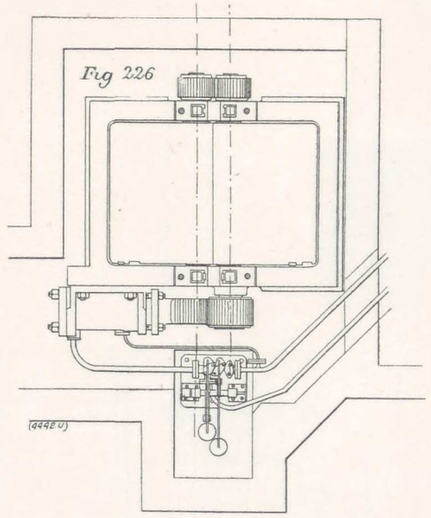
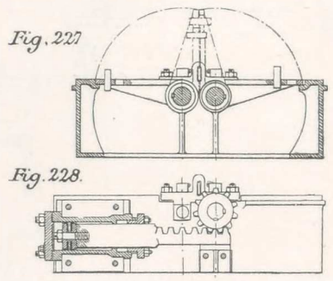


Fig. 225.

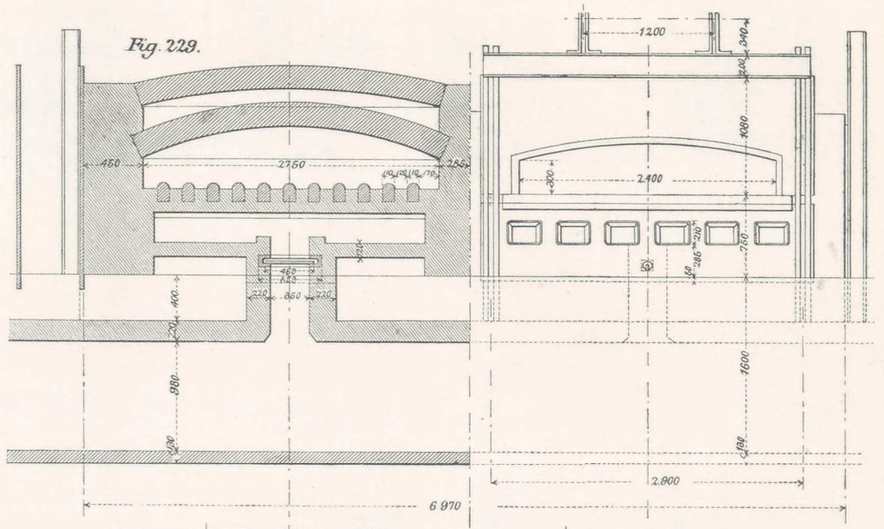


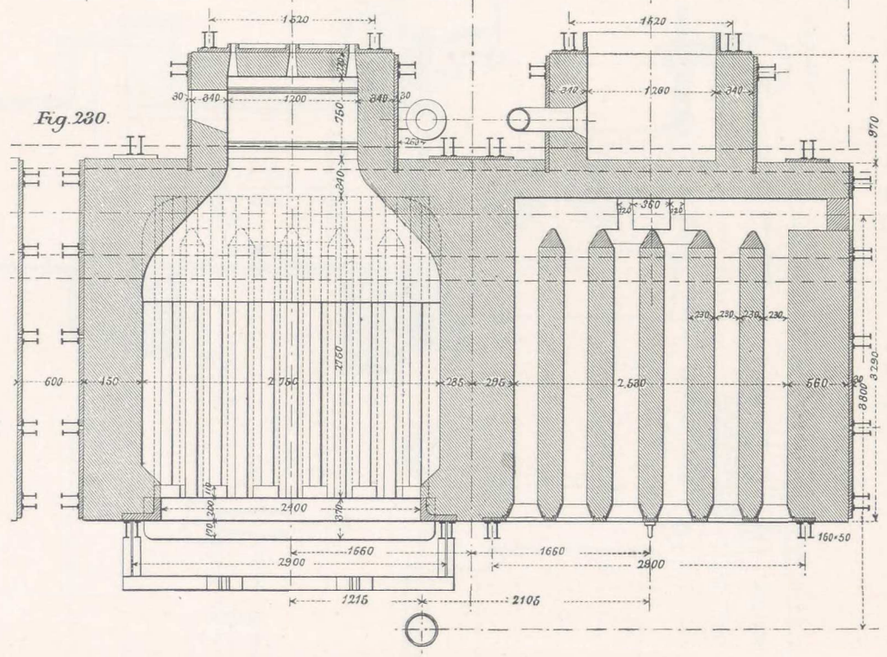
Elevation and Plan of Slab Mill.

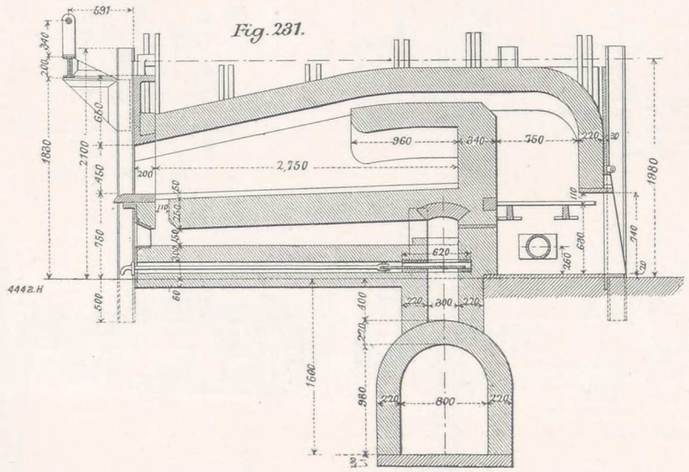




Hydraulic Doubling Machine.



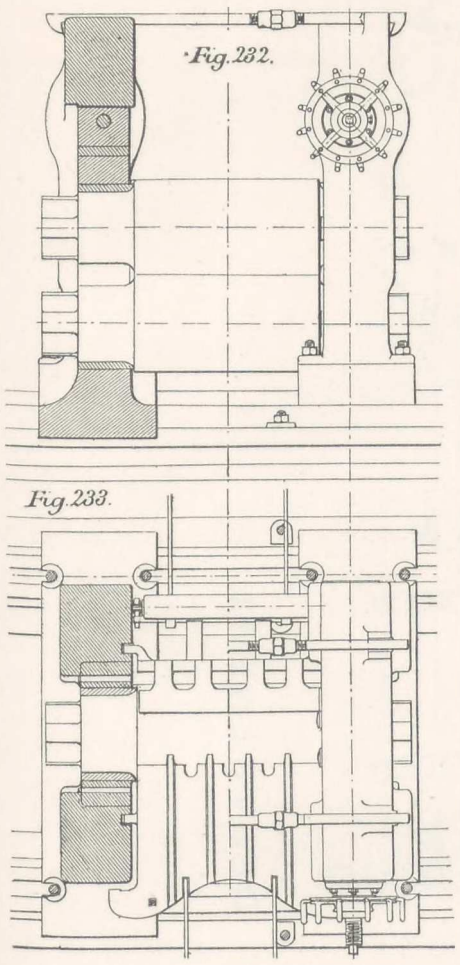


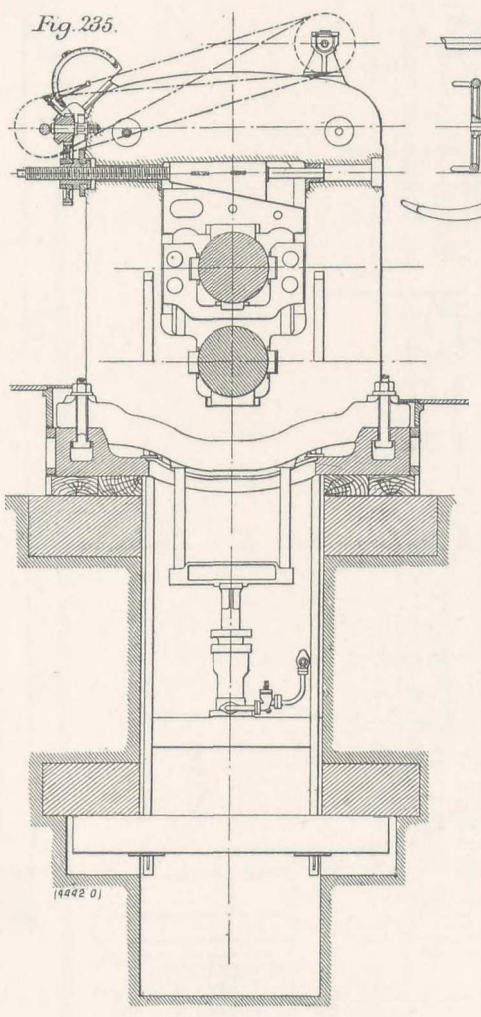


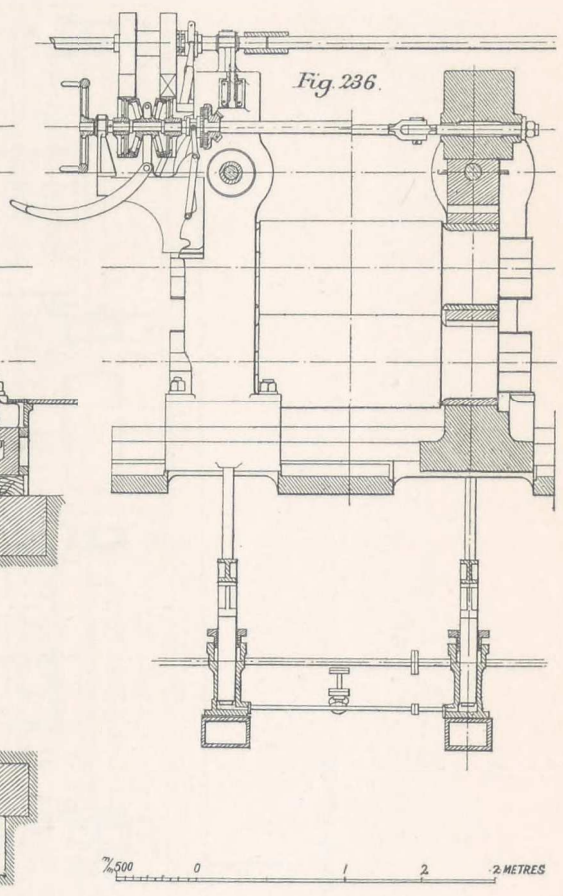
Re-heating Furnace for Slabs and Plates.

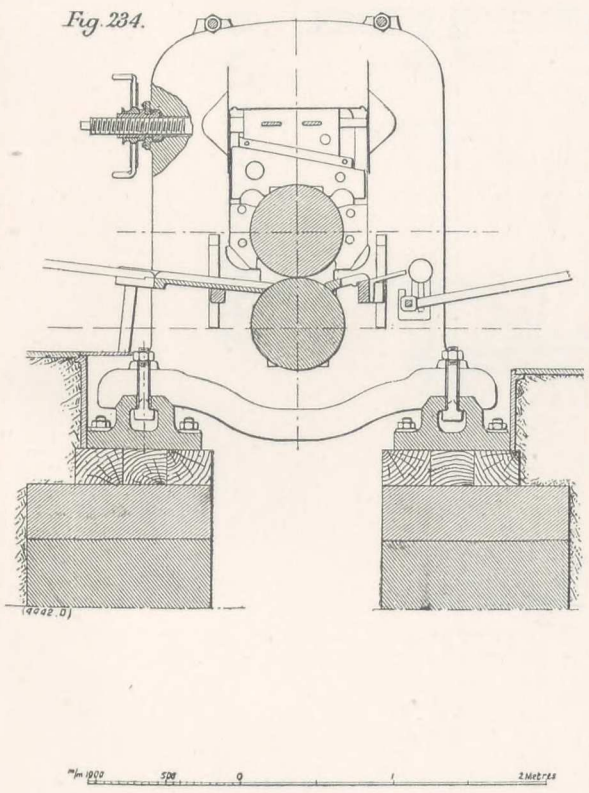
PLATE XLIV.

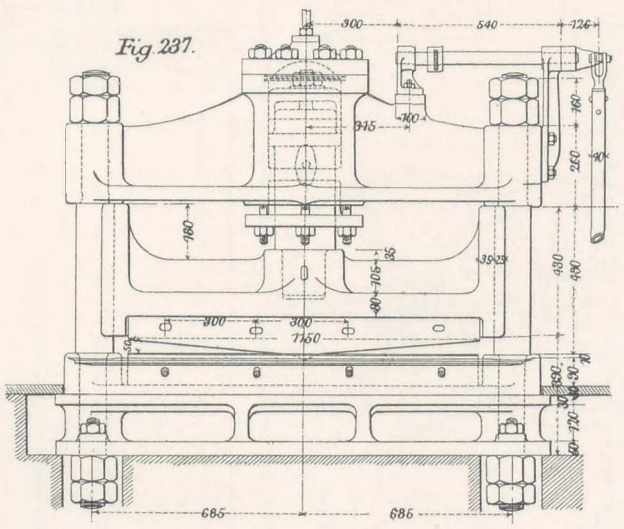
THE ROLLING MILL DEPARTMENT.

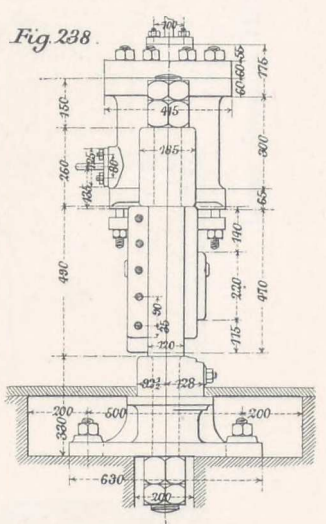


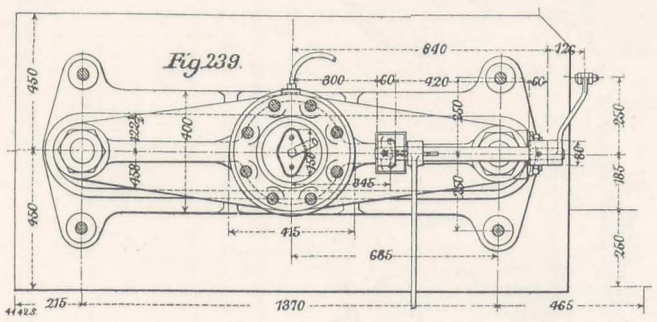


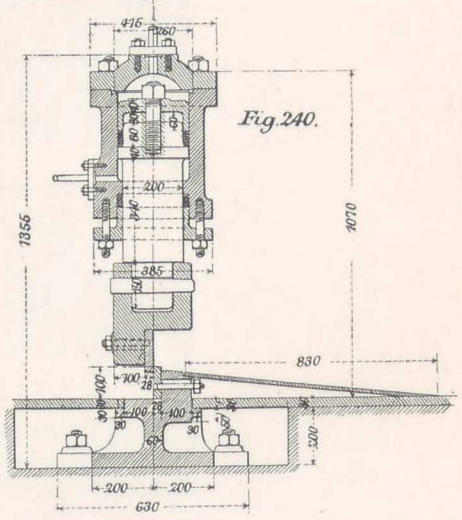












Details of Roll Housings and Trimming Shears.

Fig. 241.

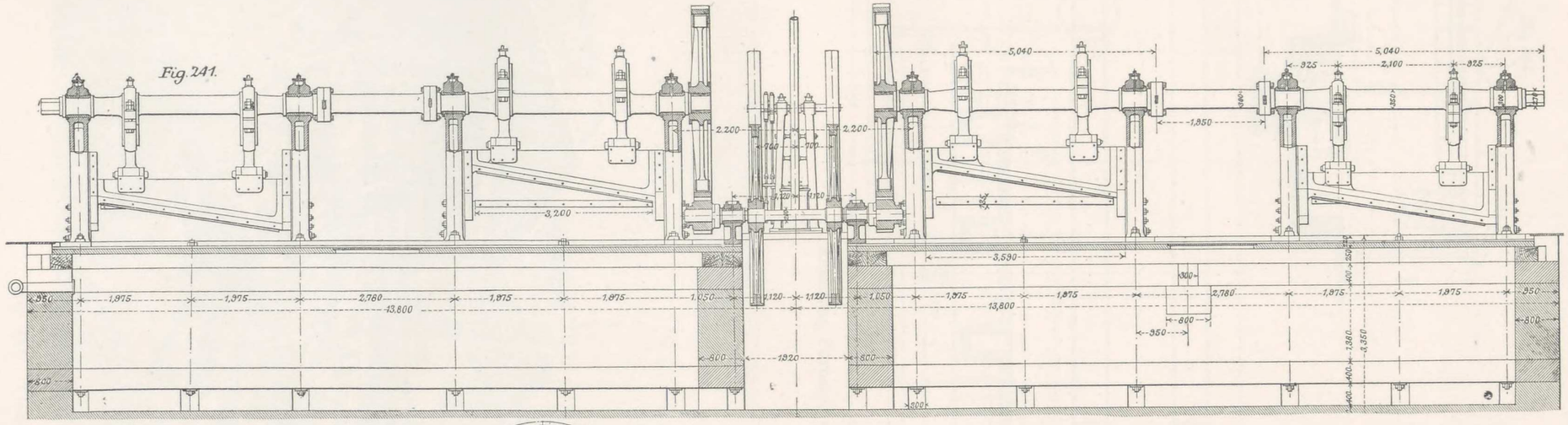


Fig. 242.

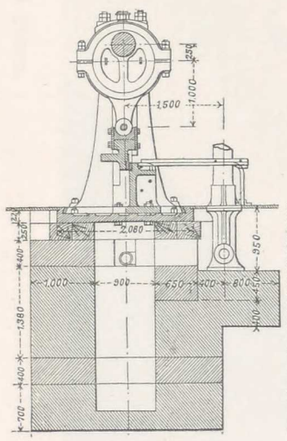


Fig. 243

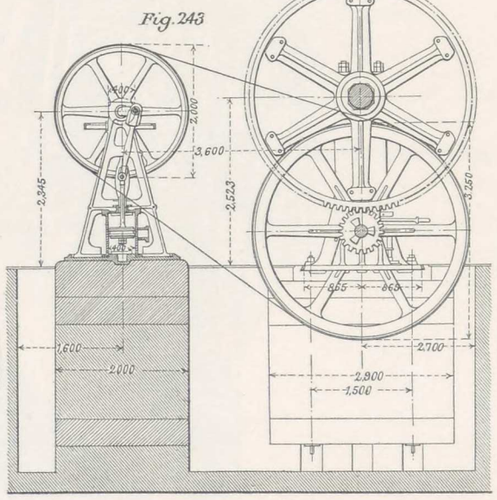
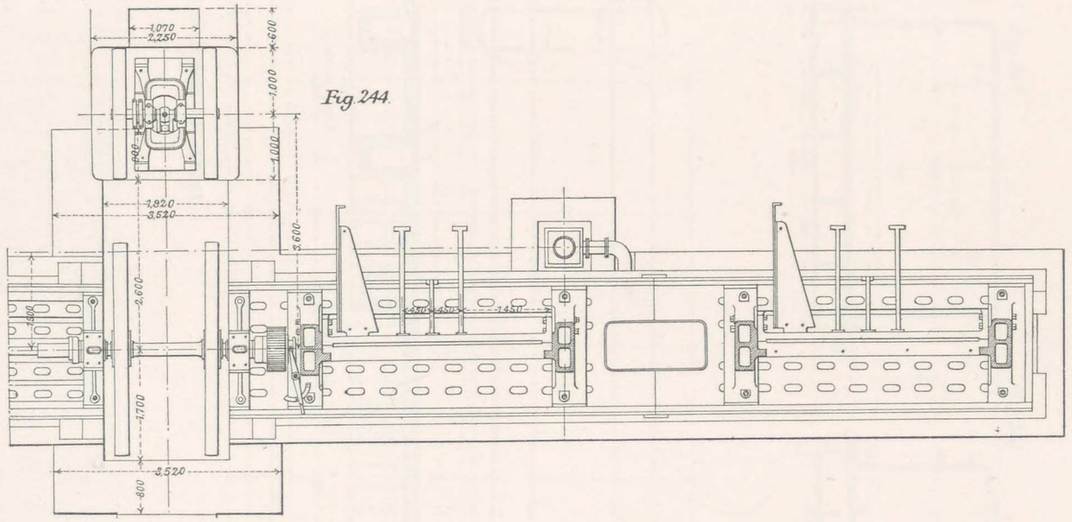


Fig. 244.



Large Shearing Machines for Cutting Sheets.

PLATE XLVI.



THE ROLLING MILL DEPARTMENT.

Fig 245.

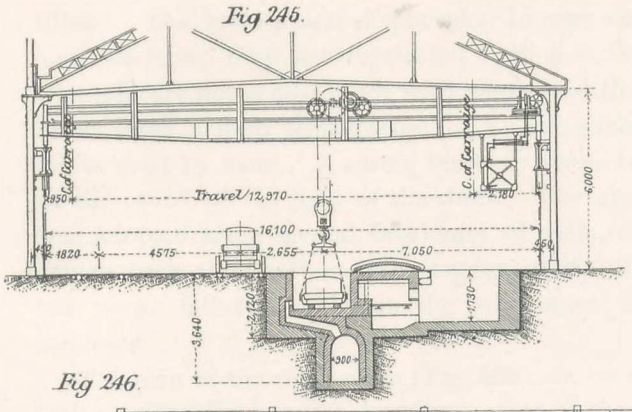


Fig. 247.

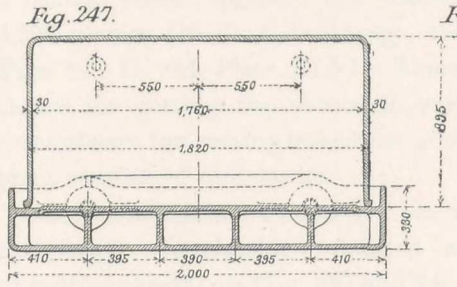


Fig. 248.

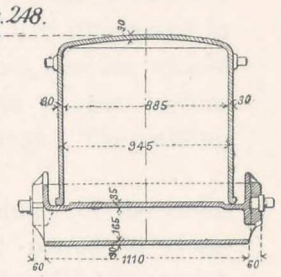
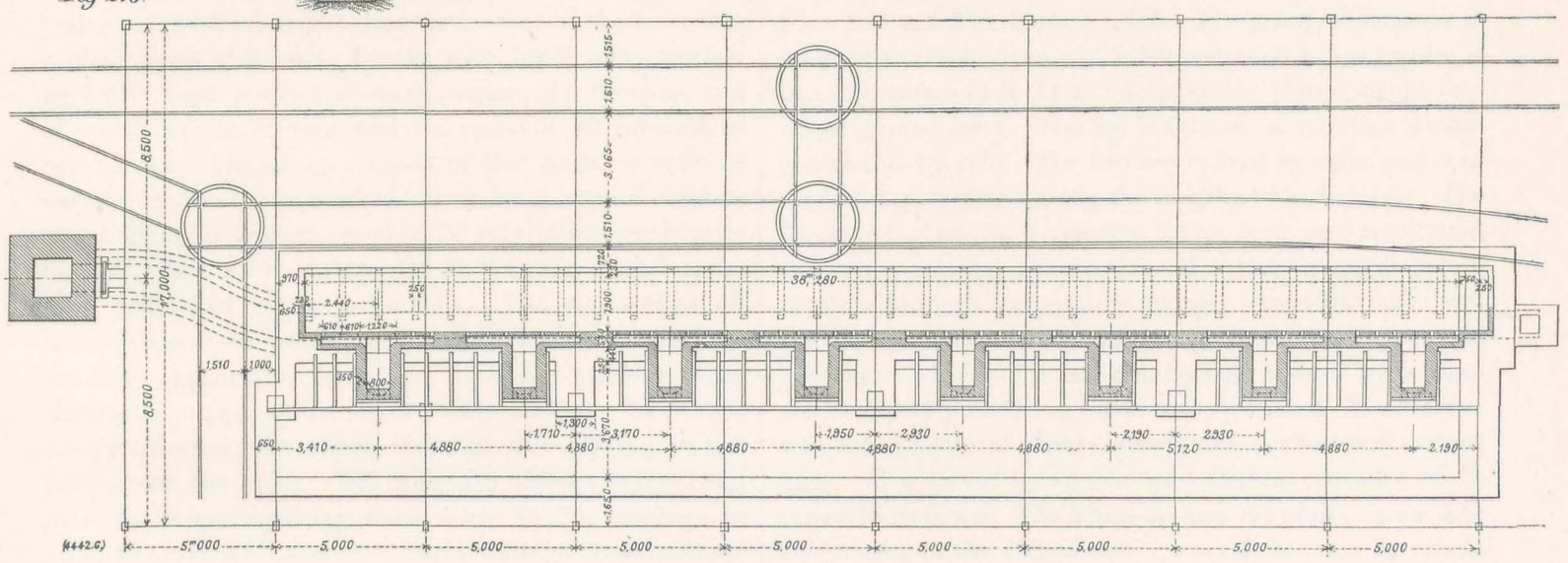


Fig 246.



Annealing Furnaces and Boxes for Sheets.

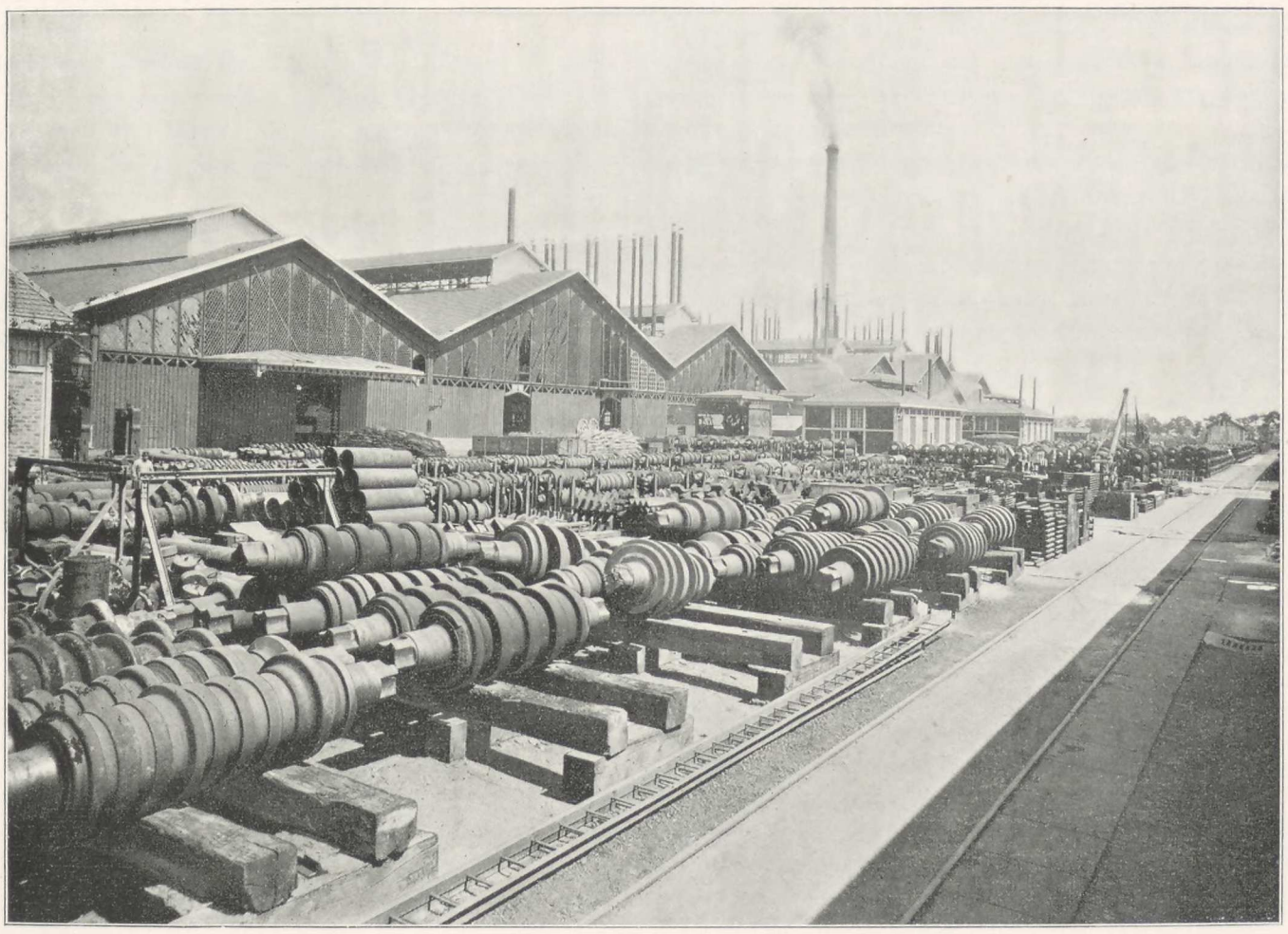


Fig. 249. View of Roll Stores.

fillets. The brasses are of phosphor-bronze, and have a large surface; they are lubricated with hot-neck grease. The rolls are not cooled down with water, and the bearings often reach a high temperature. The roll-setting screws are worked by hand. A spring buffer is placed in a cavity in the centre of the body of the shaft. This arrangement was adopted after several breakages of rolls, which had driven back the shaft and the engine itself. The buffer has never failed to prevent the recurrence of similar accidents.

The plan of the sheet mills (Fig. 223) shows two other trains besides the one just described. One of these consists of four pairs of housing frames with small rolls, worked by a 250 horse-power horizontal engine, the flywheel rim of which weighs 30 tons, and the speed is 40 revolutions per minute. The other consists of five pairs of rolls of various lengths; it is worked direct by a vertical engine, which gives an average speed of 35 revolutions per minute to a flywheel 9.500 metres (31 ft. 2 in.) in diameter, the total weight of which is 72 tons. The rim weighs 48 tons. These two trains are provided with the necessary accessory apparatus, hydraulic doubling machines and shears for cutting off the edges of the sheets. An electric 15-ton traveller runs above the mills for putting in and taking out the rolls. The rolls are always turned and fitted up in the repairing shop, never in the housings, in order to prevent all loss of time in rolling. Besides these mills, there is another set beyond the line of the plate mills. It consists of three pairs of housing frames; two serve for rolling special sheets and the third for cold rolling after shearing.

There are, therefore, for sheet rolling, 17 pairs of rolls, all of hard cast iron, worked by four engines, which act direct on the rolls; there is no intermediary toothed-wheel gearing, and the engines are provided with heavy fly-wheels.

Shearing Machines.—The sheets immediately after rolling are placed on trucks and carried to the shearing machines. One type of shears for cutting off the corners is shown in Figs. 237 to 240, Plate XLV. Most of the sheets are cut to size under four large combined shears worked by a central steam engine. The blades of these shears are 3.200 metres (10 ft. 6 in.) long; they are illustrated in Figs. 241 to 244, Plate XLVI. There are, besides, special shears for cutting the sheets to various shapes, besides three shears for cutting out circles and rings. The pickling plant consists of nine tanks.

Close-Annealing Plant.—In the vicinity of the mills, the sheets are classified, marked and placed in close-annealing chests (see Figs. 247 and 248, Plate XLVII.) which are taken on trucks to annealing furnaces placed in the neighbouring building; these furnaces are illustrated by Figs. 245 and 246, Plate XLVII. The group of furnaces is 40 metres (131 ft.) long and 1.900 metres (6 ft. 3 in.) wide; it is 1.200 metres (3 ft. 11 in.) deep, and is placed completely below ground level. The top is formed of movable arches placed side by side. The furnace is fired by eight grates of the usual type placed along the length of the furnace. The flames circulate in a passage before they are distributed through openings, the section of which is regulated to obtain a uniform temperature, namely, about 700 deg. Cent. (1292 deg. Fahr.) in the centre of the annealing chests. The chests consist of a cast-iron bottom, covered by a cast-steel bell, the joint being made with fine sand. The furnace will hold 90 tons of sheets, distributed in chests of various sizes. It is served by an overhead electric traveller, of 15 tons lifting power. The lifting in and out of the chests, and the placing of the arched covers, are effected rapidly; three close-annealing operations are completed per week; the coal consumed averages 140 kilogrammes (308 lb.) per ton of sheets, fire lighting included. This furnace is only used for annealing ordinary-quality sheets. The sheets that require special handling, and annealing at a higher temperature, such as dynamo sheets, for instance, are annealed separately in other furnaces.

In the same building thin sheets are stored according to weight and sizes in special frames, and in quantities varying between 1,200 and 1,500 tons. Fig. 249, Plate XLVII., gives a good idea of the enormous accumulation of rolls of all kinds that are kept in stock by Messrs. Schneider and Co. The view is of one part of the roll stores of the rolling mill department.

XVII.—THE NEW PLATE MILL.

OWING to the larger dimensions now demanded for armour-plates and for ship and boiler-plates, Messrs. Schneider and Co. are at present (1899) constructing a new rolling-mill, which will be the most powerful one in the world, and will contain the latest mechanical improvements to insure rapid, easy, and economical working. Although all the details of this mill are not yet quite completed, a description of this splendid installation must be given, to complete the review of the rolling-mill department. It may be remarked, in passing, that the whole of the calculations and designs have been completed by Messrs. Schneider and Co., at their Creusot Works.

The plant, which will be placed at the south of the rolling-mill department, will consist of a reversing rolling-mill in two sets, and of a slabbing mill. It will cover an area of 140 × 85.950 metres = 12,033 square metres (14,500 square yards); this space was previously occupied by the first group of puddling-mills and half of the second group, which are to be removed. The building that covered the first group of puddling-mills will be extended over the space now occupied by the scrap depôts, and which will serve in future as a finishing shop for rolled material.

The new building will consist of five spans parallel with the centre line of the mills, and utilised as follows: a span over the fuel and boilers; one over the furnaces and rolling mills; one over the cooling beds; the fourth and fifth spans will cover the shearing, annealing, planishing, inspection, and delivery spaces.

Figs. 250 and 251, Plate XLVIII., show the arrangement of the shop, and the way followed for the supply of fuel and metal; they also show how delivery of material will be effected. Electric travelling cranes will traverse the length of each span (except that over the boilers); they will be so arranged that it will be possible for them to be run over the railway from, and to, which material is delivered. Delivery will therefore take place from each bay separately: a matter of great importance, as no changes in the gearing will be needed that otherwise would have been necessary for transporting an ordinary ship or boiler-plate, immediately after an armour-plate that may weigh 60 tons.

Fuel is brought by a special coal-track to the south side of the shop, a transverse line being used to take it to the storage in the first bay, the empty cars leaving by a line placed on the north end of the shop. The boilers, which are under the same span, are heated by the waste gases from the furnaces; these boilers are of the vertical multitubular type which has been already described.

The furnaces are five in number, each with four flat grates supplied with blast. They embody many improvements on those already described, especially as regards the manufacture of large-sized armour-plates, which are heated both from above and below. In the furnaces previously described (see page 88, *ante*), the armour-plates are heated in the natural way, from the top only; and in order to heat them from below, it is necessary to close the chimney damper almost completely for the flames to circulate beneath; in consequence, more flame escapes through the furnace doors than through the flue—that is to say, through the boiler placed on a line with the furnace; the furnace doors get quickly burnt up, and the boiler hardly produces any steam. These disadvantages disappear with the new furnaces, the heating of the plates from above and from below, being independent one from the other. The time taken up by re-heating will be notably reduced, and the output proportionately increased.

A special system is followed for removing the ashes from the furnaces: when the grate bars are drawn, the ashes fall into a vertical conical ash-box, closed at its base by means of a hydraulic joint-valve. There is an ash-box for each grate, and they are all arranged on two lines in a wide gallery under the furnaces, in which are laid two tracks of .800 metre (31½ in.) gauge, for removing the ashes, by means of trucks. These trucks consist of wrought-iron boxes placed on bogies. When these are filled and run out of the gallery, the box is lifted by one of the overhead travellers, placed above the furnaces, emptied in a wagon, and replaced on its bogie.

In this same bay, near the furnaces, are the re-heating pits, in which are placed the ingots for the slabbing mill.

Two electric overhead travellers, one of 85 tons and one of 15 tons, serve this span; the former is chiefly used for carrying armour-plates to and from the furnaces by means of the **C** suspending device already described; the smaller crane is used for the re-heating pits. Both travellers are arranged for working at various speeds.

The Armour-Plate, Ship, and Boiler-Plate Mill.—This consists of two parts, namely: one roughing mill at one end of the train, and one finishing mill near the engine. Both sets are identical; but in the first the rolls will be of grey iron, whilst the second set will be provided with chilled rolls; in default of chilled rolls, hematite iron rolls, of special quality and as hard as possible, will be used.

Fig. 250

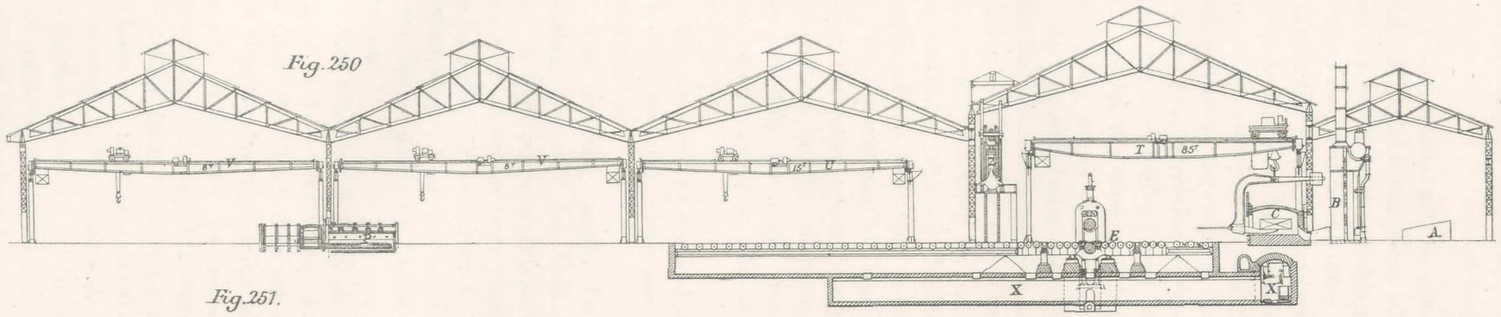
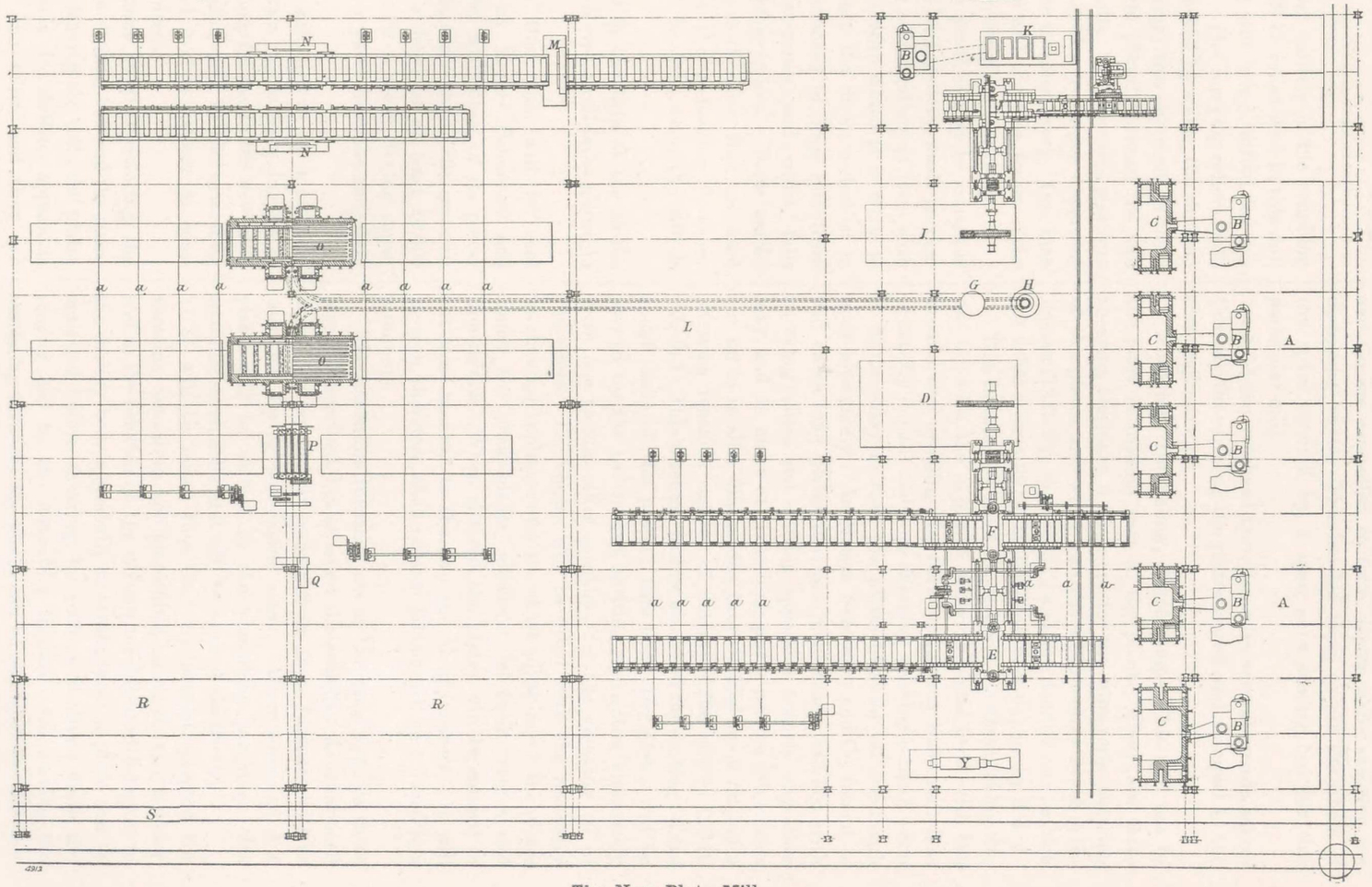


Fig. 251.



The New Plate Mill.

A. Coal storage.
B. Multitubular boilers.
C. Re-heating furnaces.
D. Engine for the 4.250 m. (13 ft. 11¼ in.) mill.
E. Roughing mill.
F. Finishing ,,
G. Steam drying apparatus.
H. Chimney of annealing furnaces.
I. Slabbing mill engine.
J. Slabbing mill.
K. Re-heating pits.
L. Cooling bed, tracing space, and depôt of plates ready for shearing.
M. Cross-cutting shears.
N. Edge-cutting shears.
O. Annealing furnaces.
P. Planishing machine.
Q. Shears for cutting test-pieces.
R. Inspection and delivery space.
S. Delivery line.
T. 85-ton electric travelling crane.
U. 15-ton electric travelling crane.
V. 8-ton electric travelling crane.
X. Underground gallery.
Y. Roll lathe.
Z. Apparatus for turning over the plates in course of rolling.
a. Shifting apparatus.

PLATE XLVIII.

THE WOLFSON WING
OF THE
DEPARTMENT

The principal dimensions of the mill are:

Diameter of rolls	1.200 m.	3 ft. $11\frac{1}{4}$ in.
Length of rolls	4.250 m.	13 ft. $11\frac{1}{4}$ in.
Total length	6.550 m,	21 ft. $5\frac{13}{16}$ in.
Weight of rolls	—	43 tons
Rising of finishing roll	0.500 m.	$19\frac{11}{16}$ in.
,, roughing ,, ...	1.000 m.	$39\frac{3}{8}$ in.
Total height of standards, not reckoning the screws	5.560 m.	18 ft. $2\frac{13}{16}$ in.
Weight of standards	—	48 tons
Maximum weight of ingot rolled... ...	—	60 tons

Armour-plates will be rolled entirely in the roughing mill. Ship and boiler-plates will be rolled first in this mill and afterwards in the finishing-mill, being shifted for this purpose from one to the other. The carrying rollers, both in front and in the rear, are worked by steam, the shifting device being worked by electricity; the electrical switches are in the centre of a platform placed between the two sets, and above the coupling shafts; on this same platform are also five levers for working the hydraulic apparatus (four receivers and a device for turning over). One man will control the three switches and the five levers. The roll-setting screws will also be worked by electricity.

As a special feature of the plant, it may be remarked that each set is erected over a long gallery, made perpendicular to the axis of the mills; this gallery is level with that of the re-heating furnaces, with which it is made to communicate. This will facilitate the direct collection in trucks, of the scale that is produced in large quantities in the manufacture of armour-plates, and which falls under the rolls and the carrying rollers. These trucks are run out on the same line with those that are used for removing the ashes from the re-heating furnaces, and, on an emergency, this can be done when the mill is in full work.

The rolls will be changed with the help of the 85-ton overhead traveller, which also serves a roll-lathe placed in the same bay.

The reversing engine for this train will be condensing, and will be built by Messrs. Schneider and Co. A high range of expansion will allow of its power being varied within large limits, according to the material to be rolled; it is designed to develope at least 10,000 horse-power. Near the engine is a steam-drying apparatus, heated partly by the waste gases from the annealing furnaces.

The Slabbing Mill.—This mill, driven by a separate engine, will be used to roll down ingots weighing up to 12 tons. It will roll slabs not only for use in the new mill, but also for the plate-mills mentioned in the preceding pages. It also will be erected over a gallery in communication with that of the furnaces.

Cooling Beds.—The span next to that covering the furnaces and mills, contains the cooling bed and the space for tracing out the plates. On leaving the rolls, the plates are carried sideways to the beds, by shifting apparatus that extends to the rear of the mills, and they are traced as soon as they have cooled down sufficiently. The cooling bed measures 80.500 × 26 metres = 2093 square metres (2,500 square yards); this large area was necessary, owing to the conditions prescribed in France as regards inspection. As a rule, no plate can be sheared until the inspector has seen it as it leaves the rolls, and has stamped it for cutting off test pieces; and as inspectors cannot witness the manufacture of the whole of their orders with a view to stamp them as they are rolled, Messrs. Schneider and Co. are compelled to form depôts while awaiting the inspectors' visits. This has led them to use the whole of the space covered by a span as a cooling bed for this particular mill.

A 15-ton overhead traveller, with several speeds, serves this bay for carrying the plates traced and stamped to the shearing-machines.

Shearing, Annealing, Planishing.—This will not be the least interesting part of the plant. There are three shearing machines, a large one for the transverse shearing of the plates, and which can cut 4.200 metres by 50 millimetres (13 ft. $9\frac{5}{16}$ in. by 2 in.), and two smaller ones, which cut 2.000 metres by 50 millimetres (6 ft. $6\frac{11}{16}$ in. by 2 in.).

This installation has been designed by Messrs. Schneider and Co. with the object of shearing plates level with the ground, and avoiding the work of turning them round, as is usually done if only one shearing machine is used, when it is necessary to turn the plates to shear off the rough ends alternately. As Messrs. Schneider and Co. intend to roll extra long plates, that are more easily handled with carrying rollers and shifting apparatus than in any other way, and as many of these long plates will be afterwards cut up to smaller dimensions, they decided upon having a shearing machine capable of cutting 4.200 metres (13 ft. $9\frac{5}{16}$ in.). This machine will be also used for cutting off the rough ends of the plates; this done, the plates will be carried by the rollers and shifting apparatus alternately from one to the other machine, for the shearing off of the edges. The shears will be fitted with the necessary mechanical appliances for the exact adjusting of the plates under the shear-blades, whatever be their weight and dimensions. When sheared, the plates will be carried in the same manner to the two annealing furnaces. It will be seen, therefore, that manual labour will be reduced to a minimum.

The annealing furnaces are of the same type as those already described, but of larger dimensions. As mentioned above, the waste heat coming from these furnaces will be used for drying the engine steam. When annealed, the plates will be shifted to the planishing machine; this contains seven rolls, and will be worked electrically.

It will be noted that the arrangement adopted for shearing, annealing, and planishing, owing to its symmetry and to the position of the various machines with regard to the cooling bed, is specially advantageous: a plate can be annealed before shearing, by shifting it direct from the cooling bed to the annealing furnace. On leaving the annealing furnaces, the plates can be planished before they have completely cooled down. These advantages will prove

of great value in the case of very thick or comparatively hard plates.

The two spans that contain the shearing, annealing, and planishing plants also cover the space in which the plates will be finally inspected and delivered. Delivery on railway trucks will be made by means of two 8-ton electric overhead travellers. In this space there will be a shearing machine placed above the floor level, and provided with casters to carry the plate in course of being sheared; this machine will be used for cutting test-pieces out of the plates, and for cutting plates to shape, especially circular plates.

Two important annexes will be built for the production of the necessary steam and electric energy. The boilers, engines, etc., for this new plant are in course of construction in Messrs. Schneider and Co.'s Works.

XVIII.—THE CONSTRUCTION DEPARTMENT.

Historical.—When in 1836 Mr. Eugène Schneider acquired the then relatively small works of Creusot, they comprised a few shops for the construction of engines. The foundry was the most important of these shops; it was laid out to make castings not only for the engines built in Creusot, but also other castings, such as rolls, for which a demand came from many small forges which then existed in France. Next in importance were the boiler-shops, in which were made a great many of the low-pressure boilers then in use. Small-power engines for coal mines, for supplying air to blast-furnaces, for rolling mills, &c., were erected in the fitting-shops, which were small and scantily supplied with machine-tools, though sufficient, nevertheless, for the requirements of the period.

At that time the question of railways and steam navigation had been scarcely raised in France. French industrials, however, soon discovered the advantages that might be gained by their development, and lost no time in their endeavours to co-operate with each other, for the construction of railways and the use of steam for the propulsion of ships. Mr. Eugène Schneider quickly saw the importance he could give to the Creusot Works by manufacturing these new types of engines, and he laid out a well-equipped plant accordingly.

In 1837 Messrs. Schneider and Co. put in hand their first locomotive, followed in 1838 by their first marine engine, and they continuously maintained their efforts to increase the means of production, in order to be prepared for further demands which, they could foresee, would soon arise. The French Government asked them to construct the engines for two steam corvettes; they undertook the commission without hesitation.

In these same works Messrs. Schneider and Co. constructed, between 1837 and 1850, a large amount of machinery of many kinds, locomotives, marine engines, stationary engines for all purposes, steam hammers, rolling-mill plant, &c. In 1850 they decided still further to increase the power of production; the existing shops were pulled down one after the other, and replaced by new ones adapted for larger machinery. One shop, however, still exists that dates as far back as 1840.

An important feature of Messrs. Schneider and Co.'s construction works at the present time is their exceptionally comprehensive character, comprising as they do all the industries that contribute to the building of steam engines, such as the production of iron and brass castings; the manufacture of iron and steel forgings; the fitting and erecting of all these products, and the manufacture of complete boilers of all types.

The Creusot Works are not limited to one single branch of engine construction, such as either marine or fixed engines, or locomotives. Messrs. Schneider and Co. were the first engineers in France to construct complete the whole of these types, constantly developing their plant so as to maintain it at the ever advancing standard of the various markets.

The general arrangement of the Construction works, as they exist at the present time, is shown on plan, Figs. 252 and 253, pages 96 and 97, in which the following references are given; it should be explained that these two figures together complete the plan, which had to be divided from exigencies of space.

A. General offices of the department.
B. Iron foundries.
C. Brass foundry.
D. Sand-preparing shop.
E. Chipping shop for castings.
F. Smithy.
G. Tempering and annealing plant.
H. Iron and steel boiler works.
I. Copper boiler works.
J. Dépôt of copper and copper pipes.
K. Marine engine fitting and erecting shops.
L. Locomotive engine fitting and erecting shops.
M. Milling and grinding shop.
N. Painting-room for locomotives and tenders.
O. Shop for delicate work and the manufacture of tools.
P. Pattern-making.
Q. Wood dépôt.
R. Pattern dépôt.
S. Packing and delivery shed.

The following is a general description of this important department of the Creusot Works.

General Offices.—The estimating and drawing offices employ 100 engineers and draughtsmen; these have charge of all estimates and the preparation of working drawings. Two large rooms are set apart for this purpose; underneath are the archives. These are of considerable importance and interest, as they contain all the plans and tracings which have accumulated during 60 years; the files have been re-classified recently, in perfect order, so that information about previous work done, can be quickly and accurately obtained. The engineers have also at their disposal a well-supplied technical library. These offices are supplemented by a printing, engraving, photographing, and copying department, for the preparation of albums of machinery, &c.

The *personnel* for the management of the work in progress, and for the general account-keeping of the department, occupy offices in the same building.

Foundries.—There are three iron foundries. Each is fitted with steam cranes, cupolas, and drying stoves, and is entirely independent of the two others, as regards the making of moulds and castings. The preparation of sand

and loam is, however, carried on in a separate shop, which supplies the three foundries.

The output of the foundries is about 10,000 tons per year. The castings represented by this figure do not all form parts of engines built in the construction works, though these constitute an important item. It must be remarked here that these three foundries turn out all the iron castings that are required for the numerous departments of Creusot, and owing to the constant growth of the works, the castings necessary for the extension and maintenance of plant, contribute much to the total. Rolls, the cranes only being required for carrying ladles, which contain a small quantity of cast iron for reserve feeding.

According to the nature of the pieces and the uses to which they have to be put, different mixtures are employed in order to obtain a suitable quality in every case. After numerous experiments, Messrs. Schneider and Co. have established a standard series of eight mixtures, each corresponding to a different quality; for each piece they have to cast, they determine previously which of these eight qualities they will make use of, according to whether the piece be to form part of an engine built in the

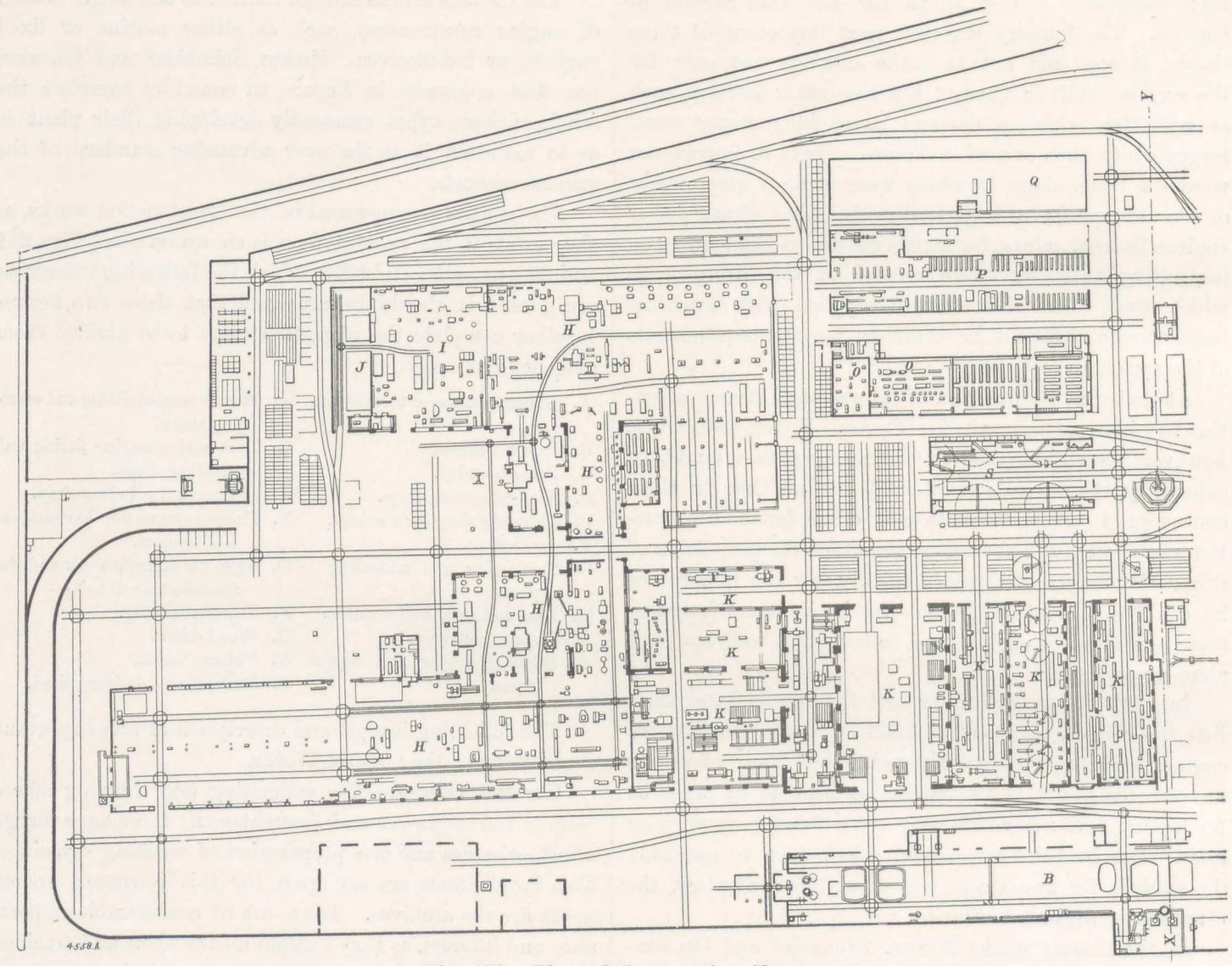


Fig. 252. Plan of Construction Shops.

housings, parts of steam hammers and presses, ingot moulds, &c., are often cast weighing 50 tons.

It occasionally happens that castings are required more than 100 tons in weight, and special means have to be resorted to for producing such heavy pieces. For this special work two cupolas have been erected on a high level above the floor of the foundry; these cupolas can cast 10 tons per hour, and as the charges are melted, they are poured into two heated receivers, each containing 50 tons. The bottom of these reservoirs is also above the level of the foundry; when everything is ready for casting, the iron is allowed to flow in a natural way to the top of the mould,

Construction works, or for use in the various other departments. This manner of classifying all the foundry work is a most valuable one, though it requires constant attention as regards the choice of pig iron and the preparation of mixtures, according to the work in progress. In order to ascertain the various grades of foundry pig, a special testing system is in use at the foundries, which gives rapid and accurate results.

The castings are made both in sand and in loam. In both cases the general manner of working is followed, namely, complete patterns are used for sand moulding, the moulds being cast in frames; the loam moulding consists

of the usual kind of masonry work, more or less intricate, according to the requirements of the piece, the mould when finished being placed in a pit, where it is cast, after having been firmly secured by earth rammed in between the mould and the sides of the pit.

The early experience of Creusot in casting chilled rolls became of special service at a later time. Since the use in fortified works of stationary, and disappearing, armoured turrets, they have cast a very large number of chilled plates for the French Government, and for Belgium, Roumania, Holland, &c. The experience acquired by Messrs. Schneider and Co. during many years has enabled them to succeed easily in the manufacture of these pieces, and to produce them of such a resistance that they can withstand the action of heavy fire.

There are in the foundries, one 60-ton travelling crane, three steam cranes of 30 tons; eleven of 20 tons; four of 15-tons; 12 cupolas; and two large reverberatory furnaces, the latter being exclusively used for melting brass for casting screws. There are besides, in the brass foundry, a small reverberatory furnace, a large crucible constantly in use and provided with a mechanical device for casting, and eight ordinary crucibles. The total annual output of the brass foundry is 350 tons.

The moulding sand is prepared in a special building fitted with all the necessary plant for crushing and screening the various mixtures. Sand pits in the near vicinity of Creusot supply almost the whole of the various materials required.

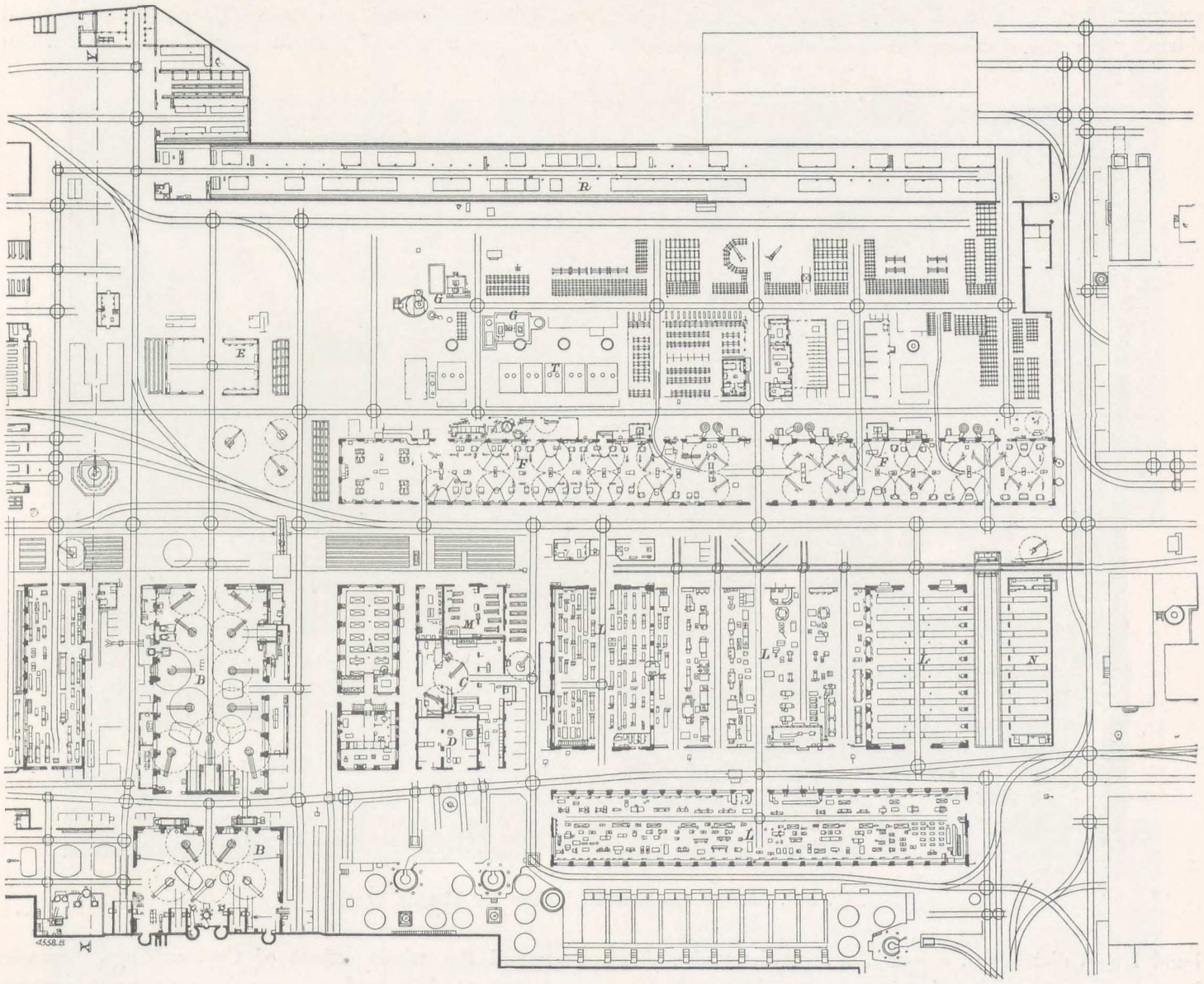


Fig. 253. Plan of Construction Shops.

Smiths' Shop.—This shop is fitted up with furnaces and steam-hammers for the working of steel ingots, the weight of which does not exceed 10 tons; all work requiring ingots of a greater weight is ordered by the Construction works from the Steel works department, which is perfectly laid out for the manufacture of all heavy forgings.

In the smiths' shop there are 22 steam hammers, varying in power from 10 cwt. to 10 tons. The larger sizes of these hammers, namely, those of 10, 8, and 6 tons, with the furnaces by which they are served, are used for forging pieces of comparatively simple shape; they are used also for

rough-forging certain pieces which are afterwards finished by hand. The smaller steam hammers are used for forging pieces which, owing to their shape and dimensions, have to be heated in the furnaces instead of on open fires, and which are more economically worked under a steam hammer than by hand. There are ten furnaces, six of which are provided with boilers heated by the waste gases. A part of the plant serves for the manufacture of drop forgings; this method is resorted to every time a series of similar pieces has to be manufactured, as they can be produced in this way with but little excess of metal, thus reducing considerably the cost of subsequent machining. There are 75 hand forges distributed among the steam hammers. The hand forges that take the largest pieces, use a steam hammer when necessary, the same hammer being able to serve several forges by alternating the heats.

The annual output of this shop is about 4,000 tons of forgings, which number several hundred thousands. As a rule, all these pieces are of steel, which has almost superseded iron in the manufacture of forgings for marine engines. For locomotives, however, many pieces of the mechanism are still made of iron, and one of the furnaces is almost exclusively used for welding the iron necessary for the manufacture of such pieces. There are also in this shop, furnaces for annealing steel pieces, and a special plant for tempering small-calibre guns which, up to the present, have been forged in the Construction works.

A laboratory for the mechanical testing of forged pieces is constantly in operation for ascertaining their quality. It has charge also of all the official tests prescribed by the Navy, War Department, and railways.

Boiler Shops.—In the boiler shops (see Figs. 254 and 255, Plate XLIX.), marine and stationary boilers of every type are manufactured, as well as locomotive boilers and locomotive work of all kinds; turrets and platform mountings for guns; copper piping, and so forth. The annual output exceeds 2,000 tons of finished work of iron or steel, and 300 tons of copper and brass. The shops are provided with a large number of powerful overhead travellers, which command the whole extent of the buildings. Smaller travellers, worked by hand, serve the tools by carrying plates from one to the other. For the erection of marine boilers there are two 50-ton mechanical travellers, and two others of 20 and 10 tons for the erection of locomotive boilers. The riveting machine is provided with a special 25-ton traveller.

Among the more important tools in the boiler shop may be mentioned a press for bending firebox plates for locomotive boilers; this has been in use for many years. A second press, very much larger and of greater power, was put down 15 years ago for stamping the largest plates used in the manufacture of steam boilers. An arrangement of cranes, worked by hydraulic pressure, enables a rapid handling of the plates from the furnaces to the

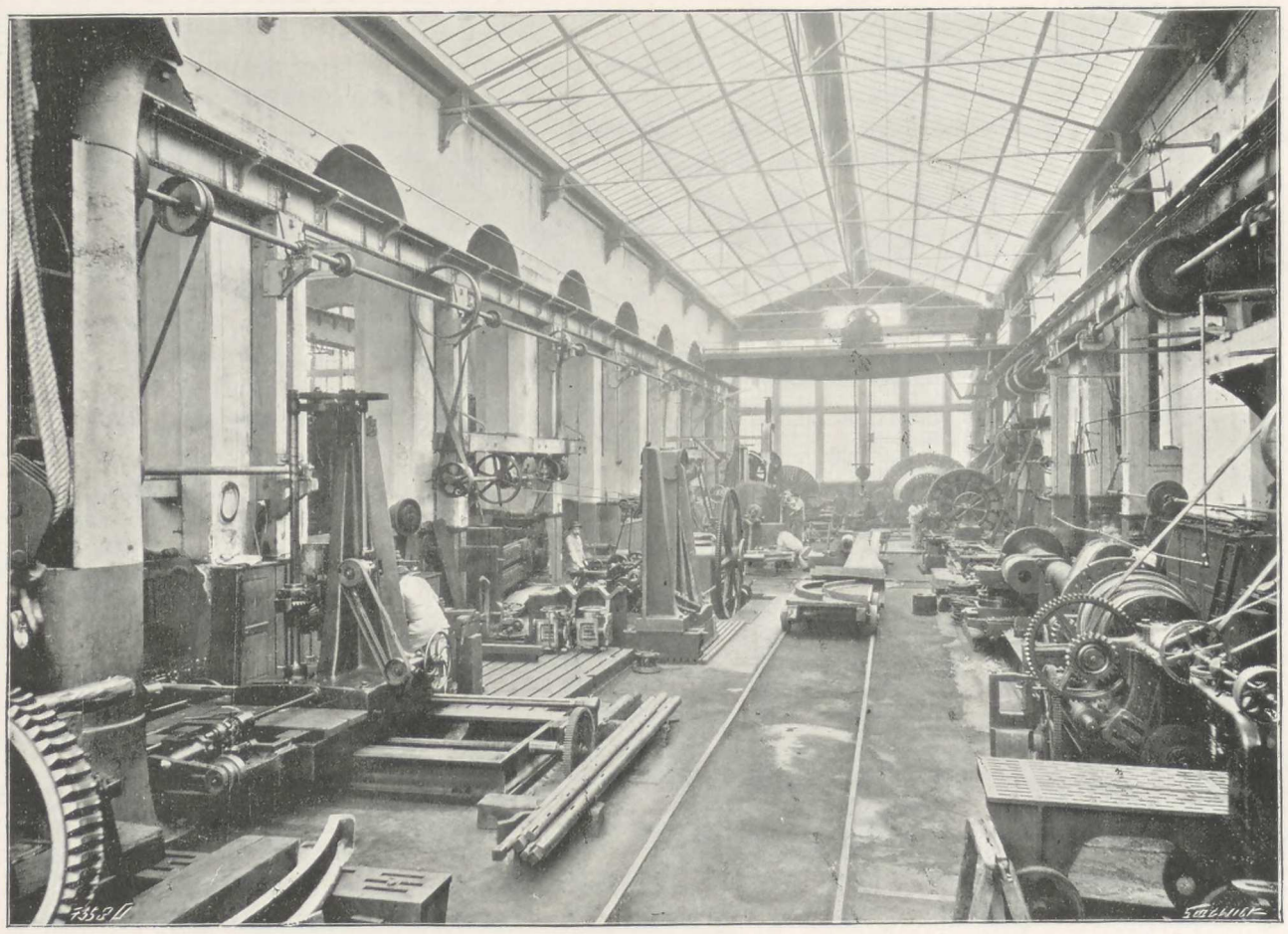


Fig. 261. Large Machine-Tool Shop for Marine Work.

THE CONSTRUCTION DEPARTMENT.



Fig. 254. Interior of Marine Boiler Shop.



Fig. 255. Exterior of Boiler Shops.

THE CONSTRUCTION DEPARTMENT.



Fig. 256. Locomotive Construction Shop.

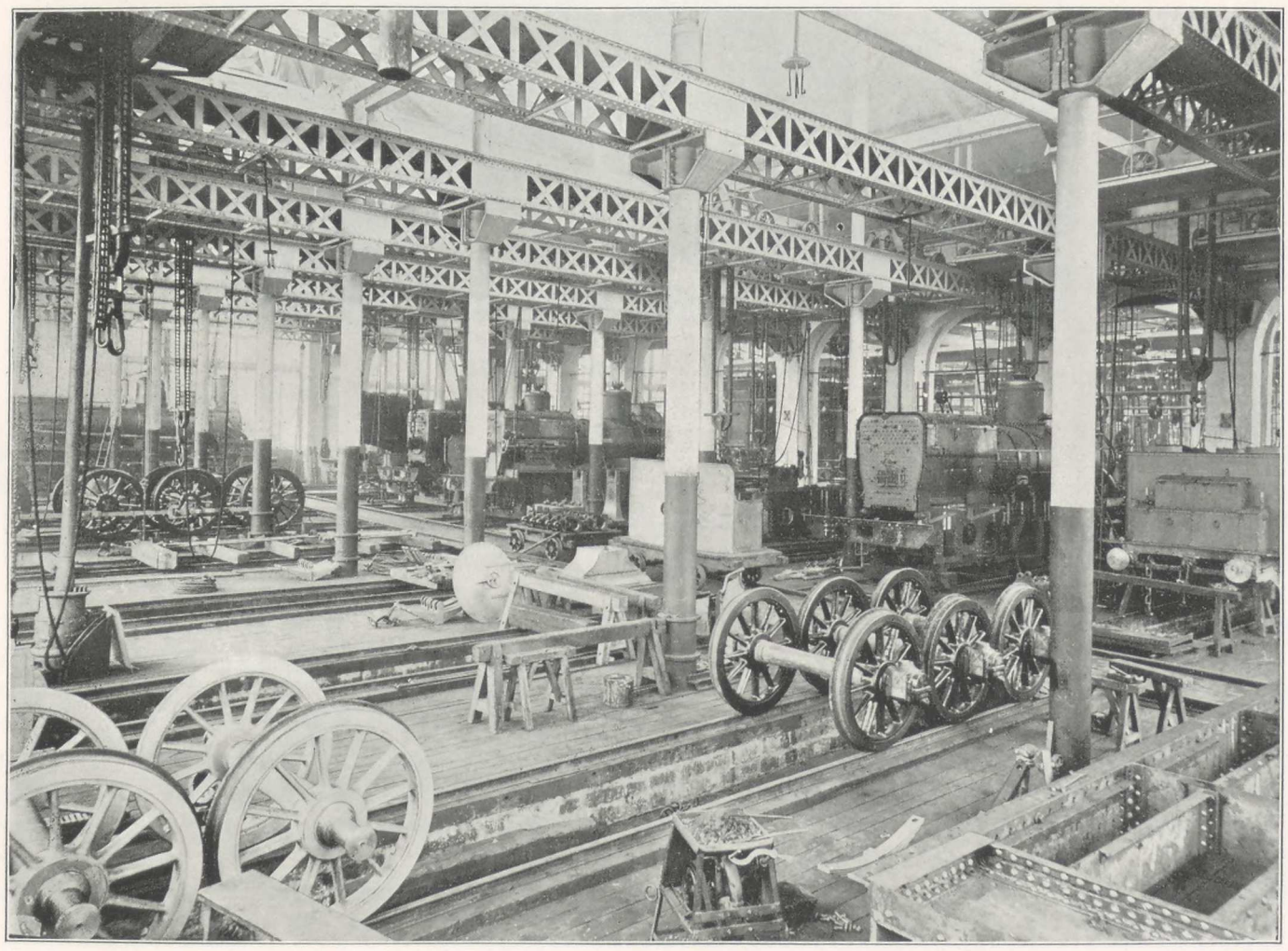


Fig. 257. Locomotive Erecting Shop.

presses, so as to prevent cooling and consequent increase in the number of heats required for intricate shapes.

Besides cylindrical boilers for the Navy, Messrs. Schneider and Co. have manufactured for several years the new types of multitubular boilers, the use of which is largely on the increase. They produce also in large numbers, stationary tubular boilers, as well as those of the more recent water-tube type. The necessary plant for manufacturing the various systems has been on several occasions modified and completed to keep it up to a high standard. The construction of frames and

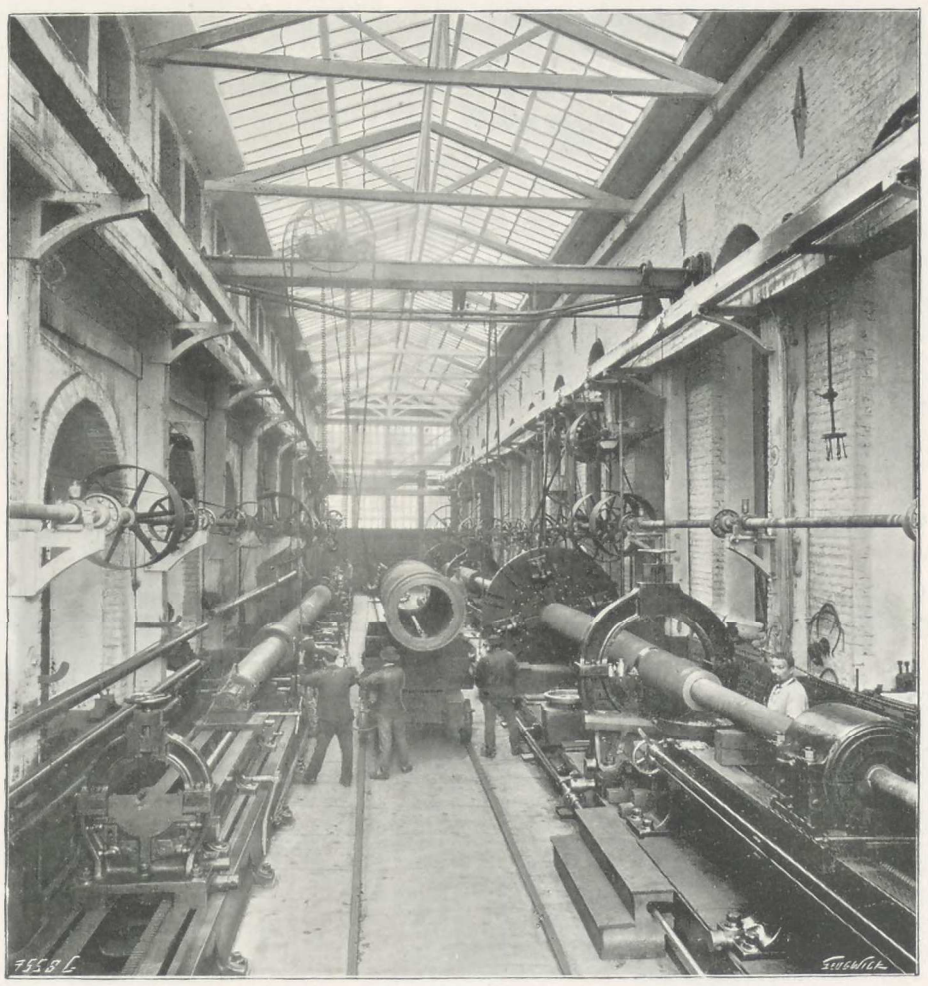


Fig. 262. Interior of Boring Shop.

platforms for land and marine turrets has acquired a great extension at Creusot, and this class of work, much of which passes through the boiler shop, is still on the increase.

Fitting and Erecting Shops.—These shops are the largest in the department; they occupy half of the total number of workmen employed in this section of the works, namely, 1,000 out of the total of 2,000. They contain more than 500 machine tools of all kinds and power, lathes, planing, drilling, boring, machines, &c. Owing to their importance, the shops have been divided into two main sections, one for locomotives, small stationary engines and torpedo-boat engines; the other for large marine and stationary engines. These divisions, however, are not absolute, and the various shops help each other in the execution of certain orders.

The section which deals more especially with locomotive work, comprises eight buildings, covering an area of 8,500 square metres (10,000 square yards); three of these contain the lathes; four others, various machine tools, one being the fitting shop; and the eighth is the erecting shop for locomotives and tenders. All these shops are provided with overhead travellers for serving the tools and for the erection of the engines. A traverser facilitates the removal of the locomotives and tenders from any one of the erecting berths to a neighbouring shop, in which they are painted. The same traverser serves to place the locomotives on the track belonging to the works, from where they are hauled to their destination. When locomotives manufactured by Messrs. Schneider and Co. are for delivery to Spain or Russia, where the gauge is different from that of the other European countries, they are delivered, ready erected, on special cars, built in such a way that the locomotives can easily be removed and placed on the gauge on which they have to run. Only those locomotives that are for delivery beyond sea are delivered in parts. Figs. 256 and 257, Plate L., are two interior views of the locomotive shops.

The section more especially set apart for the construc-

tion of large stationary and marine engines comprises ten buildings, two of which are two storeys high. These ten buildings cover an area of 9500 square metres (11,500 square yards), and are divided into turning shops, drilling, boring, and general machinery shops, one being specially equipped for erecting. They are all provided with overhead travellers, of powers varying according to the different loads to be lifted; most of the travellers work by power, either by means of endless cables, square shafts, or electric motors. Several views of these shops are given in Figs. 258 and 259, Plate LI., Fig. 260, Plate LII., and in Fig. 261.

The large erecting shop has been made of suitable height, and is provided with four 30-ton overhead travellers; engines 12 metres (39 ft. to 40 ft.) high can be erected underneath.

In these shops (see Fig. 260, Plate LII.) are all the tools for machining exceptionally large work. Among others are a surface lathe that can turn pieces weighing 60 tons, and 10 metres (32 ft. 10 in.) in diameter; lathes and boring machines which can take shafts 25 metres (82 ft.) long; a boring machine to finish boring cylinders 3 metres in diameter and 5 metres high (9ft. 10 in. by 16 ft. 5 in.); a machine for cutting double-helical teeth on wheels 3 metres (9 ft. 10 in.) in diameter; a planing machine that can work pieces 3.500 metres wide and 10 metres long (11 ft. 6 in. by 32 ft. 10 in.), &c. Fig. 262 is a view of the interior of the boring shop. These machine tools are the largest; there are, however, 40 others, which, though not quite so large, approach very closely in size and power.

Tool-Making Shop.—The manufacture of the various tools which are employed in the machine shops is centralised in one special building, fitted up with the necessary appliances for this work. After investigations and tests of the various qualities of tool-steel, Messrs. Schneider and Co. have classified them with reference to the requirements of their works. They know, therefore, exactly the right quality to use for each class of work, and the amount of care required in the forging and tempering of each kind of tool. The work having been specialised in this department, the workmen have acquired great experience in producing steel tools. There are in this shop above 30 lathes, planing and milling machines; special machines for cutting shaping tools, screw taps, &c.; sharpening machines, and many others. It keeps supplied in tools more than 700 machines, and produces all the hand tools for the fitters, boilermakers, and smiths. Only the various kinds of files are purchased from outside, as their manufacture is a speciality. In this shop are manufactured all the delicate instruments which serve for verifying the accuracy of engine parts and ordnance work.

Pattern Shop.—The few data we have given of the foundries, their importance and the variety of the work they turn out, will give an idea of the quantity of patterns that have to be made daily. Besides those for the iron and brass foundries, forming part of the construction works, all the patterns for the steel foundry are made in this shop. Though those patterns only are stored which may be wanted more than once, the pattern dépôt covers a very large area. It measures 250 metres (820 ft.) by 16 metres (52 ft. 6 in.), and is two storeys high. The contents are methodically classified, and any pieces that may be required are easily found.

THE CONSTRUCTION DEPARTMENT.

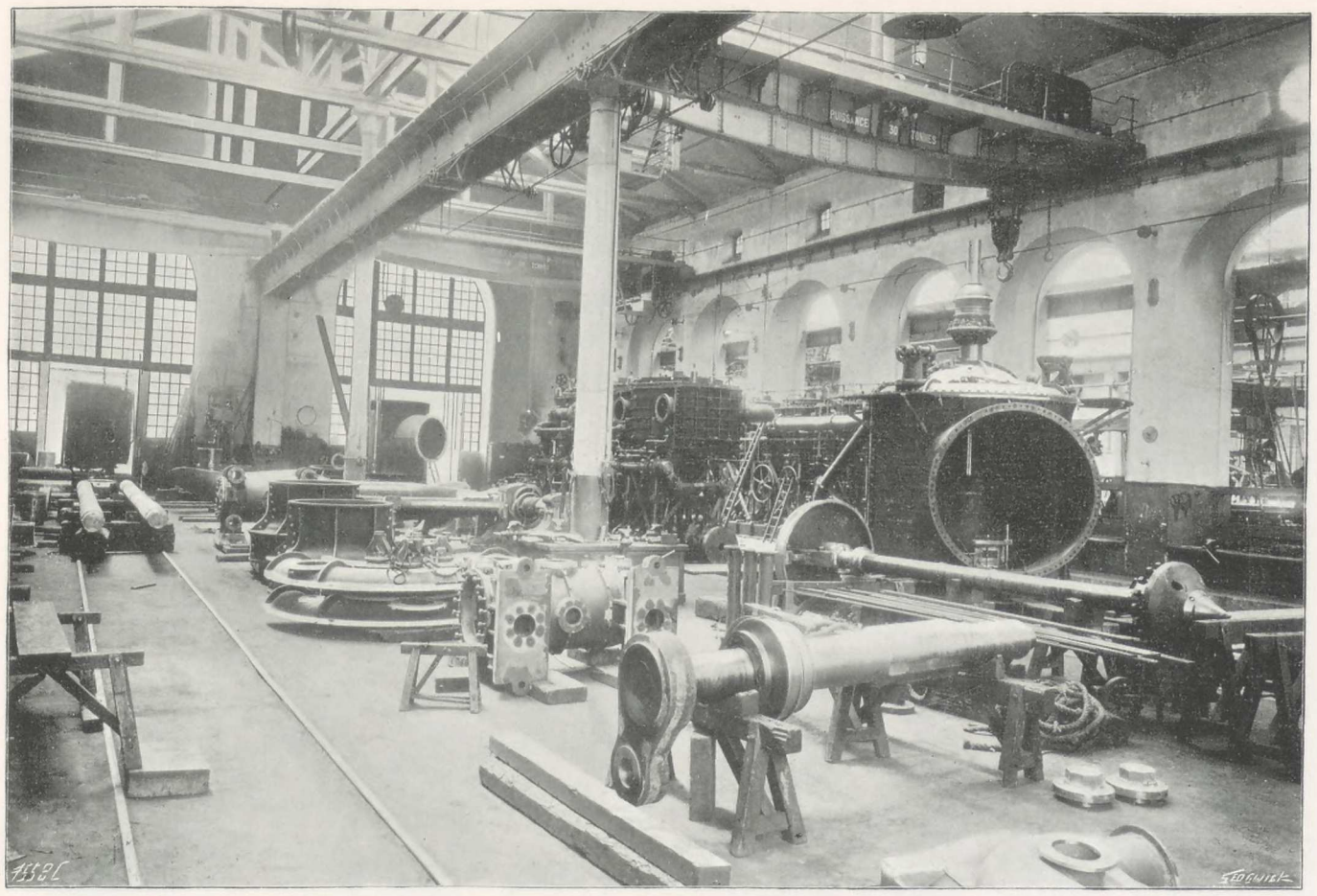


Fig. 258. Marine Engine Erecting Shop.

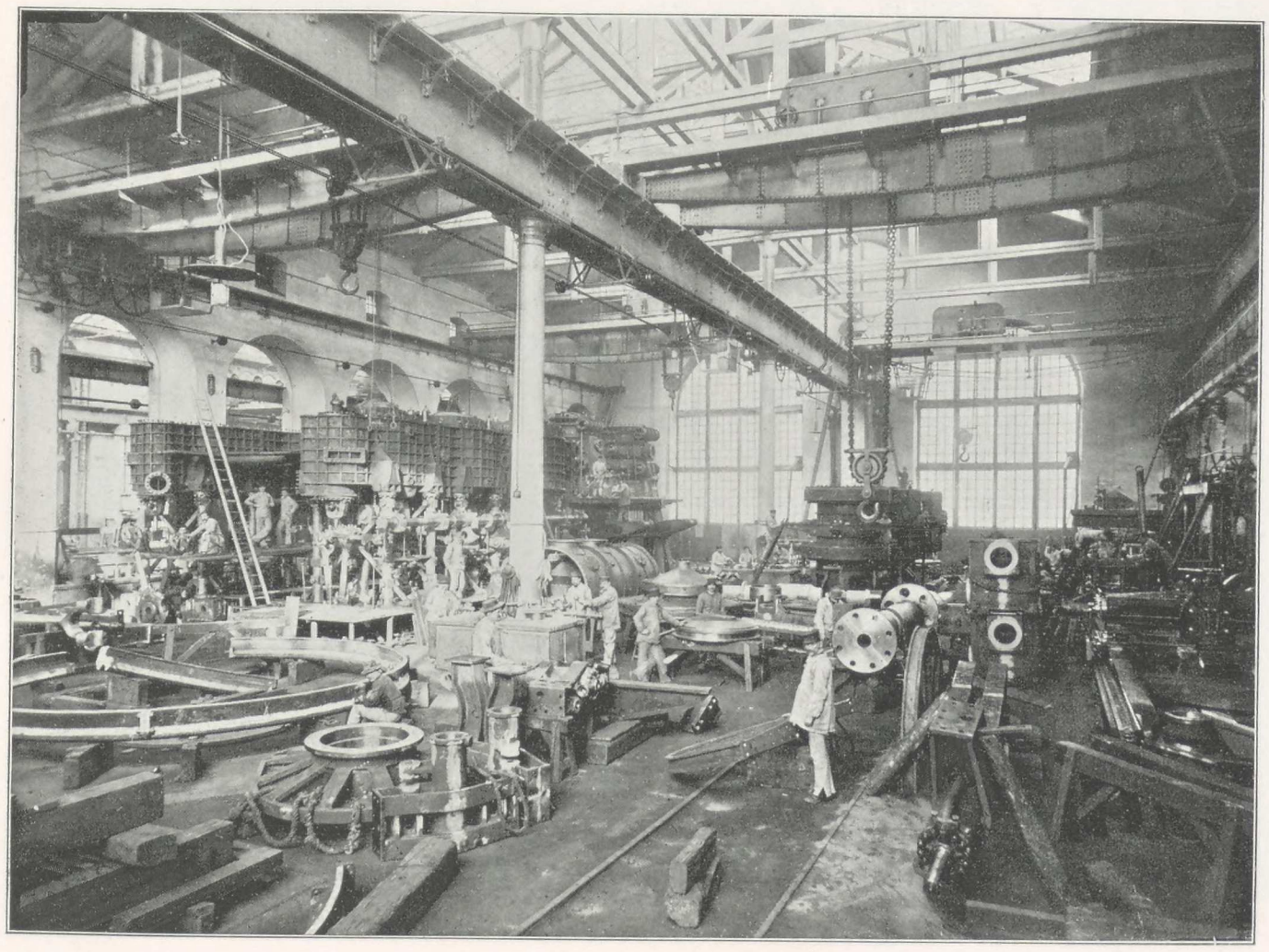


Fig. 259. Marine Engine Erecting Shop.

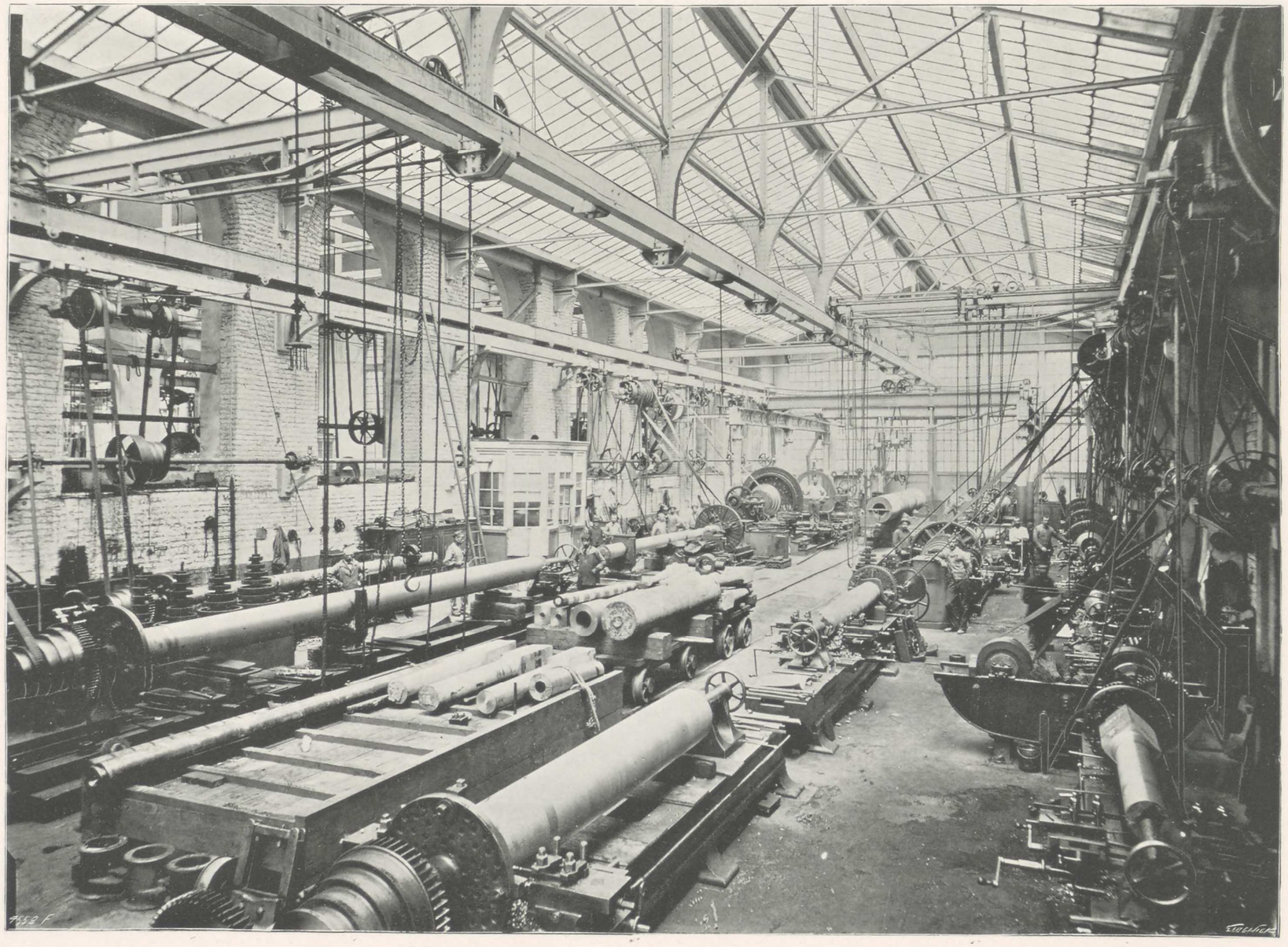


Fig. 260. Interior View of Marine Engine Shops.

THE METROPOLITAN MUSEUM OF ART

XIX.—EXAMPLES OF WORK EXECUTED IN THE CONSTRUCTION SHOPS.

I.—MARINE ENGINES.

Having described the arrangement of the Construction Department at Creusot, it will be of interest to give a description of some of the typical work that has been produced there. Commencing with marine engines, it will be seen from the annexed Table (see page 103) how large a number of such engines has been completed, aggregating nearly half a million horse-power. The commencement of this branch of work at Creusot dates back for about 60 years, the first marine engine having been completed in 1839; this was for the corvette "Pluton," a beam engine for the French Navy, indicating 660 horse-power. Besides the marine engines, of which particulars are given in the Table, Messrs. Schneider and Co. have built in their Construction Works, 90 engines for river steamers and for the following countries:

France	65
French colonies	2
Russia	4
Spain	6
Austria	6
Italy	3
Egypt	2
Japan	2
	90

Engines of the "Labrador" (Figs. 263 and 264).—The engines for the "Labrador," a frigate for the French Navy, were built by Messrs. Schneider and Co. at their Creusot Works in 1839. They were completed the same year as the engines of the "Pluton," and were followed by those for the Canada, Caraibe, Orénoque, and Albatros.

As will be seen from the illustrations, they had a vertical cylinder which worked the shaft by means of two beams placed at the bottom part of the engines, and a direct connecting-rod. Steam distribution was effected by disengaging levers and slide valves. The nominal horse-power was 450, and the linear speed of piston per second averaged 1.150 metre (3 ft. 9¼ in.). A jet condenser was used.

Engines of the "Mogador" (Figs. 265 to 267, Plate LIII.)—The engines for this frigate were built by Messrs. Schneider and Co. in 1846; they were the first oscillating engines constructed at Creusot for the French Navy. The following are some particulars:

Vertical engines, with two oscillating cylinders of equal dimensions, connected together and working paddle-wheels. Distribution by disengaging levers and slide valves; jet condenser; 650 nominal horse-power; 20 revolutions per minute; average linear speed of piston per second, 2 metres (6 ft. $6\frac{11}{16}$ in.).

The engines of the "Mogador" were considered for a long period as the best in the French Navy; this frigate rendered great service during the Crimean War. The indicated horse-power was 1,950.

Engines of the "St. Laurent" (Figs. 268 and 269, Plate LIV.)—The engines for the mail boat "St. Laurent" were built by Messrs. Schneider and Co. in 1865 for the Compagnie Générale Transatlantique for their New York service. The "St. Laurent" was the first screw steamer of this company.

The illustrations show the general arrangements of the the engines, which had two horizontal cylinders with toothed wheel gearing. The nominal horse-power was 850, and the number of revolutions of shaft, 40 per minute, the number of revolutions of propeller being 70 per minute. Steam distribution was by means of slide valves and Stephenson link motion. The linear speed of pistons per second averaged 1.750 metre (5 ft. 9 in.).

As a contrast to these very early and historical examples of marine engines constructed by Messrs. Schneider and Co., particulars will now be given of a few of the more recent and important of the engines built at Creusot for the French Navy.

Engines of the "Magenta."—The engines of this first-class French battleship are four in number, of a vertical type, with two cylinders, compound; they are connected in pairs over two shafts, each shaft driving a propeller. The principal dimensions of the engines are as follow:

	m.	in.
Diameter of high-pressure cylinder	1.060	$41\frac{11}{16}$
,, low-pressure ,, ...	2.020	$79\frac{1}{2}$
Length of stroke	1.000	$39\frac{3}{8}$

The two engines on each side of the ship can be worked, connected or disconnected, and driven separately. Each one of the four is provided with a horizontal tubular condenser, a double-acting horizontal air pump, worked by a separate compound engine, and with a centrifugal circulating pump, driven by a single-cylinder engine. All the slide valves are of the usual type, those of the high-pressure cylinder being fitted with a special expansion device. The distribution slide valves are controlled by link motion.

The reversing gear of each engine is worked either by hand or steam power, and that of each two engines on one side of the ship can be connected when the two engines are working simultaneously. All the crankshafts, intermediate,

and propeller, shafts are hollow, of forged steel; the propellers are of bronze cast in one piece. Each engine-room is provided with a ventilator fan. The boilers are eight in number, cylindrical, of the French Admiralty direct-flame type, with three furnaces each, placed in four stokeholds and connected to one single funnel.

Registered steam pressure ...	6 kilos.	85.338 lb. per sq. in.
Total grate area	52.08 sq. m.	560 sq. ft.
,, heating surface	2368.08 sq. m.	25,490 sq. ft.

The boilers are fed by four pumps placed in the engine-room; four donkey pumps in the stokeholds serve as auxiliary feed. Eight ventilators serve for ventilating the stokeholds, and for working under forced draught. The trials of the engines gave the following results:

Fig. 263.

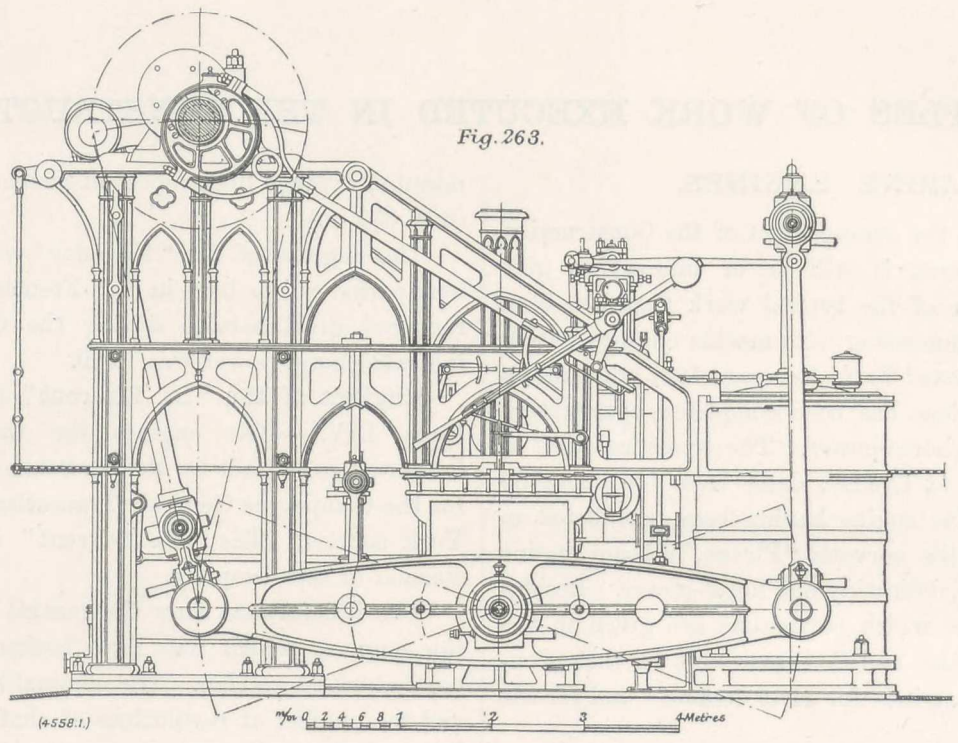
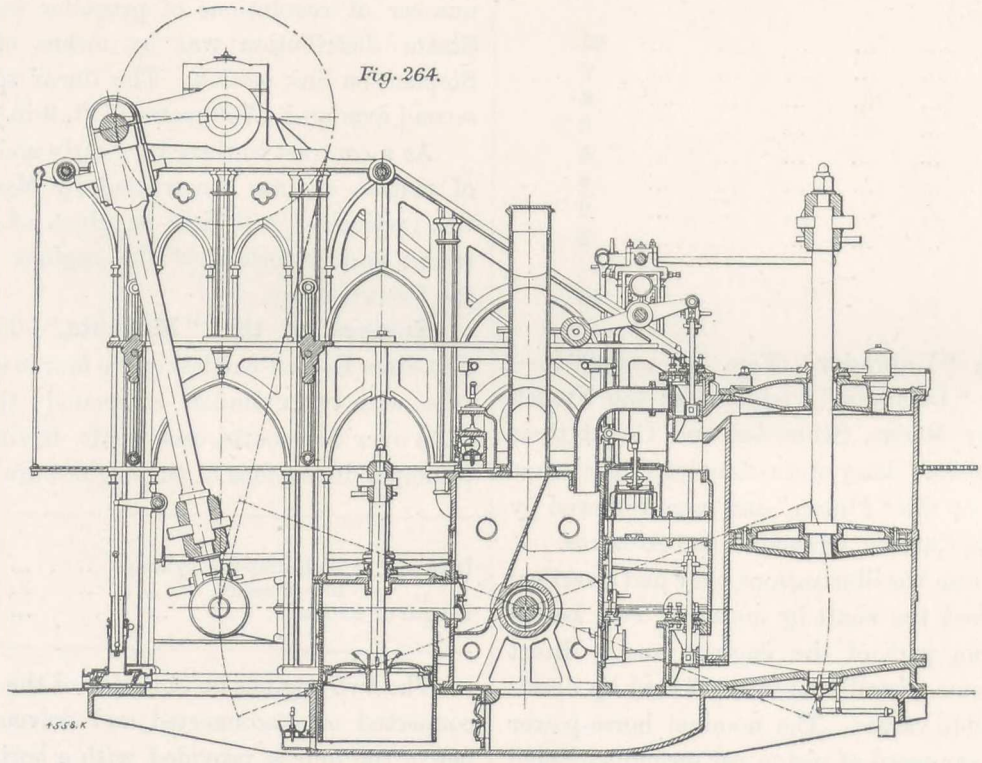


Fig. 264.



Engines of the French Frigate "Labrador," 1839.

Duration of trial ... ... hours	6	6	6	4	2
Number of engines working ...	4	2	2	4	4
,, boilers ,, ...	8	5	8	8	8
Average revolutions	72.3	57.2	70.4	84.8	87.3
Total power realised, horse-power	5,832	2,695	4,945	9,884	10,877
Coal consumption per horse-power per hour ...kilogs.	0.885	0.920	0.975	1.231	1.251
Coal consumption per horse-power per hour ... lb.	1.96	2.04	2.15	2.72	2.77

THE CONSTRUCTION DEPARTMENT.

Fig. 265.

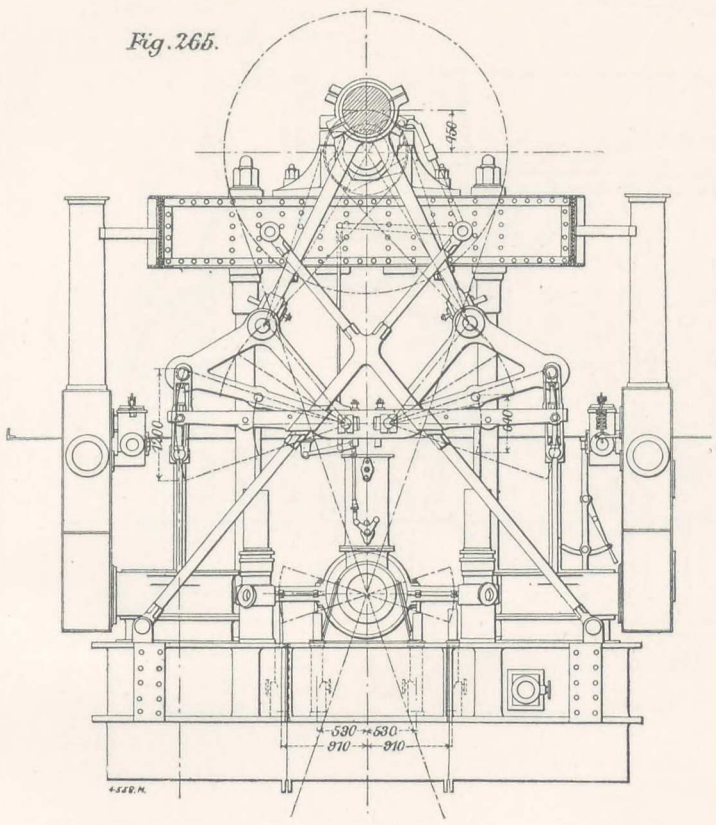


Fig. 266

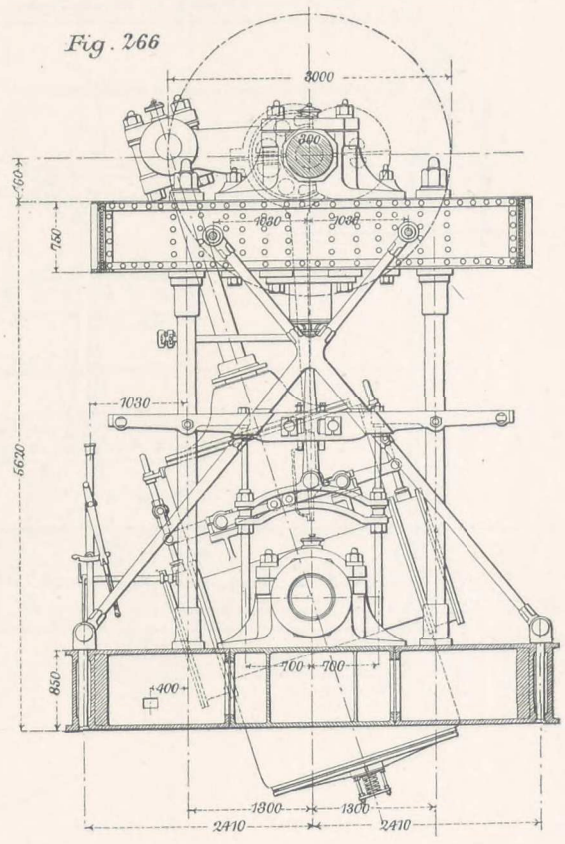
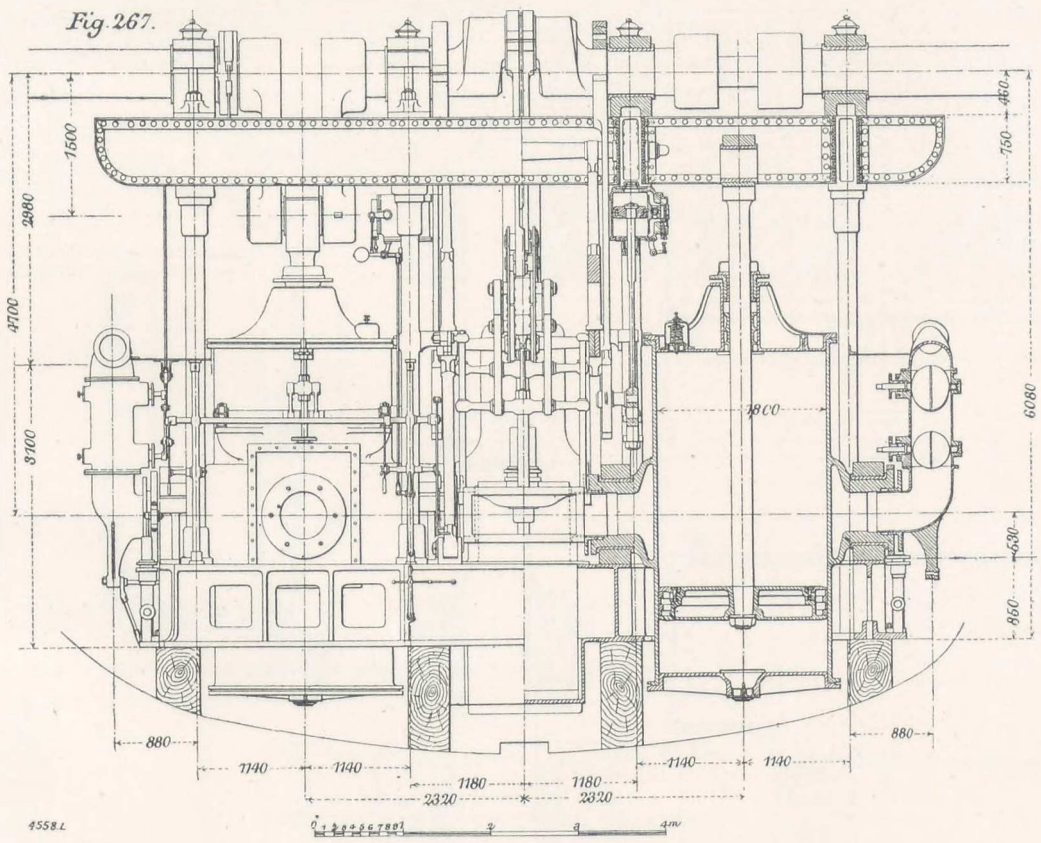


Fig. 267.



Engines of the French Frigate "Mogador," 1846.

THE CONSTRUCTION DEPARTMENT.

Fig 268

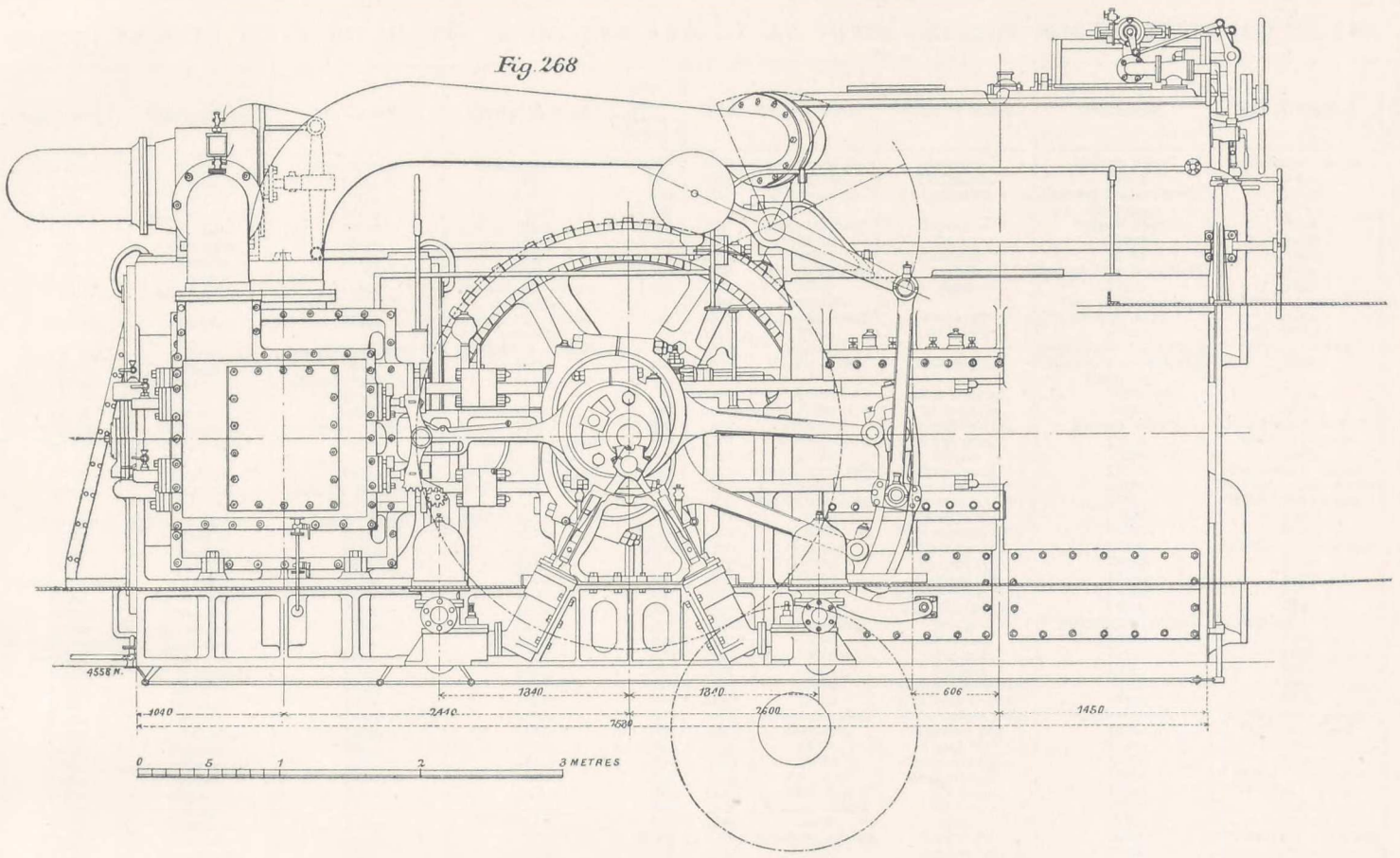
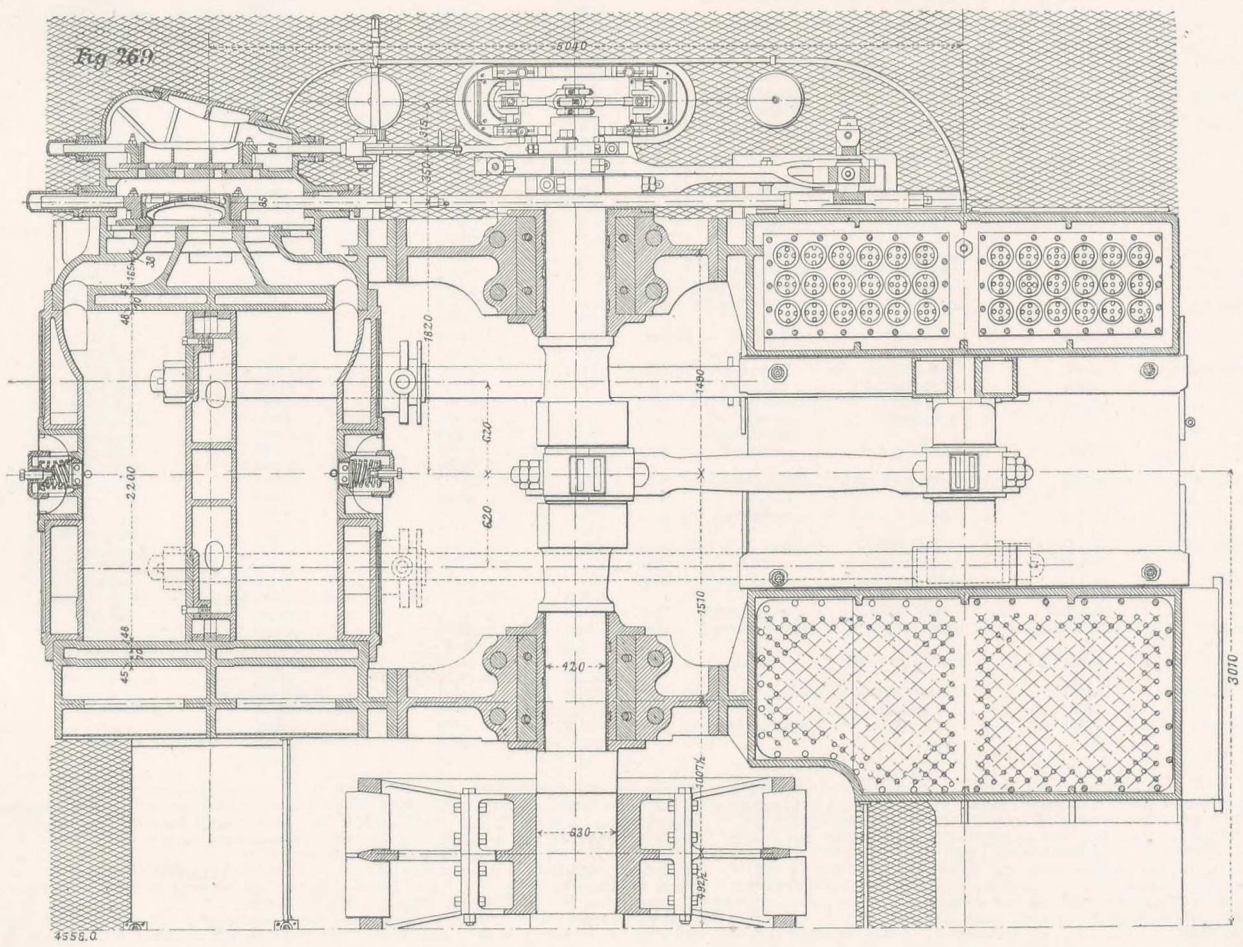


Fig 269



Engines of the "Saint Laurent," 1865.

MARINE ENGINES BUILT BY MESSRS. SCHNEIDER AND CO. AT THEIR CREUSOT WORKS, FROM 1839 TO 1898.

Date.	Class of Ships.	Name of Ships.	Destination.	Type of Engines.	Indicated Horse-Power.
1839	Corvette	Pluton	French Navy	Beam engine	660
1839	Ditto	Archimède	Ditto	Ditto	660
1839	Ditto	Cassini	Ditto	Ditto	660
1839	Frigate	Labrador (1)	Ditto	Ditto	1,350
1839	Ditto	Canada	Ditto	Ditto	1,350
1839	Ditto	Orénoque	Ditto	Ditto	1,350
1839	Ditto	Caraïbe	Ditto	Ditto	1,350
1839	Ditto	Albatros	Ditto	Ditto	1,350
1844	Yacht	Comte d'Eu	Ditto	Horizontal ; screw propeller	960
1844	Corvette	Caton	Ditto	Inclined ; screw propeller	780
1845	Packet Boat	Biche	French Mail Service	Oscillating ; paddle	450
1845	Ditto	Daim	Ditto	Ditto	450
1845	Ditto	Mérovée	French Merchant Service	Ditto	540
1845	Ditto	Oronte	Ditto	Ditto	540
1846	Frigate	Mogador (2)	French Navy	Ditto	1,950
1848	Corvette	Berthollet (3)	Ditto	Fixed vertical cylinders ; paddle	1,200
1850	Ditto	Laplace	Ditto	Horizontal ; screw	1,200
1851	Tugboat	Valencia	French Merchant Service	Horizontal ; paddle	150
1852	Warship	Prince Jérôme	French Navy	Horizontal ; screw	1,950
1852	Ditto	Fleurus	Ditto	Ditto	1,950
1852	Ditto	Wagram	Ditto	Ditto	1,950
1852	Ditto	Navarin	Ditto	Ditto	1,950
1854	Floating battery	Lave (4)	Ditto	Ditto	450
1854	Ditto	Foudroyante	Ditto	Ditto	450
1854	Ditto	Congrève	Ditto	Ditto	450
1854	Ditto	Dévastation	Ditto	Ditto	450
1854	Floating battery	Tonnante	Ditto	Ditto	450
1854	Gunboat	Dragonne	Ditto	Ditto	330
1854	Ditto	Fulminante	Ditto	Ditto	330
1854	Ditto	Mitraille	Ditto	Ditto	330
1854	Ditto	Grenade	Ditto	Ditto	330
1854	Ditto	Fusée	Ditto	Ditto	330
1854	Ditto	Avalanche	Ditto	Ditto	330
1854	Ditto	Etincelle	Ditto	Ditto	330
1854	Ditto	Flèche	Ditto	Ditto	330
1854	Ditto	Eclair	Ditto	Ditto	330
1854	Ditto	Aigrette	Ditto	Ditto	330
1854	Ditto	Alarme	Ditto	Ditto	330
1854	Ditto	Flamme	Ditto	Ditto	330
1854	Frigate	Ardente	Ditto	Ditto	2,400
1854	Ditto	Impératrice-Eugénie	Ditto	Ditto	2,400
1854	Ditto	Foudre	Ditto	Ditto	2,400
1856	Transport	Jura	Ditto	Ditto	750
1856	Ditto	Calvados	Ditto	Ditto	750
1856	Ditto	Rhône	Ditto	Ditto	750
1856	Ditto	Aube	Ditto	Ditto	750
1856	Ditto	Garonne	Ditto	Ditto	750
1856	Ditto	Finistère	Ditto	Ditto	750
1856	Frigate	Danaé	Ditto	Ditto	600
1856	Ditto	Renommée	Ditto	Ditto	600
1856	Ditto	Pandore	Ditto	Ditto	600
1856	Ditto	Zénobie	Ditto	Ditto	600
1856	Ditto	Bellone	Ditto	Ditto	600
1856	Corvette	Bajan	Russian Navy	Ditto	900
1856	Frigate	Swetlana	Ditto	Ditto	1,350
1856	Yacht	Etendard	Ditto	Horizontal ; paddle	1,200
1858	Frigate	Guerrière	French Navy	Horizontal ; screw	1,800
1858	Ditto	Hermione	Ditto	Ditto	1,800
1858	Ditto	Victoire	Ditto	Ditto	1,800
1858	Ditto	Junon	Ditto	Ditto	1,800
1858	Ditto	Pallas	Ditto	Ditto	1,800
1858	Ditto	Sémiramis	Ditto	Ditto	1,800
1859	Despatch-boat	Comète	Ditto	Ditto	360
1860	Frigate	Clorinde	Ditto	Ditto	540
1860	Transport	Allier	Ditto	Ditto	900
1860	Ditto	Ardèche	Ditto	Ditto	900
1860	Ditto	Drôme	Ditto	Ditto	900
1860	Ditto	Eure	Ditto	Ditto	900
1860	Ditto	Orne	Ditto	Ditto	900
1860	Ditto	Var	Ditto	Ditto	900
1861	Gunboat	Décidée (5)	Ditto	Ditto	180
1861	Ditto	Pique	Ditto	Ditto	180
1861	Ditto	Surprise	Ditto	Ditto	180
1861	Ditto	Tactique	Ditto	Ditto	180
1861	Frigate	Minerve (6)	Ditto	Ditto	1,500
1861	Ditto	Vénus	Ditto	Ditto	1,500
1862	Tugboat	Patient	Ditto	Ditto	90
1862	Gunboat	Diligente	Ditto	Ditto	150
1862	Floating battery	Arrogante	Ditto	Ditto	450
1862	Ditto	Implacable	Ditto	Ditto	450
1862	Ditto	Opiniâtre	Ditto	Ditto	450
1862	Ditto	Embuscade	Ditto	Ditto	450
1862	Ditto	Imprenable	Ditto	Ditto	450
1862	Ditto	Protectrice	Ditto	Ditto	450
1862	Ditto	Refuge	Ditto	Ditto	450
1862	Packet-boat	Impératrice-Eugenie	General Transatlantic Company	Beam ; paddle	2,550
1862	Ditto	France	Ditto	Ditto	2,550
1862	Ditto	Nouveau Monde	Ditto	Ditto	2,550
1862	Ditto	Panama	Ditto	Ditto	2,550
1865	Ditto	Saint Laurent	Ditto	Horizontal ; screw	2,550
1866	Frigate	Ocean (7)	French Navy	Ditto	3,800
1866	Corvette	Armide	Ditto	Ditto	1,800
1866	Coastguard ship	Cerbère	Ditto	Ditto	2,120
1866	Gunboat	Aspic	Ditto	Ditto	200
1866	Ditto	Frelon	Ditto	Ditto	200
1866	Coastguard ship	Scorpion	French Navy	Horizontal ; screw	200
1866	Gunboat	Couleuvre	Ditto	Ditto	200
1867	Packet-boat	Lafayette	General Transatlantic Company	Ditto	3,400
1867	Despatch-boat	Bouraine	French Navy	Ditto	920
1867	Ditto	Dayot	Ditto	Ditto	920
1867	Ditto	Segond	Ditto	Ditto	920
1868	Steam lighter	Andelle	French Merchant Navy	Ditto	120
1868	Ditto	Epte	Ditto	Ditto	120
1868	Tugboat		City of Bayonne	Inclined ; paddle	600
1871	Despatch-boat	Pétrel (8)	French Navy	Ditto	350
1871	Ditto	Antilope	Ditto	Ditto	350
1871	Tugboat	..	French Merchant Navy	Vertical ; screw	120
1872	Packet-boat	Washington	General Transatlantic Company	Ditto	3,400
1872	Ditto	Saint Laurent	Ditto	Ditto	3,400
1872	Ditto	Lafayette	Ditto	Ditto	3,400
1874	Ironclad	Redoutable (9)	French Navy	Horizontal ; screw	6,000
1874	Transport	Annamite	Ditto	Vertical ; screw	2,640
1874	Ditto	Mytho	Ditto	Ditto	2,640
1875	Coastguard ship	Fulminant	Ditto	Horizontal ; screw	3,500
1877	Ironclad	Courbet (10)	Ditto	Vertical ; twin screw	8,000
1877	Barbette cruiser	La Pérouse (11)	Ditto	Horizontal ; screw	2,700
1877	Ditto	Nielly (12)	Ditto	Ditto	2,700
1878	Ditto	Primauguet (13)	Ditto	Ditto	2,700
1878	Ironclad	Turenne (14)	Ditto	Vertical ; twin screw	4,000
1878	Ditto	Bayard (15)	Ditto	Ditto	4,000
1879	Ditto	Terrible (16)	Ditto	Ditto	6,060
1879	Ditto	Indomptable (17)	Ditto	Ditto	6,060
1880	Ditto	Formidable (18)	Ditto	Ditto	8,500
1881	Packet-boat	Soudan	Merchant service	Vertical ; screw	600
1881	Ditto	Montreal	Ditto	Ditto	1,200
1881	Ditto	Québec	Ditto	Ditto	1,200
1881	Ditto	Halifax	Ditto	Ditto	1,200
1882	Ditto	Château-Margaux	Ditto	Ditto	2,500
1882	Ditto	Château-Yquem	Ditto	Ditto	2,500
1883	Battery cruiser	Dubourdieu (19)	French Navy	Horizontal ; screw	3,300
1883	Gunboat	Flamme (20)	Ditto	Vertical ; screw	1,500
1883	Ditto	Fusée (21)	Ditto	Ditto	1,500
1883	Ditto	Grenade (22)	Ditto	Ditto	1,500
1884	Ironclad	Magenta (23)	Ditto	Vertical ; twin screw	12,000
1885	Launches	Six (24)	Ditto	Vertical ; screw	90
1886	Torpedo-boats	Eleven	Ditto	Ditto	5,775
1886	Ditto	Six	Ditto	Ditto	3,150
1887	3rd-class cruiser	Troude (25)	Ditto	Horizontal ; twin screw	6,060
1887	Ditto	Lalande (26)	Ditto	Ditto	6,060
1887	Ditto	Cosmao (27)	Ditto	Ditto	6,060
1887	Steam water boat	Filtre	Ditto	Vertical ; screw	100
1887	Torpedo-boats	Fourteen	Japanese Navy	Ditto	8,925
1887	Gunboat	(28)	Chinese Navy	Inclined ; twin screw	2,400
1888	1st-class cruiser	Alger	French Navy	Vertical ; twin screw ; triple expansion	8,000
1888	Torpedo-cruiser	Wattignies	Ditto	Horizontal ; twin screw ; triple expansion	4,000
1888	Torpedo-boats	Three of 34 m.	Ditto	Vertical ; triple expansion	1,800
1888	Ditto	Ditto	Ditto	Ditto	1,800
1889	Destroyer	Léger	Ditto	Vertical ; twin screw ; triple expansion	2,200
1889	Ditto	Lévrier	Ditto	Ditto	2,200
1890	2nd-class protected cruiser	Chanzy	Ditto	Horizontal ; twin screw	8,300
1890	Torpedo-boats	Three of 36 m.	Ditto	Vertical ; screw	3,000
1890	Ditto	Two of 34 m.	Japanese Navy	Ditto	1,200
1890	Steam launches	Four of 8.850 m.	French Navy	Ditto	60
1891	Destroyer	Fleurus	Ditto	Horizontal ; twin screw	3,800
1891	Ironclad	Charles-Martel	Ditto	Vertical ; twin screw	13,500
1891	Torpedo-boats	Two of 36 m.	Ditto	Vertical ; screw	2,000
1892	Torpedo-cruiser	Foudre	Ditto	,, twin screw	11,500
1892	Torpedo-boats	Three of 37 m.	Ditto	Vertical ; screw	4,050
1893	Ditto	Two	Ditto	Ditto	420
1893	Destroyer	Casabianca	Ditto	Vertical ; twin screw	5,000
1894	Ironclad	Charlemagne	Ditto	,, three screws	14,500
1895	2nd-class cruiser	Protet	Ditto	,, twin screw	9,000
1896	1st-class despatch-boat	Kersaint	Ditto	Vertical ; screw	2,200
1896	Launch	One of 13 m.	Ditto	Ditto	38
1896	Torpedo-boats	Six first-class	Ditto	Ditto	9,000
1896	Launches	Two of 13 m.	Ditto	Ditto	76
1897	3rd-class cruiser	D'Estrées	Ditto	Vertical ; twin screw	8,500
1897	Ditto	Infernet	Ditto	Ditto	8,500
1897	Torpedo-boat	Five first-class	Ditto	Vertical ; screw	7,500
1897	Training ship	Nadiejda	Bulgaria	,, twin screw	2,600
1897	Torpedo-boats	Five first-class	French Navy	Vertical ; screw	4,500
1897	Ditto	Three first-class	Ditto	Ditto	4,500
1898	Protectedcruiser	Dupetit-Thouars	Ditto	Vertical ; three screws	19,600
1898	Ditto	Kléber	Ditto	Ditto	17,100
1898	Torpedo-boats	Six	Ditto	Vertical ; screw	1,500
				Total	421,674

(1) Weight per indicated horse-power 448 kilogrammes (990 lb.) ; speed of piston 1.150 metres (3 ft. 9¼ in.). (2) Weight per indicated horse-power, 244 kilogrammes (540 lb.) ; speed of piston, 2 metres (6 ft. 6⅛ in.). (3) Weight per indicated horse-power 280 kilogrammes (618 lb.) ; speed of piston, 1.133 metres (3 ft. 8⅝ in.). (4) Weight per indicated horse-power 271 kilogrammes (600 lb.) ; speed of piston, 2 metres (6 ft. 6⅛ in.). (5) Weight per indicated horse-power 305 kilogrammes (672 lb.) ; speed of piston, 1.300 metres (4 ft. 3⅞ in.). (6) Weight per indicated horse-power 245 kilogrammes (540 lb.) ; speed of piston, 1.920 metres (6 ft. 3⅝ in.). (7) Weight per indicated horse-power 217 kilogrammes (480 lb.) ; speed of piston, 2.427 metres (7 ft. 11⅝ in.). (8) Weight, per indicated horse-power, 349 kilogrammes (770 lb.) ; speed of piston, 0.800 metre (2 ft. 7½ in.). (9) 68 revolutions ; weight per horse-power, 174 kilogrammes (384 lb.) ; speed of piston, 2.835 metres (9 ft. 3⅝ in.). (10) 77 revolutions ; weight per horse-power, 144 kilogrammes (317 lb.) ; forced draught ; speed of piston, 2.567 metres (8 ft. 5 in.). (11) 88 revolutions ; weight per horse-power, 153 kilogrammes (337 lb.) ; forced draught ; speed of piston 2.500 metres (8 ft. 2½ in.). (12) Forced draught. (13) Forced draught. (14) Forced draught. (15) Forced draught. (16) Forced draught. (17) Forced draught. (18) 80 revolutions ; weight per horse-power, 150 kilogrammes (331 lb.) ; speed of piston, 2.667 metres (8 ft. 9 in.). (19) Forced draught. (20) Forced draught. (21) Forced draught. (22) Forced draught. (23) 90 revolutions ; weight per horse-power, 116 kilogrammes (256 lb.) ; speed of piston, 3 metres (9 ft. 10⅛ in.). Forced draught. (24) Forced draught. (25) 140 revolutions. Forced draught ; weight per horse-power, 89 kilogrammes (196 lb.) ; speed of piston 4.270 metres (14 ft. 0⅛ in.). (26) 140 revolutions. Forced draught ; weight per horse-power, 89 kilogrammes (196 lb.) ; speed of piston 4.270 metres (14 ft. 0⅛ in.). (27) 140 revolutions. Forced draught ; weight per horse-power, 89 kilogrammes (196 lb.) ; speed of piston 4.270 metres (14 ft. 0⅛ in.). (28) 140 revolutions. Forced draught ; weight per horse-power, 89 kilogrammes (196 lb.) ; speed of piston 4.270 metres (14 ft. 0⅛ in.)

Engines of the "Alger."—The first-class cruiser "Alger" has two main vertical engines, of equal power, triple-expansion, each engine driving a screw propeller. The principal dimensions are the following:

	m.	in.
Diameter of high-pressure cylinder ...	0.860	$33\frac{13}{16}$
,, mean-pressure ,, ...	1.360	$53\frac{1}{2}$
,, low-pressure ,, ...	2.060	81
Stroke	0.850	$33\frac{7}{16}$

Each engine is provided with a horizontal tubular condenser, with brass tubes, two single-acting vertical air pumps, and one centrifugal circulating pump, these pumps being worked by a separate two-cylinder engine.

The high-pressure slide valves are cylindrical; the mean and low-pressure slide valves are of the usual flat type, and are balanced. They are all controlled by link motion. Each engine is fitted with reversing gear, worked by hand or steam power. The pistons are of cast steel, each one being fitted with two rods, united at their lower end by a crosshead, which carries the connecting-rod pins and guide sliding-blocks. The foundation plates which support the crankshaft bearings, and the frames which support the cylinders, are also of cast steel. All the crankshafts, intermediate, and propeller shafts, are hollow and of forged steel; the propellers are of bronze of a special quality, cast in one piece.

The condensed water discharged by the air pumps of each main engine, is collected in a tank fitted with filters through which it passes before returning to the boilers

Special evaporators for the production of fresh water are used for making good waste in the feed. The boilers, of the Belleville type, as prescribed by the French Admiralty for this cruiser, are 24 in number; they are placed in eight compartments, and are connected with two funnels. The principal characteristics of the boilers are the following:

Registered steam pressure ...	17 kilogs.	241.8 lb. per sq. in.
Total grate area	70.08 sq. m.	754 sq. ft.
,, heating surface	2068.28 sq. m.	22,263 sq. ft.

The boilers are fed by eight Belleville pumps worked by separate motors.

The maximum total power contracted for was 8,000 indicated horse-power at 120 revolutions, with a maximum pressure of 12 kilogrammes (170.7 lb. per square inch) at the valve chests. The trials gave the following results:

Duration of trial ... ... hours	6	24	12	4	6
Number of engines working ...	2	2	2	2	2
,, boilers ,, ...	9	18	24	21	8
Average revolutions	74	101.5	115.4	116.1	
Total power realised, horse-power	2,055	5,346	8,038	8,231	828
Coal consumed per horse-power per hour ... ...kilogs.	0.650	0.700	0.735	0.764	0.865
Coal consumed per horse-power per hour ... ... lb.	1.4	1.5	1.6	1.7	1.9

86-Ton Torpedo Boats.—Messrs. Schneider and Co. have in course of construction 21 of these torpedo boats.

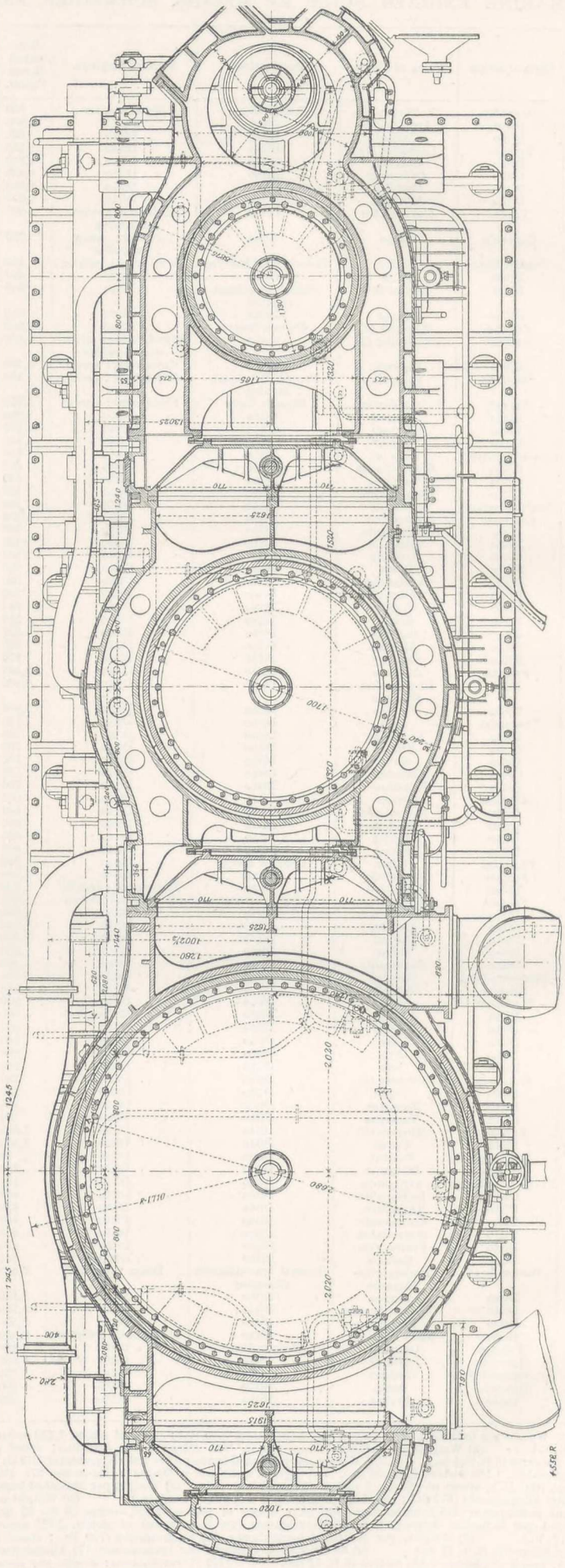


Fig. 279. Plan of the Triple-Expansion Engines of the French Ironclad "Charles Martel."

Fig. 270

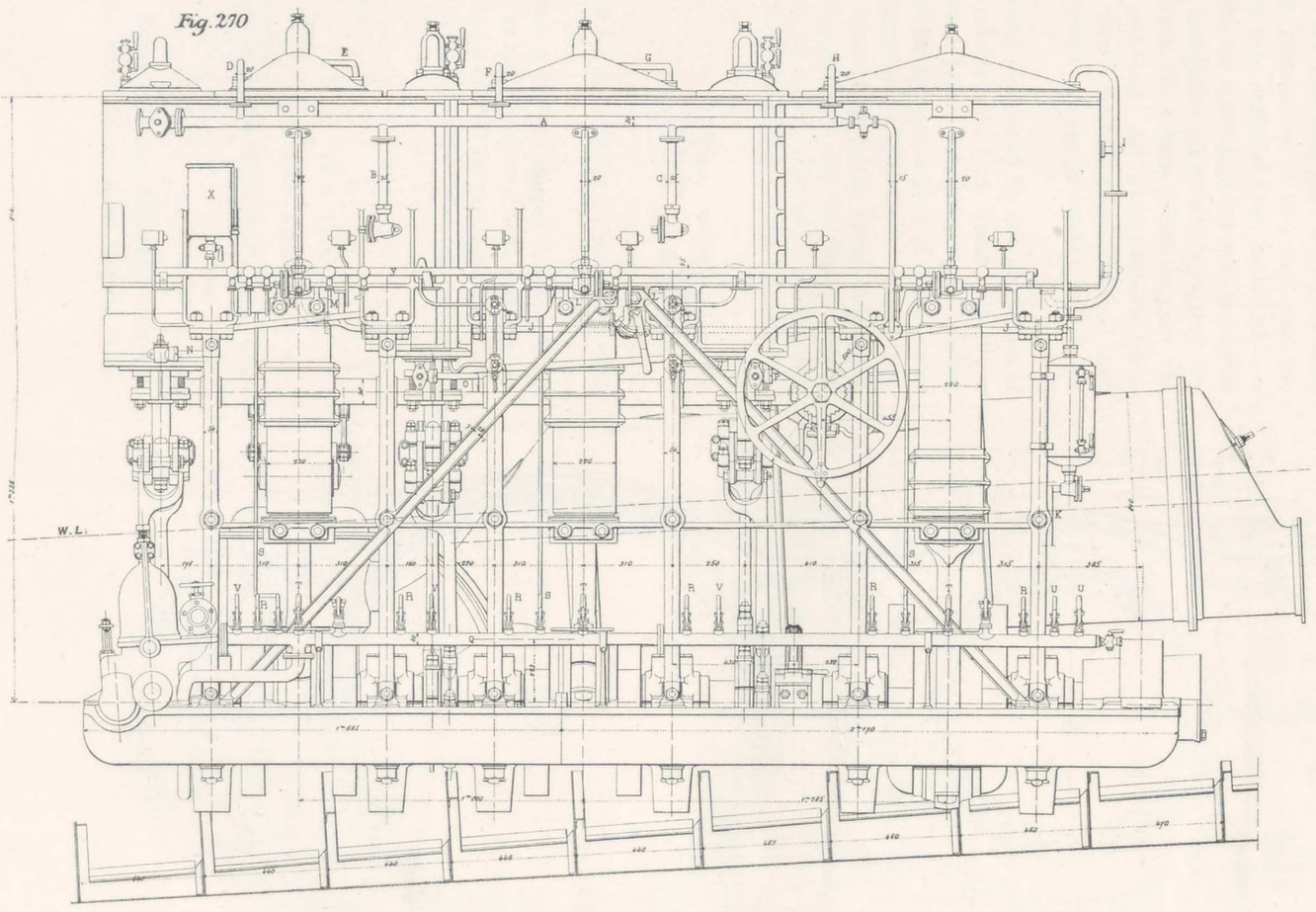


Fig. 271

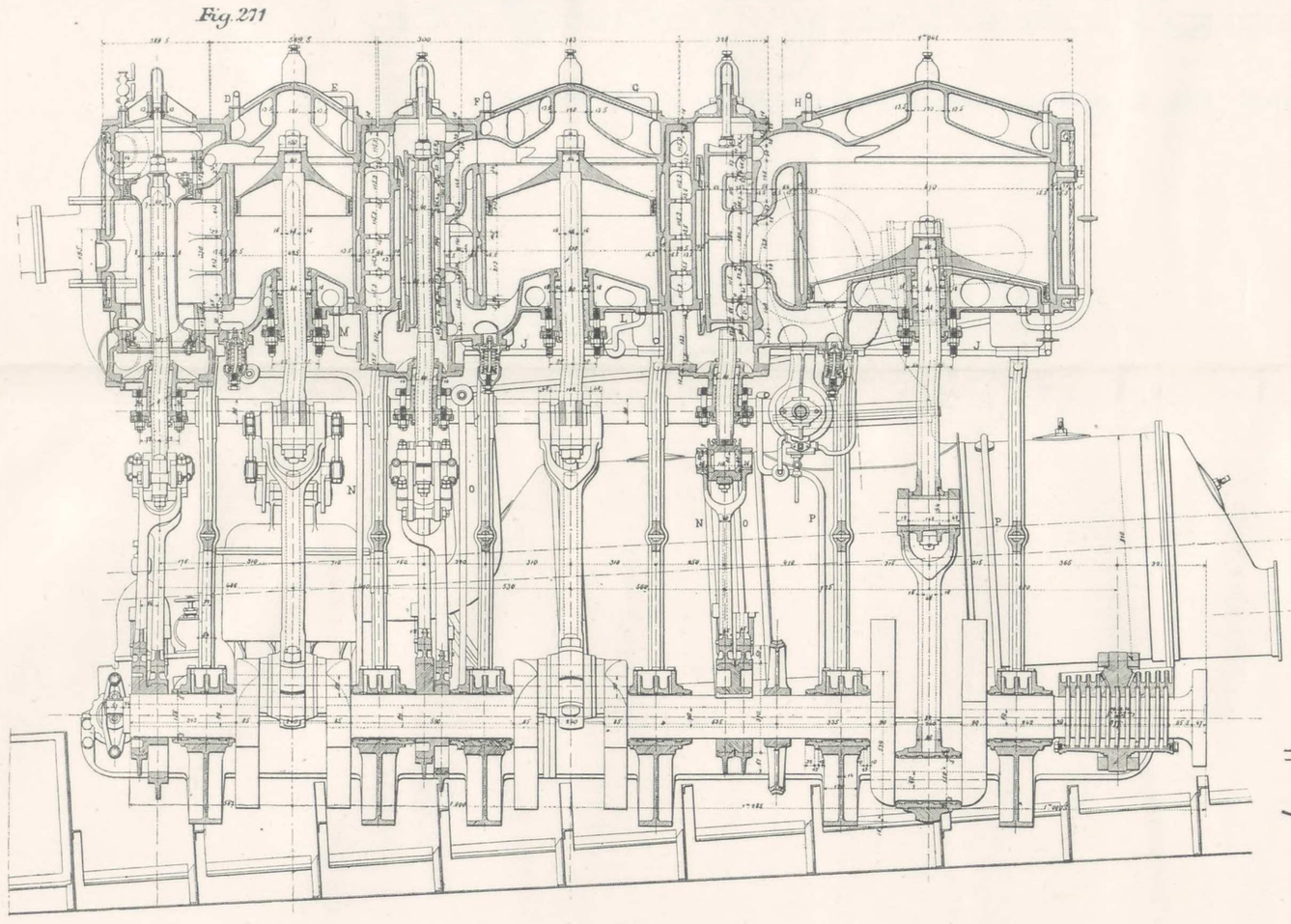


Fig. 272

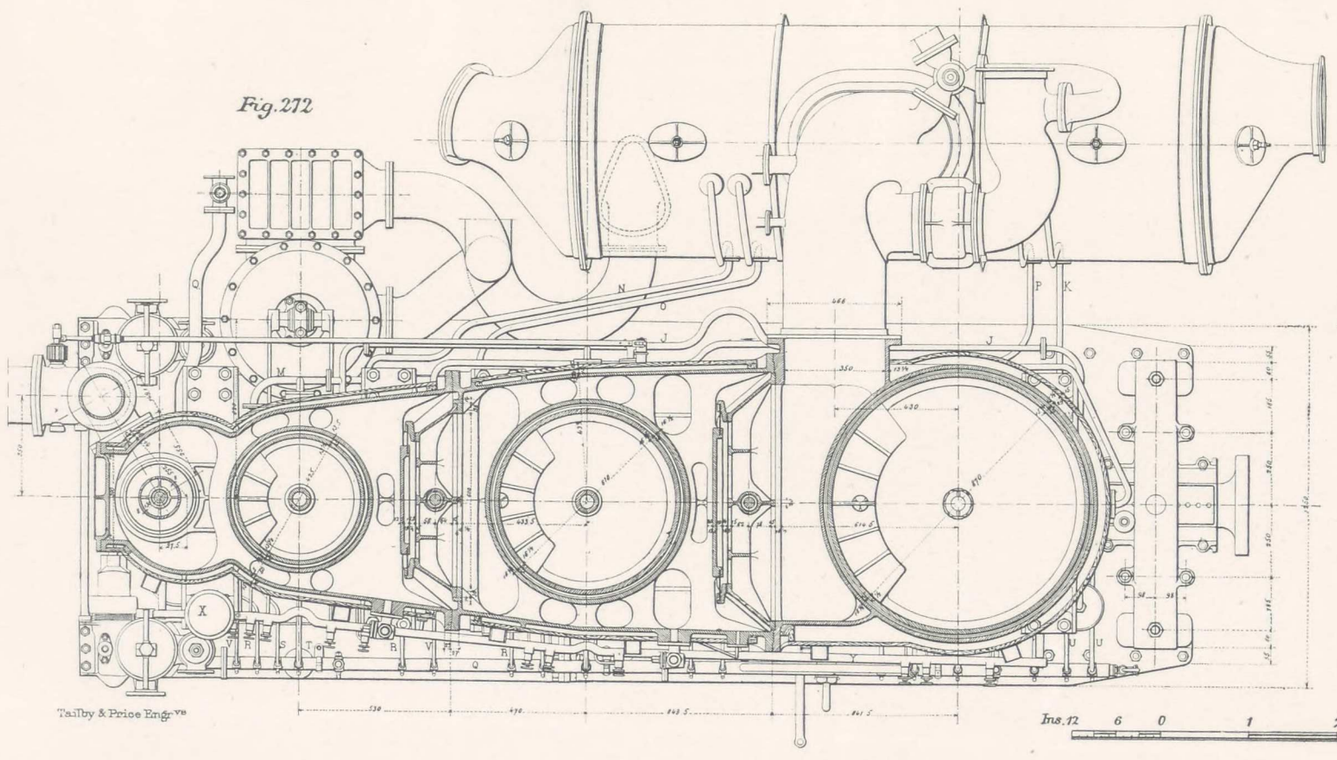


Fig. 273

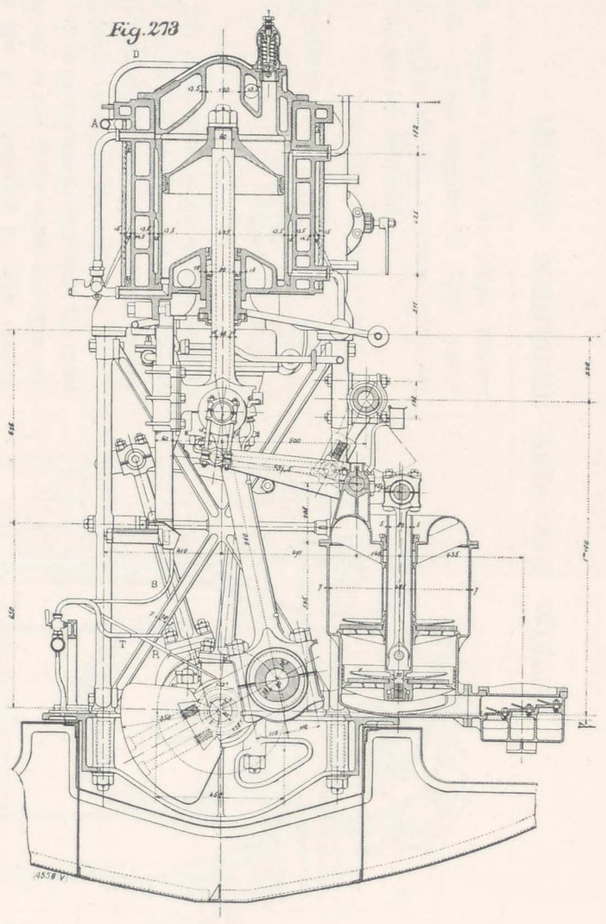


Fig. 274

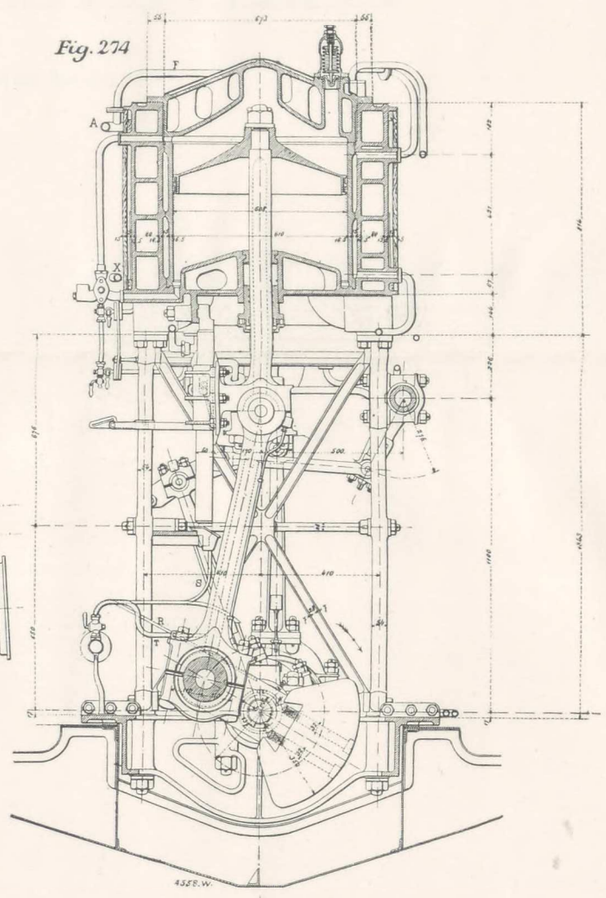
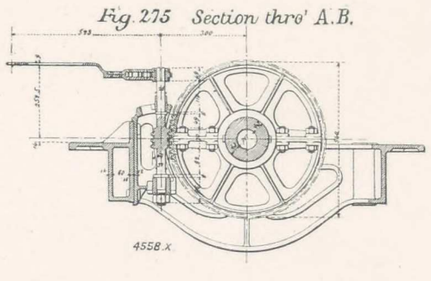


Fig. 275 Section thro' A.B.

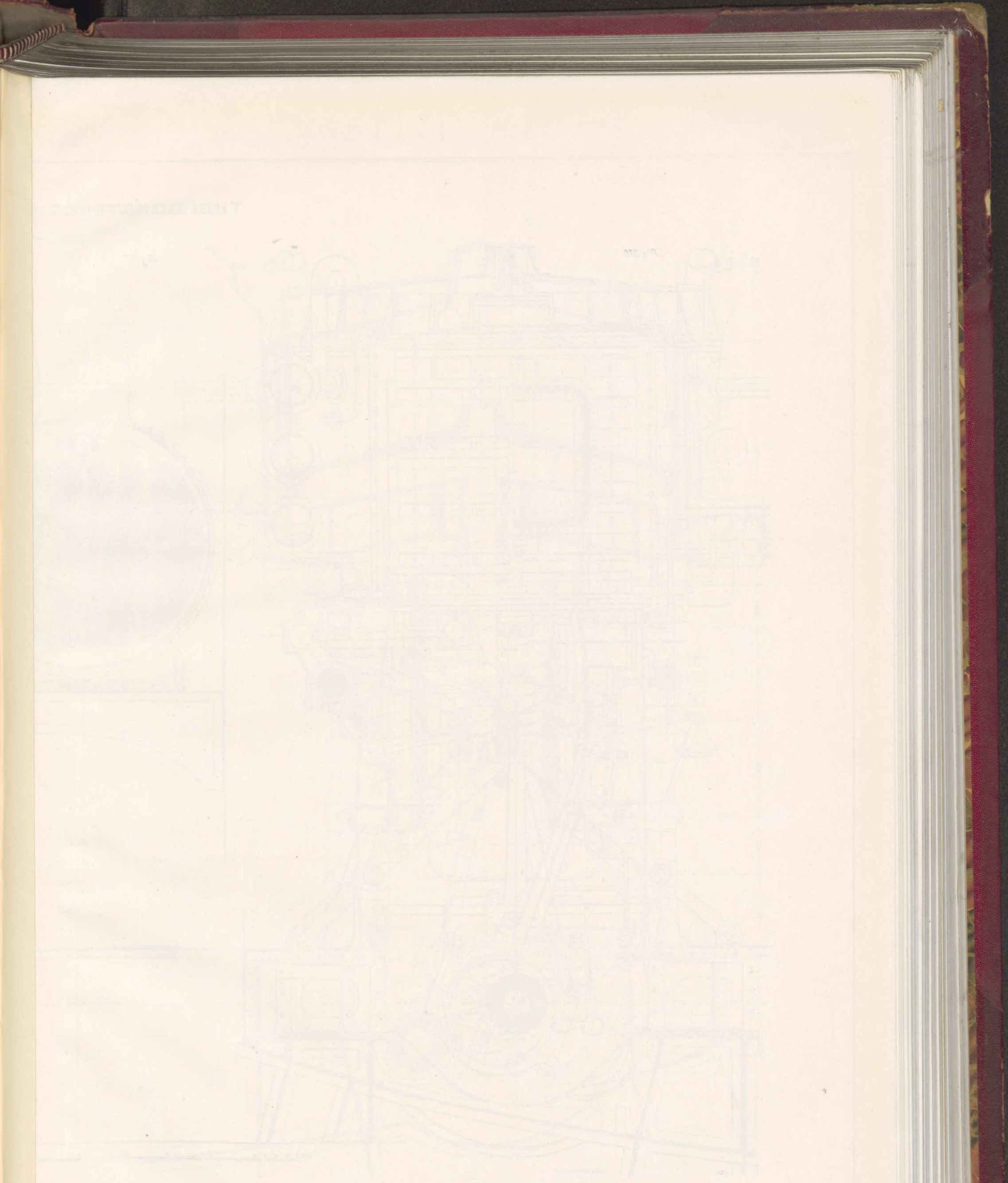


Tailby & Price Engrs

Ins. 12 6 0 1 2 3 4 5 6 7 8 Feet

Triple-Expansion Engines for French First-Class Torpedo-Boats.

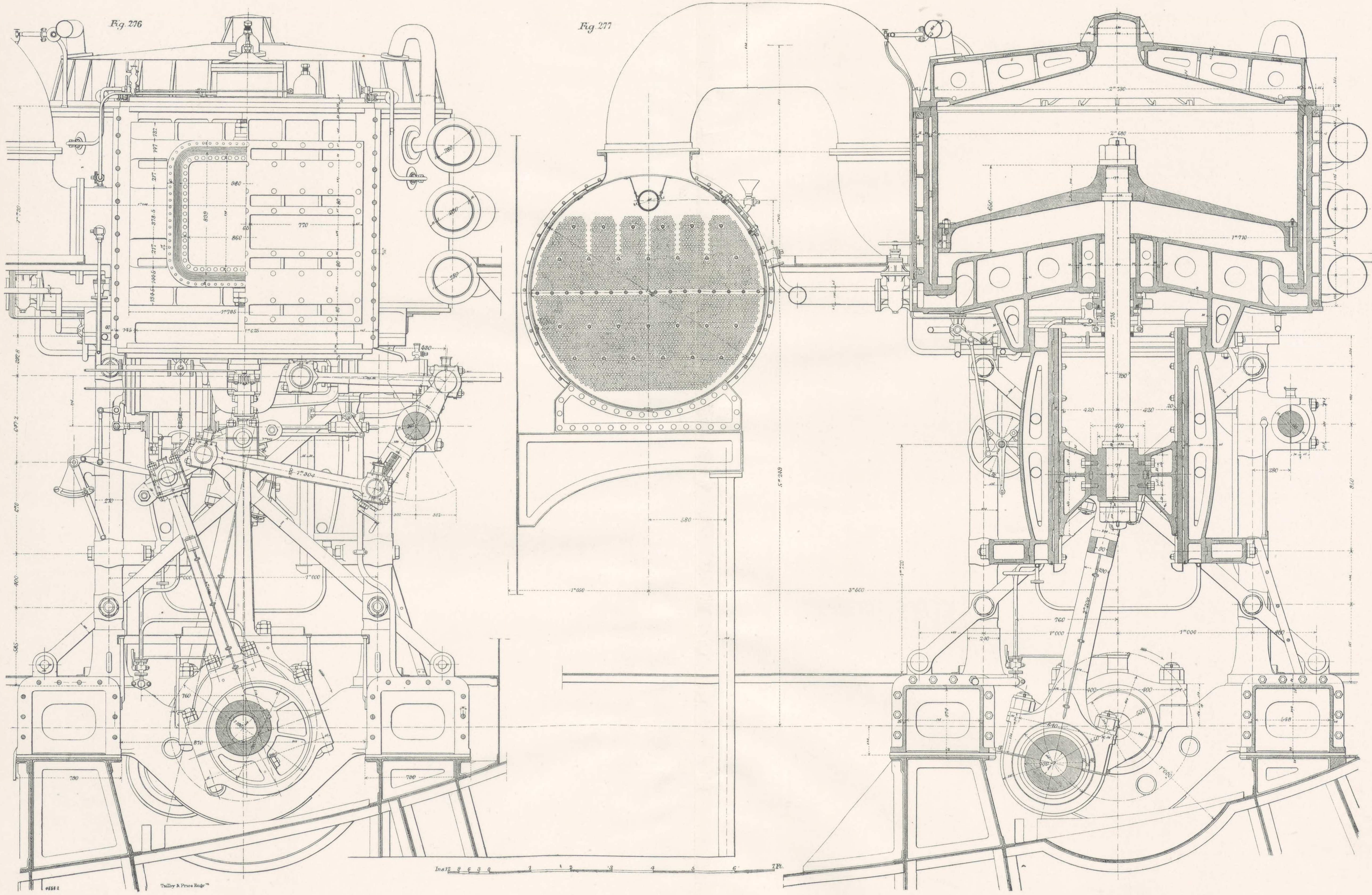
PLATE LV.



THE CONSTRUCTION DEPARTMENT.

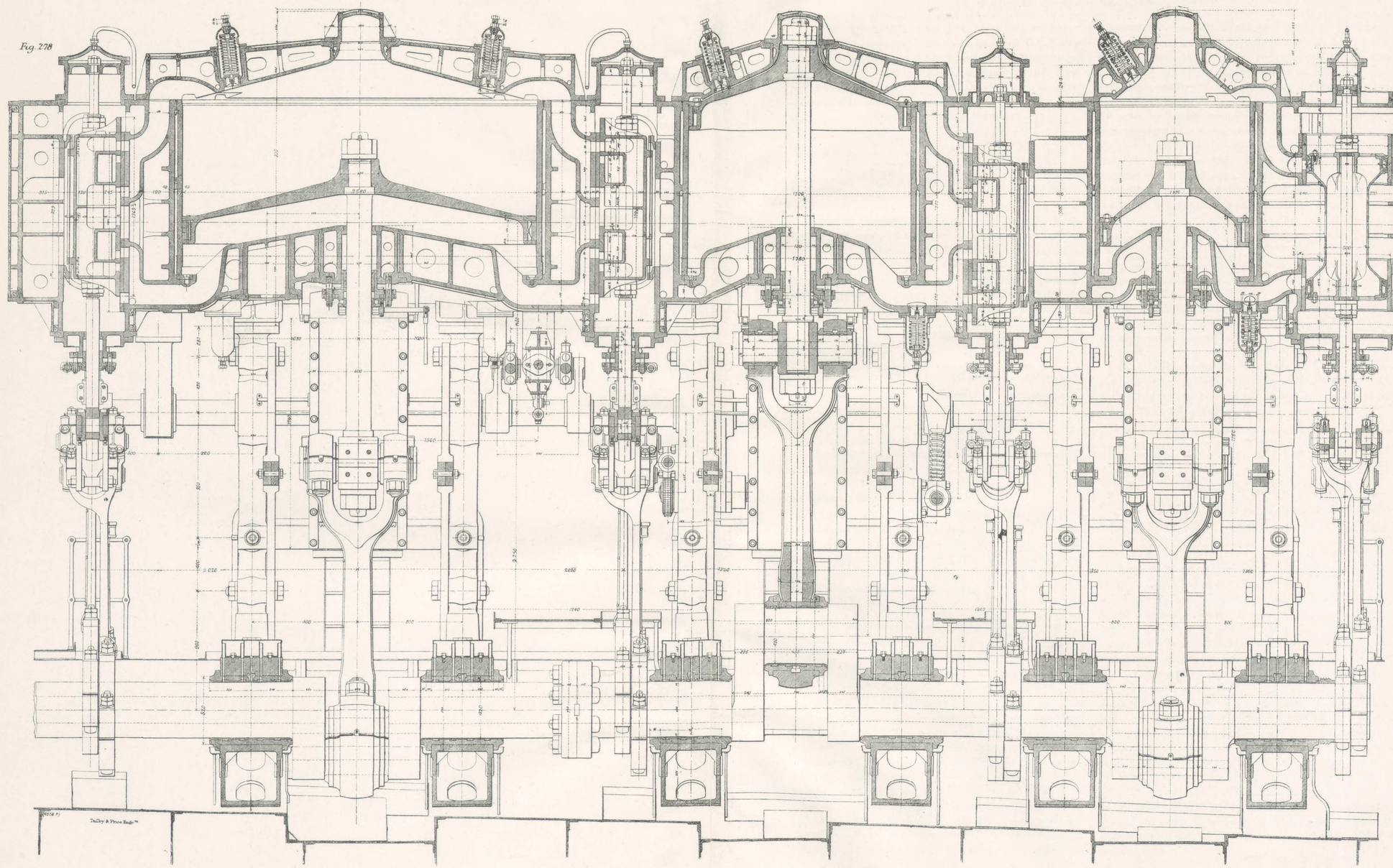
Fig 276

Fig 277



Triple-Expansion Engines of the French Ironclad "Charles Martel."

Fig. 278



Triple-Expansion Engines of the French Ironclad "Charles Martel."

(See Figs. 270 to 275, Plate LV.) The engines are of 1,500 horse-power, and each boat has two Du Temple boilers, as prescribed by the French Navy Department. The engines are vertical, with three cylinders and triple-expansion, provided with a tubular surface condenser, the air and feed pumps being worked direct from the main engines. The following are some dimensions:

	m.	in.
Diameter of high-pressure cylinder ...	.425	$16\frac{11}{16}$
,, mean-pressure ,, ...	.610	24
,, low-pressure ,, ...	.870	$34\frac{1}{4}$
Stroke	.450	$17\frac{11}{16}$
Revolutions	360	360

When the torpedo-boat is under steam, circulation in the condenser is produced naturally by running ahead. When the boat remains stationary, the circulation is effected by means of a small centrifugal pump. A filter is fitted to the discharge of the air pump, in order to cleanse the water, which serves to make good waste in the feed. An evaporator is provided for the production of fresh feed water. A reheating apparatus is fitted on the discharge of the feed pumps.

Registered steam pressure ...	15 kilogs.	213.3 lb. per sq. in.
Total grate area	4.56 sq. m.	48.45 sq. ft.
,, heating surface not covered with water	210.00 sq. m.	2260.45 sq. ft.

The boilers are provided with a donkey pump, which works independently of the feed pumps.

Forced draught is obtained by means of a ventilator, placed in the stokehold. The boilers are fitted with fire-box and ashpit doors, and gas outlet flues, so as to prevent all return of flame into the stokehold.

Engines of the "Charles Martel."—The engines of this magnificent ship are illustrated on Plates LVI. and LVII. (Figs. 276 to 278), and by Fig. 279. They are of the vertical type, with three cylinders, triple-expansion, of equal power, driving twin screws. The principal dimensions of the engines are the following:

	m.	in.
Diameter of high-pressure cylinder ...	1.130	$44\frac{1}{2}$
,, mean-pressure ,, ..	1.700	$66\frac{15}{16}$
,, low-pressure ,, ...	2.680	$105\frac{1}{2}$
Stroke	1.100	$43\frac{5}{16}$

Each engine is provided with a condensing plant, consisting of a wrought-brass tubular condenser, three vertical single-acting air pumps, and one centrifugal circulating pump. The pumps are worked by a separate engine. The high-pressure slide valves are cylindrical, the mean and low-pressure ones are of the flat type and are balanced. All the slide valves are governed by link motion. The reversing gear, which can be worked by hand or steam power, controls the steam admission in the cylinders. The pistons are of cast steel and are conical in shape. The foundation plates which carry the crankshaft bearings are of cast steel; the columns on which the cylinders are supported are of forged steel. All the crank-shafts, intermediate, and propeller, shafts are hollow, and of forged steel; the propellers are of special bronze, with blades fitted on. Each engine-room is provided with two ventilators, one for delivering fresh air in the engine-room, and one for exhausting the hot air. The condensed water delivered by the air pumps of each engine is collected in a tank provided with filters, whence it is delivered again into the boilers. Special evaporators serve for producing fresh water to make good loss. There are 24 boilers of the Lagrafel and d'Allest type, as prescribed by the French Admiralty for this battleship, placed in four stokeholds the boilers are connected with two funnels.

Registered steam pressure ...	15 kilogs.	213.3 lb. per sq. in.
Total grate area	95.20 sq. m.	1024.8 sq. ft.
,, heating surface not covered by water	3000.00 sq. m.	32,292 sq. ft.

The boilers are fed by eight Thirion pumps, worked by separate engines. The ventilation of the stokeholds and working under forced draught are insured by eight ventilators.

The maximum total power prescribed was 13,500 horse-power at 95 revolutions, with a maximum steam pressure of 12 kilogrammes (170.7 lb. per square inch) in the steam chest. The trials gave the following results:

Duration of trial ... ... hours	6	6	4	24	6
Number of engines working ...	2	2	2	2	2
,, boilers ,, ...	8	16	24	24	24
Average revolutions	52.4	70.5	97	87.5	92.7
Total power realised, horse-power	2,186	5,545	14,931	9,800	12,620
Coal consumption per horse-power per hour ... ...kilogs.	0.762	0.624	0.796	0.753	0.736
Coal consumption per horse-power per hour ... ... lb.	1.68	1.38	1.76	1.67	1.63

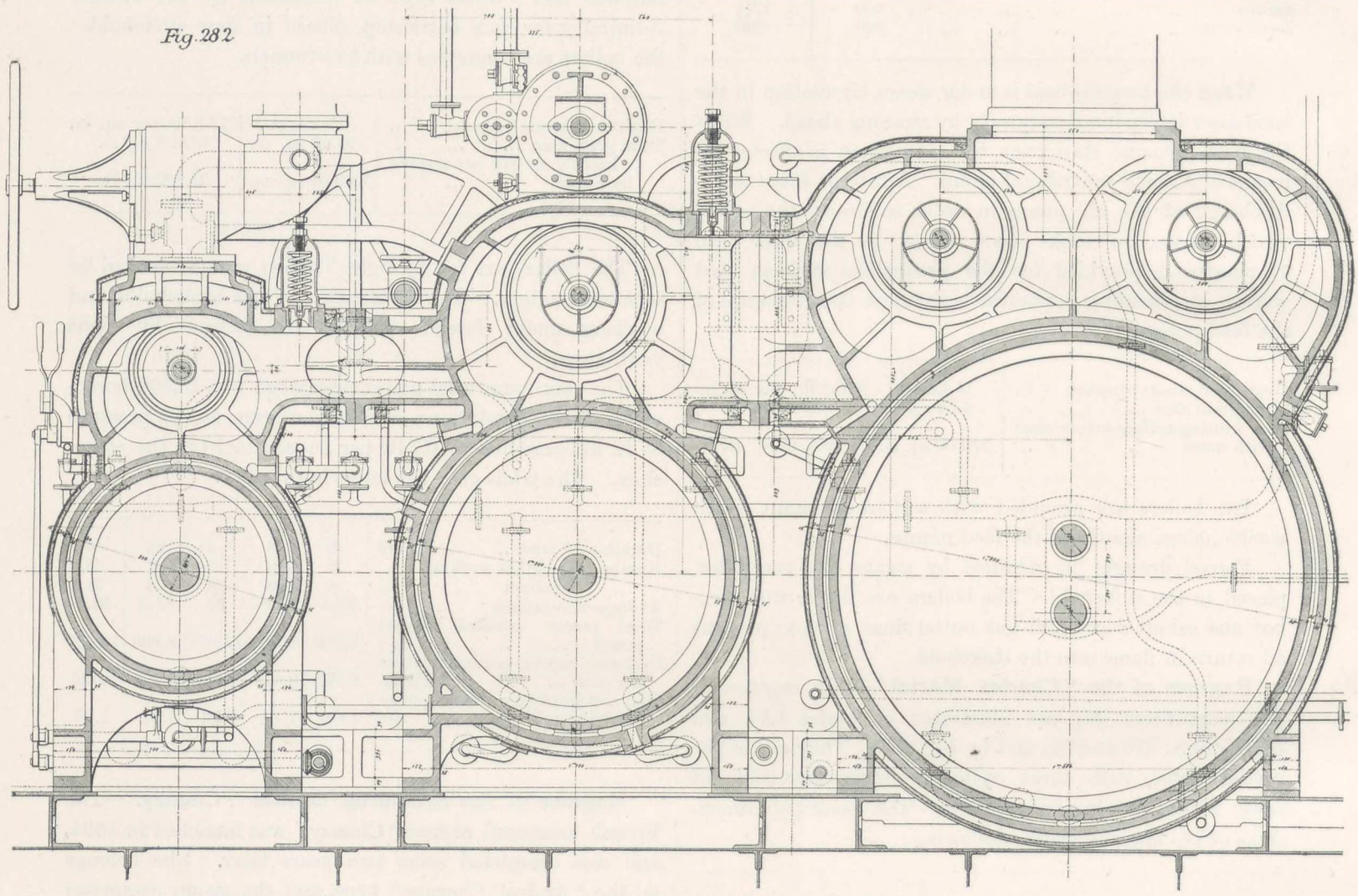
Engines of the Armoured Cruiser "Chanzy."—The French armoured cruiser "Chanzy" was launched in 1894, and was completed some two years later. She belongs to the "Amiral Charner" type, and the group comprises four ships—the "Charner," "Bruix," "Chanzy," and "Latouche-Treville"—the last-named having been launched in 1892. The "Chanzy" is built wholly of steel, and is 110 metres long (360 ft. 10 in.); 14 metres beam (45 ft. 11 in.); and 6 metres (19 ft. 8 in.) draught. The displacement is 4,750 tons, and the indicated horse-power of the engines is 8,300. There are two screws, and the speed attained is 19 knots. The armoured protection of all four vessels is similar, and consists of a belt of 95 millimetres (3.74 in.); the turrets are protected with the same thickness; and there is an armoured deck of 50 millimetres (1.97 in.). The armament is as follows: Two 19-centimetre (7.47 in.) guns; six of 14 centimetres (5.51 in.) quick-firing; four 65-millimetre (2.56 in.), also quick-firing; four similar guns of 49 millimetres (1.85 in.), and six machine guns.

The main engines, which were built by Messrs. Schneider and Co. (see Figs. 280 and 281, Plate LVIII., and Fig. 282), are horizontal, three-cylinder triple-expansion, each driving a propeller. The principal dimensions are the following:

	m.	in.
Diameter of high-pressure cylinder...	0.800	$31\frac{1}{2}$
,, mean-pressure ,, ...	1.200	$47\frac{1}{4}$
,, low-pressure ,, ...	1.900	$74\frac{13}{16}$
Stroke	0.900	$35\frac{7}{16}$

blocks are, moreover, fitted to the cylinders by forged-steel crossbars. All the crankshafts, intermediate, and propeller shafts are hollow, of forged steel; the propellers are of special brass, cast in one piece. Each engine-room is provided with a ventilator. The condensed water discharged by the air pumps of each engine is collected in a tank provided with filters through which it passes before going to the boilers. Special evaporators serve for the production of fresh water for the feed make up; the boilers are thus fed entirely with fresh water. There are 16 boilers

Fig. 282.



Engines of the French Protected Cruiser "Chanzy."

Each engine is provided with a condensing installation, consisting of a wrought-brass tubular condenser, two single-acting vertical air pumps, and a centrifugal circulating pump. The pumps are worked by a separate engine.

All the slide-valves are cylindrical; the high-pressure cylinder is fitted with one, while the mean and low-pressure cylinders have each two. The steam distribution motion is on the Marshall system.

The reversing gear, which is worked by hand and by steam power, allows of regulating the degree of admission of steam in the cylinders. The pistons are of cast steel and conical in shape. The foundation plates on which rest the crankshaft bearer-blocks, are also of cast steel; the bearer-

of the Belleville type, as prescribed by the French Admiralty for this cruiser, placed in two stokeholds and connected in two funnels.

Registered pressure	17 kilogs.	241.8 lb. per sq. in.
Total grate area	64.50 sq. m.	694.3 sq. ft.
Total heating surface not covered by water	1,814 ,,	19,526 ,,

The boilers are fed by eight pumps of the Belleville type. The stokehold ventilation and the working under forced draught, are insured by eight ventilators. The maximum total power prescribed was 8,300 indicated horse-power, with a maximum pressure of 12 kilogrammes

THE CONSTRUCTION DEPARTMENT.

Fig. 280

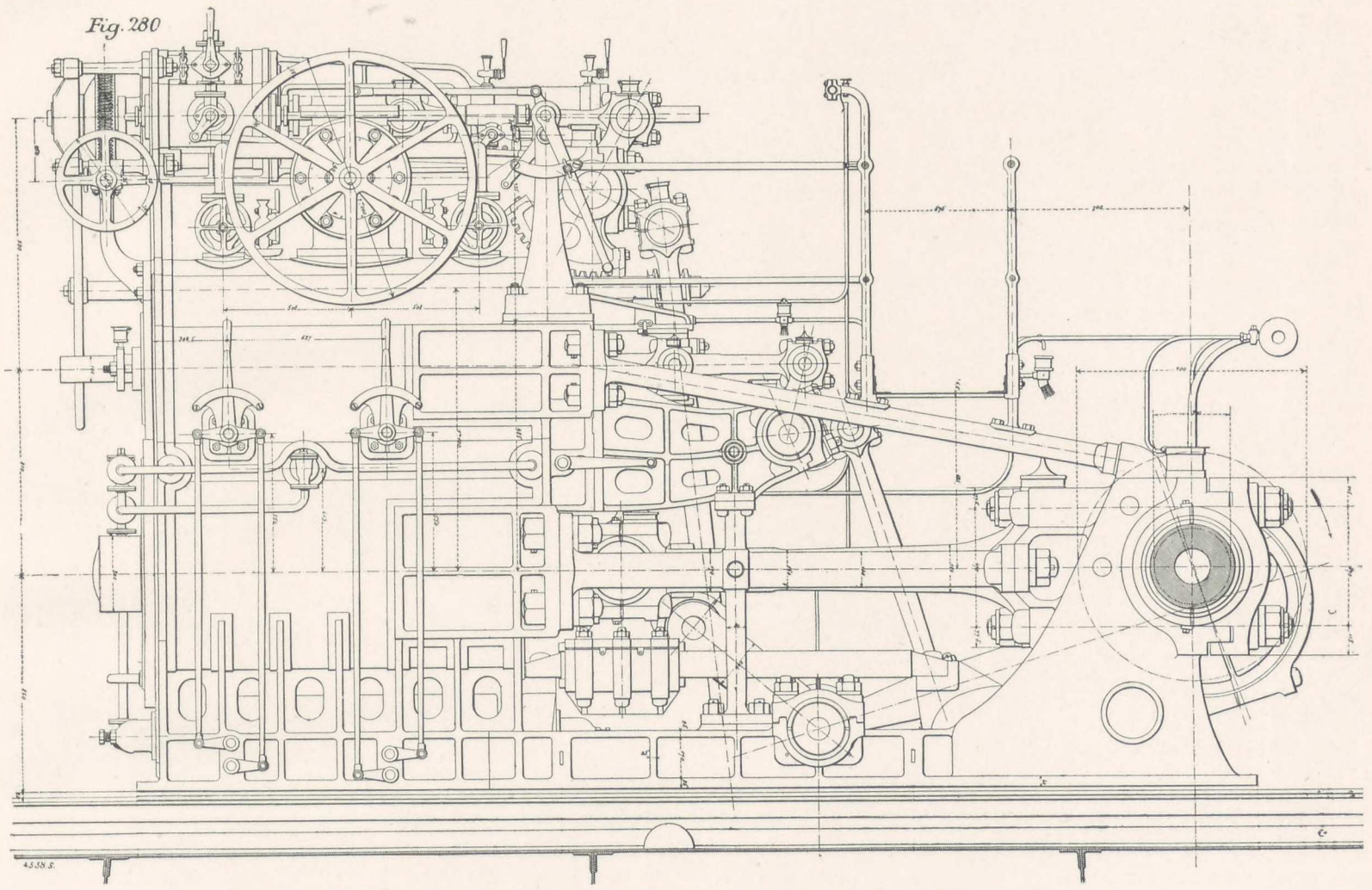
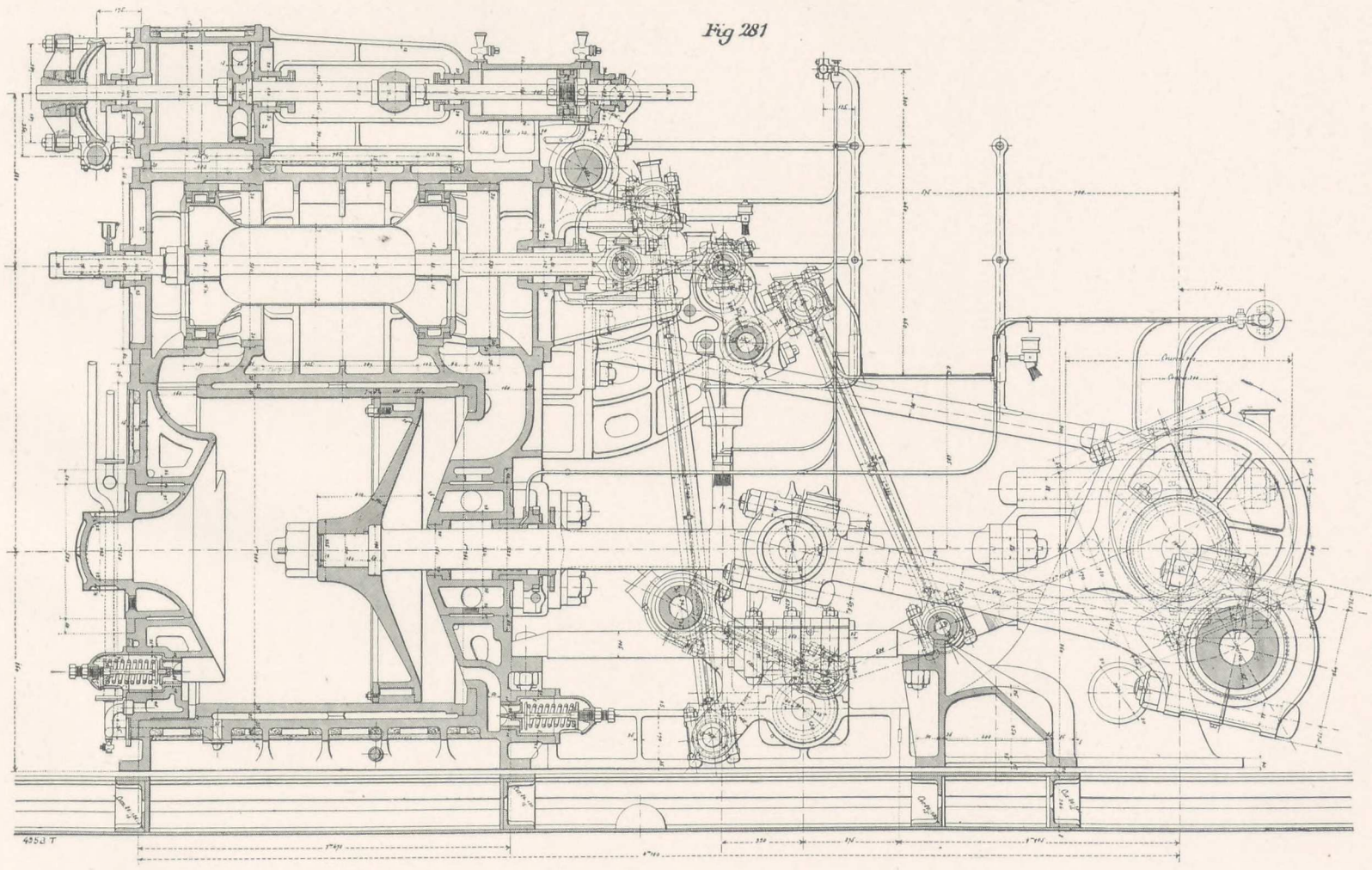


Fig 281



Engines of the French Protected Cruiser "Chanzy."

THE CONSTRUCTION DEPARTMENT: LOCOMOTIVES.

Fig. 284

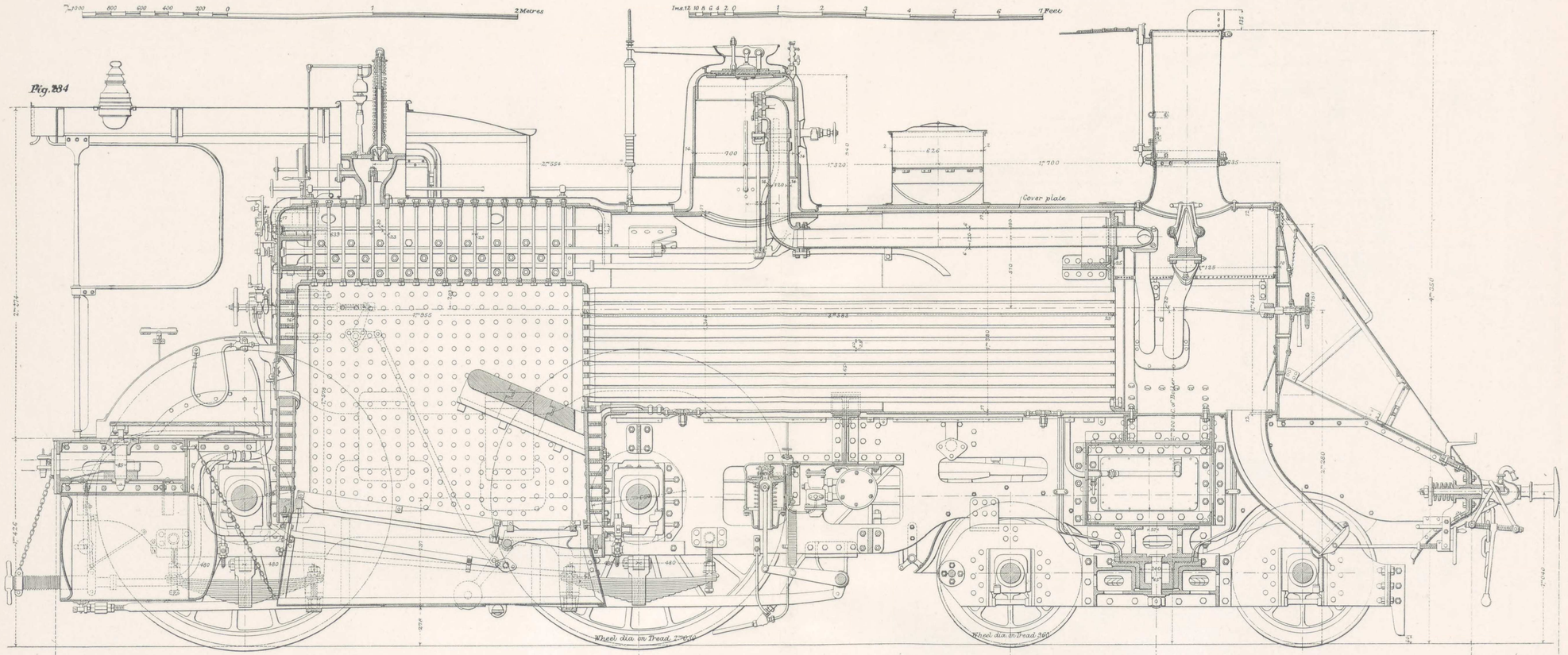
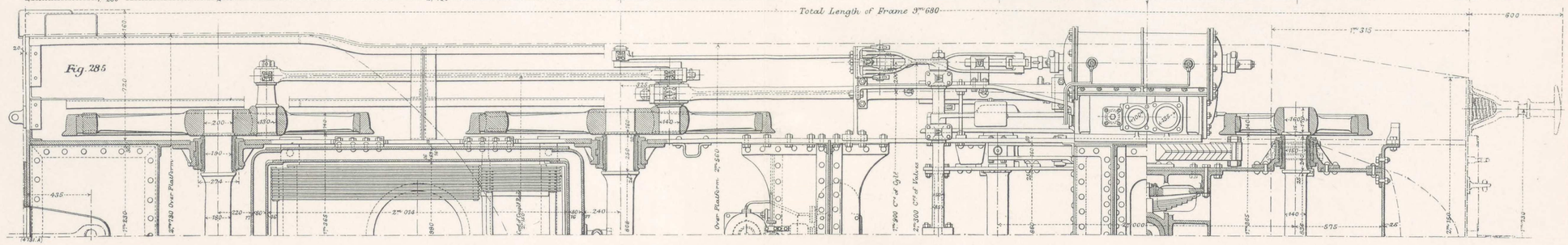


Fig. 285



Outside Cylinder Express Passenger Locomotive for the French State Railways.

Fig. 286

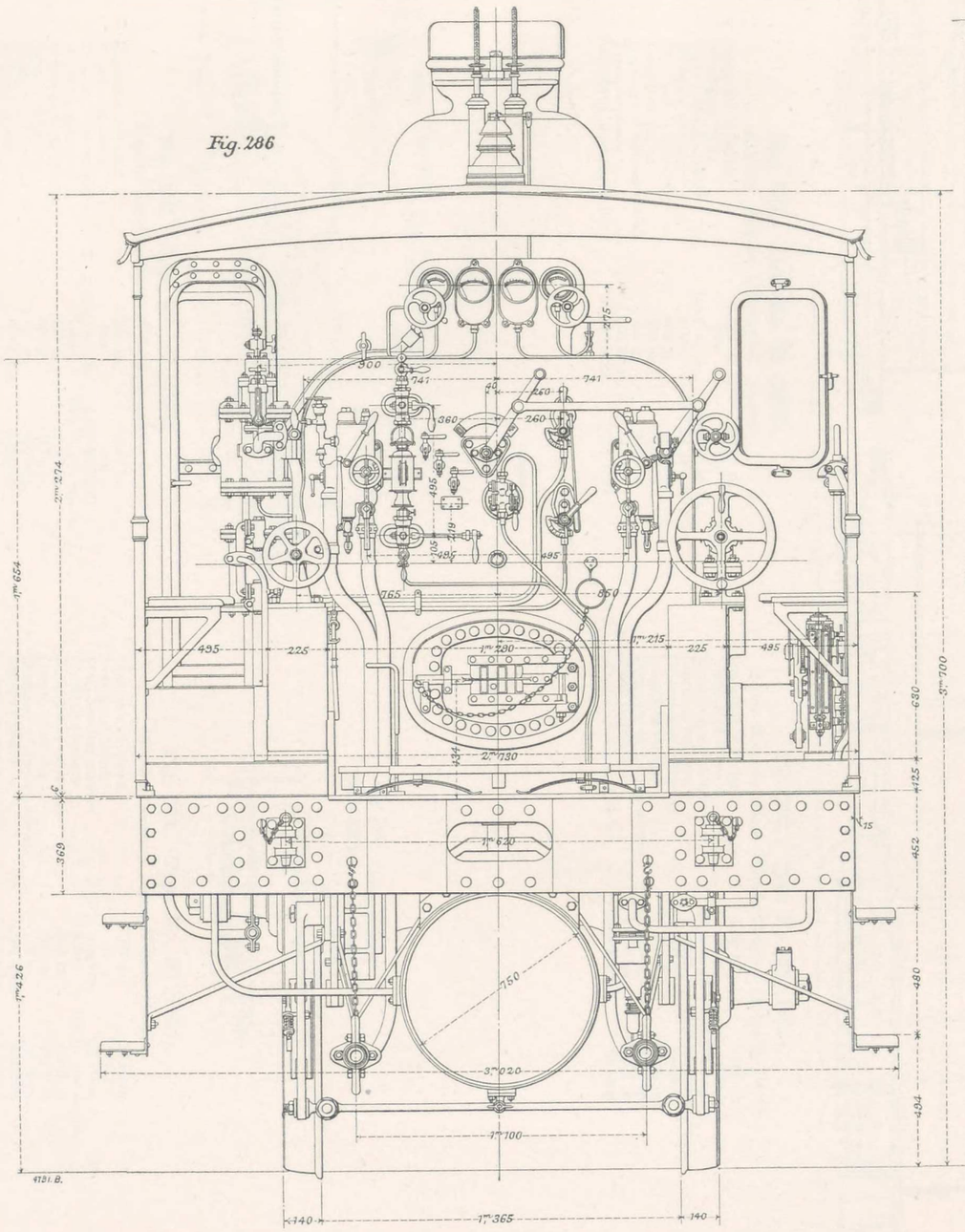
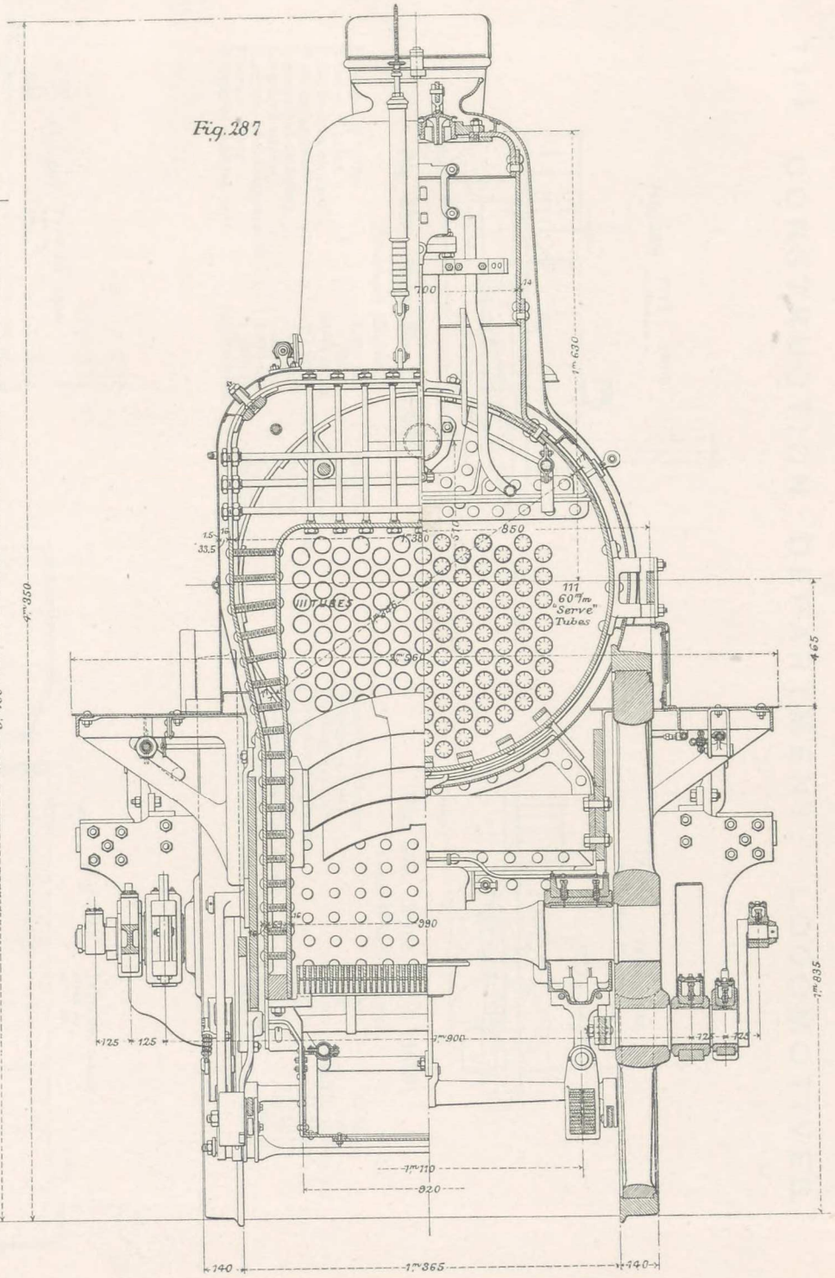


Fig. 287



Outside Cylinder Express Passenger Locomotive for the French State Railways.

PLATE LX.

THE CONSTRUCTION DEPARTMENT: LOCOMOTIVES.

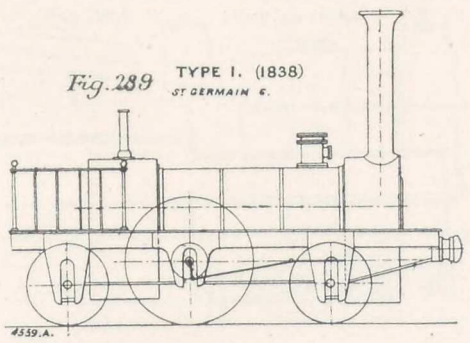


Fig. 289. Type No. 1 (1838).

Passenger Engine.

Diameter of boiler	1.050 m.	41.34 in.
Number of tubes	120	120
Total heating surface	48.52 sq. m.	457.5 sq. ft.
Working pressure	6 kilos.	85.3 lb. per sq. in.
Diameter of cylinders	.330 m.	12.99 in.
Length of stroke...	.464 m.	18.27 in.
Diameter of driving wheels ...	1.670 m.	65.75 in.
Tractive power	1,200 kilos.	2645 lb.
Weight in working order ...	15,500 kilos.	15.5 tons

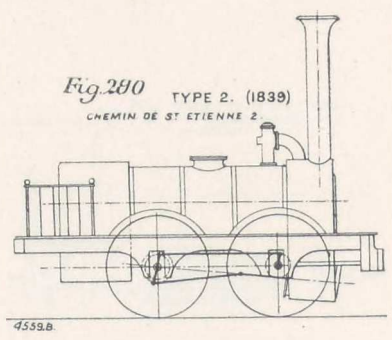


Fig. 290. Type No. 2 (1839).

Four Wheels Coupled.

Diameter of boiler	1.050 m.	41.34 in.
Number of tubes	96	96
Working pressure	6 kilos.	85.3 lb. per sq. in.
Diameter of cylinders	.300 m.	11.81 in.
Length of stroke...	.400 m.	15.75 in.
Diameter of driving wheels ...	1.380 m.	54.33 in.
Tractive power	1,000 kilos.	2,200 lb.
Weight in working order ...	9,500 kilos.	9.5 tons

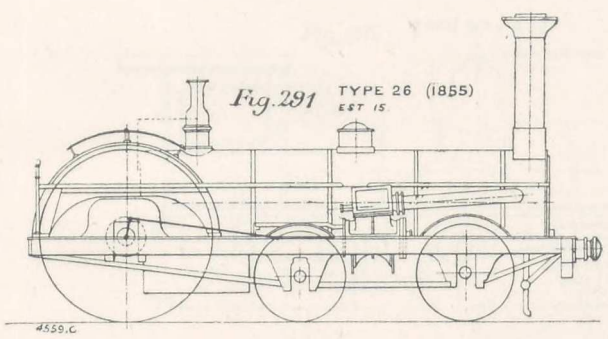


Fig. 291. Type No. 26 (1855).

Express Engine (Crampton System).

Diameter of boiler	1.267 m.	49.88 in.
Number of tubes	180	180
Total heating surface	100.6 sq. m.	1,082.88 sq. ft.
Working pressure	7 kilos.	99.5 lb. per sq. in.
Diameter of cylinders	.400 m.	15.75 in.
Length of stroke	.560 m.	22.05 in.
Diameter of driving wheels ...	2.300 m,	90.55 in.
Tractive power	4,750 kilos.	3,858 lb.
Weight in working order ...	27,800 kilos.	27.8 tons

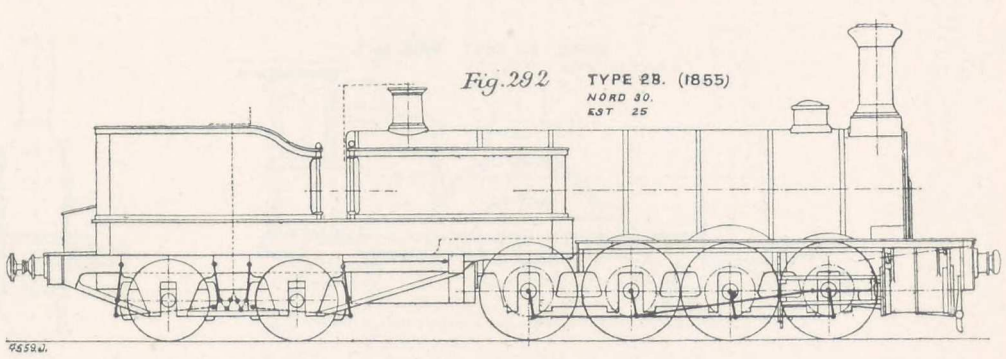


Fig. 292. Type No. 28 (1855).

Goods Engine, Eight Wheels Coupled (Engerth System).

Diameter of boiler	1.50 m.	59.06 in.
Number of tubes	235	235
Total heating surface	196.4 sq. m.	2,109.8 sq. ft.
Working pressure	7 kilos.	99.5 lb. per sq. in.
Diameter of cylinders	.500 m.	19.69 in.
Length of stroke	.660 m.	25 98 in.
Diameter of driving wheels ...	1.260 m.	49.60 in.
Tractive power	5,900 kilos.	13,007 lb.
Weight in working order ...	63,000 kilos.	63 tons

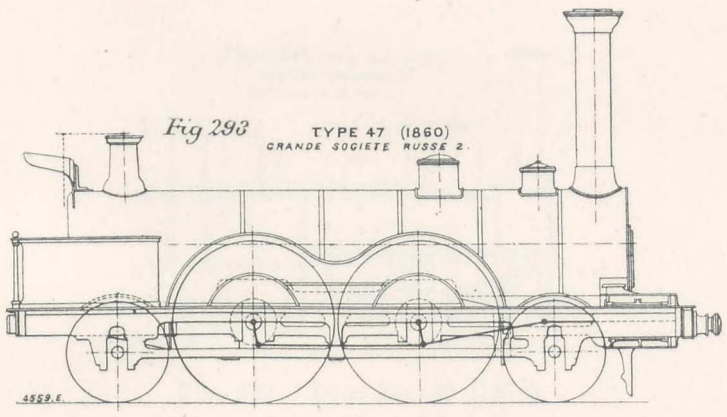


Fig. 293. Type No. 47 (1864).

Express Engine, Four Wheels Coupled.

Diameter of boiler	1.278 m.	50.31 in.
Number of tubes	180	180
Total heating surface	123.3 sq. m.	1,327.22 sq. ft.
Working pressure	7 kilos.	99.5 lb. per sq. in.
Diameter of cylinders	.440 m.	17.33 in.
Length of stroke	.600 m,	23.62 in.
Diameter of driving wheels ...	2.100 m.	82.78 in.
Tractive power	2,500 kilos.	5,511 lb.
Weight in working order ...	39,500 kilos.	39.5 tons

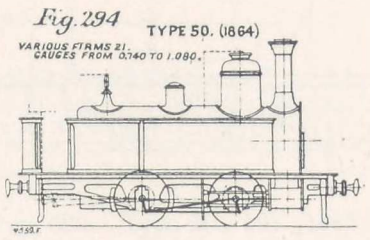


Fig. 294. Type No. 50 (1864).

Tank Engine, Four Wheels Coupled.

Diameter of boiler	.760 m.	29.92 in.
Number of tubes	73	73
Total heating surface	16 5 sq. m.	177.60 sq. ft.
Working pressure	9 kilos.	128 lb. per sq. in.
Diameter of cylinders	.204 m.	8.03 in.
Length of stroke	.360 m.	14.17 in
Diameter of driving wheels ...	.760 m.	29.92 in.
Tractive power	1,200 kilos.	2,645 lb.
Weight in working order ...	7,300 kilos.	7.3 tons

THE CONSTRUCTION DEPARTMENT: LOCOMOTIVES.

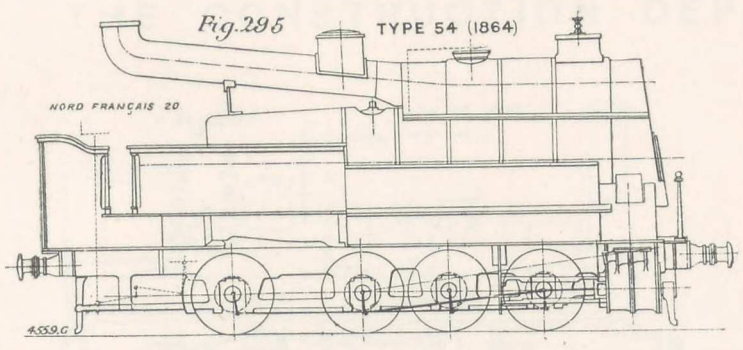


Fig. 295. Type No. 54 (1864).

Goods Engine, Eight Wheels Coupled.

Diameter of boiler	1.278 m.	50.31 in.
Number of tubes	356	356
Total heating surface	167 sq. m.	1,797.64 sq. ft.
Working pressure	8 kilos.	113.78 lb. per sq. in.
Diameter of cylinders	.480 m.	18.90 in.
Length of stroke...	.480 m.	18.90 in.
Diameter of driving wheels ...	1.065 m.	41.93 in.
Tractive power	5,400 kilos.	11,904 lb.
Weight in working order ...	43,500 kilos.	43.5 tons

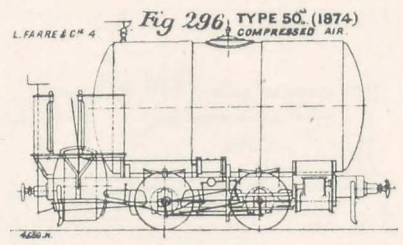


Fig. 296. Type No. 50a (1874).

Compressed Air Engine, Four Wheels.

Diameter of main receiver ...	1.700 m.	66.93 in.
,, small ,, ...	.820 m.	32.29 in.
Pressure in main ,, ...	12 kilos.	170.68 lb. per sq. in.
,, small ,, ...	4 kilos.	56.9 lb. per sq. in.
Diameter of cylinders	.204 m.	8.03 in.
Length of stroke...	.360 m.	14.17 in.
Diameter of wheels	.760 m.	29.92 in.
Weight of engine	6,400 kilos.	6.4 tons

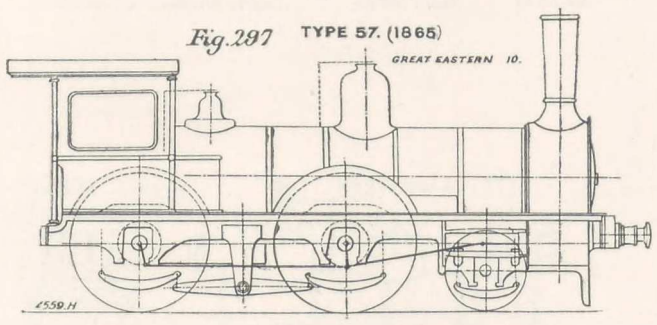


Fig. 297. Type No. 57 (1865).

Mixed Engine, Four Wheels Coupled.

Diameter of boiler	1.220 m.	48.03 in.
Number of tubes...	192	192
Total heating surface	102.43 sq. m.	1,102.46 sq. ft.
Working pressure	10.5 kilos.	149.3 lb. per sq. in.
Diameter of cylinders	.432 m.	17.01 in.
Length of stroke...	.610 m.	24.01 in.
Diameter of driving wheels ...	1.861 m.	73.27 in.
Tractive power	4,200 kilos.	9,259 lb.
Weight in working order ...	32,500 kilos.	32.5 tons

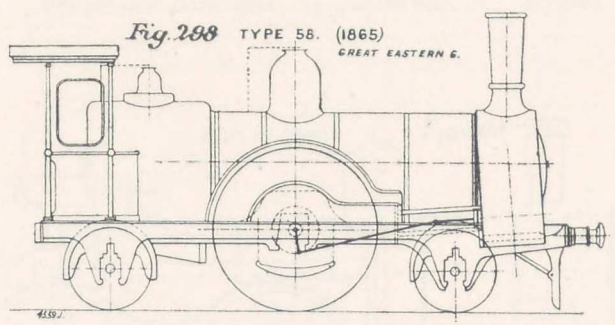


Fig. 298. Type No. 58 (1865).

Express Engine.

Diameter of boiler	1.220 m.	48.03 in.
Number of tubes	190	190
Total heating surface	104.50 sq. m.	1,124.89 sq. ft.
Working pressure	10.5 kilos.	149.36 lb. per sq. in.
Diameter of cylinders	.406 m.	15.99 in.
Length of stroke...	.610 m.	24.01 in.
Diameter of driving wheels ...	2.165 m.	85.23 in.
Tractive power	3,200 kilos.	7,054 lb.
Weight in working order ...	31,000 kilos.	31 tons

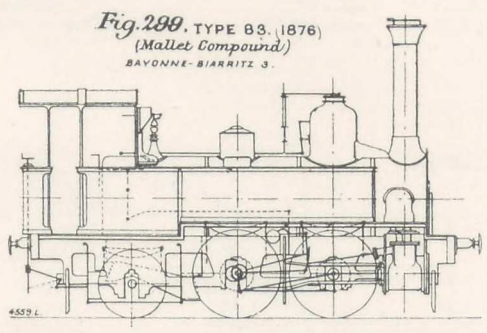


Fig. 299. Type No. 83 (1876).

Compound Engine, Four Wheels Coupled.

Diameter of boiler	1.000 m.	39.37 in.
Number of tubes	125	125
Total heating surface	45.9 sq. m.	494 sq. ft.
Working pressure	10 kilos.	142.2 lb. per sq. in.
Diameter of high-pressure cylinder	.240 kilos.	9.45 lb. per sq. in.
Diameter of low-pressure ,,	.400 m.	15 75 in.
Length of stroke	.450 m.	17.72 in.
Diameter of driving wheels... ...	1.200 m.	47.24 in.
Tractive power, working compound	1,100 kilos.	2,425 lb.
,, working full pressure	2,300 kilos.	5,071 lb.
Weight in working order	21,000 kilos.	21 tons

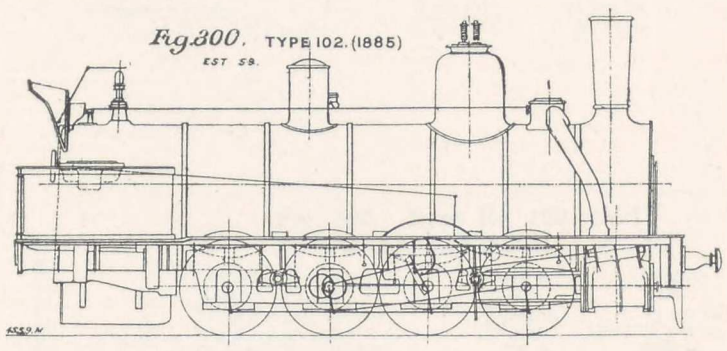


Fig. 300. Type No. 102 (1885).

Goods Engine, Eight Wheels Coupled.

Diameter of boiler	1.500 m.	59.06 in.
Number of tubes...	203	203
Total heating surface	184.4 sq. m.	1,984.8 sq. ft.
Working pressure	9 kilos.	128 lb. per sq. in.
Diameter of cylinders	.500 m.	19.69 in.
Length of stroke	.660 m.	25.98 in.
Diameter of driving wheels ...	1.260 m.	49.59 in.
Tractive power	8.250 kilos.	18,188 lb.
Weight in working order ...	49,800 kilos.	49.8 tons

THE CONSTRUCTION DEPARTMENT: LOCOMOTIVES.

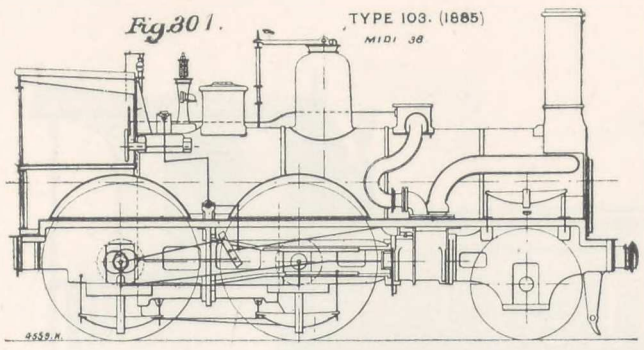


Fig. 301. Type No. 103 (1885).

Express Engine, Four Wheels Coupled.

Diameter of boiler	1.280 m.	50.39 in.
Number of tubes...	194	194
Total heating surface	106.3 sq. m.	1,144.2 sq. ft.
Working pressure	10 kilos.	142 lb. per sq. in.
Diameter of cylinders	.440 m.	17.33 in.
Length of stroke	.600 m.	23.62 in.
Diameter of driving wheels ...	2.000 m.	78.74 in.
Tractive power	4,050 kilos.	8,927 lb.
Weight in working order ...	42,600 kilos.	42.6 tons

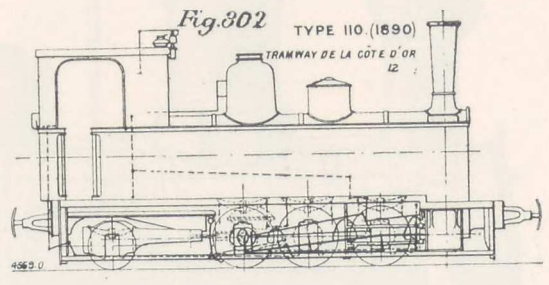
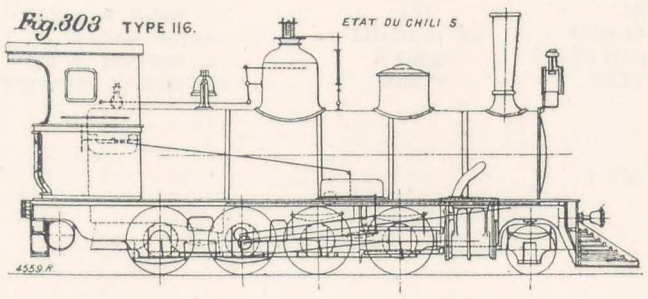


Fig. 302. Type No. 110 (1890).

Tank Engines, Six Wheels Coupled.

Diameter of boiler	1.020 m.	40.16 in.
Number of tubes	134	134
Total heating surface	53.12 sq. m.	571.79 sq, ft.
Working pressure	12 kilos.	170.68 lb. per sq. in.
Diameter of cylinders	.320 m.	12.60 in.
Length of stroke	.380 m.	14.96 in.
Diameter of driving wheels ...	.800 m.	31.50 in.
Tractive power	4,080 kilos.	8,995 lb.
Weight in working order ...	25,100 kilos.	25.1 tons



Fig, 303. Type No. 116.

Goods Engine, Eight Wheels Coupled.

Diameter of boiler	1.140 m.	44.88 in.
Number of tubes	142	142
Total heating surface	73 sq. m.	785.8 sq. ft.
Working pressure	10 kilos.	142 lb. per sq. in.
Diameter of cylinders	.370 m.	14.57 in.
Length of stroke	.450 m.	17.72 in.
Diameter of driving wheels ..	.910 m.	35.82 in.
Tractive power (.55 steam admission)	4,720 kilos.	10.406 lb.
Weight in working order ...	27,500 kilos.	27.5 tons

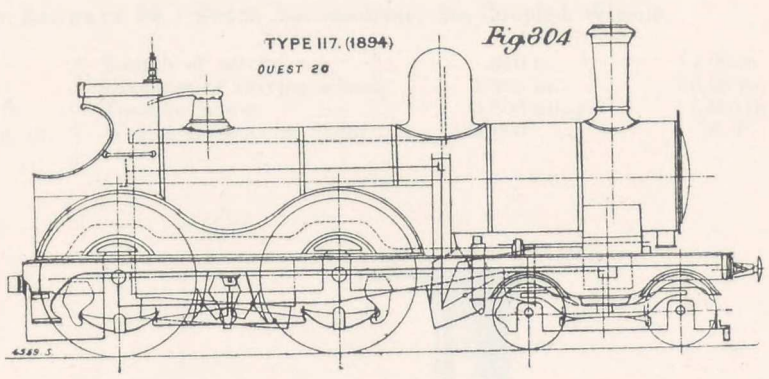


Fig. 304. Type No. 117 (1894).

Express Engine, Four Wheels Coupled.

Diameter of boiler	1.287 m.	50.67 in.
Number of tubes	197	197
Total heating surface	111 m.	1,199.1 sq. ft.
Working pressure	12 kilos.	170.6 lb. per sq, in.
Diameter of cylinders	.460 m.	18.11 in.
Length of stroke	.660 m.	25.98 in,
Diameter of driving wheels ...	2.040 m.	80.32 in.
Tractive power	5,350 kilos.	11,794 lb.
Weight in working order ...	46,400 kilos.	46.4 tons

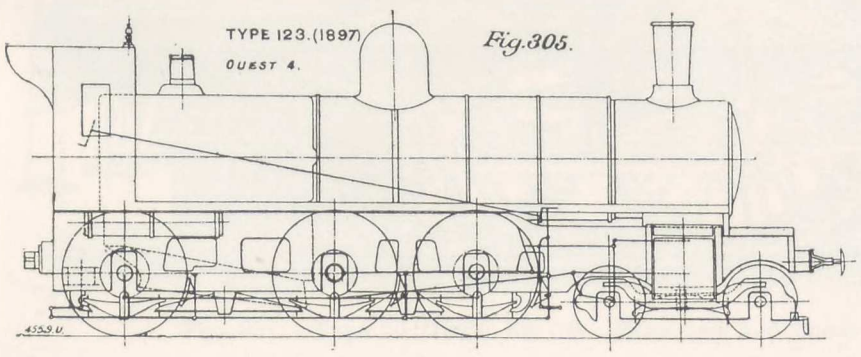


Fig. 305. Type No. 123 (1897).

Six Wheels Coupled and Bogie Truck.

Diameter of boiler	1.504 m.	59.22 in.
Number of tubes	112	112
Total heating surface ..	178.5 sq. m.	1,921 sq, ft.
Working pressure	12 kilos.	170.6 lb. per sq. in.
Diameter of cylinders ...	.510 m.	20.08 in.
Length of stroke	.660 m.	25.98 in.
Diameter of driving wheels	1.650 m.	64.96 in.
Tractive power	8,100 kilos.	17,857 lb.
Weight in working order ...	59,800 kilos.	59.8 tons



THE CONSTRUCTION DEPARTMENT: LOCOMOTIVES.

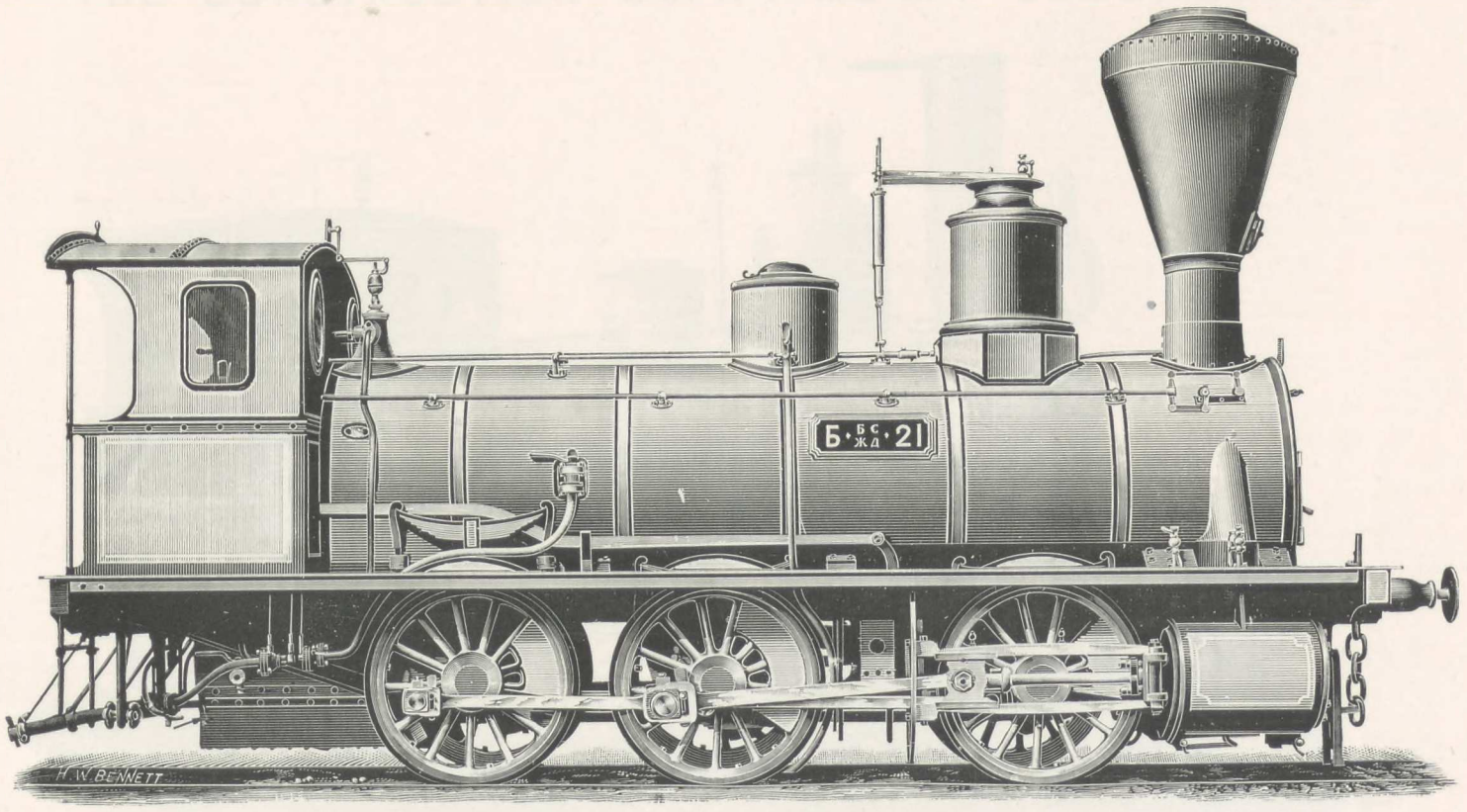


Fig. 306. Type 67 (1867). Various Russian Railways 98. Goods Locomotives, Six-Coupled Wheels.

Diameter of boiler ...	...	1.254 m.	49.37 in.	Length of stroke		.610 m.	24.00 in.
Number of tubes ...	...	151	151	Diameter of driving wheels		1.295 m.	50.98 in.
Total heating surface	...	115.95 sq. m.	1248.43 sq. ft.	Tractive power		5.200 kilogs.	11,466 lb.
Working pressure ...	...	8 kilogs.	113.78 lb. per sq. in.	Weight in working order ...		35.000 ,,	35 T
Diameter of cylinders	...	.460 m.	18.11 in.				

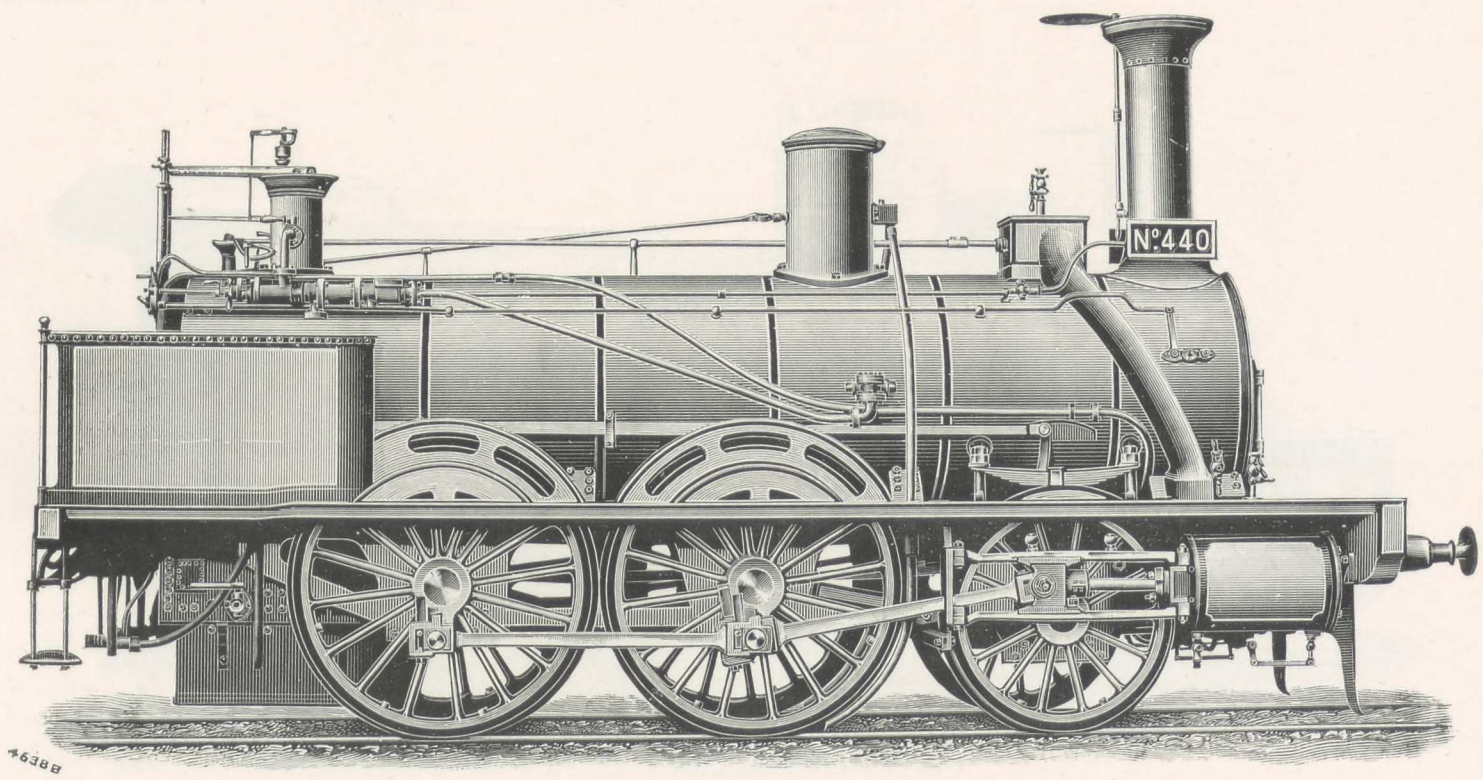


Fig. 307. Type 70 (1869) Est 10. Passenger and Goods Locomotives; Four-Coupled Wheels.

Diameter of boiler ...	...	1.256 m.	49.44 in.	Length of stroke		.560 m.	22.05 in.
Number of tubes ...	...	157	157	Diameter of driving wheels		1.690 m.	66.53 in.
Total heating surface	...	106.28 sq. m.	1144.30 sq. ft.	Tractive power		3.000 kilogs.	6615 lb.
Working pressure ...	...	8.5 kilogs.	120.896 lb. per sq. in.	Weight in working order ...		31.000 kilogs.	31 T
Diameter of cylinders	...	.400 m.	15.74 in.				





THE CONSTRUCTION DEPARTMENT: LOCOMOTIVES.

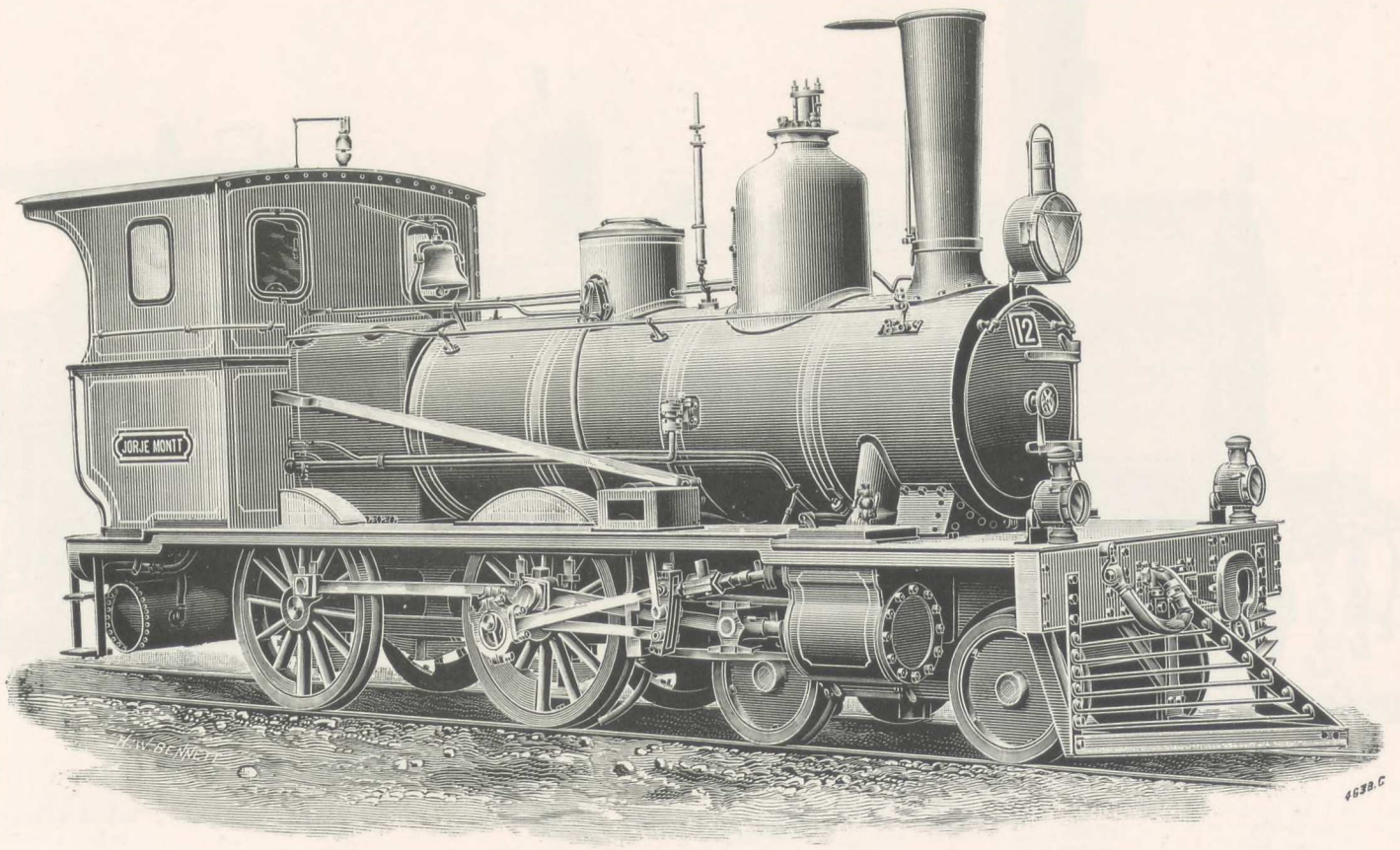


Fig. 308. Type 112. Chilian State Railways 5. Passenger Locomotive, Four-Coupled Wheels and Bogie Truck.

Diameter of boiler...	...	.960 m.	37.80 in.	Length of stroke	.406 m.	15.98 in.
Number of tubes ...	...	113	113	Diameter of driving wheels	1.140 m.	44.88 in.
Total heating surface	...	51.30 sq. m.	552.20 sq. ft.	Tractive power	2.700 kilogs.	5.950 lb.
Working pressure ...	...	10 kilogs.	142 lb. per sq. in.	Weight in working order ...	19.500 kilogs.	19.5 T.
Diameter of cylinders	...	.330 m.	13 in.			

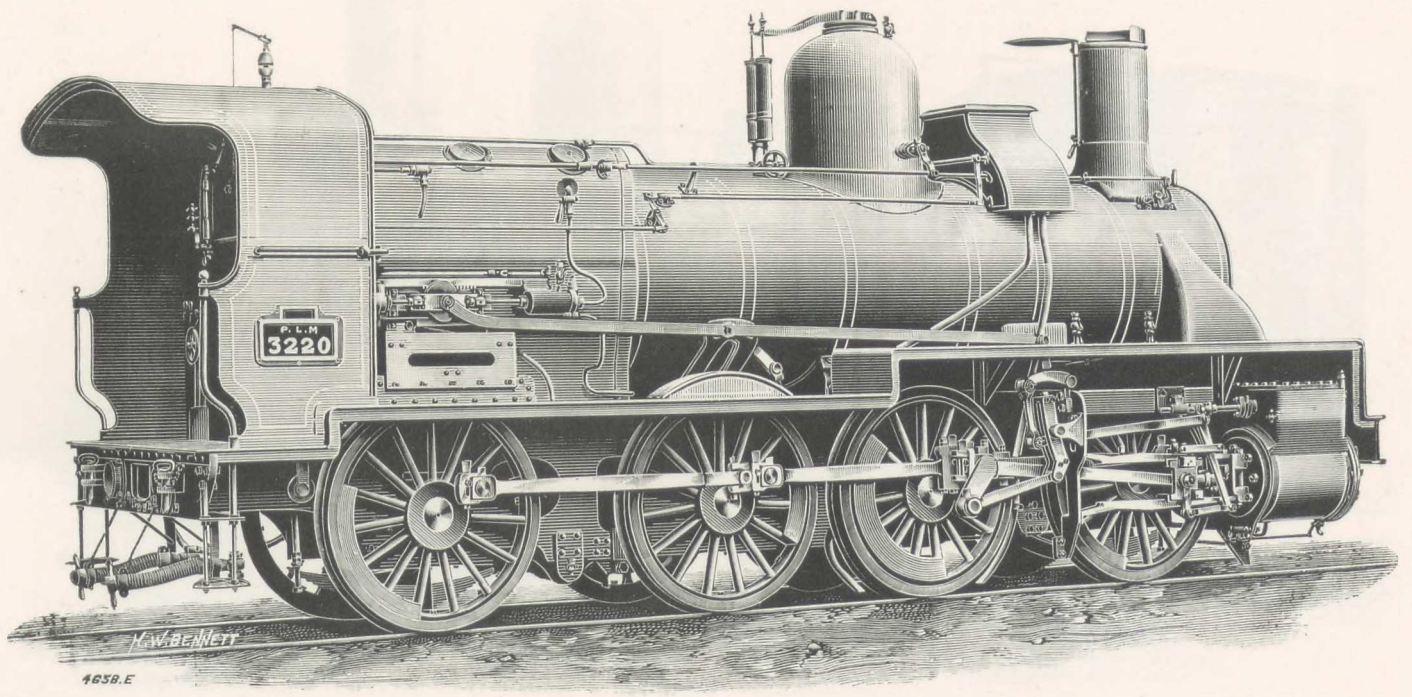
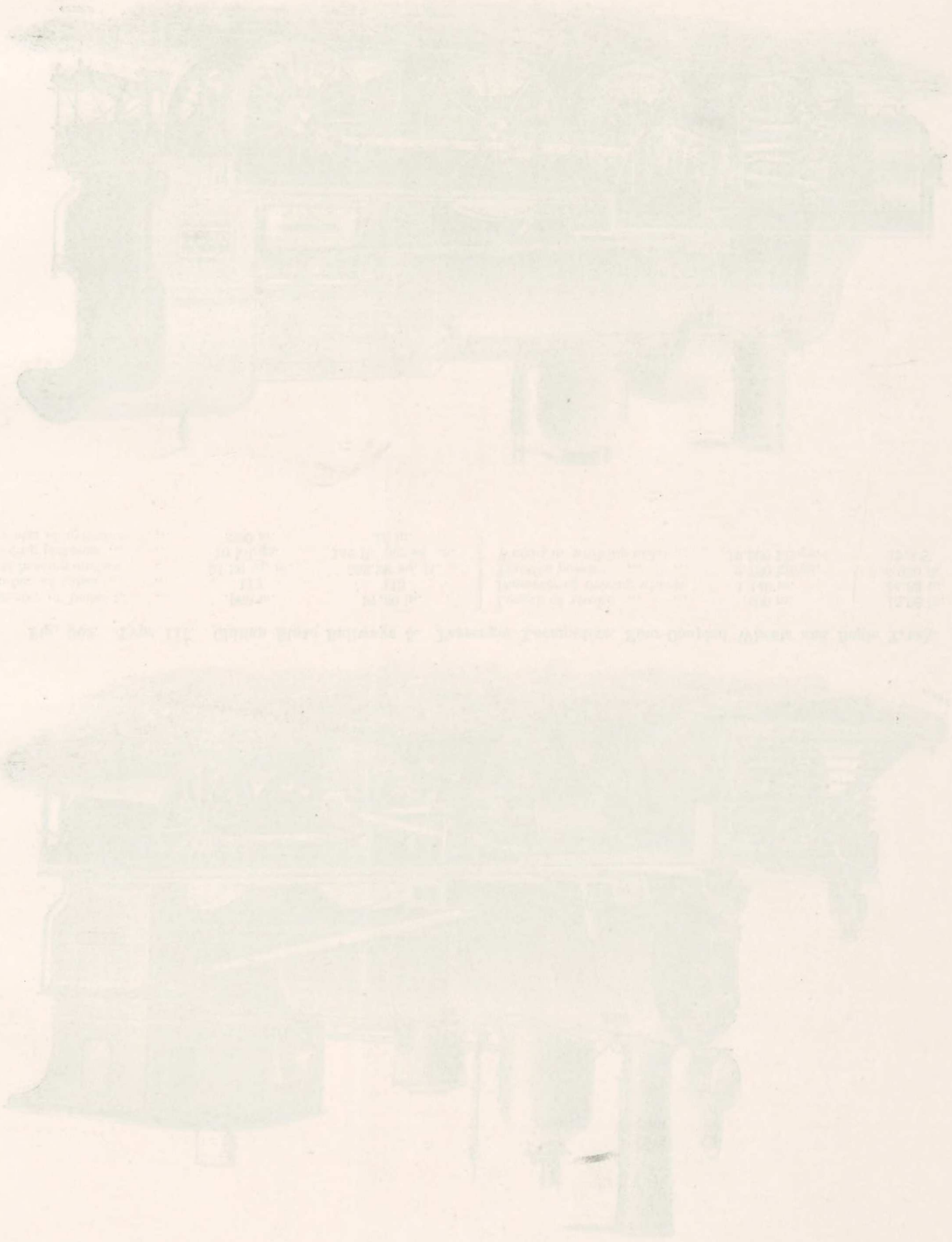


Fig. 309. Type 114 (1893). Paris-Lyons Mediterranean Railway 25. Compound Locomotive, Eight-Coupled Wheels,

Diameter of boiler...	...	1.385 m.	54.53 in.	Diameter of cylinders, low-pressure	.590 m.	23.23 in.
Number of tubes ...	...	139	139	Length of stroke	.650 m.	25.59 in.
Total heating surface	...	88.15 sq. m.	949 sq. ft.	Diameter of driving wheels	1.510 m.	59.44 in.
Diameter of cylinders, high-pressure	.360 m.	14.17 in.	Tractive power	8.470 kilogs.	18,668 lb.
				Weight in working order ...	53.900 kilogs.	53.9 T.



THE CONSTRUCTION DEPARTMENT: LOCOMOTIVES.

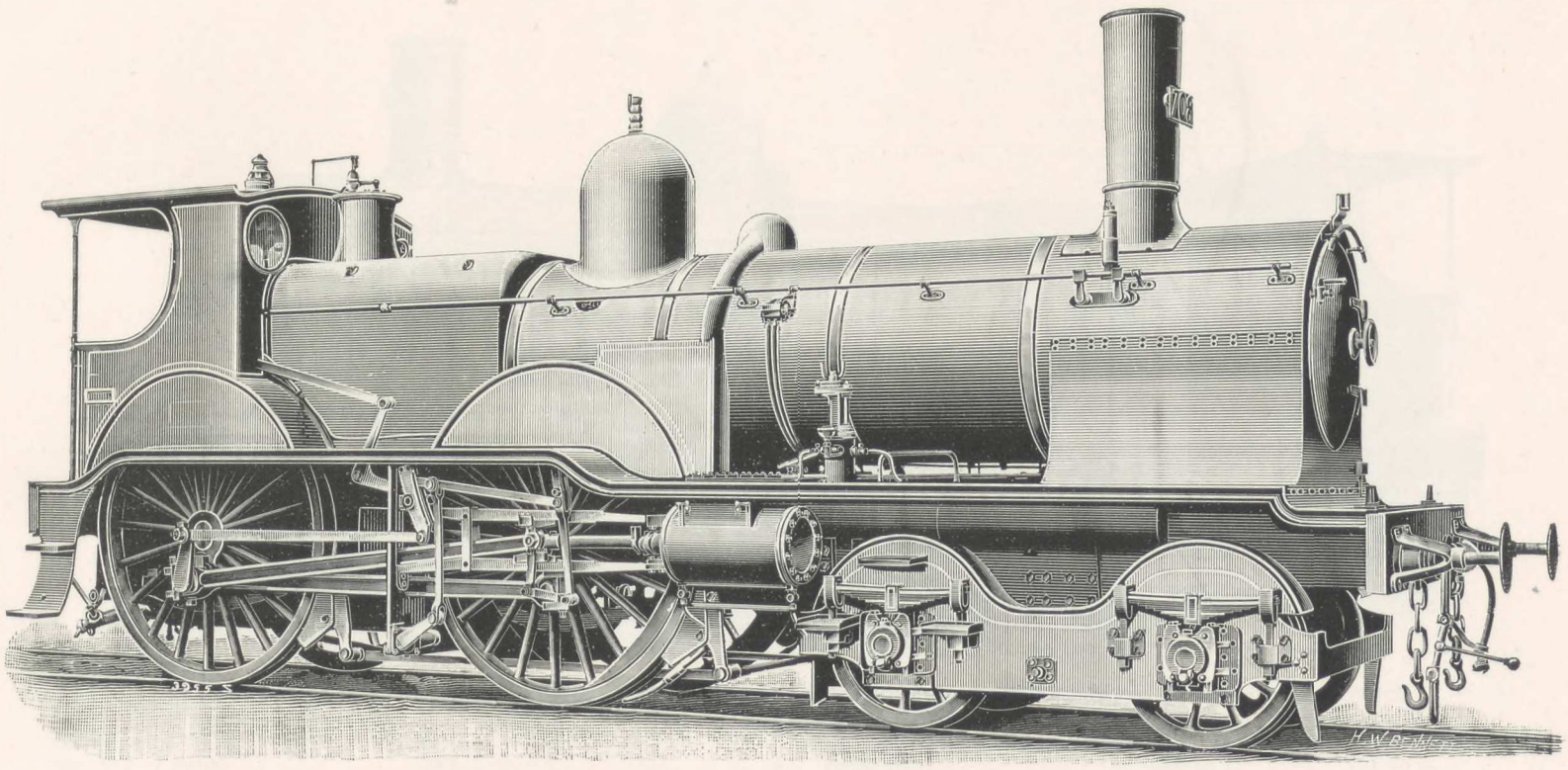


Fig. 310. Type 118 (1894), Midi 12. Compound Four-Coupled Wheels, and Bogie Truck.

Diameter of boiler	1.260 m.	49.60 in.	Diameter of cylinders, low-pressure	.530 m.	20.86 in.
Number of tubes	94	94	Length of stroke	.640 m.	25.19 in.
Total heating surface ...	145.16 sq. m.	1561.93 sq. ft.	Diameter of driving wheels	2.130 m.	83.85 in.
Working pressure	14 kilogs.	199.12 lb. per sq. in.	Tractive power	4.760 kilogs.	10,376 lb.
Diameter of cylinders, high-pressure	.340 m.	13.38 in.	Weight in working order	50.300 kilogs.	50.3 T

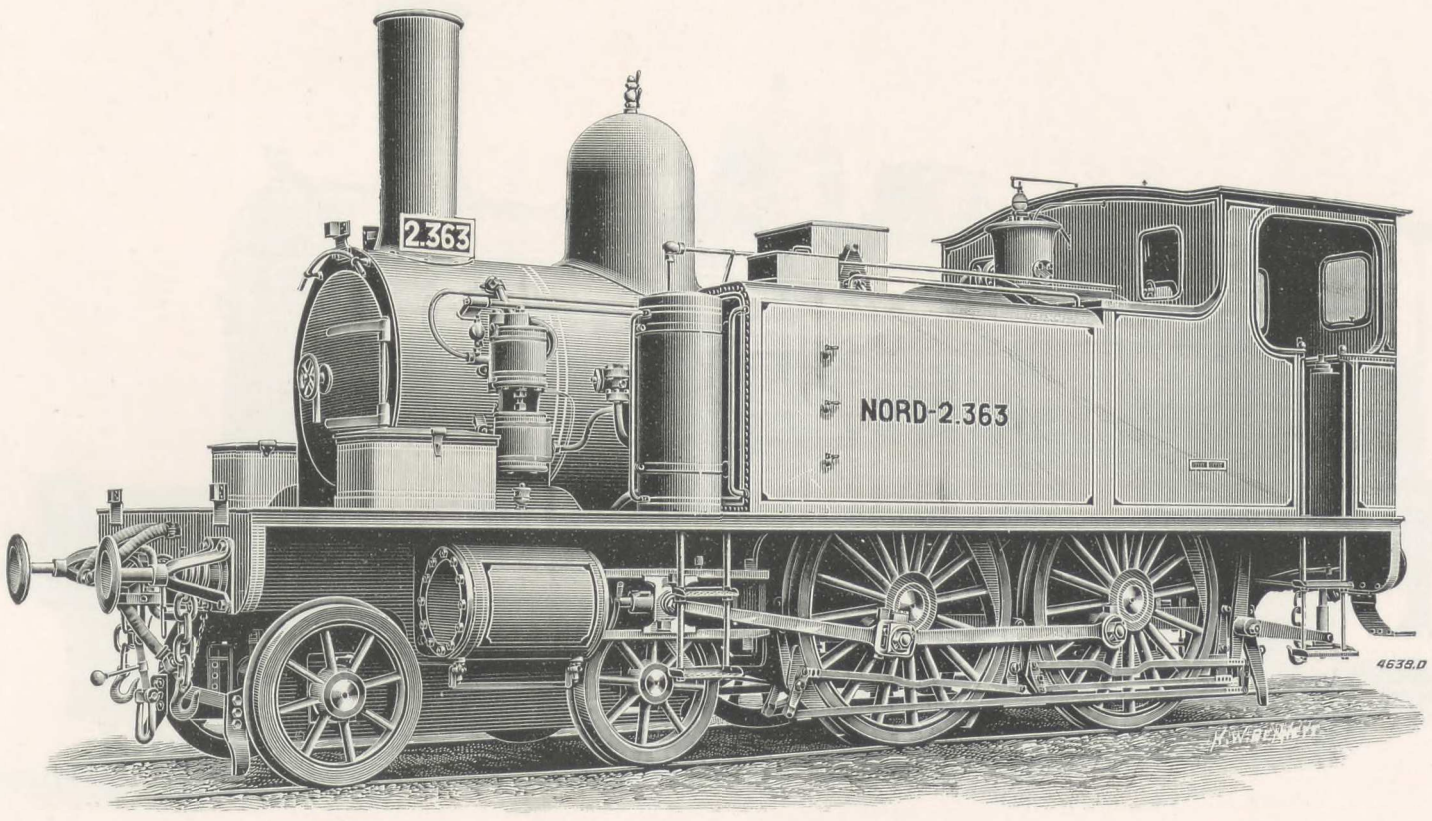


Fig. 311. Type 120 (1895), Nord 20. Tank Locomotives, Four-Coupled Wheels and Bogie Truck.

Diameter of boiler... ...	1.300 m.	51.18 in.	Length of stroke	.600 m.	23.62 in.
Number of tubes	198	198	Diameter of driving wheels	1.664 m.	65.51 in.
Total heating surface ...	85.000 sq. m.	914.96 sq. ft.	Tractive power	4.150 kilogs.	9150 lb.
Working pressure	10 kilogs.	142 lb. per sq. in.	Weight in working order...	42.500 kilogs.	42.5 T
Diameter of cylinders ...	.420 m.	16.53 in.			



THE CONSTRUCTION DEPARTMENT: LOCOMOTIVES.

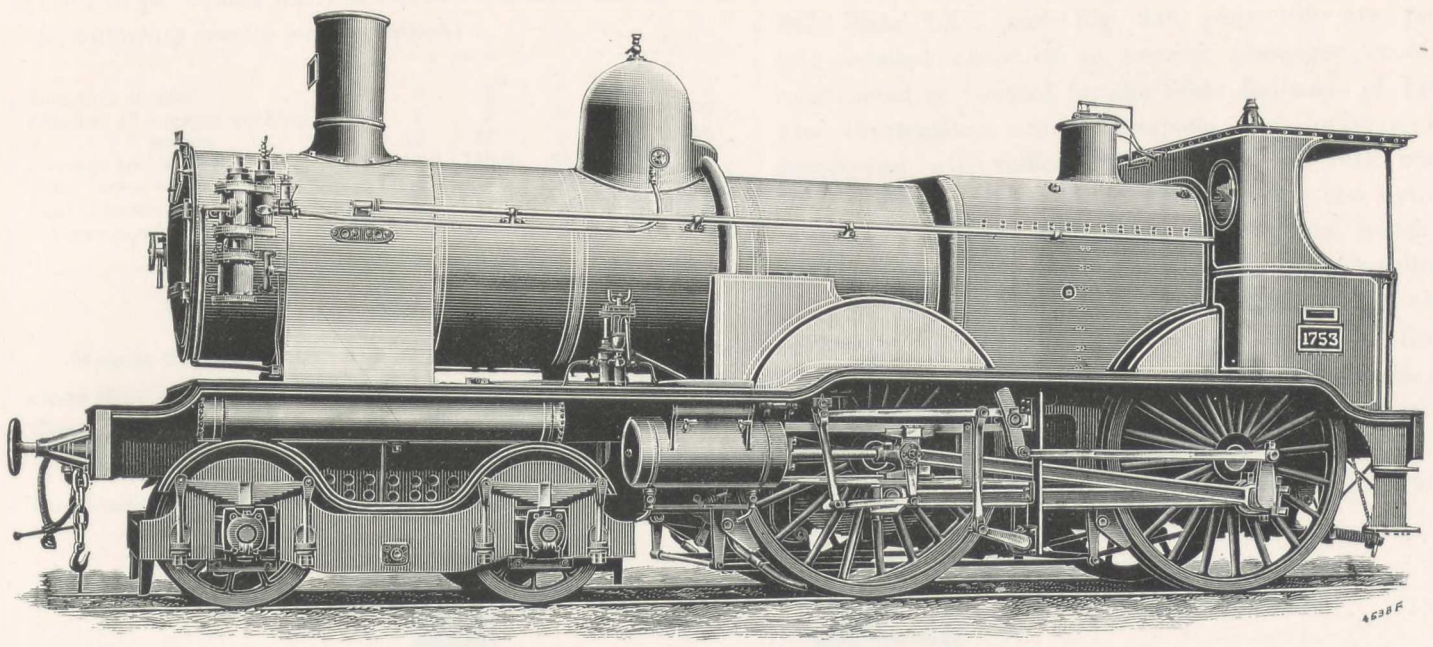


Fig. 312. Type 121 (1895), Midi 12. Compound Locomotives, Four-Coupled Wheels and Bogie Truck.

Diameter of boiler	1.380 m.	54.33 in.	Diameter of cylinders, low-pressure	.550 m.	21.65 in.
Number of tubes	111	111	Length of stroke	.640 m.	25.19 in.
Total heating surface ...	157.40 sq. m.	1694.30 sq. ft.	Diameter of driving wheels	2.130 m.	83.86 in.
Working pressure	14 kilogs.	199.12 lb. per sq. in.	Tractive power	5.100 kilogs.	11,240 lb.
Diameter of cylinders, high-pressure	.350 m.	13.78 in.	Weight in working order...	53.900 kilogs.	53.9 T.

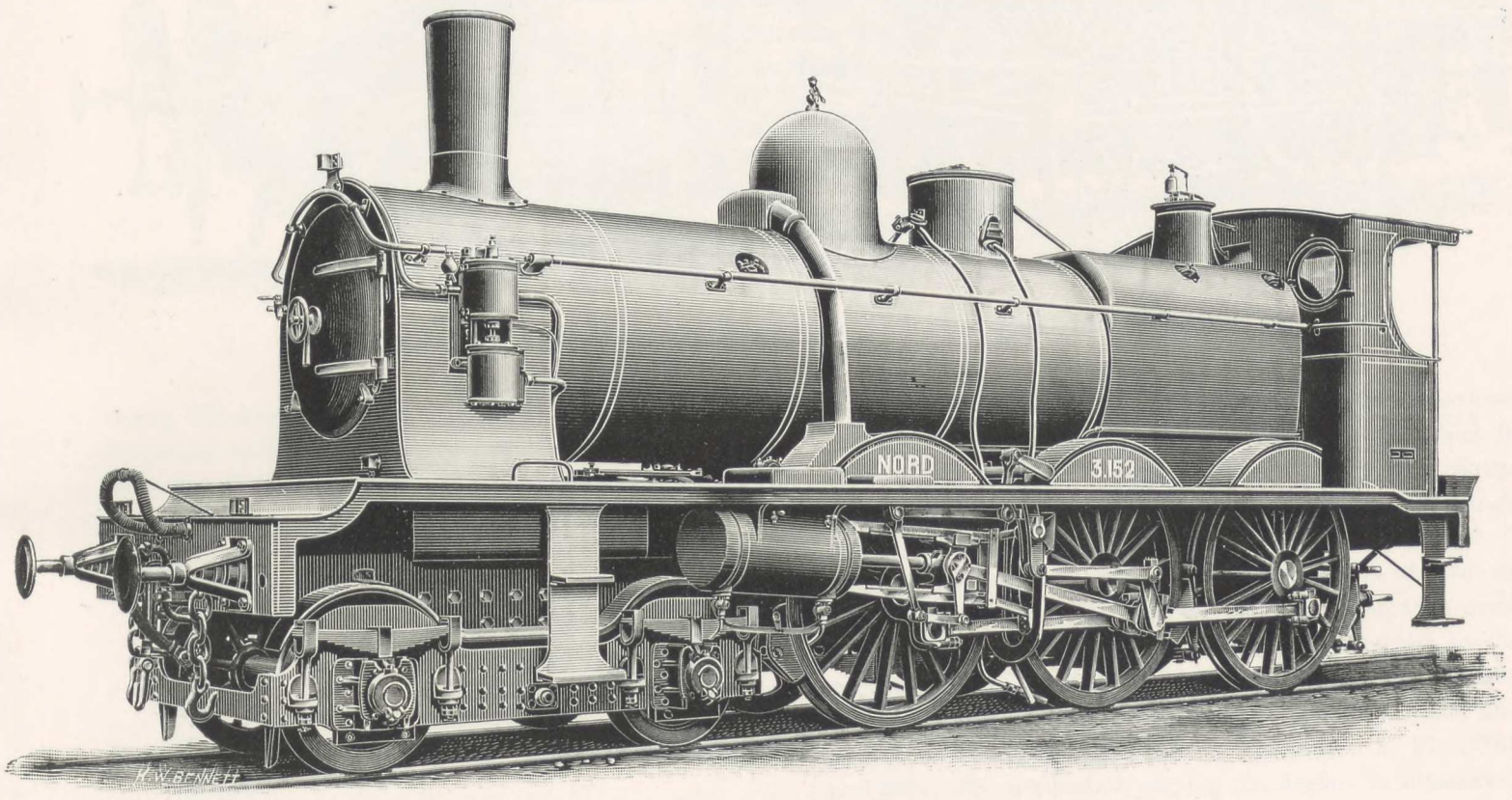


Fig. 313. Type 126 (1898), Nord. Compound Six-Coupled Wheels and Bogie Truck.

Diameter of boiler	1.380 m.	54.33 in.	Diameter of cylinders, low-pressure	.550 m.	21.65 in.
Number of tubes	107	107	Length of stroke	.640 m.	25.19 in.
Total heating surface ...	187.97 sq. m.	2023. sq. ft.	Diameter of driving wheels	1.750 m.	68.89 in.
Working pressure	15 kilogs.	213.34 lb. per sq. in.	Tractive power	6.450 kilogs.	14,222 lb.
Diameter of cylinders, high-pressure	.550 m.	13.78 in.	Weight in working order...	58.400 kilogs.	58 T 4



(170.7 lb. per square inch) at the valve chests. At the trials the following results were obtained:

Duration of trial ... ... hours	3	2	6	24	8
Number of engines working ...	2	2	2	2	2
,, boilers ,, ...	12	16	8	16	16
Average revolutions	112.4	118.6	80.5	104.2	115
Total power realised, horse-power	7,385	8,765	2,386	5,404	7,482
Coal consumption per { kilogs.	0 965	0.936	0.644	0.809	0.791
horse-power per hour { lb.	2.18	2.06	1.42	1.78	1.75

II.—LOCOMOTIVES.

Messrs. Schneider and Co. have built 2,684 locomotives since they commenced this branch of engineering in 1838. Figs. 289 to 313, Plates LXI. to LXVII., are diagrams of some of the principal types, and to each figure the leading dimensions are appended; they form interesting illustrations of the progress effected by Messrs. Schneider and Co. in this branch of their Construction Department. The following list indicates the manner in which these locomotives have been distributed:

	Locomotives.	Tenders.
France	1,863	1,443
French colonies	9	—
Russia	367	361
Spain	253	238
Italy...	82	78
Egypt	22	20
Switzerland	14	3
England	16	16
Belgium	18	—
Austria	2	—
Turkey	3	—
Portugal	8	8
Argentine Republic	17	15
Chili...	10	10
	2,684	2,192

In Fig. 283, and Figs. 284, 285, Plate LIX.; Figs. 286, 287, Plate LX.; and Fig. 288, page 109, are general and detailed views of an express passenger locomotive constructed at Creusot for the State Railways of France. The illustrations are so complete that only a short description will suffice. The engine has four coupled wheels and a four-wheeled front truck; the cylinders are placed outside the deep plate frames which are extended well forward of the truck, and bevelled at the end to receive the sharp bow-plate covering of the smokebox door, a device introduced to reduce the air resistance when running at high speeds. With the same object, the front of the driver's cab is finished with a pointed curve, as will be seen by reference to the general elevation, Fig. 283. The construction of the truck is

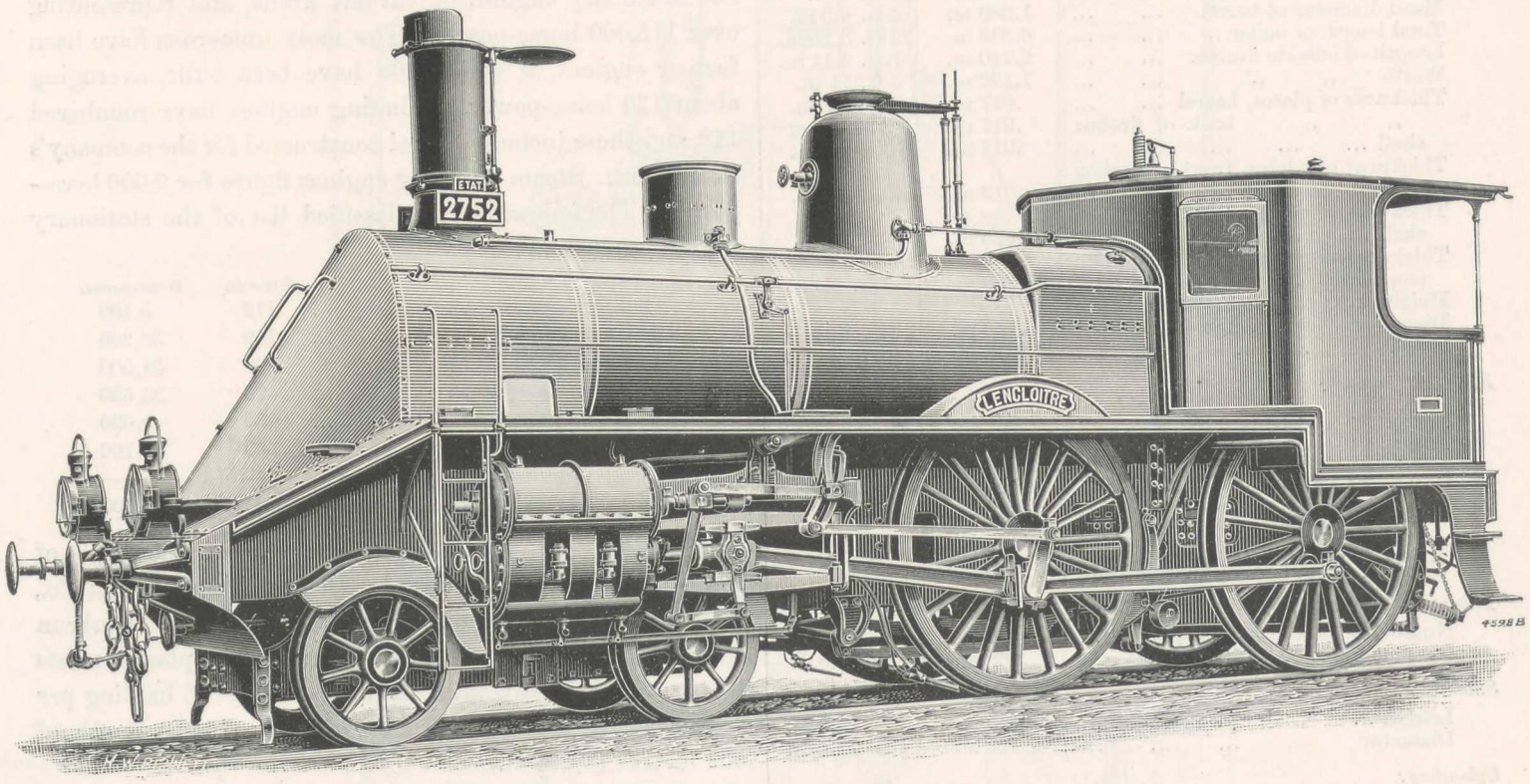


Fig. 283. Express Passenger Locomotive for State Railways of France.

clearly shown in the plan, and longitudinal and transverse sections; it is so arranged that the centre pin on which it turns allows a lateral movement on each side of the centre line of 1 in., the motion being controlled by plate springs (see Figs. 285 and 288). The boiler and outside firebox shell are of extra mild steel plates, and the tubes are of steel on the Serve system. The firebox and the front tube-plate are of copper. The firebox is of the Belpaire type, and is placed between the driving wheels, so that a considerable depth is available; it is fitted with a brick arch, and the details of the drop-bars in front are shown in Figs. 284 and 287. The method of staying the firebox is illustrated by Figs. 284 and 287; the firebox stays are of copper. The boiler is fitted with three safety valves, two of which are on the dome, and the third over the firebox. The boiler is fed by two 9.5 millimetres Friedmann injectors placed at the back of the firebox, as will be seen from Fig. 286. The

exhaust is of the variable type, and can be controlled from the driver's footplate. Steam admission to the cylinders is regulated by Walschaert's gear, and, as shown in Fig. 288, the valves are cylindrical; an air valve is placed on each steam admission pipe to allow the entrance of air during admission, when the engine works with a closed regulator. The reversing gear is operated by a quick-motion screw. This engine and the others built on the same patterns are provided with a Wenger compressed-air brake, of the model prescribed by the French State railways. A continuous acting Bourdon lubricator is adapted to the slide valves, and is operated off the link motion.

The following are some of the leading particulars of this locomotive:

Boiler:		
Length between tube plates	3.582 m.	11 ft. 9 in.
Mean diameter of barrel	1.380 m.	4 ft. 6.3 in.
Total length of boiler	6.865 m.	22 ft. 6.25 in.
Length of outside firebox	2.240 m.	7 ft. 4.11 in.
Width ,, ,,	1.192 m.	3 ft. 11 in.
Thickness of plates, barrel	.017 m.	.67 in.
,, ,, back of firebox shell	.017 m.	.67 in.
Thickness of plates, front of firebox shell	.019 m.	.75 in.
Thickness of plates, sides of firebox shell	.025 m.	.98 in.
Thickness of plates, front tube-plate (copper)	2.300 m.	7 ft. 6½ in.
Height from rails to centre of boiler		
Diameter of steam dome	.700 m.	27.56 in.
Height ,, ,,	.940 m.	37.0 in.
Firebox (Copper):		
Length	1.995 m.	6 ft. 6.54 in.
Width	.990 m.	38.97 in.
Weight at back	1.878 m.	6 ft. 2 in.
Grate area	2.05 sq. m.	22.066 sq. ft.
Thickness of tube-plate	.030 m.	1.18 in.
,, back ,,	.016 m.	.63 in.
,, side ,,	.018 m.	.71 in.
Width of water space front and back	.080 m.	3.15 in.
Tubes:		
Number of tubes (Serve type)	111	111
Outside diameter of tubes	.065 m.	2.56 in.
Smokebox:		
Length	1.125 m.	3 ft. 8.28 in.
Diameter	1.414 m.	4 ft. 7.64 in.
Cylinders:		
Diameter	.440 m.	17.32 in.
Length of stroke	.650 m.	25.59 in.
Distance from centre to centre of cylinders	1.900 m.	74.80 in.
Distance from centre to centre of valve spindles	2.300 m.	90.55 in.
Frames:		
Total length of frame	9.680 m.	31 ft. 9.11 in.
Clear distance between frames	1.230 m.	4 ft. 0.42 in.
Thickness of frames	.030 m.	1.18 in.
Height of buffers above rail	1.040 m.	3 ft. 5 in.
Distance between buffers	1.730 m.	5 ft. 8 in.
Width of floor plate	2.730 m.	8 ft. 11.5 in.
Thickness of truck frame	.025 m.	.98 in.
Width of truck frame	0.86 m.	33.86 in.
Height from rails to footplate	1.835 m.	72.28 in.
Wheels:		
Number of coupled wheels	4	4
,, truck ,,	4	4
Diameter of coupled wheels	2.030 m.	79.92 in.
,, truck wheels	.960 m.	37.79 in.
Distance between coupled wheels	2.700 m.	8 ft. 10.30 in.
,, ,, truck ,,	2.000 m.	6 ft. 6.74 in.
Distance between front driving and gear truck wheel	2.550 m.	8 ft. 4.40 in.
Total wheel base	7.25 m.	23 ft. 9.44 in.
Diameter of driving axles	.180 m.	7.08 in.
,, truck ,,	.140 m.	5.51 in.
Heating Surface:		
Firebox	11.10 sq. m.	119.47 sq. ft.
Tube (including ribs)	147 sq. m.	1582.3 sq. ft.
Total heating surface	158.10 sq.m.	1701.77 sq. ft.
Volume of Boiler:		
Water	4.040 c.m.	142.67 c. ft.
Steam	2.140 c.m.	75.57 c. ft.
Total	6.180 c.m.	218.24 c. ft.
Effective steam pressure	14 kilos per sq. cent.	199.122 lb. per sq. in.
Tractive effort with 55 per cent. admission	6,050 kilos.	5 tons 19 cwt
Weight of engine, empty	45,600 kilos.	44 tons 17 cwt
,, ,, in working order	50,200 kilos.	49 tons 8 cwt
Gauge	1.450 m.	4 ft. 9 in.
Length over buffers	10.295 m.	33 ft. 9.25 in.
Height from rail to top of chimney	4.400 m.	14 ft. 5.18 in.

III.—STATIONARY ENGINES.

Messrs. Schneider and Co. have constructed nearly 900 stationary engines of various kinds, and representing over 115,000 horse-power. The most numerous have been factory engines, of which 268 have been built, averaging about 130 horse-power. Winding engines have numbered 112, and these include several constructed for the company's own mines. Steam pumping engines figure for 9,000 horse-power. The following is a classified list of the stationary engine production:

	Number.	Horse-power.
Winding engines	112	5,100
Blowing engines	109	38,200
Factory engines	268	34,500
Rolling mill engines	93	25,650
Steam pumping engines	139	9,050
Miscellaneous	169	3,100
Total	890	115,600

Winding Engines.—As an example of the type of winding engine constructed by Messrs. Schneider and Co., may be described one built a few years ago for the Beaubrun coal mines, in the district of St. Etienne. The plant consists of two-coupled horizontal engines, capable of hauling per day of eight hours, 1,000 tons of coal, from a depth of 500 metres (1,640 ft.).

	m.	in.
Diameter of cylinders	0.800	31½
Stroke	1.600	63

The speed is 65 revolutions per minute when hauling from the depth of 500 metres.

In designing these engines, Messrs. Schneider and Co. had specially in view economical working as regards consumption of steam, combined with a simple type of mechanism, and accuracy in running, the latter being one of the most important conditions required of engines of this kind. They are expansion engines; the steam inlet and outlet ports have a large section and the dead spaces have been reduced to a minimum.

The steam distribution is effected by means of the usual type of slide valves. Complicated mechanisms such as the Corliss and Sulzer types; valve distribution with cams or eccentrics; distribution by means of two slide valves one over the other, &c.—were set aside as costly and requiring too minute attention, and as not being necessary for obtaining the low degrees of expansion at which

hauling engines can run. Such engines should be of sufficiently large dimensions to be capable of hauling, in case of need, a loaded cage with one cable. As they are, moreover, generally built with an ultimate view to haul from increasing depths, the dimensions of their steam cylinders

The reversing and the expansion gear, governed by two eccentrics and a Gooch link, are worked by the same lever, this being an essential condition. The reduction of dead spaces is obtained by the division in two parts of the distribution slide valves, the separate slides being placed

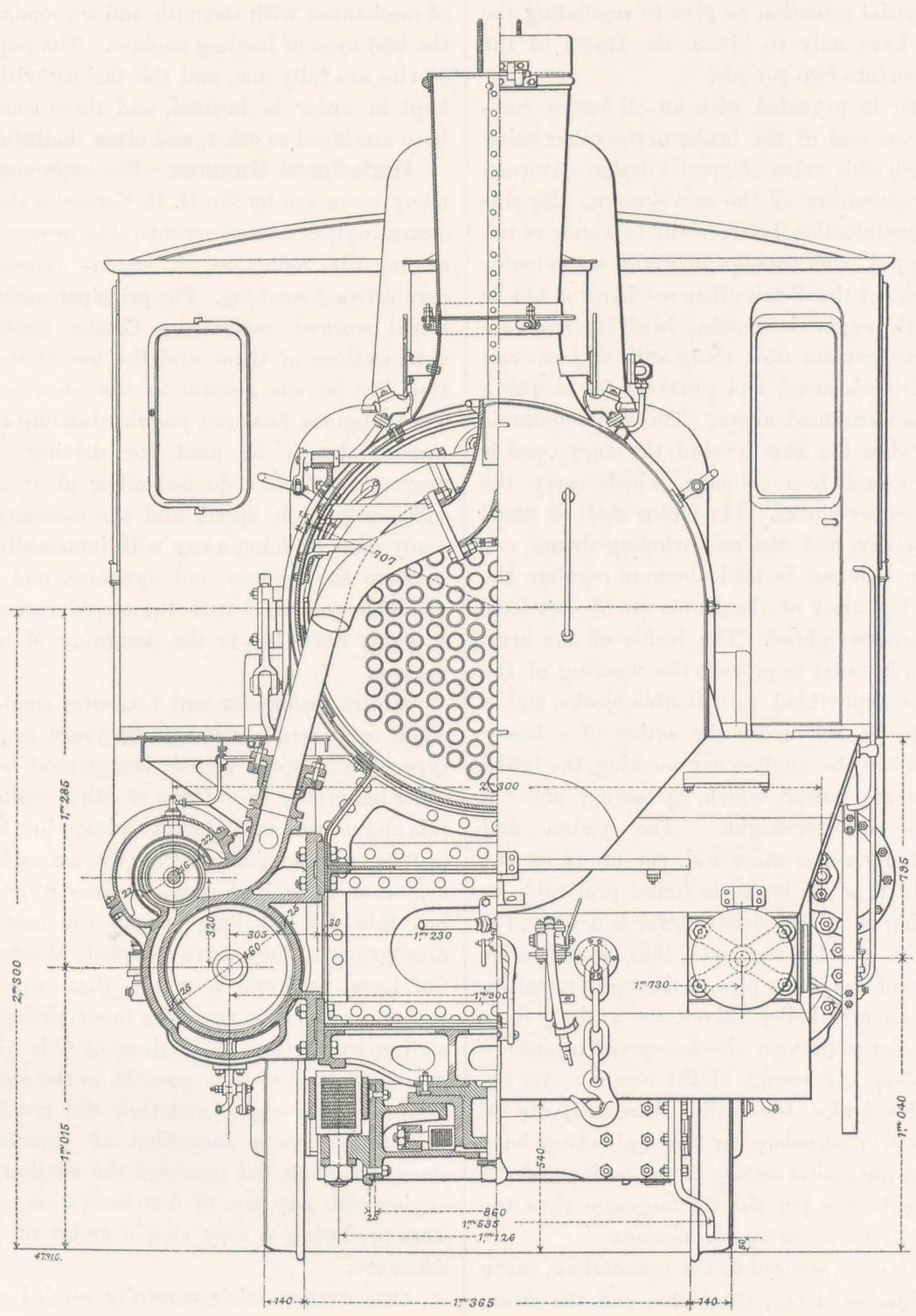


Fig. 288. Express Passenger Locomotive for State Railways of France.

are found excessive for all normal work. This unfavourable state of things renders a low degree of expansion and a low initial steam pressure necessary, especially as the engines are non-condensing, and considering also the loss of effective power that would arise through the pressure at the end of each stroke being below the counter-pressure at the exhaust.

at the ends of the cylinder. The free inlet of steam and a low counter-pressure at the exhaust, are insured by the large sections of the steam ports. The valves are worked through a servo-motor. The maximum admission, corresponding to the dimensions of the link, is .78; this is sufficient for starting with safety, whatever be the various

positions of the cranks, and for executing accurately all the manœuvres. The degree of expansion is increased as soon as the engines are started. In order to secure this, the driver brings the reversing gear lever into an intermediate position, and he completes the travel of the lever when the cable has run out or in. Owing to this arrangement, the drivers have no special attention to give to regulating the expansion; they have only to divide the travel of the reversing gear lever into two periods.

The servo-motor is provided with an oil brake, communication from one end of the brake to the other being regulated by a small slide valve of special design, governed by the checking mechanism of the servo-motor. By this slide valve all communication between the two ends of the brake can be stopped, and consequently the servo-motor piston and the links of the distribution mechanism can be maintained, when the engine is working, in all intermediate positions. The arrangement does away with all jerks and reactions on the driver's arms, and provides for working with expansion, as mentioned above. The servo-motor is placed vertically below the floor level of the engine, and is supported by two cast-iron columns, which carry the reversing shaft plumber-blocks. The motor shaft is fitted with the brake pulley, and the two winding drums, one fixed and the other that can be made loose to regulate the length of cable. The arms of the drums are of cast iron, and they are counterweighted. The inside of the arms is lined with wood, in order to prevent the wearing of the cables. The brake is provided with double blocks, and is arranged so as to be set under the action of a heavy counterweight. When the engines are working, the brake is taken off by steam power, which, by acting under a piston, lifts the counterweight. The piston and counterweight fitted on the same rod, act direct on the brake lever. This type of brake is found preferable to those for the setting of which steam power is used, and is much more reliable, as the accidents that would arise owing to a fracture of the steam pipe, or through premature closing of the automatic boiler valves, are entirely done away with. In order to prevent shocks, special means are provided to regulate the escape of the steam. All the pieces forming the brake, the pulley excepted, are of forged steel, of ample dimensions for the strains they have to withstand. The automatic setting of the brake, and the stoppage of the engines when the hauling-cage rises too high, are obtained by means of special devices.

Strong hollow frames, secured to the foundations, carry the crankshaft plumber-blocks, the slides, and the steam cylinders. This type of frames was deemed by Messrs. Schneider and Co. preferable for these engines to the closed-in types, as the regulating of the slides and pistons after wear is more easily effected; the arrangement also gives facility for levelling of the engines when the foundations get distorted, which is often the case in the close vicinity of mines. Another great advantage is that the connecting-rods are well in sight of the driver; moreover, this type of frames enables the two engines to be firmly secured together by means of strong cross-frames, which maintain the crankshaft plumber-blocks in position, and thus prevent all strains on the crankshafts and the heating of the brasses. In the Beaubrun engines there are three such cross-frames.

It is claimed that these engines, in combining simplicity of mechanism with strength and economical working, form the best type of hauling engines. The requirements of the service are fully met, and the facility with which they are kept in order is insured, and these conditions have not been sacrificed to other, and often doubtful advantages.

High-Speed Engines.—The improvements ntroduced many years ago by Mr. G. H. Corliss in the construction of steam engines, caused considerable progress to be realised as regards reduction in steam expenditure and the regularity of working. The principal engineers all over the world worked under the Corliss patents, or adopted modifications of them, and the use of the Corliss engine type has become general in the most varied industries. These engines, however, notwithstanding their advantages cannot always be used for driving dynamos; their mechanical devices do not allow of their working at a sufficiently high speed, and the necessity that exists in many cases of doing away with intermediate transmissions between the engines and dynamos, and the small space available, combined with the consideration of first cost of a plant, have led to the designing of high-speed steam engines.

Messrs. Schneider and Co., who commenced electrical work on a large scale several years ago, manufacture a type of high-speed engine, the general features of which differ materially from those of other makers. A model of this engine was exhibited at Chicago in 1893 and at Lyons in 1894. Economical working was a consideration generally neglected when high-speed engines were first introduced, but this did not long remain the case. Owing to the arrangements they have adopted, Messrs. Schneider and Co. have produced a motor that works economically, without sacrificing anything to simplicity of construction, an important item in engines of this kind. Their aim was to keep as near as possible to the steam consumption of the Corliss engine, and they did not have recourse, to obtain this, to a succession of expansions in several steam cylinders, but provided the single cylinder of their engine with a system of distribution as perfect as possible, thus producing a very simple motor of high mechanical efficiency.

Comparative trials, carefully carried out, have shown the consumption of steam in these engines to be below that of most of the high-speed compound engines used in electric lighting installations. The steam inlet and outlet valves are worked independently one of the other; the dead spaces are very small, owing to the use of separated slide valves acting on both ends of the cylinder; the cylinder is perfectly drained, as the outlet valves are at the bottom; and the quick opening of all the steam ports is obtained by the arrangements chosen for working the slide valves.

THE CONSTRUCTION DEPARTMENT.

Fig.314

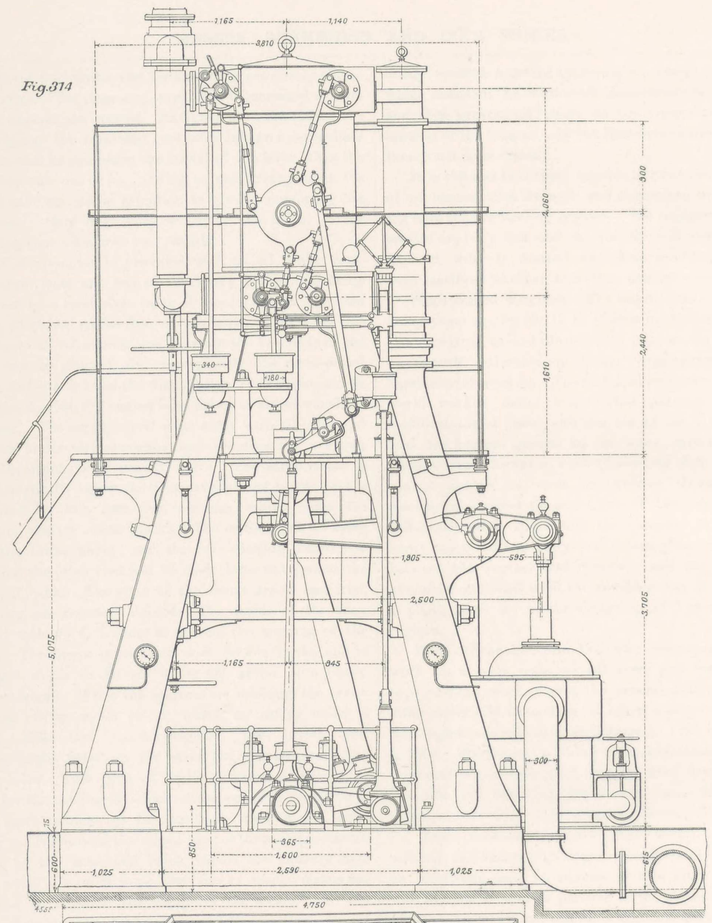


Fig.315

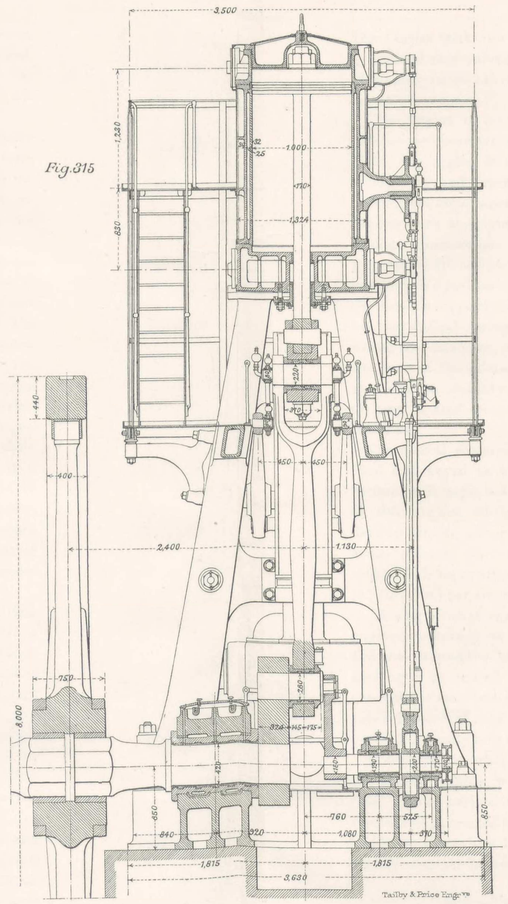


Fig.316

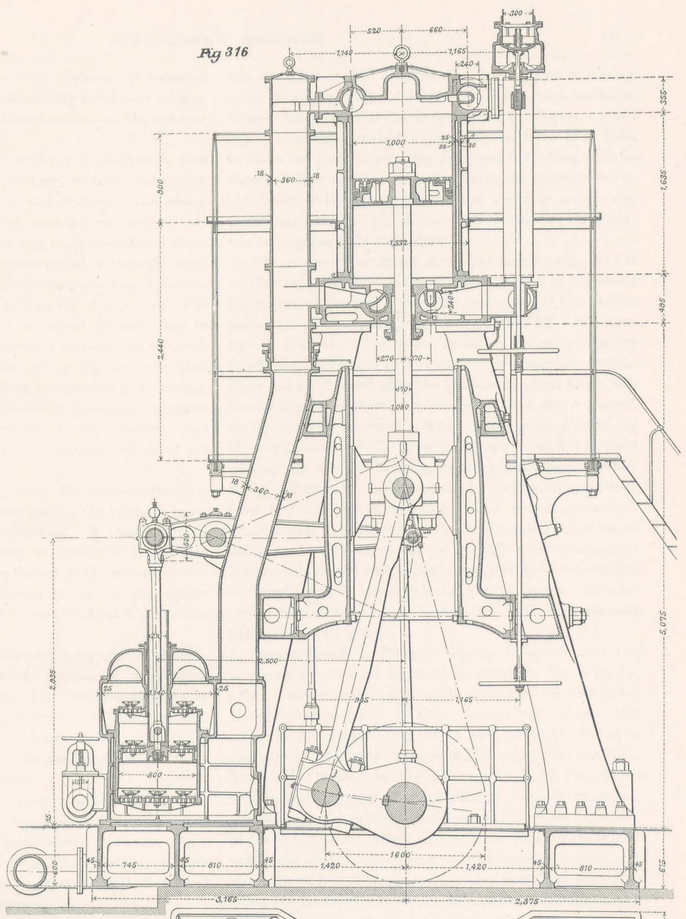


Fig.317

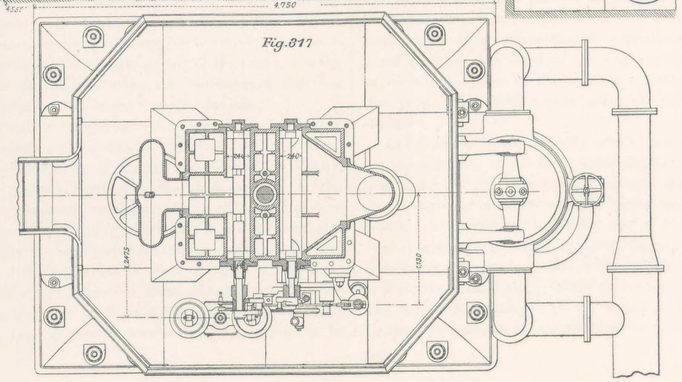
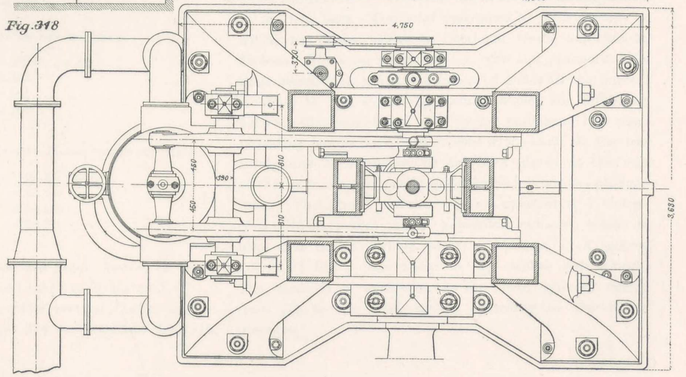


Fig.318



Diameter of cylinder	1.00 m.	39.37 in.	
Length of stroke	1.60 m.	62.99 in.	
Number of revolutions	60	60	
Initial steam pressure	3.5 kilos.	49.78 lb. per sq. in.	
,, ,, ...	,,	.20 admission ;	670 I.H P.
,, ,, ...	,,	.25 ,,	775 ,,
,, ,, ...	,,	.30 ,,	875 ,,
,, ,, ...	4 kilos.	56.9 lb. per sq. in.	
,, ,, ...	,,	.20 admission ;	755 I.H.P.
,, ,, ...	,,	.25 ,,	875 ,,
,, ,, ...	,,	.30 ,,	970 ,,

Vertical Rolling-Mill Engine.

The Corliss inlet valves have been replaced by balanced cylindrical slide valves, with alternating rectilinear motion. These slide valves are double ported, as also are the exhaust valves.

The engine is horizontal, working a crankshaft that rests on two bearings cast in one piece with the foundation plate; the engine is therefore self-contained, and easily transported and erected. The foundations required are not of great importance. According to circumstances, these engines work the dynamos either direct or through intermediate transmissions, and in order to drive two dynamos, the crankshaft carries a flywheel pulley at each end. The governor is fitted inside one of the flywheels, according to the American principle; it consists of two weights balanced by two helical springs, which act on the eccentric that works the admission slide valves by modifying the stroke, the lead at the admission remaining practically constant. In order to simplify lubrication of the governor, and to keep it free from dust, all the mechanical parts are closed in.

The special eccentric that moves the exhaust valves is fixed and keyed on the motor shaft. The cylinder body, bottom, and cover are steam-jacketed. A standard type of this engine, when running at 250 revolutions, can develop on the piston 200 indicated horse-power, with a steam pressure of 7 kilogrammes (99.561 lb. per square inch). This represents a piston speed of about 4.150 metres (13 ft. $7\frac{3}{8}$ in.) per second.

A long series of experiments have been made with these engines, especially as regards the regularity of working and the consumption of steam. The former quality leaves nothing to be desired. The governor is so sensitive that the speed is maintained almost constant, the variations being below 2 per cent., and the greatest variations in the loads producing hardly any oscillations.

Consumption trials have been made with a non-condensing engine, working dynamos under a constant load. These various trials lasted each a minimum of six hours, and gave excellent results as regards efficiency. We need not enter into the details of these trials, and shall simply state the following figures:

Initial Pressures on Steam Piston.

5.300 kg.	= 75.382 lb.	per sq. in.
6.200 ,,	= 88.183	,,
7.000 ,,	= 99.561	,,
8.000 ,,	= 113.784	,,

Steam Consumption per Indicated Horse-Power per Hour.

12.350 kg.	= 27.227 lb.
11.450 ,,	= 25.243 ,,
10.950 ,,	= 24.140 ,,
10.350 ,,	= 22.817 ,,

With condensing engines the above figures of steam consumption would be reduced by 15 to 20 per cent.

Rolling Mill Engines.—The vertical Corliss engine, which is illustrated by Figs. 314 to 318, Plate LXVIII., was designed in the Construction Department to work a series of rolling mills. Owing to the small space available, Messrs. Schneider and Co. were obliged to adopt a vertical type. A certain number of these engines have been built by them for their own rolling mills and for rolling mills in Russia. They have one steam cylinder, the steam distribution being on the Corliss system, and the four valves and gear being arranged in the same way as with the horizontal Corliss engines built at Creusot.

The condenser air pump is vertical, single-acting, and is worked by a cast-iron beam fitted to the top of the steam piston-rod. Two floor plates give free access to the various parts that require attention and lubricating. The four frames that carry the steam cylinder, and on which are fitted the slides, are hollow and of rectangular section. They are firmly secured to the foundation plate, which also carries the motor shaft plumber-block; they are, moreover, firmly secured together. When running at a speed of 70 revolutions, which Messrs. Schneider and Co. have adopted for various installations, they work very satisfactorily and develop under the most advantageous conditions from 900 to 1,000 horse-power. The steam cylinder is 1 metre ($39\frac{3}{8}$ in.) in diameter, the stroke being 1.600 metre (63 in.). These vertical engines for high powers and speed are much in favour at Creusot; they give great satisfaction as regards wear of steam cylinder, piston, glands, and rods; their first cost, however, is higher than that of horizontal engines of equal power.

Steam Draining Pumps.—Messrs. Schneider and Co. put down in 1869 at their St. Laurent pit (see page 14, *ante*) a steam draining pump to discharge all the water from the lowest depths of their Creusot coal mines. The water is lifted from a depth of 420 metres (1,378 ft.) at the rate of 150 cubic metres (5,298 cubic feet) per hour. The engine placed at the pit's mouth is on the Woolf system, with two single-acting cylinders, variable expansion, and is provided with a condenser. The large cylinder piston is connected direct to the main pump rods, which works the shaft pump placed at the bottom of the pit, and the series of five forcing pumps placed one above the other down the pit shaft. The main rod is of wood strengthened by flat iron bars. The total resistance to be overcome lifting the water, added to frictional losses, amounts to 88 tons. The total weight of the rods and plungers, with their accessories, *plus* the columns of water in the pumps, amounts to 148 tons. To counterbalance the difference between this weight and the forcing resistance, two compensating pumps have been erected in the shaft on the top levels, and a counterweight has been placed at the end of the lever beam, opposite the end which holds the plunger rods. The stroke in the smaller cylinder is 2 metres (6 ft. $6\frac{11}{16}$ in.); that in the expansion cylinder, which is also that of the whole series of pumps, is 4 metres (13 ft. $1\frac{1}{2}$ in.). The speed is $3\frac{1}{2}$ strokes per minute. The duration of admission in the small cylinder varies from $\frac{70}{100}$ to the total stroke, according to the steam pressure.

The following are the diameters of the various cylinders:

	m.	ft.	in.
Diameter of admission steam cylinder ...	1.850	7	$0\frac{7}{8}$
,, expansion ,, ...	2.600	8	$6\frac{3}{8}$
,, shaft pumps	.380	1	3
,, forcing pumps	.500	1	$7\frac{1}{4}$

Steam is supplied by the boilers at a pressure of 4.500 kilogrammes (64 lb. per square inch). The installation is completed by a steam winch, which is used for inspecting the shaft and pumps, and keeping them in perfect working order.

Lifting and Forcing Pumps.—The construction of lifting and forcing pumps for various industrial uses, such as those for graving docks, for town water works, for sewage works, &c., forms one of the specialities in which Messrs. Schneider and Co. have been highly successful. Among other installations they have executed the water works plant for Paris, Lyons, Nimes, Avignon, Cairo, and Assiout (Egypt).

The Lyons installation comprises five lifting and forcing pumps; it was built a few years ago for the Compagnie Générale des Eaux. Each pump is worked direct by a horizontal, single-cylinder, condensing engine, with steam distribution on the Corliss system. The pump consists of a double-acting plunger, which works in two barrels that communicate one with the other through the suction box and the air vessels. The pumps are fitted with brass valve seats; the valves are of metal, of small dimensions, very light, and on the Corliss type. Directly above the forcing valves are placed air vessels of large capacity; the vessels communicate with each other at the top through a pipe, so that for each stroke of the pump the total quantity of air stored in the vessels may be taken advantage of.

Owing to the large sections of the suction and forcing valves, and the convenient position of the air vessels, these pumps work most smoothly at the comparatively high speed of from 40 to 50 revolutions per minute.

Factory Engines.—Messrs. Schneider and Co. have supplied a large number of engines for driving machine tools, to the gun factories of Tulle, St. Etienne, and Châtellerault. (See Fig. 319, Plate LXIX.).

All these engines are of the horizontal condensing type, with one steam cylinder, the distribution being on the Corliss system, and varying from 150 to 600 horse-power. Two 600 horse-power engines at the Châtellerault factory may be mentioned as a type. These are coupled to a single crankshaft, which carries in its centre a flywheel 8 metres (26 ft. 3 in.) in diameter, 2 metres (6 ft. $6\frac{11}{16}$ in.) wide at the rim, and weighing 52 tons. The flywheel carries two independent leather belts, which work various groups of dynamos and transmissions. Each engine is provided with a condenser, placed below the floor level, and the vertical single-acting air pumps are worked by countercranks fitted to the main crankpins. Feed and drain pumps are connected to the air pumps. The steam cylinders are .850 metre ($33\frac{1}{2}$ in.) in diameter, the stroke being 1.600 metre (63 in.). The initial steam pressure on the pistons varies between 5.5 to 6 kilogrammes (78.227 lb. to 85.338 lb. per square inch). The engines run at 60 revolutions per minute, and steam is supplied to those at Châtellerault by a range of eight boilers, each having two internal furnaces and a heating surface of 132 square metres (Fig. 320, Plate LXX.).

Compressed Air Plant.—The history of the transmission of power by compressed air in Paris dates back as far as 1881, and commenced by the completion of a scheme for distributing uniform time by pneumatic impulses throughout the city. A concession was granted to Mr. Victor Popp, and a large degree of success attended the scheme. The subscribers became numerous, and the small works which had been established in the neighbourhood of Belleville had to be enlarged, and the system of mains extended. The delivery of compressed air to motors of small power developed into a large trade, and there were many installations of compressed air engines up to 150 horse-power, used for electric lighting, refrigerating, &c. The system was found especially promising in its application to small motors for driving sewing and other machines, crowded with the operatives, into a small space, as the exhaust air from the motors supplied an efficient means of ventilation. In 1891 the works at Belleville were quite insufficient to supply the demand, and the construction of a large central station on the left bank of the Seine, opposite Vincennes, and near the terminal station of the Orleans Railway, was decided on. The works were laid out to have a capacity of 24,000 horse-power, and of these 8,000 horse-power, divided into four units of 2,000 horse-power each, were erected. This, with four batteries of boilers, constituted the installation, which was placed in the hands of Messrs. Schneider and Co. by the Compagnie Parisienne de l'Air Comprimé.

We shall limit our description to the engines, which constitute the most interesting feature of the installation, and which are illustrated by Figs. 321 to 330, Plates LXXI. to LXXIV.

The engines are vertical, direct-acting, working three cranks; the compressing cylinders are placed directly above the steam cylinders. The latter are arranged for triple-expansion working, while the air compressor, for which the Compagnie Parisienne selected the Riedler system, is compound with three cylinders.

The boilers (see Fig. 322, Plate LXXII., are registered for a pressure of 12 kilogrammes (170.7 lb. per square inch), the steam being admitted to the high-pressure cylinders at 10 kilogrammes (142.2 lb. per square inch). The compressors are calculated for delivering air at a pressure of 8 kilogrammes (113.8 lb. per square inch) to the receivers. Fig. 323, Plate LXXIII., gives a good idea of the arrangement of the compressed air main. The engines run normally at 60 revolutions per minute, but they are able, exceptionally, to run at 72 revolutions.

The steam distribution mechanism of the small cylinders is on the Corliss system. In the intermediate and low-

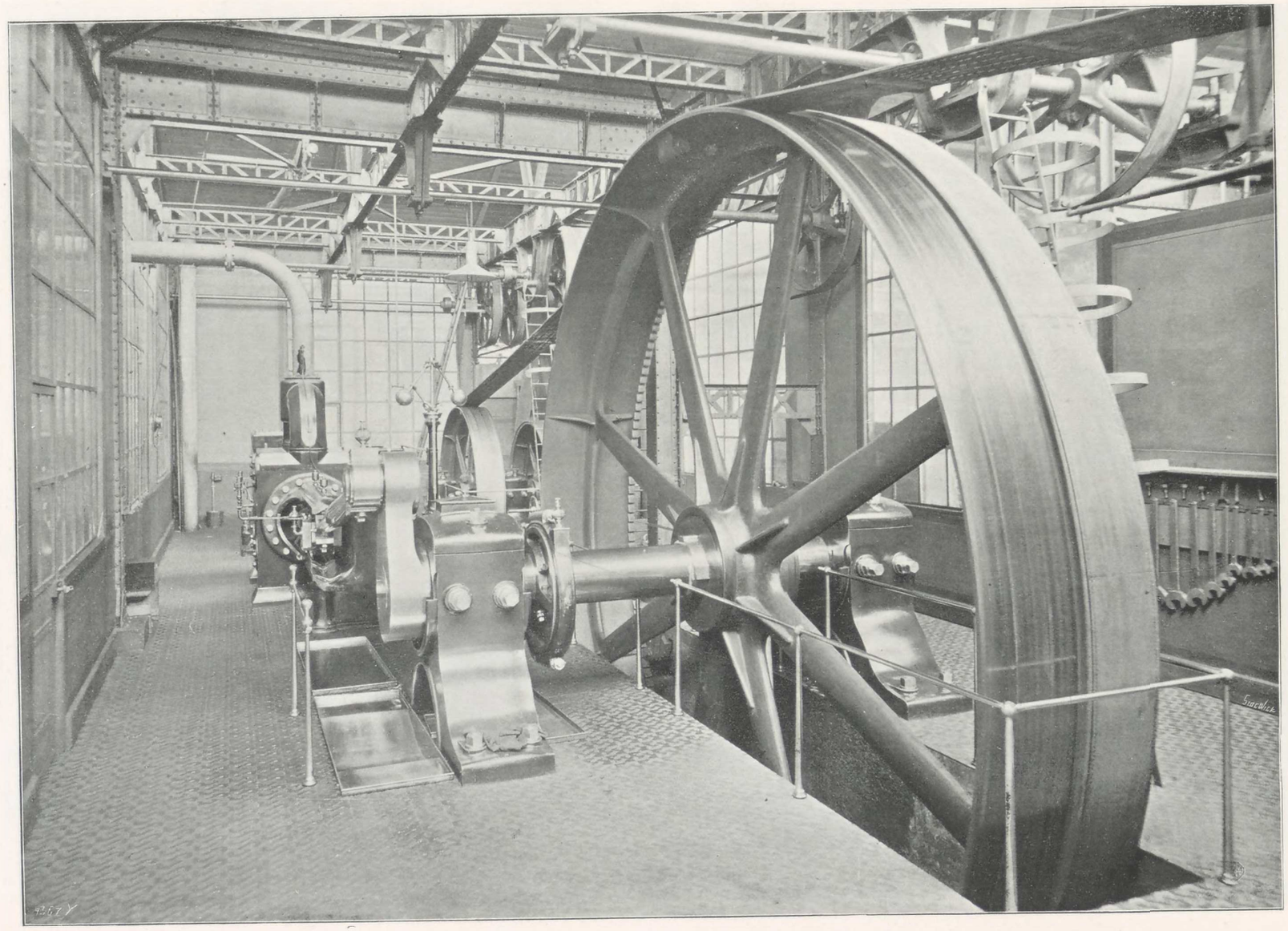


Fig. 319. 600 Low-Pressure Horizontal Condensing Engine at the St. Etienne Gun Factory.

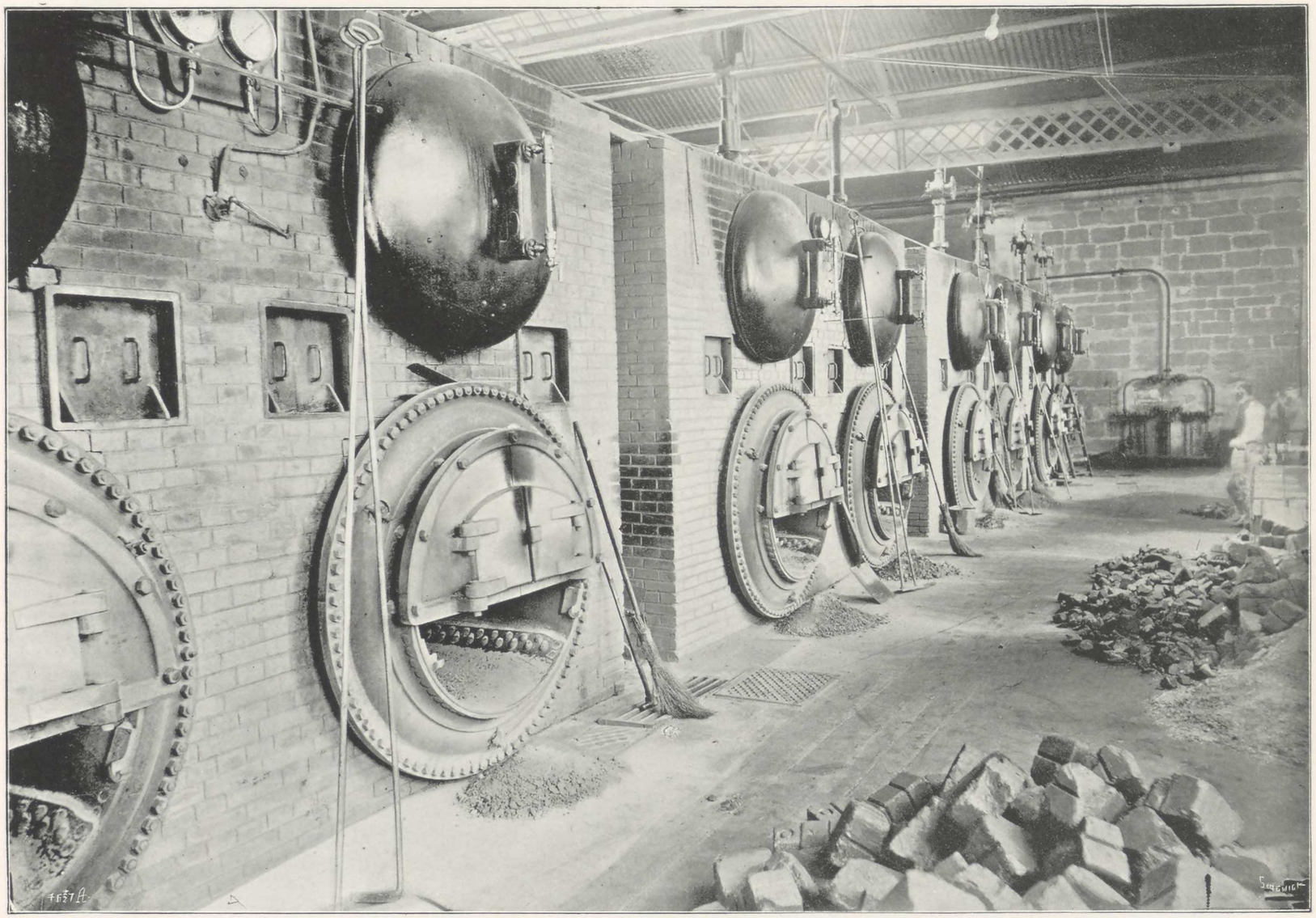


Fig. 320. Group of Boilers at the French Small Arms Factory, Châtellerault.

THE CONSTRUCTION DEPARTMENT.

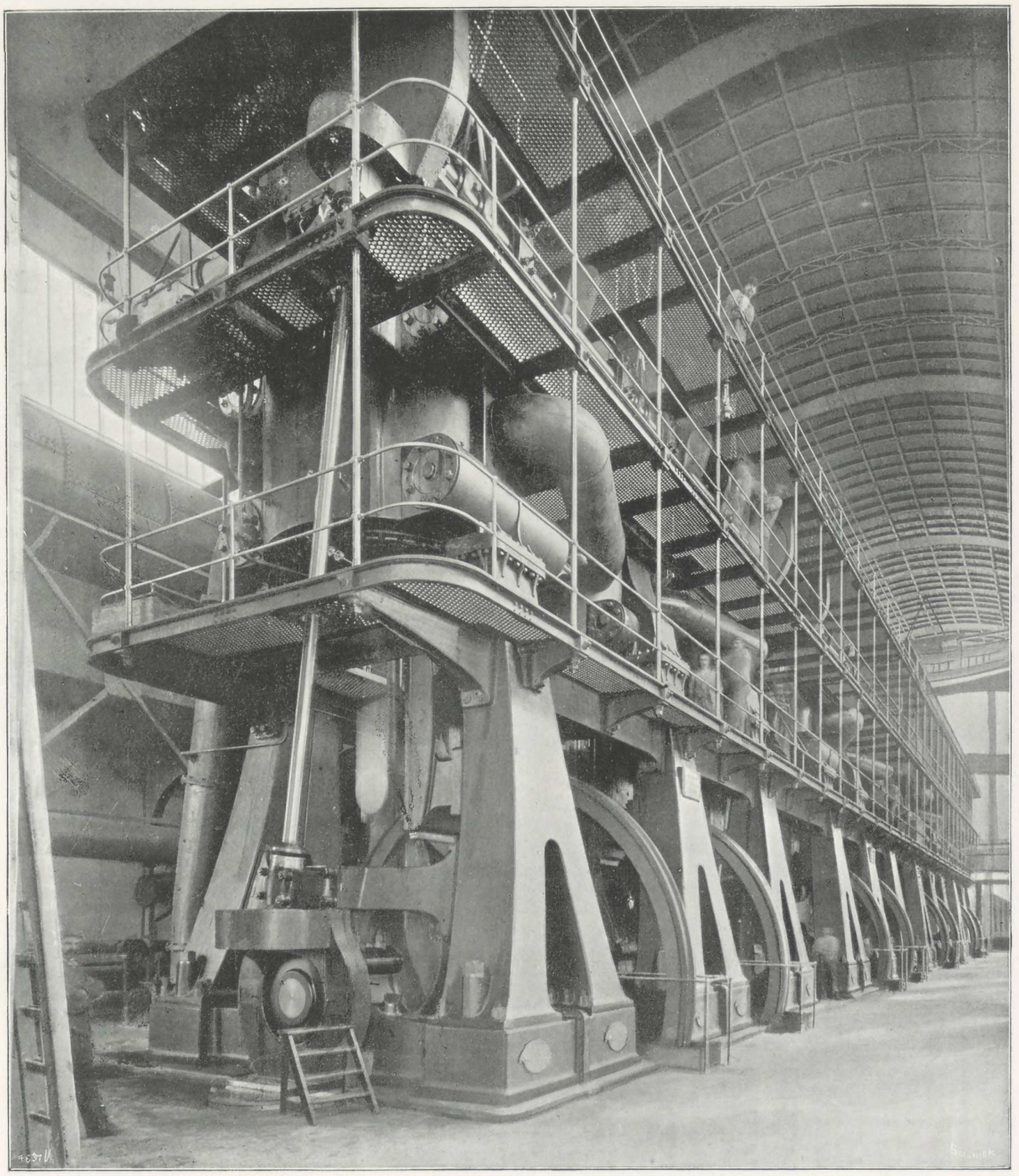


Fig. 321. Groups of 2,000 Low-Pressure Engines and Air Compressors, constructed for the Compagnie Parisienne de l'Air Comprimé.

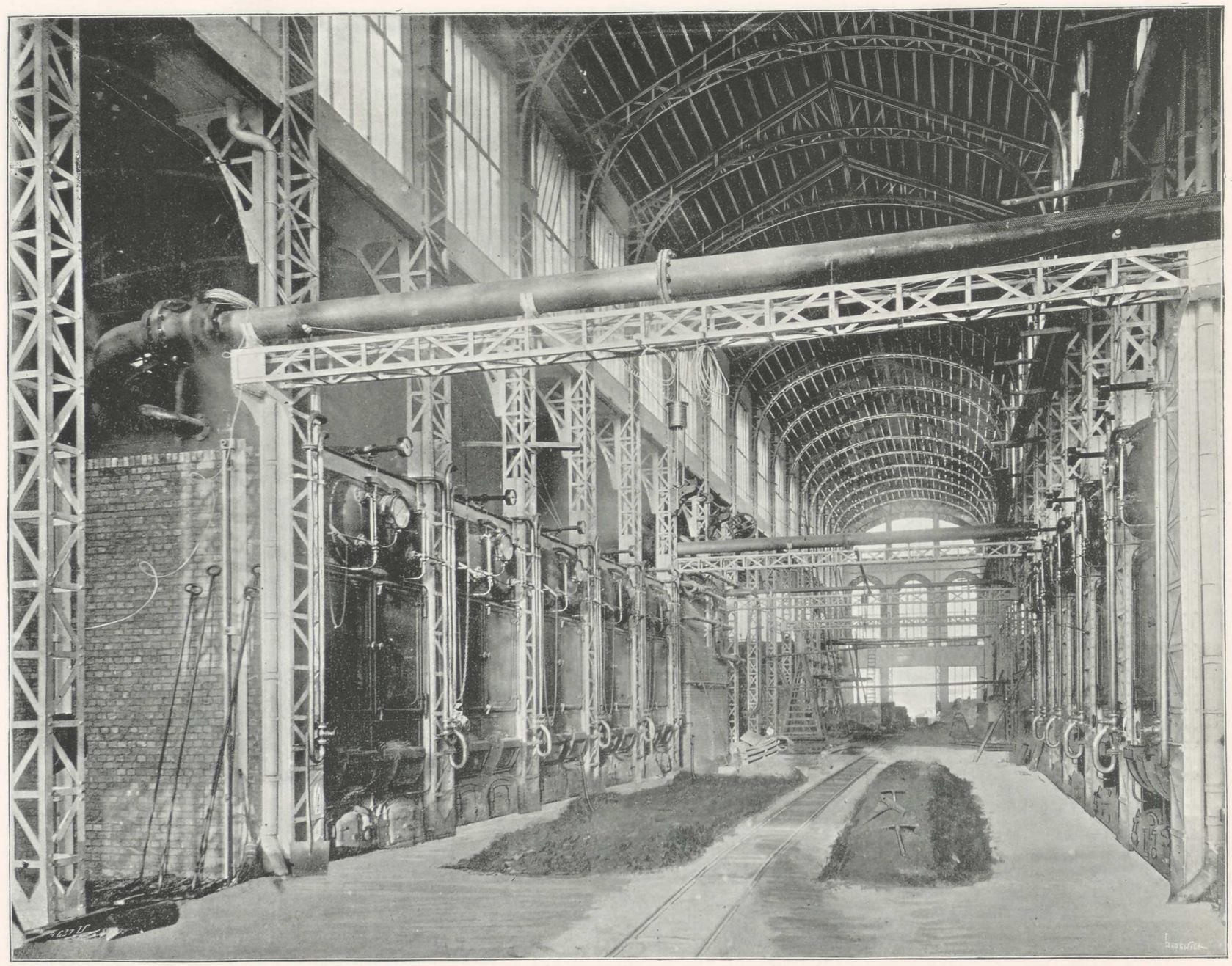


Fig. 322. Group of Boilers at the Central Station of the Compagnie Parisienne de l'Air Comprimé.

THE CONSTRUCTION DEPARTMENT.

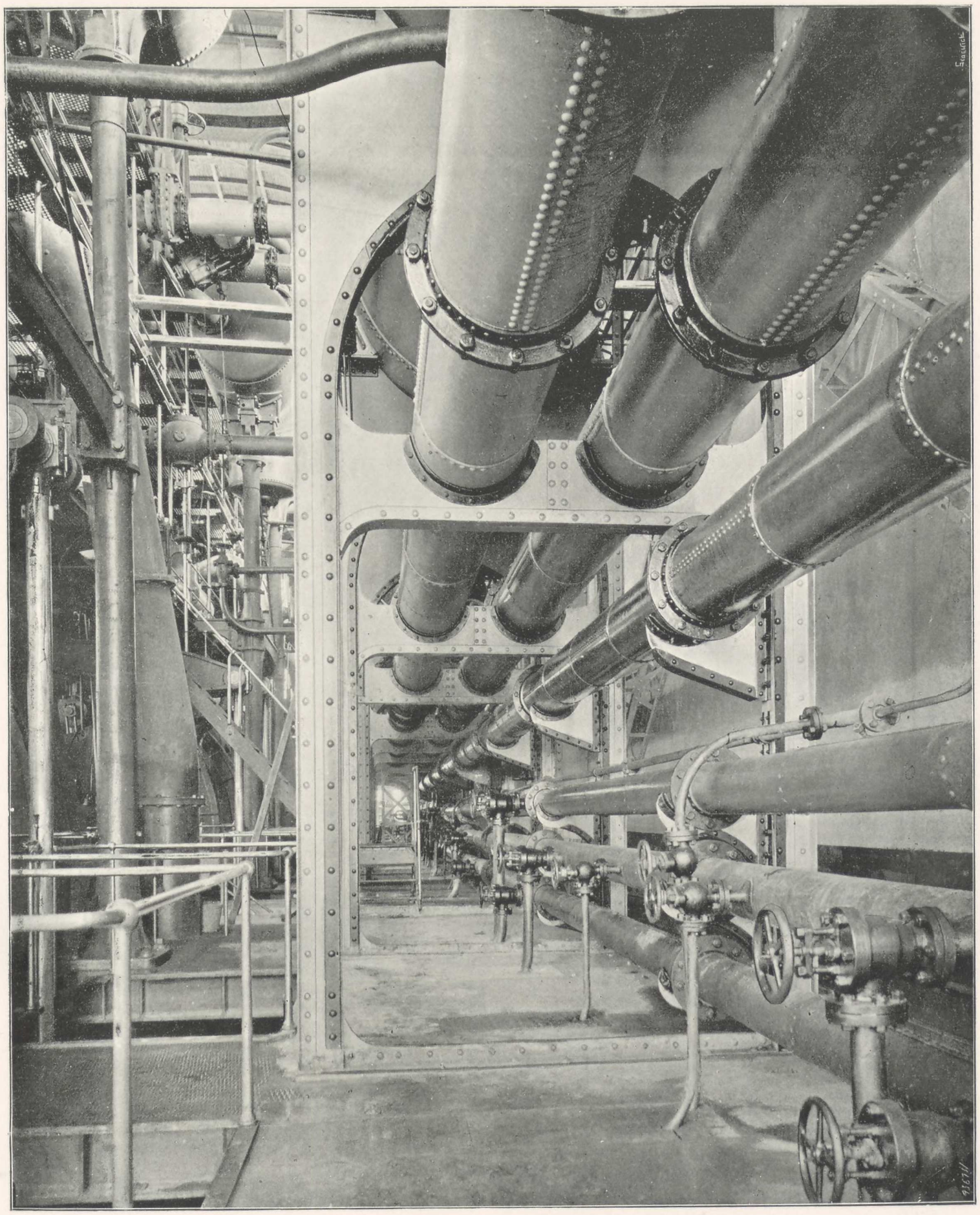
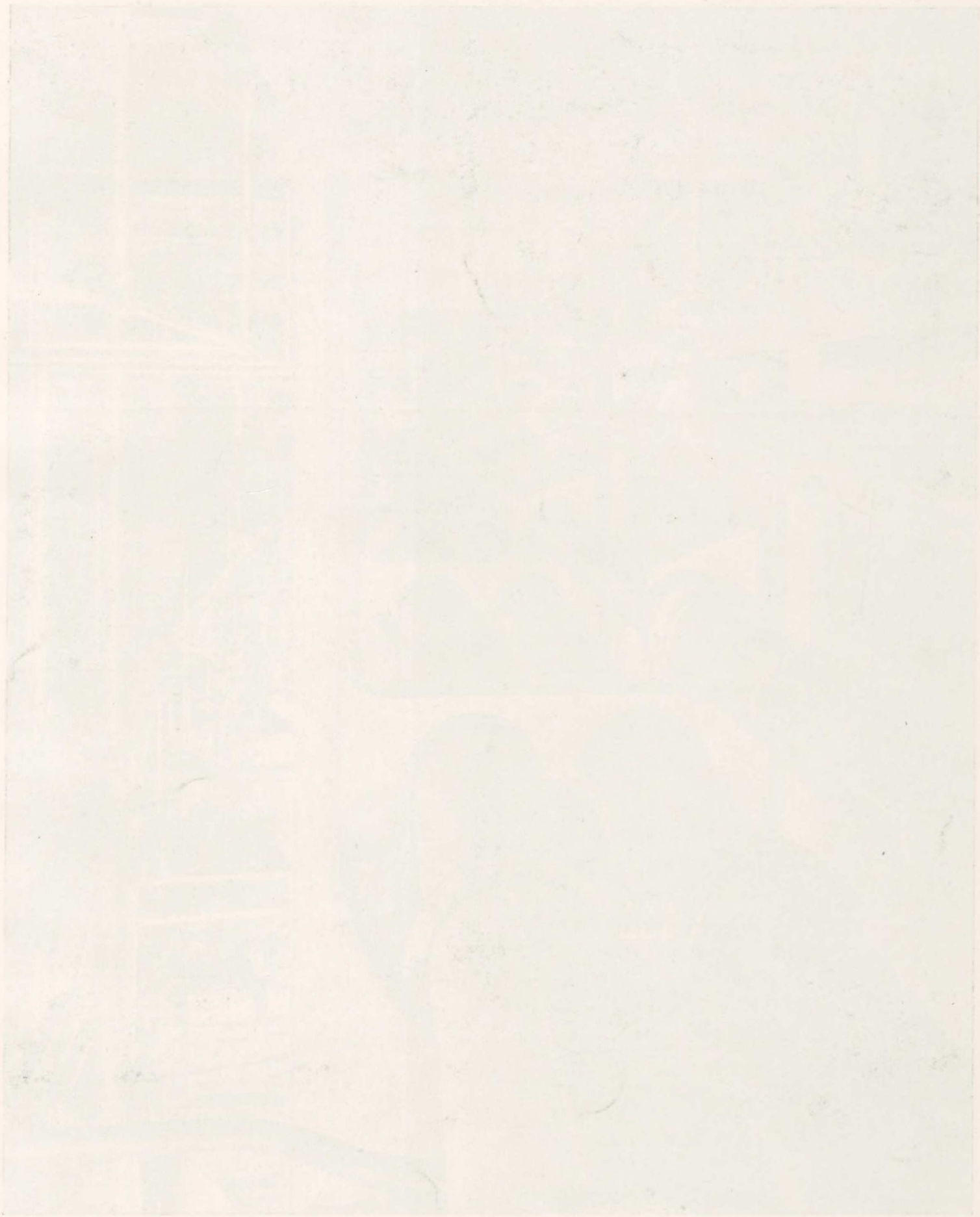


Fig. 323. Compressed Air Main Gallery, Compagnie Parisienne de l'Air Comprimé.



THE CONSTRUCTION DEPARTMENT.

Fig. 324

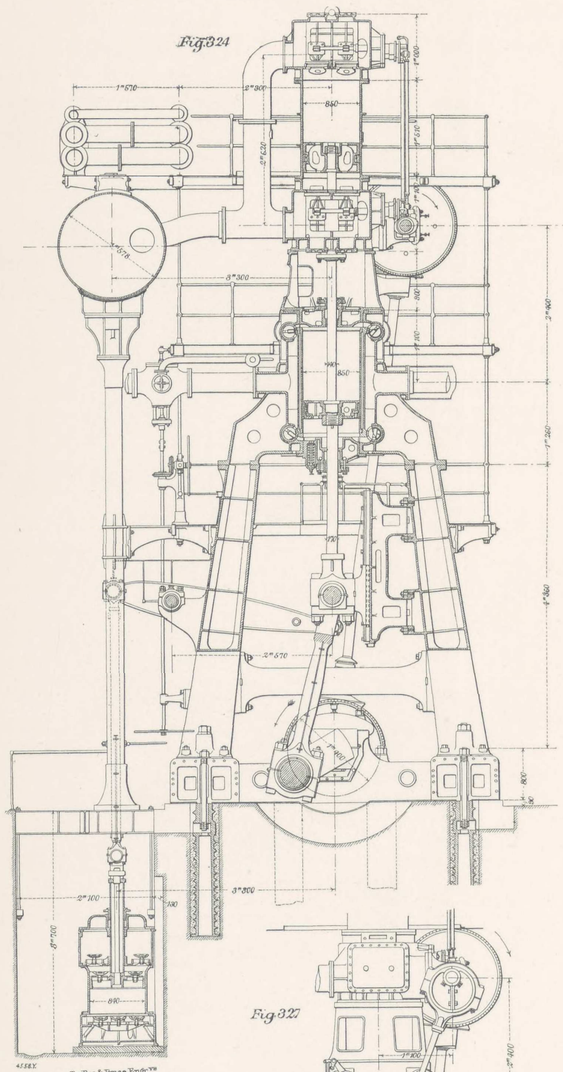


Fig. 325

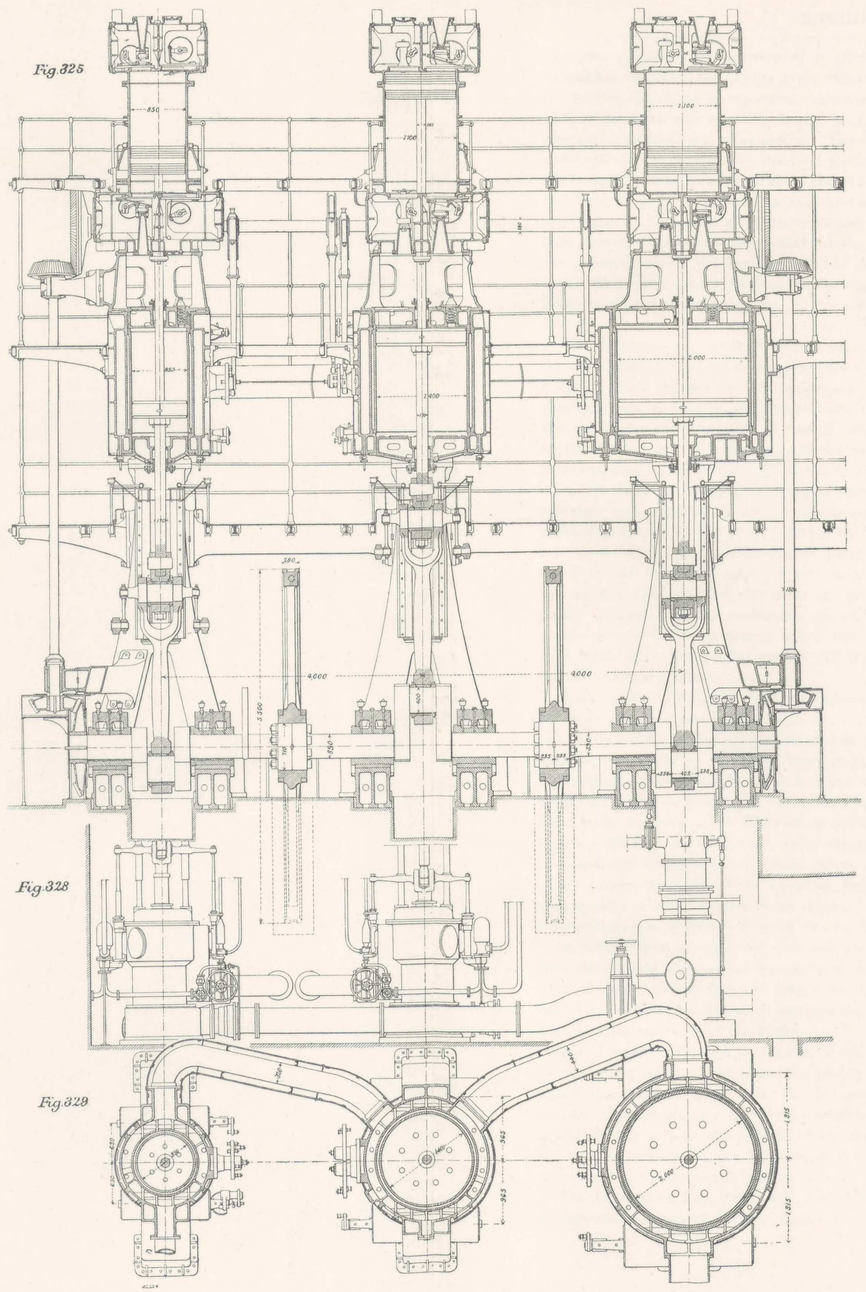


Fig. 326

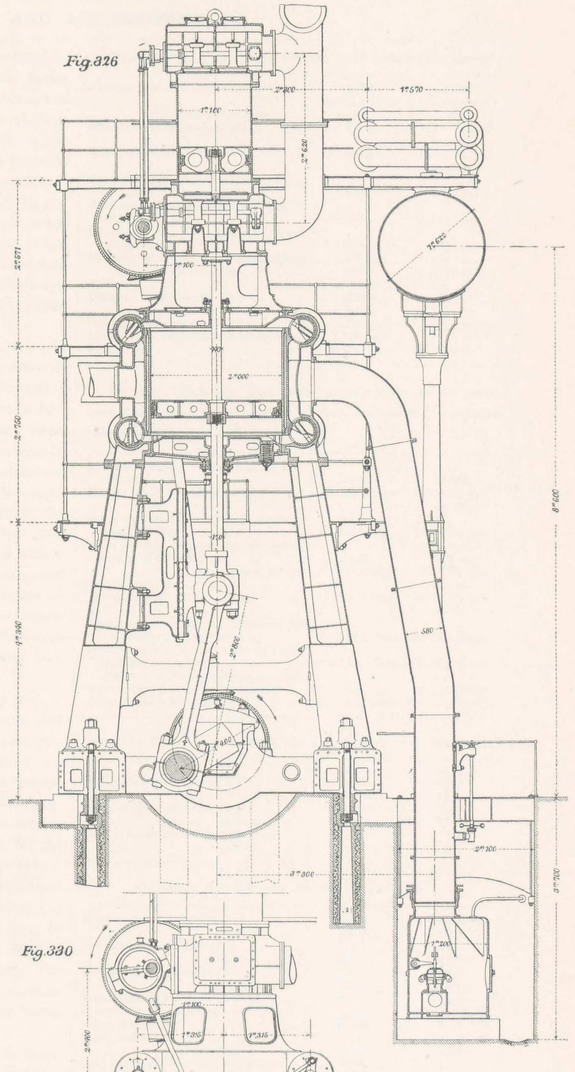


Fig. 327

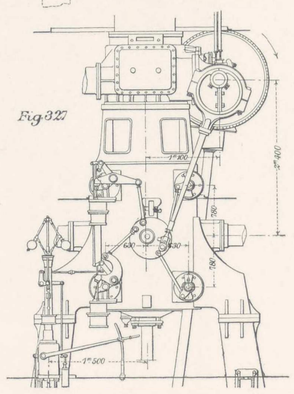
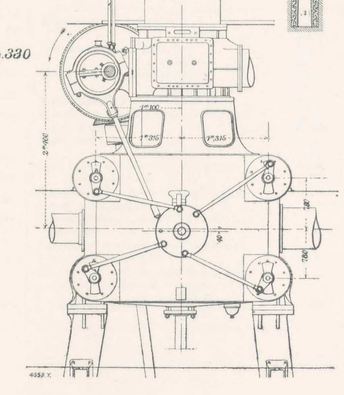


Fig. 328

Fig. 329

Fig. 330



2,000 Horse-Power Triple-Expansion Engines and Air Compressors.

pressure cylinders, the distribution is effected by four cylindrical valves of the Corliss type, without any device for varying the degree of expansion. All these valves and connections work very smoothly, though they are of large size and comparatively quick-acting. Expansion in the small cylinders is regulated by hand. A governor prevents the engines running at a higher speed than 72 revolutions; moreover, in order to prevent an excessive strain on the working parts in case the air pressure should rise to a too high degree, a special governor slackens the speed when the pressure exceeds 8 kilogrammes (113.8 lb. per square inch). These three means of regulating the engines, though independent one of the other, act on the same expansion device.

The eccentrics that work the distribution valves, and the cams which act on the compressor valves, are fitted to a special shaft, carried by the compressor lower valve chambers, and worked by the crankshafts through two vertical shafts and four sets of toothed wheels. Each engine is fitted with two flywheels, keyed to the crankshaft couplings. The crankshafts of the four engines are placed in the same line; the frames that carry the steam cylinders and compressors, and to which are fitted the piston slides, are strongly fixed together by hollow cast-iron cross-beams. Three platforms of perforated plates, one above the other, and provided with ladders, surround the engines, and give free access to all the mechanical parts. The whole of the condensers, air, feed, and drain pumps, are conveniently placed below the engine-room floor level, in a space 3.700 metres (12 ft.) deep, well lighted, and free of access.

Each engine is provided with a condenser, placed in the same vertical plane as the large steam cylinder, and two vertical single-acting air pumps worked by cast-iron balance levers fitted to the piston heads of the small and intermediate steam cylinders. The feed and drain pumps are placed on the air pumps, and are worked by crossheads fitted to the air-pump rods. Brass valves and india-rubber flaps are fitted in the compressor valve chambers, for the admission and delivery of air; these valves open freely, owing to the difference of air pressures, but are closed mechanically in order to prevent all shocks. Two of the three compressing cylinders draw in the air, and force it in an intermediate wrought-iron reservoir placed parallel with the engines, and carried by cast-iron columns; the third cylinder draws the air from the intermediate reservoir, increases its degree of compression, and forces it in the main reservoirs of the works.

Air is drawn in through the louvres on the roof; these are in communication, through the box girders and hollow pillars that support them, with the low-pressure compressors. Special pumps, with valves worked mechanically on the Riedler system, independent of the main engines, deliver the water necessary for cooling the air in the compressors and intermediate reservoirs.

The illustrations, Figs. 324 to 330, Plate LXXIV., show the detailed arrangement of these engines.

The following are some further data concerning them:

Normal power of each engine ...	2,000 horse-power.	2,000 horse-power.
,, revolutions per minute ...	60	60
Pressure of compressed air	8 kilogs.	113.8 lb. per sq. in.
Steam pressure in boilers	12 kilogs.	170.7 lb. per sq. in.
Diameter of high-pressure steam cylinders	.900 m.	$35\frac{7}{16}$ in.
Diameter of intermediate steam cylinders	1.400 m.	$55\frac{1}{8}$ in.
Diameter of low-pressure steam cylinders	2.000 m.	$78\frac{3}{4}$ in.
Diameter of low-pressure compressors	1.100 m.	$43\frac{1}{4}$ in.
,, high-pressure ,,	.780 m.	$30\frac{11}{16}$ in.
Stroke	1.400 m.	$55\frac{1}{8}$ in.
Diameter of flywheels	5.500 m.	18 ft.
,, air pumps	0.800 m.	$31\frac{1}{2}$ in.
Stroke of air pumps	0.550 m.	$21\frac{5}{8}$ in.
Diameter of intermediate reservoirs	1.600 m.	63 in.
Length of ,, ,, ...	9.000 m.	29 ft 6 in.

Several efficiency and coal consumption trials have been made with these engines; below are given the results obtained during one of them:

Average number of revolutions per minute	59.635	59.635
Mean pressure in boilers	11.050 kilogs.	157.2 lb. per sq. in.
Mean pressure at the high-pressure cylinder valve	10.290 kilogs.	146.4 lb. per sq. in.
Mean vacuum in condenser in centimetres of mercury	71.63	$28\frac{3}{16}$ in.
Air pressure at compressors: Low pressure ...	2.300 kilogs.	32.7 lb. per sq. in.
Air pressure at compressors: High ,, ...	7.200 kilogs.	102.4 lb. per sq. in.
Temperature of air on entrance in low-pressure compressors	4.82 deg. Cent.	40 deg. Fahr.
Temperature of air at outlet of high-pressure compressor	20.6 deg. Cent.	69 deg. Fahr.
Mean temperature of feed water: Before passing through feed water heater ...	17 deg. Cent.	63 deg. Fahr.
Mean temperature of feed water: After ditto	60 deg. Cent.	140 deg. Fahr.

Average Work on the Steam Pistons given by the Diagrams.

	kilos.	lb. per sq. in.
High-pressure cylinder, top	3.025	43.0
,, ,, bottom ...	3.055	43.4
Intermediate cylinder, top	1.203	17.1
,, ,, bottom ...	1.209	17.1
Low-pressure cylinder, top	.632	9.0
,, ,, bottom ...	.572	8.1

Indicated Horse-Power on the Steam Pistons.

High-pressure cylinder, top	308.8	308.8
,, ,, bottom ...	309.8	309.8
Intermediate cylinder, top	340.1	340.1
,, ,, bottom ...	340.2	340.2
Low-pressure cylinder, top	366.6	366.6
,, ,, bottom ...	331.0	331.0
Total indicated horse-power	1996.5	1996.5
	kilogs.	tons cwt. qr. lb.
Rough coal consumed during the 8 hours' trial	10,424	10 5 0 24
Slack and ashes	555	10 3 19
,, ,, percentage	5.32	5.32
Coal burnt during trial, difference ...	9,869	9 14 1 5
,, per hour	1,233.62	1 4 1 4
Steam lost per hour through leakage and condensation	569.67	11 0 24
Corresponding amount of coal lost per hour	63.3	1 0 27
Amount of coal consumed per hour in working the engine	1,170.32	1 3 0 5
Amount of coal consumed per hour and per indicated horse-power on the steam pistons $= \frac{1170.32}{1996.5} =$ ...	.586	1.29 lb. per I.H.P. per hour.

Miscellaneous Work.—Of miscellaneous work completed in this department may be mentioned the following:

Steam hammers	183
Steam and hydraulic cranes, overhead travelling cranes, accumulators, hydraulic presses, forging machines, punching machines, shears, plate-straightening machines, cutting machines, plate sawing machines, lathes, boring machines, armour-drills, planing machines, milling machines, rolling-mill plant, elevators, turbines, &c.	501

Boilers of various types (apart from those delivered as forming part of the marine engines and locomotives enumerated above):

a.	Reserve boilers for marine engines	260
b.	,, ,, locomotives	70
c.	Stationary boilers	1,575
d.	Boilers for travelling cranes, &c.	125
e.	Various (for distilleries, chemical works, &c.)	145
	Total	2,175

XX.—THE ELECTRIC CONSTRUCTION DEPARTMENT.

MESSRS. SCHNEIDER AND CO. manufacture in this department dynamos, electric motors, transformers, and all kinds of direct and alternating-current machines and plant, together with auxiliary apparatus.

The electric construction department consists of two main shops, situated at the south end of the Creusot Works (see general plan, Fig. 23, Plate IV.; they are shown to a larger scale by Fig. 331. The first shop was built about ten years ago, but owing to the large demand for electrical machinery, a rapid increase in the size of the department, and its equipment, became necessary. It now covers an area of 13,000 square metres (140,000 square feet). Previously to the installation of a special department, the electrical apparatus required were manufactured in a comparatively small way in the engineering shops of the Creusot Works.

The following references are explanatory of Fig. 331:

A. Laboratory.
B. Electrical offices.
C. Cabinetmakers' shop.
D. Dynamo store.
E. Stores for materials.
F. Plate stores (5-ton travelling crane).
G. Packing and forwarding room.
H. Painting shop.
I. Heavy dynamo-erecting shop.
K. Machine shop (lathes and milling machines).
L. Machine shop (planing and boring machines, &c.).
M. Winding machines (20-ton and 25-ton travelling cranes, and small dynamo-erecting shop).
N. Fitting shop.
O. Electrolytic plant.
P. Offices.
Q. Drying stoves.
R. Current-generating station.
S, T. (Part of gun department.)

The main building consists of a central bay, 16 metres (52 ft. 6 in.) wide, with two lower lateral bays, 10 metres (32 ft. 10 in.) wide each. The flooring is of concrete. Heavy cast-iron columns carry the roofing, the transmission brackets, and the tracks on which run 15 and 30-ton overhead travelling cranes. This shop serves for the fitting of all mechanical parts of small and medium-sized electric machines, and for the erection of large dynamos. The lateral bays above mentioned are occupied by machine tools of all descriptions and power. The very large pieces are, for the present, machined in the adjoining shops, which form part of the ordnance department. One of the bays is specially set apart for stamping, cutting out, and putting together, dynamo sheets; it contains stamping machines, lathes, and hydraulic presses, the largest of which are adapted for finishing drum armatures up to 3 metres (9 ft. 10 in.) in diameter. The erection of small and medium-sized dynamos, as well as the fitting of accessory gear and winding, are carried on in another building, which is of more recent construction. This building consists of two bays with iron trusses of 10 metres (32 ft. 10 in.) span, which rest on the walls, and on a series of columns similar to those above mentioned. It is 3,000 square metres (32,300 square feet) in area, without counting the annexes. Two large glazed sliding doors serve for giving access to railway trucks for the delivery of material. This building is divided into two distinct parts, one for the erecting of dynamos and fitting of accessory gear; the other for winding, stove drying, and making commutators; the flooring is paved with wood blocks. In the division reserved for fitting and erecting accessory gear, hand vices are placed on a bench which runs along the wall. The main transmission shaft is worked by electric motors, and motion is transmitted to the various machine tools and lathes by means of wood pulleys.

Winding armatures, magnets, &c., is carried on in a separate building, in order to prevent metallic dust from penetrating into the coils. Each workman has his own complete set of tools, and every facility is given him, so that he may carry out rapidly the work he is entrusted with. In order to reduce the cost of labour to a minimum, each class of work is specialised and executed in series as far as is practicable. This manner of proceeding renders the workmen skilful in their respective branches, and does away almost entirely with errors which are difficult to ascertain and to correct after an intricate job is completed. The manufacture of insulating coil casings, a very important item, as well as the preparation of cardboard and mica, and, as a rule, all work more minute than difficult, is carried out by a special *personnel*, who work together in a separate room. Coils, according to their size, are made either by hand or mechanically on winding machines. In each case a revolution counter, mounted on the axis of the coil or on the winding machine shaft, enables the winder, without any special attention, to know exactly the number of turns wound. The winding machines are driven off the main transmission by intermediate shafting, or by small electric motors worked from the central station. Winding armatures of all kinds is done by hand; when this has been completed, the connections, welding, and insulation, undergo careful testing previous to delivery to the dynamo-erecting shop; the drums, coils, &c., are afterwards dried in stoves which are arranged in such a manner that they can be rapidly served by the overhead travelling cranes. The whole of the shop is heated by steam at low pressure.

Movable and fixed blowpipes are placed along the walls for welding the coils, or for heating certain pieces. These blowpipes are branched on two mains, one for gas, the other

for air, and provided with valves within easy reach of the workmen, for regulating the blast. Four electric travelling cranes, constructed at Creusot, one of 20 and three of 5 tons, serve the shops from one end to another; these cranes are illustrated by Figs. 332 to 334, Plate LXXV. The overhead tracks, formed of cross girders, are carried on one side by the columns, and on the other by stanchions built into the walls. The electric travelling cranes take direct current, at 220 volts, by means of carbon brushes, which slide on naked conductors supported along the track by porcelain insulators. The various movements of each travelling crane are independent one from the other; a dynamo works each one, the movement being controlled from a cabin for the 20-ton crane, and from the floor level for those of 5 tons. The lifting speed can be varied within certain limits,

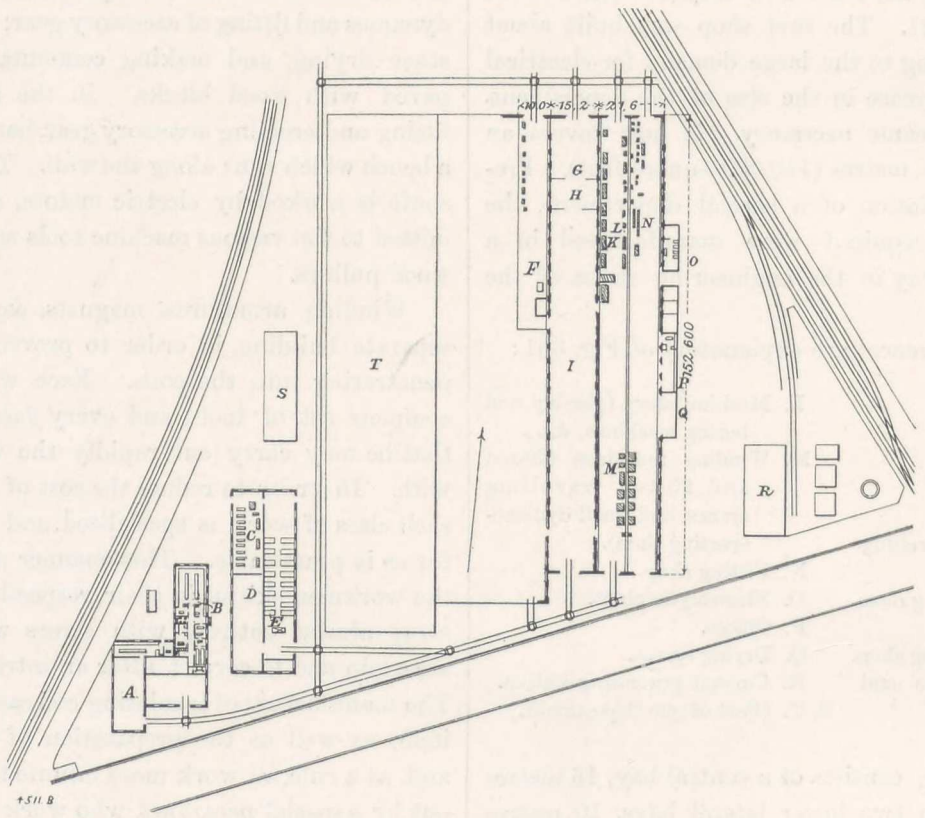


Fig. 331. Plan of Electrical Construction Department.

according to the load and the manœuvres required. For lowering loads, the corresponding dynamo is short-circuited under a resistance that can be regulated, thus enabling the speed to be controlled. The handling of these travellers is very simple, and they are found quite satisfactory. As they contain hardly any wheel gearing, there is practically no noise or vibration, even when all the cranes are working simultaneously. Several two-phase current dynamos, which drive various shafts and machine tools, are supplied from a 2000-volt generating group, situated in the central lighting station 2 kilometres distant. The bare wires which conduct the current are supported on iron columns and run to the primary coils of transformers, placed in the electric construction shops, where the current is reduced to 110 volts, at which it is taken up by the motors. The current necessary for the travelling cranes and other motors, is supplied at 220 volts by a generating station situated near the electric construction works. This station, which also supplies current to the ordnance works, contains engines of 700 horse-power in all, but it was designed with a view of increasing to 1000 horse-power. The overhead uninsulated line ends on an iron standard fixed to the roof of the electric construction works. The lighting of the works is insured by low-tension alternating currents, supplied by transformers which receive the current from the central lighting station above mentioned. The arc lamps which are used are of 30 volts and 12 amperes; they are placed along the walls and against the columns, at intervals of about 10 metres (32 ft. 10 in.). They are branched on 50-volt circuits, and a self-induction device placed in series with each lamp absorbs the excess current, with hardly any expenditure of power. Incandescent lamps of 16 candles, on the 110-volt circuit, and provided with metal screens, supplement the lighting. The incandescent lamps for lighting machine-tool work, are made portable.

Before final delivery, all the machines undergo tests, according to the conditions under which they will have to work. These tests are made in a laboratory which adjoins the shops, and which is fitted up completely with all the most modern appliances. Dynamos and motors are also tested in working, under conditions as near as possible normal. Insulation and overcharge tests are fully carried out, and the machines are only delivered when all the tests have been satisfactory. Dynamos and other machines, after testing, are fitted up and painted, and a final test, on the spot, with no load, furnishes the proof that they have been re-erected with all due care. Much attention is given

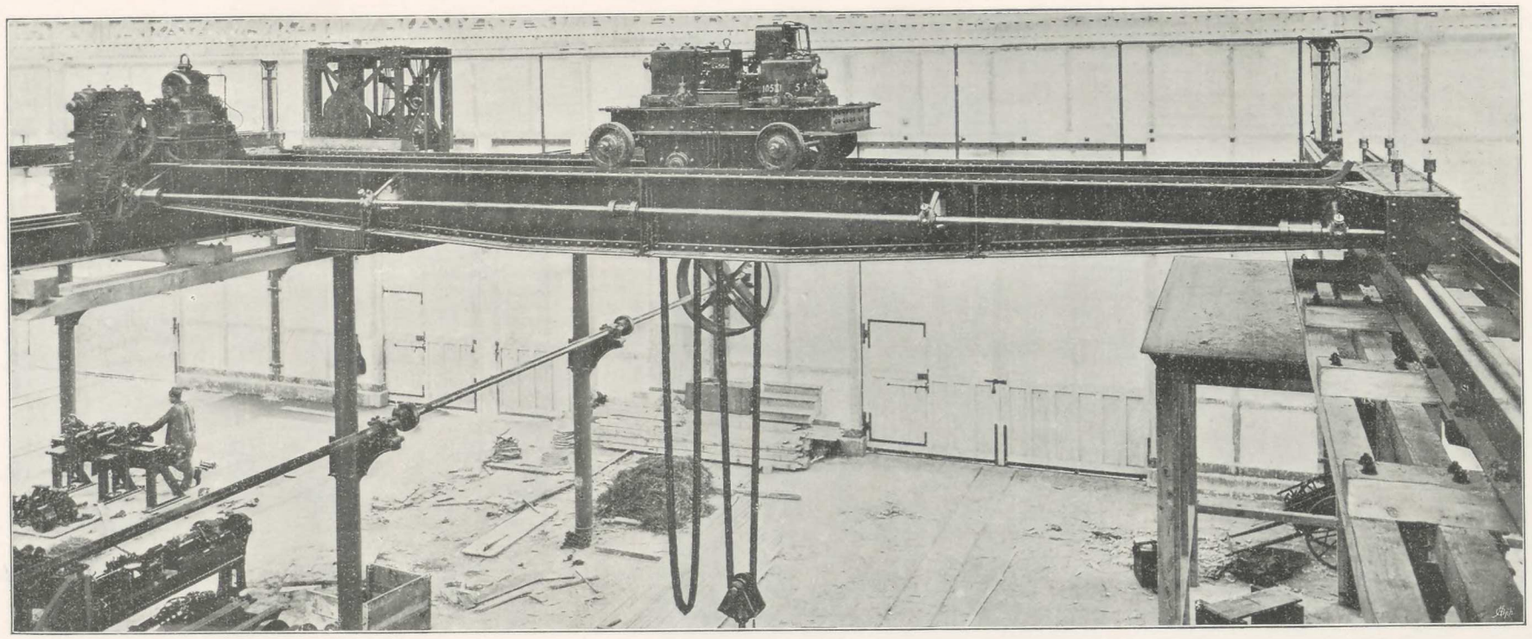


Fig. 332.

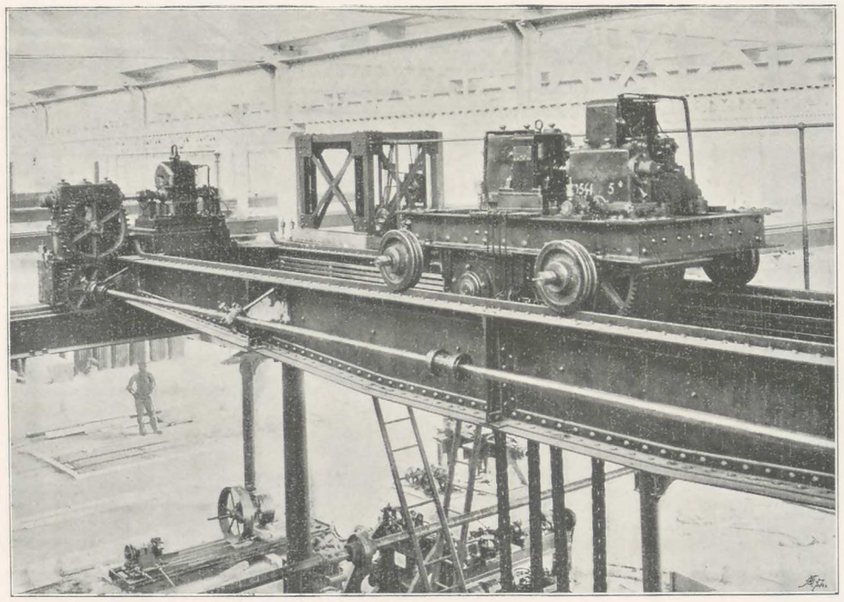


Fig. 333.

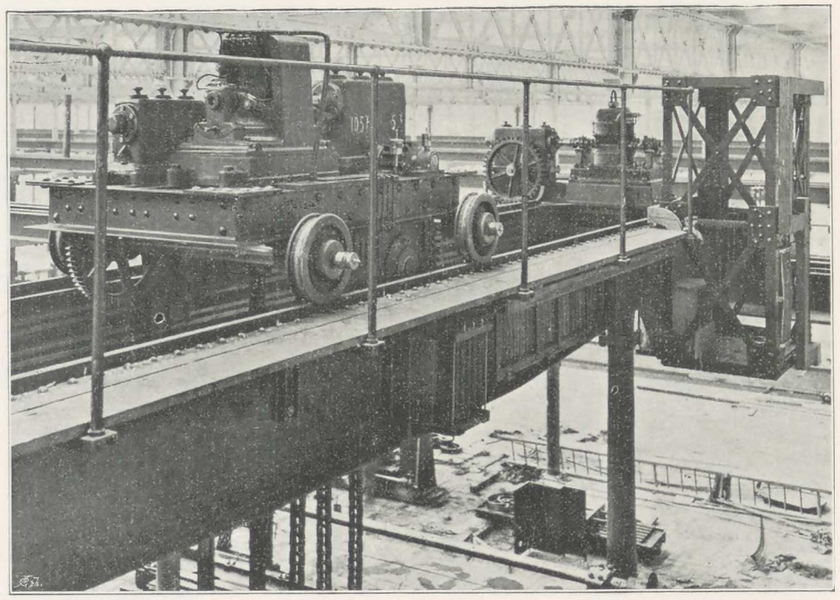


Fig. 334.

Five-ton Electric Travelling Crane.

THE ELECTRIC CONSTRUCTION DEPARTMENT.

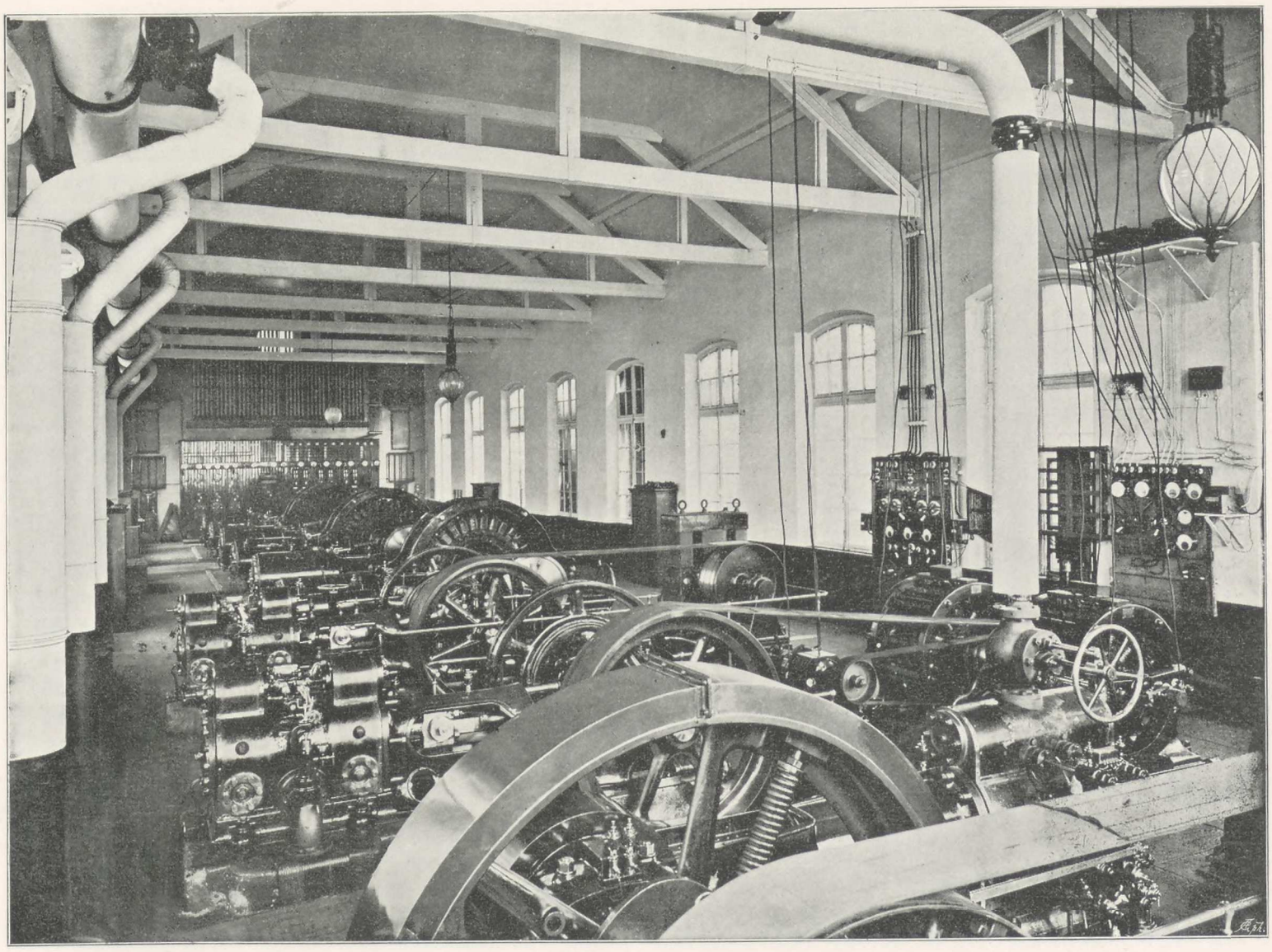
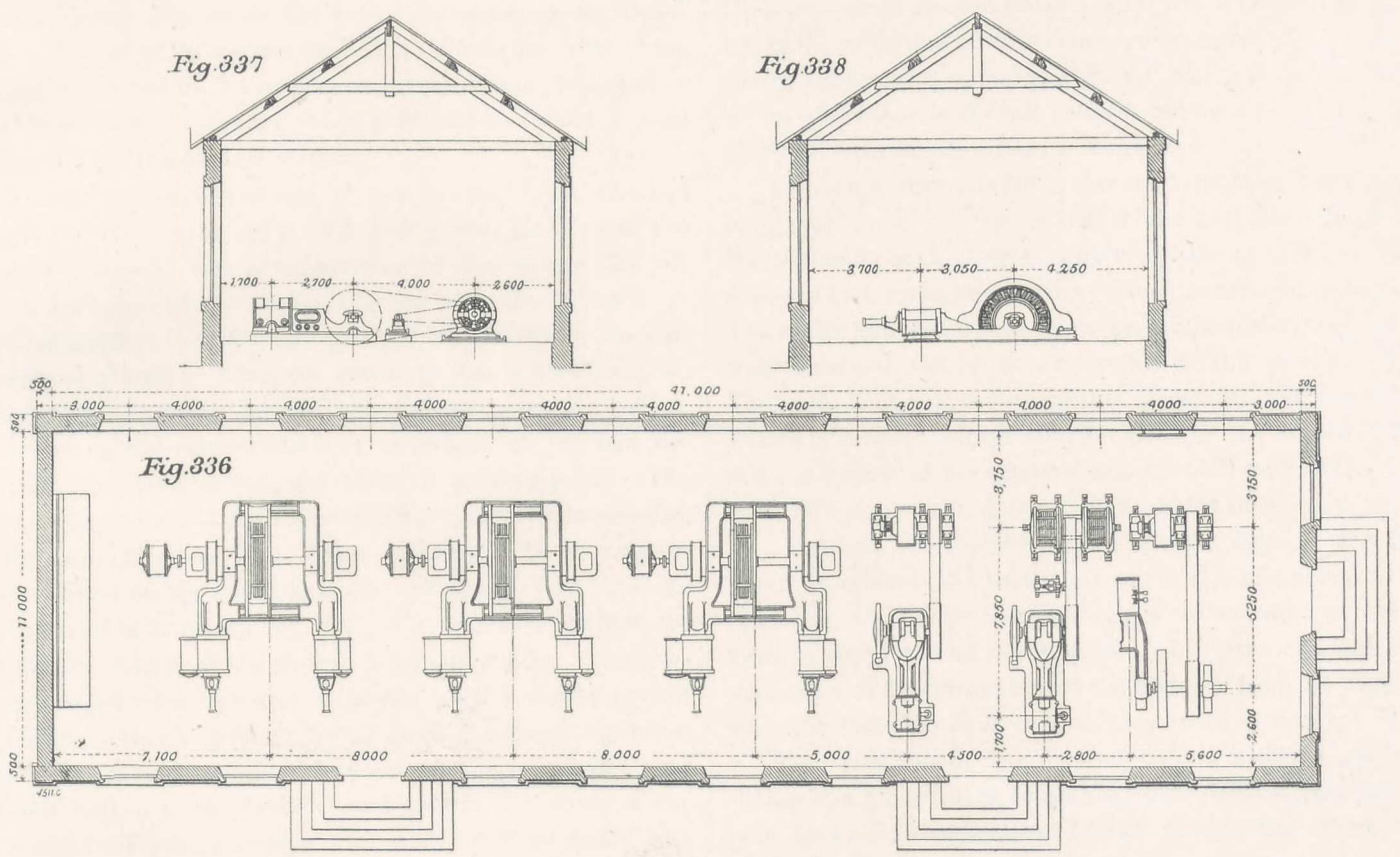


Fig. 335.



Central Lighting Station.

to packing, for which watertight cases are used, and each machine is delivered with a detailed statement giving the tests it has undergone and the instructions for its working.

The Central Lighting Station.—Messrs. Schneider and Co. commenced lighting their Creusot Works with arc lamps 20 years ago, and, since that date, gas lighting has been gradually superseded. At first, direct-current dynamos were placed on the spot where the current was needed, and near the boilers and engines belonging to the various departments. In 1891 there were at the Creusot Works, several direct and alternating current installations, which represented a total of about 150 horse-power. At that time it was decided to light the new hospital, then in course of construction, by electricity, and a large central station was designed for generating the energy necessary to light both the works and the hospital.

Owing to the great area to be dealt with, Messrs. Schneider and Co. decided upon an alternating system with a 2,000-volt current, and with transforming sub-stations placed at the main points of utilisation. In 1893, when the engine-room was erected, the necessary provisions having been made for future extensions, two electrical groups, one of 100 horse-power and one of 300 horse-power, were put down. The amount of current required was, however, under-estimated, and the following year another group of 300 horse-power was installed; whilst in 1897 the original 100 horse-power group was replaced by a third one of 300 horse-power. Besides these three groups which serve for electric lighting, the station contains two sets, consisting each of a single-cylinder steam engine of 125 horse-power and a direct-current Ganz dynamo, which supplies current at 220 volts to the electric travelling cranes of adjacent shops, and a third set of the same power, consisting of a steam engine similar to the above, and a two-phase generator, formed of two connected Ganz dynamos; this plant supplies current to the motors in the electrical department and laboratory; these are about 1500 metres (about 1 mile) distant from the central station.

The boilers employed are of the tubular type, and are heated very economically with the waste gases from the blast-furnaces. The arrangements of the works did not allow of placing the steam engines near the boilers; it was necessary, therefore, to provide about 200 metres of overhead piping to bring the steam to the central station. The result is a rather heavy drop of steam pressure; owing, however, to the economical way in which the boilers are heated, the arrangement, as a whole, is advantageous. The steam engines are of the Creusot compound type, horizontal, with two cylinders, and steam jacketed. These engines drive direct on the dynamo shaft. Steam is distributed by cylindrical balanced valves, worked by eccentrics, which are driven by cranks at the ends of the main shafts. The low-pressure cylinder eccentric is keyed to the shaft; that of the high-pressure cylinder forms part of a speed regulator, with centrifugal weights that act on the expansion gear of the high-pressure cylinder and modify the throw of the eccentric. These machines run at 160 revolutions, and develop 300 horse-power, with an initial pressure of 7 kilogrammes (99.56 lb. per square inch) in the high-pressure cylinder. The variation of speed between the working with no load and with full load, reaches 6 per cent.

The dynamo of each set is an alternating-current single-phase Ganz machine, the frame of which is bolted to the engine bedplate, and between the two cylinders, so that the revolving field magnet is in the axis of the bedplate, and is mounted on the main engine shaft. The field magnets which revolve within the fixed armature ring are supplied with a low-tension direct current by means of rings revolving on the shaft against fixed brushes. The field magnets are built of thin plates with 32 radiating arms, each carrying a coil, the frame being mounted on a cast-iron centre keyed to the shaft. The main frame of the alternator consists of two cast-iron rings carrying the fixed armature, with as many coils as there are poles in the field magnet. All of the coils are so mounted and fixed that they are interchangeable, and are easily removed for repairs, and as easily replaced.

The armature coils are grouped in series, and the ends of the armature circuit are brought to two primary terminals, placed on a protecting cover at the bottom part of the alternator. The fixed part of the alternator is easily removed to facilitate the inspection of the field magnets. The exciting current is furnished by a direct-current four-pole dynamo, placed on an extension of the shaft, and driven by an elastic clutch.

The switchboard of the generating dynamo is somewhat similar to that used at the Decize Mines, already referred to. The current regulation is effected by means of an automatic field rheostat on the Ganz system, which acts on the exciting dynamos. Coupling in multiple is regulated from a phase indicator, formed of incandescent lamps, which are extinguished as soon as synchronism takes place. Above the switchboard is a charge rheostat, which is used to bring up an alternator to its full output before connecting it in multiple with another then in work.

Two main lines, one 500 metres and the other 1400 metres long, start from the switchboard bars, and are extended to the two ends of the works, supplying current to the primary mains, which correspond to the various transforming stations. The main and secondary lines are uninsulated, carried on iron standards, fitted to the roofs of the various shops. The main that supplies current to the south-east part of the works is placed underground for part of its length. This main is formed of a concentric armed cable, 150 metres long and 50 square millimetres (0.078 square inch) section, laid in a conduit .500 metre ($19\frac{11}{16}$ in.) deep. Beyond the part where it crosses the telegraph wires, the line is aerial and branches off in several directions to supply current to various shops and to the hospital; the latter can absorb a maximum of 20 kilowatts, and the distance from its junction with the main is about 1500 metres (about 1 mile).

Each department is provided with a switchboard consisting of a glass frame, containing one high-tension double-pole make-and-break, one Blathy meter for alternating

currents, two safety fuses, two terminals, and two lamps. The supply to all the transforming stations of one department is regulated by this same switchboard, so that each meter gives the sum of electric energy used in every section. When only one department is served, the meter is placed preferably on the secondary circuit of the transformers. At the central station a total meter registers the energy in kilowatt-hours supplied by the alternators. Besides the switchboard of the main primary circuit, the transforming stations are fitted with a secondary switchboard formed of a panel and two make-and-breaks, one for primary, the other for the secondary, circuit. The transformers, which are of the Ganz type, reduce the current from 2,000 to 110 volts, at which the incandescent lamps are worked. Speaking generally, the distribution of incandescent lighting is by loop circuits, with safety fuses for each lamp, or series of lamps, as the case may be. For lighting with arc lamps the system of three-wire distribution has been adopted, making use of an intermediate terminal, which allows the branching of a neutral wire and the formation of two 50-volt bridges. The lamps are of the Brianne type, of 12 amperes, working at 33 volts at the terminals, with variable focus. As they are branched on 50-volt bridges, the excess of voltage is economically absorbed by a self-induction coil, inserted on the lamp circuit. When regulated, these lamps work satisfactorily.

In the shops they are provided with a reflector and shade, but are not fitted with a protecting glass. They are placed, as a rule, 4 or 5 metres above the floor level; but they can be raised or lowered by means of a pulley over which the suspension cable of each lamp passes. For lighting the yards and dépôts, the lamps are carried on standards 10 metres high, by a cable which winds round a small winch placed at the base of the standard, and enclosed in a box. These lamps are set at a height of 9 metres, and are fitted with reflecting shades and a transparent protecting glass. Two vertical rods, fixed to the standards, serve to guide the lamp when it is lowered for inserting fresh carbons. The box above mentioned contains the self-induction coil for regulating the arc, and a switch for cutting off the current. At the present time, the central station supplies current to 4,000 incandescent and 400 arc lamps Figs. 335 to 338, Plate LXXVI, are respectively a general interior view, sections, and a plan of the central lighting station.

Electric Tramways.—Creusot has recently supplied the material for an electric tramway (see Figs. 339 and 340) in the district of the Alps. This material is on the Thury system, for which Messrs. Schneider and Co. are the sole concessionaires for France and her colonies. The generating station is built outside the town, and consists of two groups of Thury 220 horse-power generators, self-exciting, with a speed of 325 revolutions, and giving at full charge an output of 250 amperes at 600 volts. The frame, of hexagonal shape, contains the field magnets. It is divided into six cores, carrying inductor coils and an equal number of polar extensions on the magnets. The frame rests on a cast-iron foundation plate, with the interposition of double wedges, which isolate it magnetically and electrically. The armature consists of a smooth laminated ring, fixed on a cast iron centre; it is drum-wound, and carefully insulated from the shaft. It carries the commutator, which is mounted on a cast-iron socket, with arms cast in one piece with it. For counteracting the effects of centrifugal force, the armature conductors placed round the circumference of the ring are held by steel wire, and the connecting strips are inclosed in cast-iron covering rings of suitable shape. The self-lubricating bearing blocks are fixed on the foundation plate, their base being turned on the same centre on which the inductors were bored, so as to



Fig. 339. Electric Tramway.

insure a perfect centreing of the armature. Carbon brushes are used; they do not spark on the commutator. Their positions are regulated by means of a screw adjustment, which acts on a movable brush-holder disc, and which turns on the commutator bearing block. The dynamo, fixed on slides, rests on porcelain insulators, embedded in the foundations, and which protect it against atmospheric disturbances.

These dynamos, owing to the range in their power of working, are very suitable for tramway central stations; they can be driven several hours at an excess of 25 per cent. without any dangerous overheating, and for short periods at an excess of 30 per cent. A repairing and maintenance shop is built near the central station; the dynamo which works the transmission shafting is a 2 horse-power Thury machine, supplied direct with current from the central station. The car dépôt is also near the central station. The switchboard consists of two marble slabs on an oak mounting, and is fitted with all the grouping, starting, safety apparatus, &c., belonging to the generating dynamos. These apparatus consist of field rheostats with automatic regulator, ammeters, voltmeters, make-and-breaks, disconnectors, releasing apparatus for current intensity, and lightning arresters. The automatic regulator acts in relation with the compound winding, in order to maintain constant the potential difference at the terminals of the generating dynamos. It consists of an arrangement that governs the direction in which the field rheostat handles are moved, these being worked by a small direct-current electric motor. This regulator acts perfectly as regards rapidity and precision. The automatic disconnector with which each generating dynamo is provided, serves to cut out the circuit of the dynamo, when it cannot usefully supply current to the system, owing to the fall of its voltage. The releasing arrangement for current intensity, fitted to the switchboard, works through a feeder; it serves to cut off automatically the current supply of a line in which a short circuit is produced, which would damage the dynamos. The apparatus for protection against atmospheric disturbances is the usual notched lightning arrester, working in conjunction with reaction coils and condensers. All the devices are placed on the front of the switchboard, the connections are in the rear, and the rheostat resistances are placed in a cupboard underneath. In order to facilitate access in case of repairs and accidents, a passage is provided between the rear of the switchboard and the wall. This passage is closed by a door.

The tramway consists of two diverging branches; one is 12½ kilometres in total length, and the other 5 kilometres, with a maximum gradient of 6 per cent. over a length of 300 metres. Two uninsulated cables start from the switchboard, and supply current to the trolley wires.

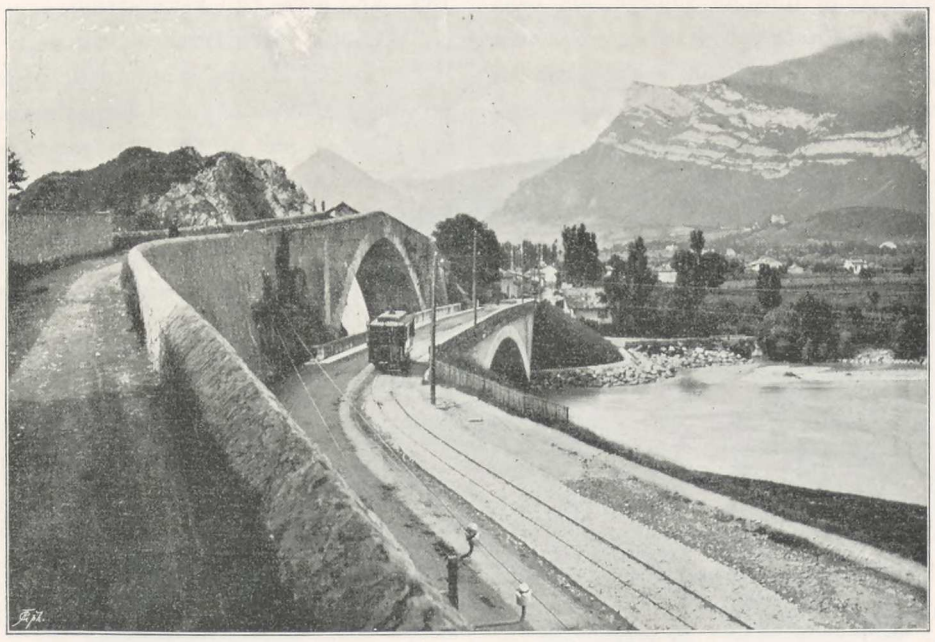


Fig. 340. Electric Tramway.

For one of the branches the cable has a section of 180 square millimetres (.279 square inch) for one-half the length of the line, and a section of 50 square millimetres (.078 square inch) for the other half.

For the other branch, the feeder has a section of 110 square millimetres (.171 square inch) for part of its length, the section at the other end being 50 square millimetres (.078 square inch). The feeder and contact wires are united every 300 metres.

In the interior of the town, the trolley and bracket poles are formed of iron tubes socketed in each other, and secured at the sockets by means of ornamented rings. Their lower end is let in a concrete foundation to a depth of 2 metres. In the streets, where the track is alongside the pavement, the poles are provided at the top with tubular arms, to which are fixed the trolley-line insulators. Where the line is in the centre of the streets, steel wire stretched between iron poles, or fixed in the walls of opposite houses,

serves to carry these insulators. The line, of hardened copper wire, is 6.250 metres (20.6 ft.) above the track where the poles stand; these are 35 to 40 metres apart, and the maximum deflection for this distance is not over .240 metre (say, 10 in.), so that the minimum height of the line above the track is 6 metres (19 ft. to 20 ft.). Outside the town wooden poles, impregnated with cupric-sulphate, are used, the arms being of the same type as those fixed on the iron poles. The feeders rest also on wooden poles, and along the track they rest on the same poles as those used for the trolley wire. The track is 1 metre (3 ft. $3\frac{3}{8}$ in.) gauge, with rails 36 kilogrammes per metre (72 lb. per yard) in the interior of the town; outside the town it is formed of Vignole rails 20 kilogrammes per metre (40 lb. per yard). As the return current is brought through the rails, these are connected by means of copper fishplates; besides this, transverse conductors join the two lines of rails forming the track.

The rolling stock consists of nine automotor cars, each with two motors; nine hauling cars, and two goods vans. They have two driving axles and multiple suspension, the body resting on the frame with the interposition of springs, which insure a very smooth running. These cars hold 38 persons, namely 6 first class and 32 second class, of whom 20 stand on the platforms in front and in the rear. Couplings at each end enable the cars to be hauled, in case of accidents.

The motor inductor and armature coils are wound in series; the motors are of tetrapolar type, with two inductor coils only, the cast-iron shell being in two parts, hinged together. The toothed armature is ring-shaped, with two carbon brushes on the commutator. Each motor is suspended under the body of the car by two springs, which work in opposite directions; and it rests besides on the axle, which it drives by toothed-wheel gearing at a ratio of 4.5 to 1. The motors run at a speed of 600 revolutions, and develop normally 25 horse-power. At the present time, owing to the use of cast steel instead of cast iron, tram motors of the same speed as those above, and taking up an equal amount of space, develop normally 30 horse-power. The circuit opening of the motors and the speed regulation are effected by the working of the starting gear, fitted on both ends of the cars by means of a detachable lever. The motors are always grouped in multiple; a special current reverser enables a damaged motor to be easily disconnected. Speed regulation is obtained by gradually inserting in the motor circuit, metallic resistances controlled by the driver. When the working lever is vertical, the motor circuit is cut off; in moving it to the right, the current goes progressively to the motors; while in moving it to the left, the motors are short-circuited on the resistances. If at that moment the cars are moving, the motors work on the resistances, which act as a brake, without wearing the mechanical parts, and especially without taking power from the central station.

The trolley through which the current is taken by sliding contact is spoon-shaped; it is fitted at the end of a metallic tube, and made to turn horizontally. The tube is movable round a centre, and is guided in a cast-iron socket, mounted on a pivot fixed on the roof on the centre line of the car. Two compensating springs unite the trolley bar to the cast-iron socket, and insure a generally constant pressure on the contact wires. Each car carries a safety arrangement for the motors; it consists of a lightning arrester and a fuse cut-out, each provided with a magnetic spark-arrester, which acts on the arc, produced in the safety apparatus by atmospheric disturbances or by a short circuit of the motors.

The inside lighting of each car is insured by five incandescent lamps, of 16 candle-power, connected in series on the 500 volts of the line, and arranged so that the extinction of one does not entail the extinction of the others. The car discs are lighted by five incandescent lamps of 10 candle-power, connected in the same way as the former.

The tramway in question has been in work since April, 1897, and gives full satisfaction.

Various Electrical Work.—In Figs. 341 and 342, Plate LXXVII, are some further examples of the work produced in the Electrical Department at Creusot. Fig. 341 is a view of one of the large armatures made by Messrs. Schneider and Co.; Fig. 342 is a standard type of electric light plant for the French Navy; and Figs. 343 to 346, Plate LXXVIII., are illustrations of a three-phase alternator and motor of which many are constructed in the department.

Three-phase Motor.—For sizes below 8 horse-power, the field magnet in this type is fixed and the armature made to revolve with closed winding. The inductor winding is annular with star connections. It consists of a laminated annular core, provided with grooves open on the inside circumference, and which receive the coils. The inductor core is on a gun-metal shell, on which are fitted cast-iron bearing blocks fixed to the motor frame. A grooved ring of plates on a cast-iron centre keyed to the shaft forms the revolving armature. The armature, drum-wound, is fitted with copper bars placed in the grooves and united, so as to establish a short-circuit winding.

For motors above 8 horse-power the armature is fixed, and the inductor made to revolve. The fitting of the movable part is similar to that of the motors above described, but the winding is different. The inductor is drum-wound, and receives three-phase currents through the intermediary of rings placed on the shaft, and metallic brushes. The armature is drum-wound and two-phase in order to attenuate the variations in elements in the various positions of the inductor with regard to the armature. The grooved plates, as with the small motors, are fitted together direct on a cast-iron shell bolted on the frame which carries also bearer blocks, the bases of which are placed concentric with the shaft.

For starting with an element superior to the normal, without occasioning the intensity to reach an excessive figure, liquid rheostats are interposed in the two-phase circuits of the armature. Increase in speed is obtained by

THE ELECTRIC CONSTRUCTION DEPARTMENT.



Fig. 341. Transporting a Large Armature.

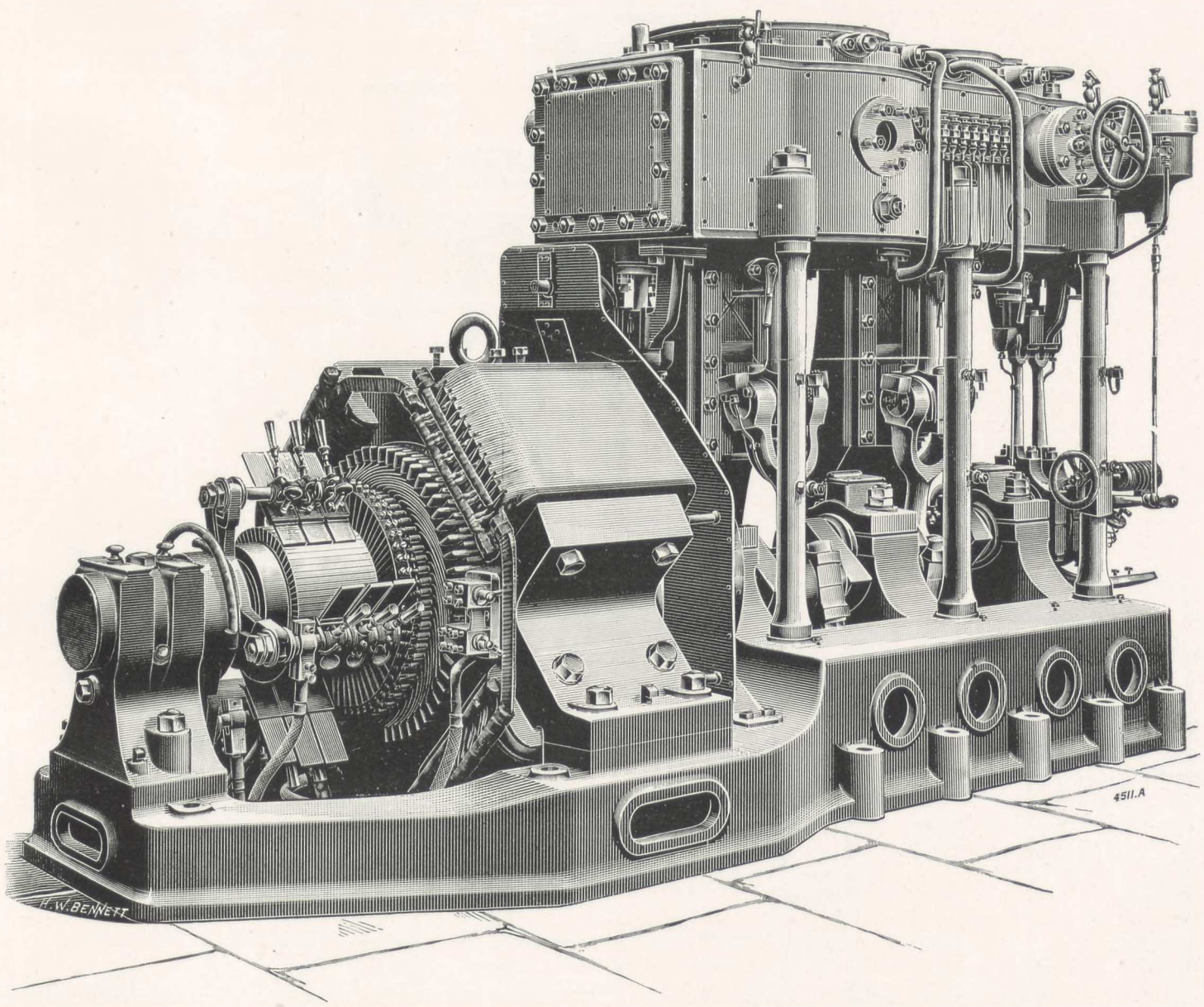


Fig. 342. Electric Light Plant for the French Navy.

THE ELECTRIC CONSTRUCTION DEPARTMENT.

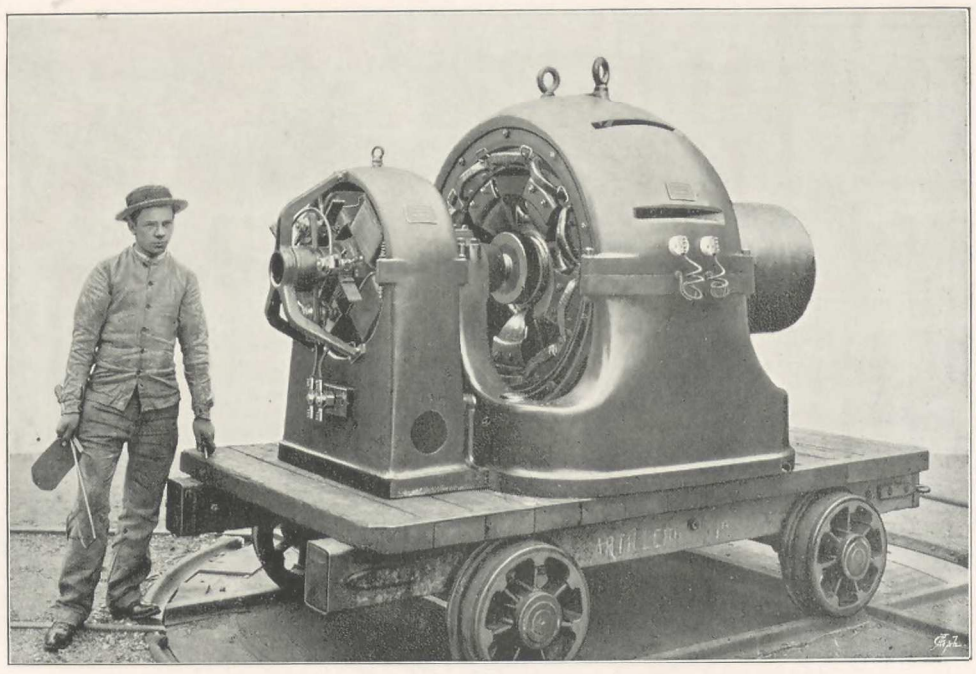
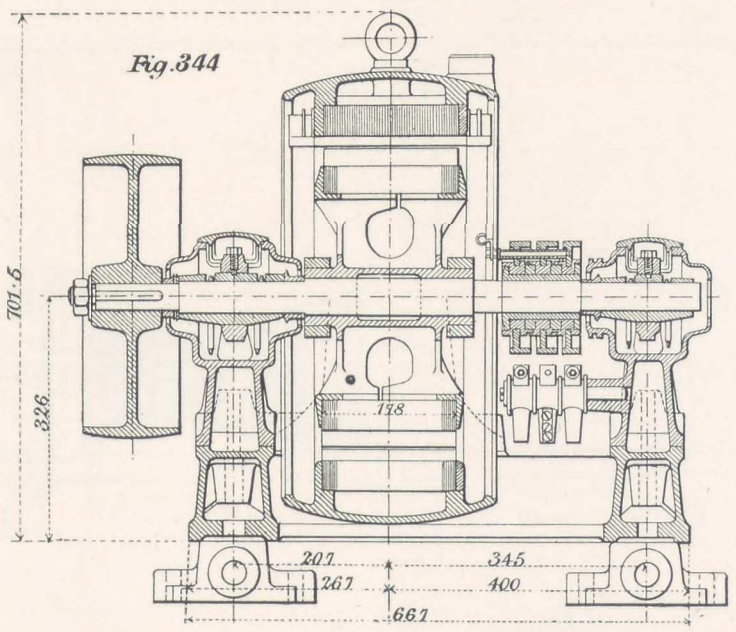
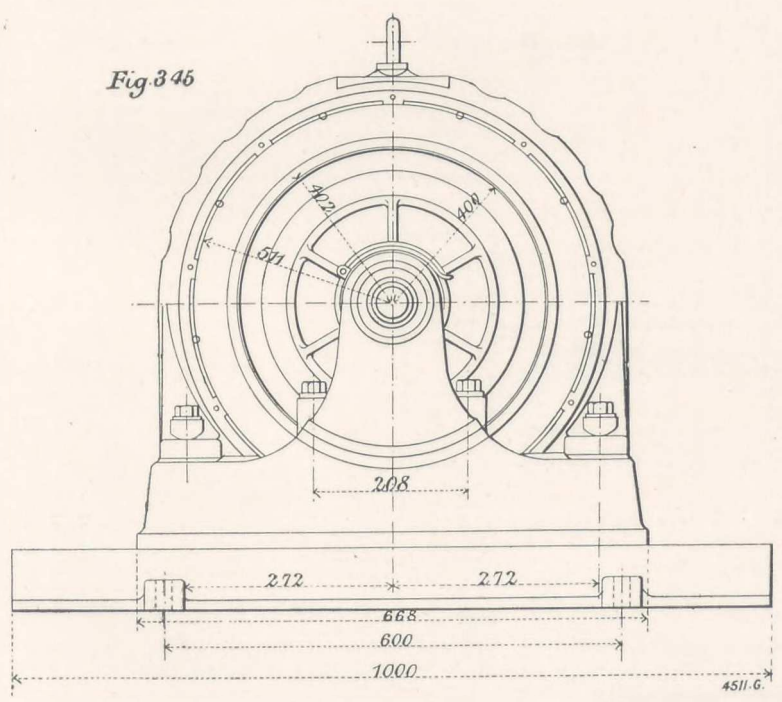
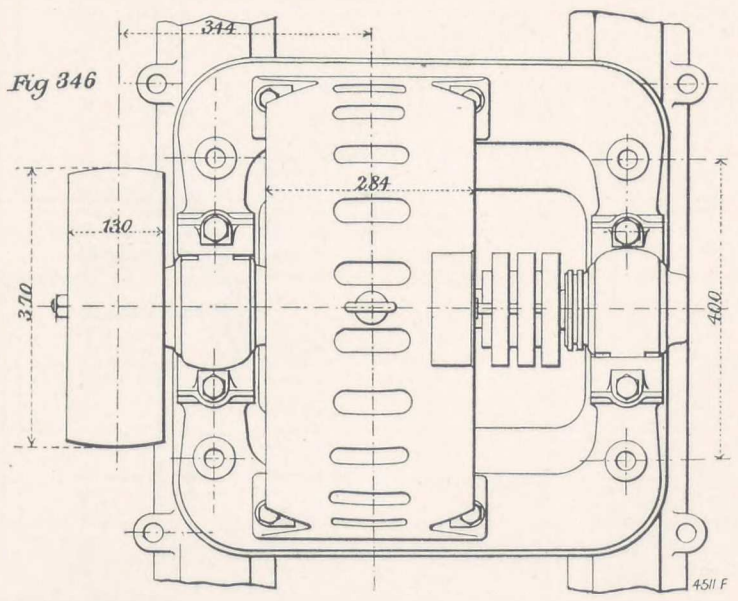


Fig. 343. Three-Phase Electric Alternator.







Three-Phase Electric Motor.

THE ELECTRIC CONSTRUCTION DEPARTMENT.

Fig. 347

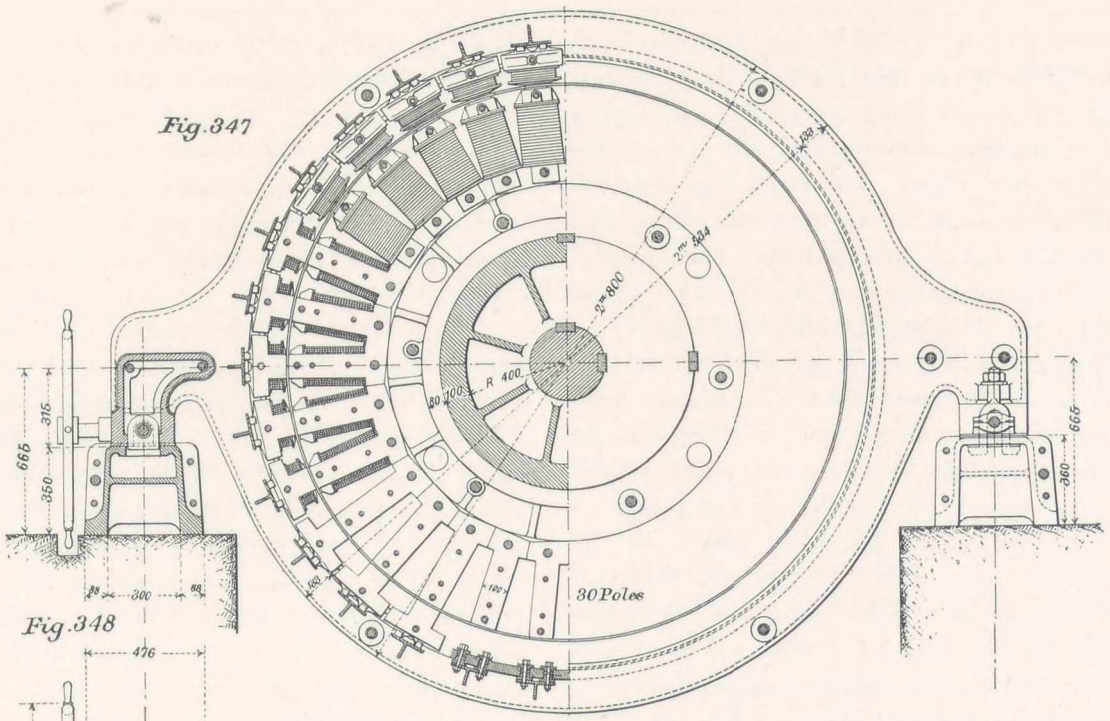


Fig. 348

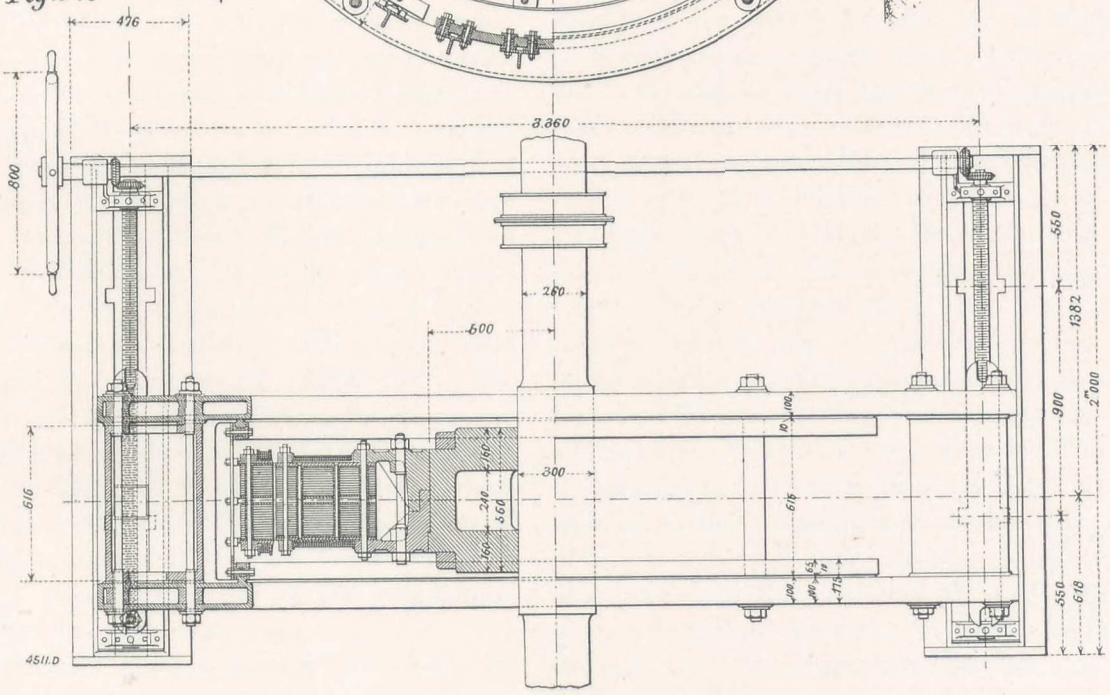
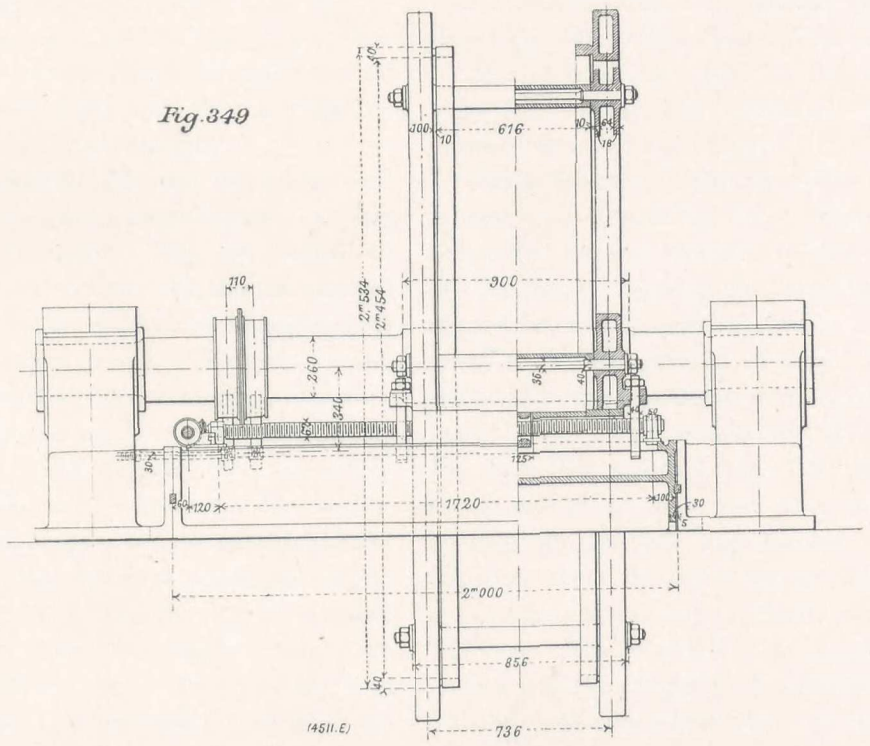


Fig. 349



Three-phase Alternating Machine.

diminishing the liquid resistance progressively, and when the normal speed is obtained a special arrangement places the armature coils in short circuit.

The complete series of three-phase motors made by Messrs. Schneider and Co. range from $\frac{1}{100}$th of 1 horse-power to 120 horse-power; the efficiency and power factors are high. For instance, the 3 horse-power machine has an efficiency of 80 per cent., and as power factor, 75 per cent in full load, with a slip of from 4 to 5 per cent.

Single-Phase Transformers.—The single-phase transformers built by Messrs. Schneider and Co. are on the Ganz system; they are of the cased-in type, with closed magnetic circuit formed of two piles of sheets E-shaped, joined together, with the horizontal arms placed opposite each other between four wrought-iron uprights. The primary and secondary coils, one above the other, are lodged in the recesses thus formed. In the manufacture of the primary coils, high conductivity copper wire is used generally; while for the secondary ones, flat copper bands are used, as with these a better utilisation of the space available is insured. As the coils in this type of transformers are in direct contact with the metallic parts of the magnetic circuit, their perfect insulation is of great importance, and requires all the care and attention of the manufacturers. The minute attention given by Messrs. Schneider and Co. in the choice of the insulating material and in the preparation of the coils, has enabled them to obtain an insulation which can sustain without inconvenience, a current of 15,000 volts. The transformer rests on porcelain insulators, in which are enclosed the lower ends of the uprights. The coils, placed vertically, are protected by a sheet-iron cover, which envelopes the transformers and facilitates ventilation in the same time, by forming a conduit for the ambient air. A cast-iron plate placed at the top of the transformer carries the terminals and the lifting rings.

Of these transformers, eight types are built from 500 watts to 25 kilowatts. The efficiency varies from 90 per cent. for the small, to 97 per cent. for the large, type. For those of 1 to 25 kilowatts, the total potential fall, from no load to full load, is not above 2 per cent. on non-inductive circuits, and 5 per cent. on inductive circuits.

Three-Phase Transformers.—Messrs. Schneider and Co. make 11 types of three-phase transformers, varying in power from 2 to 100 kilowatts. They are formed of laminated columns, square in section, with angles rounded off and placed at the angles of an equilateral triangle, their ends being united by V-shaped pieces. The primary and secondary circuits, star-connected, consist of concentric coils which envelope the columns, leaving free spaces to facilitate ventilation and insulation. The primary and secondary coils are manufactured in the same way as for the single-phase transformers, and can resist a tension of 15,000 volts without inconvenience. Two cast-iron plates, on which rest four holding-down bolts, render the whole machine secure; the lower plate is fitted with stands, and the top one is provided with a lifting ring. The primary and secondary terminals, mounted on porcelain insulators, are fixed on the lower V-shaped piece under the coils. A perforated plate, which rests on the uprights, envelopes the transformer; three openings in the envelope, which are closed when the transformer is working, give free access to the coils and terminals. Trials made with a 75-kilowatt transformer have shown an efficiency of 97.5 per cent. in full load, and a total potential drop of 2 per cent. between no load and full load on a non-inductive circuit.

Three-Phase Alternators.—The three-phase alternators and motors built by Messrs. Schneider and Co. are of the Ganz system. They are fitted with a revolving armature and fixed coils, and are therefore without movable contact The revolving part is of cast steel keyed on the shaft and is made with laminated polar projections. The exciting coil, the centre of which is on the axis of the shaft, generates the current which goes through two distinct armatures; the total number of turns in the winding of these is in the ratio of 1 to .86. As the right-hand polar projections extend beyond the left-hand ones over one-fourth the angular space between two neighbouring poles, there results in the armatures a difference of 90 deg. in the succession of currents; these, grouped according to Scott's system, give the difference of 120 deg. at the dynamo terminals. The part of the armature coils opposite the revolving mass is formed of laminated segments, fitted together in a cast-iron shell; this shell completes the magnetic circuit, and is embodied in the frame. The inductor coil is supplied by an exciting tetrapolar dynamo, placed on the end of the shaft opposite the pulley. The alternator shaft carries the armature and commutator; the inductor poles, fitted with branches, the fields of which are inclined on the generatrices of the armature drum, are set in a cast-iron shell fixed to the frame. This type of alternator can yield simultaneously single-phase and three-phase alternating currents. In alternating the coils in a suitable way, two-phase currents can also be obtained, without modifying the general system of manufacture. (See Figs. 347 to 349, Plate LXXIX.)

Messrs. Schneider and Co. build six machines of this type, from 42 to 280 kilowatts; their efficiency varies between 90 and 91 per cent.

Paris Electric Lighting.—One of the most important contracts for electric lighting hitherto completed by Messrs. Schneider and Co., was that for the Sector on the left bank of the Seine, forming an important part of the Paris Municipal electric lighting scheme. The concession for the great work was granted on December 11, 1890. The area included in the concession comprised the whole of the left bank of the Seine within the Municipal limits, and the Iles de la Cité and St. Louis. The distance from the station to the end of the concession was about 7 miles, and it was decided to generate high-tension currents (3,000 volts), reducing them by transformers before distribution. The generating station is at Grenelle, near the Point du Jour Viaduct. The works occupy an area of 13,000 square metres, and the company (Compagnie du Secteur de la Rive Gauche) possesses a coal wharf on the Seine. The leading

dimensions of the boiler-house are: Length, 94 metres (308 ft.); width, 18 metres (59 ft.); height to springing of roof, 10 metres (32 ft. 9 in.). The engine-house is an iron-framed structure 105 metres (344 ft. 6 in.) long, 16 metres (52 ft. 6 in.) wide, and 12.50 metres (41 ft.) high. The boiler and engine-houses are connected. The total capacity of the boiler-house is for 20 generators, arranged in four groups of five boilers each; of these 18 would be sufficient to supply the maximum requirements of the sector, leaving two in reserve. The engine and dynamo-house is large enough for 10 groups, of which eight would meet the maximum demand, leaving two in reserve. The boilers are of the multitubular type, with groups of tubes fixed inclined in a fireclay setting, and a steam receiver above. The following are the principal dimensions, &c., of these generators:

Registered working pressure ...	12 kg.	170 lb. per sq. in.
Heating surface of tubes ...	183.20 m²	1972 sq. ft.
Total heating surface	210.00 m²	2260 sq. ft.
Grate area	4.50 m²	48.44 sq. ft.
Number of tubes	108	108
Outside diameter of tubes	100.0 mm.	3.94 in.
Length of tubes	5.4 m.	17.8 in.
Water space	13.3 m.³	469.71 cub. ft.
Steam	4.9 m.³	173.05 cub. ft.

The engines that drive the exciting machines run at a speed of 200 revolutions, and have an indicated horse-power of 125. The dynamos are alternating-current machines of the Zipernowsky system, with 40 poles; they each have a capacity of 400 kilowatts at 3,000 volts, their normal speed is 125 revolutions, and they weigh 23 tons. The exciting dynamos are of the ironclad type, with six poles; their normal capacity is 300 amperes and 110 volts, with a speed of 200 revolutions.

The main engines are compound horizontal with two cylinders, and driving the same shaft; they can be worked with condensers, or with direct exhaust. Steam is distributed by piston valves operated by eccentrics on an extension of the main shaft; the low-pressure distribution valve is keyed to the shaft; that for the high-pressure cylinder is a

Fig. 350

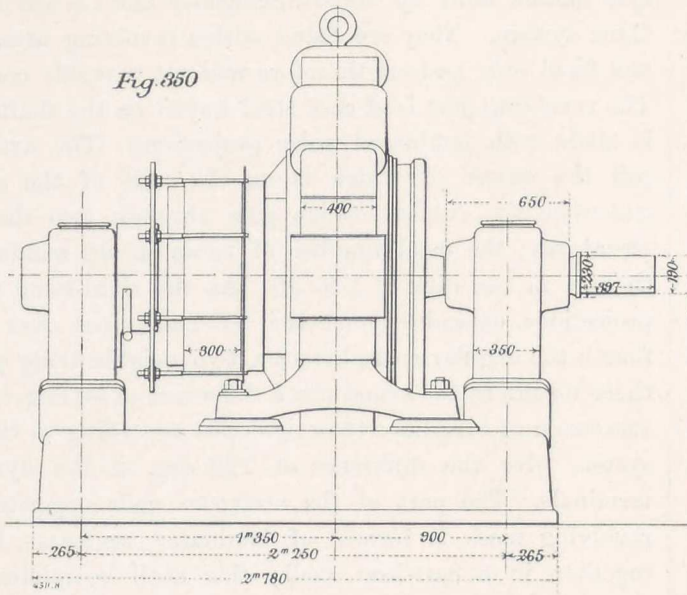
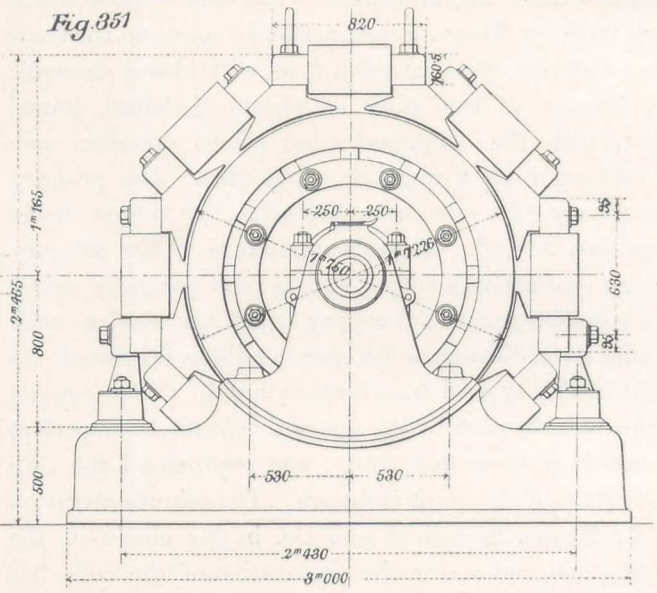


Fig. 351



Eight-Pole Continuous-Current Dynamo.

Fig. 353.

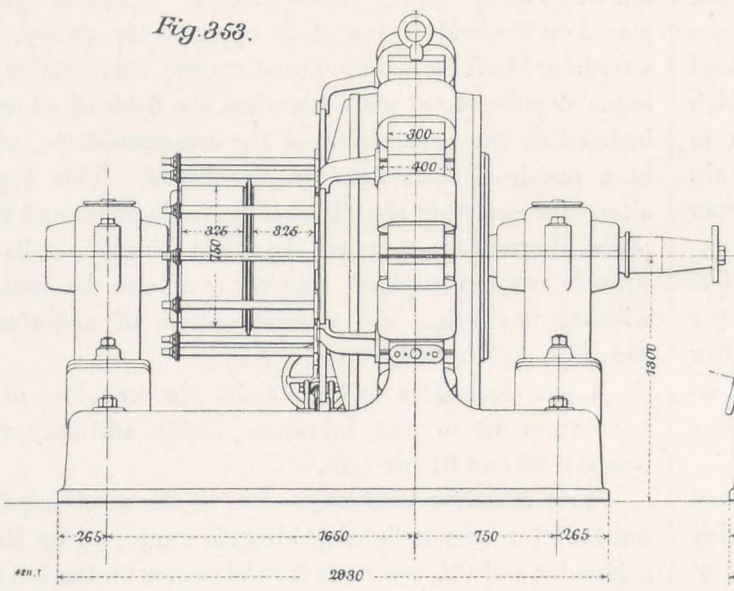
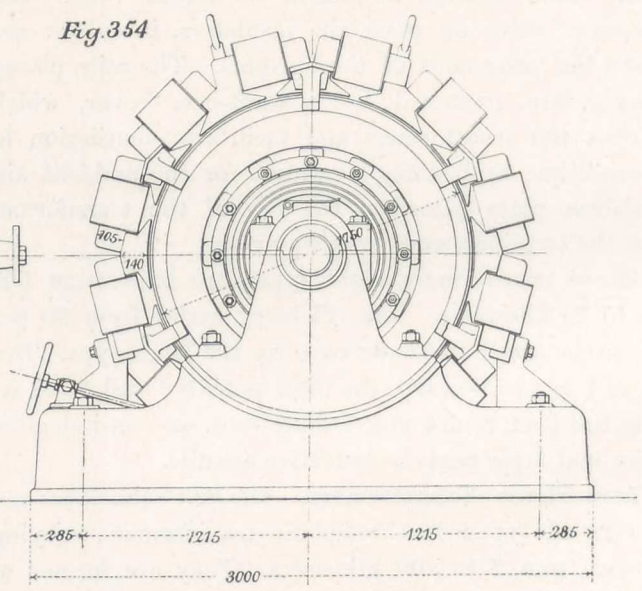


Fig. 354



Twelve-Pole Continuous-Current Dynamo.

part of the regulating device, and is mounted on a separate shaft; the range of steam admission varies from zero to half-stroke. The following are the leading dimensions of these engines:

Diameter of high-pressure cylinder	.550 m.	21.653 in.
,, low-pressure cylinder ...	.850 m.	33.464 in.
Length of stroke	.900 m.	35.433 in.
Number of revolutions	125	125
Initial pressure on small piston ...	8 to 9 kg.	113.8 to 128 lb. per sq. in.
Indicated horse-power	700	700

The whole of the machinery connected with this large installation was furnished by Messrs. Schneider and Co.

Electro-Chemistry and Electro-Metallurgy Dynamos.—Important industries have been developed of late years in the production by electrolysis of soda, chlorate of potash, aluminium, and carbide of calcium. Appended are notices of several types of dynamos manufactured by Messrs. Schneider and Co. for such industries.

800 Horse-Power Dynamos.—Octagonal 800 horse-power, self-exciting, 700-volt dynamos, on the Thury system, for the manufacture of chlorate of potash, have recently been built at Creusot. Each dynamo consists of a magnetic shell, formed of eight electro-magnet cores supporting the inductor coils and eight branches bolted on the magnets. Two lifting rings facilitate the handling of this arrangement; it rests on a cast-iron frame with the interposition of cast-iron supports, gun-metal wedges and mica sheets, which insure the magnetic and electric insulation of the mass. This machine is illustrated by Figs. 350 to 352.

The armature is drum-wound; it consists of a laminated smooth ring, mounted on connected reglets of a cast-iron studded nave keyed on the shaft. The reglets carry, by means of arms cast on them, the cast-iron socket which acts as a nave for the commutator, this being driven by a disc keyed on the shaft.

Rolled-out cables constitute the armature conductors; they are connected by means of strips, protected against the effects of centrifugal force by a coupling circle in two parts. The coils are fixed by a certain number of steel wire hoops, which press the conductors on the smooth surface of the ring. Carbon brushes, 72 in number, are mounted on eight insulated copper rods, fixed on a cast-iron circular plate, worked by screw gearing carried by the bearing block on the commutator side. The bushes are lubricated automatically; the level of the oil in the boxes can be ascertained at any moment.

The dynamo is, when possible, worked by turbine, by means of a Raffard coupling-box. Its speed is 240 revolutions, and it does not spark when under full load. This type has invariably given most complete satisfaction.

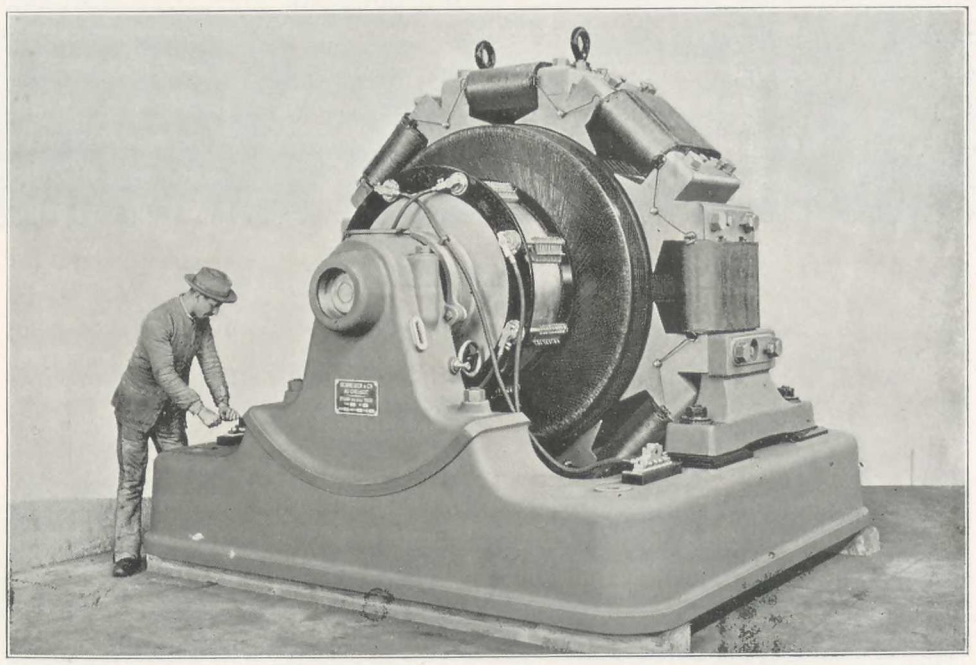


Fig. 352. Eight-Pole Continuous-Current Dynamo.

Self-Exciting 450 Horse-Power Dynamo.—This is also of the Thury type, but is a 12-pole machine (see Figs. 353 and 354, and Fig. 355, Plate LXXX.); a number of these dynamos have been manufactured at Creusot. The method of construction of the inductor and armature and the winding are practically similar to those of the machines just described. As this type, however, gives 100 volts and 3,000 amperes in full load, the commutator is made wide and small in diameter, compared with that of the armature. It has been found necessary, in consequence, to place a hoop in the middle of the commutator, to prevent deformations which might otherwise arise in erecting, during the tightening of the segments.

The carbon-holder rods are connected to a cast-iron circular plate, guided by six gun-metal supports, maintained by screws on the shell. The displacement of the brushes

is effected by a wheel, which works a screw that acts on a nut forming part of an arm fitted to the plate.

These dynamos are perfectly driven by a turbine, the speed of which is 260 revolutions; it carries a wheel keyed direct on the dynamo shaft.

500 Horse-Power Dynamo. — Twelve-pole Thury dynamos have been constructed for electrolytic soda manufactories. They can each supply a current of 5,000 amperes, at 75 volts; they are built with two commutators, and two different armature windings, placed across the same core.

The armatures are ring-wound, and the coils enclose bars lodged in open grooves. The carbons, 360 in number, are arranged on each brush-holder, in the same manner as in the last machine above described. Their displacement is also effected by two screwing devices. The turbine wheel is keyed on the end of the dynamo shaft; it runs at 250 revolutions per minute.

700 Horse-Power Alternator.—Several of these alternators, built by Messrs. Schneider and Co., are in use at various works for the manufacture of carbide of calcium. They are of the Thury type, with undulatory current; they include two armatures, without movable coils. The shell is of cast iron, in two parts, fitted together horizontally. It carries two cast-iron sockets, in which are fitted the armature coil core-plates; each of the armature windings consists of a certain number of coils, formed of bars united together by evolvent joints. The ends of the coils are welded on copper coupling-circles placed each side of the dynamo and provided with movable connections which allow of obtaining, by a simple shifting, a variable voltage as required in the various phases of manufacture. Strong copper rods unite the coupling-circles to the terminals; each of these consists of two gun-metal blocks fitted together and fixed to the frame. (See Fig. 356, Plate LXXX.)

The inductor constitutes the rotary part of the machine; it consists of a cast-steel block, carefully balanced, provided with polar projections, which revolve opposite the armature cores. The magnetic current necessary for working is created by an annular exciting coil, held in a groove inside the shell, between the two armatures. In full load, the exciting does not exceed .2 per cent., and the efficiency reaches 95 per cent. This dynamo combines strength with high efficiency under a wide range of conditions, in quite a remarkable manner. It was originally designed for a speed of 600 revolutions, and exhaustive trials have proved that it can be allowed, without any danger, to run at more than double that speed.

THE ELECTRIC CONSTRUCTION DEPARTMENT.

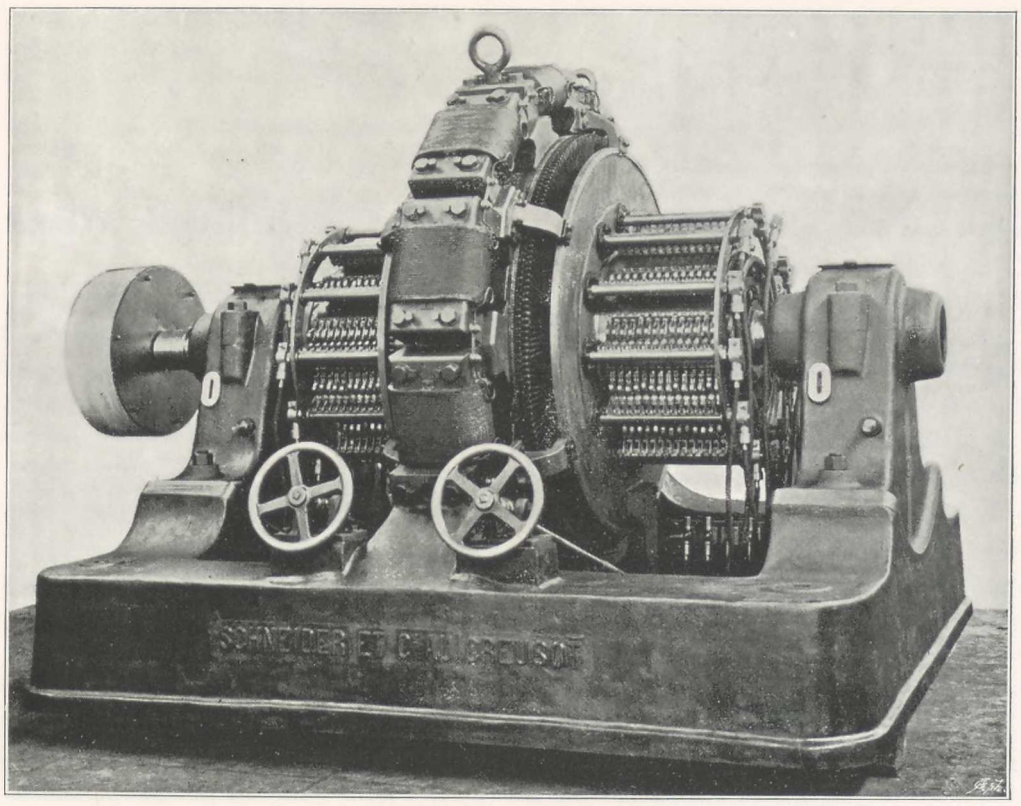


Fig. 355. Twelve-Pole Continuous-Current Dynamo.

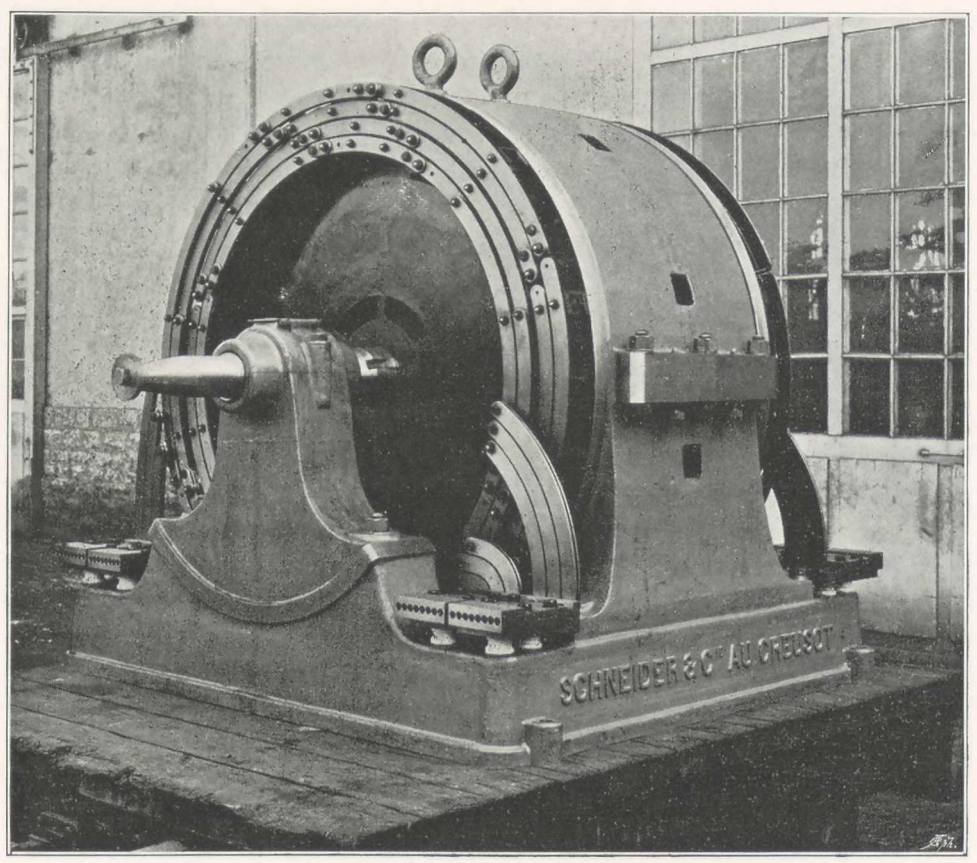


Fig. 356. Alternating-Current Dynamo.

XXI.—SHIP AND BRIDGE-BUILDING DEPARTMENT, CHALON-SUR-SAÔNE.

History.—The shipbuilding and bridge-construction yard belonging to Messrs. Schneider and Co. is situated at Chalon-sur-Saône, 40 kilometres (25 miles) distant from Creusot, though it forms a part of the works.

Messrs. Schneider established this yard in 1839. During the first four years (from 1839 to 1843), there were not more than 40 or 50 workmen employed, as boiler-makers, rivetters, carpenters, smiths, labourers, &c. The tools were of a primitive kind, and consisted almost entirely of punching and shearing machines, worked by hand. There were but two buildings, a small shed covering the machine tools, and a house, the ground floor of which was occupied by the two forges, the first floor containing the manager's office and the foreman's lodging. At that time the yard was used exclusively for the building of iron boats, those first completed being the "Allobroge," "Ville de Turin," "Citis," &c., and this fact caused the yard to be styled the "Bateau de fer," a name under which it is often now called in the district. In 1843 the yard acquired more importance, Messrs. Schneider and Co. having put down a 10 horse-power steam engine and machine tools worked mechanically, such as punching and shearing machines, lathes, &c. Besides this, the number of forges was increased. Very shortly after, the company launched the first tug, "Le Griffon," which was built for the Saône navigation; then followed larger boats for service on the Rhône —"L'Aigle du Rhin," "La Foudre," "L'Ouragan," "Le Mississippi," and "Le Missouri;"—and later, other tug-boats for the Saône, "Le Vengeur," "La Ville d'Autun," "La Ville de Mâcon," &c.

The construction of the early French railways greatly aided the development of this department of Messrs. Schneider and Co.'s works, owing to the fortunate circumstance that Chalon was at that time the terminus of the line from Paris. From 1847, when the Paris train used to stop at Chalon, until 1854, when the line was carried as far as Lyons, the Chalon yard enjoyed a most flourishing period. Messrs. Schneider and Co. then built all the large transport boats for traffic on the Rhône, such as "L'Océan," "La Méditerranée," "Le Mistral," "Le Sirocco," "Le Crocodile," "Le Marsouin," &c.; the grapnel-boats "La Ville d'Arles," "La Ville de Beaucaire," and "La Ville de Valence," which served to help the barges over the rapids; and the passenger boats "Le Zéphir," "L'Eole," "L'Eclaireur," &c.

Besides these they built various pleasure boats, among others "La Seine," for the French Emperor; "L'Ariel" and "Le Dauphin," which were ordered by the Pasha of Egypt for navigation on the Nile. The reputation Messrs. Schneider and Co. had obtained in boat construction spread far and wide, and they executed important orders for navigation on the Po and the Danube. The plant was increased periodically, in order to keep it in relation with the work ordered; in 1853 a new machine-tool shop was built, and in the following year it was provided with a 30 horse-power engine. During the above brilliant period of ship construction, the French railways had developed in a marked degree, and Messrs. Schneider and Co. devised means of giving to this department of their works a still greater extension, by undertaking bridge-building on a large scale. The first bridges were built in 1853 for the Paris-Lyons Railway Company, and erected near the Lyon-Vaise railway station.

During the ten years from 1853 to 1863, there were built 450 bridges for French and foreign railways: the Paris-Lyons Railway; the Besançon, Saint-Dizier, Ardennes, Strasbourg, and Brives lines; the Savenay to Lorient Railway; the Dordogne lines; the Lorient to Quimper, Auray to Napoléon-Ville, Rhône to Mont-Cenis, Lausanne to Fribourg Railways; in Italy, the Civita-Vecchia bridge; in Spain and Portugal, bridges over the Tagus, &c.

During this same period they constructed other important bridge work, such as the Cherbourg swing bridge for the French Admiralty in 1858, the Brest swing bridge in 1859 for the "Ponts et Chaussées;" the latter construction, being a most remarkable one for the time, will be referred to later. The increasing development in the railways brought to Messrs. Schneider and Co. work of another kind, in the shape of locomotive tenders, which have always been one of the specialities of their Chalon department. From 1853 to 1863 they manufactured 460 bodies of tenders for the Lyons, West of France, North of Spain, Saragossa, Seville to Cordoba, Lombardy, Venetian, and other railways.

Another important speciality, due to the same cause, is the construction of iron buildings; this department completed the goods station of Bercy in 1858, the repairing and maintenance shops of the Rome station in 1859, the Civita-Vecchia railway station, that of Alicante, &c. In 1863 the motive force in the Chalon works amounted to 50 horse-power.

During the following years, bridge-building continued to flourish. In 1864 and 1865, thirty-eight bridges were constructed for the Haute-Marne Canal; in 1866, the Rio de Janeiro roller-bridge; in 1868 and 1869, a complete

series of bridges for Algiers; in 1869 and 1870, the magnificent Stadlau bridge in Austria, were among the works completed by the company. Meanwhile, Messrs. Schneider and Co. continued making progress with their shipbuilding work; they built at that time the tugboats "Anatole" and "Anna," for service on the Volga; pleasure boats for the Neva; launches for the Compagnie Transatlantique; and floating cranes for the French Navy.

When the pneumatic processes of sinking foundations came into use, Messrs. Schneider and Co. took up the method, and made a speciality of the manufacture of caissons. The first were built in 1865, and were for the Arles and St. Gilles bridges. In 1867 the engine power of the shops was increased from 50 to 80 horse-power.

During the Franco-German War, 1870-1871, the current work at Chalon decreased considerably, and Messrs. Schneider and Co. directed all their efforts to the rapid execution of orders for national defence; they manufactured at that time large quantities of ironwork for ammunition caissons, gun-limbers, siege and field gun carriages, &c.

Immediately after peace was concluded in 1871, when the country became busy in making good its losses, Messrs. Schneider and Co. continued to develop the artillery work they had commenced manufacturing during the war. In 1874 they delivered the ironwork for 1,360 gun-carriages; in 1877, 150 gun-carriages for 90-millimetre guns; in 1880, 210 gun-carriages for small calibre, siege, and garrison guns.

The bridges that had been destroyed during the war (the Athis, d'Orival bridges, &c.) were reconstructed. The French railway system was further developed, and larger numbers of new bridges were required in consequence, as well as ironwork for stations, and so forth. The Chalon works soon gained the first rank in these various constructions, and from 1874 to 1884 they delivered one bridge for the line from Lyon to Montbrison; nine bridges for the line from Bourg to Chalon; 24 bridges for the Dôle to Poligny Railway; 18 bridges for the line from Narbonne to Bize; 83 bridges for the line from Gap to Briançon; 40 bridges for the Corsican railways; besides the Vienna bridge over the Danube; the Basle bridge over the Rhine; 19 bridges for the St. Gothard Railway; 41 bridges for the Réunion Island, of which one is 100 metres (328 ft.) long in one span, over the Mât River; one 520 metres (1,706 ft.) long, with ten spans, and one 420 metres (1,378 ft.) long, with eight spans; 58 bridges for the West Argentine Railway Company; 90 spans for Senegal, and 19 other bridges for the Argentine Republic.

During the above period, General Marcille, then Major of the Corps of Engineers, devised a type of portable military bridges, capable of carrying the same loads as the fixed bridges they are destined to replace, when the enemy have destroyed a certain number of the spans. The War Department entrusted Messrs. Schneider and Co. with the construction of these portable bridges, in spans of 10, 15, 20, and 30 metres (1884-1886).

Notwithstanding this large amount of bridge work, the construction of iron buildings and marine work followed their regular course. Among the most important orders of this same period may be mentioned the Paris station of the Paris-Orleans Railway Company (1869); the machinery hall for the Paris International Exhibition of 1878; the latter work, embodying more than 4,000 tons of iron material, was executed in one year, including the time taken up by designing and erecting. It would take too long to enumerate all the marine work in detail, but reference should be made to the 10-ton floating crane for Toulon Arsenal (1873); a 50-ton pontoon-derrick for Brest Arsenal (1876); 20 coaling-barges for the Brest and Cherbourg Arsenals (1877); a slush-boat, "Le Balayeur," for Toulon Harbour (1879); two floating dock-gates for Saïgon (1879); two for Cherbourg and Lorient (1882-1884). Since the latter date, the construction of such gates has become one of the specialties of Messrs. Schneider and Co.'s Chalon works. They have built most of those of the French arsenals.

In 1885, Messrs. Schneider and Co. commenced the construction of torpedo-boats. The boilers and engines are built at Creusot, and the hulls and armament in their Chalon yard, the torpedo-boats being delivered complete afloat at Toulon.

The first order they secured in 1885, from the French Government, numbered 11 torpedo-boats 35 metres (114 ft. 10 in.) long, of 20 knots speed. In 1887-88 they built ten similar boats, and one 34 metres (111 ft. 6 in.) long, of the same speed, for the Japanese Government. The French Navy further ordered three torpedo-boats 34 metres (111 ft. 6 in.) long, of 20 knots speed, and five 36 metres (118 ft.) long, of the same speed (1889-92); two hoisting torpedo vedette boats 19 metres (62 ft. 4 in.) long, 17 knots speed (1894); eight torpedo-boats 37,500 metres (123 ft.) long, of 24 knots speed (1897); and six hoisting torpedo-boats 19 metres (62 ft. 4 in.) long, and 18 knots speed (1898).

During the period from 1885 to 1898, the Chalon yard continued steadily developing, and the various sections were constantly in full work. Thus the bridge-building department delivered during that time to the Chilian Government more than 10,000 tons of bridges, some of which—such as the Viaduct over the Malleco, which will be described further on—are remarkable for the boldness of their design. We may mention besides, the Morand Bridge over the Rhône, at Lyons (1889-90): the Claps Viaduct, 215 metres (705 ft.) long (1890-91); the bridge over the Borcea, 418 metres (1,371 ft.) long, built in 1893-94 for the Roumanian Government; several bridges for the Jonage canal, in the vicinity of Lyons (1896); the bridges for the Longeray-Divonne railway line (1897); those for the Hanoï Lang-Son line in Tonkin (1897-98); the bridge over the Cher, at Chabris (1897); three swivel bridges for Cette (1897-98); the Hué bridge in Annam, 400 metres (1,312 ft.) long; the Fleurville bridge over the Saône, 173 metres (567 ft.) long; and lastly, the

"Alexander III." bridge, over the Seine, in Paris, one of the monumental features of the 1900 exhibition.

The building section has delivered a large quantity of framework for mines, trusses for works and factories, the most remarkable being the Creusot rolling-mill building; the Forges and Chantiers boiler shops at Mouisséques; the coal-sorting and washing sheds for the Montceau mines, near Creusot; and lastly, the railway station at Santiago (Chili), consisting of a truss without tension-rods, of 50 metres (164 ft.) span, and 25 metres (82 ft.) high.

The Public Works section has constructed a large number of caissons for compressed air foundations, notably in 1893, those for the Borcea bridge above-mentioned, which were sunk 31 metres (114 ft.) deep; in 1897, those for the Tonkin bridges, which were sunk to depths varying from 12 to 24 metres (39 ft. to 78 ft.); those for the Hué bridge (1898), &c. There have also been delivered from this section, hulls for tug-boats, slush-boats, a hull for a twin-screw dredger of 400 horse-power for Rochefort Harbour, the hulls for three suction-dredgers of 250 cubic metres (8,830 cubic feet), and for two slush carriers of 350 cubic metres (10,595 cubic feet) for Russia, &c.

The following list shows the successive development of this department of Creusot works:

Years.	Area Covered.	Motive Power.	Number of Workmen.	Ratio between the Engine Horse-Power and the Number of Workmen.
	acres	horse-power		
1839	2.471	0	40	
1843	3.707	10	150	1 h.-p. for 15 workmen.
1854	4.942	30	300	1 ,, 10 ,,
1863	5.684	50	400	1 ,, 8 ,,
1867	5.684	80	450	1 ,, 6 ,,
1876	7.414	100	500	1 ,, 5 ,,
1885	12.356	130	500	1 ,, 4 ,,
1898	16.557	310	900	1 ,, 3 ,,

Besides the torpedo-boats above-mentioned, the marine section has delivered a large number of other work, such as 50 and 16-ton floating shears for the French Government (1887); a tug-boat for the Blanzy coal mines; two steam water-boats, "Oasis" and "Filtre" (1886); a double-berthed floating dock for docking torpedo-boats in Toulon Harbour (1888); a floating dock gate for Toulon (1888); 14 towing barges, and four tugs of 1,000 horse-power for the Rhône Navigation Company; transportable lighters for the Madagascar campaign, and numerous other classes of work.

Abstract of Shipbuilding Work in Hand.—Messrs. Schneider and Co. have now (1899) on their slips, and in course of completion:—

Nine first-class torpedo-boats, 37.500 metres (123 ft. ½ in.) in length, of 24 knots speed, for the French Navy.

Six hoisting torpedo-boats, 18.200 metres (50 ft. 8½ in.) in length, of 18 knots speed, for the French Navy.

Two screw slush boats, 43.900 metres (144 ft.) in length, of 900 tons displacement, for the Russian Government.

Two paddle tugboats, 60 metres (196 ft. 10 in.) in length, of 1000 horse-power, for the Rhône service above mentioned.

One floating dock gate, of galvanised steel, for the Saïgon graving dock.

Two floating dock gates, of galvanised steel, for the Missiessy Docks, Toulon.

Two military masts for the battleship "Iena."

One backing of the Gueydon type for firing experiments for Lorient Harbour.

The most important Works at Chalon are those of Messrs. Schneider and Co. They are exceptionally well situated, as regards the transport of raw material and finished products. Placed as they are at the junction of the Saône and the Canal du Centre, they are within easy reach by water of Havre and Marseilles. They are served, moreover, by a siding line of the Paris, Lyons and Mediterranean Railway.

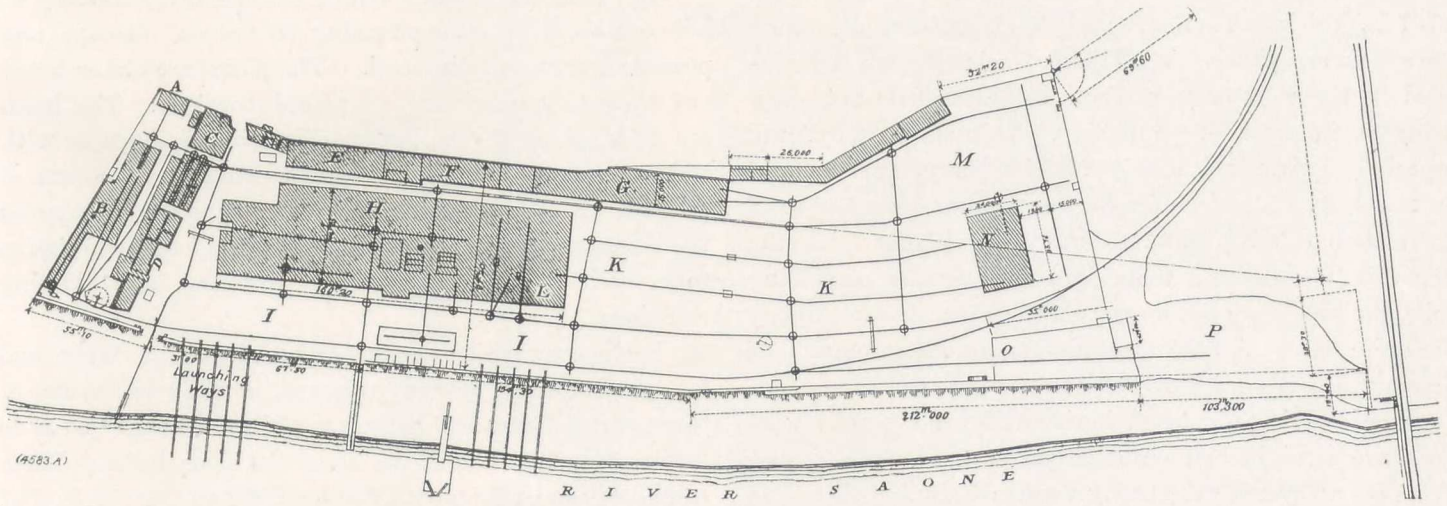


Fig. 357. Plan of Engineering and Shipbuilding Yard, Chalon-sur-Saone.

Arrangement of Works.—Fig. 357 shows the arrangement of the bridge and shipbuilding yard of Messrs.

Schneider and Co., at Chalon-sur-Saône. The following list explains the letters of reference:

A. Galvanised sheet stores.
B. Galvanising shops.
C. Joiners' shop.
D. Offices, &c.
E. Smiths' shop.
F. Stores.
G. Moulding room.
H. Machine-tool shop.
I. Boat-building slips.
K. Bridge erection yard.
L. Tender construction shop.
M. Store for plates, sections, &c.
N. Shed for planishing rolls.
O. Wood stores.
P. Depôt for finished material awaiting transport.

Dépôt of Material.—The trains which bring every morning sheets, plates, bars and sections, arrive on the siding line, the wagons being distributed direct to the various places, where unloading is effected by means of steam cranes. The sheets, plates, and wide flats are deposited in the rear of the planishing shop, while the sections are deposited opposite the straightening shop.

Planishing Shop.—This is a very light iron building; it is provided with a set of rolls for planishing plates from 3 to 30 millimetres ($\frac{1}{8}$ in. to $1\frac{3}{16}$ in.) thick, and another set for sheets $\frac{1}{4}$ millimetre to 2 millimetres (.0098 in. to .0787 in.) thick. There are also 10 slabs for finishing off the sheets and plates. The thicker steel plates are straightened in the rolls only, as the specifications do not allow using the hammer for planishing. Thin sheets only, and especially galvanised sheets for the Navy, are finished on the slabs. A series of rollers extending for a length of 25 metres (82 ft.) serve to carry the plates from the dépôt to the machine tools. On leaving the planishing rolls, the plates are put on the slabs to ascertain that they are quite flat. All the transmission is underground, thus leaving the rolls quite free of access.

Besides being planished horizontally in the rolls, wide flats are straightened on edge under a powerful press; this does away with the costly work of planing the edges, and has the advantage of leaving the webs of built-up girders rather over size; they are made flush when the angles are riveted on, thus insuring a perfect bearing.

Sections are straightened by means of hand screw-presses, which are also used for cold-bending the medium-sized sections and light ship frames. The shop containing the presses is in communication with the tracing room.

Moulding Room.—This is an iron building, fitted with tracks on which travel two $1\frac{1}{2}$-ton overhead cranes which traverse the whole of the shop length. Owing to its large dimensions, 95 by 16 metres (311 ft. by 52 ft.), full-size templates can be laid out for bridge work, iron work for buildings, and for the longitudinal moulds of boats.

There are in France two methods of laying out iron bridge and other construction work. The first consists in tracing separately from complete drawings, the pieces that are used as patterns, and in then making iron templates. By the second method, all the similar pieces are traced in the room, on a full-sized model of the piece. This second method requires a little more labour than the first, but as it gives more accurate results, it is the only one followed at the Chalon Works. To facilitate the handling of the pieces received from the planishing shop, a track runs in the tracing-room. The overhead travelling cranes unload the cars and distribute the pieces according to the tracing work in progress. In laying out ships' hulls, the methods currently in use are followed. The transverse mould which serves during the whole of the construction to determine the form of the ship and the frames is kept on movable iron floors, formed of stiff panels fitted together in numbers which vary with the size of the tracing required.

Punching and Boring Shop.—On leaving the mould-room, the templates are sent direct to the punching machines, the plates to be reproduced being brought out of store. Those sections forming types of which many copies are required, are first sent to the reproducing shop which adjoins the moulding-room, and then to the punching machines, when all the centres have been marked. Two horizontal punching machines serve for making the holes in curved frames; this saves having recourse to drilling, which is costly, and does away with the inconvenient pits near the machine, which would otherwise be necessary.

Mild steel being now generally in use, it is necessary to bore out the holes after punching to prevent damage and possible fracture of the steel. The plates are either bored out separately, or several are placed together. The holes are enlarged by the drilling machines in the shops, or with small compressed-air drills when the work is in course of erection. A 50 horse-power air-compressing engine supplies the necessary motive power, through underground mains to a series of portable boring, chipping, and riveting machines.

Boring-out and countersinking holes in large and heavy plates for marine purposes, is done by means of three suspended radial drilling machines, arranged so as to work at a height of 20 in. from the floor level. These machines can drill plates 3.200 by 1.500 metres (10 ft. 6 in. by 4 ft. 11 in.) without being shifted. A series of carrying rollers, arranged at the height of the trucks and of the machines, allow the latter to be supplied with plates with little trouble.

Riveting.—As a rule, specifications prescribe now only mechanical riveting. Two methods are in use at Chalon—hydraulic and pneumatic riveting.

The hydraulic riveting machines are placed in the machine-tool shop, and are used more especially for all light work; the pieces to be riveted are held together by bolts, and are brought on trucks under the machines which are suspended from pivoting cranes.

The pneumatic machines, on the contrary, are fixtures, being placed on the ground upon masonry foundations, underneath overhead travelling cranes which run over a space 25 to 30 metres (82 ft. to 98 ft.) in length; the riveting machines are served in front and at the back by trucks. This plant is in the centre of the erecting yard, and is used for riveting heavy and cumbersome pieces, such as parts of large bridge beams.

When the riveting processes are completed, the pieces are sent direct to the painting shed, where they are painted, marked, weighed, and delivered. Loading and unloading



Fig. 359. The Shipbuilding Yard at Chalon.

is done by means of three steam cranes, two of 10 tons and one of 4 tons. These cranes are specially arranged for rapidly shifting the load; they are fitted with buffers, and act as locomotives for hauling wagons.

Machine-Tool Shop.—The machine-tool shop contains punching, shearing, planing, drilling, boring machines, &c.; it measures 160 metres by 45 metres (525 ft. by 147 ft.). The shop is driven by a 200 horse-power Corliss engine, built by Messrs. Schneider and Co. A high-speed 150 horse-power engine is being put down to drive the dynamos for lighting and the transmission of power; this second engine will serve as a reserve in case of repairs to the Corliss engine.

Steam is generated in two sets of boilers; one set comprising four tubular boilers with inside firebox, and the other, three water-tube boilers of 100 square metres (1076.43 square feet) heating surface; these were also built by Messrs. Schneider and Co., at Creusot. These two sets of boilers are arranged so as to work together or separately. The boilers also supply steam to the steam hammers in the forges.

The machines which absorb the most power are grouped on the main transmission near the engine; among them are the hydraulic accumulator pumps which supply power for the riveting machines, and for all the chasing work, for the rolls for the shaping of plates and the manufacture of knee plates for the larger ships' frames. This machine can take plates 5.600 metres (18 ft. 4½ in.) long, and 28 to 30 millimetres (1⅛ in. to 1 3/16 in.) thick.

Smiths' Shop.—This shop is fitted with three double-acting steam hammers of 30, 10, and 8 cwt. respectively. They are used for the forging of stems, stern-posts, rudder-frames, &c., when these pieces do not exceed 30 cwt.; for stanchions, pillars, railings; for all the forged pieces for bridges, locomotive tenders, &c. This shop is in communication with the repairing shop for the tools, and the fitting shop for forged work. The smiths who shape the angles have a separate forge near the machine-tool shop.

Ship Yard.—The shipbuilding part of the department is well equipped, and work is carried out on the most modern method; the operations are confined to torpedo-boats and other vessels of moderate tonnage. The workmen are divided into two classes, one for working up sheets for torpedo-boats, launches, yachts, small tugs, &c.; and the other for plate working for tugboats, dredgers, floating gates, &c. Messrs. Schneider and Co. have gained a well-deserved reputation for the manner in which their ship work is finished. A general view of the shipyard is given in Fig. 358; and Fig. 359, Plate LXXXI. is an engraving of a first-class torpedo-boat built by Messrs. Schneider and Co.

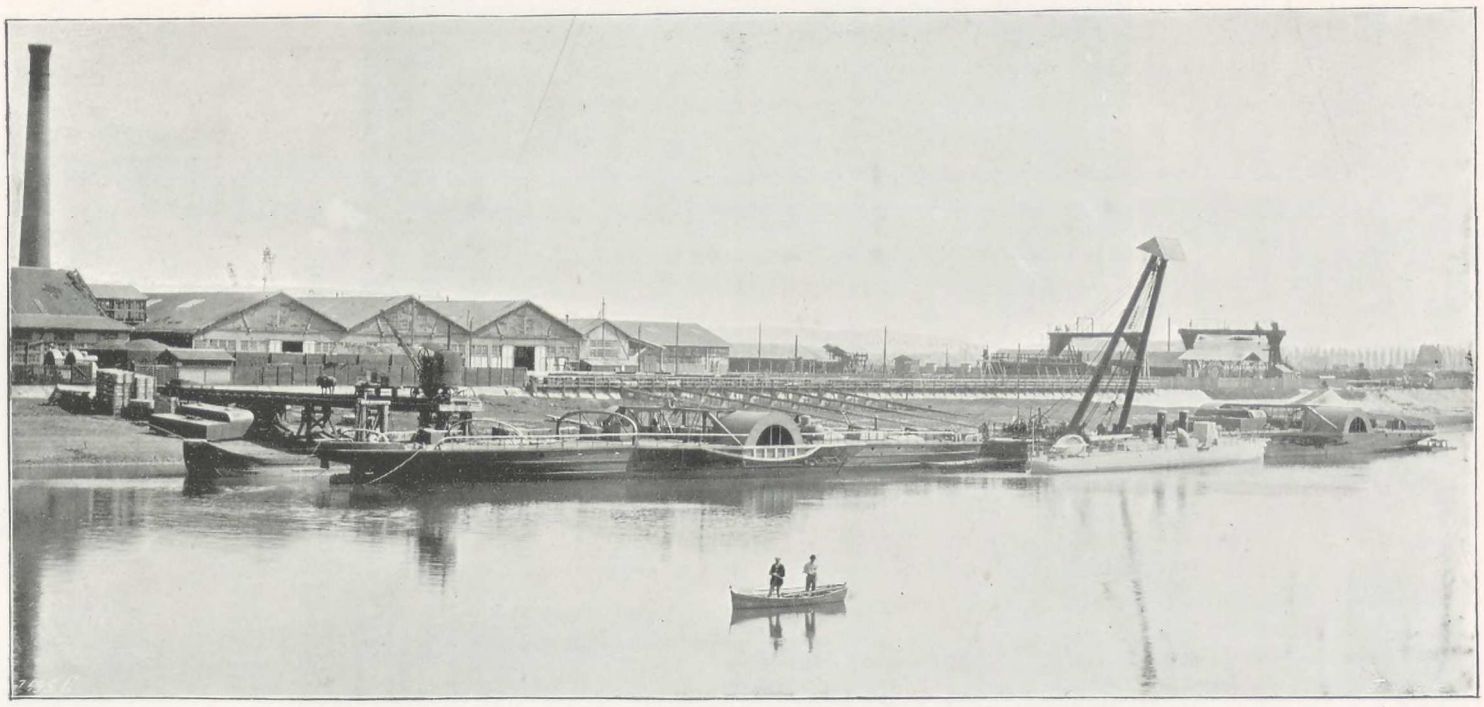


Fig. 358. General View of Chalon Works, showing Launching Ways and 1000-Ton Tugboat.

All frames for light craft are bent cold in the screw presses already referred to; those for large boats are formed on slabs by means of clamps which insure the accuracy of the shapes. The bars are heated on open fires, provided with several tuyeres which permit of heating them over a length of 1 metre at a time. When there are series of similar pieces to be worked, they are heated in a furnace 10 metres (33 ft.) long. Thin sheets are shaped cold either under small rolls or by wood templates; thicker plates are shaped under the heavy set of rolls already mentioned, the plates being slightly heated previously. Stem and stern plates alone are worked in a bed of clay, after having been heated in a furnace, as they have to undergo more elaborate processes of shaping. The building slips, which have hitherto been uncovered,

are now being roofed over by a light-framed shed, so that the work may be carried on in all weathers.

Launching.—The small depth of the Saône not allowing the usual way of launching, inclined planes have been designed for launching the hulls sideways. Two sets of slides have been laid down, with an incline of 12 in 100, ready for the launching. The speed of the hull on reaching the water is from 6 to 8 metres (19 ft. to 26 ft.) per per second. These inclined ways are clearly shown in Fig. 358, which also illustrates a part of the yard, and a 1,000-ton tugboat, built by Messrs. Schneider and Co., at Chalon.

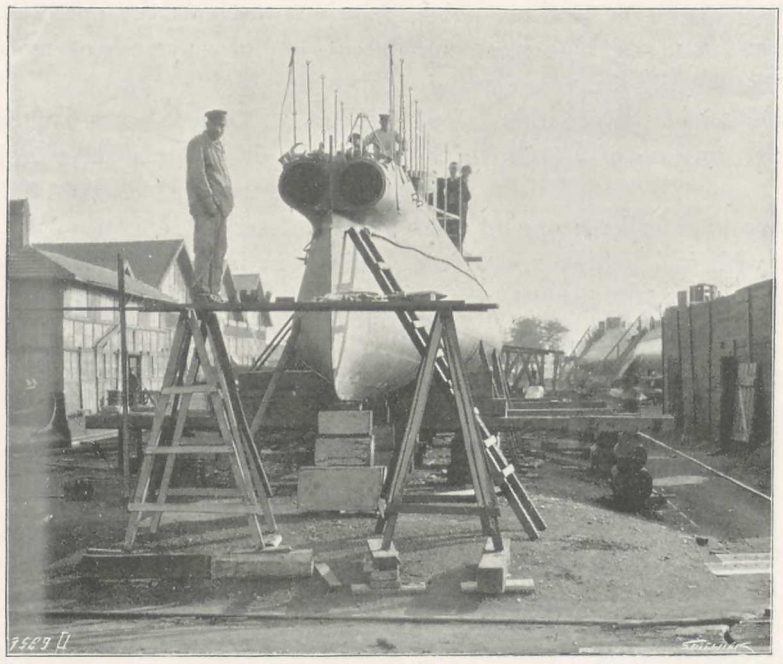


Fig. 360. The Shipbuilding Yard, Chalon-sur-Saone.

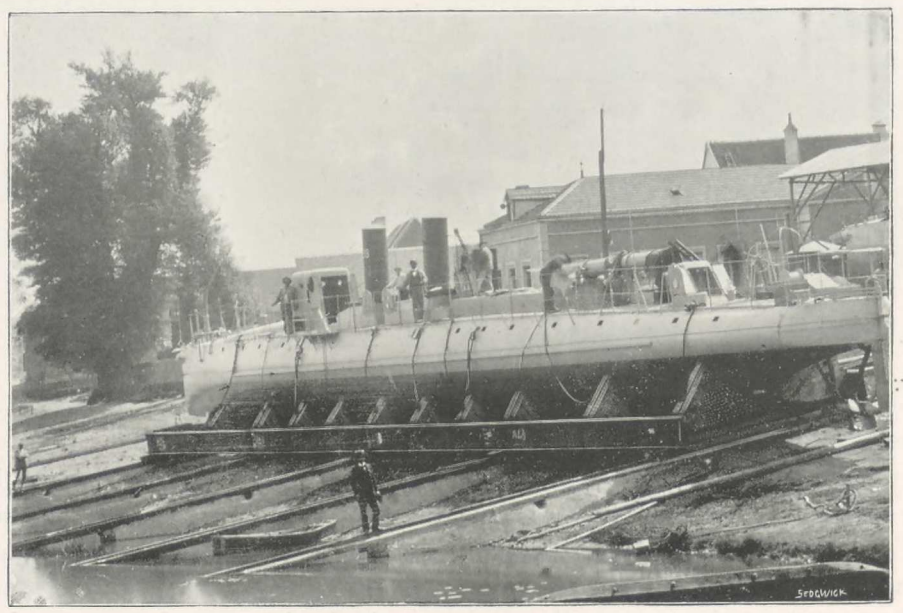


Fig. 361. The Shipbuilding Yard, Chalon-sur-Saone.

and two berths have been dredged out of the bottom of the river for this purpose. The large hulls, which are fitted with their boilers and engines when afloat, are launched over one of these berths, where the depth of water at the end of the slip and at low water is only 1.80 to 2 metres (5 ft. 11 in. to 6 ft. 7 in.). The hulls are allowed to slide direct on the slip and are held, while the blocks are being knocked out by cables which are cut when everything is

The second slip is used for launching torpedo-boats, and smaller tugboats previously fitted up with their boilers and engines. At the end of the slip the depth of water at low-water mark is 3 metres (9 ft. 10 in.). The boats are constructed on an iron cradle which rests on the slip through the interposition of oak blocks. A four-drum steam winch forms part of the launching installation; two of the steel cables worked by the winch, serve to hold back

the cradle carrying the boat previous to its reaching the water, when the resistance of the water and the friction of the timbers—these are not coated with tallow—are higher than the accelerated force of gravity.

The iron cradle serves also to pick up in the river, and to haul up the slip, the tugboats which are sent to the Chalon yard for repairs. Figs. 360 and 361 show the arrangement of these slipways; while Fig. 362 shows a first-class torpedo-boat, built by Messrs. Schneider and Co., afloat and ready for delivery down the Saône and the Rhône to Toulon Harbour.

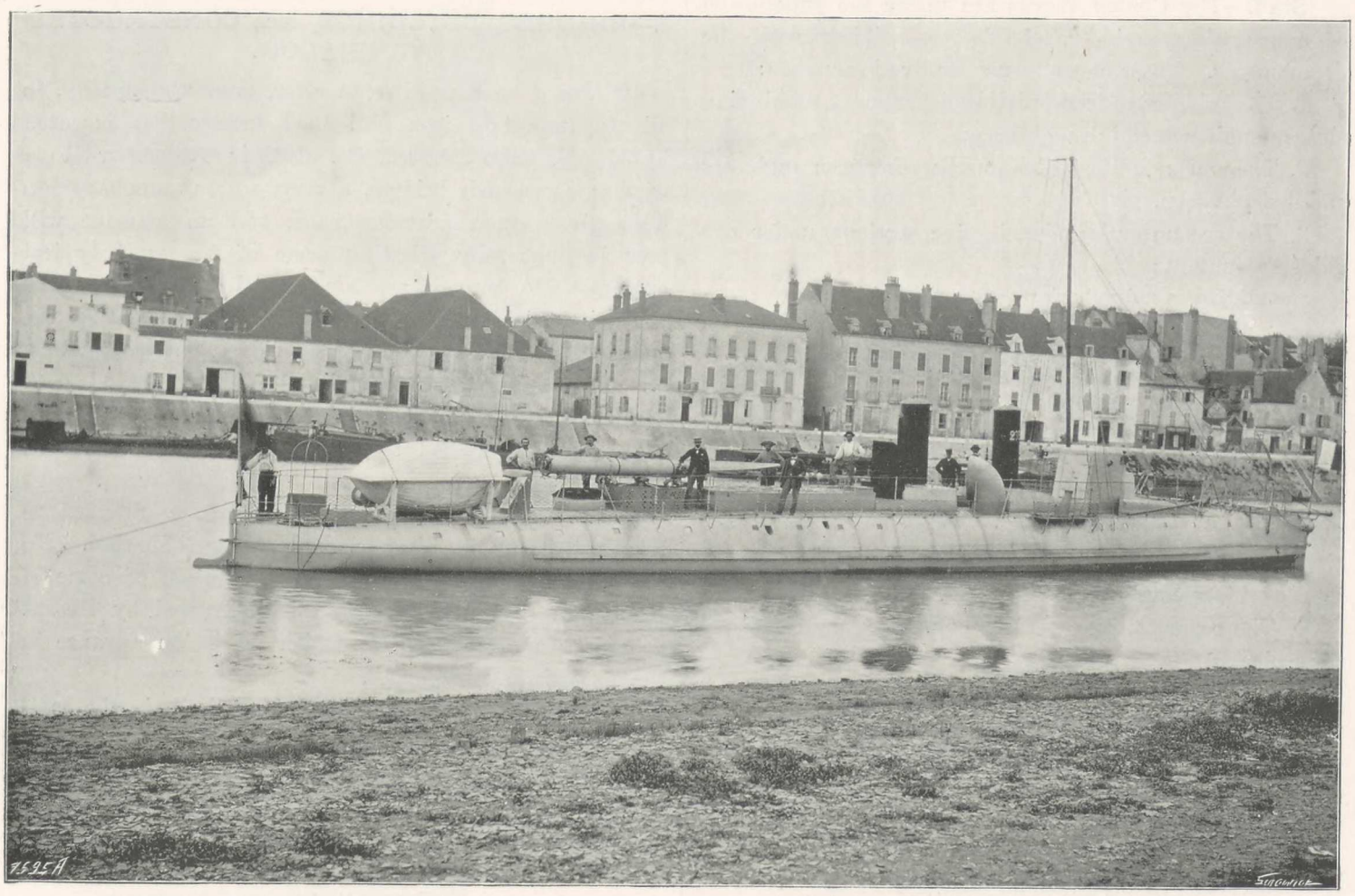


Fig. 362. First-Class Torpedo-Boat.

The putting on board and erecting of machinery and boilers for the larger boats, are effected by the 10-ton cranes, which run on the wharf; for loads above 6 or 7 tons, the 30-ton shears shown in the view are used.

Galvanising Plant.—Galvanising is one of the special industries carried on in the Chalon works. The first plant was put down in 1877, when the French Navy commenced the use of galvanised sheets and sections in the construction of hulls. In the beginning the plant was used exclusively for galvanising marine work, but subsequently it was increased for treating merchant sheets and all kinds of iron and steel work, such as lightning conductors, baths, pans, sugar moulds, &c.

The plant has been entirely remodelled recently, and consists of ten pickling tanks containing muriatic acid at 10 deg. Beaumé, and one cleaning tank, for the preparation of black sheets. As the pickling takes from 2 to 2½ hours, a large stock of pickled sheets is always prepared in advance. Before galvanising, the pickled sheets are steeped in a cleaning bath containing a weak solution of acid; they are then dried in three return-flame stoves. This process, though more costly, gives much better products than the drying by sal-ammoniac.

There are three galvanising baths constantly in work; their dimensions are the following:

—	Length.			Width.			Height.			Total Annual Output.
	m.	ft.	in.	m.	ft.	in.	m.	ft.	in.	tons.
No. 1	7.500	24	7	.650	2	2	1.500	4	11	2,800
,, 2	5.000	16	5	.650	2	2	1.500	4	11	2,400
,, 3	2.700	8	11	1.000	3	3	1.700	5	7	2,500

The capacity of the plant is therefore of 7,000 to 8,000 tons per year. This total is, however, not always reached, owing to irregularity of orders, delivery of black sheets, &c.

The baths, No. 1 and 2, serve more especially for galvanising material for the construction of boats, while No. 3 is used for galvanising merchant sheets and the various manufactured articles mentioned above. The old plant contained a bath 10 metres (32 ft.) long for galvanising

long sections, but it was done away with as too costly, and the long sections are now galvanised in two operations in the No. 1 bath. Various mechanical devices for galvanising were designed and applied at the Chalon Works some time ago; they gave more or less economical results, but to the detriment of the quality, adherence of the zinc, and appearance of the sheets. Messrs. Schneider and Co. preferred, consequently, to make a sacrifice in this respect, and to keep to their process of drying the sheets, which they plunge afterwards slowly in the bath, using for this purpose a special device which holds three to six at sheets a time, according to their weight.

Staff.—The Chalon Works are under the supervision of a managing engineer, who is responsible for all the departments. These departments are five in number:

1. The bridge and iron-building department, numbering sixteen engineers and draughtsmen.

2. The marine office, which numbers fourteen engineers and draughtsmen.

3. The accountant's office, in five sections, under one chief accountant:

a. Estimates and cost-prices section, three clerks;
b. General accounts, four clerks;
c. Stores, four clerks;
d. Labour account keeping, six clerks;
e. Salary accounts, two clerks;

making twenty accountants in all, to whom are added three clerks who have charge of the galvanising plant; the inspector of all rolled iron and steel received; the delivery clerk and storekeeper. There are, besides, four timekeepers—one for an average of 220 men—giving a total of thirty employés in this office.

4. The correspondence office, comprising one chief and three clerks.

5. The shop management, consisting of one manager, eight foremen, and one chief labourer, as follows:

Two foremen for bridge and iron building work.
Two foremen for marine work.
One foreman tracer.
One foreman carpenter and joiner.
One foreman smith and fitter.
One foreman of the galvanising plant.
One foreman labourer, over two gangs, one to keep the tools supplied, and one for loading and unloading material.

This is equivalent to one foreman for about 100 men. Each foreman has under his orders a certain number of chiefs of gangs, or chief erectors (one per class of work). There are therefore:

Managing engineer	1
Engineers and draughtsmen	30
Accountants and correspondents	34
Foremen	10
	75

for 850 to 900 workmen, or one for eleven workmen.

The technical staff occupies two large rooms, one being set apart for bridges and buildings, and the other for all marine work.

The accountants are divided among several offices, according to the work they are intrusted with, the accounts being centralised in the main office.

The correspondents are in a special office, which communicates with that of the manager.

The foremen have a desk in their respective shops.

The archives, duly classified, contain the working drawings of all the orders executed in the works from the commencement. They constitute a most useful reference.

A photo-copying room, fitted up with all the most modern appliances, serves for the preparation of plans required by the various administrations.

I.—BRIDGES, BUILDINGS, &c., CONSTRUCTED AT CHALON.

It would be impossible to refer, even very briefly, to all the important iron and steel construction executed by Messrs. Schneider and Co. at their Chalon-sur-Sâone works; as regards bridges, a very general summary has been given on a previous page, and an attempt will now be made, by selecting some of the most typical examples, to convey an idea of the important part Messrs. Schneider and Co. have taken in initiating the principal processes of erecting bridges, methods which have been since generally followed. The methods employed by them, as early as 1860, can effectively be traced as being now applied to the viaducts of most modern construction.

Each one of the viaducts now to be referred to constituted, for its time, a decisive step forward. To illustrate this, we will describe the erection of some of the typical viaducts and bridges constructed by Messrs. Schneider and Co., each of which marks an advance in the method they originated.

After passing in review the bridges built in the commencement, we shall deal with some detail upon the more recent constructions, as these are more interesting from a technical point of view, and show that Messrs. Schneider and Co. have never ceased to hold a front rank in these specialities, although a laudable emulation has caused them to have many competitors.

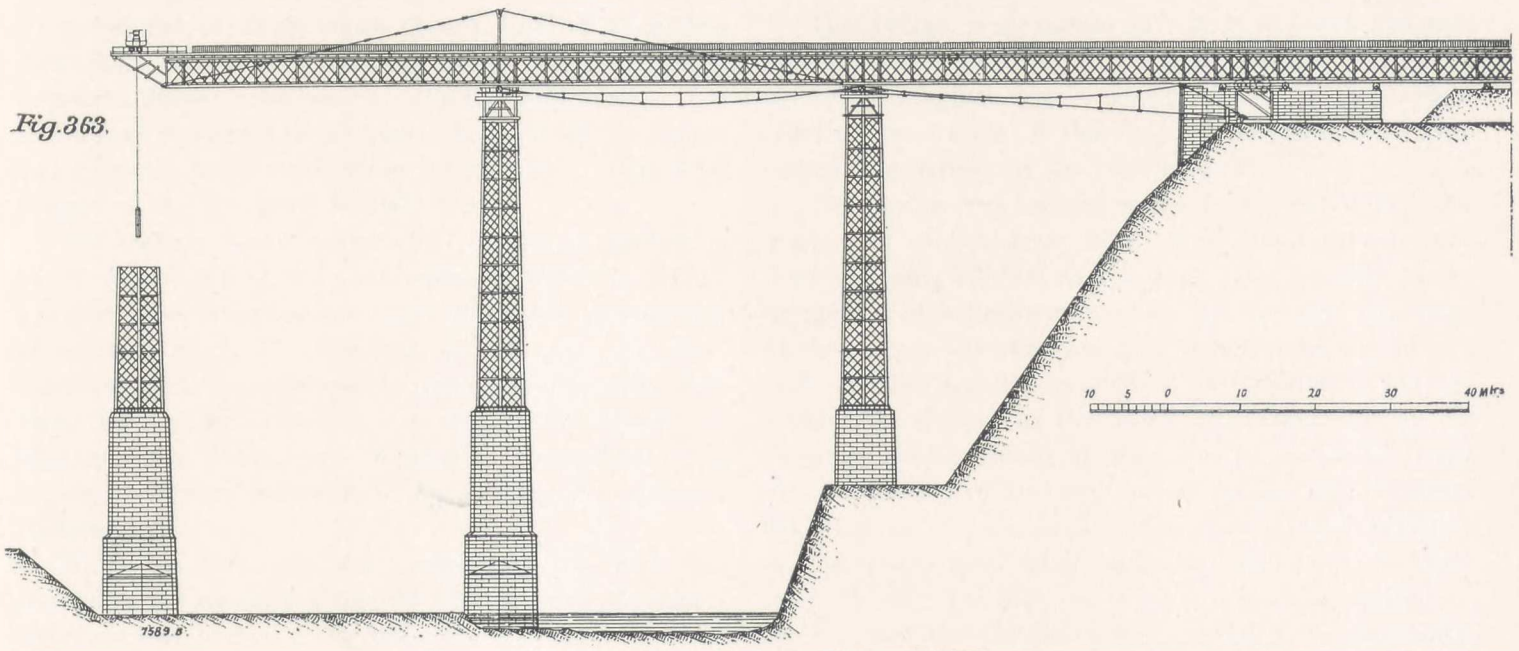
The first work of erecting bridges without staging dates as far back as 1859, when it was followed with success by Messrs. Schneider and Co., for the large Fribourg viaduct, and afterwards in a still bolder manner for the "El Cinca" bridge, (Spain), in 1866.

Fribourg Viaduct (Fig. 363, Plate LXXXII.).—This important construction is on the line from Lausanne to Fribourg, over the Sarine. It is 333.72 metres (1,095 ft.) in total length; the rails are 76 metres (249 ft.) above the level of low-water mark. The track is on the top of the girders, which are continuous. There are seven bays, each of 48.800 metres (160 ft.) span; piers are of iron 43.23 metres (141 ft. 10 in.) high.

The piers are erected on masonry foundations, the height of which varies according to the configuration of the ground. For the highest pier the foundation is

THE SHIP AND BRIDGE-BUILDING DEPARTMENT.

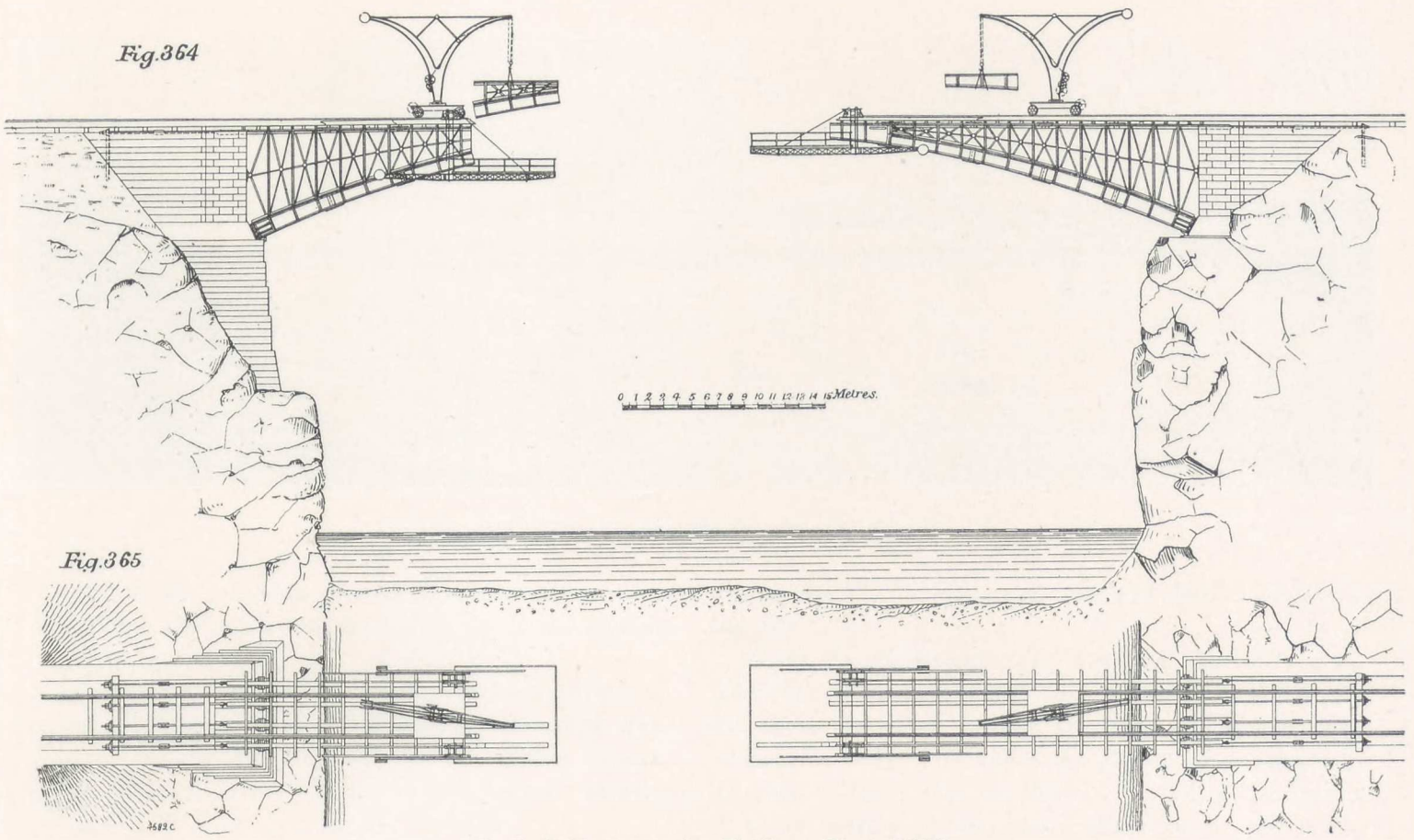
Fig.363.



Erection of the Fribourg Viaduct, 1859.

Fig.364

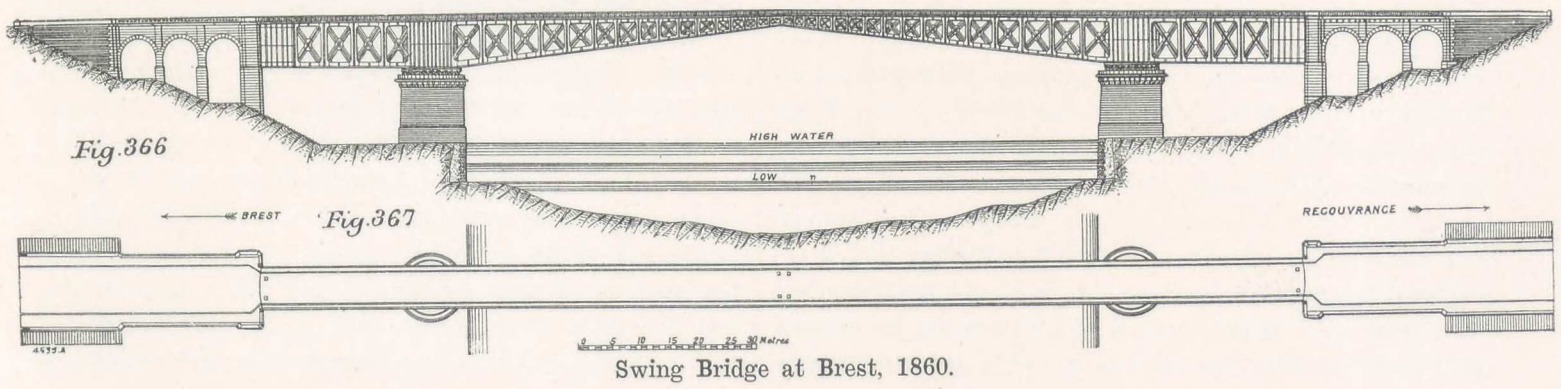
Fig.365



Road Bridge over the El Cinca River, 1866.

Fig.366

Fig.367



Swing Bridge at Brest, 1860.

29 metres (95 ft.) high, which gives a total of 72 metres (236 ft.). The masonry of the basement is hollow; it measures 20.000 cubic metres (706.400 cubic feet). The girders are 4 metres (13 ft.) high; the trellis of the bridge and piers is made with close intersections. The total weight of the ironwork is 3000 tons.

The iron superstructure was first erected on a platform to the rear of one of the abutments; it was then pushed along so as to bring one end above the masonry basement of the first pier. The ironwork of this pier was afterwards erected, the overhanging part of the superstructure being used to facilitate this. In order not to strain the superstructure during this work, it was supported by a system of columns and cables in the manner of suspension bridges.

When the first pier was erected, its top part was secured to the masonry abutment by stays, and the superstructure was pushed along until the end arrived above the masonry basement of the second pier; the ironwork of this second pier was then erected in the same way as the first. Thus the work was carried on until the opposite abutment was reached.

It is certain that this work could not be completed at the present time in a more efficient or economical way; it is not astonishing, therefore, that the process followed for the erection of the bridge attracted great attention at the time, and has been widely imitated.

Bridge over the El Cinca River (Figs. 364 and 365, Plate LXXXII.).—Another application of the same process of erection, the boldness of which appeared still greater in the case of this bridge, confirmed its advantages. Messrs. Schneider and Co. erected in a similar manner the iron arched bridge of 70 metres (229 ft.) span, which they built in 1866 over the river El Cinca, in Spain.

This road-bridge crosses the river at a spot where the banks are very steep; they are about 35 metres (115 ft.) high. The iron girders are four in number and are arched; the rise is 7.58 metres (24 ft. $10\frac{7}{16}$ in.), and the radius of the soffit 80.040 metres (262 ft. 7 in.).

The bridge is 6 metres (19 ft. 8 in.) wide between railings. This small width made it necessary to provide carefully designed cross-bracing. The uprights which transfer the weight of the road to the girders are connected transversely by close trellis-work.

This bridge was erected without any scaffolding; the work was carried from both sides simultaneously, the junction being effected at the key. The top part of the bridge was first firmly secured in the masonry abutments by the ends, and the two brackets thus formed, served as a track for the hoisting machines. A balanced footbridge which was shifted as the work progressed, served for carrying the workmen; it was always suspended from the last portion of the arch when erected, and followed the work as it progressed. It was exceedingly difficult to find workmen having sufficient confidence in their chief, to meet the dangers which the erection seemed to involve; and the Creusot engineers had to be constantly on the foot-bridge in order to encourage the men by their presence. The erection was completed most satisfactorily.

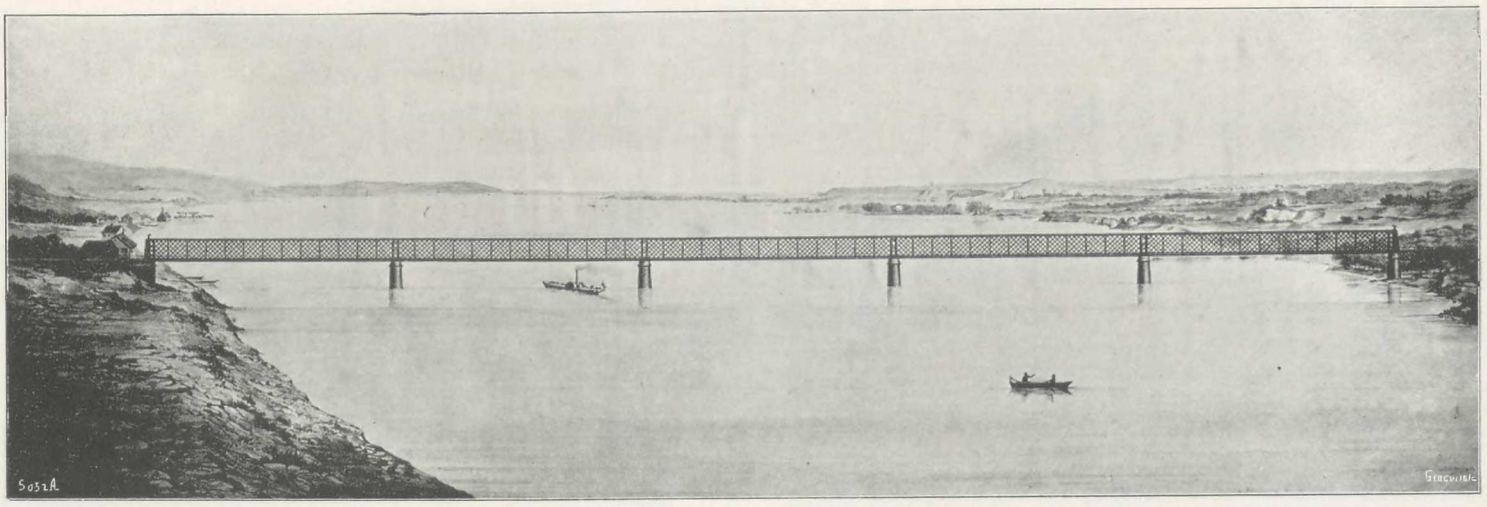


Fig. 368. The Stadlau Bridge over the Danube.

Brest Swing Bridge (Fig. 366 and Fig. 367, Plate LXXXII).—This bridge was built a few years before the one above described, namely, in 1860, and was a very remarkable work. It unites the Recouvrance suburb to the town of Brest over the Penfeld, leaving a free height of 19.500 metres (64 ft.) above the highest water-mark. The distance between the piers is 105.700 metres (346 ft. 9 in.), and from centre to centre of piers 117,600 metres (385 ft. 10 in.). The structure is turned by toothed-wheel gearing worked by hand. The girders are 7 metres (23 ft.) high over the piers. The weight of wrought-iron work forming the bridge is 850 tons; there are, besides, 320 tons of cast iron, the gearing contributing largely to this figure.

Orival Bridge.—This bridge, which was built for two railway tracks in 1864, is formed of six bays of straight continuous girders, 50.800 metres (166 ft. 7 in.) span. Its erection was one of the remarkable operations of the period.

Bridge over the Chiffa.—This bridge, built in 1869, on the road to Algiers, is a good type of curved girder work; it is in four bays of 200 metres (656 ft.).

Stadlau Bridge.—This crosses the Danube, near Vienna; it was built in 1870 for the Austrian State Railways, and is shown in Fig. 368. It is formed of straight girders, of about 400 metres (1,312 ft.) in length, in five practically equal spans. The girders are 7.590 metres (25 ft.) high, of close trellis-work. Their erection was specially interesting, owing to the enormous mass of metal—above 2,000 tons—that had to be dealt with.

Many other important bridges executed by Messrs. Schneider and Co. for foreign countries, notably Austria, Spain, Portugal, South America, &c., must be passed over; those concerning which a few data have been given above are the most interesting of early date, and reference will now be made to some others more recent, and possessing special features of construction and mode of erection.

Viaduct over the Malleco (Figs. 369 to 375).—This viaduct is at the head of the railway built by the Chilian Government some years since, to establish a means of communication between the north of Chili and the towns of the south, such as Valdivia and Osorno. The crossing of the Malleco River was one of the greatest difficulties encountered, and the construction of the line was long delayed owing to the importance of the bridge work required. The Malleco River is not more than 20 metres wide (66 ft.), but over the whole of its course it runs in a deep valley, so that it was necessary to erect a very high bridge. In the design that was finally adopted, and which was followed by its execution in 1888-90, the level of the rail is more than 100 metres (328 ft.) above the bottom of the valley.

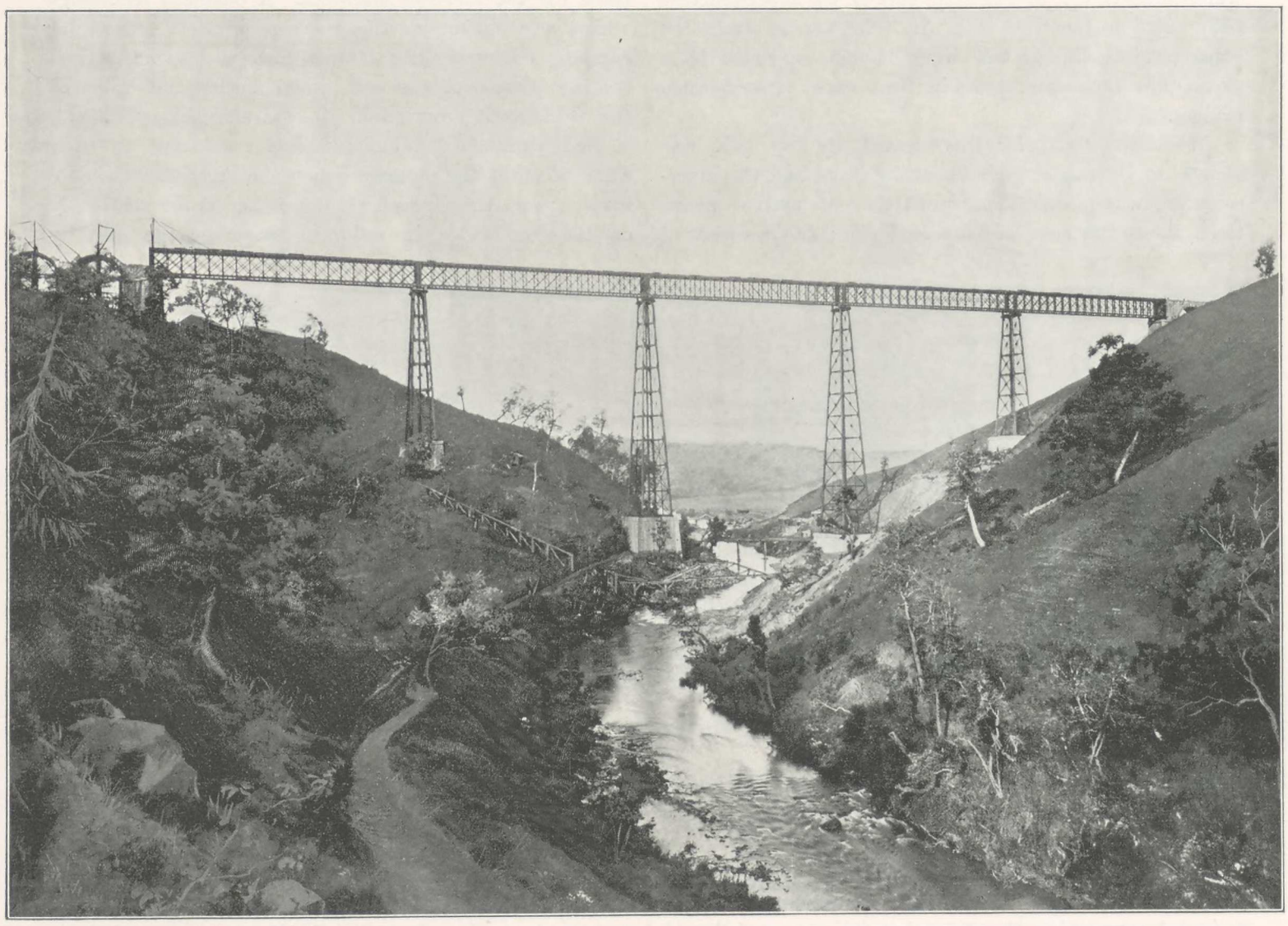


Fig. 369. Viaduct over the Rio Malleco, Chili.

The viaduct is in 5 spans. The main continuous girders are 347.500 metres (1139 ft. 10 in.) in total length; all the spans are equal,—69.500 metres (228 ft.). The superstructure is arranged for a line of 1.680 metres (5 ft. $6\frac{1}{8}$ in.) gauge placed on the top members. The piers are exceptionally high, 75.700 metres (248 ft. 3 in.). Owing to this great height, the conditions of stability under the action of the wind were of extreme importance, and were taken into account before all other conditions in designing the work.

The problem was solved in a most satisfactory manner, and the superstructure was erected without it having been necessary to stay the top of the piers.

Mild steel of 45 kilogrammes per square millimetre (28.57 tons per square inch) and 25 per cent. elongation was used throughout in the construction.

The main girders are 7 metres (23 ft.) high, and are 4.500 metres (14 ft. 9 in.) distant from centre to centre. The top and bottom flanges are single webbed, and are fitted to the soleplates by angles. The trellis work consists of a quadruple system of bars placed at an angle of 45 deg., the diagonal of the squares thus formed is 3.400 metres (11 ft. 2 in.) and all the bars being ⊔ shape, the strength of the construction is considerable. The trellis is made wide and open, in order to offer a comparatively small surface to the action of the wind. The ⊔ section was the most practical one to use for this work, on account of the process of erection Messrs. Schneider and Co. intended to

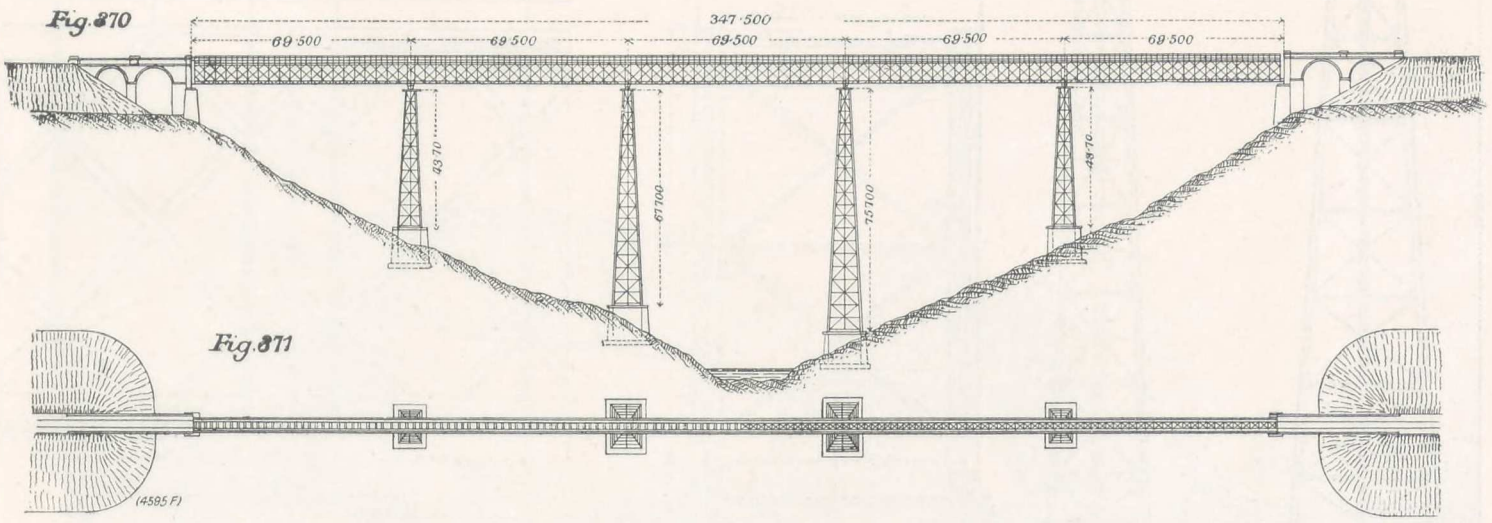
The girders are strengthened in the following manner :

1. By a double set of horizontal cross-bars placed at the top and at the bottom of the main girders, underneath the beams. They form cross-stays, the length of which is equal to the distance between the girder uprights.

2. By vertical transverse cross-bars, which unite the girders together opposite each upright. They form cross-stays, separated by a middle horizontal cross-bar.

Thus constructed, the superstructure possesses ample stiffness, and can resist all actions which tend to deform it, whether they be produced by the force of the wind or the weight of the load carried.

Piers.—The superstructure is carried on four piers of various heights ; the two end piers are 43.700 metres (143 ft. 4 in.) high from the masonry base to the top of the pier. One of the middle piers, on the right bank of the Malleco River, is 67.700 metres (222 ft.) high,



Details of Viaduct over the Rio Malleco, Chili.

follow, and during which the bars undergo alternate efforts of tension and compression. The top and bottom members of the girders are united by verticals 3.400 metres (11 ft. 2 in.) apart, which hold all the elements together. These uprights consist of a web stiffened on the outside by four angles. The various ties of the trellis bars and uprights are divided over the frames in such a manner as to reduce, as much as possible, the distance between two consecutive ties. This is an advantageous arrangement, as it largely reduces local and temporary strains that arise in the lower ribs, owing to the action of the rollers in the erecting operations.

The girders are made with steel plate pannels on the lengths above the piers ; these pannels are 1.500 metres (4 ft. 11 in.) wide between the two uprights, and are strengthened by a third vertical placed over the centre of the bearing. The girders are joined at the top by beams placed above each upright ; two lines of longitudinal sleepers, 1.800 metre (5 ft. 11 in.) distant from each other, rest on the lower side of the beam angles. They carry the oak ties on which the rails are fixed.

and the other 75.700 metres (248 ft. 4 in.). The piers are firmly set in the masonry bases, and the volume of these bases is such that the work has a perfect stability, and cannot be overturned by the force of the wind. In the calculations this force was reckoned at 270 kilogrammes per square metre (55 lb. per square foot) when the bridge is empty, and at 170 kilogrammes per square metre (34.800 lb. per square foot) when it carries a moving train. This last figure is a maximum in this case, as the force it represents is capable of overturning empty wagons and preventing all circulation on the line. Though these forces are exceptional, the piers have been so calculated that the strains of the metal do not exceed in any part, 10 kilogrammes per square millimetre (6.35 tons per square inch.) under the weights of the loads or the force of the wind.

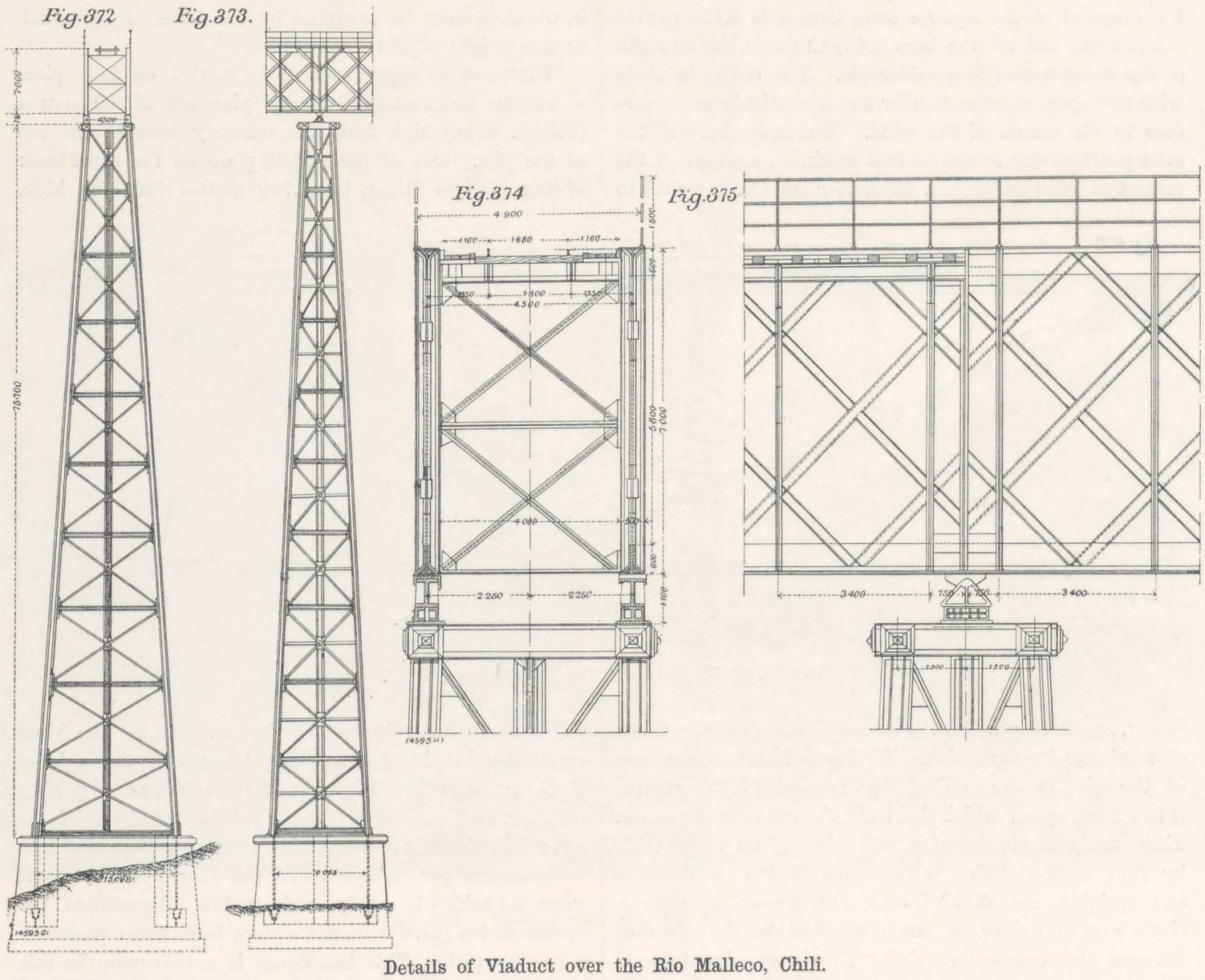
The piers are formed of four posts, placed in the shape of a pyramid and directed to one point; they are consequently of a very neat architectural appearance. The dimensions at the top are the same for all the piers, namely, 4.500 metres (14 ft. 9 in.) from centre to centre of

the posts across the width of the viaduct, and 3 metres (9 ft. 10 in.) lengthwise. The dimensions on the level of the masonry base are the following :

—	75.700 m. Pier.			67.700 m. Pier.			43.700 m. Piers.		
	m.	ft.	in.	m.	ft.	in.	m.	ft.	in.
Width (transversely to axis of viaduct)	15.098	49	6	13.978	45	10	10.618	34	10
Length	10.065	33	$0\frac{1}{4}$	9.318	30	7	7.078	23	$2\frac{3}{4}$

The posts are united together by means of stiffening cross-bars, thus reducing the surface exposed to the force of the wind; they form cross-stays with horizontal ties in the middle. The ties of all the piers correspond to each other in the same horizontal plane. The piers have all the same slope, and are, therefore, absolutely identical one with the other at the same distance from the top. Beside the four corner posts above mentioned, which are reckoned upon to bear the vertical strains, there is in each pier a vertical column, which serves to maintain the pier upright, and on which are fastened the cross-stays and horizontal ties. The section of this column is the same as that of the four corner posts.

For the section of the posts and columns Messrs. Schneider and Co. have endeavoured to adhere, as far as was practicable, to a circular form, and adopted that produced by eight ⌣-bars, the sides of which form an angle of 112 deg. 30 min. with the web. They put down at their Creusot Works special rolls for manufacturing these bars. The diameter of the circle inscribed in the section of the posts is .500 metre ($19\frac{11}{16}$ in.) the flanges of the sections are outside, which allows them to be united easily and increases their resistance.



Details of Viaduct over the Rio Malleco, Chili.

The foundation-plates of the posts are of steel 18 millimetres ($\frac{11}{16}$ in.) thick, joined to the post by 16 ribs; they distribute the pressure equally on the masonry basement. The foundation-plate tie-rods are built in the masonry at several intermediate points. The beams of the top which carry the bearing arrangement are caisson-shaped, with three webs. They are united by tie-rods and diagonal bars, which act as stiffeners. The posts are fitted with wrought-iron foundation bolts, in 7.500 metres (24 ft. 7 in.) of masonry. The nuts are fixed hot, in order to prevent their becoming loose, which might occur

THE SHIP AND BRIDGE-BUILDING DEPARTMENT.

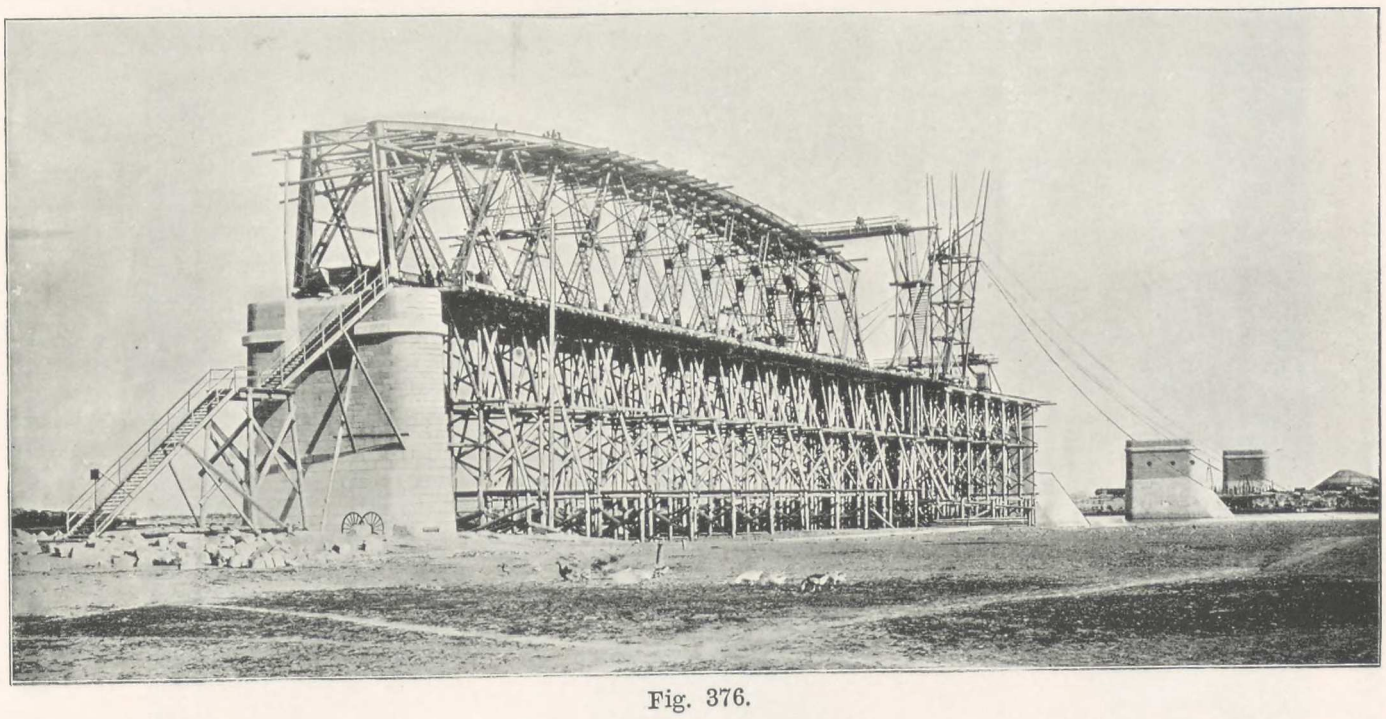


Fig. 376.

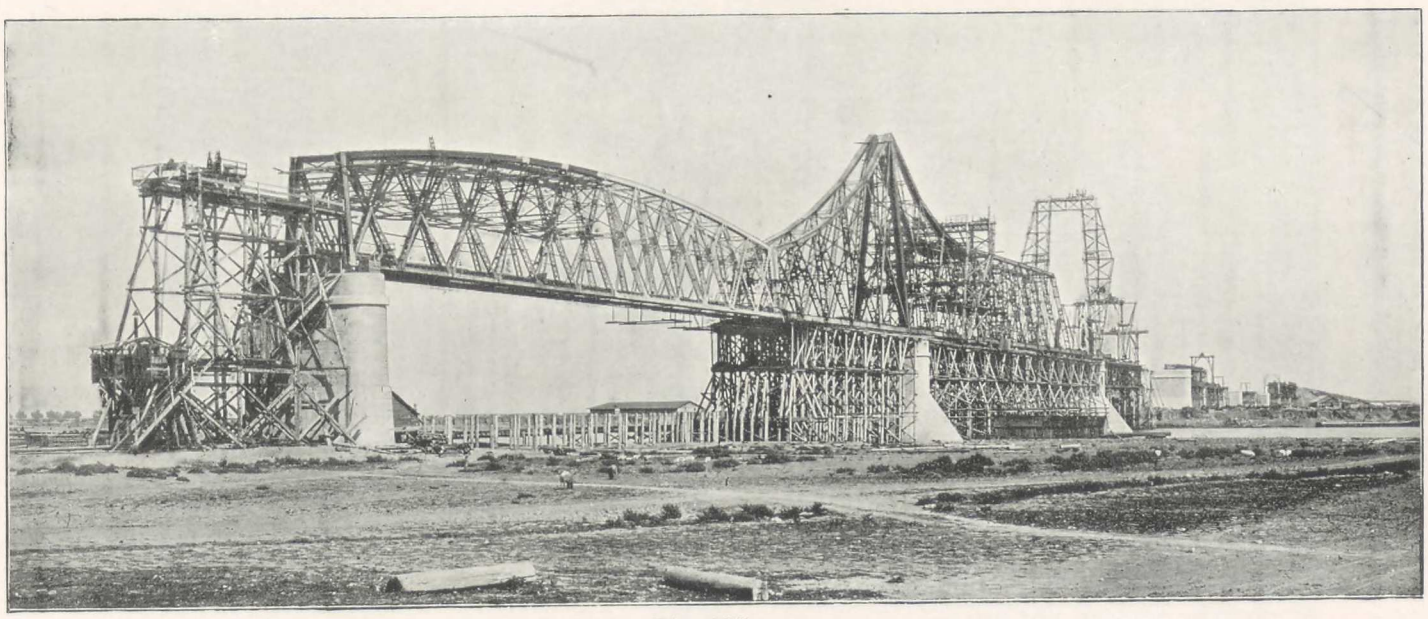


Fig. 377.

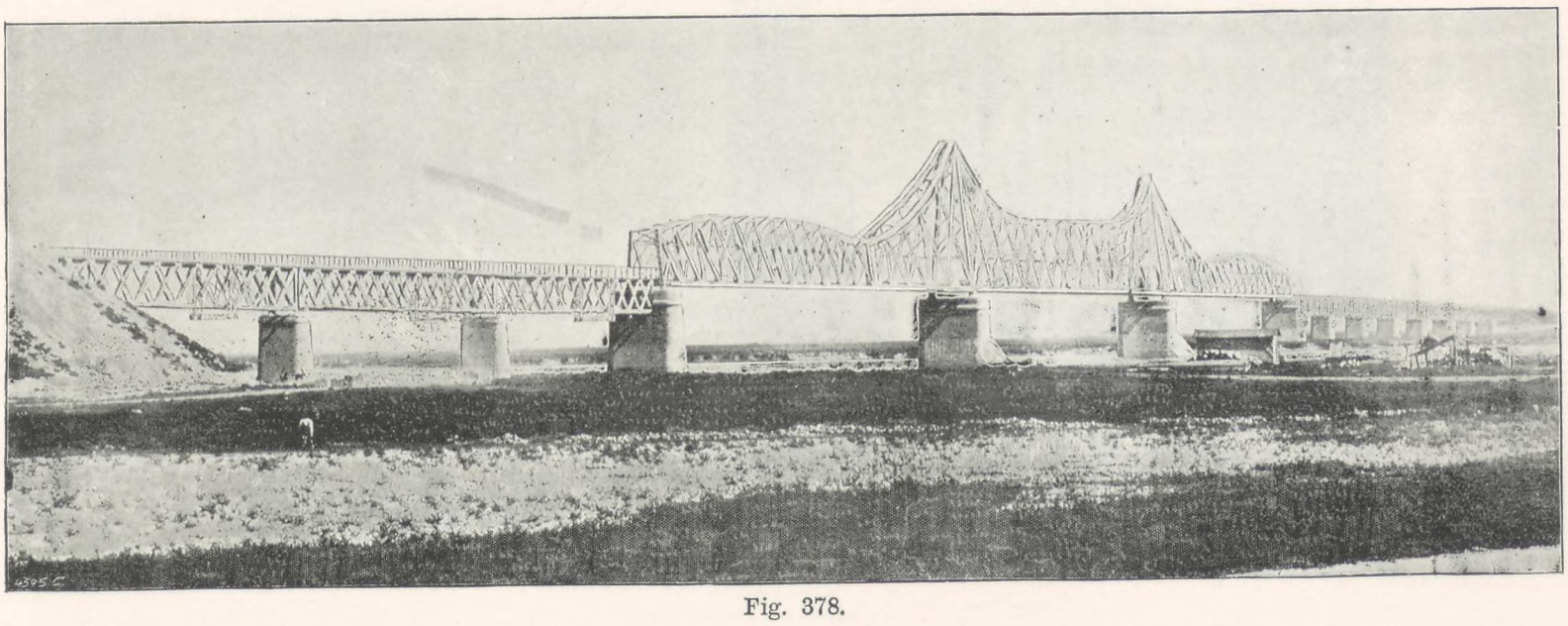


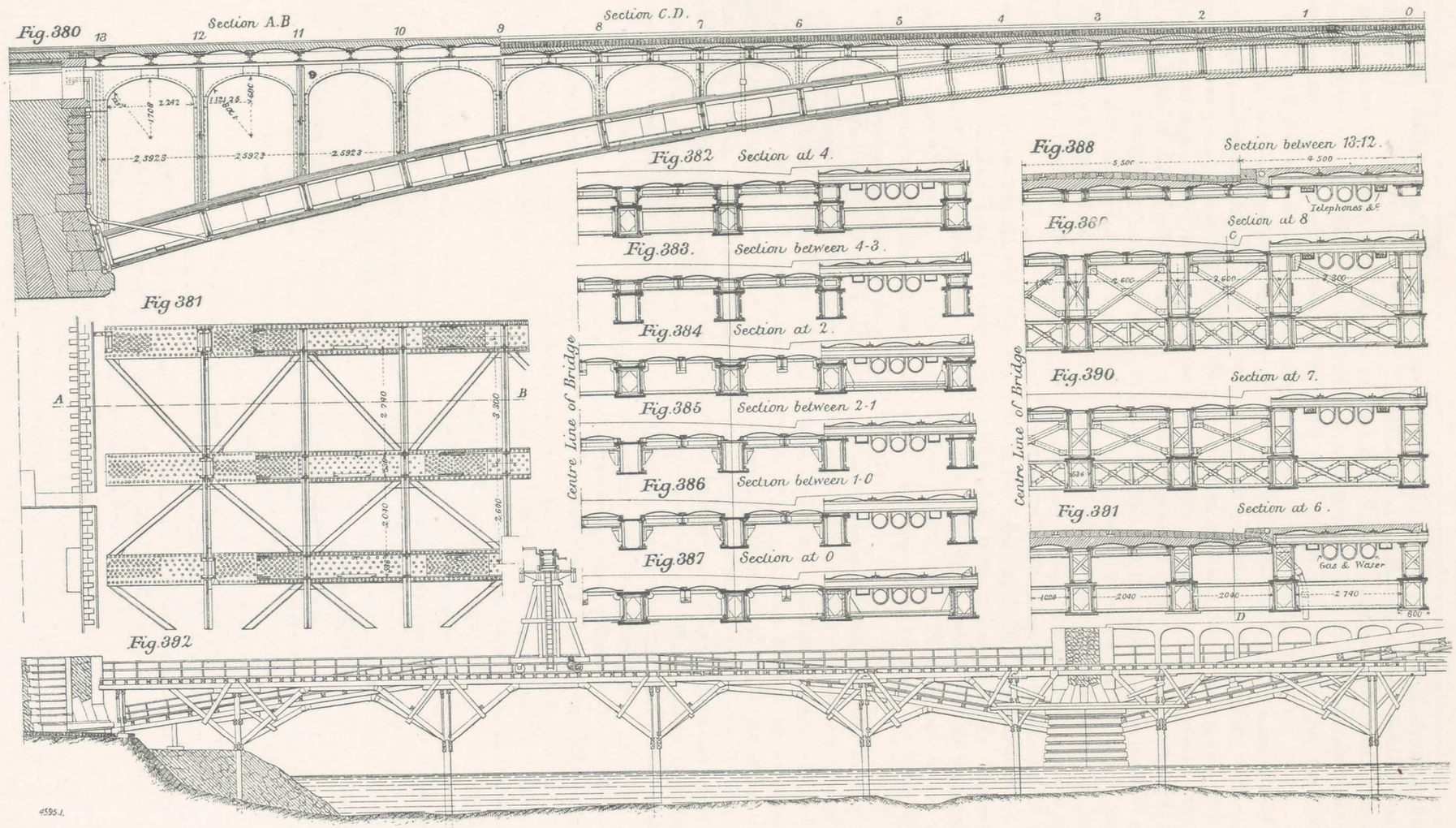
Fig. 378.

The Borcea Viaduct.



Fig. 379. The Morand Bridge over the Rhone at Lyons.

THE OHIO AND BRIDGE-CONSTRUCTING DEPARTMENT.



Details of the Morand Bridge over the Rhone at Lyons.

owing to the vibration; this was only done when the erection was completed.

The piers were erected in sections, with the help of a flooring that was raised as the work progressed, and in starting from the base. The changes in the scaffolding, and the raising of the material, as well as the lifting of the workmen, were effected with the help of a portable steam engine and steam winches. The erection of the superstructure was commenced in September, 1889, and was completed end of April, 1890; it was carried out entirely on the right bank of the Malleco, on the side of the north abutment. A platform 95 metres (311 ft.) in length, in the rear of the abutment, served for the erection; the abutment masonry work was stopped at 8.100 metres (26 ft. 7 in.) below rail level, in view of the erection of the superstructure.

When a length of 90 metres (295 ft.) had been completely riveted, it was pushed along until it overhung by 15 metres (49 ft.), the wall of the north abutment. These operations were carried out without accidents, the most difficult part of the work being to reach the first pier, as it was necessary to place a counterweight in the rear of the superstructure already erected on the platform. Thirty tons of string-pieces belonging to the third span served for this purpose. The final operation required about 100 men.

The flexion of the front end of the superstructure during the launching never exceeded .530 metre (20⅞ in.) below the roller plane. When it reached each pier, the front end was lifted by 100-ton hydraulic jacks, to enable rollers to be introduced for continuing the advance.

After each launching operation, the rollers were withdrawn and the superstructure was made to rest on provisional cast-iron chairs. When the whole length of the superstructure had been launched, it was lowered by .260 metre (10¼ in.) and made to rest in the final bearings; lowering was effected progressively, 40 to 50 millimetres (1½ in. to 2 in.) at a time, by means of hydraulic jacks.

The whole work weighs 1,410 tons, namely, the piers 660 tons and the superstructure 750 tons. The erection was carried out by Chilian workmen, under the supervision of skilled foremen sent by Messrs. Schneider and Co.

Bridge over the Borcea (Figs. 376, 377, and 378, Plate LXXXIII.) — The Borcea is a branch of the Danube; it is divided into two arms by the Balta island, which consists of a large tract of marshy ground, frequently overflowed, and situated on the Roumanian Railway from Bucharest to Kustendje. This railway will acquire a great extension of traffic, as it forms, in combination with the Black Sea maritime service, a second line for the Orient express. The whole of the viaduct constitutes one of the finest works of modern times; it is of such an importance—it weighs 13,000 tons—that in order to be able to execute it within the period prescribed, it had to be ordered from three large works; Messrs. Schneider and Co., were entrusted with the part over the Borcea; the Fives-Lille Company, with that over the other arm of the Danube, and the Cockerill Company with the Balta Viaduct, which unites the two. This is throughout a cantilever bridge. Messrs. Schneider and Co. supplied the whole of the steel necessary for the viaducts over the arms of the Danube (1893-4).

The Borcea Viaduct is 418.20 metres (1372 ft.) in its main part, not including the approach viaducts. It is in three spans, a central one of 140 metres (459 ft. 3 in.) and two shore spans of 139.100 metres (456 ft. 4½ in.). The girders are of various heights, reaching 33.360 metres (109 ft. 6 in.) over the piers; they are inclined one towards the other, being 9 metres (29 ft. 6 in.) apart at the base and 2.630 metres (8 ft. 7½ in.) at the top, from centre to centre of frames, in the section over the piers. This arrangement has the advantage of reducing the importance of the top cross-stays. The framework of the girders is tubular; the trellis is constituted by diagonals without uprights. The superstructure tie-bars are fixed direct to the lower girder frames. The top part of the superstructure is strongly braced, in case the train should leave the rails.

The foundations were executed with the help of caissons and compressed air. This work was surrounded with great difficulties, as it was necessary to descend to a depth of 30 metres (99 ft.); the air pressure in the chambers was dangerous for the men, and the height of the water sometimes reached 10 metres (33 ft.) above low-water mark. It was, however, carried out without any serious accident.

The erection was effected partly by rafting (semi-parabolical shore-end girders), and in part with the help of a temporary bridge (cantilever girders). The work of pile-driving was difficult owing to floods and ice, and it was necessary to build especially strong staging. Trucks fitted with steam winches served to raise the material and to carry the pneumatic riveting machines. The specification prescribed mechanical riveting on the spot. Notwithstanding the serious impediments of all kinds due to the climate, the action of the river, the absence of skilled workmen, and the importance of the work, combined with the short time given for its execution, the results obtained exceeded those that had been hoped for. The Roumanian engineers may be praised for this gigantic viaduct designed by them.

Morand Bridge over the Rhône at Lyons (Figs. 379 to 392, Plates LXXXIV., LXXXV., and Figs. 393 to 398). — This bridge was built in 1888-90 at the spot occupied by an old wooden bridge on pile piers, which had been constructed in 1774 by the architect Morand.

It consists of three arches of steel throughout and owing to local conditions the arches had to be made unusually flat.

The ribs are very shallow, being .800 metre (31½ in.) at the key, and 1 metre (39⅜ in.) at the springing The width of the bridge between railings is 20 metres (65 ft. 7 in.); the road is 11 metres (36 ft. 1 in.) wide, with a pavement each side, of 4.500 metres (14 ft. 9 in.). The

longitudinal floor line of the whole bridge is an arc of circle with a radius of 5,206 metres; it meets the abutment walls at an incline of 1 in 50.

The principal dimensions of the arches are as follows:

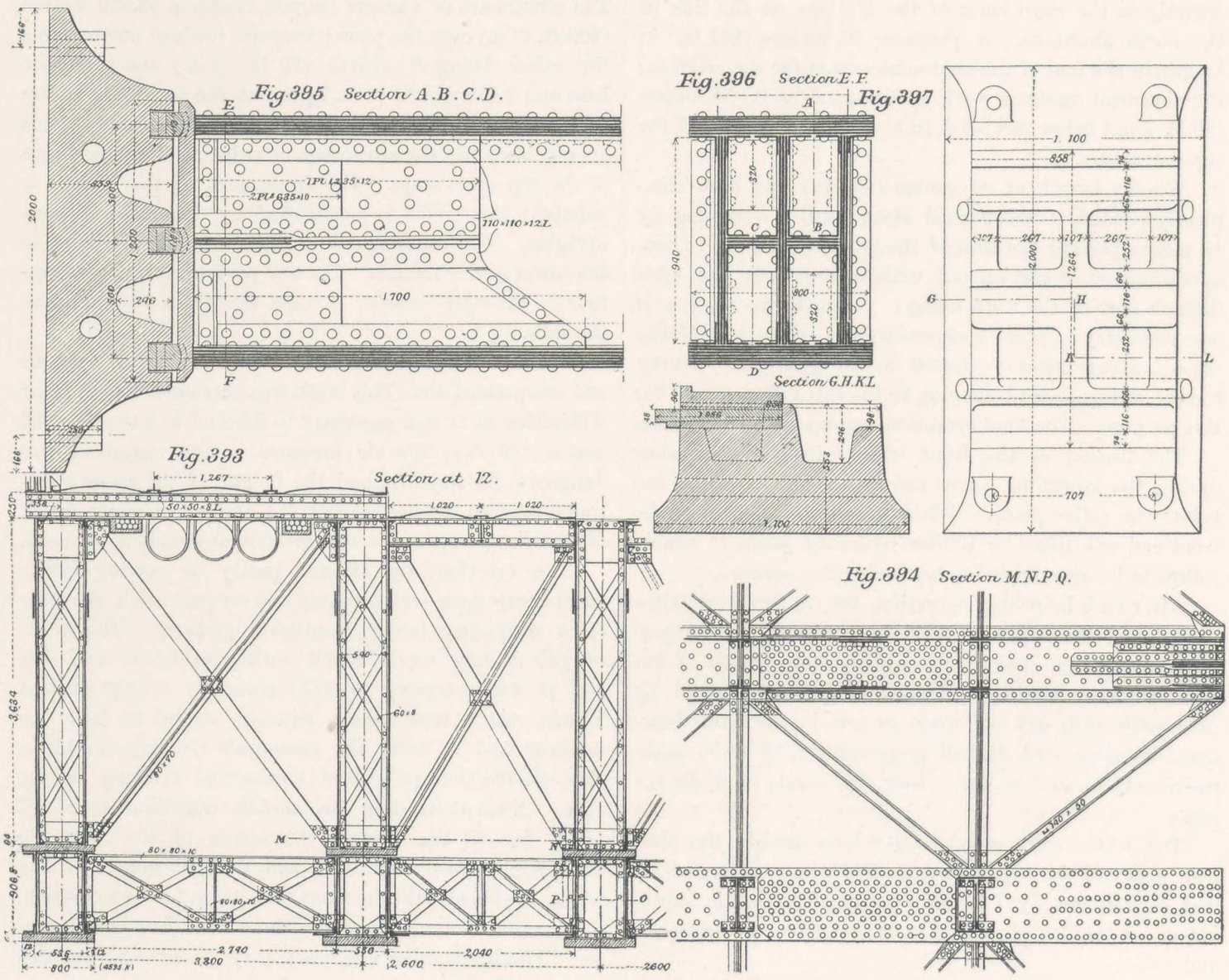
—	Openings.	Rise.	Depression.	Radius.
	m.	m.		m.
Central arch ...	67.40	4.44	$\frac{1}{15.18}$	130.113
End arches ...	64.00	3.96	$\frac{1}{15.91}$	127.264

This work is remarkable from an architectural point of view, and it may be said it solves admirably the difficult problem that had to be met, inasmuch as all the inconveniences that might have arisen through such a limited rise have been done away with.

The division of the width to be bridged, into one central, and two end, arches. was determined in such a way as to balance the pressures on each side of the piers under average conditions of temperature and equality in the load on the side spans. The ribs rest on hinges at the springing, and are continuous at the key. The hinges were wedged after completion of the work, and at a temperature approaching the average; therefore the arches act, under the action of permanent loads, as being jointed at the springing; and under the action of extreme temperatures and surcharges, as being rigid owing to their bearing over the whole of their height. The trials proved, moreover, that in this way the vibrations had been prevented as far as was practicable; diagrams taken during tests show them not to have exceeded 0.0015 in. anywhere.

The construction at the works, and the erection on the spot, were conducted with great success, and the bridge was completed without the least accident.

The foundations of the piers were made by means of compressed air caissons; the excavations showed a succession of layers of sand and gravel, which constitute, to a great depth, the subsoil of the Rhône bed. The foundations of the abutments, not being exposed to damage by water, were not made deep; those of the piers, on the contrary, were carried 12.600 and 13.920 metres (41 ft. 4 in. and 45 ft. 10 in.), as undermining was to be feared owing to the great rapidity of the river. The



Details of the Morand Bridge over the Rhone at Lyons.

piers are made with pointed cut-waters up stream, and carry columns formed of Scotch pink granite. The springings of the arches rest on large stone blocks of great resistance; these are carried on stone masonry made parallel to the ends of the arches and the abutments. The roadway is paved with wood blocks for lightness.

Each span consists of eight ribs 2.600 metres (8 ft. 6⅝ in.) distant from centre to centre under the roadway and 3.300 metres (10 ft. 10 in.) under the pavements. The ribs are built up of plates and angles, and are box-shaped, with double vertical webs; the flanges are .800 metre (31½ in.) wide; the ribs are divided in 26 sections in the central span and into 24 parts in the end spans. They are united by beams and stiffening bars. Opposite each division the ribs carry vertical uprights which enlarge at the top so as to form a series of small arches; these are surmounted by the string piece that carries the iron superstructure.

The ends of the ribs bear on the piers and abutments through the intermediary of three curved sockets, placed in the middle above each flange of the ribs, so that the effort is always received between two of the hinges in the various combinations of surcharges and temperature. The ends of the ribs were carefully planed, and they rest against steel plates 77 millimetres (3 in.) thick, which are grooved for taking the three bearings. The pressure is transmitted to the masonry through a first course of cast-iron plates. The spans were constructed and wedged on the bearing hinges at an average temperature; the end hinges were wedged after completion of the bridge, also at a temperature approaching normal.

The steel used in the construction of the Morand bridge has a breaking strain of 47 kilogrammes per square millimetre (29.84 tons per square inch), with a maximum elongation of 24 per cent.

For erecting the ribs, Messrs. Schneider and Co. built a continuous centring, which rested on piles driven in the river. Two portable cranes lifted the pieces for each half of the bridge. The railway at both ends served for the carriage of the pieces.

The erection began on the upstream half of the bridge: the ribs were forwarded from the Chalon Works in sections corresponding to two divisions; these were placed on wood bearings and fitted together in their final positions. The reduction in pitch which the permanent load was calculated to produce being 40 millimetres (1$\frac{9}{16}$ in.), the keys were heightened by 60 millimetres (2$\frac{5}{16}$ in.) to compensate for the tightening of joints, and bearings and flattening of the lead, placed between the first-course plates and bearing blocks.

When the erection of the upstream half of the bridge was commenced, the ribs were placed by careful levelling in the exact position they had to occupy, taking into account the temperature at which the centring was to be taken down. They were lifted by means of jacks, and the wood wedges were tightened more or less. When this was effected, each rib rested on five wedges placed at top, on the sides, and at the springing, and which corresponded approximately to the trestles of the staging. After the adjustment of the work was complete, the centre pins were hammered tight on the whole three arches; in passing from one rib to the other, care had to be taken that the tightening should be uniform; with this view, it was completed by one single gang of workmen. The middle, and then the sides of the ribs, were lifted by means of jacks, and the wedges that held up the ribs were removed, the work being carried out as before, on three ribs of the same longitudinal series the wedges placed near the first courses were then destroyed with axes. The total time taken up by the striking of the centres did not exceed three hours.

When the centring had been taken down, it was removed to the down-stream half of the bridge, where the system was repeated with equal success.

The Alexander III. Bridge.—(Figs. 399 and 400, and Figs. 401 to 463, Plates LXXXVI. to XCII., and Fig. 464).—Among the conspicuous engineering features which will distinguish the Paris Exhibition of 1900, the new and permanent bridge over the Seine, to be known as the Pont Alexander III., will be of leading interest to engineers because of its bold construction and correct detail, and to the general public because of its beauty of design. The Alexander III. Bridge will survive the ephemeral splendour of the Exhibition, and will form a permanent attraction in the marvellous Seine perspective, which constitutes one of the striking beauties of Paris.

Before giving a brief description of the work and of the processes adopted in its erection, we should mention that the designs of the bridge are due to the eminent engineers, MM. Résal and Alby. The Administration des Ponts est Chaussèes entrusted the preparation of detailed drawings of the bridge, jointly to Messrs. Schneider and Co., of Creusot, and the Fives-Lille Company. In accordance with a contract made between these two firms, Messrs. Schneider and Co. have especially in their charge the work of erecting the bridge, including the design, construction, and erection of all the temporary work required. It is scarcely too much to say that this part of the undertaking has involved more skill in design, and ingenuity, than the permanent bridge itself.

All that part of the work undertaken by Messrs. Schneider and Co., including erection, was entrusted to their Chalon yard.

General Description of the Work.—In the scheme of the engineers, to whom is due the general arrangement, as well as the details, of the Exhibition, the Alexander III. Bridge figured essentially as a monumental and decorative work, designed to fulfil the following conditions:

1. The bridge was not to mask the view of the Invalides, which is to be brought out conspicuously by the new avenue between the Champs-Elysées Fine Art palaces, and the axis of which, as well as that of the bridge, coincides with the centre of the Esplanade des Invalides.

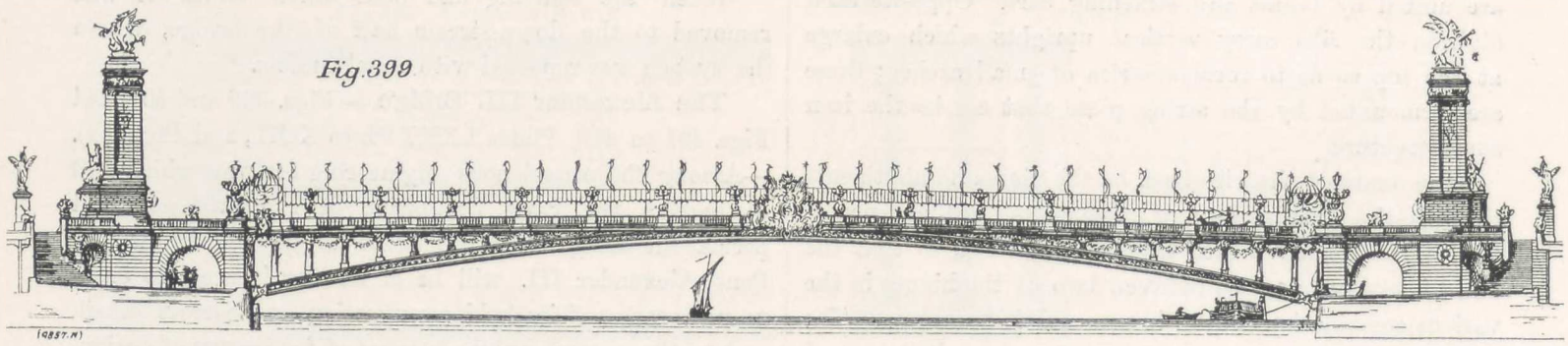
2. It was not to interfere with the beautiful view of the Seine, as seen from the Place de la Concorde bridge, a

view unique of its kind, owing to the succession of bridges, and to the active navigation.

3. It was to be of such a width as to harmonise with that of the new avenue (328 ft.), that forms the approach on the Champs-Elysées side, while it was desirable not to cover too great a space of the river.

Great difficulties arose, due to the bend of the Seine between the Concorde and Invalides Bridges, which renders navigation particularly difficult at that part; and in order not to increase these difficulties, it was necessary to maintain a sufficiently wide channel for the traffic, and especially for long tows, before passing under the Invalides Bridge. As, on this account, piers in the stream were inadmissible, a low arch was the only type that allowed the fulfilment of all the conditions required.

Fig. 399



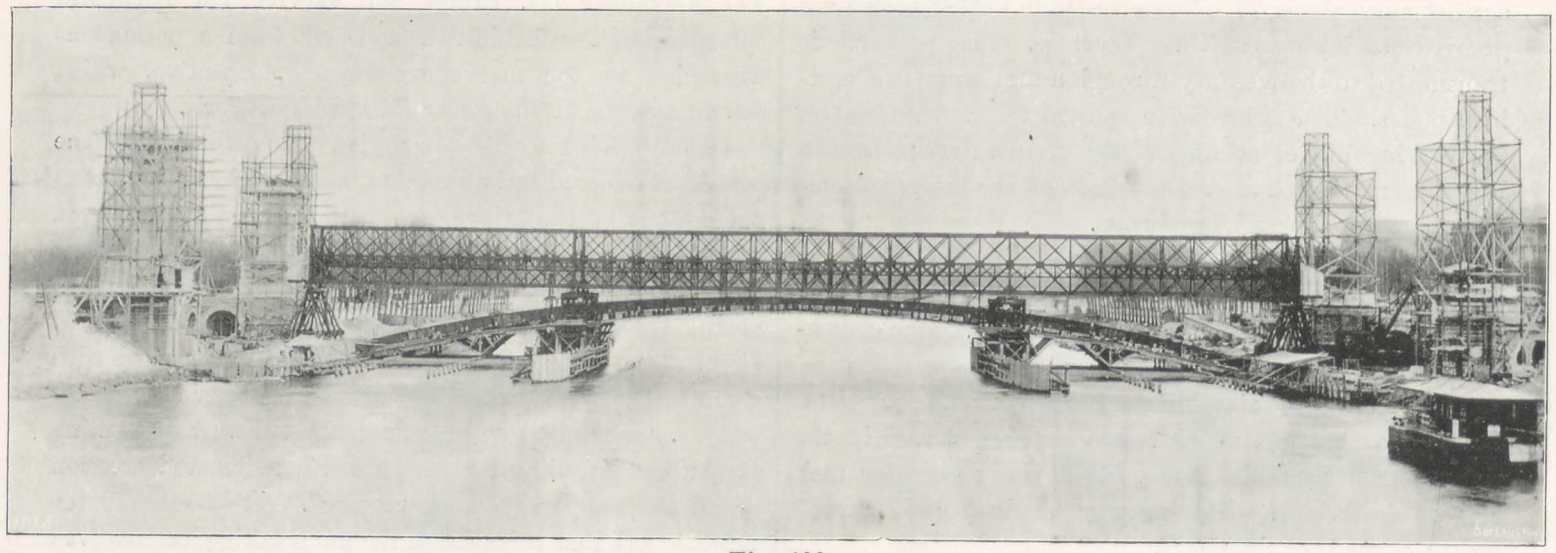
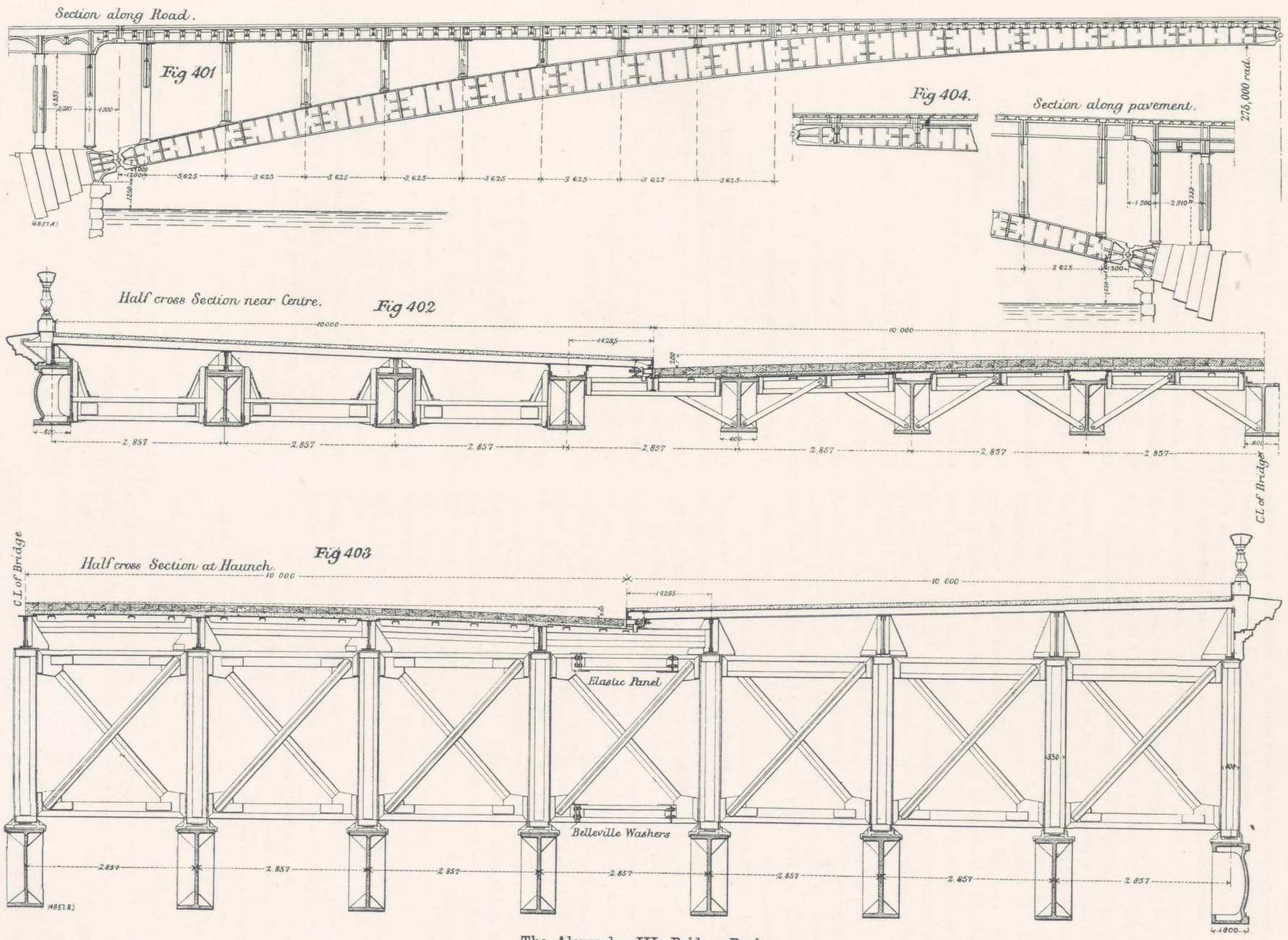


Fig. 400.
The Alexander III. Bridge, Paris.

Fig. 400 gives an idea of the general design. The main girders are segmental, and made with three joints; the river span is approached on each side by land spans. The longitudinal centre line of the bridge coincides with that of the new avenue, and it crosses the river at an angle of 83 deg. 38 min. The distance of 155 metres (508 ft.) between the faces of the abutments is divided into three parts, namely, land spans each 22.50 metres (74 ft.) wide each, and the main span, the clear length of which, measured in its centre line, is 109 metres (358 ft.) between the abutments. The shoes that carry the joints at the springing project .75 metre (29½ in.) over the abutment faces, so that the joints at the springing are 107.50 metres (353 ft.) distant from centre to centre.

The bridge is 40 metres (131 ft.) wide between the hand-rails; this width is occupied by a centre roadway 20 metres (65 ft. 6 in.) in width, and by two footways, each 10 metres (32 in. 9 in.) wide. Longitudinally, the road is made with two inclines of 0.02 per metre (2 in 100), united at the centre by the arc of a circle, the chord of which is 32 metres (105 ft.) in length, and the radius 800 metres (2,624 ft.). Transversely the rise in the centre of the road is 20 centimetres ($7\frac{7}{8}$ in.).

The main structure of the bridge consists of 15 ribs placed at equal distances apart. These ribs are formed of a series of cast-steel voussoirs, the joints being normal to the median curve of the arch; the voussoirs are designed so as to be wholly in compression, but to facilitate erection they are joined together by a few bolts. The cross-section of the inner voussoirs differs from that of the outer ones. The cross-section of the latter is ⊏-shaped, but with a curved web formed on the outside and provided with ribs, while the inner voussoirs are I-shaped, the width of all flanges being .600 metre ($23\frac{5}{8}$ in.), the total depth varying from .850 metre ($33\frac{7}{16}$ in.) to 1.500 metre (59 in.). The webs are .050 metre (2 in. bare) thick throughout; the thickness of the lower flange varies from .050 metre (2 in. bare) to .060 metre ($2\frac{3}{8}$ in. bare). The voussoirs have



The Alexander III. Bridge, Paris.

an average length of 3.650 metres (11 ft. 11⅝ in.), and their weight varies between 4 and 6 tons. The general appearance of the bridge and of its construction are illustrated by Figs. 401 to 403, Plate LXXXVI.

It was necessary to design the bridge as a three-hinged arch, so as to render its stability almost independent of variations in temperature, and to insure the coincidence of the pressure curves in the vicinity of the neutral axis, in order to maintain the ribs in compression.

One of the most striking peculiarities of the arch is its flatness, the rise being only $\frac{1}{17.12}$, which is less than that of any other arched bridge built in France. This of course, throws considerable pressure on the abutments (288 tons per metre run of bridge, or approximately 825 tons on each springing).

The tests specified for the cast steel employed are the same as those prescribed for rolled steel, namely, a tensile strain of 42 kilogrammes per square millimetre (26.67 tons per square inch), with an elongation of 22 per cent. As the specific weight of the various steel castings made at Creusot for this bridge gives an average of 7.65, it may be said that perfection is almost attained as regards homogeneity of metal.

The superstructure is of rolled steel; it consists mainly of a series of longitudinal lattice girders, and of transverse girders. Near the abutments the former are supported by uprights, resting on the ribs, and connected to them by cast-steel shoes. Nearer the centre the longitudinal girders bear direct on the ribs, the extrados of which are cast with special bearing surfaces, planed in order to secure a perfect contact.

The arches, spandril uprights, and longitudinal girders are stayed transversely and vertically, near the abutments by diagonal bracing, at the centre and under the pavement by stays which run the whole depth of the ribs; at the top and under the roadway by inclined bars which prevent the ribs from distorting.

The longitudinal bracing consists of a complete flooring of flat plates, which covers the whole surface of the bridge; this flooring is carried under the sidewalks by steel joists that rest on the longitudinals, and under the roadway by girders also attached to them and placed between the ribs. The roadway is paved with wood blocks, so as to reduce the weight. The curbs are of cast steel, and in order to allow free transversal expansion of the roadway, they bear against a series of spiral springs.

The base of the railing and balustrade are of cast iron; the railings and pilaster heads are of brass. The cast-iron ornaments of the face of the outer ribs consist of a frieze fixed to the curved webs of the rib; of a casing on the spandril uprights; of a cornice along the whole length of the bridge, and supporting the railing; of garlanded pendants in the spandril; and of a suitably ornamented carving in the centre of the arch.

Foundations.—A complete knowledge of the subsoil allowed the builders to secure the stability of the abutments, notwithstanding the great pressure from the ribs. On the right bank, beneath recent sandy clay alluvium, a layer of sand was found, covering a bed of hard limestone. On the left bank, the top alluvium consists of gravelly sand; hard limestone is also found under a bed of sand and pebbles, but at a higher level than on the right bank.

The masonry of each abutment is rectangular in plan, measuring 33.50 metres (110 ft.) by 44 metres (144 ft.). Each mass of masonry has been sunk by compressed air, by means of one caisson, divided into five working chambers, normal with the river. These chambers are filled with cement concrete, the remainder of the masonry being formed of quarry stones laid in cement. In the rear of each spring course, are four beds of rough-faced granite, set normal to the pressure, which reaches a maximum of 48 kilogrammes per square centimetre (682.7 lb. per square inch); that on the ordinary masonry does not, however, exceed 18 kilogrammes (256 lb.) at the joint with the last layer of granite blocks; the vertical pressure per square centimetre of bearing on the foundation does not exceed 3 kilogrammes (42.67 lb. per square inch). The relation between pressure and weight, under the most unfavourable conditions, does not reach 0.50. The mass of masonry is so proportioned as to carry back the strains from the bridge to a point more than 30 metres (98 ft. 6 in.) distant from the face of the abutment.

Erection.—The work of erection has been a most interesting operation, owing to the size and novel design of the bridge itself, and to the method followed. On account of the difficulties to navigation between the Concorde and Invalides bridges, it was necessary to leave in the middle of the river a 50-metre (164-ft.) channel unobstructed, and of sufficient height to enable the largest boats to pass. Moreover, the bridge being a single span, the construction of false works, built on piles driven in the river, was out of the question. It was necessary, therefore, to erect two half temporary bridges, one on each bank, formed of beams well braced together, and to use a roller bridge for supporting the cast-steel arches in the middle part of the river. Two types of roller bridges were available; in one, the track would have been placed on the series of piles driven in the river at the edge of the channel; this would have given a range of 52 metres (170 ft.) only for the roller bridge. In the other, the track would have been made on the abutments, in which case the temporary bridge would have covered the permanent one, thus constituting a formidable structure 120 metres (394 ft.) span.

The second type, though more costly, was decided on, as it was feared that a settling of the piles would take place under the heavy loads to be carried, and also as ice drifts and wreckage during the rising of the river might entail failure of part of the sets of piles.

In order to reduce as much as possible the chances of such accidents, groups of protecting piles were driven on each side of the channel; these end in a fixed signal up-

stream and in a groin 30 metres (98 ft.) in length on the right bank, to which the current takes all boats and floating material after passing under the Concorde Bridge.

For the sake of economy, it was intended to build a roller bridge adapted for erecting one rib at a time; but this idea had to be abandoned, owing to the risk that would be incurred in leaving the first rib, even when firmly secured, and proceeding with the second.

The roller bridge, which it was decided should be employed in the construction of the bridge, consists of two straight lattice girders, 120 metres (394 ft.) long between end verticals, and 7.50 metres (24 ft. 6 in.) high. The transverse distance between these girders is 5.714 metres (18 ft. 8 in.). The frames consist of plain I-bars, the lattice work being double. The vertical uprights are placed at such a distance apart as to be equal to the length of the horizontal projections of the arch voussoirs, namely, 3.625 metres (11 ft. 11 in.). In the centre of the bridge the three spaces that correspond to the bridge key have been reduced, owing to the lesser length of the key voussoirs.

The two girders are joined together by a series of frames consisting of two vertical uprights, united at the middle of their height by a horizontal stay; this stay and the inside surfaces of the uprights carry brackets, on which are placed a rail track for the trucks that serve in the erection of the arches. Above the stay the frames are further strengthened by horizontal bars, level with the top trusses. Below the stay-bar a space has been left free for the carrying of the pieces forming the arches.

In the lateral spans the lower part of the vertical uprights is inclined so as to rest on the frame soleplates. In the central span, on the contrary, the lower part of these uprights, as well as that of the track bracket supporting frames, is arranged so as to be fitted with suspension-rods level with the lower soleplates of the frame.

The framework thus formed would not have sufficient strength to resist the force of the wind, which is considerable, owing to the surface exposed, not only by the roller bridge, but also by the superstructure and the arches under erection. It has, therefore, been stiffened by a lattice girder, placed horizontally at the middle of the height, the framing of which, made of I bars, unites the uprights at the joints of the lattice work. The end frames of the bridge are stayed by inclined cross-braces for the whole of their length.

To relieve the bridge during the erection of the arches, and to reduce the vibrations caused by the wind, and which would have caused great trouble in the adjustment of the voussoirs, intermediate bearings have been provided, the outside series of outer centre piles being employed for this, the piles having been strengthened for that purpose.

The bearings are placed on triple-ribbed beams, laid parallel with the bridge and carried on a trestle of iron posts, the uprights of which are directly above the series of piles. The trestles are placed in the space adjoining that of two arches in course of erection; they are taken down after the erection of each group of ribs. They do not rest direct on the piles, but on a string-piece placed on the top, so as to distribute the load over a set of six piles. These arrangements, which seem out of proportion to the vertical load carried (a series of twelve piles can easily bear a load of 300 tons) are rendered necessary by the force of the wind, which displaces in a marked degree the resultant line of efforts applied to the intermediate bearing frame.

On the banks the bridge bearings are carried on triple beams, laid parallel to the river. These form the top edge of the trestle. Below, in a line with each of the bearings, are six uprights which divide the load on the truck body above the truck rollers of the bridge. These standards are 5.85 metres (19 ft. 2 in.) high; the track is 4-metre (13 ft. 1 in.) gauge, the distance between the end rollers of one series being 11.50 metres (37 ft. 9 in.). The rollers are ten in number, the centre set of each series being fitted to the ends of the two standards. The roller truck is stayed with bars placed in a line with each pair of rollers. The whole is further stiffened by two other sets of stays, one uniting the standards at half their length and forming a horizontal bed around the trestle, the other joining the middle of the trimmer to the middle of the trunk frames.

The roller-bridge framework is made throughout of rolled steel bars, while all bearing parts are of cast steel. The tests prescribed for the rolled steel are the same as those for that used in the construction of permanent bridges, namely, 42 kilogrammes, tensile strength per square millimetre (26.67 tons per square inch), and 22 per cent. elongation.

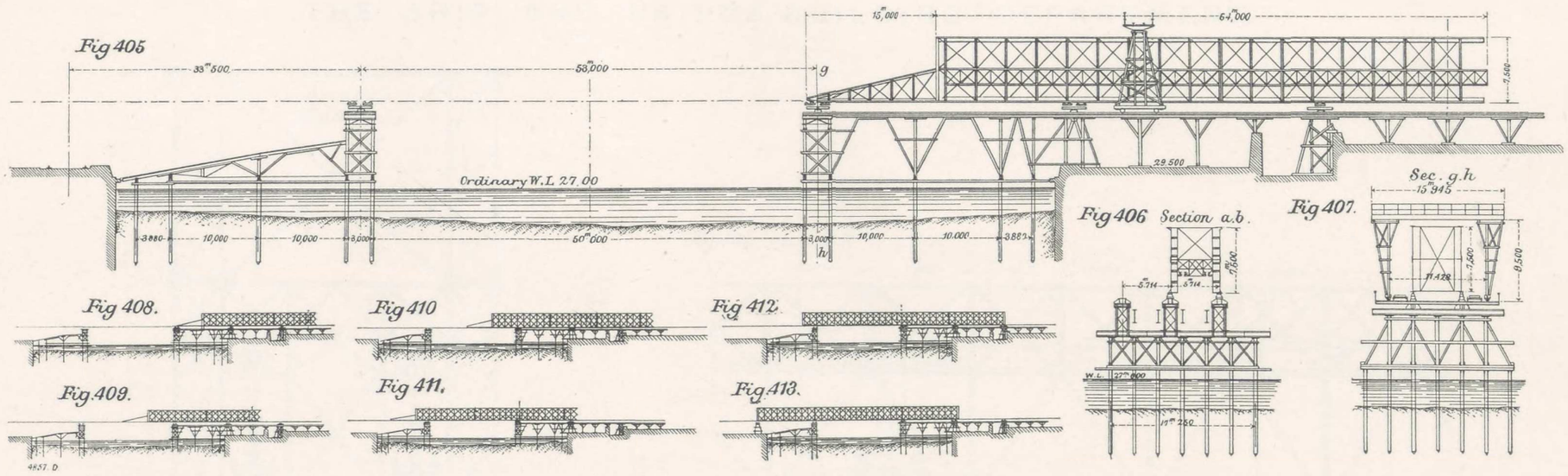
The weight of the material employed in the construction of the roller bridge is divided as follows:

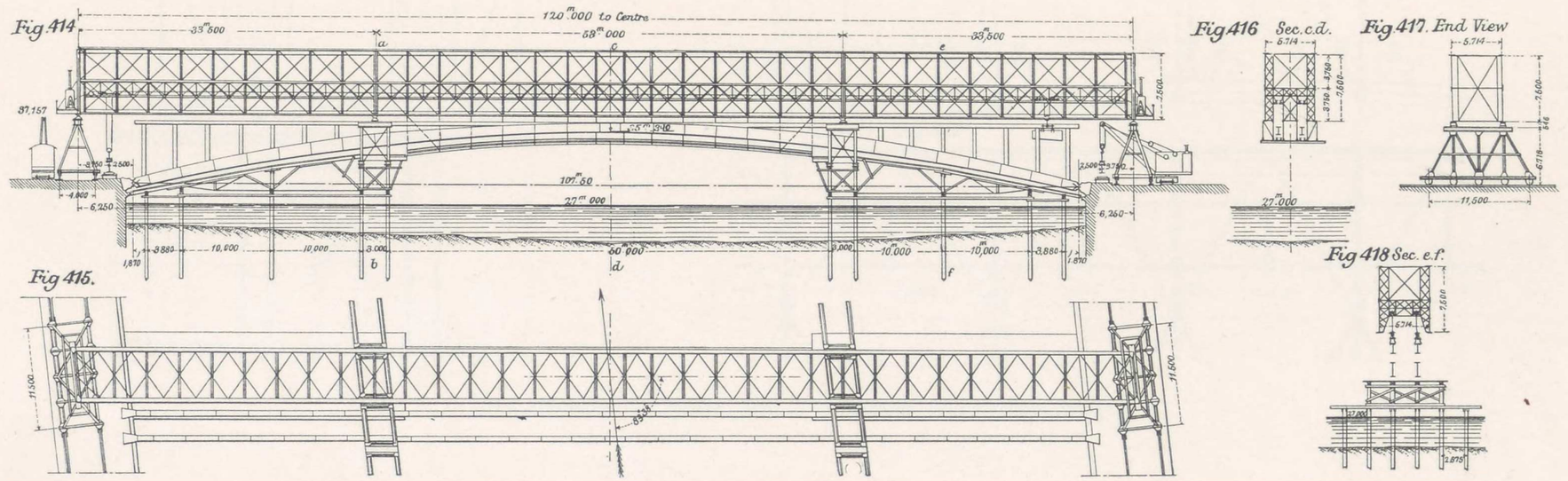
	Tons
Roller bridge proper, with bearings	238.5
Bank trestles	47.0
Winch platform, pulley carrying beams, ties, swing trees	25.5
Two steam winches	14.0
Total of movable part	325.0
River piles	58.5
Total	383.5

To the weight of the movable part should be added, during erection, the weight of the wood flooring, 10 tons.

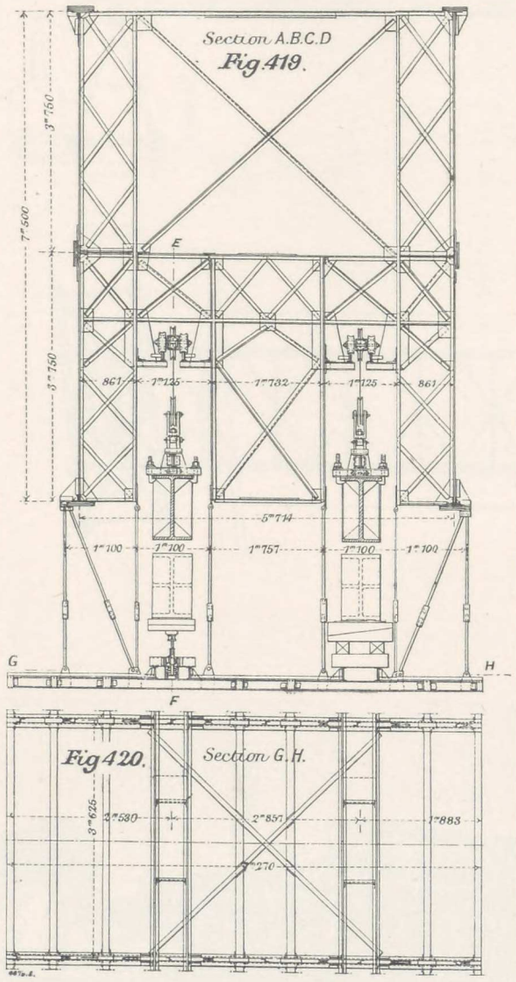
Stability of Roller Bridge.—The roller bridge has been designed to withstand not only vertical loads, but also a horizontal wind pressure of 120 kilogrammes per square metre; it has been reckoned that the strain on the steel might reach 12 kilogrammes per square millimetre (7.62 tons per square inch) of gross section under the action of vertical loads, and 13 kilogrammes (8.25 tons) under that of the wind.

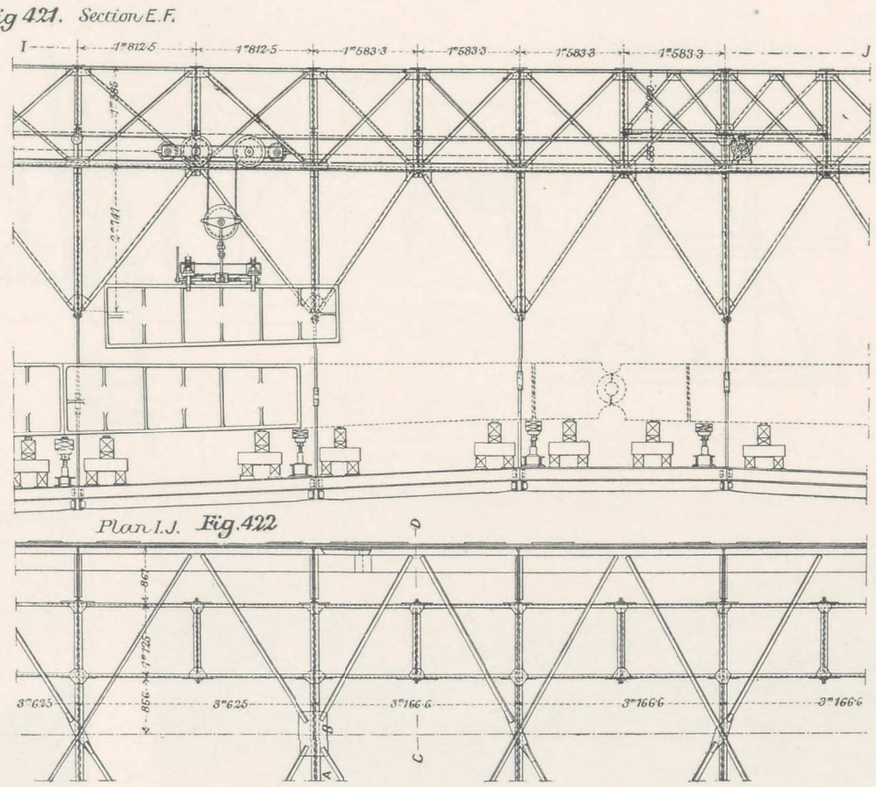
It is under the action of its own weight, increased in the middle by the weight of the centres, that the moment of flexure is at a maximum, and the coefficient of 12 kilogrammes per square millimetre (7.62 tons per square inch) of gross section is reached. It should be remarked that





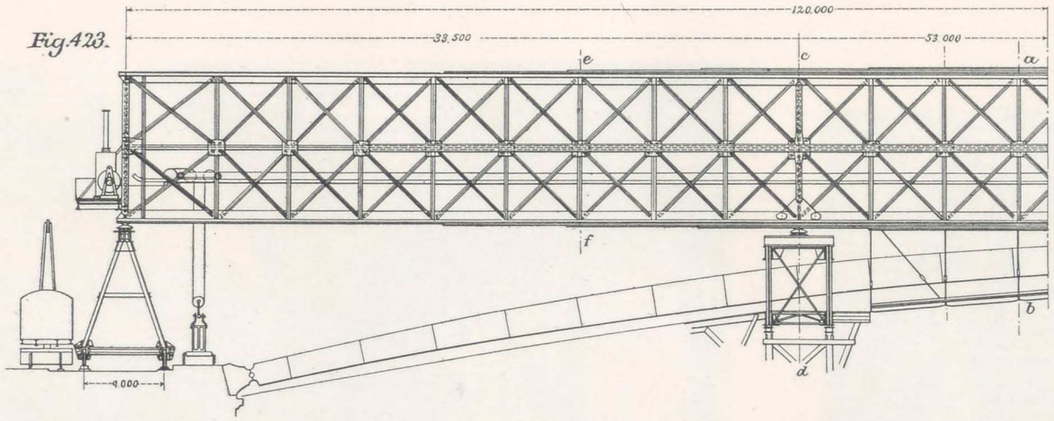
The Alexander III. Bridge; Method of Erection by Travelling Bridge.





The Alexander III. Bridge; Method of Erection by Travelling Bridge.

Fig.423.



Section a.b. Fig.426 Section c.d

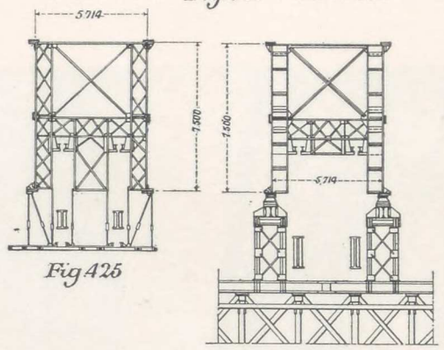


Fig 425

Fig.424.

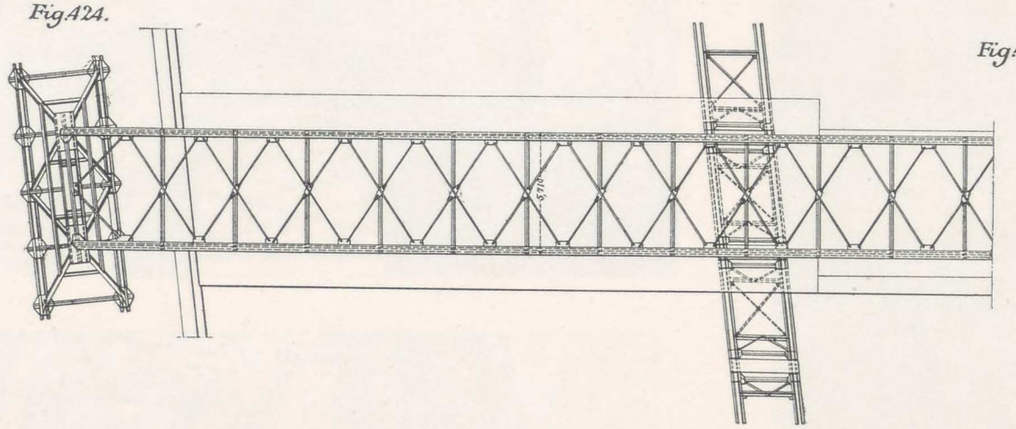


Fig.427. Section e.f.

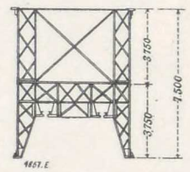
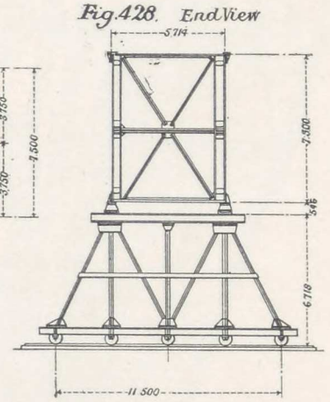
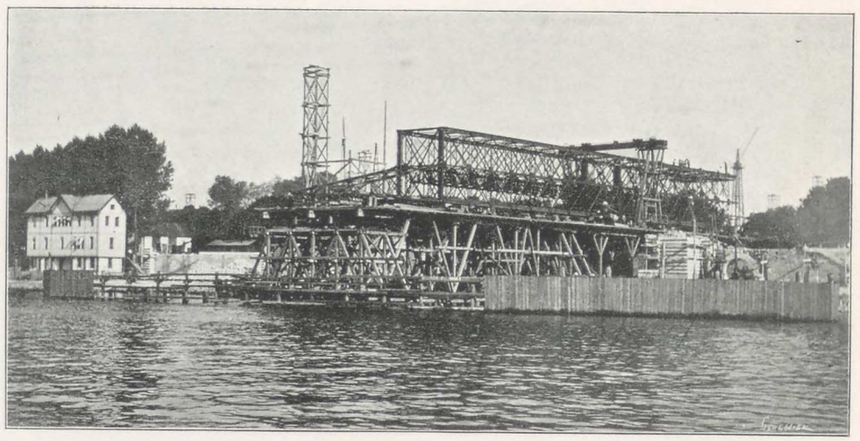


Fig.428. End View





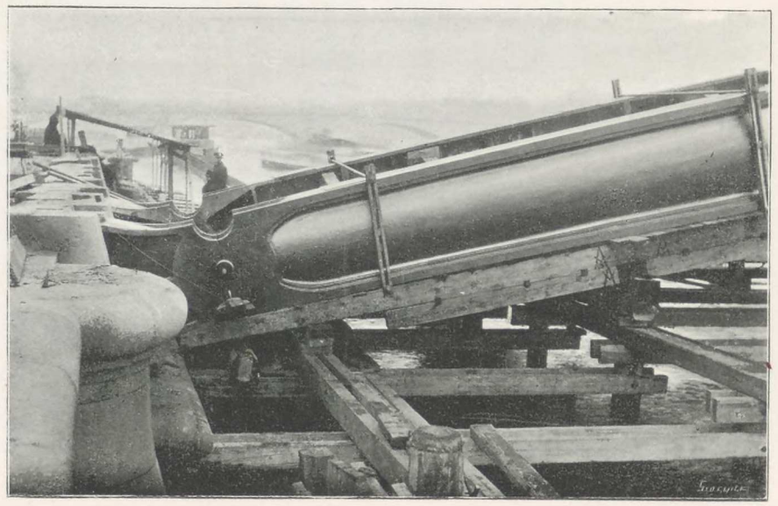


Fig. 429. Fig. 430.

The Alexander III. Bridge; Method of Erection by Travelling Bridge.

PLATE LXXXIX.

THE SHIP AND BRIDGE-BUILDING DEPARTMENT.

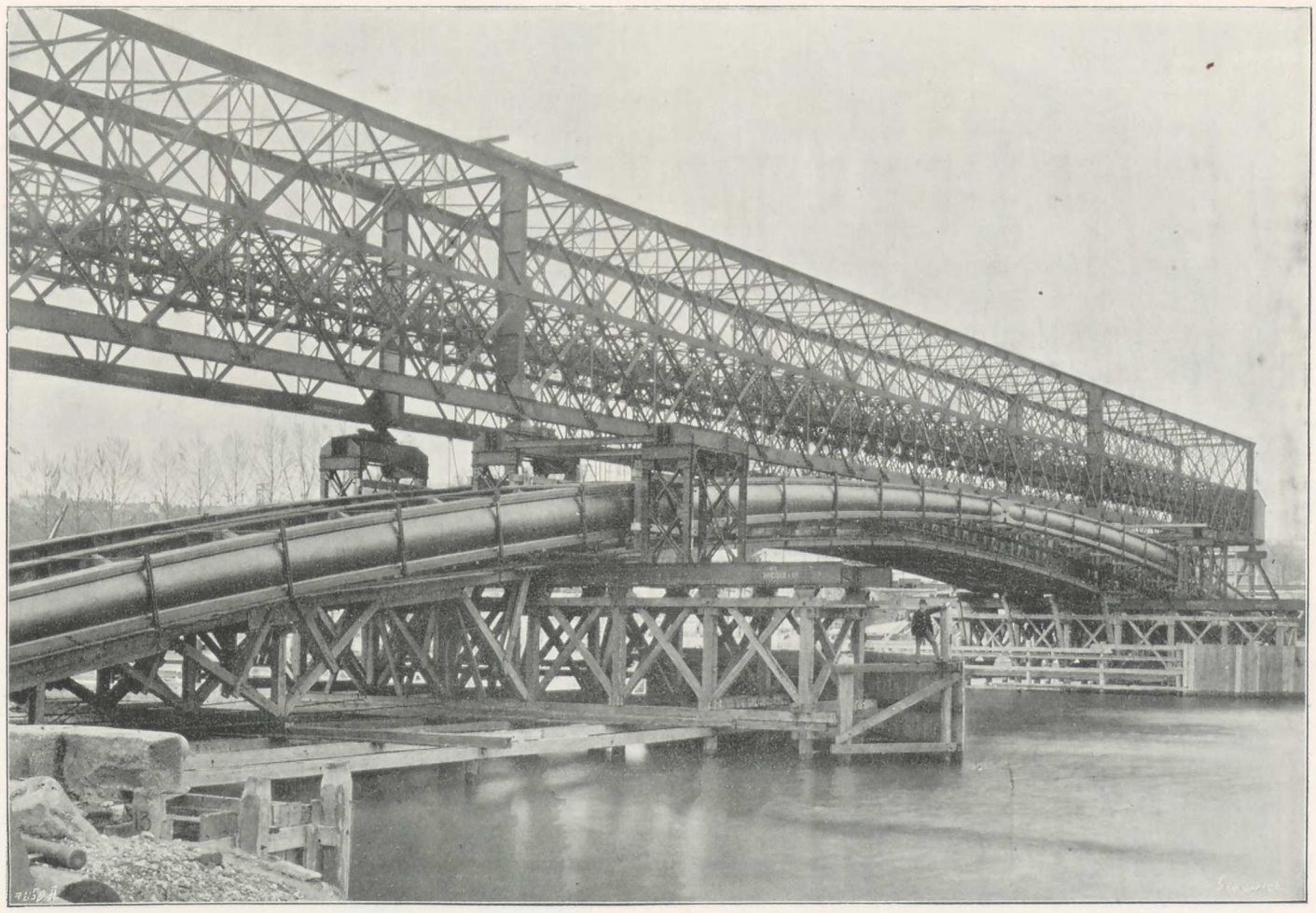


Fig. 431.

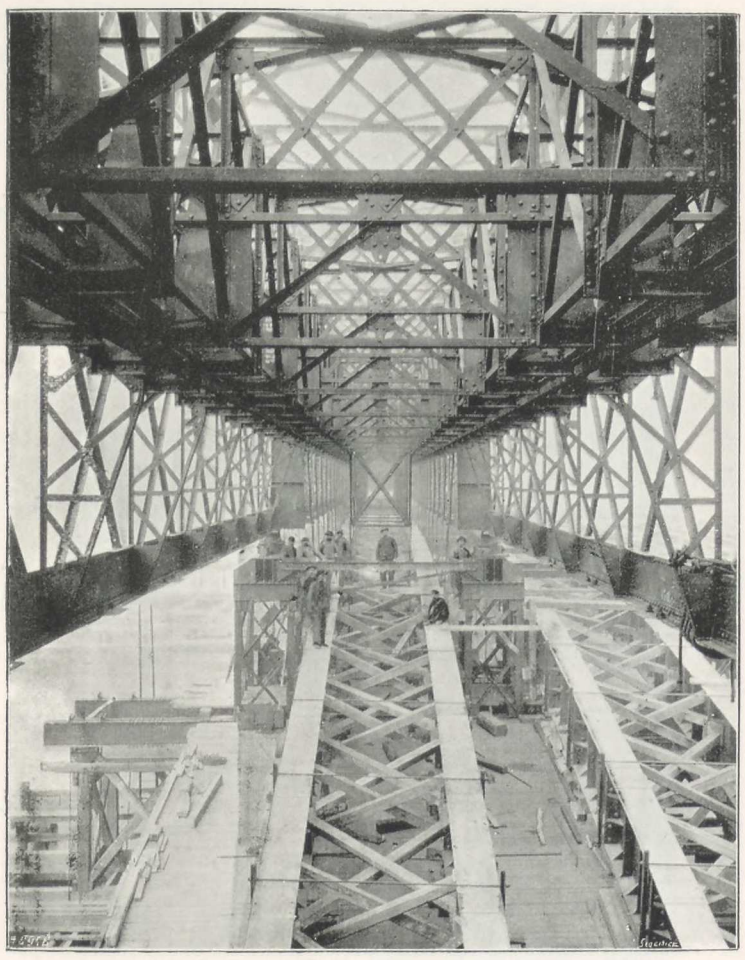


Fig. 432.

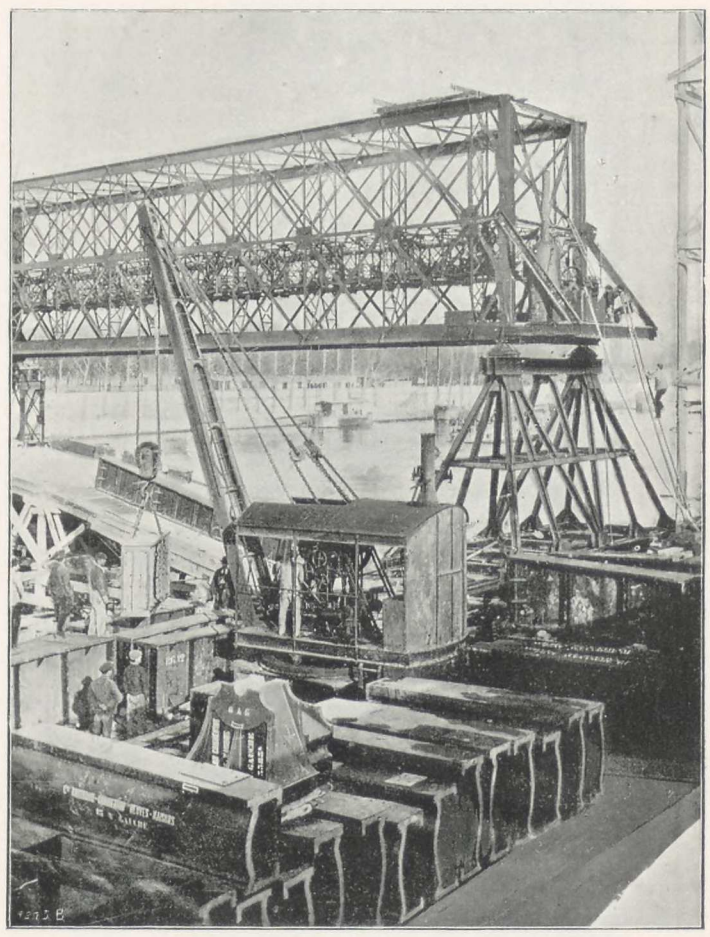


Fig. 433.

The Alexander III. Bridge; Progress of Erection.

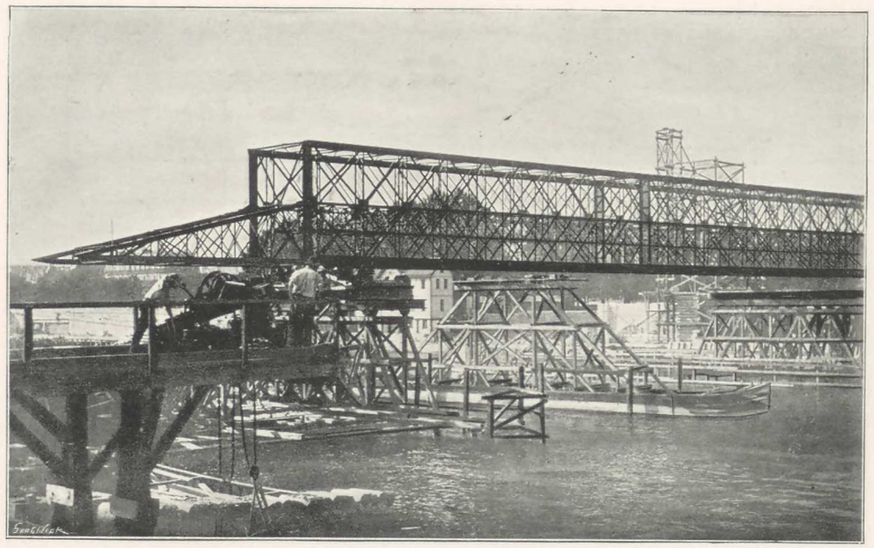


Fig. 434.

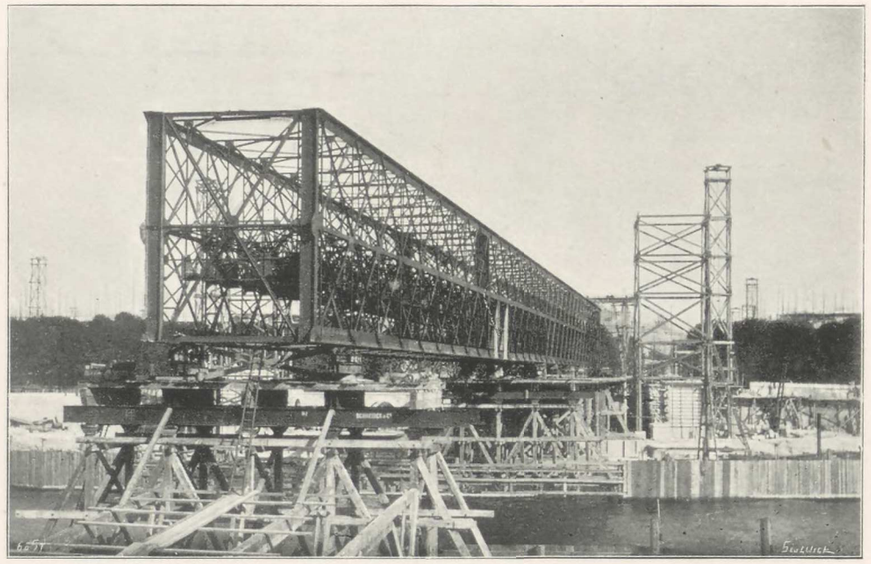


Fig. 435.

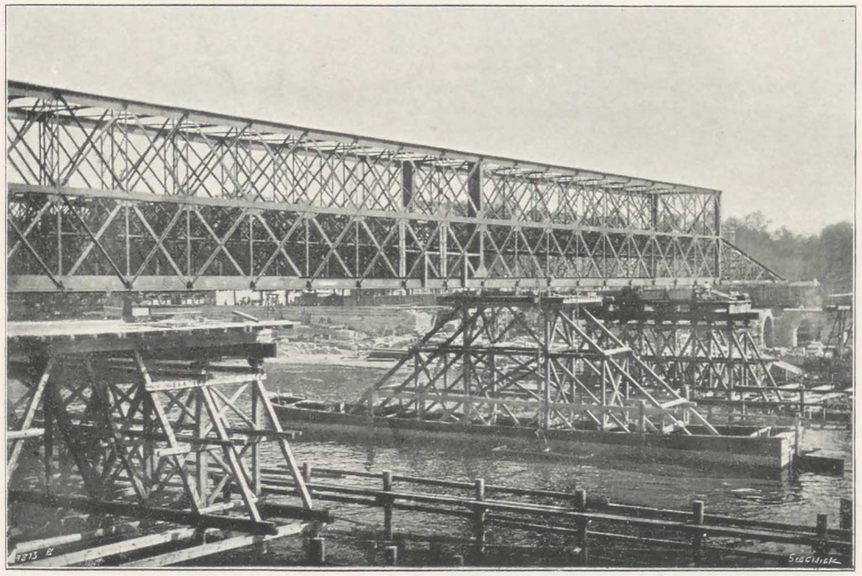


Fig. 436.

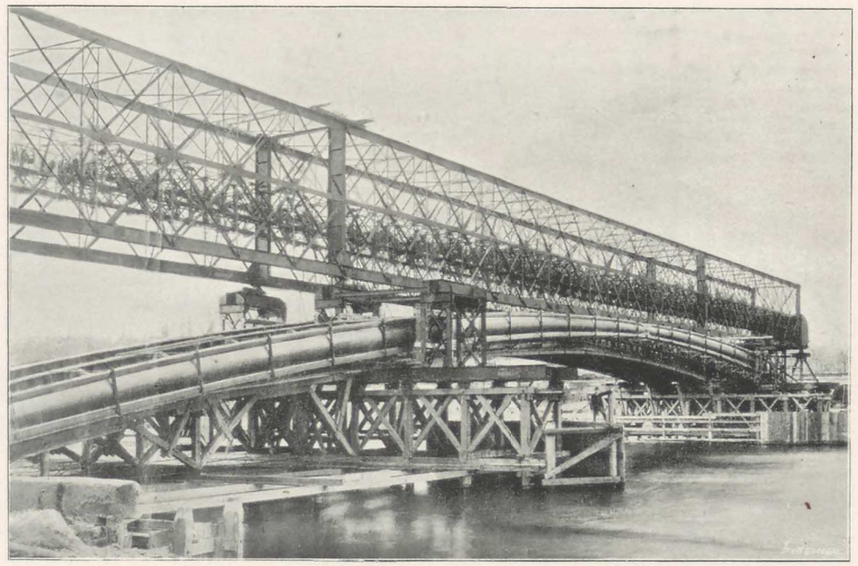


Fig. 437.

The Alexander III. Bridge; Progress of Erection.

THE BRITISH MUSEUM DEPARTMENT

Fig 438

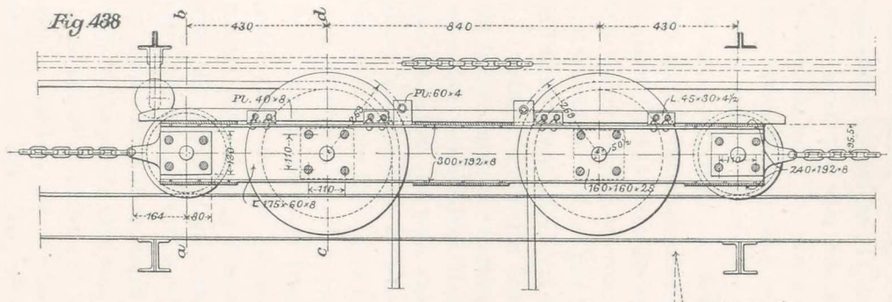


Fig 439.

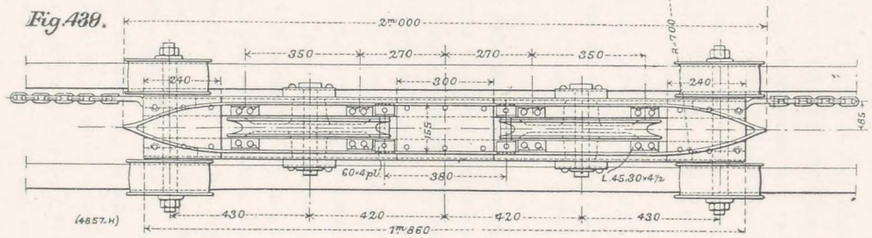


Fig 440. Section thro' a.b.

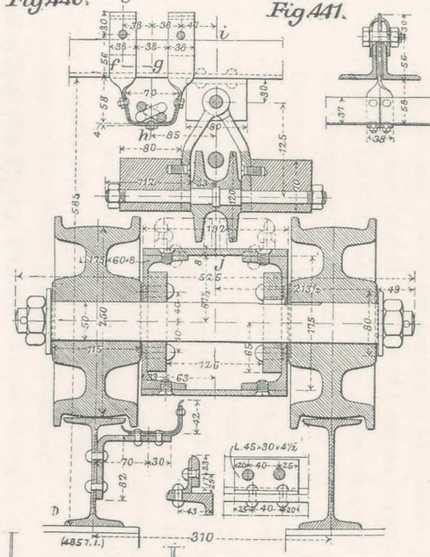


Fig 441. Sec.n thro' e.f.g.h.

Sec.n thro' i.j.

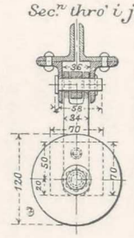


Fig 442.

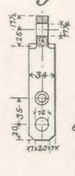


Fig 443

Sec.n thro' c.d.

Fig 444.

Fig 462.

Fig 463.

Fig 445.

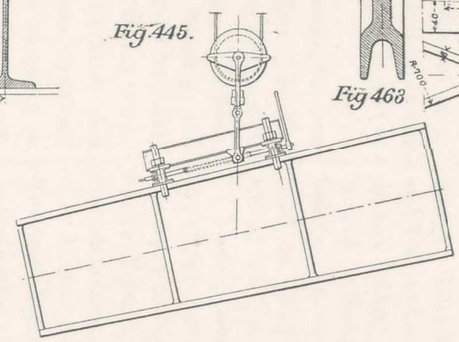


Fig 446.

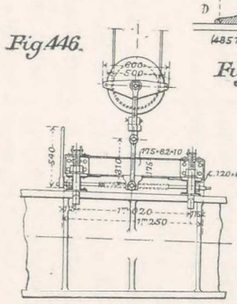


Fig 447.

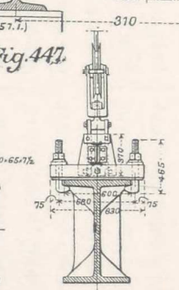


Fig 448.

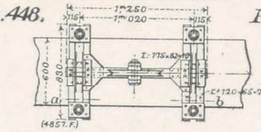


Fig 456.

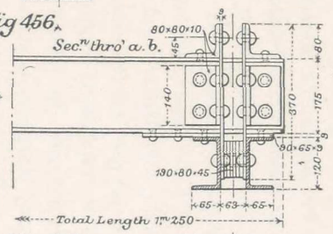


Fig 457.

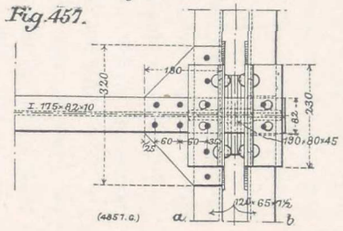


Fig 458. Section thro' c.d.

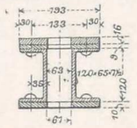


Fig 459.

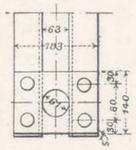


Fig 460.

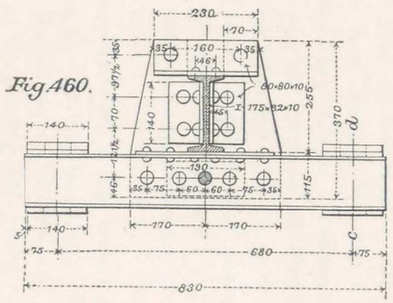


Fig 461

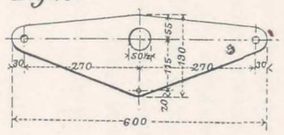


Fig 449.

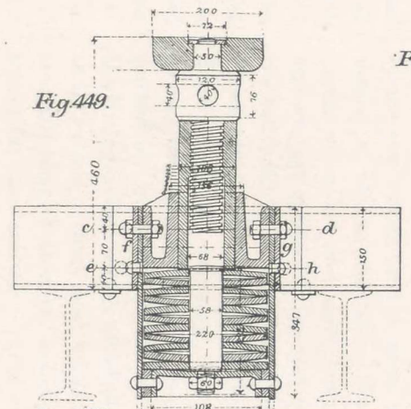


Fig 452.

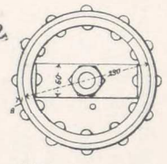


Fig 453.

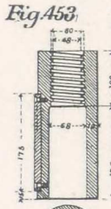


Fig 454.

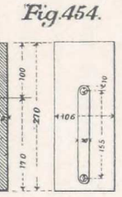


Fig 455.



Fig 450. Section e.f.g.h

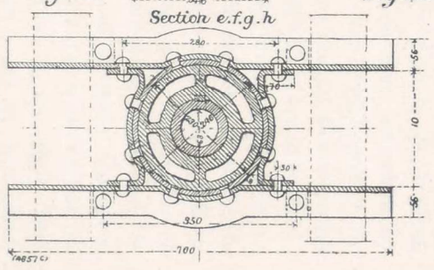
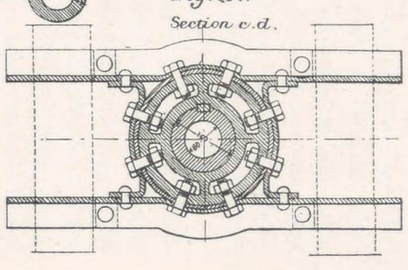


Fig 451. Section c.d.



The Alexander III. Bridge; Details of Erecting Plant.

PLATE XCII.

the bridge has to bear these strains only at short intervals, when it is shifted from one series of arches to the following. For this operation a calm day is always chosen, so as to reduce the strain on the horizontal stay girder, the moment of flexure of which, under the action of the wind, is also at a maximum for the 120-metre (394-ft.) span.

It will be seen, therefore, that the roller bridge behaves differently during shifting and during erection. In the first case, it rests solely on the end trestles, mounted on wheels, and is calculated to be self-supporting, while bearing the surcharge due to the suspended flooring and erection tackle. In the second case, it is lifted by screw jacks and lowered on supports in a line with the intermediate piles, so that it can be compared to a three-span bridge, *i.e.*, with one 53-metre (174 ft.) central span and two 33.50-metre (110-ft.) shore spans. The supports on the piles are, however, maintained slightly lower than those on the abutments, as the weight of the arches that acts on the middle part would cause the bridge to sag in the centre, which would tend to make it rise with regard to the roller trestles. This, however, might have been avoided by curving the girders; but, on the other hand, it would have been more difficult to deal with girders so shaped, and it was deemed preferable to let the roller bridge be slightly curved in its central part during erection, which, moreover, facilitates placing the voussoirs.

Erecting the Roller Bridge.—It was thought, at first, that the bridge could be erected on one of the banks and floated in place; owing, however, to its great dimensions, especially its height, 17 metres (55 ft. 9 in.) above the river level, the idea was abandoned. In erecting, great difficulties had to be overcome, as there was not sufficient space available on either bank to erect it completely, nor indeed, enough to erect a section that would cross the 53-metre (174 ft.) wide channel. The bridge was therefore built in three operations.

In order to reduce the strains developed in the bridge framework during overhang in the second operation, one end was fitted with a light tapering head 15 metres (49 ft.) in length (Plate LXXXVII.).

During erection the lower frames had to transmit to the lattice bars the reactions from the bearings, when they were not immediately above the bearings. These bars had, therefore, in each panel consecutively, as it came above the bearings, to bear local strains which increased the work upon them to a large degree. The frames had been stiffened to resist local strains, the height of the webs having increased from .450 metre ($17\frac{11}{16}$ in.) to .550 metre ($21\frac{5}{8}$ in.); in addition, steel stanchions join the central part of these frames to the lattice work, in a line with the middle of each panel. As these arrangements were not thought sufficient, strengthening was completed by the addition of an angle-bar to the top of the frame webs in the panels that were liable to be most distressed.

As the river traffic was on no account to be interfered with, a floating row of piles was moored, for the sake of prudence, in the centre of the channel, and was adjusted at such a level that by means of a few wedges it was possible to place it in contact with the underside of the bridge. This was done only as a precautionary measure, and the device was not used at all during the erection of the bridge, the 53-metre (174 ft.) wide channel being crossed without any difficulty. The strain on the metal reached 15 to 16 kilogrammes per square millimetre (9.52 to 10.16 tons per square inch) of section at the end of the operation.

Three causes contributed to the lowering of the end of the girder during erection and launching: 1. Deflection of the beam under the action of the dead load; 2. variations in the direction of the bearing line, owing to the settling of the scaffolding, elastic shortening of the woodwork, &c.; and 3. local deformation produced in the lower framing. The first element was estimated at .15 metre ($5\frac{7}{8}$ in.), and to compensate for the elements that could not be calculated in advance, the end was raised by .20 metre ($7\frac{7}{8}$ in.). All the operations were carried out without much trouble; each one took a half day, and during the second operation, navigation was stopped from 5 A.M. to 7 A.M. only.

The forward travel of the bridge was obtained by means of two winches working on two sets of tackle fixed to the set of piles to the right. The shifting device comprised beams fitted with two or four rollers, according to the loads to be transferred to the scaffolding.

The roller bridge behaved well, as also did the wood scaffolding. During the greatest overhang the support placed above the starting point settled by 16 millimetres ($\frac{5}{8}$ in.); while that in the rear settled by 5 millimetres ($\frac{3}{16}$ in.), the end of the bridge having drooped 136 millimetres ($5\frac{3}{8}$ in.). The end, however, met its bearings without trouble and without it being necessary to lift it, the complete launching taking place without any stoppage. To add to the precautions already taken, the panel uprights subjected to the greatest strains were strengthened with timber stanchions placed in the centres.

Erecting the Arches.—Each arch is erected by starting from both ends at once; therefore two ribs in course of being laid occupy four gangs who meet at the key. The various operations are shown in the illustrations, Figs. 405 to 437, Plates LXXXVII. to XCI. Two steam cranes take the sections from the dépôt on the banks, and lift them on trucks which are used to carry them under the service bridge, from which they are taken by means of steam winches. These are double-acting by means of cables, and serve both for raising the voussoirs and conveying them to the spot where they are to be fixed; the roller bridge is fitted with tracks for this purpose, on which run the erection trucks, two in number, for each rib. Each truck has, therefore, to serve a 60-metre (196 ft. 10 in.) run of ribs; this necessitates a perfect system of conductors both for the endless conveying chain and for the lifting cable; to this effect the endless chain runs in a trough made of sheet steel, while the cable is supported on specially-shaped sheaves, arranged so as to allow free travel for the trucks. These sheaves are in two parts,

so that the cheeks can be separated. The separating of the sheaves is effected automatically by the trucks; these carry a spindle which, in engaging in the groove of the sheaves, insures the separation of the cheeks while the truck passes; two counterweights afterwards bring the cheeks into contact. (Figs. 438 to 463, Plate XCII., are details of the erection gear.)

The sections of the ribs are deposited either on the suspended flooring or on the wood centres of the service bridges. They are then adjusted, this being a very delicate operation. They are first lowered by using the steam winch brakes, on oak wedges placed at the ends of each voussoir, the wedges serving to give an approximate position, final adjustment being obtained by means of small plates that bear on the oak wedges. Sledge-hammers cannot be used, as the suspended flooring is not adapted to withstand violent shocks; screw-jacks are not available, as the flooring is not strong enough to afford abutment. A special device has therefore been designed by which the direction of the sections can be regulated in a vertical plane, according to the position they have to occupy in the rib, the angle formed with the horizontal diminishing progressively to the springing to the key.

The voussoirs are held by four hooks under the top flange (Fig. 445, Plate XCII.); these hooks are united in pairs transversely to the voussoirs by small stays held by a rod. The position of the cable with relation to the transverse centre line of the rod is made to vary by means of a screw, so that the centre of gravity of the voussoir can be altered at will with relation to the suspension point. When suspension is effected at a greater or less distance from the centre, the voussoir is more or less inclined to the horizontal, and this enables the foreman to determine in advance the required angle by his ordinate and abscissæ table. This same table is also used for the vertical adjustment of the ribs, before striking the centres, as follows: Two sights placed at each end of the roller bridge determine the horizontal plane, according to which the heights of the rods laid on the four corners of each voussoir is traced, to obtain the required height. When necessary, the level is corrected by slightly lifting the voussoirs by means of levers, small iron wedges being inserted between the voussoirs and the top plate. In order to obtain a slight lateral displacement, the lower plate is drilled with holes in which levers are inserted to shift the voussoirs to their final place. The horizontal spacing of the sections is constantly verified by means of steel gauges placed between the voussoirs of the arch last erected, and the one in course of erection. The difficult part of the transverse adjustment of the ribs lies in the perfect adjustment of the first segments. Each half rib is inspected and passed at the works on a full-sized centre, on which all the voussoirs are fitted together previous to delivery, so as to verify that they are of the exact dimensions and that they join perfectly; consequently, if the work on the spot is started correctly, each half arc rights itself on its whole length.

Each two adjacent sections are joined by means of ten 36-millimetre ($1\frac{7}{16}$ in.) bolts. When all the sections are fitted together, the centre is struck, and this necessitates a fresh adjustment of the whole rib, as the temperature influences in a marked degree the variations in the height of the key; it is therefore necessary to adjust all the ribs at a medium temperature, which is taken as a basis for the operations. In order to facilitate corrections due to variations in temperature or to undetected imperfections in manufacture, a special joint has been made at the key, the extent of which is made to vary by the interposition of plates of different thickness.

The segments of two ribs of a group being adjusted, they are stayed both horizontally and vertically, by provisional wood bracing placed so as to withstand compression, and by steel tie-bars to maintain the exact distance apart, the wedges are then removed. Special care has had to be taken during these operations to ascertain that none of the screw-jacks works to a greater extent than its neighbour, as a fracture of the suspension rod might ensue Recording screw-jacks are therefore used to enable the foreman to check their working.

These jacks (see Figs. 449 to 454, Plate XCII.) consist of a cylindrical casing formed of a steel plate which rests through two sleepers riveted to it on the steel string-pieces of the suspended flooring. The action of the loads on the head of the screw-jacks is transmitted through a screwed rod fitted with a nut to a series of Belleville springs that rest on the bottom part of the envelope. Each variation in weight gives a corresponding variation in the compression of the springs, by which the rods can be graduated up to 16 tons.

When the wedges are driven all the screws-jacks are operated simultaneously, the effort being increased by a half-ton each time. When the two ribs are raised sufficiently to free all the oak blocks, iron wedges, &c., the joints are put in place; the jacks are then eased with equal precautions, the level of the two joints being maintained constant by means of a water-level, which enables the foreman to ascertain that the motions of the two ribs are simultaneous. A pair of ribs can also be lowered by a series of successive operations, one gang of men working alternately on the up-stream and on the down-stream ribs, provided that the difference in the level by lowering, does not exceed 10 millimetres ($\frac{3}{8}$ in.) to 15 millimetres ($\frac{5}{8}$ in.).

When the two first ribs are self-supporting and are well stayed, the service bridge is shifted on its rails, to be used in the erection of a second pair. When in working position, the roller bridge flooring suspension bars are arranged so as not to involve taking down the flooring for shifting, but simply the removal of one of the bars in every two of each group. When the first two groups of ribs were set free, the up-stream set of piles were removed and brought down-stream; the bank centres also were shifted, to be used in erecting the third group; this shifting is very easily effected, owing to the interposition of oak sole-beams between the heads of the piles already driven, and

Fig.465.

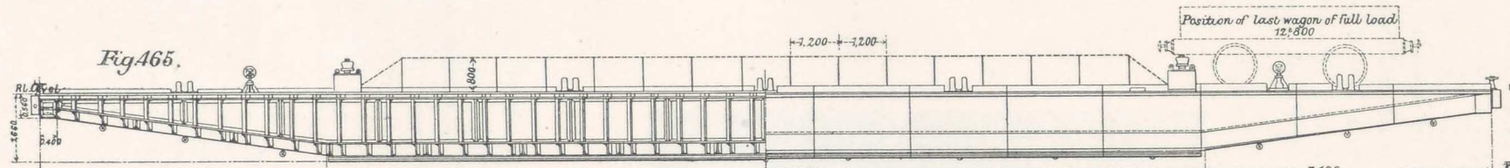


Fig.466.

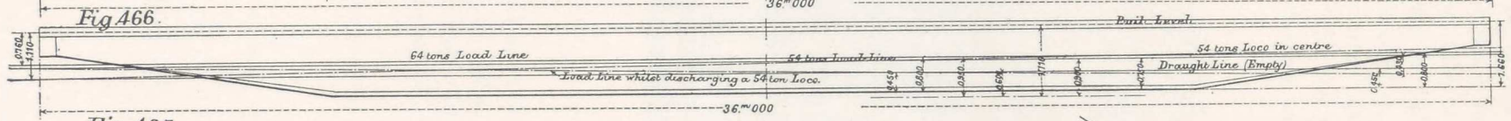


Fig.467.

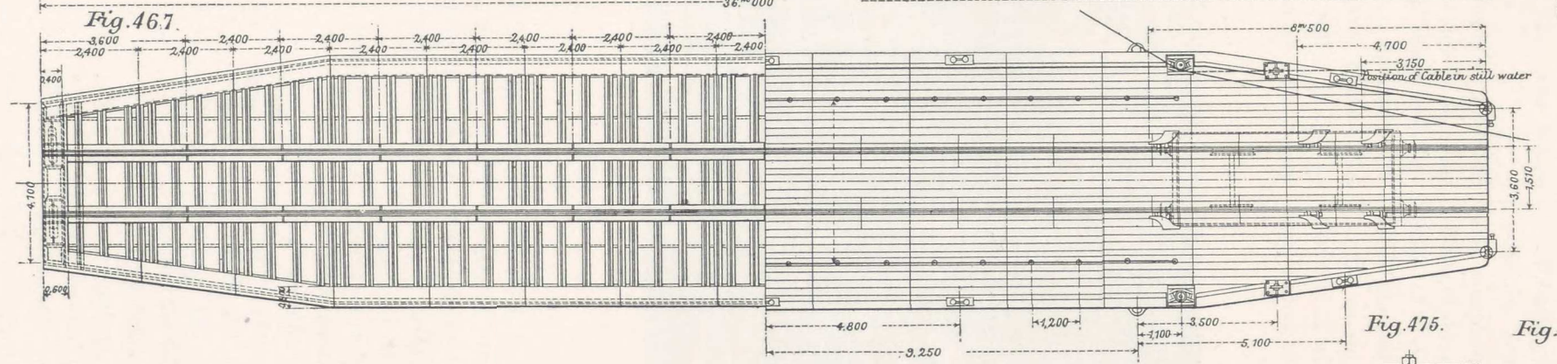


Fig.468

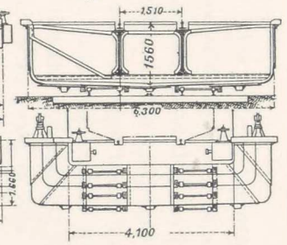


Fig.469.

Fig.470.

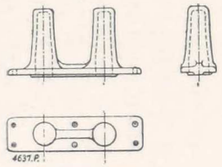


Fig.471.

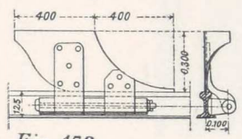


Fig.472.



Fig.473.

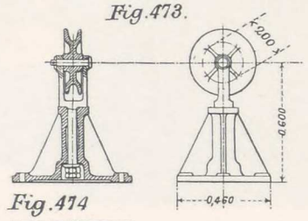


Fig.474

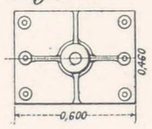


Fig.475.

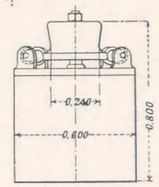
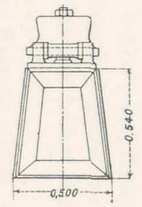
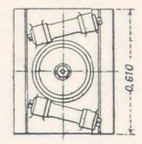


Fig.476





Messrs. Schneider and Co.'s System of Floating Bridges.

the whole of the movable centres; these centres are made to advance in one operation by means of screw-jacks.

In practice it has been found that ten days are sufficient for the foreman to effect all the operations required for the putting in place a pair of ribs; these operations involve the bringing of the segments on the spot, their fixing, adjustment, freeing the rib, and shifting the roller bridge and centres to the following group of ribs.

The setting free of a pair of ribs is made at intervals of one month, in order, when the roller bridge is over one group of ribs, to erect, by means of the steam winches, all the corresponding heavy parts of the superstructure, such as uprights and stays, string-pieces, girders, &c. It is not necessary, therefore, for the roller bridge to be brought back for these operations, as the less heavy pieces can easily be shifted from a movable flooring resting on the ribs. The erection of all rolled material, while offering certain difficulties in exact fitting, is effected rapidly, owing to the small number of rivets that have to be put in place on the spot.

The amount of the work, as regards tonnage, being approximately as follows:—

	Tons.
Weight of cast-steel arcs	2,000
,, corresponding rolled material ...	2,000
,, viaducts on shore ends	450
,, tramway coverings	250
,, abutments of same	100
,, cast steel for tympanum shoes and kerbstones	250
,, cast iron	250
	5,300

The above description will give a general idea of the Alexander III. Bridge as it will appear when completed. It also shows the means adopted for its erection. These means, owing to their importance, have involved considerable outlay; but Messrs. Schneider and Co. were desirous of completing the erection within the time prescribed, so that the bridge should form part of the great Exhibition of 1900.

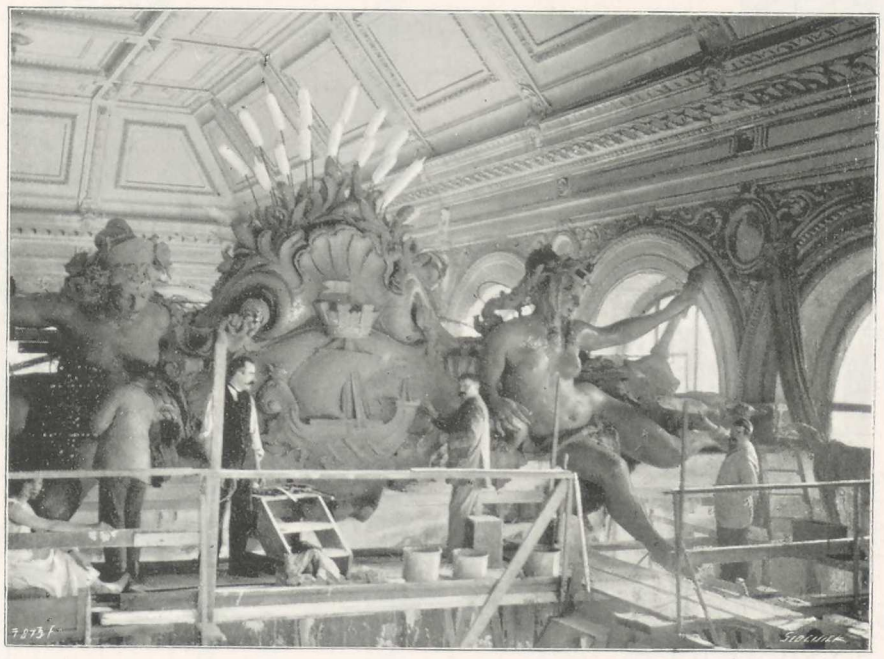


Fig. 464.

Floating Bridges (Figs. 465 to 476, Plate XCIII.).—Messrs. Schneider and Co. have made a very minute and complete study of the problem which consists in re-establishing the working of a railway from one bank of a river to the other, when it has been temporarily stopped owing to the destruction of a viaduct.

Let us suppose a river 450 metres (1,476 ft.) wide, the currents of which have a rapidity of 3 metres (9 ft. 10 in.) per second, the height of the water varying by 3 metres (9 ft. 10 in.). The traffic per day of 12 hours that is to be carried between the two banks, amounts from 280 to 480 effective tons, depending upon the use of one or two floating bridges. The loads have to include locomotives, wagons, or troops, the weight of the locomotives being calculated at 54 tons and 64 tons.

After carefully looking into the matter, and taking into account several examples of profiles and nature of ground; the various ways in which the loads would be divided; the various methods of taking apart and transporting the apparatus, &c., Messrs. Schneider and Co. adopted the following material:

1. A floating bridge (Figs. 465 to 469, Plate XCIII.) of a total weight of 61 tons, formed of 15 sections of 2.400 metres (7 ft. 10½ in.), bolted together, with the interposition of india-rubber packing, in order to insure their being perfectly watertight.

The ends of the floating bridge being bevelled enable

it to be moved along the inclines of the banks; the central part, embodying step girders with rails, forms the railway line. The principal dimensions are the following:

	m.	ft.	in.
Length	36	118	0
Width	6.300	20	8
Depth	1.520	5	0
Draught, empty	.450	1	$5\frac{3}{4}$
,, with a load of 54 tons ...	.750	2	$5\frac{1}{2}$
,, ,, 64 ,, ...	.800	2	$7\frac{1}{2}$

fluctuations of the river, or the differences in the loads carried; it can also be perfectly regulated on a horizontal plane, so that the rails of the two banks can always be made to correspond exactly with those of the floating bridge.

3. Two 3-ton steam winches with boilers, used to raise and lower the loads over the inclined banks of the river.

4. A 7-ton portable crane for lifting the bridge

Fig.477.

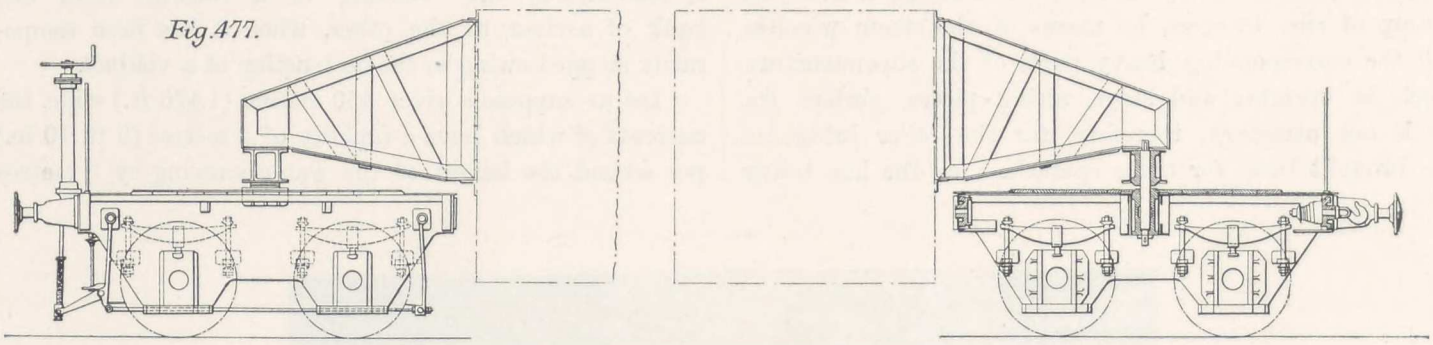


Fig.478.

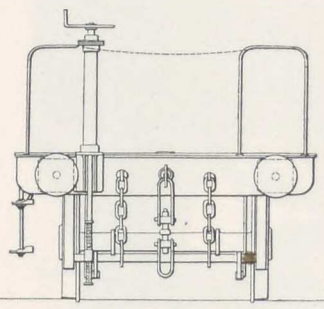


Fig.479.

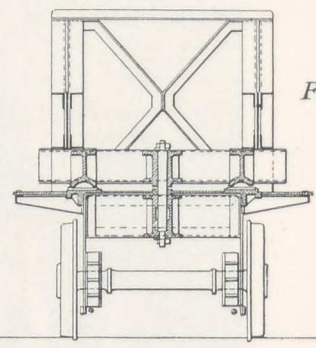


Fig 480

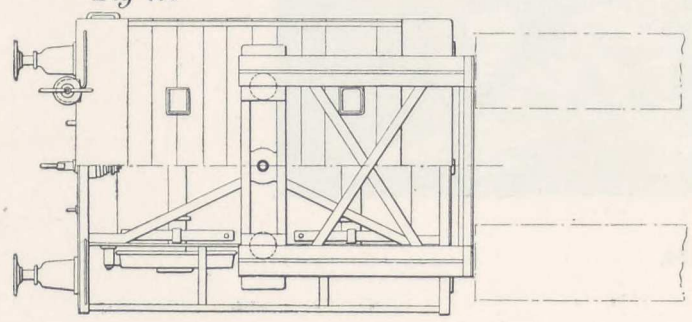


Fig 481.

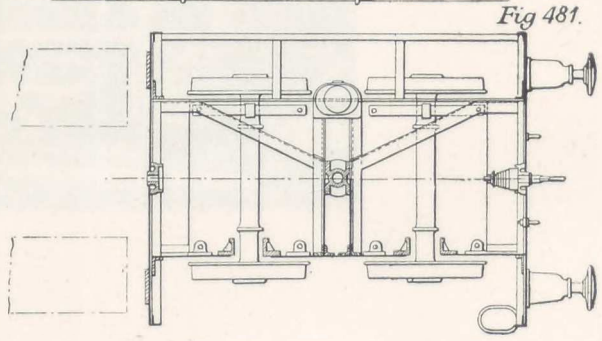


Fig.482.

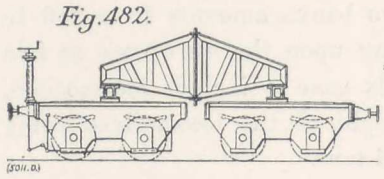
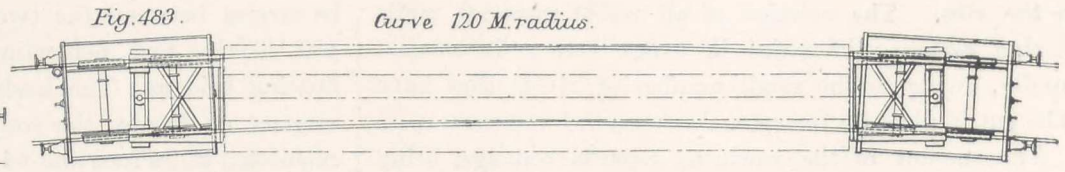


Fig.483.

Curve 120 M. radius.



The Marcille System of Military Bridges.

The bridge is fitted with bitts, pulleys, cleats, rings, screw-jacks, drain pump, &c.; in short, with all the various accessories necessary to its working (see Figs. 470 to 476, Plate XCIII.).

2. Two junction trucks, wedge-shaped, serve to establish a communication between the rails on the bank and those that are afloat, by travelling on a rack incline, previously laid upon the banks of the river to be crossed. A special arrangement enables the adjusting of the apparatus to the various levels which result from the sections, the junction trucks, the guide-rope, &c., in short, for handling all the parts that are transported on trucks.

When it is proposed to use this method of crossing a river, the ends of the railway line are first set in order, and the banks are prepared for the operations that have to be effected.

Preliminary operations include the repair of quays; the laying of tracks to the main portion of the line that has not been tampered with; and fixing the lifting gear, which must be calculated for raising to the level of the

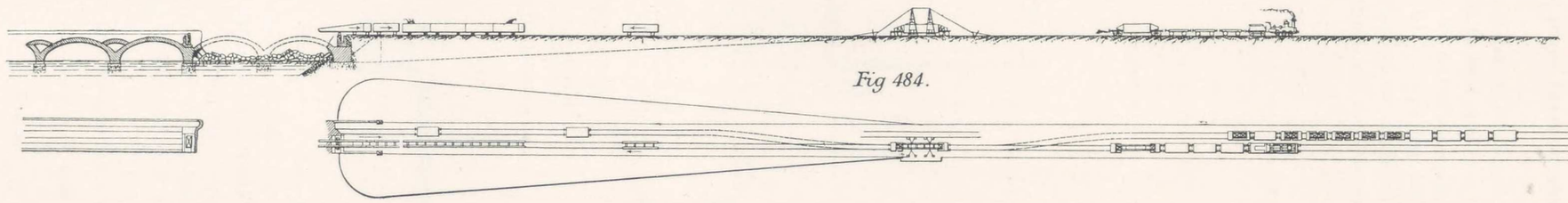


Fig 484.

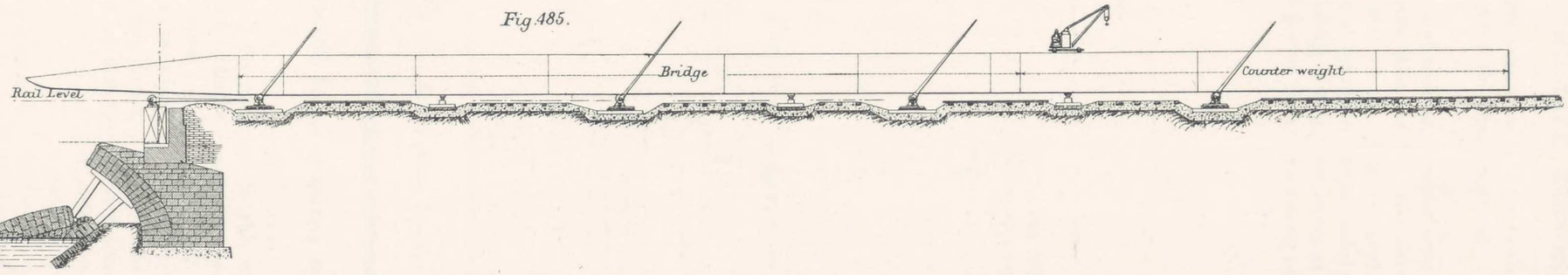


Fig 485.

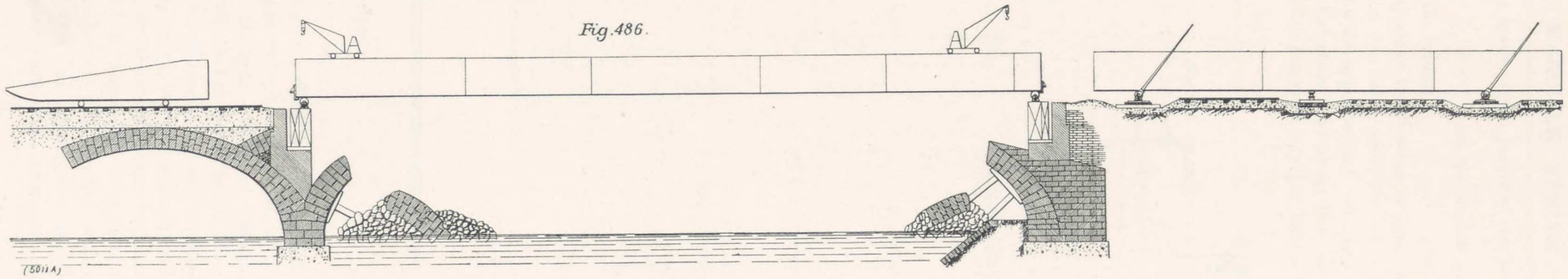


Fig 486.

The Marcille System of Military Bridges.

PLATE XCIV.

line, or lowering to the bridge, wagons of 20½ tons, so as to arrive at the above figure of 480 tons given for the daily traffic.

With the use of tackle, combined with that of winches, it will be possible to deal with the locomotives, these not being included in the estimated weight of traffic.

All the material being on one bank, the first operation is to fix the moorings of the guide rope; the bridge is then erected and launched, and the junction truck put in place.

In twelve hours, seven journeys can be effected, which represent

$$40 \times 7 = 280 \text{ tons of goods}$$

carried over the bridge.

In making use of two floating bridges, one being loaded or unloaded on one bank, while the other is being loaded or unloaded on the opposite bank—the two not being made to travel at the same time along the guide rope, and in reckoning twelve journeys only per twelve hours, as there is in this case a certain amount of lost time in the manœuvres—the traffic amounts to 40 × 12 = 480 tons.

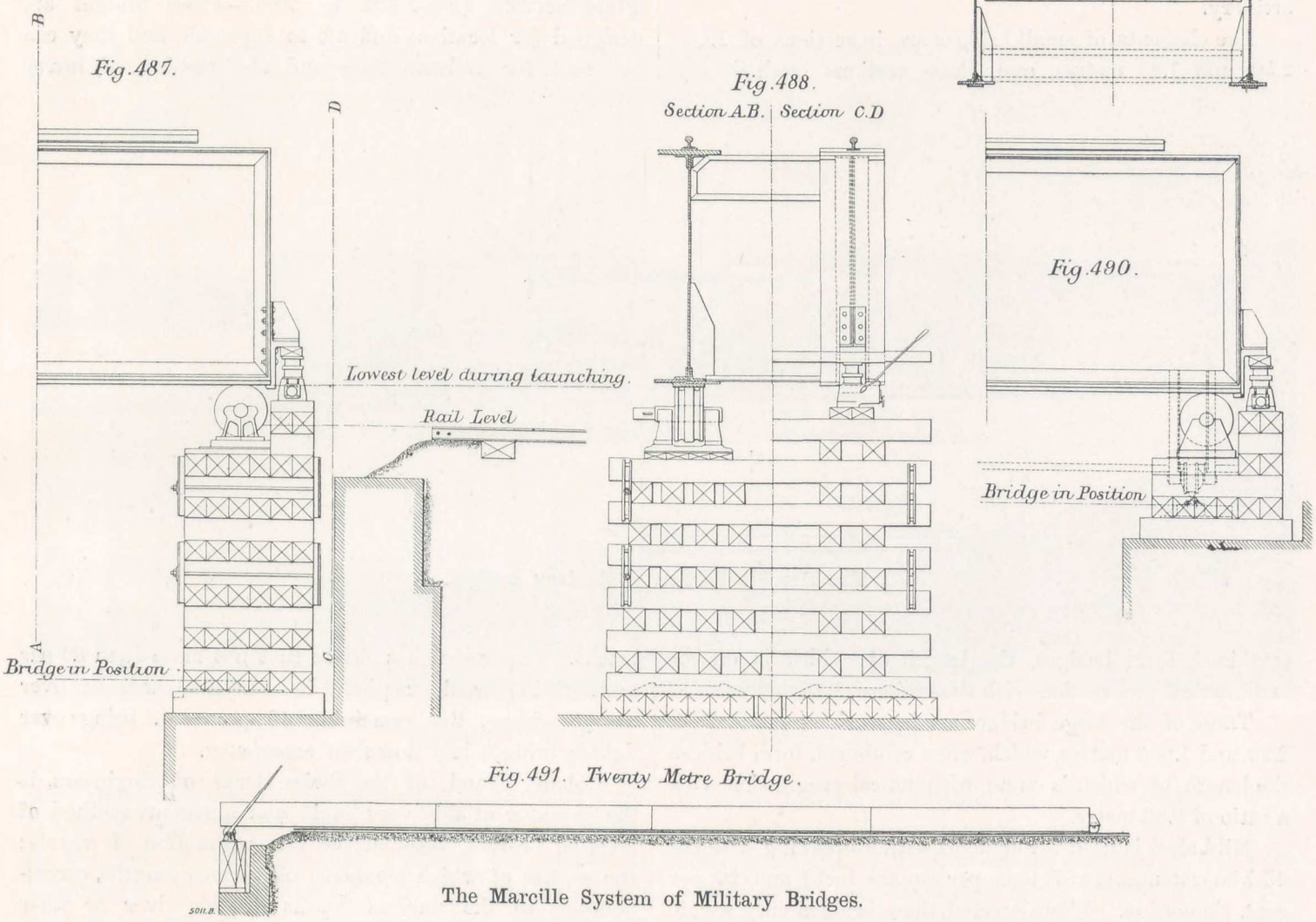


Fig. 487. *Fig. 488.* *Fig. 489.* *Fig. 490.*

Fig. 491. Twenty Metre Bridge.

The Marcille System of Military Bridges.

The bridge serves first for the transport of all the gear and apparatus required on the opposite bank, namely, a 7-ton crane, the other truck, a winch and its boiler.

The apparatus for lifting and lowering the loads have been designed with a view to easy transport; they do not, therefore, take up much room and are kept as low in power as practicable.

One bridge can be loaded as follows with:

Four	16	ton 0 cwt.	wagons	= 64	tons	= 40	tons of goods
Three	20½	,, 0	,,	,,	= 61½	,,	= 36	,, ,,
Five	12	,, 16	,,	,,	= 64	,,	= 40	,, ,,

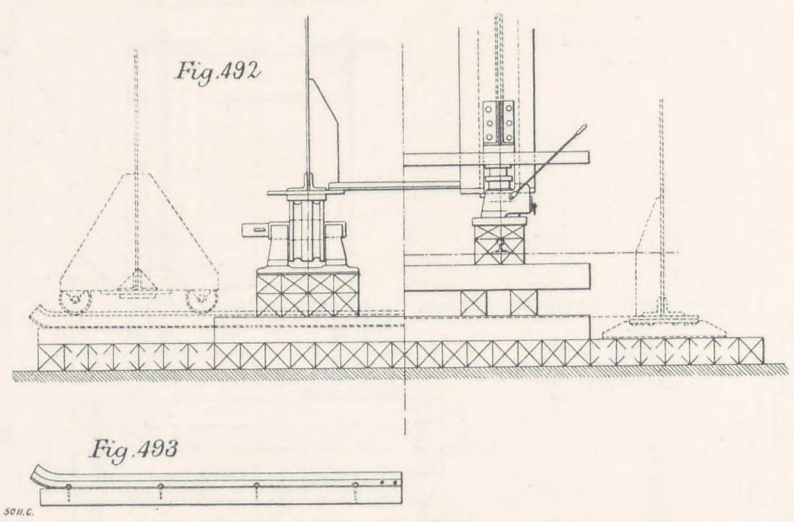
Military Bridges — General Marcille's System (Figs. 477 to 483; 484 to 486, Plate XCIV.; and Figs. 487 to 493).—The experience gained through the observation of recent military operations has demonstrated the necessity of organising, in times of peace, sufficient material of a suitable kind to repair the bridges and railways destroyed by the enemy. The problem was a difficult one to solve, and after full investigation the French Government Commission decided to adopt the type proposed

by General Marcille, as being that which met the purpose best.

The Marcille bridges are divided in two groups, large and small; they are essentially portable, and are divided in sections as large as can be conveniently handled.

The small bridges are in two classes: those of 10 metres (32 ft. 10 in.) and under, and those of 10 to 20 metres (32 ft. 10 in. to 65 ft. 7 in.). They are made to receive the railway line on the top. The large types are also in two classes: from 20 to 30 metres (65 ft. 7 in. to 98 ft. 5 in.) and from 30 to 45 metres (98 ft. 5 in. to 147 ft. 7 in.). The large bridges are made for top or bottom line indifferently, and in both cases they can be fitted with a wood flooring for the passing of troops and artillery.

The elements of small bridges are in sections of 10, 5, 2.50, and 1.25 metres, and these sections methodically



The Marcille System of Military Bridges.

combined, form bridges, the length of which is on an arithmetical progression with the ratio of 1.25 metres.

Those of the large bridges are in sections of 10, 7.50, 2.50, and 1.666 metres, which, when combined, form bridges the length of which is on an arithmetical progression with a ratio of 0.83 metre.

Mild steel is used throughout, with a breaking strain of 45 kilogrammes (28.57 tons per square inch) and 20 per cent. elongation. When erected, these bridges only weigh, per running metre, 550, 785, 1,500, and 2,200 kilogrammes for spans of 10, 20, 30, and 45 metres. The time required for erection on the spot is as follows:

Bridges of	10	20	30	45 metres.
	6	12	46	80 hours.

The various elements are stored in dépôt in such a way as to form complete sections of line; all the sections can be put on trucks, and can pass under the French railway wagon gauges. Loading and unloading are effected with great rapidity, with the help of shears forming part of the material. These bridges have already rendered great service in time of peace, for the rapid replacing of works that necessitated urgent repairs, and the experiments already made tend to show that in time of war their great reputation would be fully justified.

The system, which is different from Messrs. Schneider and Co.'s system of floating bridges, is illustrated by Figs. 477 to 483; 484 to 486, Plate XCIV., and by Figs. 487 to 493. Fig. 484 shows in elevation and plan the general arrangement of the plant for spanning the two broken arches. In Fig. 485 the bridge is shown supported on the hauling rollers, by which it is moved over the gap, and takes its bearings as in Fig. 486. The method of forming the bearings is illustrated in Figs. 487 to 493, as well as the means provided for lowering the ends upon the bedplates.

Military Bridges — Colonel Pfund's System for Field Service (Figs. 494 to 502).—These bridges are designed for locations difficult to approach, and they can be used for railway lines and the passing of heavy trucks. Experience has shown that not more than 60 per cent. of the traffic required in war time will be over heavy bridges, the remaining 40 per cent. being over lighter bridges laid down on emergency.

Colonel Pfund, of the Swiss Corps of Engineers, is the inventor of this very rapid and ingenious method of erecting bridges, based on the forward motion of wheels; the spokes of which would be of various lengths, corresponding to the various depths of the river or other obstacle to be crossed. With this view the "axles" that serve to hold the superstructure carry at each end a socket in which pass two movable pointed piles, that can be made fast at any height by means of a screw or a pin.

a. Infantry Bridges.—Each bridge consists of the superstructure, the bridge-forming device, and an intermediate support; each bay is 7 metres (23 ft.) span from centre to centre of the double **X**-piles and 1.200 metre (3 ft. 11 in.) wide, this width being sufficient for the crossing of troops two abreast, and of horses in single file. The intermediate support (which is similar to the bridge-form-

forming device, but with single piles), reduces the span to 3.500 metres (11 ft. 6 in.). The superstructure is calculated for a concentrated load of 400 kilogrammes (say 8 cwt.), or a uniformly divided load of 250 kilogrammes (say 5 cwt.) per metre run.

The superstructure can be made up in sections of sizes suitable for transport by mules; this was done with the bridges supplied by Messrs. Schneider and Co. to the Argentine Republic. A bridge can also be built up simply by wood girders or logs found on the spot, as has been done in Switzerland, Spain, Sweden, &c.

The erection of the bridges is a very simple operation. The intermediate support and the bridge-forming device are first applied to the shore end of the superstructure; two men stand forward, holding each a pile at an equal angle (about 60 deg.). Each man drives a pile at this incline in the bed of the river, and tightens the socket at command of the superintending officer; each then takes hold of the second pile. The squad push forward the superstructure and this advances, describing an arc of circle, the centre of which is the bearing point of the pile in the bed of the river. On command of the officer the squad stops the forward movement of the superstructure; the second pile has been brought in front of the first one, the two together on each side forming an **X**. The two men previously mentioned then drive this second pile, and the operation is proceeded with in the same way until the bridge is laid.

The forward movement takes a maximum of one minute for a 2-metre length of superstructure. This method can be followed in places where pontooneers would not be able to fix their trestles; it is also well adapted for crossing narrow gorges.

b. Bridges for all Corps of Military.—Only a few modifications of the above method of bridge construction, are necessary to facilitate the crossing of rivers by all corps of troops. The bridge-forming device and the intermediate bearings are arranged for placing side by side, two widths of superstructure; the width is thus increased to 2.400 metres (7 ft. 10½ in.), and is therefore sufficient for wheeled traffic and horses.

Channel Bridge.—One word in passing concerning this scheme, in which so many engineers have been eagerly interested.

When the company that had been formed for designing a bridge over the channel applied for Government approval (1894), submitting the design worked out in every detail by Messrs Schneider and Co., and, as regards the foundations, by Mr. Hersent, the execution of this work seemed nearer realisation than at the present time. It is possible, however, that in the future a fresh current of opinion will set up in favour of the execution of such an important work. Therefore, the bridge designed by Messrs. Schneider and Co. is still of actual interest. The calculations prove, without a doubt, that it is possible to build a gigantic viaduct, notwithstanding what has been said to the contrary; it will consequently be of interest to describe the main points of the design.

The proposed bridge (see Fig. 503) is 33,450 metres (20¾ miles) long; it is in a straight line, and the greatest depth is 51 metres (167 ft.). Along its whole length the sea bottom consists of heavy chalk beds. Messrs. Schneider and Co.'s design embodied spans of 500 and

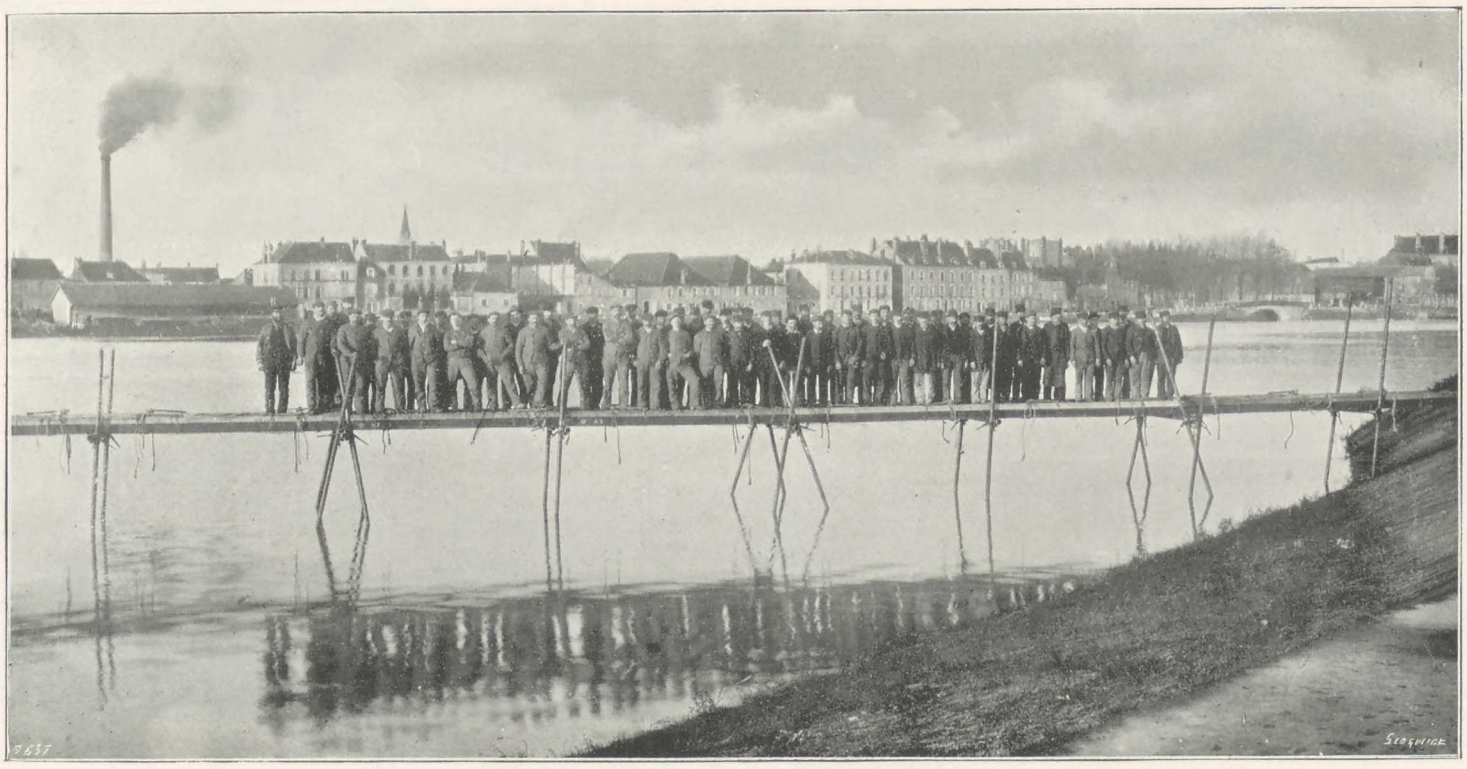
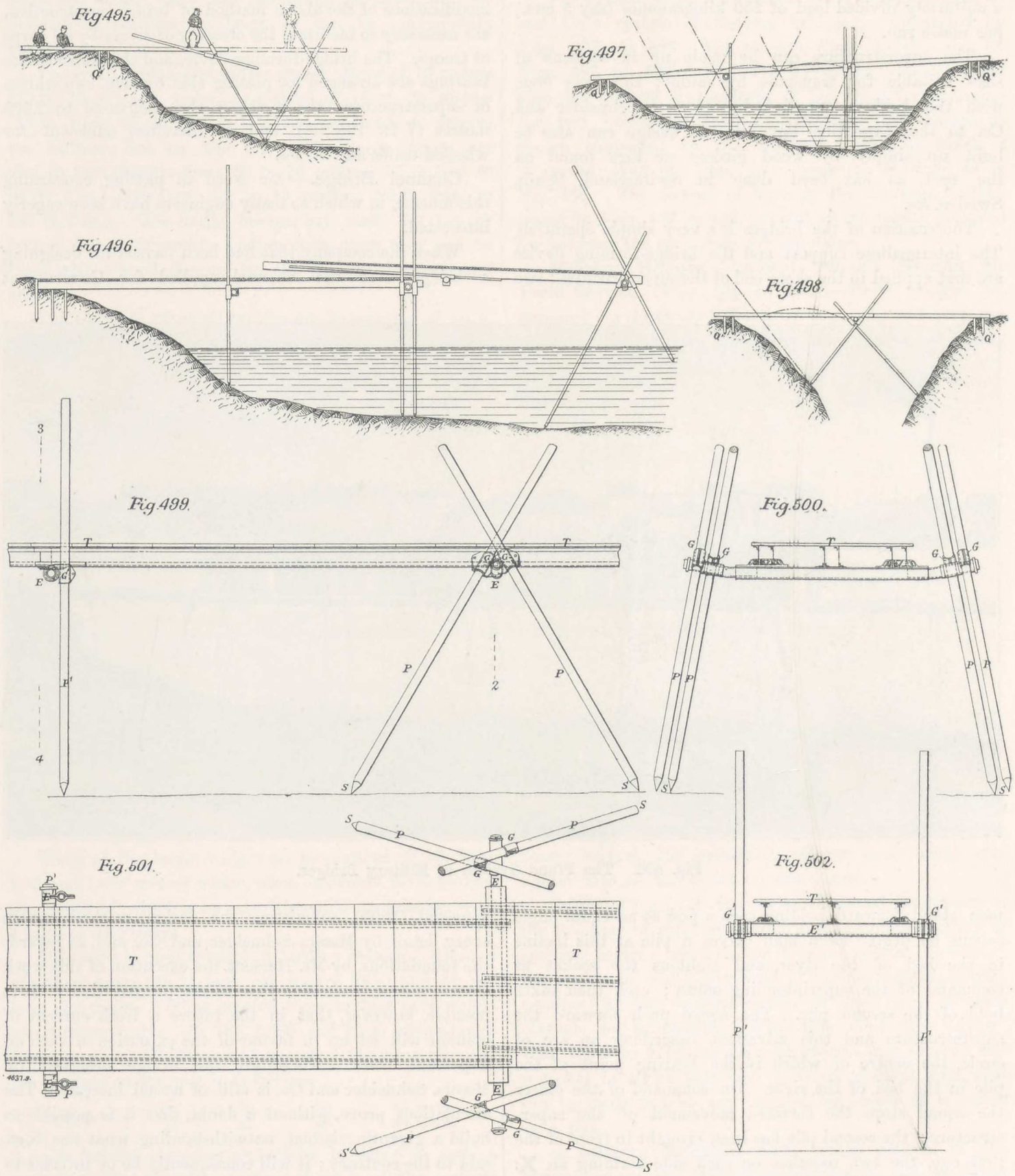


Fig. 494. The Pfund System of Military Bridges.

400 metres (1,640 ft. and 1,312 ft.). The foundations were to be executed with the help of compressed air, notwithstanding the great depths. (M. Hersent has described fully the means he intended taking in order to overcome the difficulties of this part of the work.) The superstructure rests on iron pillars, which are erected over masonry piers; the iron pillars are tubular; there are two on each masonry pier, and their head has the shape of an ogival truncated dome, on which the girder rests.



The Pfund System of Military Bridges.

The minimum height from low-water mark to the bottom part of the girders is 61 metres (200 ft.); the rail level is 70.450 metres (231 ft.) above low-water mark. The large spans of 500 metres (1,640 ft.) consist of two

cantilever trusses each of 187.500 metres (615 ft.), on the ends of which are fitted smaller central girders 125 metres (410 ft.) long. The 400-metre (1,312-ft.) spans are formed by the joining together of two large trusses, thus balancing the overhang of the 500-metre (1,640-ft.) spans. The joint is of a special kind, which allows for expansion while it maintains both ends level. The arrangements which support the girders on the pillars are fixed.

The main girders are on the Warren type; their maximum height at the parts over the pillars is 63.150 metres (207 ft.); they are 38 metres (124 ft.) high at the centre of the 400-metre span, and 11 metres (36 ft.) at both ends of the small 125-metre central girder.

The two main girders are made slanting one towards the other; the cross-section of the work is, therefore, trapezoidal. The distance from centre to centre of the lower frames over the pillars is 25 metres (82 ft.); the top frames are 5 metres (16 ft.) apart. The two main girders are united together by lower horizontal stays, and by a series of transverse stays in the same plane as that of the trellis-bars that withstand compression strains.

The superstructure is designed for two railway lines, and is placed on transverse girders made of Warren three-link beams, which carry four rows of string-pieces made of trellis girders of various heights, firmly fixed and stayed together. The outside rows of string-pieces are fitted with brackets to which are fixed screen railings 3 metres (9 ft. 10 in.) high, and which serve to reduce the action of the wind on the trains. Other screens, arranged to intercept the wind, are fitted to the main ribs of the girders; these have enabled the realisation of an important saving on the total weight of metal.

Such are the principal data of the Channel Bridge. All the details concerning the construction and erection have been considered with the greatest care, and the plant of Messrs. Schneider and Co.'s Chalon Works is adapted for its rapid construction. It is estimated that seven years would be required for completing this huge work.

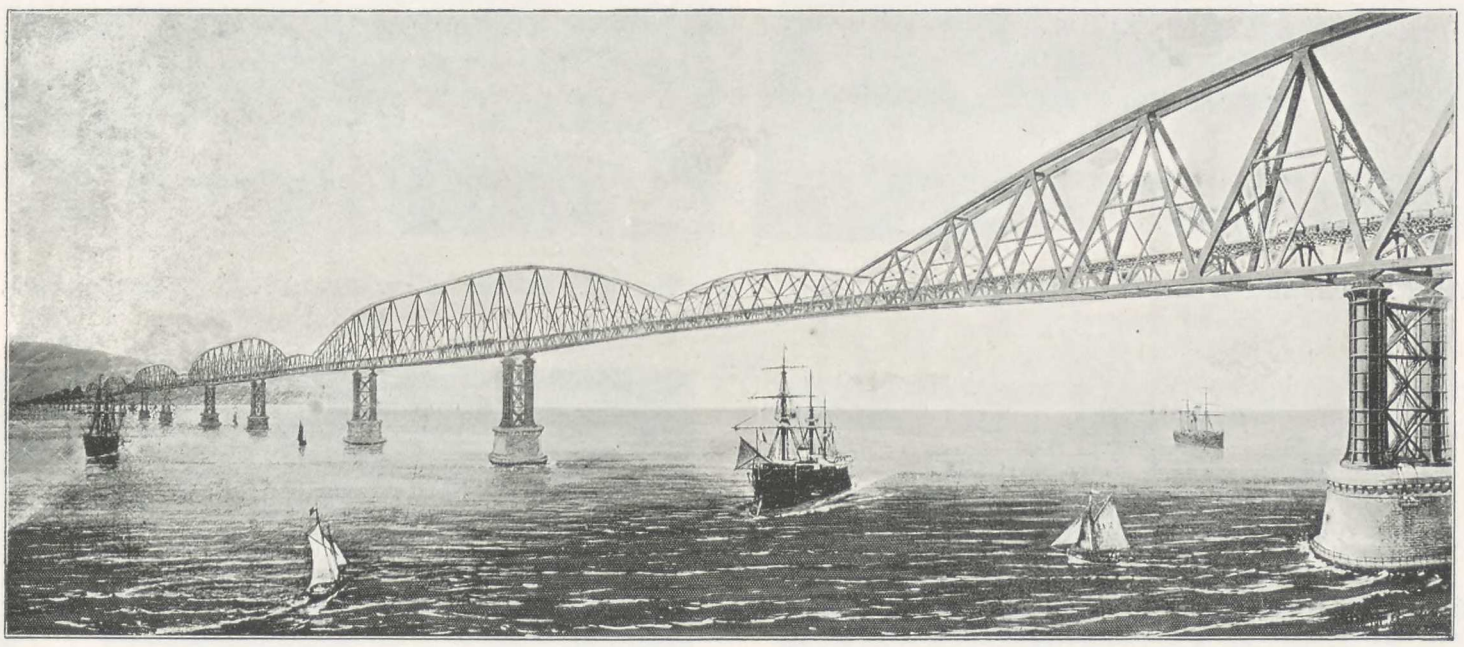


Fig. 503. Design for the Channel Bridge.

Iron Buildings.—As has been shown in the history of the Chalon Works, the progress realised by Messrs. Schneider and Co. in the construction of iron buildings has always been on a par with that realised by them in bridge construction. The firm have made a speciality of constructions for works and factories, and they were the first to build large-span halls, such as the Orleans Railway Station in Paris, the Machinery Hall for the Paris Exhibition of 1878, the Santiago (Chili) Railway Station, &c.

It is not necessary to enter into too many details with regard to these constructions, as they are well known and have often been described. It will be sufficient to give general data concerning those buildings which may be considered as types.

1. The Paris Railway Station of the Orleans Railway Company (1869).—The principal characteristics of this type of construction are lightness and perfect perspective of the trusses, the two combining to form a building in which ventilation and lighting are fully insured. Previous to the construction of trusses without ties, the Polonceau trusses were those which best fulfilled all the conditions required, and this form was adopted by Messrs. Schneider and Co. in the construction of the main gallery of this railway station.

The execution of these trusses was a bold undertaking for the time; they are 52 metres (170 ft.) in span, the ridge plate being 28 metres (92 ft.) high. The hall is 280 metres (919 ft.) in total length; the trusses rest on ornamental brackets fitted in the walls. On each side of the central bay there are two smaller

ones 28 metres (92 ft.) wide. The distance between each truss is the same for the three halls, namely, 10 metres (32 ft. 10 in.) from centre to centre of the principal rafters. The whole of the ironwork weighs 1.400 tons (see Figs. 504 and 505).

The erection had to take place, as is always the case when railway stations are transformed, without interfering with the traffic and without endangering the life of the girders, and are placed 12.45 metres (40 ft. 10 in.) apart from centre to centre. The purlins are 3.84 metres (12 ft. 8 in.) apart, and are trellised on their whole length. There are three rows of rafters per roof-bay; these rest on the purlins through the interposition of curved brackets. The rafters carry a series of iron ⊔-shaped bars, on which is fixed the roofing. The roofing consists of alternate series of corrugated sheets and glass. Strong stays,

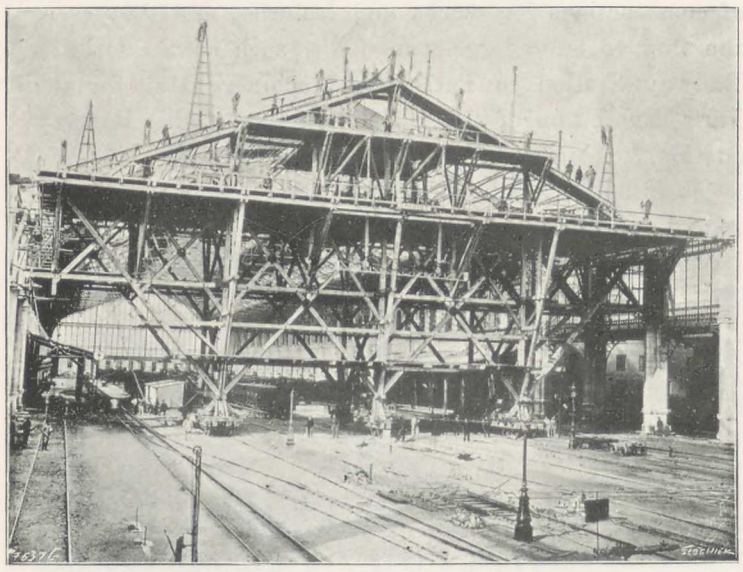


Fig. 504. Erection of the Orleans Railway Station, Paris.



Fig. 505. Interior of the Orleans Railway Station, Paris.



Fig. 506. Santiago (Chili) Railway Station.



Fig. 507. Machinery Hall, Paris Exhibition, 1878.

passengers and employés. To this end the framework was raised and erected with the help of a gigantic gantry, provided at various levels with erection floors and derricks.

Santiago (Chili) Railway Station (1897).—This is quite a recent construction; it has been carried out on modern lines, in such a manner as to obtain the maximum free space available (see Fig. 506). The trusses are made with three hinges and without tie-rods. They are of 48.20 metres (158 ft. 3 in.) span; the height to the ridge plate is 25 metres (82 ft.); they are made with trellis-box placed under the ⊔-shaped pieces, unite all the trusses, thus forming a series of inclined girders which largely increase the stability of the building.

The gable-end is ornamented in the mauresque style of cast-iron fittings. The total weight of the ironwork is 1,000 tons.

This roof was erected during a period of very great traffic, with which it did not at all interfere. The scaffolding consisted of two distinct parts, the storing stage for the material and the erecting gantry; the storing

stage carried a platform 25 metres (82 ft.) high and 5 metres (16 ft. 5 in.) wide, on which ran a steam winch which worked a double derrick. The gantry was arranged so as to cover the complete space between two bays, and consisted of a series of floors which served to support each

2. Halls for Exhibitions.—Machinery Hall of the Paris Exhibition of 1878.—A fixed rule for buildings of this kind cannot be set down beforehand, as their size and shape depend entirely upon the space available, the nature of the exhibits, the extent to which the ornamental



Fig. 508. Shop for the Forges et Chantiers de la Mediterranée.

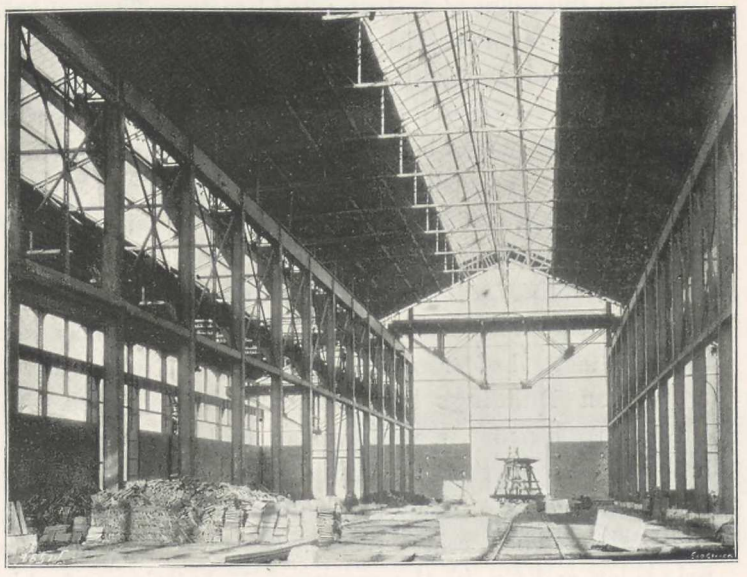
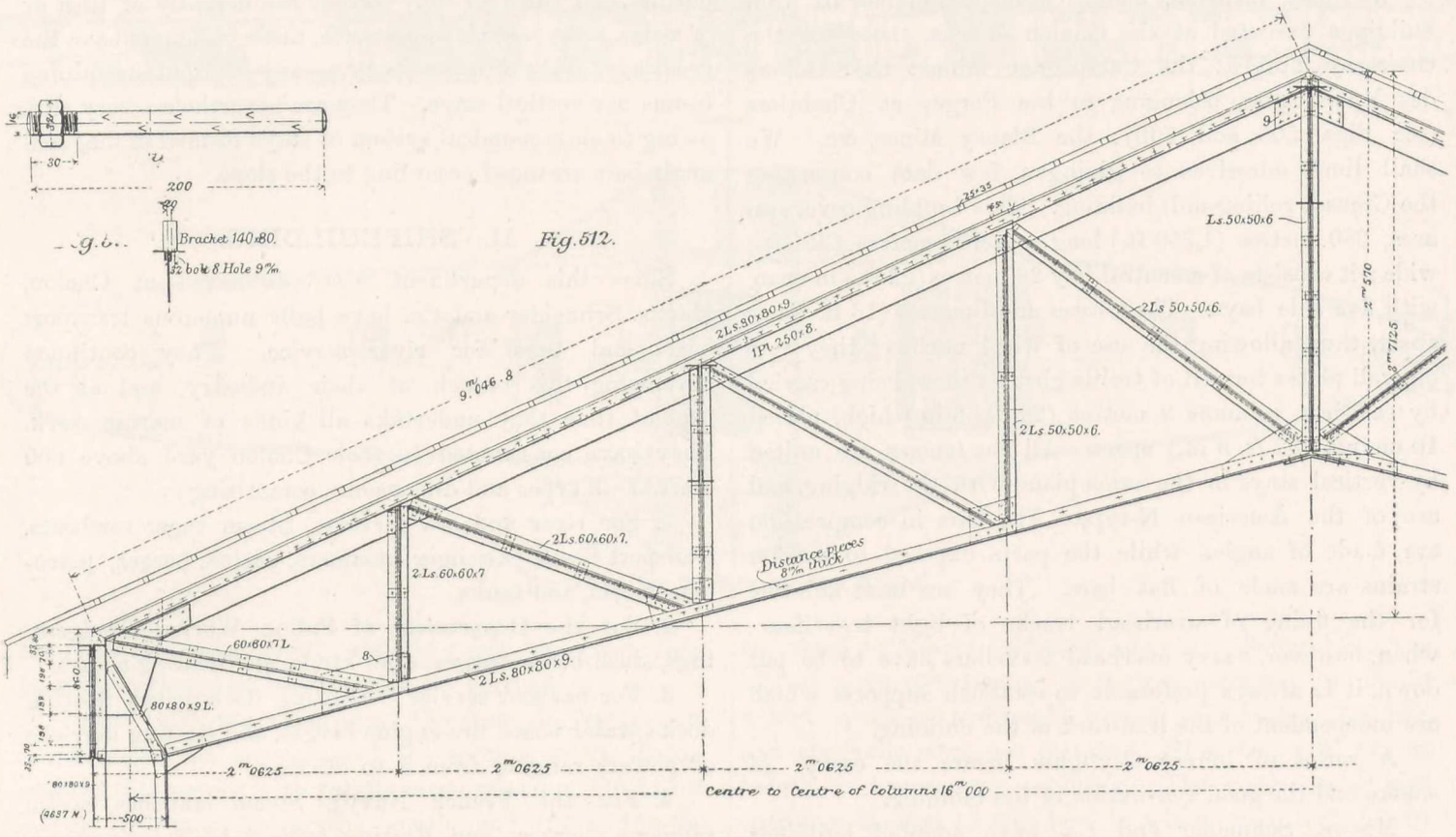


Fig. 509. Shop for the Forges et Chantiers de la Mediterranée.



Light Trusses.

half truss during erection and riveting, until the time when the ridge rotulas were put in place.

The erection was superintended most satisfactorily by the foreman belonging to the Chalon Works, and who has charge of all the bridges and buildings delivered by Messrs. Schneider and Co. to Chili.

part has to be carried, &c. Their designing is as much the work of an architect as that of a civil engineer. It may be added, however, that one generally expects, for each exhibition, to witness a step forward realised in civil engineering. The great machinery hall of the Paris Exhibition of 1878 (see Fig. 507), built by Messrs.

Schneider and Co., was particularly remarkable in this respect. It illustrates the first type of truss built without tie-rods, and this was a bold departure for the time from the usual forms adopted, owing to the comparatively large span, namely, 33.60 metres (110 ft.). The trusses were 15 metres (49 ft.) distant from centre to centre, their height to the ridge plate being 24.11 metres (78 ft. 6 in.). They rested on iron pillars; the principal rafters were in the shape of double-trellised box girders. The trusses were united by series of trellised purlins which carried the rafters, the latter being covered by battens, on which was fixed the zinc roofing.

The nave was 650 metres (2,132 ft.) in length, the weight of the ironwork being 3,735 tons.

The building was erected with a gantry similar to that used for the Orleans Railway Station. We may add that this method of erection is now generally followed.

3. Iron Buildings for Works and Factories.—To obtain good results in this type of buildings, it is absolutely necessary that the metal should be judiciously distributed, so as to obtain a construction at once strong and light. The great experience acquired by Messrs Schneider and Co. in the execution of buildings of this kind has won for them a well-deserved reputation.

We may mention, among a large number of iron buildings executed at the Chalon Works, those for the Guérigny Forges; the Campagnac Mines; the Ateliers des Mouissèques, belonging to the Forges et Chantiers (see Figs. 508 and 509); the Blanzy Mines, &c. We shall limit ourselves to giving a few data concerning the Creusot rolling-mill building. This building covers an area, 380 metres (1,250 ft.) long and 110 metres (361 ft.) wide; it consists of a central bay 28 metres (92 ft.) in span, with five side bays. The trusses are 5 metres (16 ft. 5 in.) apart, thus allowing the use of wood purlins; they rest on wall plates formed of trellis girders, these being carried by cast-iron columns 9 metres (29 ft. 6 in.) high, placed 10 metres (32 ft. 9 in.) apart. All the trusses are united by vertical stays in the same plane with the ridging, and are of the American N-type. The bars in compression are made of angles, while the parts exposed to tension strains are made of flat bars. They are most suitable for the fixing of overhead tracks of light travellers; when, however, heavy overhead travellers have to be put down, it is always preferable to establish supports which are independent of the ironwork of the building.

A series of louvre skylights insure the escape of smoke and the good ventilation of the building.

Messrs. Schneider and Co. have adopted buildings of this type on a large scale in their Creusot Works; among others the main armour-plate shop which is 430 metres (1,410 ft.) long and 50 metres (164 ft.) wide; the tempering and annealing shop, 277 metres (908 ft.) long and 24 metres (78 ft.) wide. All the overhead tracks and their supports for the travellers, ranging from 5 to 100 tons, used in the Creusot Works, have been built in the Chalon Department.

4. Light Iron Work for Sheds.—Messrs. Schneider and Co. have of late designed a complete series of trusses with full calculations for the span, the distance apart, the importance of the various elements, &c., in order to arrive at the strict minimum of weight, and the least possible number of supports, as these often prove inconvenient. The sheet-straightening shed of the Chalon Works illustrates this type of light building, which is found convenient in sugar factories for the storage of beetroot, and they are largely used in various other industries for dépôts of dry goods and warehouses in which vans have to circulate freely.

Light trusses, well designed, can be placed from 10 to 12 metres (32 ft. to 39 ft.) apart in 16-metre (52 ft. 6 in.) spans; such conditions could not be obtained in wood constructions (see Figs. 510 to 512). Their stability is ample, as they are calculated for a vertical surcharge of 50 kilogrammes per square metre (10.240 lb. per square foot) of covered surface, and a wind pressure of 120 kilogrammes per square metre (24.580 lb. per square foot) of vertical surface of pitch.

The purlins are trellised and placed far apart; there is only one ridge purlin, one wall plate, and one intermediate purlin. The wood rafters are fixed direct to the purlins, and the roof may consist indifferently of tiles or of slates. As regards appearance, these buildings have the great advantage of not embodying any horizontal straining beams nor vertical stays. They are nevertheless very stiff, owing to an economical system of stays formed of diagonal angle-bars arranged according to the slope.

II.—SHIPBUILDING.

Since this department was established at Chalon, Messrs. Schneider and Co. have built numerous transport boats and tugs for river service. They continued developing this branch of their industry, and at the present time they undertake all kinds of marine work. They have constructed in their Chalon yard above 600 craft of all types and dimensions, comprising:

1. For river and sea service: Steam tugs, towboats, transport boats, passenger steamers, yachts, barges, petroleum boats, and tanks.

2. For the Department of Public Works: Dredgers, tugs, slush-boats, barges of all kinds, and floating shears.

3. For harbour service: Floating dock gates, floating docks, water-boats, fire-engine barges, and floating derricks of powers ranging from 5 to 60 tons.

4. For the French Navy: Steam launches, steam pinnaces, barges, and floating bridges built in sections, boats for bridge building, service boats, gun boats, vedette boats, and torpedo-boats of all speeds and dimensions.

Tugboats for Service on the Rhône. — Among the most recent constructions which deserve notice may be mentioned the tugboats for service on the Rhône (Figs. 513, 514, and 515). These steam up the rapids against currents of 9 to 12 kilometres (4 to 6½ knots), with convoys carrying 600 tons of goods.

The solving of the problem of the Rhône navigation was attended with many difficulties, and for more than 50 years, numerous modes of traction, as varied as they were ingenious, were tried one after the other, without success. None of the numerous experiments made ever gave full satisfaction.

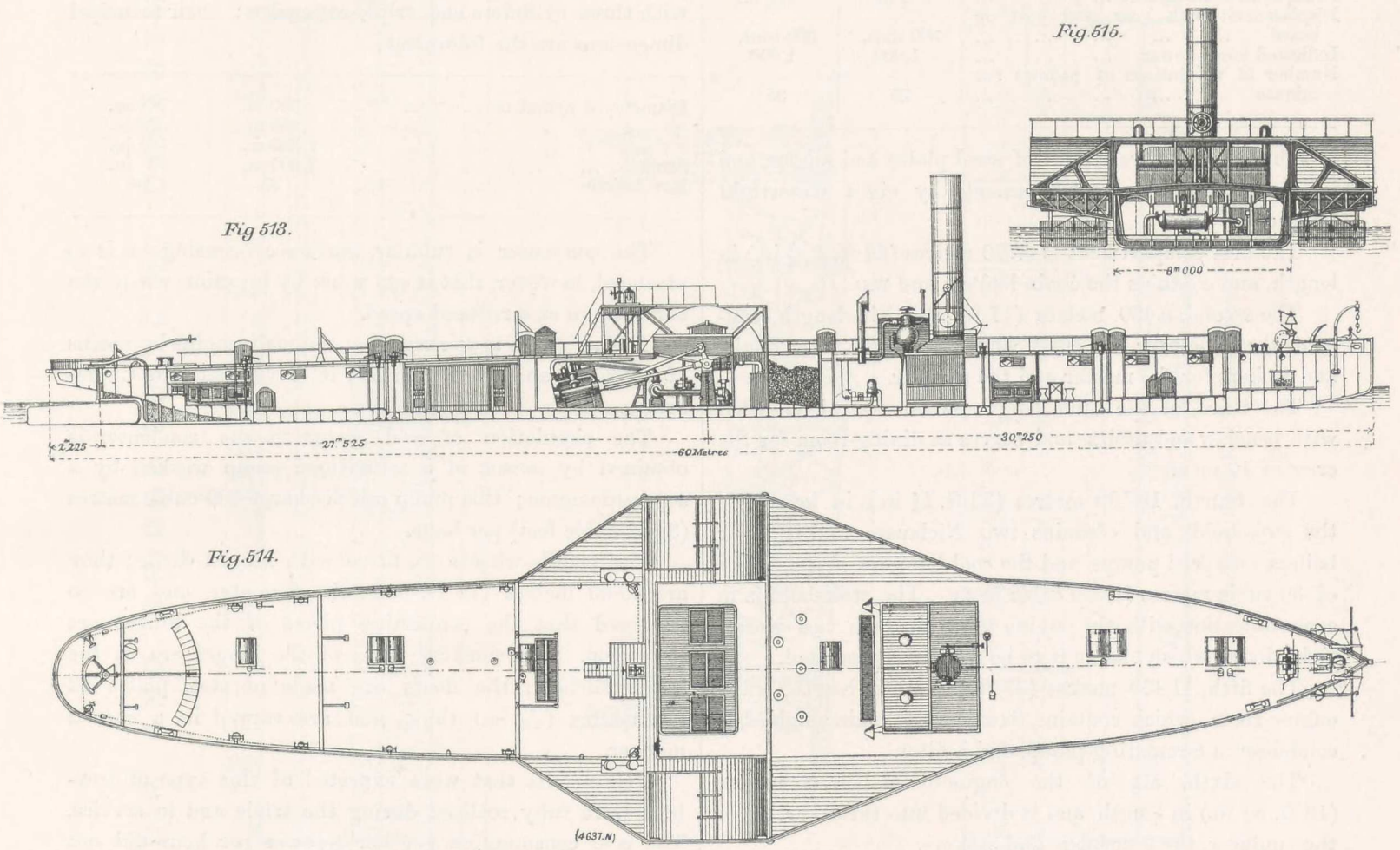
Notwithstanding the improvements in the Rhône navigation, which have resulted in obtaining a draught of water of 2 metres (6 ft. 6 in.) during 280 days of the year, and a draught of 1.600 metre (5 ft. 3 in.) during 60 more days; it remains a very rapid river, with steep inclines, and consequent strong currents which complicate the navigation to a marked degree. The boats are drawn down the river at a great speed, while in going up stream they have to work against the force of the current.

Until 1896, the Compagnie Générale de Navigation, which holds the monopoly of the service on the Rhône, effected this service with paddle cargo steamers, 110 to 160 metres (360 ft. to 524 ft.) in length, and 120 to 150-ton light-draught lighters. The paddle steamers insured the service down and up stream, while the lighters ran down stream loaded and were brought up stream by the "grappin" (grapnel boat). This was a kind of tugboat of about 500 horse-power, fitted in its centre with a large toothed wheel which, by ploughing in the bed of the river, enabled the boats to cross the difficult places, notwithstanding the force of the current.

In 1894, this company entertained the idea of transforming this primitive material, and of replacing it by a single system of towing large lighters from St. Louis to Lyons. The programme consisted in going up the Rhône from St. Louis to Pont St. Esprit, and from Tournon to Lyons, with the help of tugboats towing convoys of two barges loaded with 600 tons of goods; and in establishing between Pont St. Esprit and Tournon, where the current is especially strong, a series of extra tugboats, forming a relay, and which would help the convoys to cross the rapids.

The designing and building of these tugboats and the construction of a number of the lighters were entrusted to Messrs. Schneider and Co. The problem was all the more complicated, as it was necessary to obtain a high speed on a draught limited to 1 metre (39⅜ in.), and the hulls were not to exceed 60 metres (197 ft.) in length, to insure easy evolution. The displacement was therefore limited to 300 tons, in which were included 20 tons of coal and 17 tons of gear, thus leaving only 263 tons for the hull, engines, and boilers. Owing to the light draught and to the impossibility of using screw propellers, worked by high-speed engines, it was absolutely necessary to have recourse to paddle-wheels, which meant employing the heaviest types of engines for a very light draught boat.

Owing, however, to the arrangements adopted, all these



Tugboats for Service on the Rhone.

difficulties were overcome, and Messrs. Schneider and Co have succeeded in keeping the weight low while giving to the paddles a useful area, large in relation to the immersed surface of the midship section of the towboat and of the lighters forming its convoy, notwithstanding the small depth of the hull.

The principal dimensions of these two towboats (Figs. 513 to 515) are the following:

Extreme length	60 m.	197 ft. 0 in.
Main breadth to outside planking ...	8 m.	26 ft. 3 in.
Maximum breadth to outside paddle-boxes	15.800 m.	51 ft. 10 in.
Mean depth amidships to outside planking	2.820 m.	9 ft. 3 in.
Draught in working trim	1 m.	39⅜ in.
Displacement with gear and coal on board	300 tons.	300 tons.
Indicated horse-power	1,000	1,000
Number of revolutions of paddles per minute	35	35

The hull is entirely built of steel plates and angles, and is divided into nine compartments by eight watertight bulkheads.

The first compartment is 6.770 metres (22 ft. 2 9/16 in.) in length, and contains the chain lockers and W.C.

The second, 5.400 metres (17 ft. 8⅝ in.) in length, contains the galley for the crew, and two cabins with bunks and lockers for the master and the skipper.

The third, of the same length as the second, is fitted with benches and tables, and serves as dining-room for the crew of 10 men.

The fourth, 10.100 metres (33 ft. 1⅝ in.) in length, is the stokehold, and contains two Niclausse multitubular boilers, two feed pumps, and the coal bunkers of a capacity of 30 cubic metres (1,060 cubic feet). The stokehold is in communication with the engine-room through two watertight doors, which enable it to be completely isolated.

The fifth, 11.450 metres (37 ft. 6¾ in.) in length, is the engine-room, which contains, besides the main engines, a condenser, a circulating pump, and a filter.

The sixth, aft of the engine-room, is 6 metres (19 ft. 8¼ in.) in length, and is divided into three berths for the engineer, the carpenter, and stokers.

The seventh, of same length as the sixth, is provided with bunks and lockers for the crew.

The eighth, 4.800 metres (15 ft. 9 in.) in length, serves as a store-room and magazine for the gear and accessories.

The ninth compartment, 4.100 metres (13 ft. 5½ in.), remains empty.

Each one of these compartments is provided with a companion ladder; the draining is fully insured by 12 hand-pumps, which are worked from the deck, two ejectors with suction to the hold, and by the circulating pump, which can discharge 100 cubic metres (3,532 cubic feet) per hour.

Besides the usual gear and accessories required by law, each towboat is provided with a windlass for 22 millimetres (1 3/16 in.) chain; two 300-kilogramme (6 cwt.) anchors, with 100 metres (328 ft.) of chain; and with a steam steering apparatus fitted on the bridge, which can cause the rudder to turn 90 deg. in 15 seconds.

The boilers are fitted with movable tubes, entirely free to expand; the tubes are so arranged that they can be removed and replaced from the front of the boilers.

The principal dimensions of the boilers are the following:

Grate area	9.80 sq. m.	105.50 sq. ft.
Heating surface	292 sq. m.	3143.17 sq. ft.
Registered pressure	15 kilogs.	213.346 lb. per sq. in.

The engines are of the inclined type, direct-working, with three cylinders and triple-expansion; their principal dimensions are the following:

Diameter of cylinders	.530 m.	20⅞ in.
,, ,, ...	.830 m.	32⅝ in.
,, ,, ...	1.350 m.	53⅛ in.
Stroke	1.600 m.	63 in.
Revolutions	35	35

The condenser is tubular, surface-condensing; it is so arranged, however, that it can work by injection when the engines run at a reduced speed.

The air pump is worked from the main engine by means of eccentric and lever gearing; it is vertical and single-acting.

The circulation of cold water in the condenser is obtained by means of a centrifugal pump worked by a separate engine; this pump can discharge 100 cubic metres (3,532 cubic feet) per hour.

The paddle-wheels are fitted with hinged floats; they are 4.800 metres (15 ft. 9 in.) in diameter, and are so arranged that the connecting pieces of the hinges are in tension. The working parts of the hinges are on the inside surface; the floats are made of steel plates 12 millimetres (7/16 in.) thick, and are curved in a special manner.

The results that were expected of this type of towboat were fully realised during the trials and in service. The coal consumption per horse-power per hour did not exceed 650 grammes (1.434 lb.), and these boats were not only powerful enough to insure the service between St. Louis and Pont St. Esprit, and between Tournon and Lyons, but they often handle the complete service between St. Louis and Lyons without assistance, as the extra tugboats which ply between Pont St. Esprit and Tournon do not work satisfactorily.

Four of these tugboats have been in service since 1896, namely, "Le Pilat," "Le Ventoux," "Le Pelvoux," and "Le Canigou;" and two others, "Le Taillefer" and "Le Galibier," are in course of completion in the Chalon yard.

Torpedo-Boats. — Messrs. Schneider and Co. have built at their Chalon yard more than fifty torpedo-boats of all dimensions, and on the most improved types, for the French, and for foreign navies. They have delivered lately to the French Navy a new type of torpedo-boat

Fig. 519.

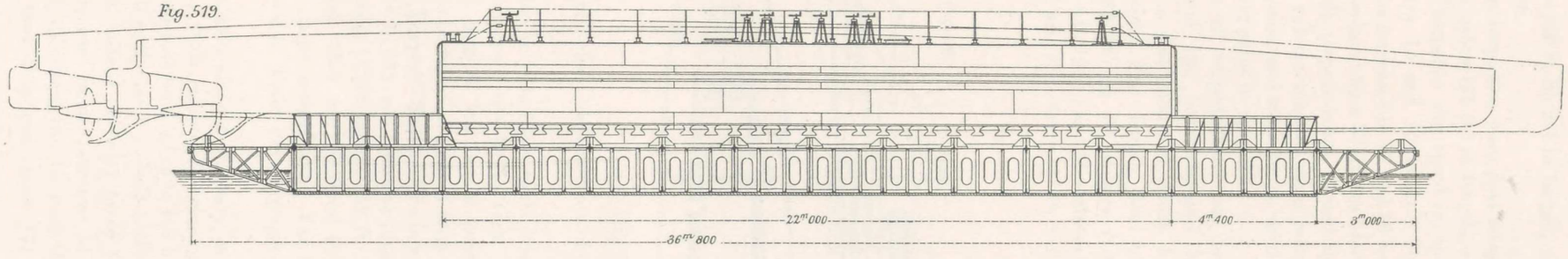


Fig. 520.

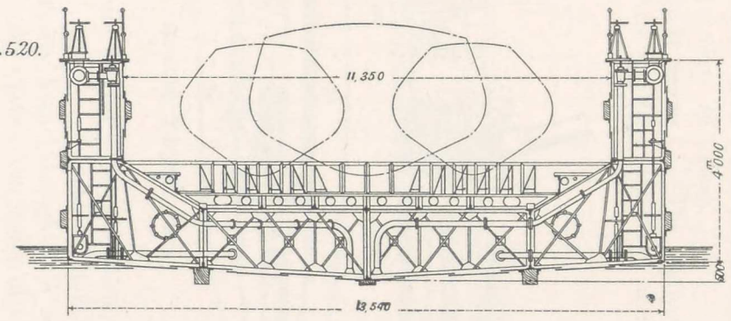
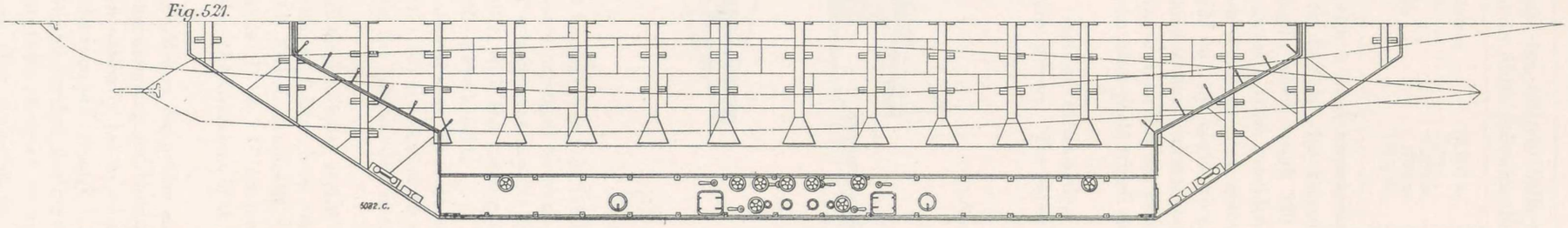


Fig. 521.



Floating Dock for Torpedo Boats.

18.200 metres (59 ft. 8½ in.) in length, which has excited a keen interest.

When spar torpedoes were first adopted, the torpedo-boats were 18 metres (59 ft.) in length, and were arranged to carry one torpedo; the speed of these torpedo-boats ranged between 14 and 15 knots. Shortly afterwards their speed was increased to 15 and 16 knots, and the spar torpedo was replaced by a Whitehead torpedo.

These small torpedo-boats, classed in the fleet under the name of vedette torpedo-boats, were shipped on the large war vessels, and were to be used for coast attack or for attacking ships in open sea.

This class of torpedo-boats has been, so to speak, abandoned, and has been replaced by another type, the dimensions and speeds of which have been successively increased. The length has been carried from 26 metres (85 ft.) to 33 metres (108 ft.); then to 35 metres (114 ft. 10 in.) and 36 metres (118 ft.), 41 metres (134 ft. 6 in.), and 45 metres (147 ft. 8 in.). These are the first and second-class torpedo-boats, for service on the high seas.

The vedette torpedo-boats could with difficulty keep the sea, as they were too light; they would only have been used in time of war, as in peace they were too cumbersome to be borne on deck of large men-of-war.

Hoisting Torpedo-Boats.—The new hoisting torpedo-boats (Fig. 516 to 518) are, like the torpedo vedette-boats above mentioned, 18.200 metres (59 ft. 8½ in.) in length; like them also, they are intended to form part of the armament of large men-of-war. Far from constituting a step backwards, their use corresponds to a real progress.

1. Because they are not unsteady, as were the torpedo vedette-boats; their radius of action is 100 miles, and, owing to a judicious form given to the hull, they can keep the sea as well as the large torpedo-boats.

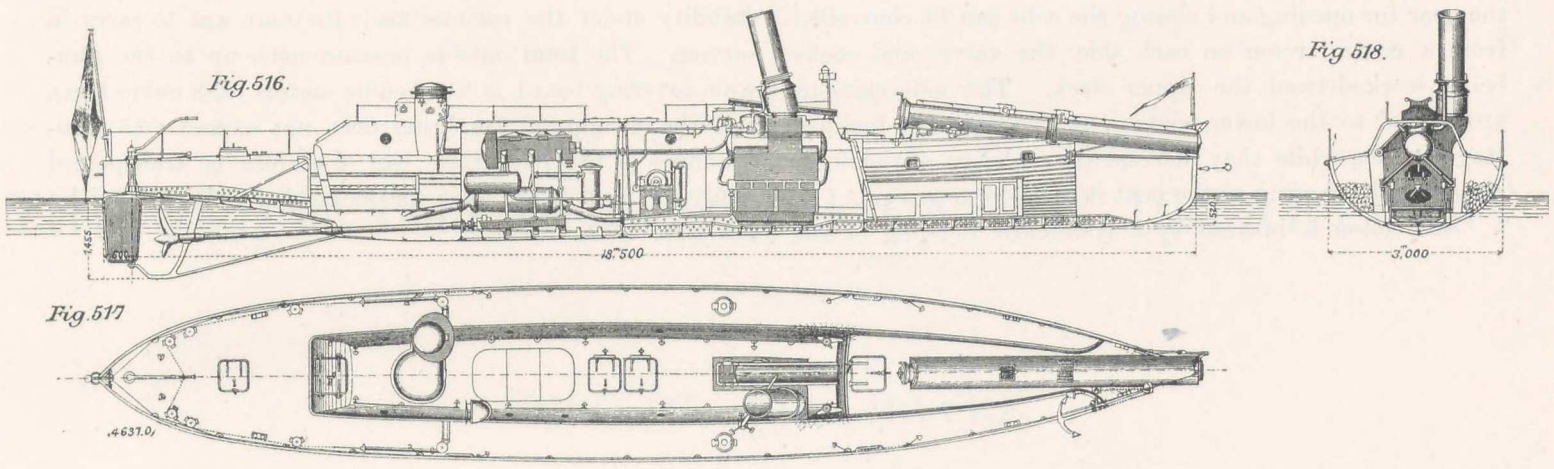
2. Because, instead of being fitted for use in time of war only, they can render services as a launch in time of peace, and, therefore, can be used daily; experiments have shown that they can steam 17½ knots even in a rough sea.

These torpedo-boats are entirely built of galvanised plates and angles, and are of the following dimensions:

Length between perpendiculars ...	18.200 m.	59 ft. 8½ in.
Extreme width amidships	3 m.	9 ft. 10 in.
Depth of hold to bottom	1.280 m.	4 ft. 2½ in.
,, bottom amidships	.700 m.	2 ft. 3½ in.
Displacement loaded	14½ tons	14½ tons

They are fitted with a fixed torpedo-launching tube, .355 metre (14 in.) in diameter, for torpedoes 5 metres (16 ft. 4$\frac{13}{16}$ in.) in length, which weigh 320 kilogrammes (705 lb.). The tube covers a room provided with lockers and chests, and which serves as crew space; aft of this room are the stokehold and the engine-room, the officer's station and that of the steersman, surmounted by a wheel-house, in which all the manœuvres are centralised. The last compartment is an after-peak, which serves as store-room.

The engines are vertical, direct-acting, two-cylinder compound, of 250 horse-power. The boiler is on the Du



Hoisting Torpedo Boat.

Temple system, of 14 kilogrammes (199.122 lb. per square inch) registered pressure, arranged to work under forced draught. A special arrangement enables the heating of the water in the boiler, with the steam generated in the vessel which carries the torpedo-boat.

The rudder is balanced, and the boat can turn on a circle of 40 metres (131 ft.) in radius in 45 seconds. Four rings serve for lifting the torpedo-boat in and out of the water.

Two of these small torpedo-boats, styled "A" and "B," are already in service, and have been very favourably reported upon by the French Admiralty. Five others, designated by the letters "D" to "I" are now in course of construction to complete the armament of the torpedo-boat cruiser La Foudre.

Floating Docks.—Messrs. Schneider and Co. having made a speciality of the designing and building of torpedo-boats, they have been naturally led to construct floating docks, for their maintenance and repairs. Among these, we may mention a double-berthed floating dock built for the French Navy in 1888, designed to raise a load of 130 tons, and a dock they delivered in 1894 to the

Argentine Government, capable of taking a load of 140 tons; the principal dimensions of the latter are the following:

	m.	ft.	in.
Total length	36.800	120	$8\frac{13}{16}$
Outside width	13.540	44	5
Width remaining free between the two lateral caissons	11.350	37	3
Height from bottom of keel to sill of dock	1.450	4	9
Height from bottom of keel to upper deck	4.600	15	2

This dock (Figs. 519 to 521, Plate XCV.) consists of a lower pontoon surmounted by two side caissons, the cross-section being thus roughly ⊔ shaped: keelsons and bulkheads constitute inside watertight compartments, each one fitted with the necessary piping for their flooding and draining.

The piping has been designed in such a manner that all the cells can be drained and flooded with sea water, either one after the other, or in groups, or altogether. All the gear for opening and closing the cells can be controlled from a central room on each side, the valves and cocks being worked from the upper deck. The side caissons are united to the lower pontoon on the inside by inclined stays, which, while they increase the stability of the dock, facilitate the shoring of the boat it is made to carry.

Immersion is insured by a systematic flooding of the watertight compartments. The dock is refloated with the help of a small pump that can discharge 220 cubic metres (7769.65 cubic feet) per hour. Torpedo-boats can, therefore, be lifted out of the water in less than $1\frac{3}{4}$ hours, immersion occupying 50 minutes, and the draining of the compartments, 45 minutes.

Portable Pontoons.—The types of portable military bridge executed by the Chalon Works have been already described; of a somewhat similar character should be mentioned, among the light work executed by Messrs. Schneider and Co. in this department, a series of small boats made for the Argentine Republic in 1896. Their principal dimensions are the following:

	m.	ft.	in.
Length	7.850	25	9
Breadth	1.620	5	$3\frac{3}{4}$
Depth	.810	2	8

These boats are remarkable for their forms, which have been designed specially with a view to insure stability under the various loads they are apt to carry in service. The total outside measurement up to the gunwale covering board, is 8.050 cubic metres (283 cubic feet), and the weight of the boats does not exceed 515 kilogrammes (1,135 lb.); they can therefore be transported easily in the military vans, and be loaded and unloaded by the men.

PART II.

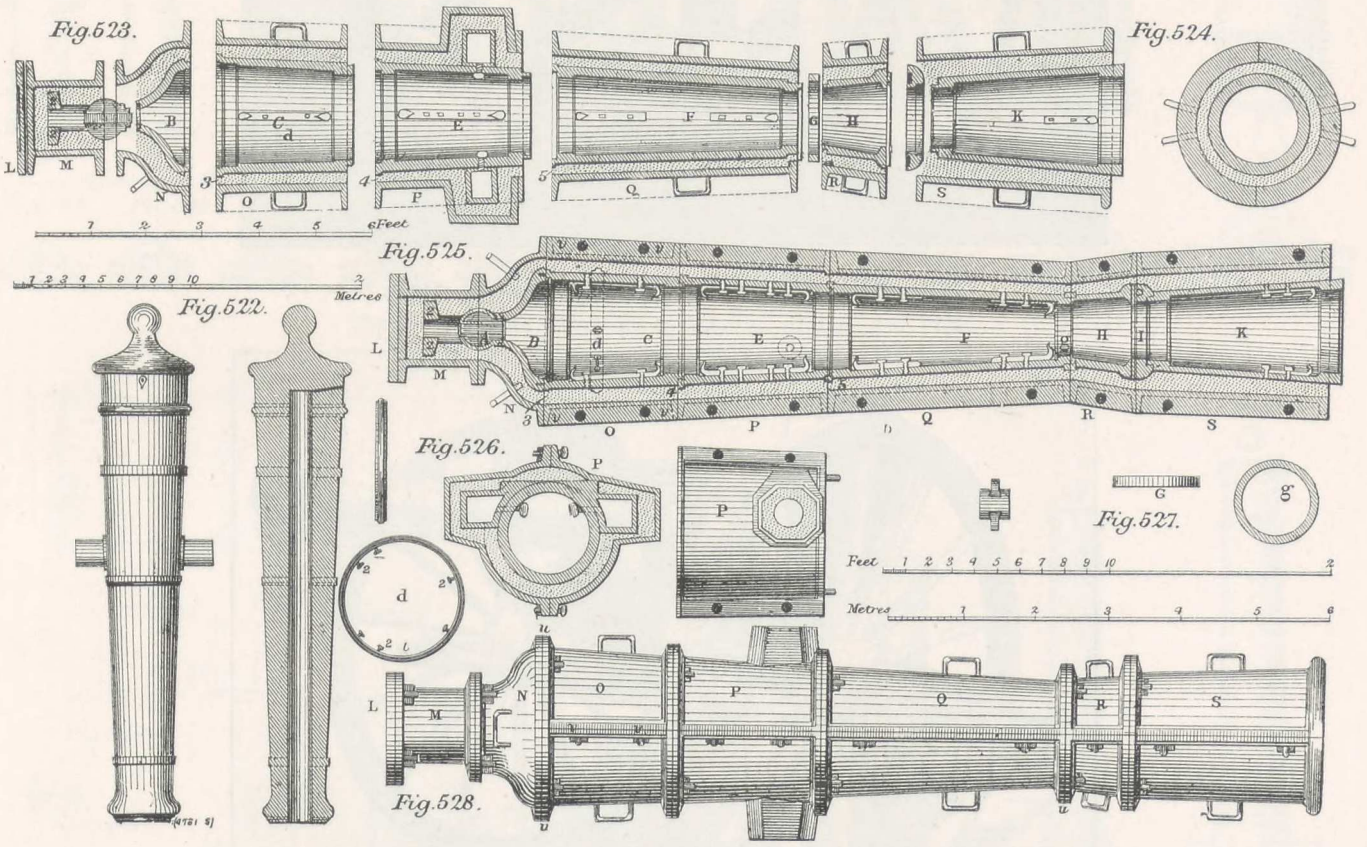
THE ORDNANCE AND FORTIFICATION DEPARTMENT.

CREUSOT AND HAVRE.

XXII.—THE ORDNANCE AND FORTIFICATION DEPARTMENT.

HISTORICAL.

At the commencement of this volume, when sketching the earlier history of Creusot, long before it passed into the possession of the Schneider family, we pointed out that during the whole period of the Revolution, as well as during the long series of war which attended the First Empire, the proprietors of the Creusot Works, manufactured war material without intermission, producing the best qualities of cast iron and bronze guns known at the



Patterns and Moulds for Bronze Guns, made at Creusot in 1792.

time, both for the army and navy, as well as large quantities of carriages and projectiles, and other war material. As a matter of historical interest, we reproduce in Figs 522 to 553 above, and on Plate XCVI., drawings which illustrate the condition of gun-making at the end of the last century. Figs. 522 to 528 show the form of a "36" calibre naval gun, and details of the patterns and moulds from which it was cast. As will be seen from these figures, the gun was cast in sand, the patterns being divided in sections A B . . . H, as shown in Fig. 523; Fig. 525 shows the various flasks in section bolted together, and Fig. 528 is an exterior view. The metal was poured at K, which served as a head and secured a sound casting; Figs. 525 and 526 show a cross-section and a side view of that section of the flask which contained the trunnions. The core forming the bore of the gun is not shown. The originals of these drawings are contained in the archives of Messrs. Schneider and Co.; the type it represents was followed in the Creusot Works, in the year 1792.

The first guns then manufactured were cast hollow. To this end, a core of loam was placed in the mould and centred by three iron studs, that were left imbedded in the metal of the breech. After the careful fettling of the casting, there practically only remained the polishing of the core with a broaching bit. This operation was carried on as follows: The gun was suspended vertically in a kind of crosshead guide, muzzle downwards; the broaching bar formed the axle of a gin that was turned by two horses, the weight of the gun on the broaching bar serving to insure the regular feed as the work progressed. Large calibre guns were too heavy to be treated by this method, and a system of counterweights was resorted to, in order to balance the excess in weight of the gun. The core was liable to shift during the process of casting, and as with the imperfect methods then in use, it constituted

a barrier to the proper flow of the metal, blow-holes frequently appeared, causing a somewhat large proportion of guns to be rejected.

This resulted in means being taken, a little later on, for casting the guns solid. These were then bored by a device practically similar to the one above mentioned. Later on still, an improvement was introduced, by which the guns were placed on horizontal supports, and caused to revolve, the boring bits remaining fixed. Series of boring bits were used successively, each one increasing the diameter of bore by 6 or 8 lines, the exact size being given by a broaching bit. This method was again improved by boring the gun at one operation to very near the exact calibre, the final trueing cut being given by a broaching bit.

Figs. 529 to 541, Plate XCVI., illustrate the series of naval guns in use at that early time, ranging from the short 4-pounder to the heavy 36-pounder; Figs. 542 to 553 are a similar series for land service, from the 2-pounder field gun to the 24-pounder siege gun. All these types were manufactured at Creusot. The importance of this place at the time is indicated by the fact that the celebrated technician, Gaspard Monge, in his remarkable work entitled "Déscription de l'art de fabriquer les canons, faite en exécution de l'arrêté du Comité de Salut Public du 18 pluviose de l'an 2 de la République Francaise, une et indivisible," several times mentions the Creusot Works as having contributed, even in those relatively remote times, to the progress realised in metallurgy and construction, especially as regards the military arts.

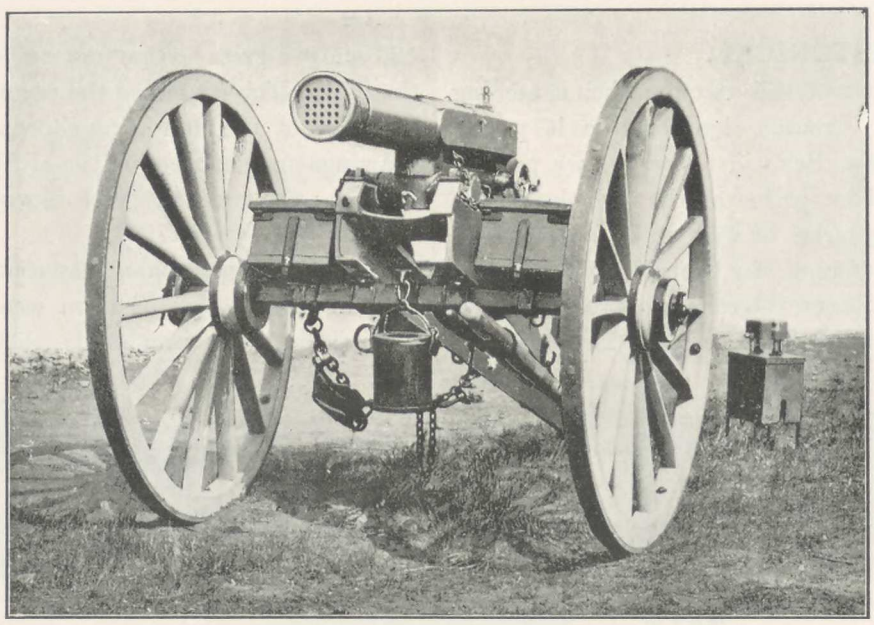


Fig. 554. Mitrailleuse, De Reffye System, 1870.

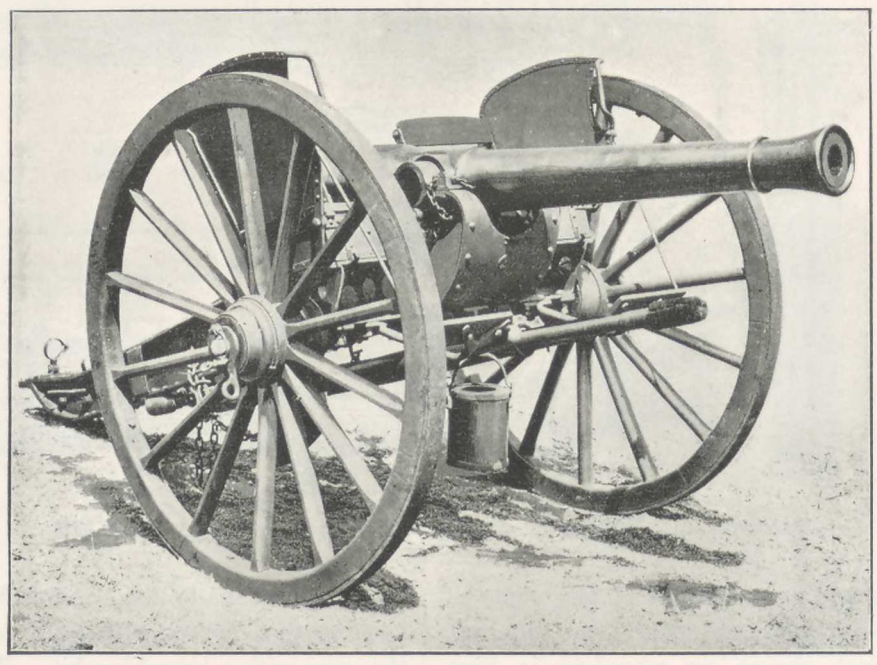
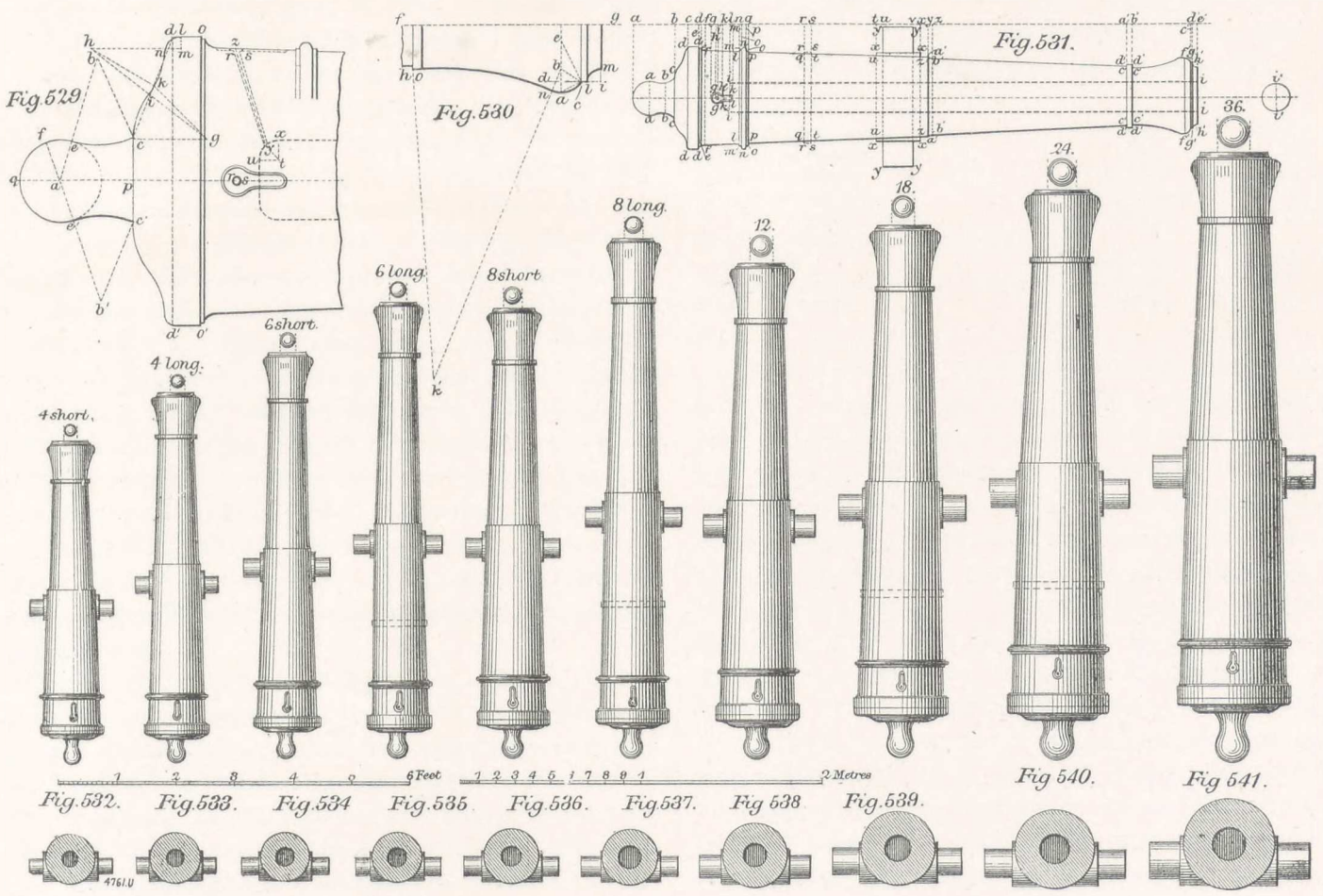
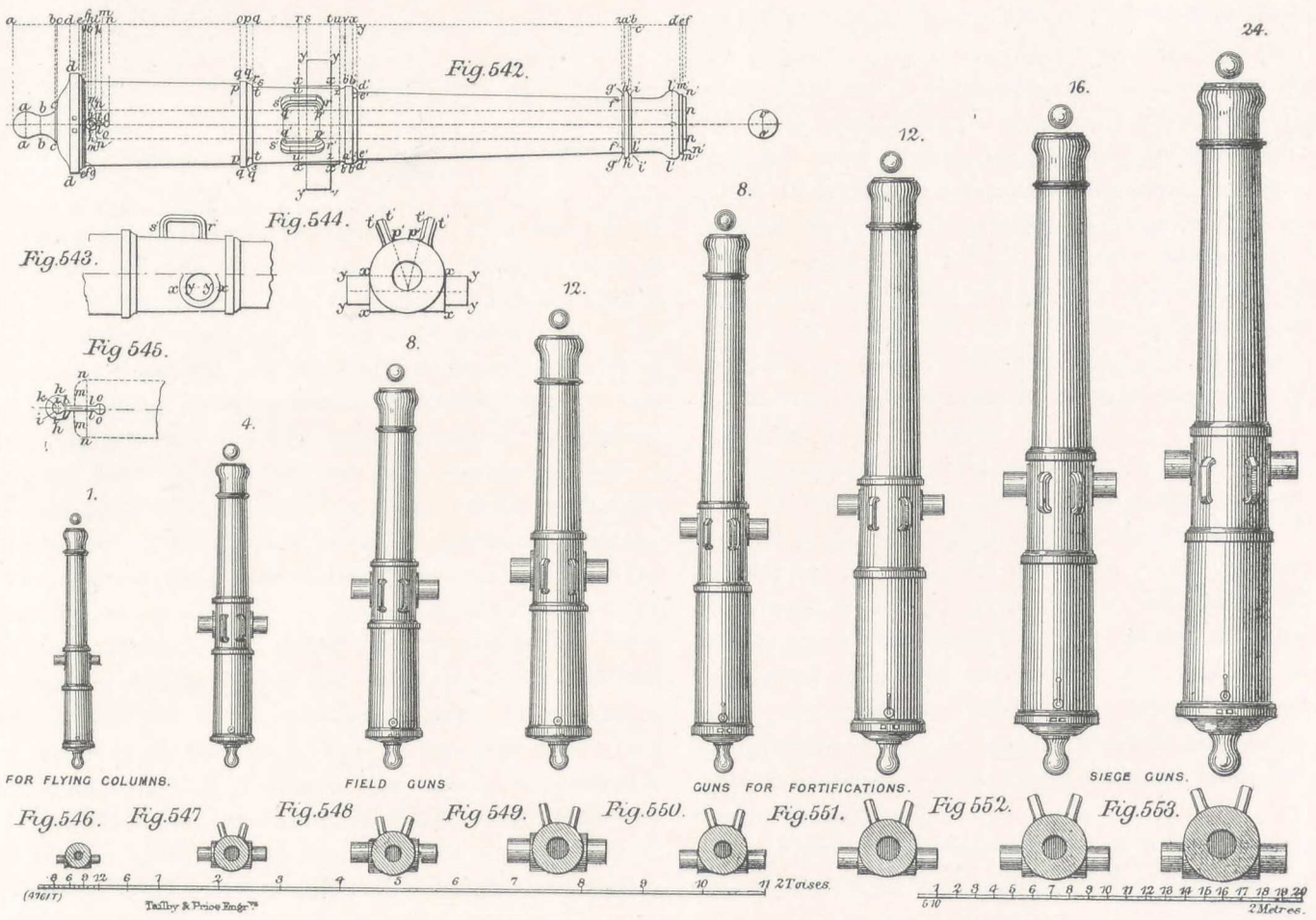


Fig. 555. Field Guns, De Reffye System, 1870.

THE ORDNANCE AND FORTIFICATION DEPARTMENT.



Types of Naval Guns Manufactured at Creusot 1792.



Types of Field, Fortification, and Siege Guns, made at Creusot, 1792.

When the permanent peace of 1815 succeeded the long period of war, the manufacture of ordnance ceased entirely at Creusot, and with it, as we have seen, the active life of the establishment, which having been for so long wholly devoted to the production of war material, had lost all its industrial connection. Fifty-five years later, in 1870, the manufacture of guns was resumed at Creusot, but only as a branch of its general industry. During the war of 1870, Messrs. Schneider and Co. were called upon by the Government of National Defence to undertake the supply of artillery to the French army; they responded to the request so promptly that, although they had to instal a special plant for the purpose, they were able to deliver, in five months, 23 batteries of "7" bronze guns, on the De Reffye system; two batteries of steel guns of the same calibre, and on the same system; 16 batteries of De Reffye machine guns; in all 250 pieces of ordnance. These were delivered in the time mentioned, together with the necessary carriages, gun-limbers, ammunition wagons, &c., making 370 pieces in all.

Illustrations are given in Figs. 554 and 555 of two De Reffye guns, one being a bronze "7" field gun, and the other a mitrailleuse. These field guns fired elongated shot, fitted with a lead covering; the cartridge was charged with compressed pebble powder, and was provided with a metallic base to prevent the escape of gas. The guns were first mounted on wood-bracketed carriages, and afterwards on the type of iron carriage shown in Fig. 555. The following are some of the leading dimensions of these guns:

Total length of gun	1.012 m.	39.842 in.
Weight	650 kilos.	13 cwt.
Diameter of bore	.085 m.	3.346 in.
Weight of projectile	7.100 kilos.	15.650 lb.
Muzzle velocity	390 m.	1280 ft.

The guns, whether of bronze or steel, were cast in one piece, and had the same shape, except that the chase in the former was swelled out, as shown in Fig. 555, while in the latter it was formed like a truncated cone. The breech end of the gun was fitted with a bracket for housing the breech-piece carrying frame; the powder chamber was made slightly conical, and a taper connected the chamber with the bore. The rifling was right handed, and of a constant pitch with 14 grooves. The breech mechanism consisted of a breech-piece with an interrupted screw; it was mounted on a hinged frame, and was operated by a handle and crank. The movement of the breech-block was guided by three bars bolted to the frame, and on which it moved to and fro in grooves. A sliding-bolt joined the frame to the gun and to the breech-piece. The front of the breech-block was made hollow, and was notched in such a manner that it engaged the base of the cartridge and facilitated the removal of the latter when the breech was thrown open. The charge was fired through a vent in the breech-piece, drilled obliquely through to the centre line of the bore.

The De Reffye mitrailleuse, Fig. 554, was made for firing 25 small-arm cartridges; these were discharged consecutively, and there was no recoil of the gun. The following are some particulars of this machine gun:

Total length of gun	1.425 m.	52.102 in.
Number of barrels	25	25
Diameter of bore	.0128 m.	.503 in.
Weight of each shot	50 grammes	1.71 oz.
,, limber loaded	604 kgs.	1328 lb.
Total weight of gun and limber fully equipped	1405 kgs.	3367 lb.
Weight of gun and carriage complete	536 kgs.	1180 lb.
Maximum range	3400 m.	11,000 ft.

The gun was made up of 25 breechloading rifled barrels, grouped inside a bronze casing; the cartridge cases were made of cardboard with a metallic base; they contained a lead bullet and the charge of compressed pebble powder. The various parts of the firing mechanism were fastened inside tongued clamps and were joined by pins. The movable breech-block contained the cartridges, and the block always went into place perfectly centred by travelling in grooves made in the rear of the breech. The charges were fired in succession by percussion. This successive firing was insured by means of a supplementary breech-block carrying the 25 firing locks and disengaging plate. When the whole series of charges had been fired, the firing plate was removed by traversing a screw, the movable breech was taken away, and was replaced by another that had been loaded in the meantime. The gun was mounted on trunnions on its carriage, and was fitted with a lateral training mechanism. The elevating gear was a screw and wheel at the rear of the trunnions, and on the carriage was placed a device for charging the breech-block with the 25 cartridges. The gun and carriage were placed in position by a lever fitted to the trail-block, and the gun could be accurately trained by means of a hand-wheel and screw that caused the piece to turn on its vertical support. Three sights were provided—a central and two lateral sights. It is almost unnecessary to say that both these types of guns are now obsolete, and they have been reproduced only to illustrate the gun work executed by Messrs. Schneider and Co. at a time prior to the thorough equipment of their works for the construction of war material.

For some time prior to 1870, discussion had been active, both in France and in England, as to the best material to be used in the construction of guns of all calibres. Perhaps in England the dispute had been more energetic than elsewhere; it was identified on the one hand with Armstrong, and on the other, to a large extent with Bessemer, the former being the advocate of iron, and the latter of steel. The exceptional advantages possessed by Armstrong inclined the weight of opinion towards iron as the most suitable material, and no doubt the conclusion influenced foreign Governments.

In France, steel was regarded with mistrust until the French Government requested Messrs. Schneider and Co. to carry out some experiments with the object of ascertaining how far steel, as a material for gun construction

could be relied on; to determine the best methods of making the most suitable steel; and to define the conditions which that metal had to fulfil. Messrs. Schneider and Co.'s works had been selected for this important investigation, as their products had even at that time early acquired a great reputation throughout Europe. Moreover, the works possessed very complete appliances for the manufacture of the highest qualities of steel, as well as efficient plant for making and finishing the smaller natures of ordnance. The experiments were carried out under the personal supervision of Mr. Schneider, and were supervised by a Commission of Artillery Officers appointed by the Government. The very prolonged and exhaustive investigation resulted in a report in favour of steel, and in a first order being given to Messrs. Schneider and Co. for six guns: two of 75 millimetres calibre, two of 95 millimetres, and two of 78.6 millimetres. The guns of 78.6 millimetres were entirely completed at Creusot; those of 75 and 95 millimetres were finished there, all but the rifling and the vent-bushing, which were done at one of the Government arsenals.

Except for the very brief period when Messrs. Schneider and Co. had, under pressure of time, and with relatively imperfect appliances, constructed field artillery during 1870, no ordnance had been manufactured at Creusot since the old days of bronze and cast iron. So that the commencement of their great gun factory dates from the year 1872, and grew out of the small Government order intrusted to them in that year. It is worth mentioning, in reference to those first six trial guns, that the perfection of the workmanship called for much admiration, no less than the excellent quality of the material employed; the breech mechanism attracted considerable attention from the fact that al parts were made interchangeable.

The period between the date of the first experiments in 1872-3 and 1875 was, comparatively, one of trial, for during those two years experiments were continually carried on at Creusot. Messrs. Schneider and Co. commenced the construction of guns as a regular department of their business in 1875, when the experimental period was over, and a large and very complete gun-making plant was installed. Simultaneously with the development of heavy artillery, advanced the improved construction of armour-plates, in which, as we have already seen, Messrs. Schneider and Co. took a leading part, especially in the production of all-steel plates, the first of these being tested at Spezia in the year 1876. One branch of this industry grew, later on, into the construction of armoured turrets for war vessels, and of chilled cast plates for land fortifications; of such armour Messrs. Schneider and Co. designed and manufactured a great variety of types, with the same good results that attended their preliminary efforts at gun-making. They secured many of the orders for the first chilled cast-iron turrets for the French Corps of Engineers, and somewhat later they executed a large amount of work for the same body, such as disappearing turrets and other fortification protective work; caponiers, cupolas, &c. Their ever-increasing means of production enabled them to supply Foreign Governments as well as that of France. Among the more important orders executed for abroad may be mentioned the turrets and other protective work supplied by them to Belgium, Roumania, and Holland, as well as turrets for ships to the Spanish and other navies.

As may be readily supposed, the present gun-making plant of Creusot is now very different from what it was in 1875; we have already referred briefly to some of the changes that have taken place in this department since it was inaugurated, and we shall now proceed to describe these changes in detail. But it should be mentioned here, that, as in the armour-plate and other departments of the Creusot works, so in the gun factory, the developments and improvements, alike in design, material, and means of construction, have been steadily constant, so that Creusot has always kept to the front in the manufacture of ordnance.

The most important step recently taken by Messrs. Schneider and Co., in connection with their manufacture of ordnance, has been the acquisition of the large and well-equipped gun factory at Havre, once belonging to the Forges et Chantiers de la Mediterranée, which was laid out by Mr. G. Canet for the manufacture of his well-known system of artillery. Messrs. Schneider and Co. have since greatly improved the equipment of their Havre works, by adding a considerable number of new appliances and machine tools. In making this important addition to their means of production, Messrs. Schneider and Co. secured the co-operation of Mr. Canet, who has now the control of the artillery departments both at Creusot and Havre. The Schneider and Canet systems of gun-making are also combined, under the name of the Schneider-Canet system.

XXIII.—THE GUN FACTORY AT CREUSOT.

From 1870 to 1888, the manufacture of artillery at Messrs. Schneider and Co.'s works was carried on continuously in the engineering department at Creusot. Owing, however, to the constantly increasing home and foreign orders to Creusot for artillery, and notwithstanding that the various shops of the engineering department had been largely extended from time to time, with the special object of adapting them to an increased manufacture of ordnance, it was found absolutely necessary in 1887 to create a new department and to equip it specially with new machinery. But the shops which, in 1887, were considered sufficiently extensive to meet the demands, for some time to come at all events, were quickly found to be too small, and have been from time to time extended. They originally covered an area of 3500 square metres (4190 square yards), and this at the present time has grown to 27,500 square metres (32,890 square yards). The artillery shops are built in the Creusot valley, to the south-east of the main works, on an embankment averaging 10 metres (33 ft.) in height above the bottom of the valley, and formed of blast-furnace slag.

The first series of shops (styled the "north shops") built in 1888, for the machining of large and medium-sized guns, for the construction of coast defence gun carriages, gun mountings, ships' turrets, and turrets for land service, rests on the embankment, upon wide-spread masonry foundations, which carry the main rows of columns; these columns, which are double, support the whole ironwork of the building.

At the present time the north shops comprise two groups of three spans each (see plan, 556, Plate XCVII.), the central spans being wider and higher than the two side ones. The west group is 35 metres (115 ft.) in width, and 172 metres (564 ft.) in length; the east group measures 37 metres (121 ft.) by 162 metres (534 ft.). The central spans are of the following dimensions: West group 15 metres (49 ft.) wide, and 10 metres (33 ft.) high; east group 17 metres (55 ft. 9 in.) wide, and 12.3 metres (39 ft.) high. The four lateral spans are similar in design, and are 10 metres (33 ft.) wide, and 8 metres (26 ft.) high. The trusses of the central spans, placed 10 metres (33 ft.) apart, rest on the double columns mentioned above. The same columns carry the tracks of the overhead travelling cranes. The trusses of the side spans are placed the same distance apart, and rest at one end on the columns, and at the other on the enclosing walls of the shops. The rails for the smaller overhead travellers rest on brackets. The trusses and purlins are of iron, and the rafters are of timber. The outside covering of the roof is of slates fixed to battens, the rafters on the inside being lined with boarding, painted white, in order to reflect the light; great care has been taken to secure sufficient lighting, the skylights and side windows being of large dimensions; the flooring consists of concrete in cement.

The general plan, Fig. 556, Plate XCVII., shows the arrangement of the north, as well as of the south, shops, to which further reference will be made. On the plan, the various departments are denoted by letters, and a Table of references is appended.

Figs. 557 to 559, Plate XCVIII., are exterior views of the gun factory; Figs. 560 and 561, Plate XCIX., are respectively views of the principal machine-shops; Fig. 562, Plate C, rifling shop showing the operation of rifling a 24-centimetre gun; and Fig. 563, Plate C, an interior view of the large lathe and rifling shop.

The south shops, which were built in 1897, especially for the construction of field and siege artillery, are separated from the north shops by the road to Montcenis communication being established between the two by a footbridge.

The shops consist of three buildings (see plan, Fig. 556, Plate XCVII.); one of seven spans, 10 metres (33 ft.) wide and 117 metres (384 ft.) in length; the two others, each of three spans, also 10 metres (33 ft.) wide 87 metres (285 ft.) in length. The three buildings are separated by yards 10 metres (33 ft.) wide. Owing to the small width of the spans, and in view of the work for which the buildings were intended, Mr. E. Schneider adopted a saw-tooth roof, the first of the kind ever made in Creusot for large buildings, the vertical sides facing the north being filled in with corrugated glass. To provide for extensions in the future, the ends of the shops are not walled in, the end columns and trusses being similar to those in the body of the building. The columns are placed 10 metres (33 ft.) apart one way, and 5 metres (about 16 ft.) apart in the other direction. They are stayed transversely by light iron girders, and longitudinally by the overhead travelling girders. The remainder of the building is of wood, and the parts of the roof looking south are covered with slates, the inside being lined with matched boarding in the same way as the north shops. The flooring consists of concrete in cement. The sides of the building are formed of timber framing filled in with brickwork. The columns are provided with brackets, placed 3 metres (9 ft. 10 in.) high, to carry the main transmission shafts.

The annexes to the north and south shops are as follows: The engineers' and accountants' offices; a depôt, 62 metres

(203 ft.) long and 21.50 metres (72 ft.) wide; a building, 29.50 metres (97 ft.) long, and 14 metres (46 ft.) wide, which contains the central steam and electric power generating station for this particular department. The boiler-house of this station covers an area of 27 metres by 14 metres (88 ft. by 46 ft.). Near the south shops is another boiler-house which measures 28 metres by 18 metres (92 ft. by 59 ft.); there are besides several sheds for warehousing material, for drying and bending wood-work, &c.

The railway system of the Creusot Works provides communication with the Artillery Department, which, of course, has in addition ample track accommodation in sidings, and in lines running through the principal shops. The usual rolling stock is used for ordinary transport, but special waggons are always held in readiness for the carriage of extra heavy or bulky pieces. Six-ton and 10-ton portable cranes are provided to handle gun parts in their rough state, as they are received from the other departments of the Creusot Works. All the gun parts are brought inside the shops on trucks, where they are taken up and distributed to the various machine tools with the help of the overhead travellers.

The north shops are provided with fourteen of these travellers, namely, one of 60 tons and two of 30 tons in the central spans; three of 15 tons and eight of 6 tons and 3 tons in the lateral spans. Each of these travellers is operated by an electric motor, driven by a belt and shaft, fitted with friction cones that transmit the motions for lifting or traversing a load. The man in charge of this work is stationed in a cabin mounted on the traveller, from which he controls all the movements by means of a series of levers.

In the south shops there is a 6-ton electric traveller for each span. All the cranes were built by Messrs. Schneider and Co.; they are provided with three electro-motors, one for each operation. As we have seen, the north shops serve for the machining of large and medium sized guns, for gun carriages for coast defence, for gun mountings, ship's turrets, and turrets for land service; and they contain all the machine tools required for this large range of work.

The central spans in which the 30- and 60-ton overhead travellers are placed, contain very large lathes, boring machines, and numerous other massive machine tools for the manufacture of large guns and their carriages or mountings, Part of this space is also utilised up for the erection of heavy and medium-sized work. The lateral west span of the west group, with two 15-ton overhead travellers, contains the lathes, boring machines, and other tools required for the finishing of medium-calibre guns, their carriages or mountings, and for the manufacture of various accessories of artillery. The other lateral span of the same group, served by overhead travellers of 3 and 6 tons, is occupied by the smaller machine tools, by lathes for turning copper fittings, by vice benches, and space is reserved for a dépôt for tools and stores.

In the west span of the east group, served by a 15-ton overhead traveller, is a range of planing machines, and a space in which the various gun parts are hand-fitted and put together; while the fourth side span forms the smiths' shop, and contains several machine tools, more especially used in the manufacture of accessory electric apparatus; in it are also placed a series of vice benches. Of the three south shops, one covers an area of 8,200 square metres (9,820 square yards), and each of the two others an area of 2,600 square metres (3,115 square yards). In the main building of the south shops, three spans are filled with lathes; one with rifling and other machine tools; and the three others are utilised as fitting shops. Here are assembled the various gun elements, and the jackets and coils are shrunk on (Fig. 564); this shop also contains the dépôt for tools and stores. The two other buildings, of three spans each, are used for the manufacture of forgings and for the working up of shields and plates; they also contain a storehouse for wood and other material, and the necessary wood-working machinery for the manufacture of wheels, caissons, &c.

Among the largest machine tools in the gun factory may be mentioned two gun-boring machines of 15 metres (49 ft. $2\frac{1}{2}$ in.) travel, and 1.200 metres ($47\frac{1}{4}$ in.) height of centres; a lathe 1.400 metre ($55\frac{1}{8}$ in.) height of centres and 15 metres (49 ft. $2\frac{1}{2}$ in.) between centres; one large horizontal surfacing lathe, that can turn up to a diameter of 8 metres (26 ft. 3 in.), and one rifling machine of 14 metres (45 ft. $11\frac{3}{16}$ in.) travel; these tools are employed for machining guns of the largest calibres. With such a plant the heaviest guns are now produced at Creusot.

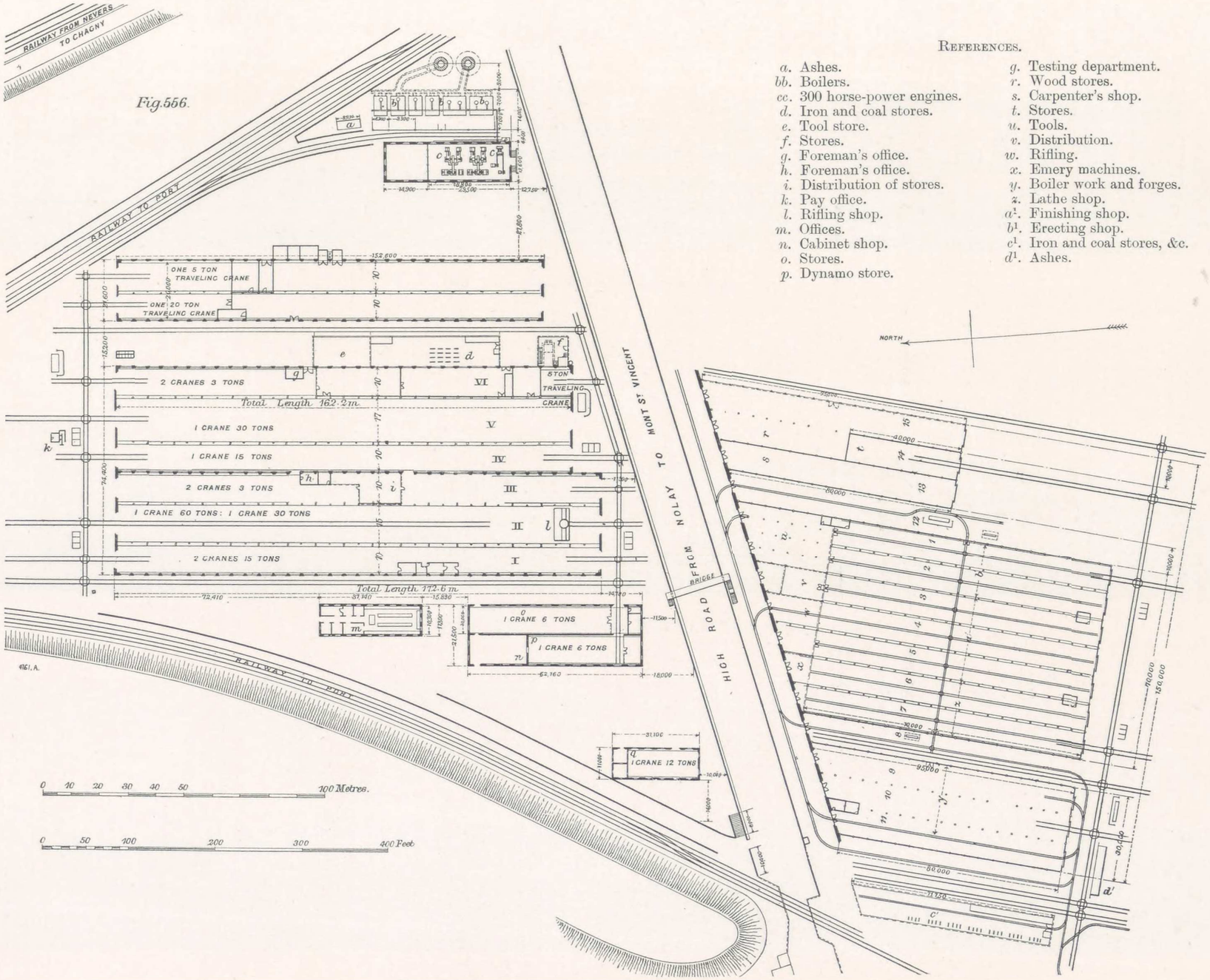
Among the larger plate-working machines, there is one 150-ton hydraulic press for stamping gun-carriage cheeks, a hydraulic rivetting machine, and two special hydraulic presses for putting on the bands of projectiles. The three steam-hammers in this department are very light, one being of 5 cwt. and one of 10 cwt., both double-acting; there is also a 2-ton hammer for the manufacture of drop forgings. This part of the plant includes also furnaces for heating, annealing, tempering, and cementing the smaller parts that enter into the construction of field artillery. The large forgings are made in the steel department, and are brought forward to the gun-shops. The plant is completed by full sets of all the necessary gauges, standard measures, instruments of precision, &c., required in the manufacture of ordnance.

In Figs. 565 to 570, Plates CI., CII., and CIII., and Fig. 571, are given several further interior views of the different shops described above.

The central electric station (Fig. 572) for the artillery department is complete in itself, and contains the necessary engines and dynamos for producing the required electric energy; it is situated near the north shops. A total of 700 horse-power is available; the electric energy is distributed by three mains.

The boilers are registered for a pressure of 9 kilogrammes (128 lb. per square inch), and are of two different

Fig. 556.



References.

a. Ashes.
bb. Boilers.
cc. 300 horse-power engines.
d. Iron and coal stores.
e. Tool store.
f. Stores.
g. Foreman's office.
h. Foreman's office.
i. Distribution of stores.
k. Pay office.
l. Rifling shop.
m. Offices.
n. Cabinet shop.
o. Stores.
p. Dynamo store.
q. Testing department.
r. Wood stores.
s. Carpenter's shop.
t. Stores.
u. Tools.
v. Distribution.
w. Rifling.
x. Emery machines.
y. Boiler work and forges.
z. Lathe shop.
a^1. Finishing shop.
b^1. Erecting shop.
c^1. Iron and coal stores, &c.
d^1. Ashes.

Plan of Creusot Gun Factory, North and South Shops.

PLATE XCVII.

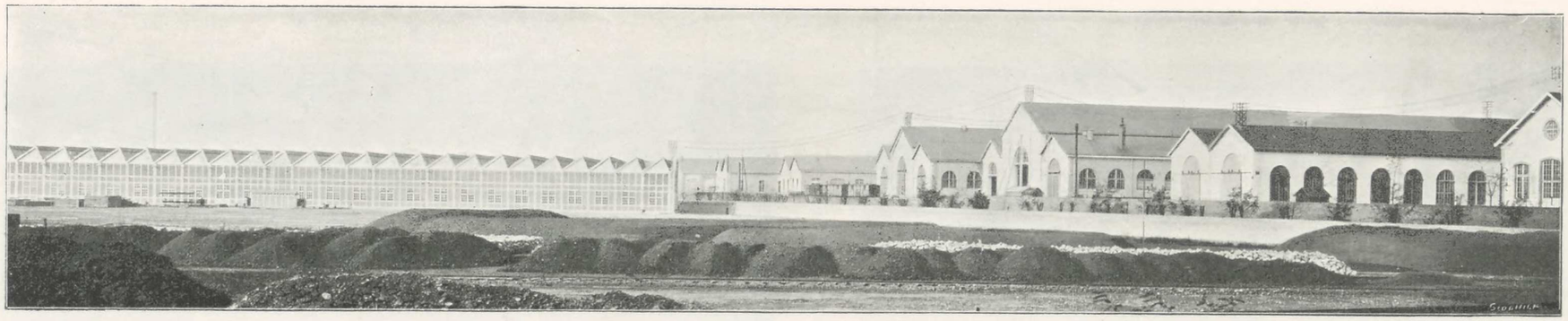


Fig. 557. East Front of Gun Factory.

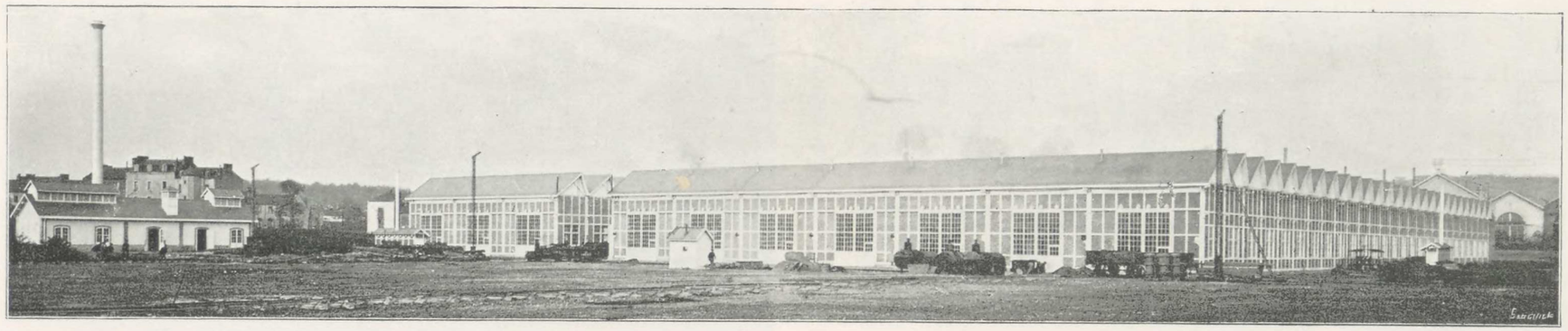


Fig. 558. South Front of Southern Division of Gun Factory.

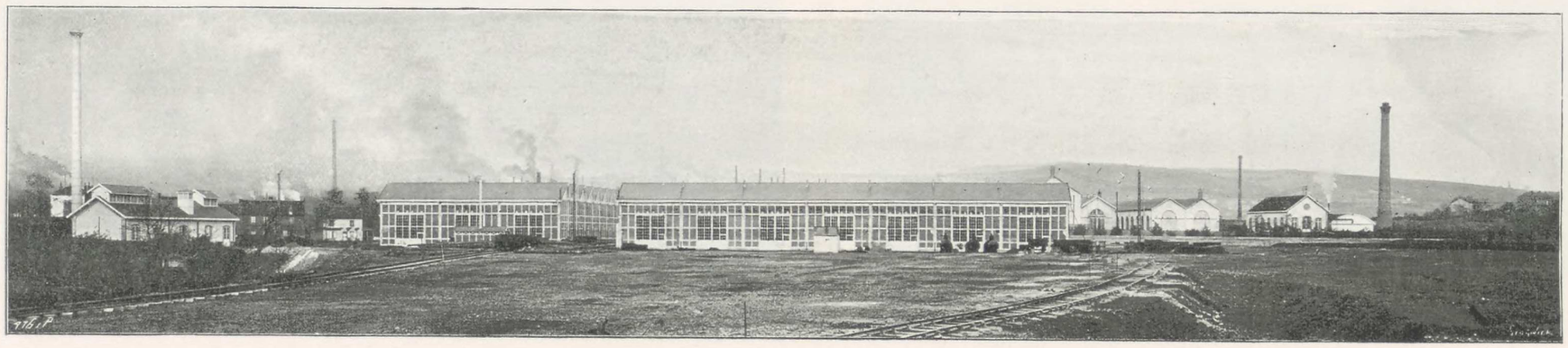


Fig. 559. South-East View of Southern Gun Factory.

THE GUN ROTOR AND SHIT

THE GUN FACTORY AT CREUSOT.

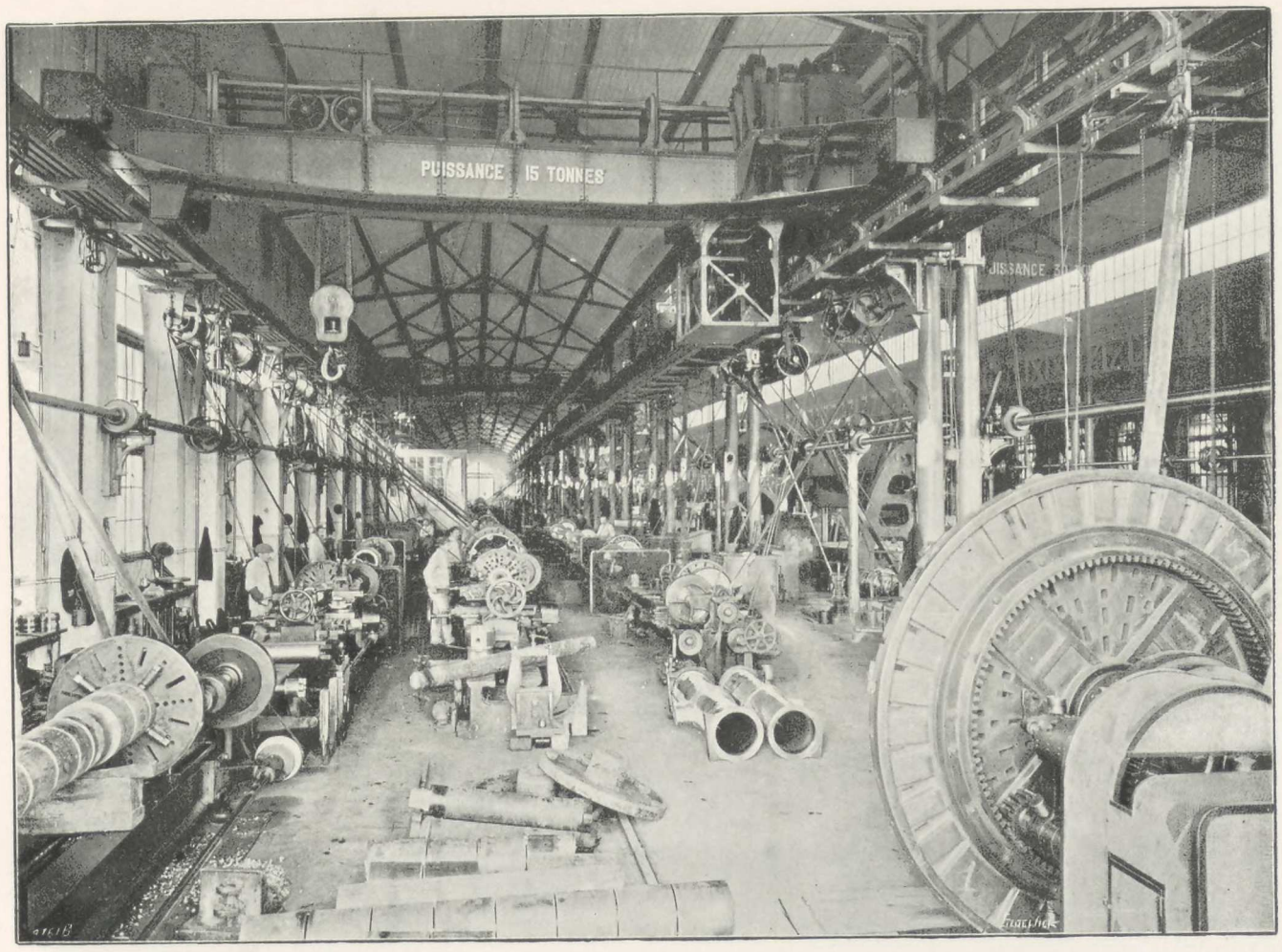


Fig. 560. Interior of Machine Shop, Span No. 1, North End (see Plan, Fig. 556).

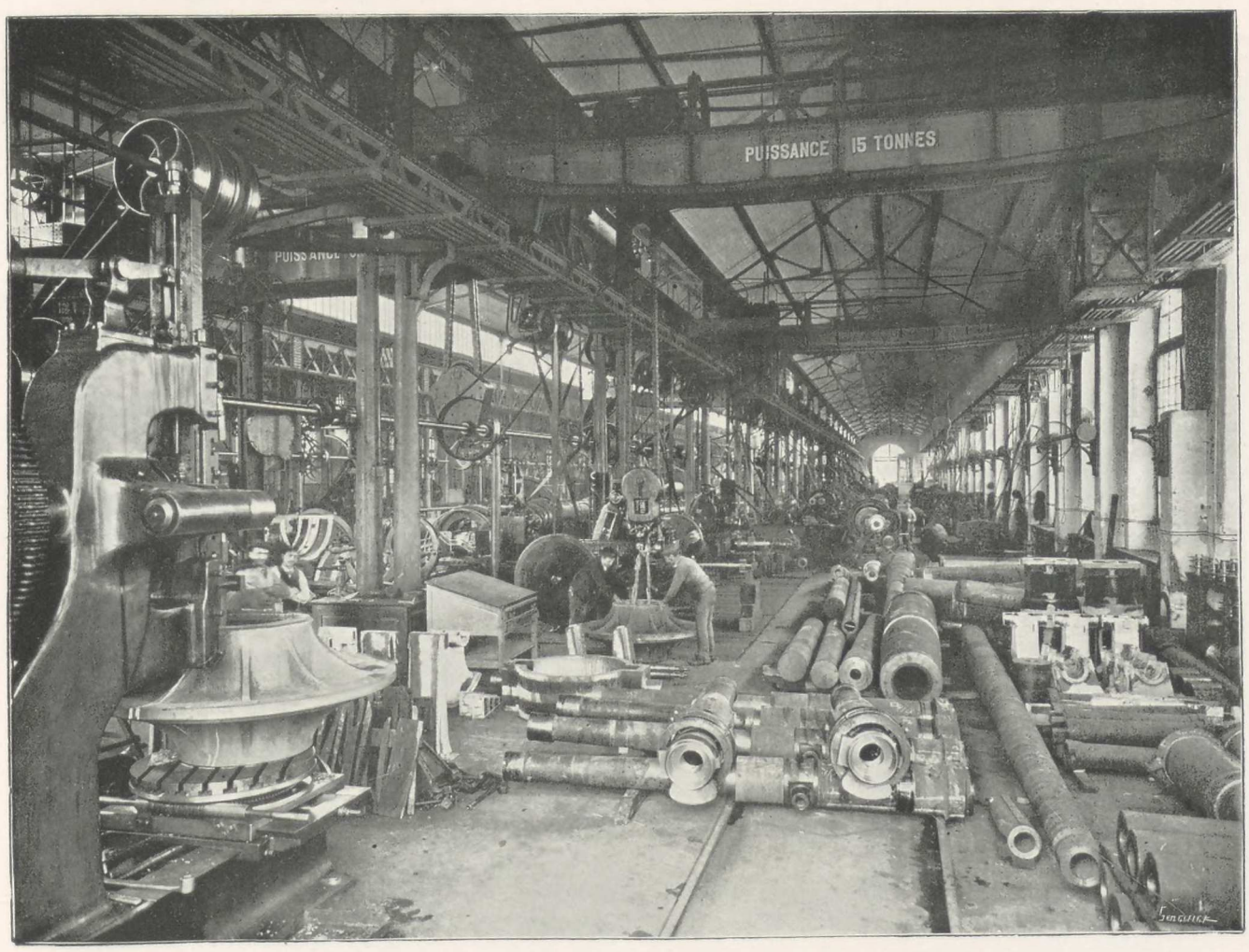


Fig. 561. Interior of Machine Shop, Span No. 1, North End (see Plan, Fig. 556).

THE GUN FACTORY AT CREUSOT.

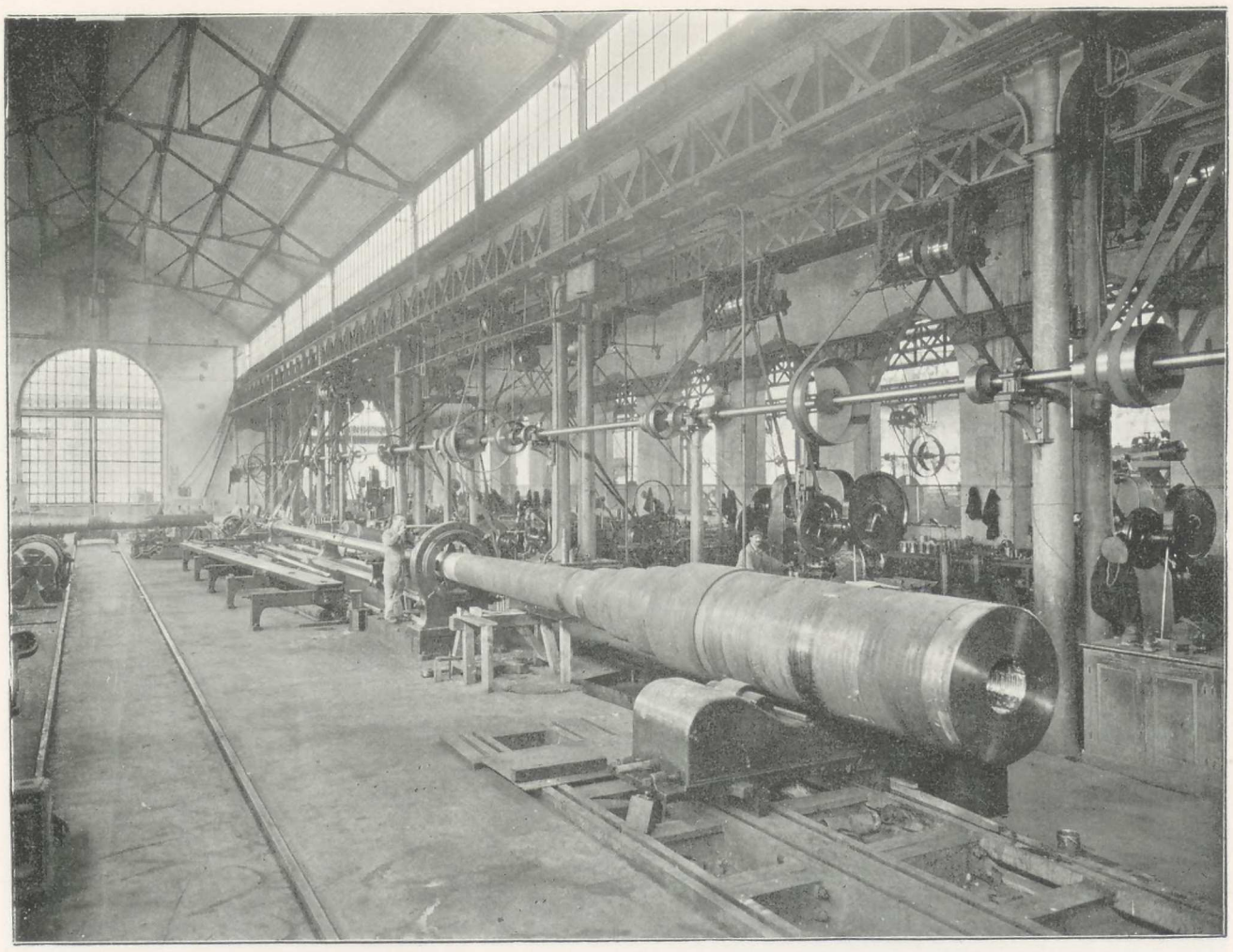


Fig. 562. **Rifling a 24-Centimetre Gun, Span No. 2, North End** (see Plan, Fig. 556).

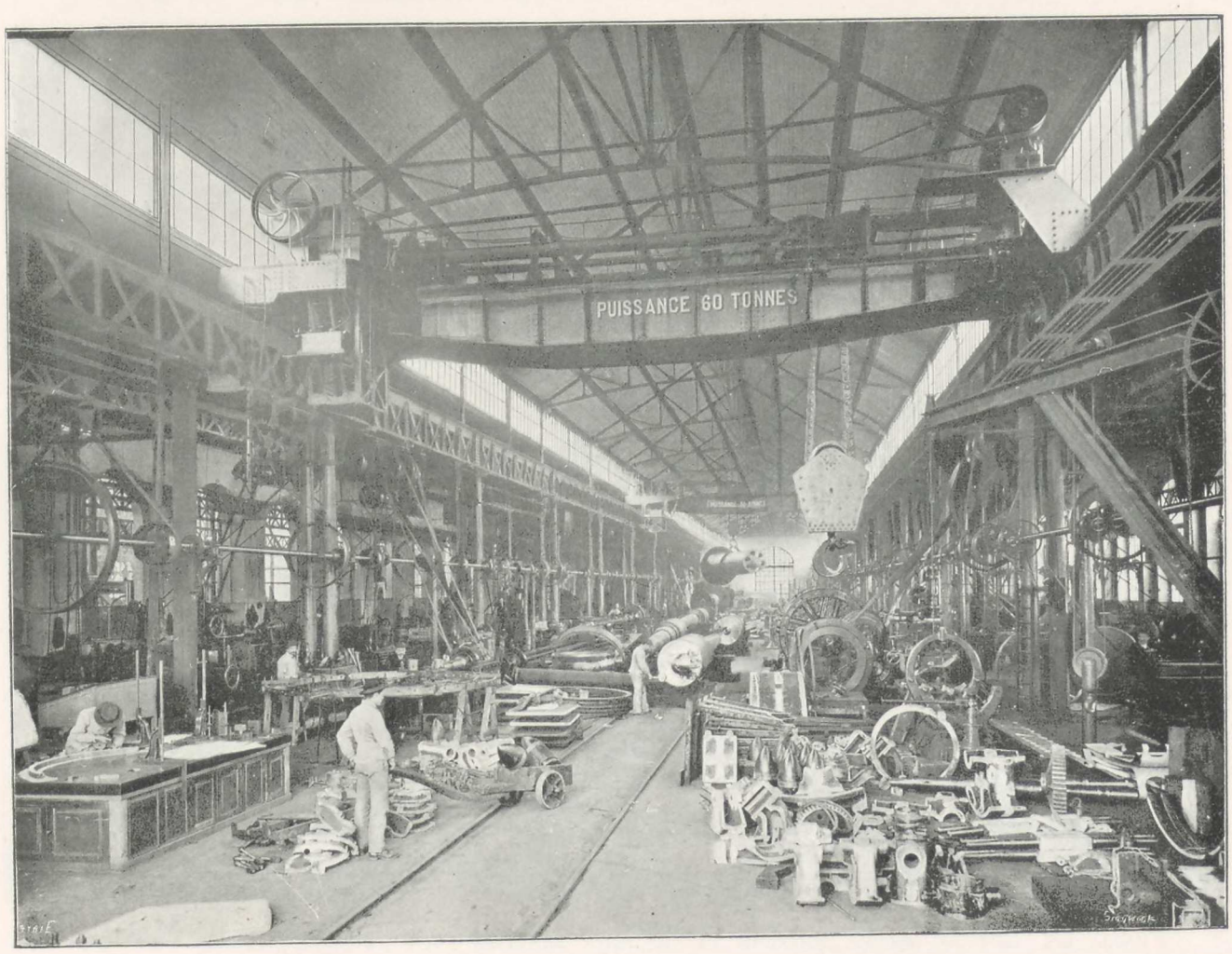


Fig. 563. **Large Lathe and Rifling Machine Shop, Span No. 2, North End** (see Plan, Fig. 556).

THE GUN FACTORY AT CREUSOT.

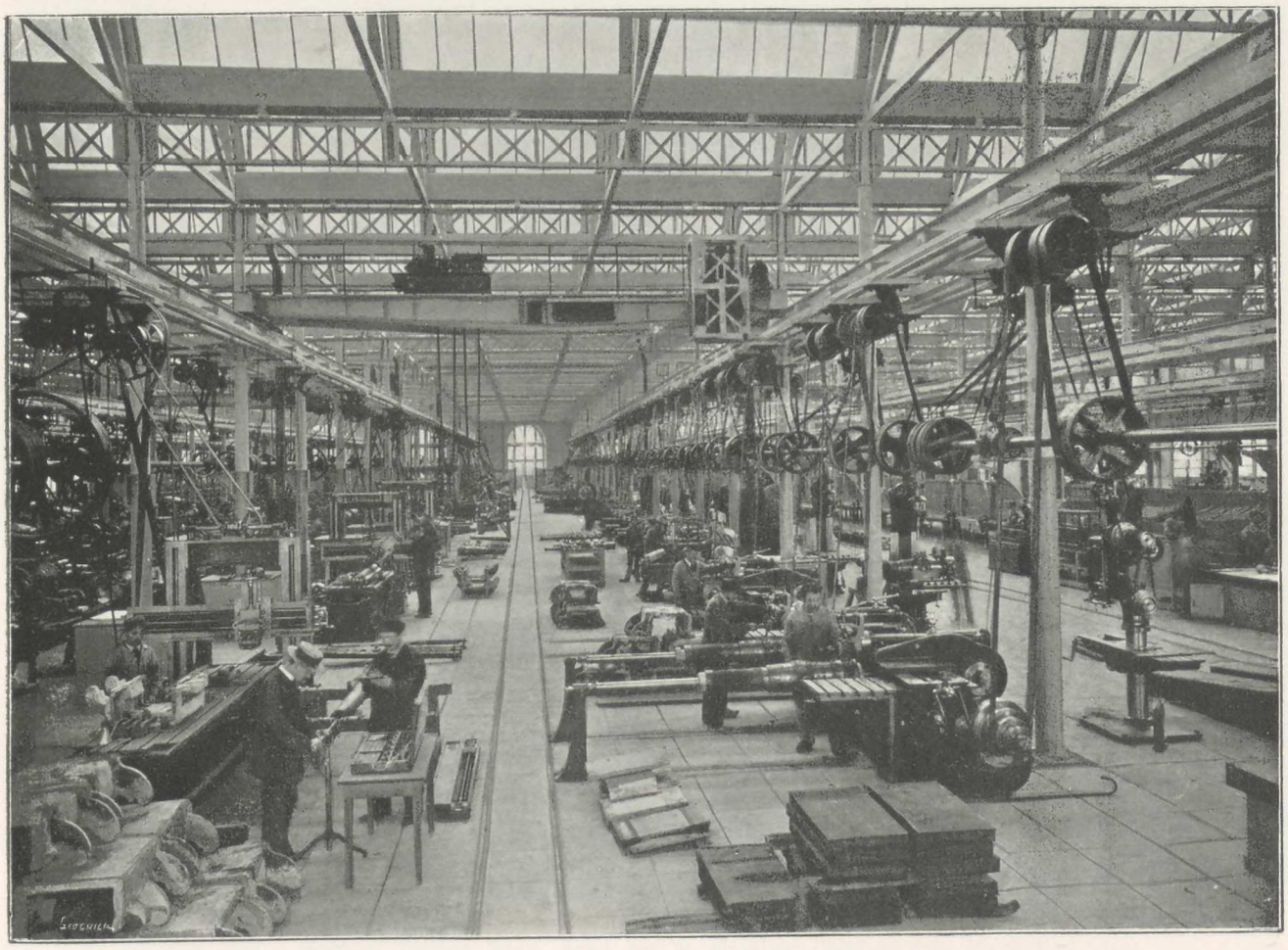


Fig. 565. **Small Machine Tool Shop, Span No. 9, Southern Section** (see Plan, Fig. 556).

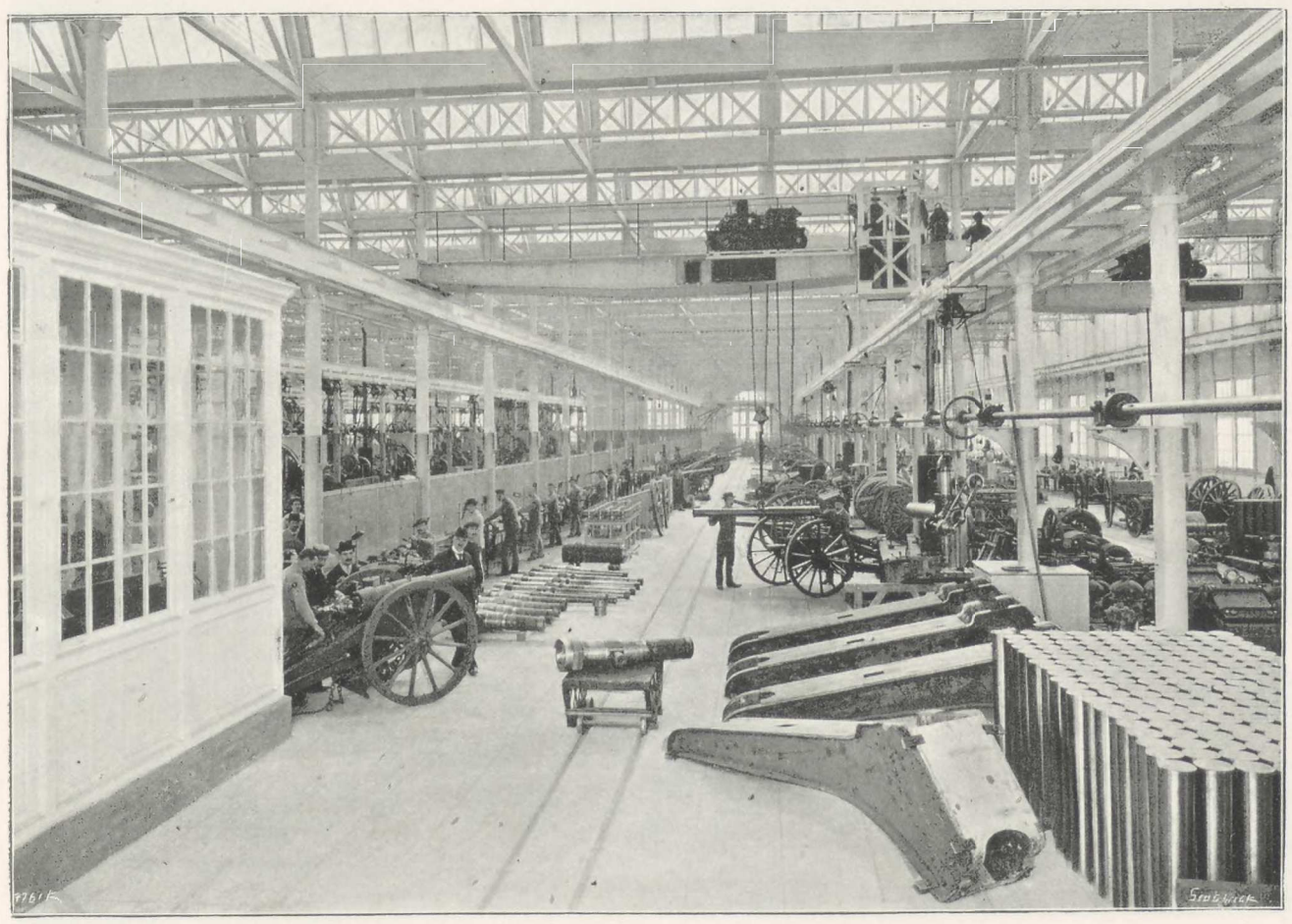


Fig. 566. **Erecting Shop for Field Batteries, Span No. 13, Southern Section** (see Plan, Fig. 556).

THE GUN FACTORY AT CREUSOT.

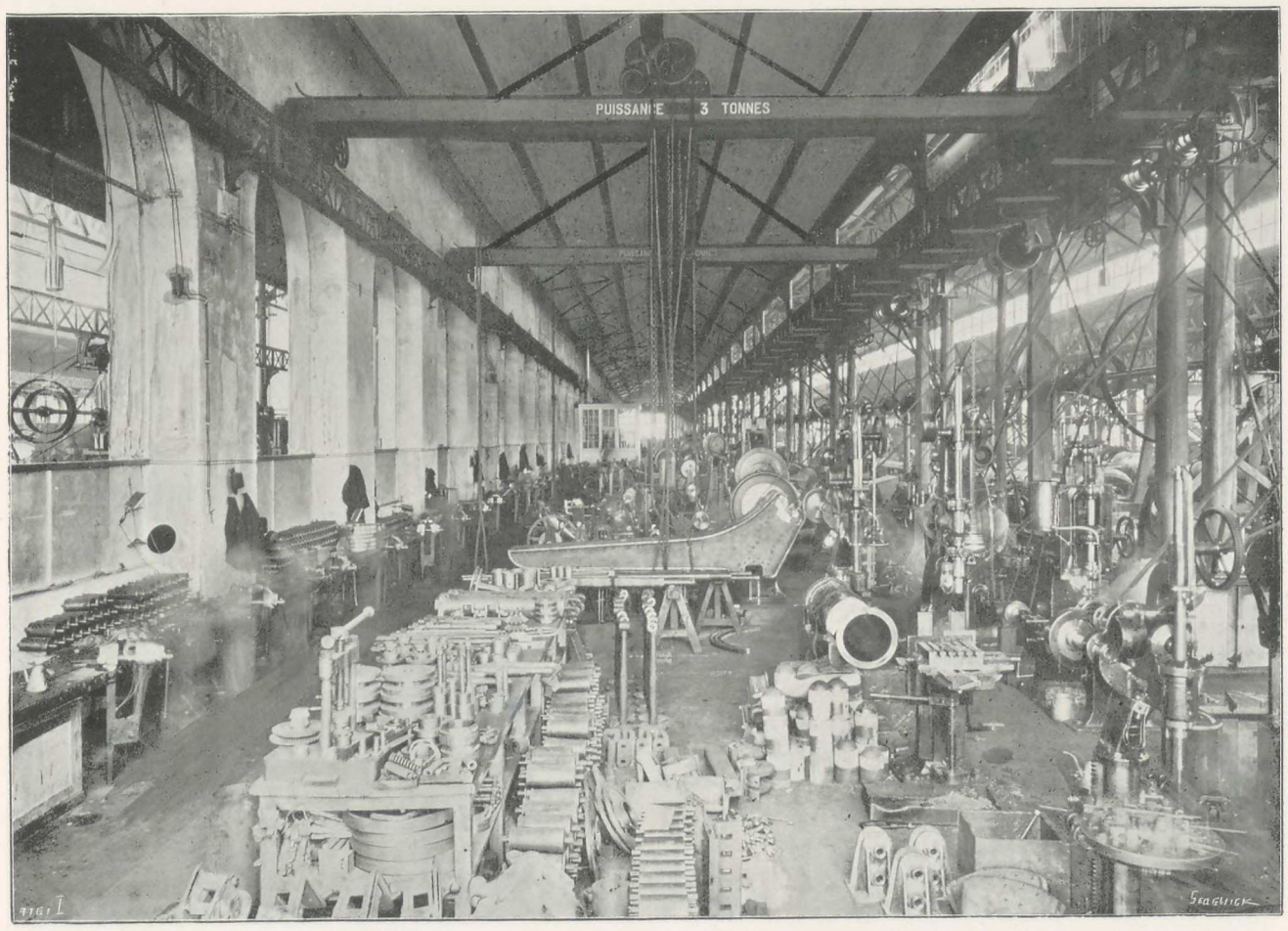


Fig. 567. Part of Fitting Shop, Span No. 3, Northern Section (see Plan, Fig. 556).

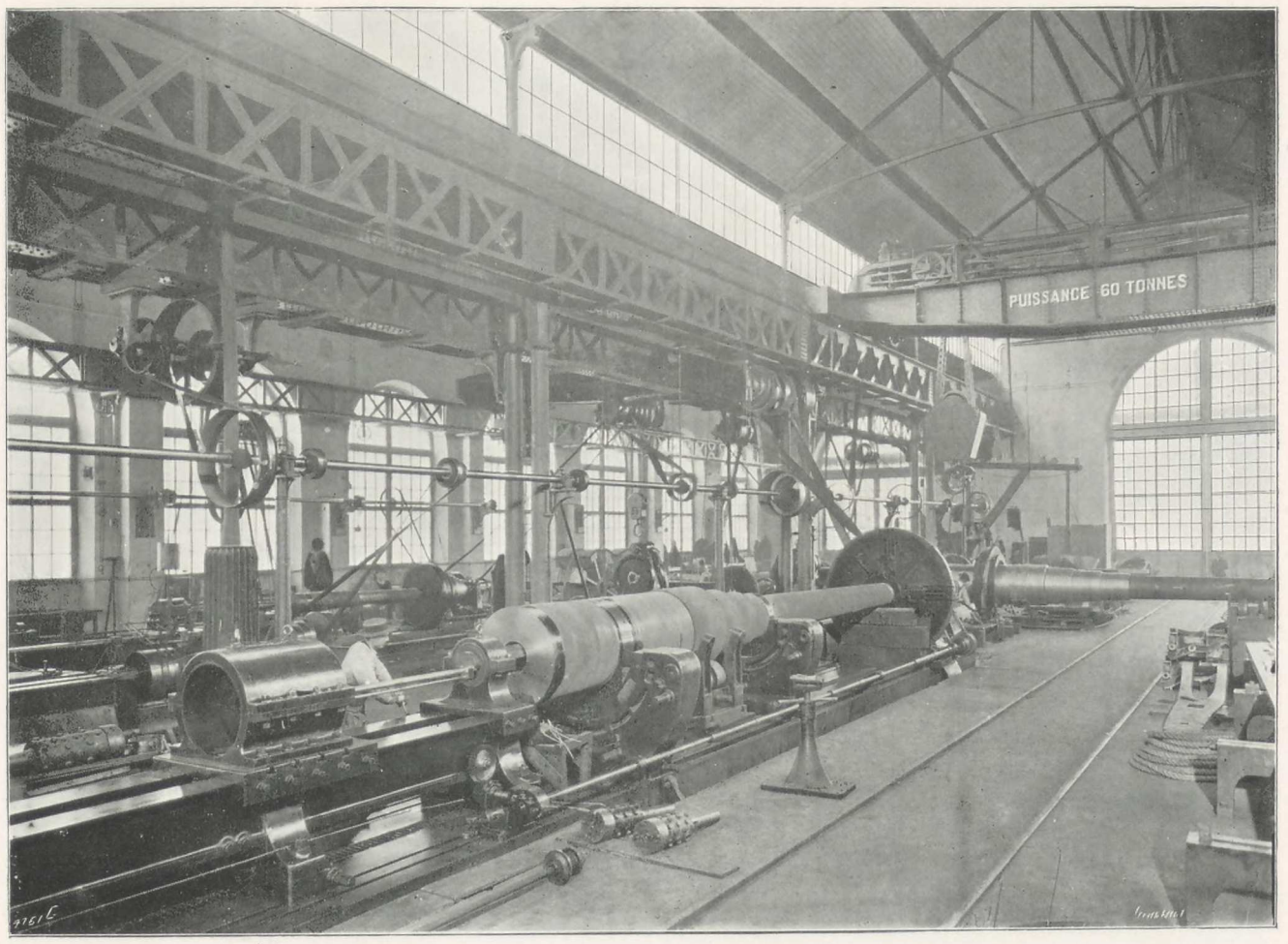


Fig. 568. Chambering a 24-Centimetre Gun, Span No. 2, Northern Section (see Plan, Fig. 556).

THE GUN FACTORY AT CREUSOT.

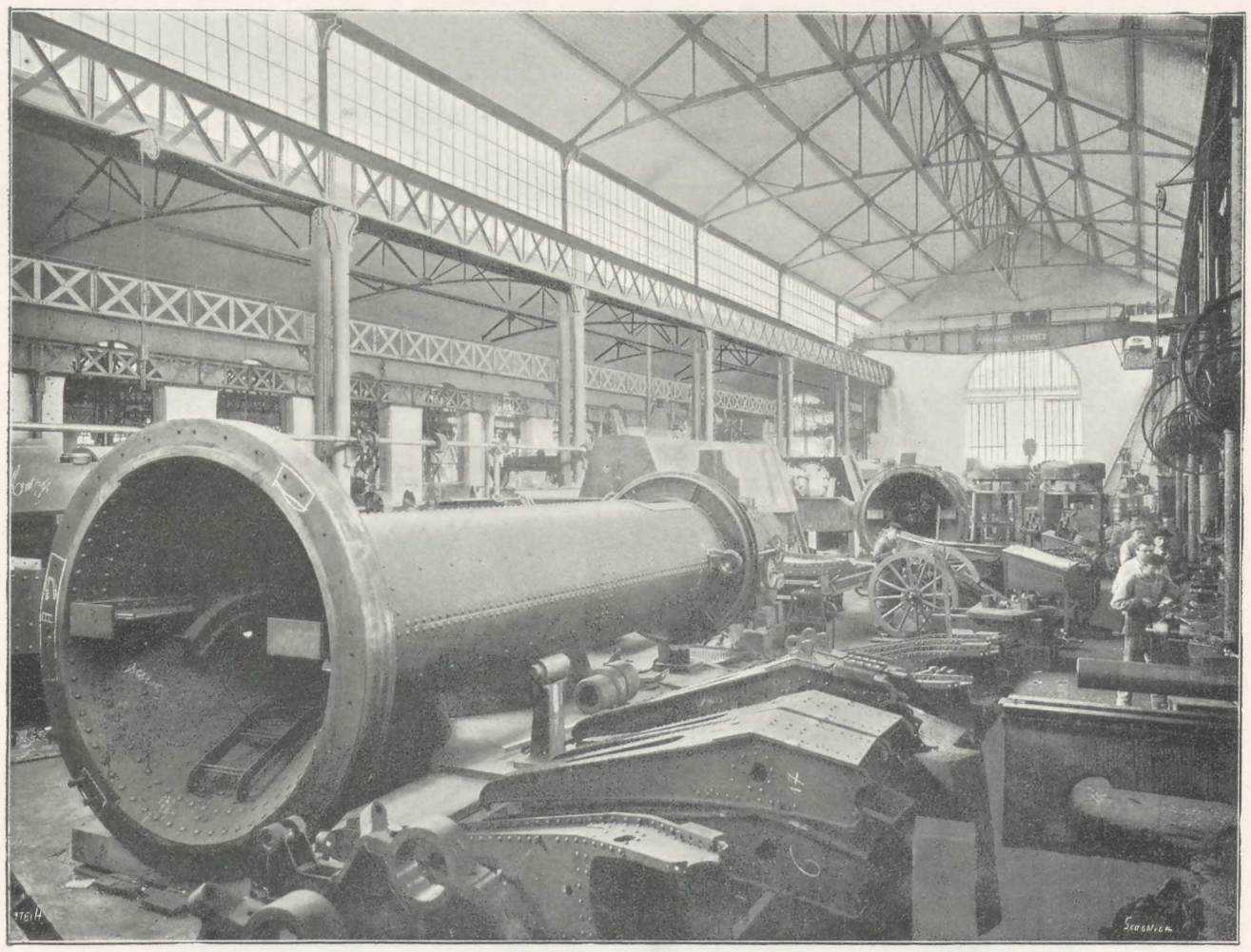


Fig. 569. **Marine Turret-Erecting Shop, Span No. 5, Northern Section** (see Plan, Fig. 556).

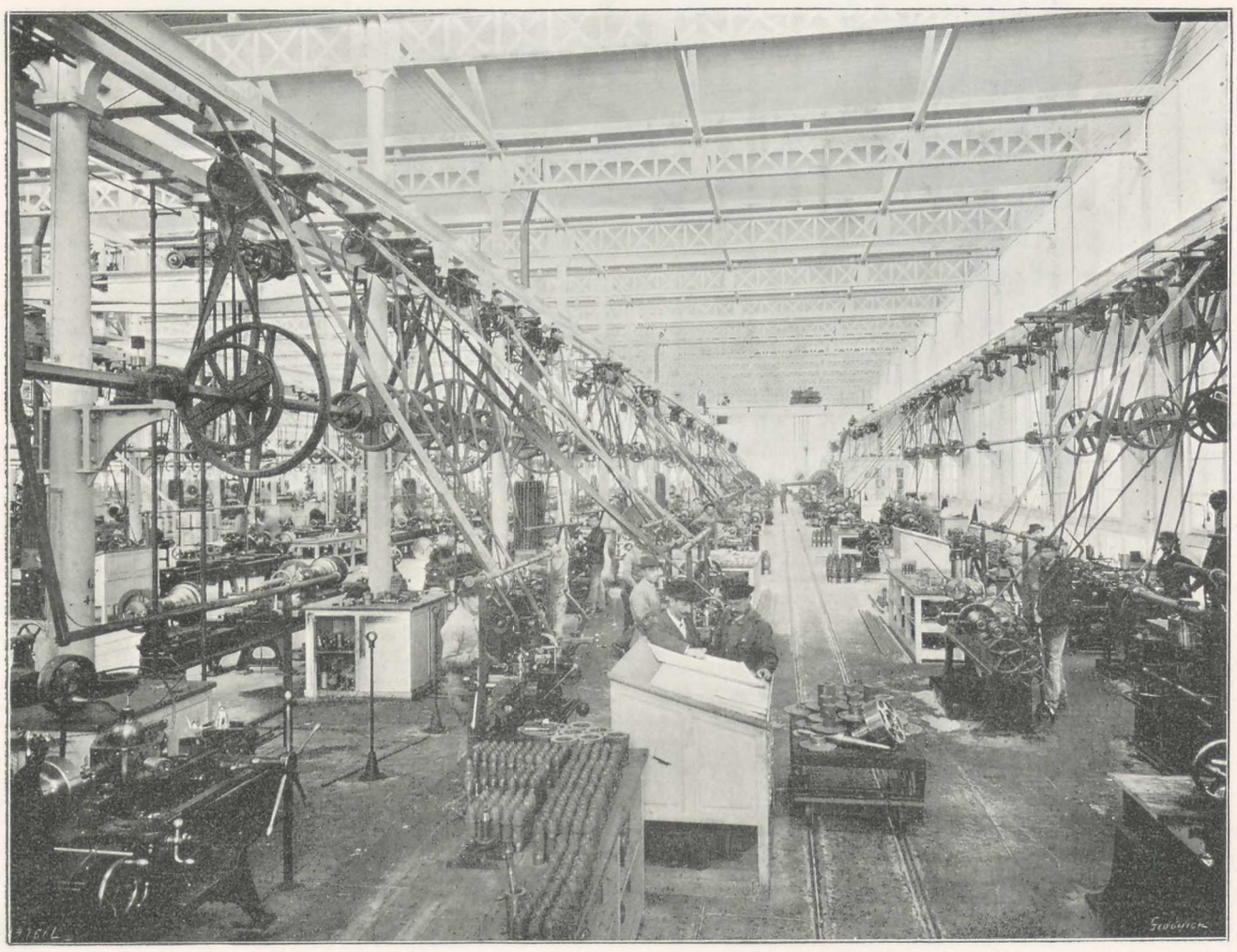


Fig. 570. **Interior of Small Machine-Tool Shop, Southern Section, Span No. 7** (see Plan, Fig. 556).

types; two groups consist each of two tubular boilers with corrugated fireboxes; a third group is formed of two multitubular boilers. The grate area is 22.50 square metres (242.19 sq. ft.); the total heating surface, 1000 square metres (10,764.30 sq. ft.). The two groups provide sufficient steam for working under full load; the third group is kept in reserve. The three steam engines are

100 horse power (one engine):

Diameter of small cylinder	.280 m. = 11 in.
,, large ,, ...	.420 m. = 16½ in.
Stroke	.320 m. = 12⅝ in.
Revolutions per minute	270

The current from each dynamo is 225 volts; the distribution is effected through three mains, and the two dynamos being connected to the driving pulley by two

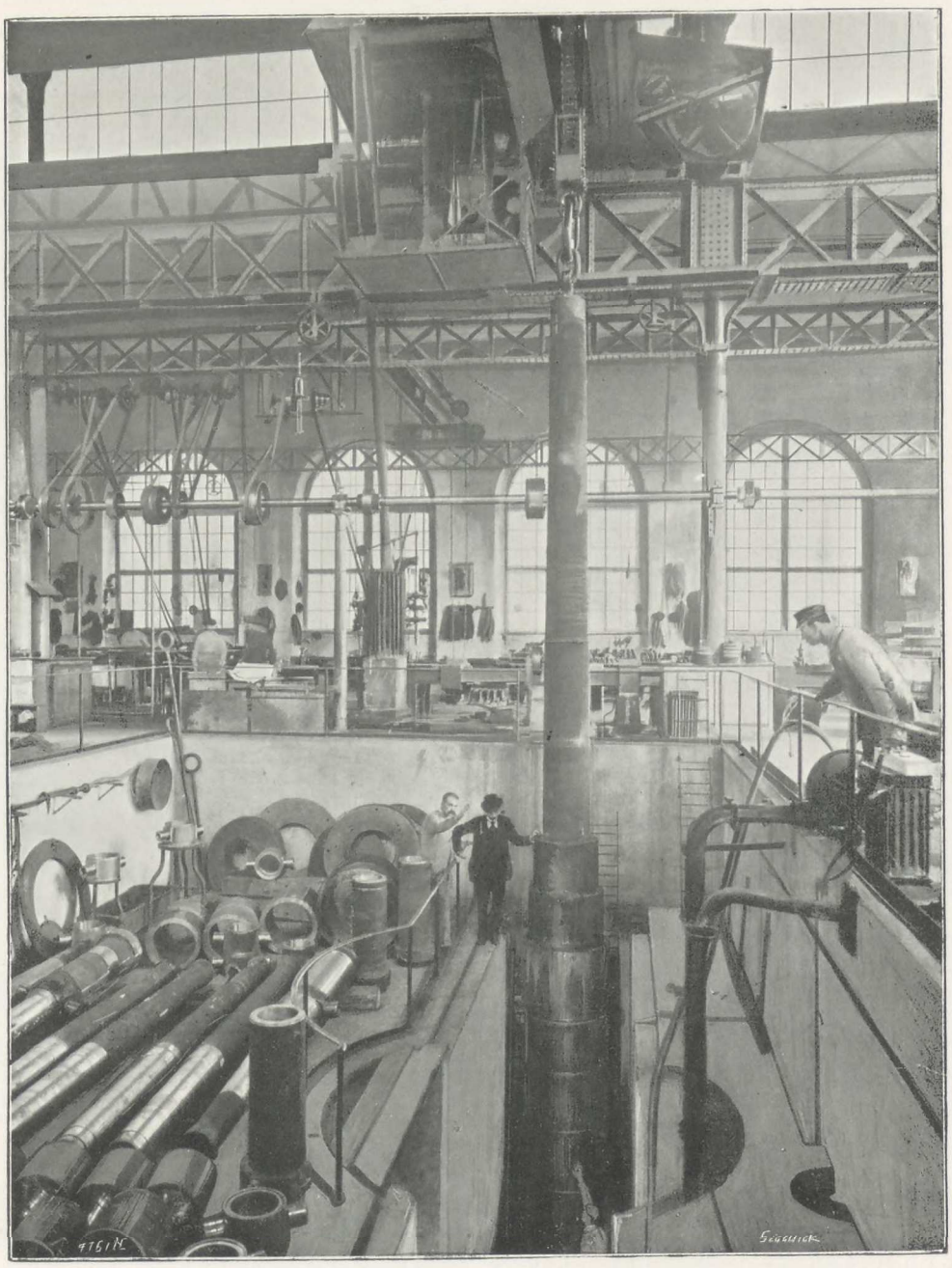


Fig. 564. Shrinking Jacket on 240-Millimetre Gun.

compound, and work under an initial pressure of 7 kilogrammes (99.5 lb. per square inch). Each one drives by means of a single belt, two direct-current Thury generating dynamos built by Messrs. Schneider and Co. The steam engines are of two types, and are of the following principal dimensions:

300 horse power (two engines):

Diameter of small cylinders	.450 m. = 17¾ in.
,, large ,, ...	.650 m. = 25⅝ in.
Stroke	.650 m. = 25⅝ in.
Revolutions per minute	165

elastic clutches, are coupled in tension, and give 450 volts on the two outside lines of the distribution. An electric regulator maintains the voltage constant, whatever be the output. The three groups of generating dynamos can be connected in multiple arc; the 100 horse-power group, however, is more especially used for night service.

The three mains are laid overhead, and consist of uninsulated cables; they supply, direct, all the fixed motors that drive the transmission shafts of the north and south shops, and a few machine-tool motors; they also supply the

motors of all the overhead travellers, through branch conductors laid along the traveller tracks, and joined to the distributing system of each traveller by means of brushes of the trolley type. Through bare wire conductors laid underground, they also furnish current to various portable electric motors, which are used for a variety of purposes in different parts of the gun-shops.

The main transmission shafts of the north shops are made in sections 5 metres (16 ft. $4\frac{13}{16}$ in.) long, and run in bearings on brackets placed 5 metres apart, fitted to the motors, varying in power from 1 to 60 horse-power, work the transmission shafts, the overhead travellers, and the isolated tools in both shops. The working current at the terminals of the motors is 210 volts. All the steam and electric motors in this department have been built by Messrs. Schneider and Co.

The north and south shops are each provided with a pit for shrinking on jackets and coils; that in the north shop can take the longest guns made; it is placed in the main west span, and is served by the 30-ton and



Fig. 571. Shop for Setting on Projectile Bands (see Plan, Fig. 556).

columns or the walls at a height of 3.20 metres (10 ft. 6 in.) above the floor; the shafts are also supported on light intermediate columns placed in the centre of the 10-metre space between each main column. The shafting in the south shops is also in lengths of 5 metres; it is carried in bearings on brackets bolted to the columns 3 metres above the floor; in these shops the columns are 5 metres apart, and the shafting, therefore, requires no intermediate supports.

In the north shops the steel shafts are solid, and are fitted with cast-iron pulleys, while in the south shops the shafts are made hollow, and carry wood pulleys, in order to reduce the loss of power, in driving them, to a minimum. In the shops, the overhead motion of the machine tools is attached to the traveller girder. Fifty the 60-ton overhead travellers. The pit in the south shops, at the north end of the fifth span, has been designed specially for dealing with field guns; it can, however, take guns 5 metres (16 ft. 4 in.) in length, and is served by a 6-ton overhead traveller.

Plate CIV. is a view of the interior of a gun and turret erecting shop at Creusot.

Jackets and coils are heated by means of gas blow-pipes of a special design; the operation is conducted slowly, the heat being always kept proportional to the expansion required; the maximum, however, never reaches 400 deg. Cent. Special straight-edged plates, fitted with electric contacts, are used to ascertain whether long jackets have bent or not under the process of expansion; these plates are laid on three generating lines of



Fig. 573. Gun and Turret-Erecting Shop.

the jacket, and the result is recorded rapidly and accurately by bell signals, the circuit being completed between the electric contacts on the straight edges when the jacket has remained perfectly straight. A system of water jets completes the installation.

The construction of artillery has, during recent years, taken new directions, the most important being that of quick-firing guns, especially of field guns; this has been much to the front of late, and has excited the keenest interest among rival manufacturers. Thus, in Germany the competition between the firm Fried. Krupp with the Gruson Works resulted in their amalgamation; a similar combination was arranged by the fusion of the Armstrong and Whitworth interests in England. It was the same motive that led Messrs. Schneider and Co. to purchase the artillery department that belonged to the Société Anonyme des Forges et Chantiers de la Mediterranée, already referred to. The purchase of this department was completed on January 28th, 1897, and in uniting their artillery works, Messrs. Schneider and Co. now practically enjoy a monopoly of gun construction in France.

The two artillery works, those of Havre and those of Creusot, form at present a single department, and Mr. Canet, who was formerly manager of ordnance at the Forges et Chantiers, is, as already stated, now manager of ordnance at Messrs. Schneider and Co.'s works.

The work of gun construction is divided between these two works, the geographical situation of which has permitted a main division to be established, Messrs. Schneider and Co. entrusting their Havre works with the construction of naval ordnance and coast defence guns, while at their Creusot works, field, siege, and garrison artillery are manufactured.

There is, however, nothing absolute in this distribution of business, and the works help one another according to the orders they have each in progress. This is all the more easy, as they both have been fully equipped with a view to the manufacture of every variety of artillery, from mountain and boat guns, to marine and coast defence guns of the largest calibre. In the following descriptions of the different natures of Schneider-Canet ordnance, no discrimination is made between those made at Creusot and at Havre.

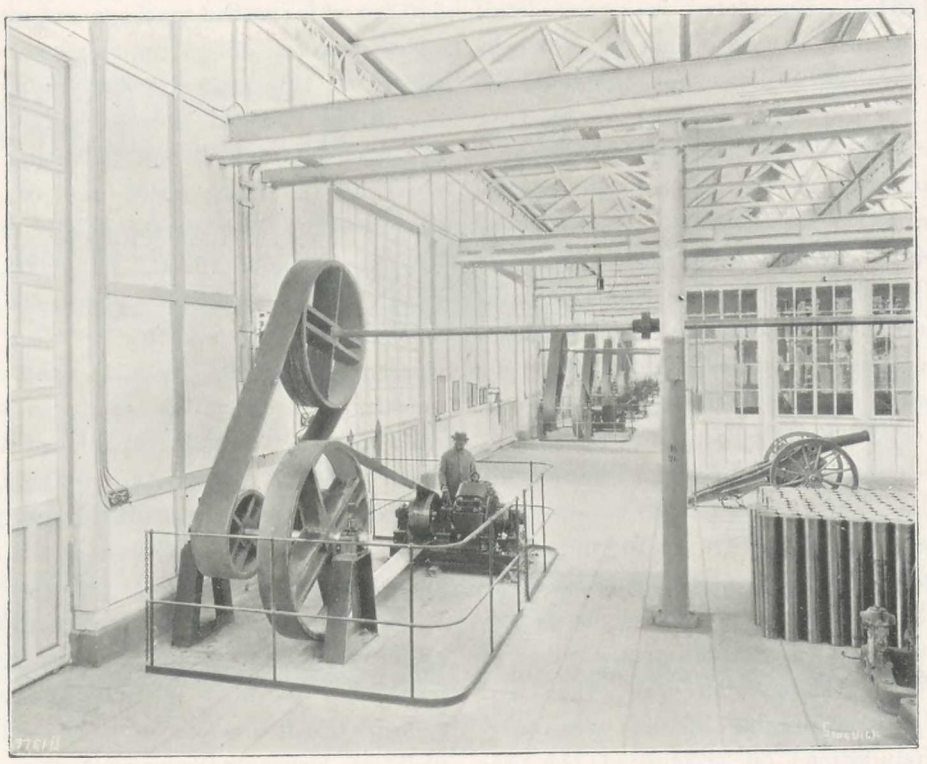


Fig. 572. Electric Power Department.

XXIV.—THE GUN FACTORY AT HAVRE.

IT has been already said that Messrs. Schneider and Co. recently acquired the very important gun factory that had been installed at Havre by the Forges et Chantiers de la Mediterranée in 1884-5. Completed in every detail under the supervision of Mr. Gustave Canet, these works represented the most advanced practice, and contained the most perfect methods, for producing guns of all calibres, from the smallest mountain batteries, to the largest naval cannon. The works occupy a large area bounded on the north by the Paris-Havre line of the Western Railway of France, and on the south by the Boulevard d'Harfleur. They adjoin the machine shops of the Forges et Chantiers Company, on the western side, while to the east lies a large area available for extensions. Every desirable facility for transport was comprised in the arrangement of the factory. Branches from the Western Railway run into the works, and from them, tracks enter all the principal shops while sidings were liberally laid down. Tracks also extend from the works to the quays and basins of Havre, for unloading such heavy objects as came by sea, and for shipping manufactured material. The machine shops cover an area of about 100,000 square feet, and consist of a number of separate buildings communicating with each other, and nearly 420 ft. in length. Considerable difficulty was found in making reliable foundations on account of the prevalence of sandy marsh on the site; the buildings and heavy tools were therefore built on piles. The motive power consists of two compound engines, each of them 80 horse-power nominal. The larger shops were provided with steam travelling cranes varying from 10 to 60 tons, and arranged to work in combination so as to handle loads weighing 90 tons. This brief description of the Havre gun factory, as it was originally constructed in 1884, is necessary as a prelude to a more detailed description of the works as they exist to-day, Messrs. Schneider and Co. having considerably enlarged and modified them, that they may be better adapted to the requirements of present practice.

Fig 574 is a plan of the gun factory at Havre: A shows the position of the general offices, stores, &c.; B, the directors' and engineers' offices, and drawing offices; C, engines and boilers; D, principal shop for construction of guns up to 20 tons; E, that of guns weighing as much as 100 tons; F, shop for 10 ton guns, torpedo tubes, &c.; G, general machine-shop; H, shop for making projectiles and fuzes; I, small machines; J, heavy machine tools; K, carpenters' shop; L, forge; M, courtyard.

At present the factory consists mainly of seven spans placed side by side; these are, of course, the original buildings, and the spans are of various widths and 126 metres (414 ft.) in length. The west span is 12 metres (40 ft.) wide; at the southern end are located the manager's office, and the offices for the engineers and staff; in the centre of this span are the engines, the labatory equipments for physical tests of metals; and the north end is arranged for packing and delivering finished products.

The six other spans are of the following widths respectively: 9 metres (30 ft.), 17 metres (56 ft.), 9 metres (30 ft.), 10 metres (33 ft.), 12 metres (40 ft.), and 15 metres (49 ft.). The height of springing of roof varies from 6 to 10 metres (20 ft. to 33 ft.).

The 17 metres (56 ft.) span is specially used for machining large calibre guns. It is thoroughly equipped with powerful lathes, capable of turning gun tubes 14 metres (46 ft.) long, and weighing 90 tons, and with surfacing lathes for turning heavy gun-carriage parts and ships' turrets. It contains also the large rifling machines and the shrinking pit.

The two spans of 9 metres (30 ft.) each, located on either side of the large shop just referred to, are used for machining guns of medium and small calibres. They contain the less powerful lathes, rifling machines, &c., as well as large drilling, mortising, shaping, boring, and planing machines, used in the manufacture of heavy gun-carriages and torpedo-launching tubes.

In the 10-metre (33 ft.) span is placed the smaller machinery, such as ordinary lathes, lathes for fine work, small shaping machines for cutting toothed wheel gearing, dividing machines, small drills, &c. The north end of this shop is set apart for the manufacture of fuzes, and there is besides sufficient space for machining breech-pieces and light gun-carriage parts.

The 12-metre (40-ft.) span is used as the fitting-shop in this the various breech mechanisms are finished, as well as torpedo-launching tubes with their gear and accessories.

The erecting shop occupies the space covered by the 15-metre (49 ft.) span; this building limits the works on the eastern side; the large area of this shop affords space for carrying out the various preliminary operations for testing breech mechanisms, carriages and mountings, torpedo-launching tubes, &c.; after these are completed, they are subjected to the reception firing tests in the proving grounds or on board ship.

Besides these shops there are two annexes; one is separated from the west span by a courtyard that opens on the Boulevard d'Harfleur, and contains the stores, the

infirmary, and the porter's lodging on the ground floor; the first floor is utilised as accommodation for the French and foreign inspecting officers. The other annexe is to the north of the works adjoining the Western of France Railway; it contains a 3-ton steam hammer, and hand forges which are employed for executing various repairs to the machine tools, &c., and also for making small forgings required in the gun shops. The large forgings are manufactured at Creusot and sent on to Havre.

The difficulties with the foundations already referred to, were, of course, also encountered when carrying out throughout; the main trusses are placed 6 metres (19 ft. 9 in.) apart; between these are intermediate trusses that are attached to the longitudinal girders between the columns. In the three western spans however, the intermediate trusses are carried by single columns that rest on the top of the masonry arches uniting the concrete masses that enclose the upper part of the piles. The iron purlins that carry the roof covering have therefore, a 3-metre (9 ft. 10 in.) span. The shops are lighted by day through skylights placed on top of all the buildings, except the west shop, which is lighted through

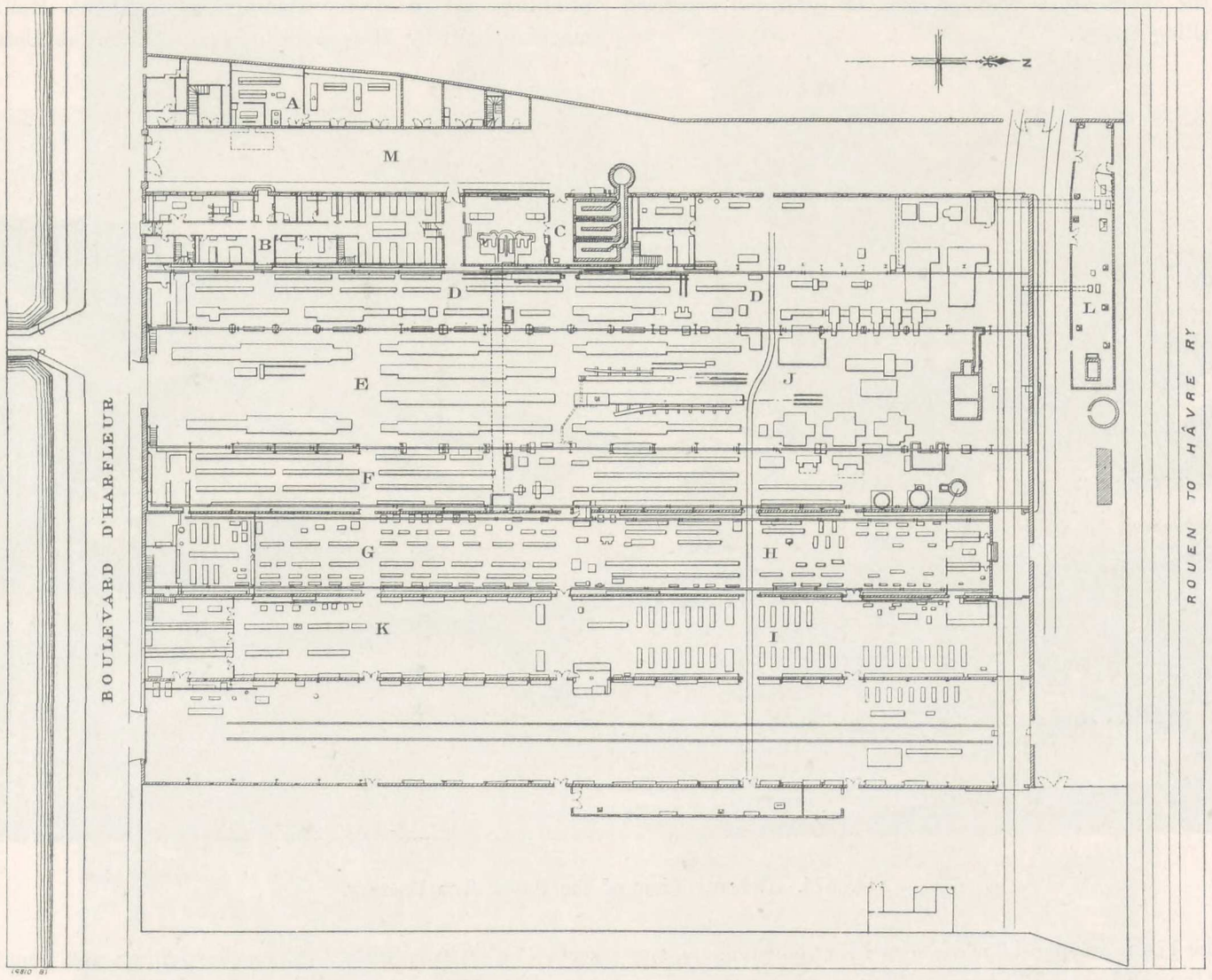


Fig. 574. Plan of the Havre Gun Factory.

extensions. The subsoil over which the Havre gun works are built, consisting of a bed of marl 9 to 10 metres (about 32 ft.) in depth, it was necessary, in order to obtain buildings of the required strength, to execute foundation works of great magnitude. The columns that support the buildings also carry the rails of overhead travellers, and they rest on piles that have been driven as deep as it was possible in the layer of marl. These piles are connected in groups of four and six, and near the surface they are embedded in a mass of concrete that serves to carry the base of the columns.

The structure of the shops is of iron and steel side windows. All the parts of the roof that are not glazed are lined inside with matched boarding. The floor of the large machine-tool shops is made of cement concrete; that of the other shops is of thick wood planking, fixed to longitudinal beams that rest on a concrete foundation. The heaviest machine tools are carried on groups of piles in the same way as the buildings.

Motive power is supplied by two vertical compound engines of 120 horse-power each. They can be worked coupled or separated, and are generally driven at a speed of 90 revolutions. Steam is supplied by two Galloway boilers, a third boiler of similar construction being kept in

reserve. The main shaft is parallel with the longitudinal (north and south) axis of the shops; power is transmitted by means of two pulleys fitted to the motor shaft; one of these drives the transmission shaft of the nearest shop, and the other operates the five remaining transmission shafts by means of underground gear.

The transmission shafts are made in sections 6 metres (19 ft. 9 in.) long, coupled together; they are supported at intervals of three metres (9 ft. 10 in.) by brackets and bearings fitted to the columns, or to the longitudinal girders midway between the columns. The latter also carry the overhead gear for the various machine tools. All the shops are served by electrically-driven overhead travelling cranes.

The 17-metre span is provided with two travellers, one of 60 tons and one of 30 tons. They can be made to run at the same speed, and thus can be combined for lifting 90-ton loads.

The two adjoining shops are served by a 30-ton, and by a 40-ton traveller, respectively. One of these shops has in addition a 7-ton traverser operated by hand.

The fitting shop contains two 3-ton electrically-worked travellers, operated from the floor level, and two 1.2-ton hand-worked traversers.

The erecting shop is served by two 30-ton travellers and four portable transporters, the wheels of which, on one side, rest on a track fitted to the columns at half their height, and on the other on a track placed on the floor level; the direction of travel is parallel with the longitudinal axis of the buildings. These transporters are used chiefly for handling the breech-blocks of large-calibre guns. The machine tools are very numerous, and are divided among the various shops in such a way as to reduce as far as possible the operation of lifting and transporting the various parts of gun and carriage works. High-speed precision tools are provided, for completing all the minute and numerous operations required in the manufacture of ordnance and ammunition.

Amongst the most powerful tools may be mentioned eight lathes for machining tubes, 14 metres (46 ft.) in length, and up to 90 tons in weight. Various types of machines are used for testing material. A Maillard machine, built by Messrs. Schneider and Co., at Creusot

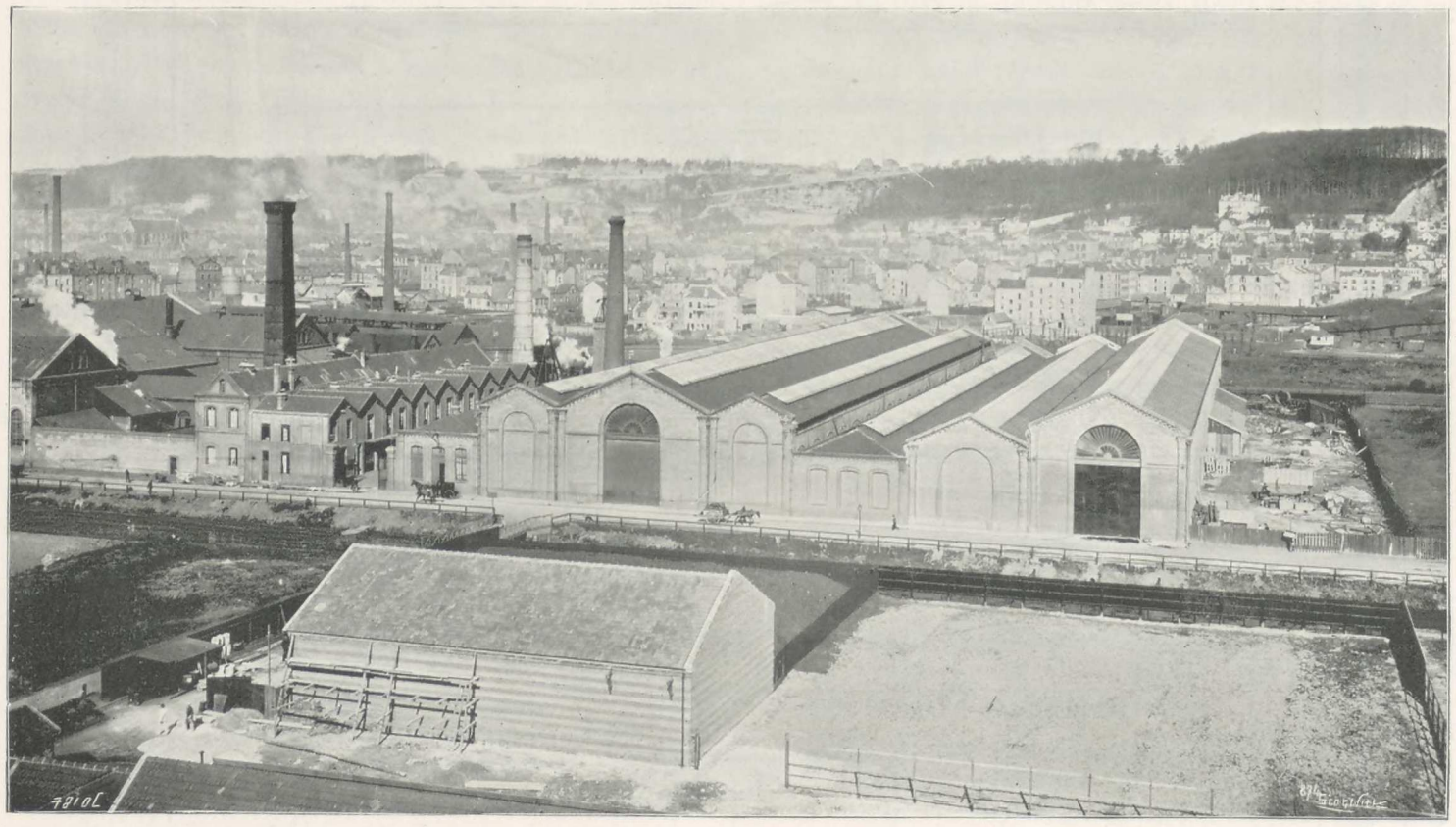


Fig. 575. General View of the Havre Gun Factory.

serves for tensile tests. Those for falling and bending tests have been constructed at the Havre works, to the specification of the French Admiralty.

The largest shrinking pit is at the north end of the main shop; it is 8 metres (26 ft.) deep, and 2.50 metres (7 ft. 5 in.) in diameter. In close vicinity is the gas-furnace plant for heating the coils and jackets. Another shrinking pit and heating arrangement of smaller dimensions is provided in the adjoining shop to the east.

Material is transported by railway, or by road, on trucks from the main (or Harfleur) entrance through the courtyard. The works are joined to the Havre railway station of the Western Company by a siding, branches from which enter all the shops near the north end, an arrangement that enables the wagons to be placed under

THE GUN FACTORY AT HAVRE.

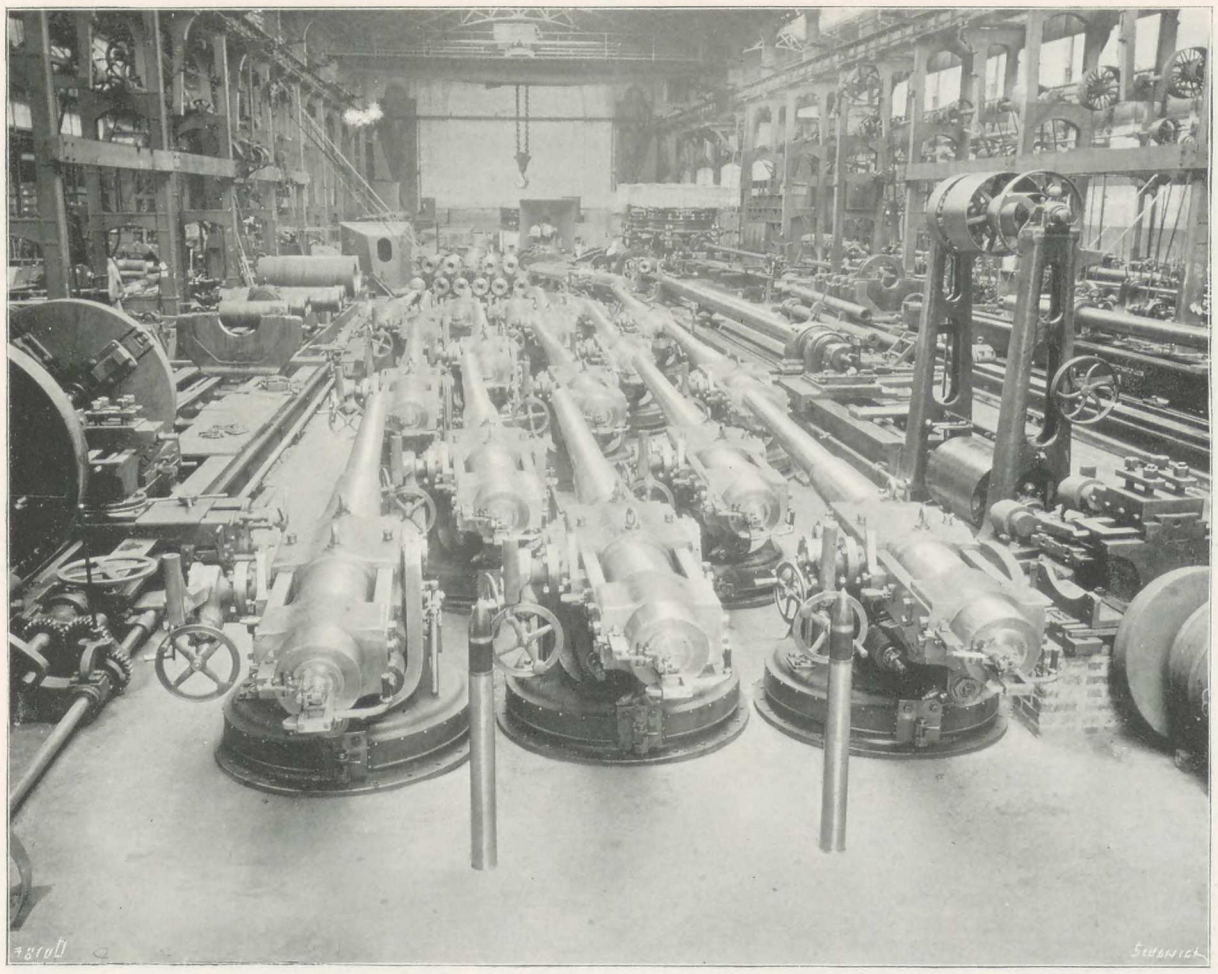


Fig. 576. Erecting Shop for Quick-Firing Guns.



Fig. 577. Machine Shop for Large-Calibre Guns.

THE GUN FACTORY AT HAVRE.

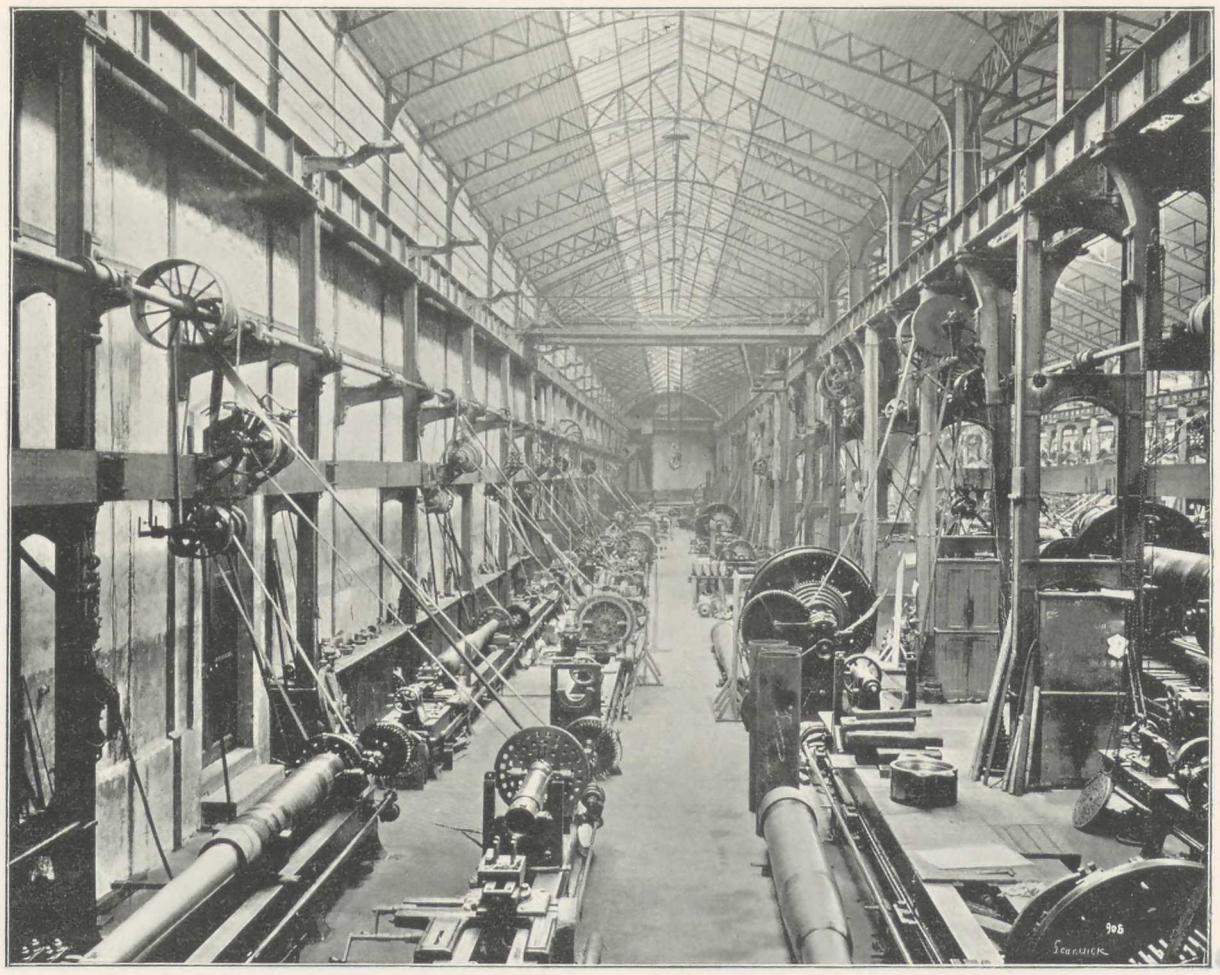


Fig. 578. Machine Shop for Medium and Small-Calibre Guns.

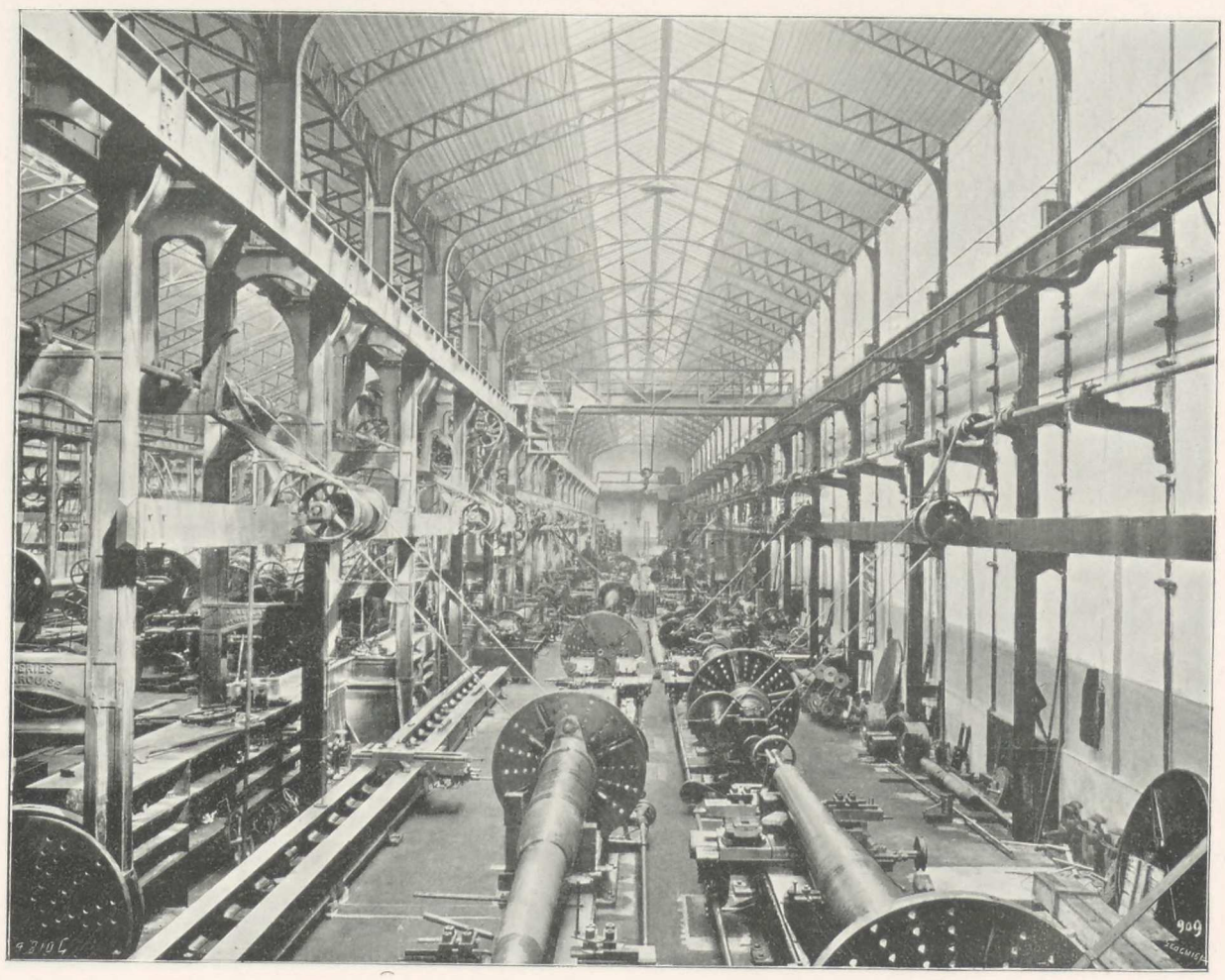


Fig. 579. Machine Shop for Medium and Small-Calibre Guns.



THE GUN FACTORY AT HAVRE.

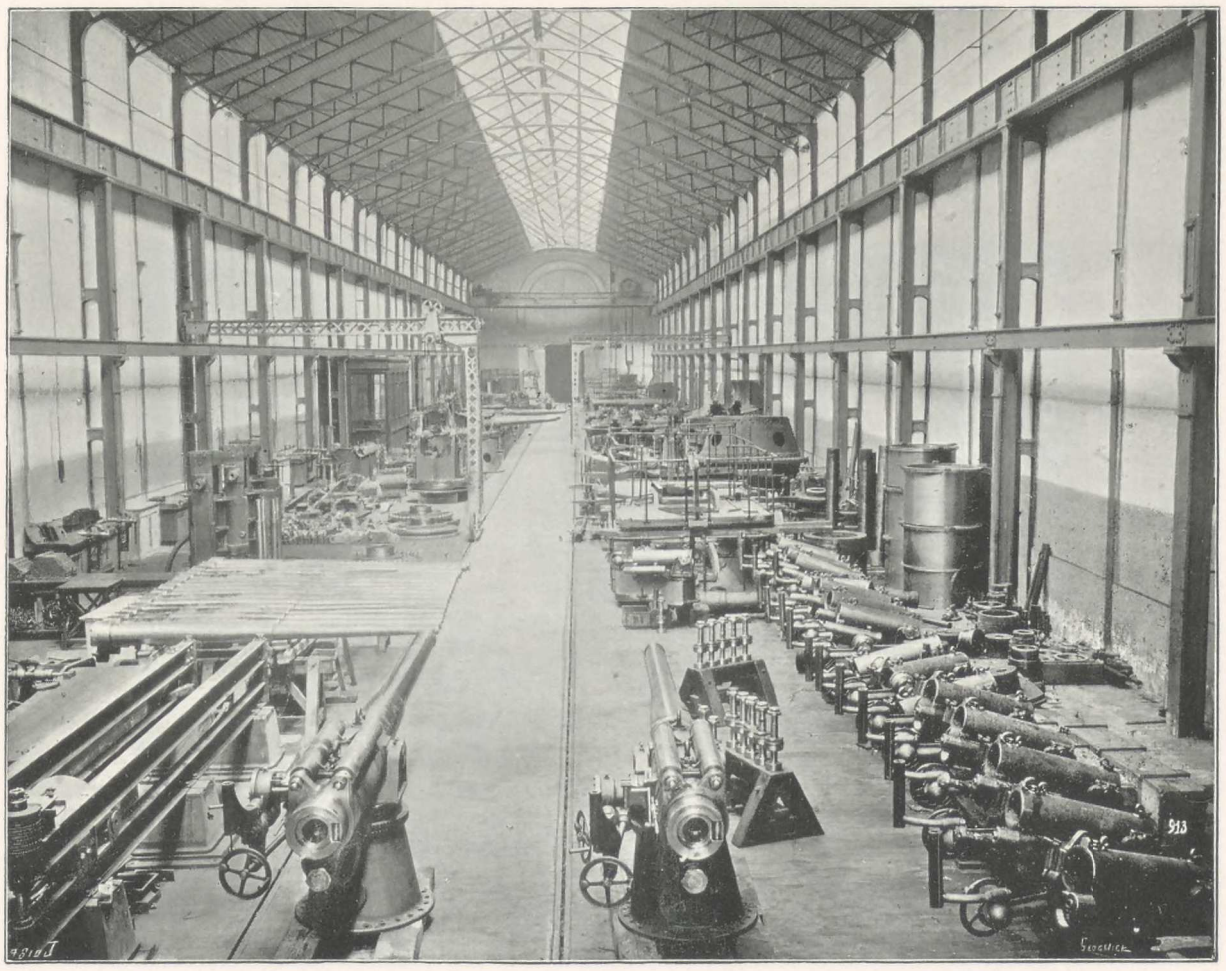


Fig. 580. Interior of Shop for Fitting Breech Mechanism, &c.

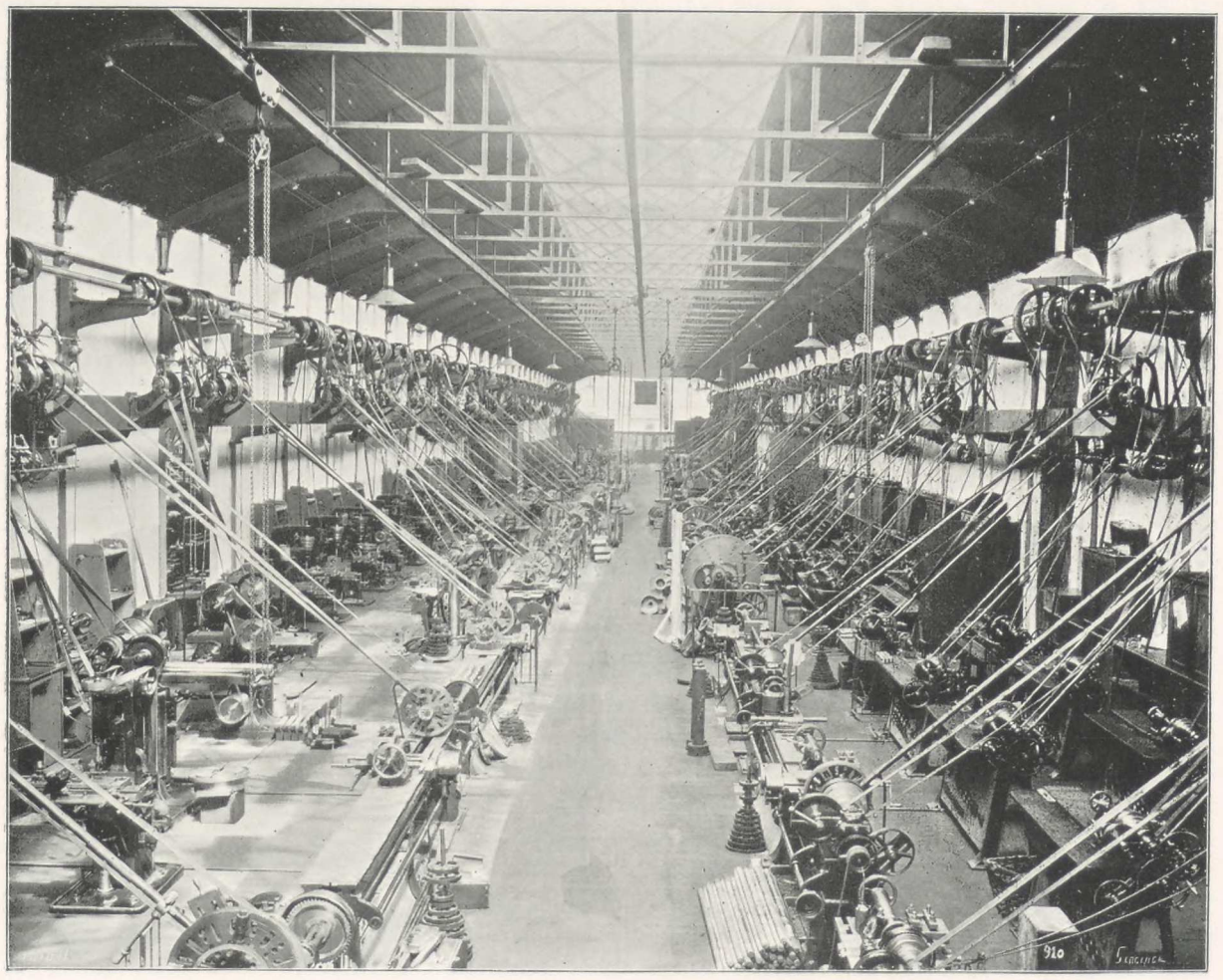


Fig. 581. Interior of Shop for Finishing Small Gun Parts.





the overhead travellers. A second line, parallel with the first, runs between the shops and the smiths' annexe, and can be utilised for siding space.

The shops are lighted at night by electricity, the current being supplied from dynamos, which besides furnishing power for the traveller motors, feeds 60 arc lamps distributed in the various shops and grouped by circuits of 10; no transformers are used. There are, besides, 400 incandescent lamps for lighting machine tools, and 150 similar lights in the offices. The incandescent lamps are furnished with current at 110 volts from a separate 45 horse-power engine and dynamo. During the day this dynamo supplies current to the electric welding plant. Fig. 575 is a view of the exterior of the Havre gun factory; Figs. 576 to 581, Plates CV., CVI., and CVII., show the interiors of the fitting and finishing and other shops, and Fig. 582 is the Works' depôt for 65-millimetre quick-firing guns.

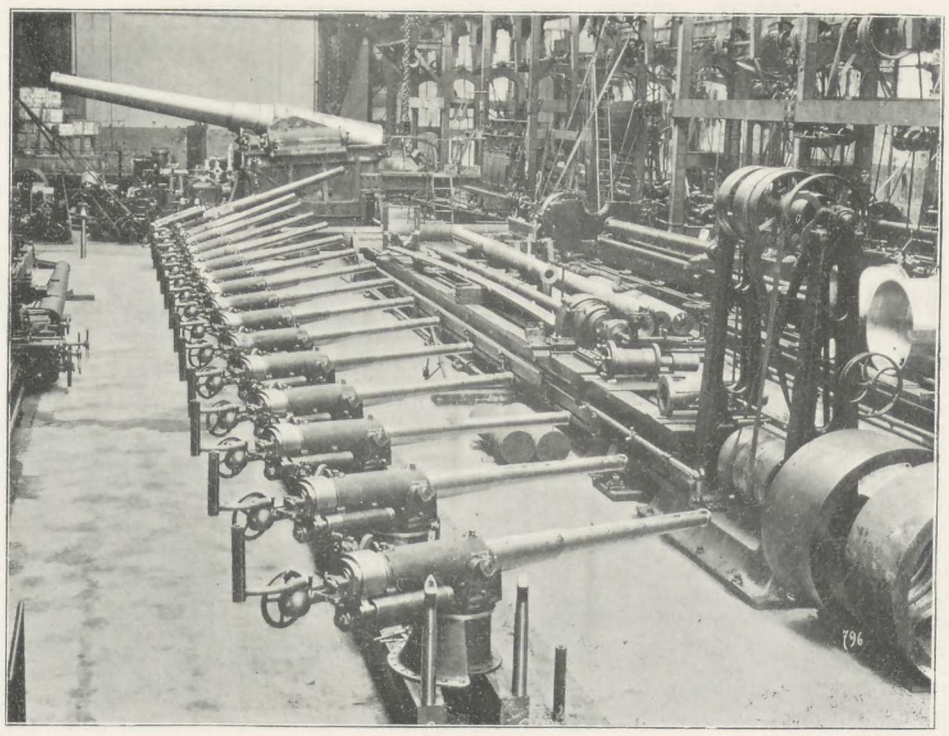


Fig. 582. Depot for 65-Millimetre Quick-Firing Guns.

XXV.—THE PROVING GROUNDS.

MESSRS. SCHNEIDER AND CO. have three proving grounds: at Creusot, at Havre, and at Tancarville.

Two of these serve more especially for inspection tests of guns and mountings, and for firing at armour plates. The third is used for ballistic tests, long-range firing, determining firing practice tables, for testing fuses and explosives, &c.

The Villedieu Proving Ground, Creusot.—The Villedieu proving ground lies 315 metres (350 yards) to the south-west of the southern groups of the Creusot shops; a plan of this polygon is given in Fig. 584, and a general view in Fig. 583. It is provided with two sand-butts, 10 and 13 metres (32 ft. 9 in. and 39 ft. 4 in.) deep, placed at one end of the ground; a third butt of smaller dimensions and 7 metres (23 ft.) deep, is situated 135 metres (410 ft.) to the rear of the left-hand butt, and in a line with it. The following numbers on the plan, Fig. 584, Plate CVIII., refer to different parts of the Villedieu installation:

1. Firing platform for 27-centimetre guns.
2. Firing platform for 12 and 15 centimetre guns.
3. Firing platform for 12 and 15 centimetre guns.
4. Track of 20-ton traveller.
5. Pit of turret for 155 millimetre 14 and 24-centimetre guns.
6. Pit of turret for 15-centimetre gun.
7. Pit of turret for 57-millimetre gun.
8. Pit of turret for 57-millimetre gun.
9. Track for 20 ton traveller.
10. 24-centimetre gun.
11. Platform for testing gun tubes.
12. Target.
13. Target for armour plates.
14. ,, ,,
15. ,, ,,
16. Shed for stores.
17. Cartridge magazine.
18. Entrance.
19. Reception room.
20. Fitters, &c.
21. Powder magazine No. 1.
22. ,, ,, No. 2.
23. Field.

Several differently arranged platforms for carrying out firing tests of field and mountain artillery, are placed in front of the right-hand butt, one part being paved with stone, while others are covered with grass, &c. Besides these, there are the following arrangements for testing guns, &c.:

Four built-up firing platforms.

Four pits 11 metres (34 ft. 6 in.) deep, in which turrets are erected and tested.

A group of powder magazines.

A casemate built near the entrance of the proving ground, in which are two chronographs with the necessary batteries and accessories. Means are provided for displacing the aerial wires, and shifting the movable range-finding screens to any distance from the guns.

There are in addition four other casemates, a priming-room, an ammunition-room, a harness dépôt, two sheds for various stores, and a reception hall for guests. A telephone, placed in a room in the porter's hall, establishes communication with all the departments and chief offices of the Creusot Works.

A railway forming part of the Creusot system connects the works with the polygon; and, as will be seen from the plan, branches and sidings give all necessary facilities of communication to different parts of the ground. The rolling stock of the line is, of course, of a special character, and adapted to the transport of the heaviest guns. The railway is provided with numerous lines and turntables for the requirements of the service. A 50-ton traverser and some portable steam cranes serve for loading, unloading, erecting, &c.

Electric current for lighting the proving ground by night, and for turret lighting, is supplied through overhead cables from the central electric station; the current required in carrying out gun tests, for driving various tools and other power transmission, is furnished from the same source. As may be supposed, the Villedieu polygon is thoroughly equipped for all kinds of tests, and for every nature of war material. The most important kinds of tests carried out here may be summarised as follows:

Testing gun tubes by firing from the tubes a gunpowder charge, placed between two projectiles.

Firing tests of all types of guns, and more especially mountain and field guns.

Testing siege and garrison carriages, gun mountings, and all the numerous types of turrets built at Messrs. Schneider and Co's. works.

Twenty guns, of calibres varying from 37 to 240 millimetres ($1\frac{7}{16}$ in. to $9\frac{7}{16}$ in.) are kept permanently mounted at the proving ground, for testing armour-plates manufactured in the armour-plate department. These guns are also used for the numerous gunnery experiments made at Creusot.

The results of all tests made are accurately ascertained and recorded, and a complete series of the gunnery instruments employed, comprising velocimeters, crusher gauges, registering pressure gauges, &c., are kept in the store rooms.

The Hoc Proving Ground, Havre.—The installation of the Hoc proving ground was carried out under the supervision of General Sebert, formerly Directeur of the Laboratoire Central de l'Artillerie de Marine. At the commencement, it contained only the necessary arrangements for gun-firing tests and the manufacture of ammunition. Messrs. Schneider and Co. extended and completed

THE PROVING GROUNDS.

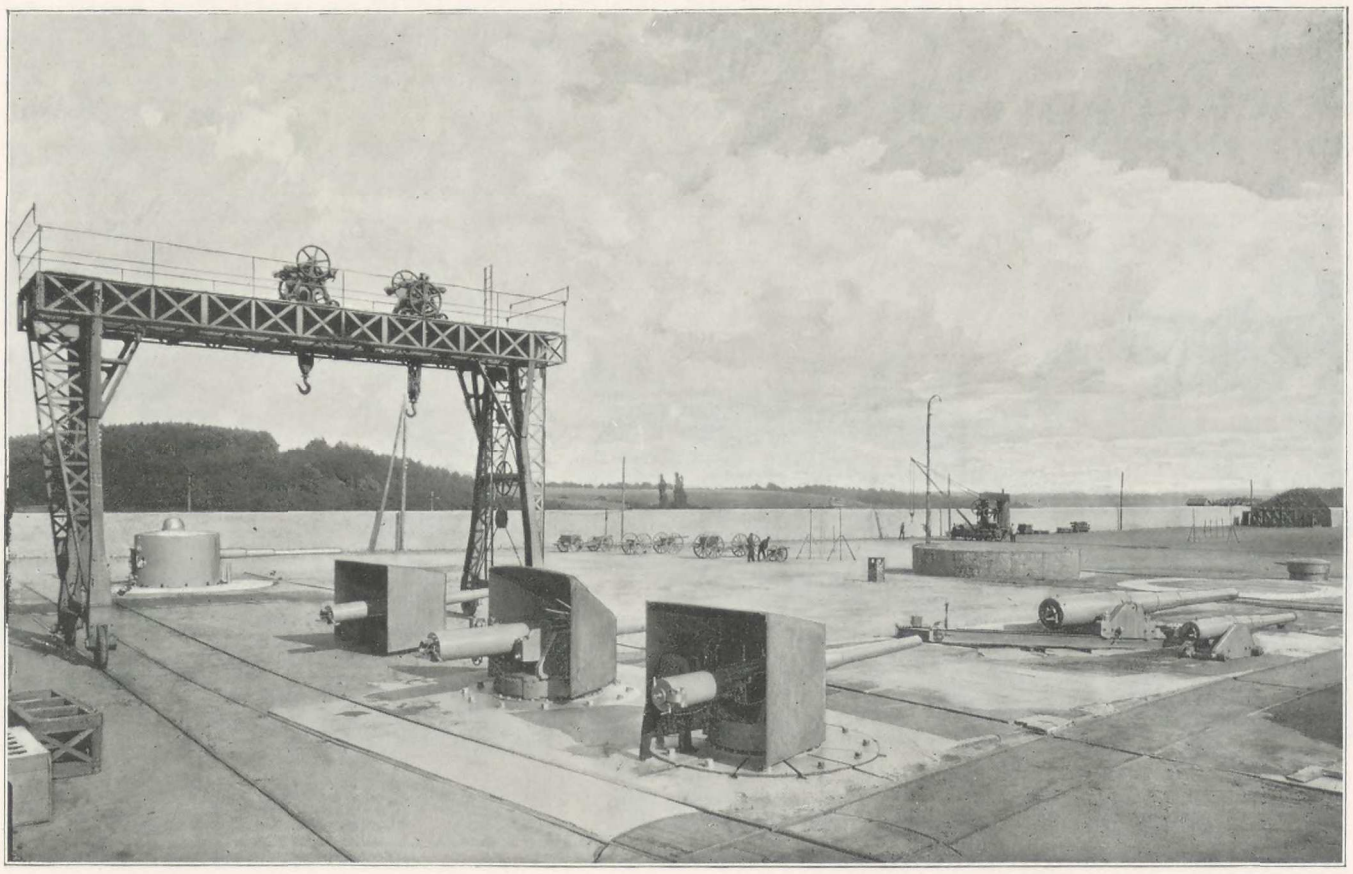


Fig. 583. The Villedieu Proving Ground.

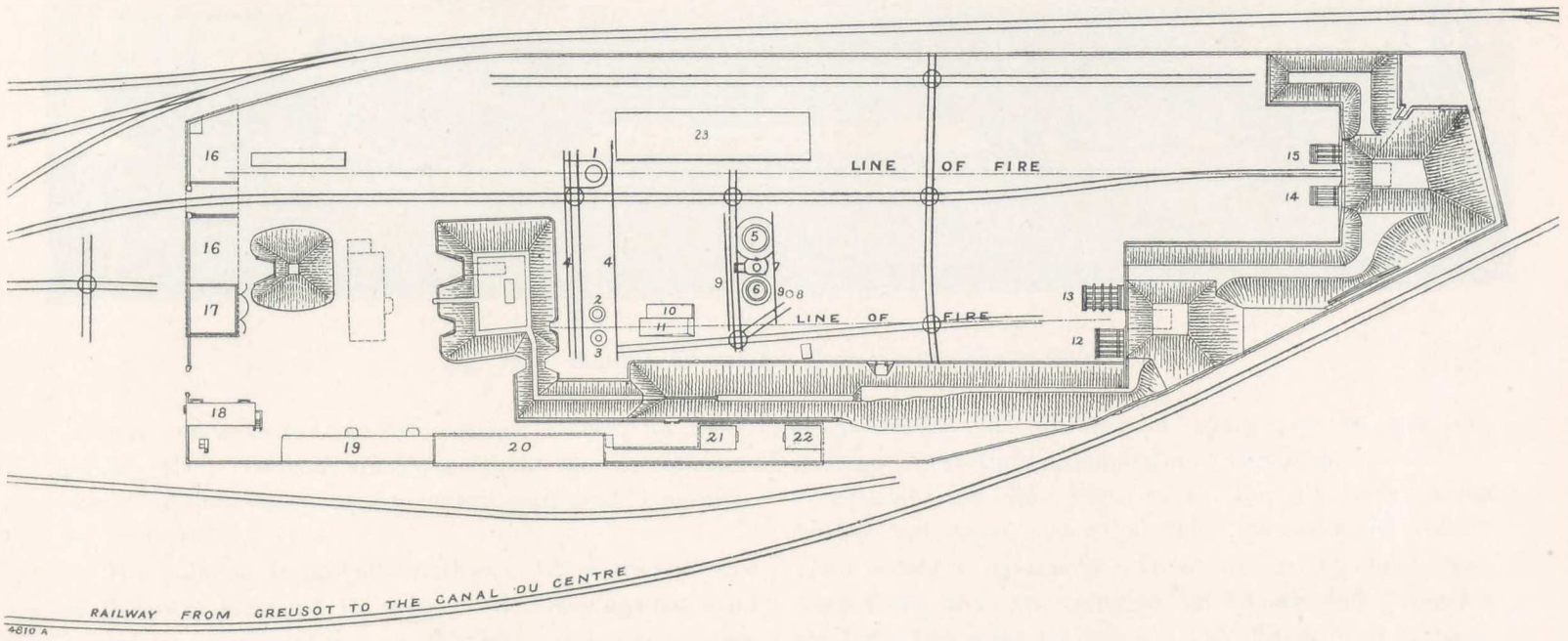


Fig. 584. Plan of the Villedieu Proving Ground.

the installation in 1897, by adding the required plant for the manufacture of primers, firing tubes, fuzes, &c.

The proving ground is located on the mouth of the Seine, and on its right bank; it is in communication with the Havre works by a road and a railway. Heavy guns are carried from the works to the proving ground on special trucks. Figs. 585 and 586 illustrate types of trucks made by Messrs. Schneider and Co. for the transport of heavy guns.

The proving ground is so arranged that guns of all calibres can be tested in every possible manner for ascertaining their ballistic qualities, their range, accuracy, power of resistance under every practical condition, and so forth.

The polygon is provided with several platforms; five of these are arranged for point-blank firing against sand butts; two others, placed on the Seine embankment, are specially adapted for firing at various angles and degrees of elevation. Guns can therefore be fired at Havre under all conditions that would be required of them in actual warfare.

The practice at the sand butts serves to measure the initial velocities of projectiles. For this purpose the usual range-finding and velocity screens are used, in conjunction with the Boulanger-Berger chronographs.

The proving ground is completely equipped with all kinds of devices and accessories required for fully ascertaining the working of guns, such as crusher gauges for measuring inside pressures, registering manometers for testing the pressure produced in hydraulic recoil cylinders, velocimeters for measuring gun-carriage recoil, &c. During the firing in the sand butts and at long range, at elevation or depression, the working of every part of gun and carriage is carefully examined and recorded.

Special care has been taken for all tests to be carried out with every possible guarantee of safety. There exists a system of signals for giving due notice when firing tests are going to take place, and casemates are built to shelter the *personnel* in charge of such tests. By means of an arrangement of mirrors, the firing staff can witness in safety the progress of various tests. Guns are fired from a distance, whether electric or percussion fuzes are used.

The powder magazines are situated on the opposite

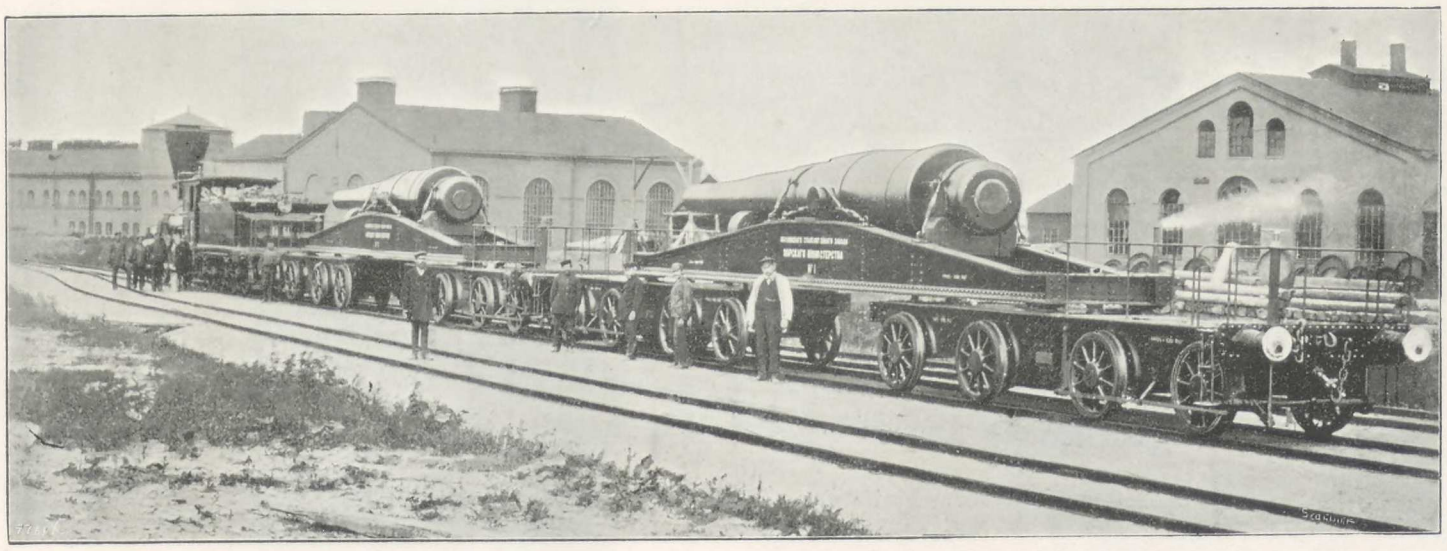


Fig. 585.

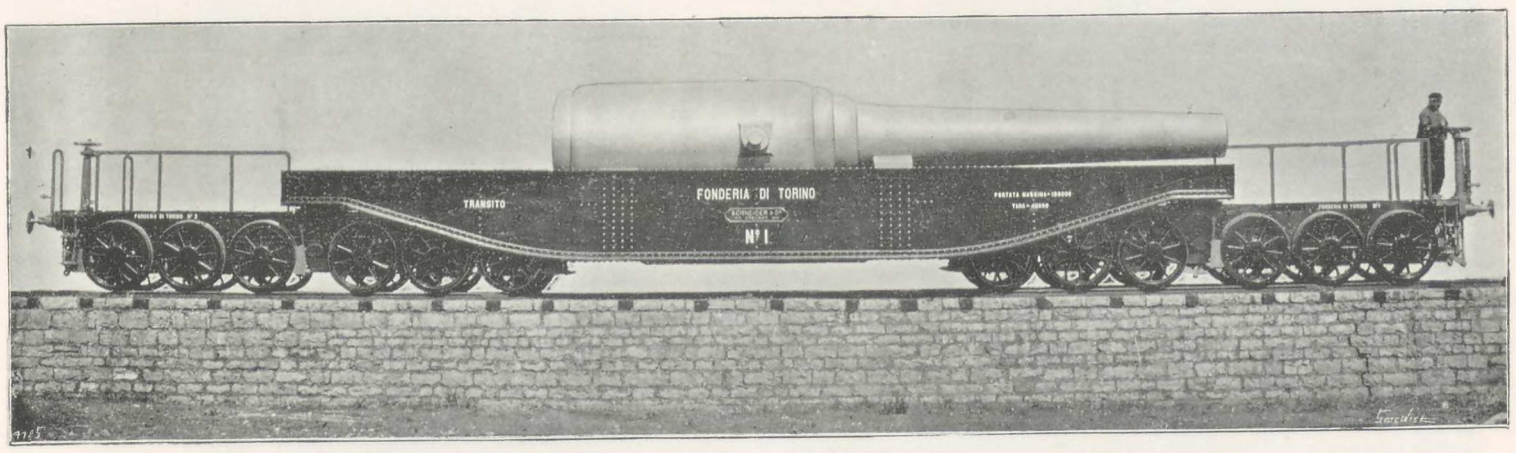


Fig. 586. Railway Trucks for Transporting Heavy Guns.

side of the platforms, at a distance from the buildings in which the charges are made up and fuzes manufactured. These buildings are of very light construction and are separated from each other by earthworks. Messrs. Schneider and Co. have increased the number of these buildings rather than their size, in order to localise the the effects of possible accidents,

The same principle has been followed in arranging the buildings for the manufacture of primers, which is a still more delicate operation; this department consists of a laboratory and charging rooms, of light construction, and each building is isolated one from the other.

The installations of the proving ground are completed by offices, warehouses, and machine-shops for carrying out the necessary repairs for the plant.

The various platforms are served by an 80-ton traversing crane, which runs the whole length of the pit, in front of the firing platforms, on a track that is connected with the line connecting the Havre works with the Hoc proving ground. There is also a pit used for testing of projectiles by bursting, and for ascertaining the relative values of various explosives and fuzes. Finally, a special installation exists for testing gun tubes with powder charges, such tests being occasionally required



Fig. 587. Platform for Firing Guns at Negative Angles.

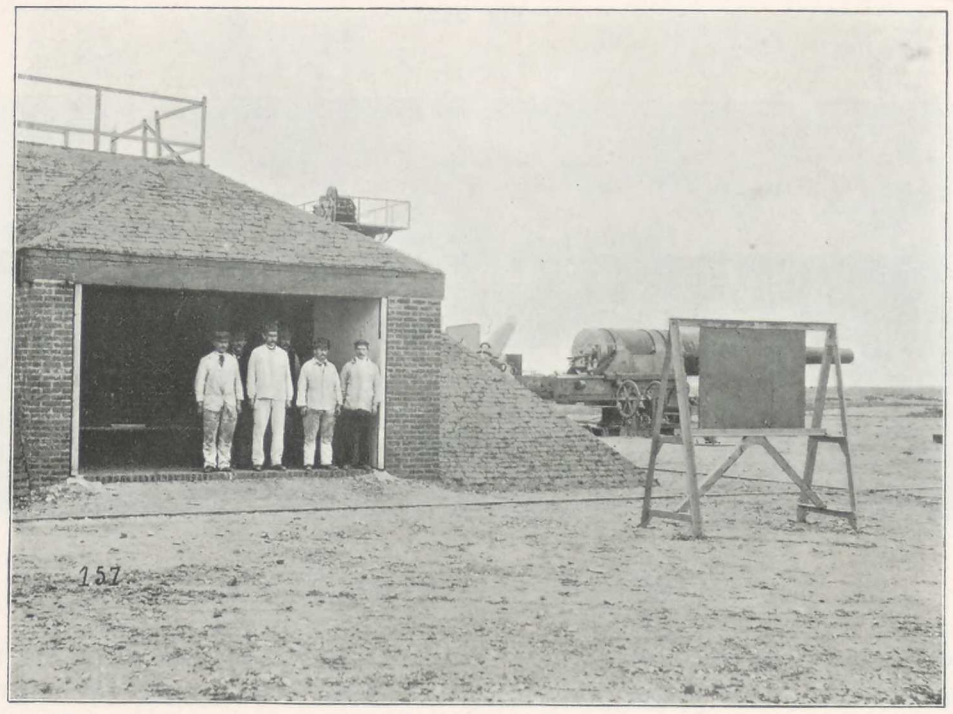


Fig. 588. Shelter for the Test Firing of Guns.

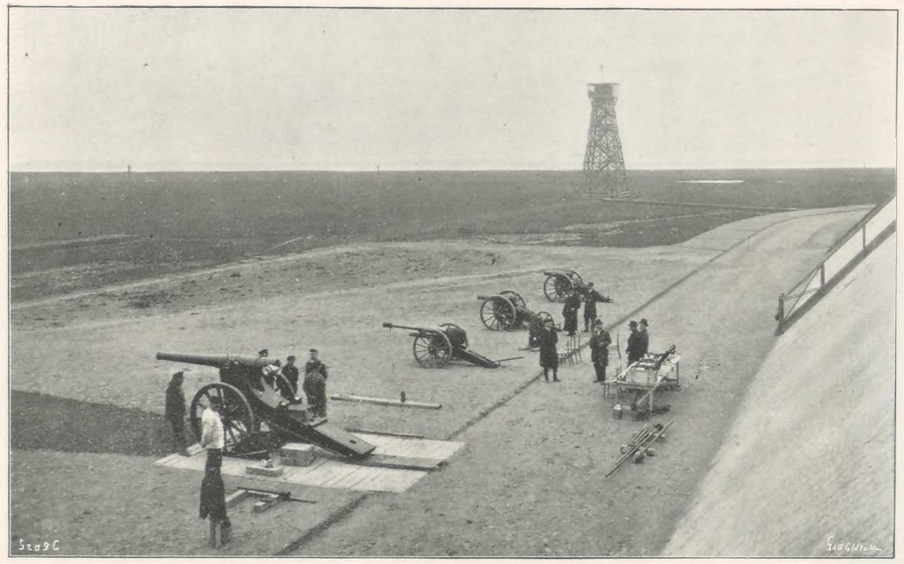


Fig. 590.

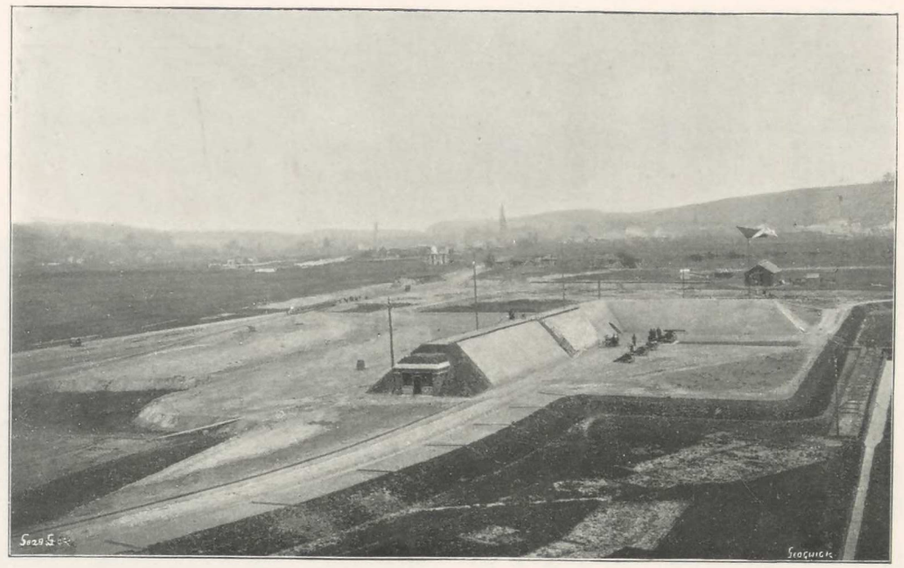


Fig. 591.

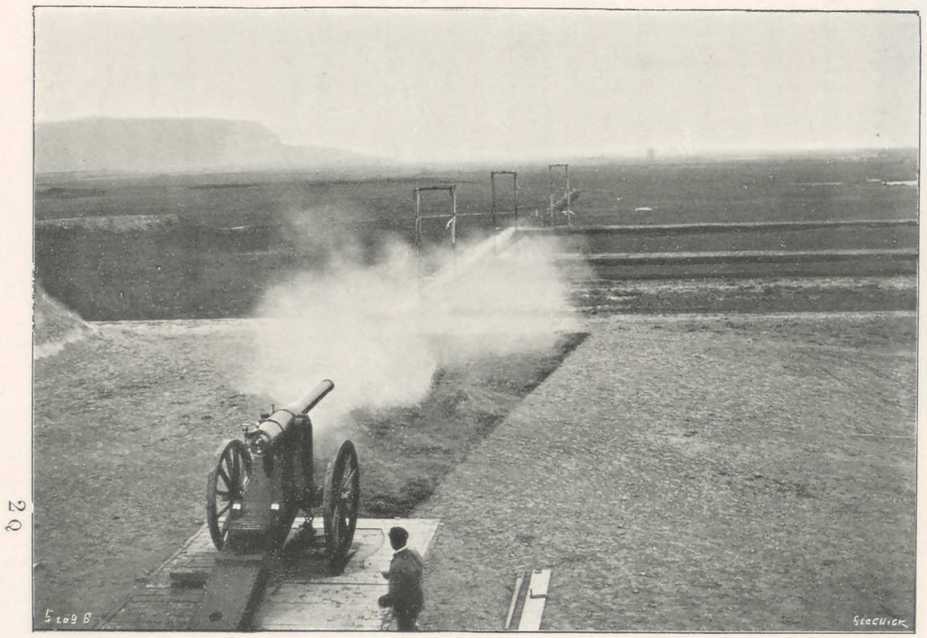


Fig. 592.

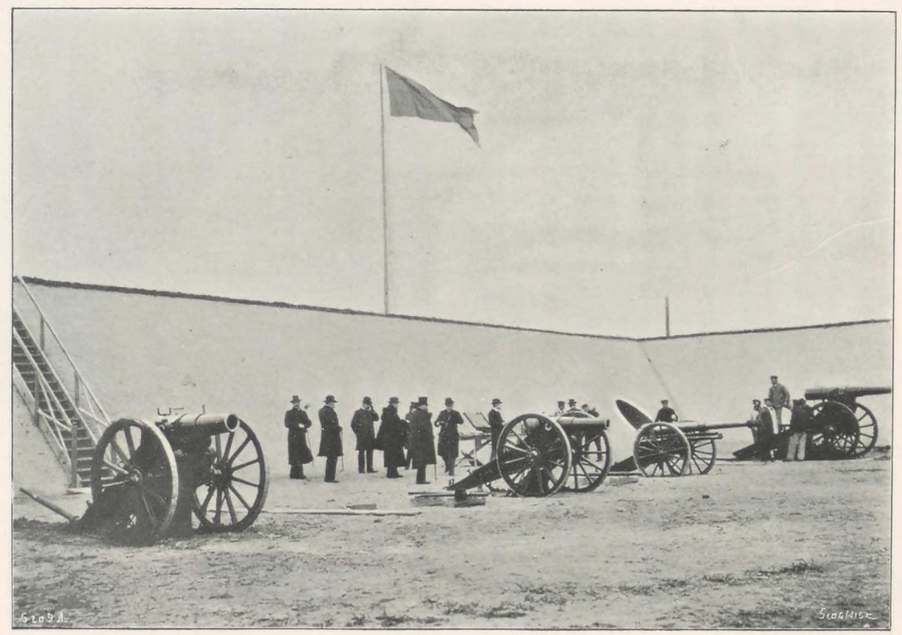


Fig. 593.

The Harfleur Long-Range Proving Ground.

in order to check the results of the physical tests to which the steel has been previously submitted.

Figs. 587 to 589 are illustrations of the Hoc proving grounds. They show respectively gun-carriages and range for depression firing; the casemate used in firing trials; and the pit in which high explosives and shells are tested.

The Harfleur Long-Range Proving Ground.—Besides the Villedieu and Hoc proving grounds already referred to, Messrs. Schneider and Co. hold on lease a large tract of land between the Tancarville Canal and the open sea, in which they have made the necessary installation for long-range firing tests. This long-range proving ground forms a natural complement to their recently-acquired extensive ordnance works at Havre.

The ground is located a few hundred yards distant from the Havre works and the Hoc polygon. The tract of land is about 10 miles in length, so that ballistic trials that require ranges of from $3\frac{1}{2}$ to $4\frac{1}{2}$ miles can be carried out under the best possible conditions for safety and close observation.

This proving ground is employed principally:

1. To compile practice tables for the various types of guns.
2. To carry out precision-firing trials at long ranges, especially with regard to field, siege, and garrison guns.
3. For firing tests with high explosives.
4. For experimental trials of fuzes.

The ground is remarkably level; it contains three main firing lines, one being used only for high explosive tests. As the south side of the ground is bounded by the sea, a large area is available during ebb tide for executing these tests with every guarantee of safety.

The illustrations (Figs. 590 to 593, Plate CIX.) give various views of this polygon, and show earthworks, ballistic installations, sea ranges, &c.

The main firing-line is fitted up with fixed platforms for the testing of guns of all calibres; at every kilometre distance from the main battery are erected protected shelters for taking observations. All the shelters are united by telephone with the central stand near the main battery. A narrow-gauge railway is laid down along the main firing-line. An observatory, 20 metres high, provided with all the required instruments for registering the temperature, barometric pressure, direction and force of wind, &c., facilitates observations from one end to the other of the proving ground. A battery in casemate is built at the head of the firing-line for the testing of high explosives. The proving ground was put in use for the first time a few months ago; it is admirably equipped for ballistic tests and long-range firing trials.

The location of the Harfleur polygon is very convenient, as it is not far from Havre, and only three hours' journey from Paris; it therefore possesses exceptional facilities to foreign commissioners and inspection officers, who may require to witness trials, or report on completed orders.

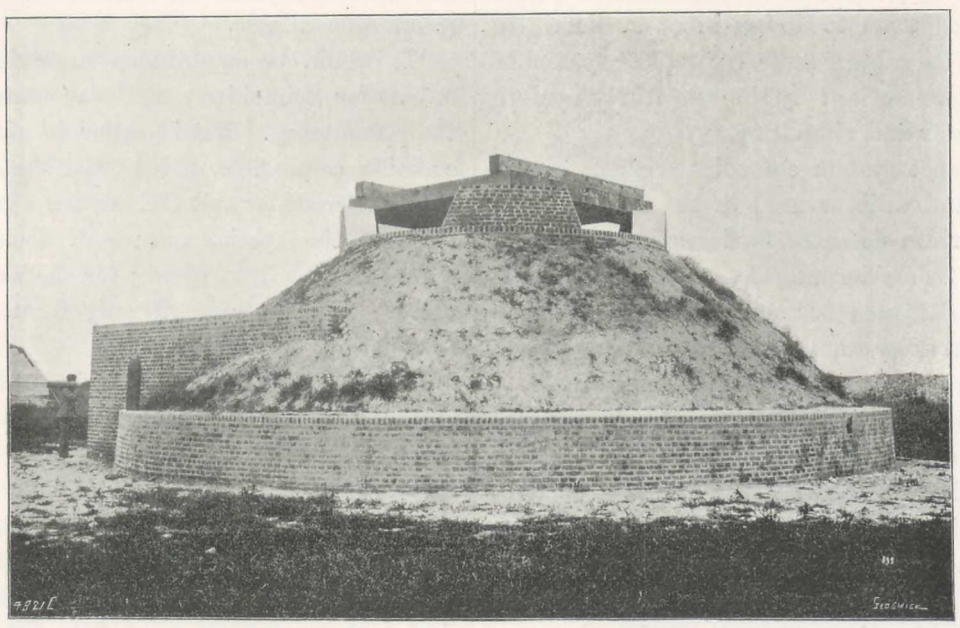


Fig. 589. Protected Pit for Testing High Explosives and Bursting Shells.

XXVI.—GENERAL DATA CONCERNING THE SCHNEIDER-CANET ARTILLERY.

THE great experience acquired by Messrs. Schneider and Co., and their long practice in the construction of war material, have enabled them to design in every detail, to prove, and to supply on a large scale, a complete system of ordnance which is characterised by the essentially modern qualities of great power and simplicity.

The Schneider-Canet system embodies, without exception, all the types and calibres used in the armament of ships, coast and garrison defences, field service, and siege operations. Messrs. Schneider and Co. are therefore in a position to fill all demands for armaments which they receive from various Powers, as well as other types to meet the particular requirements of artillery committees.

The descriptions already given show the power and completeness of the plant in the Creusot and Havre Works. It is needless to add that the constant changes and developments in the construction of artillery have made it necessary to maintain the means of production at the highest degree of efficiency; Messrs. Schneider and Co., have taken this fact into account also, and on a remarkable scale of completeness, for the rapid production of what may be called the Schneider-Canet series. It may be remarked here, though the fact is generally well known, that it is practically impossible to improvise a new type of war material possessing the required qualities for immediate service, and to put down rapidly the necessary plant for its construction, whatever be the resources available.

It would be superfluous to review the whole of the orders for Schneider-Canet war material executed up to the present day. But in order to give a general idea, as complete as possible, of the great French industry of which Messrs. Schneider and Co., are the representatives, descriptions of the special nature of some of the guns they manufacture will be given; for the ordinary and relatively old types, however, it will only be necessary to describe a few distinct classes.

In describing the various types of Schneider-Canet guns and war material, the following order will be taken: Naval ordnance; torpedo-launching tubes; ship guns in turrets; coast defence guns; field artillery; siege and garrison artillery; landing guns; mountain artillery; land turrets; projectiles; and ammunition.

The following Powers had in service, and on order, during the year 1898, guns of the Schneider-Canet system: France, Denmark, Turkey, Argentina, Russia, Greece, Holland, Uruguay, Spain, Switzerland, Japan, Mexico, Portugal, Bulgaria, China, Transvaal, Sweden, Roumania, Chili, Haiti, Norway, Servia, Brazil, Morocco and the Dominican Republic.

XXVII.—EARLIER TYPES OF NAVAL GUNS.

WE have seen that the manufacture of ordnance was recommenced at Creusot about 1870, after an interval of three-quarters of a century, and that five years later, it had passed from an experimental stage, to a departmental industry. The guns made at that comparatively recent period—and during the ten years following—belong to the types not, indeed, obsolete to-day, but antiquated, and not adapted to the best conditions of modern warfare. The wonderful display of naval and other guns made by Mr. Canet at the Paris Exhibition of 1889 was one of the first, and certainly the best, illustrations of the great change in gun design and construction that had been inaugurated four or five years before, and which has been continued on the same lines since that time.

The most important result has been the development of the quick-firing gun, which, at first made only of small calibres, has been now increased to the rank of an armour-piercing weapon, and occupies a first place in naval armament. With this change came the necessity for longer range and flatter trajectory of projectile—demands that could be met only by modifications in design and greatly increased length of bore, together with the use of a more suitable explosive than the black or brown powders in all their great varieties. The modern naval gun is therefore a very different weapon to-day to that of fifteen years ago, and examples of the different types made by Messrs. Schneider and Co. on the most recent lines will be given. But it will be convenient first to describe briefly some of the more important earlier types, which are still being manufactured by Messrs. Schneider to fill orders they receive from various Governments who continue to use such guns, either for the sake of economy or to maintain uniformity in their armament. These descriptions and illustrations will indicate to a large extent the progress made in the construction of naval guns, not of quick-firing natures.

The charges for naval guns of the earlier kinds were of black or brown powder and of the various qualities to be described hereafter; projectiles of all the different types may be fired from them. The projectiles fired from such guns consisted generally of the following classes:

Steel armour-piercing shell.
Cast-iron common shell.
Shrapnel.

Steel shrapnel were not usually included, but for attacking batteries in action, shells containing cast-iron rings or shot were used. The guns were generally fired with 9 millimetres (.354 in.) percussion tubes.

75-Millimetre (2.952-In.) Gun, on Boat Mounting. Type 1886 (Fig. 594).—Guns of this type have been delivered to the Portuguese Government for the gunboats Cacongo and Massabi.

Weight of gun	100 kg.	220 lb.
,, mounting	400 kg.	880 lb.
,, shield	110 kg.	242 lb.
,, projectile	4.6 kg.	10.2 lb.
,, charge (black powder)	.45 kg.	.99 lb.
Muzzle velocity	260 m.	835 ft.
Firing pressure	990 kg.	5.8 tons per sq. in.

The breech mechanism consists of the breech-piece, the obturator, and the striker.

The breech-block is made with an interrupted screw, having three threaded parts and three interruptions: it is

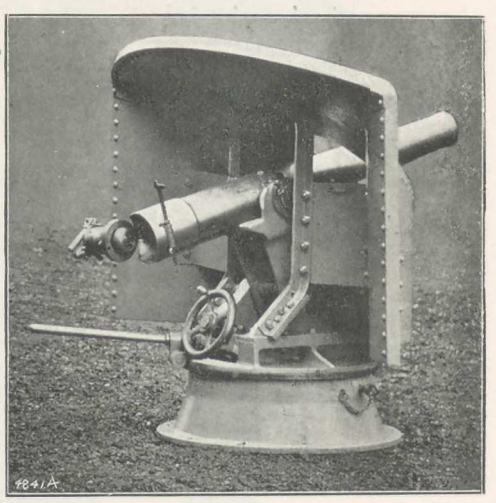


Fig. 594. 75-Millimetre Gun and Boat Carriage.

carried by a hinged ring. The obturator consists of a plastic ring placed between the movable head of the breech-block and the front end of the breech-screw. The gun is fired by a percusssion bolt, the striker acting only when the breech is completely closed, so that danger of premature fire is entirely done away with. The breech is opened or closed by means of a lever fitted with a cam; when the gun is ready for firing, the cam enters a mortice so as to prevent all accidental opening of the breech-piece. The mounting consists of a bolster, a traversing platform, and a gun-carrying frame. The bolster carries the roller path, and is fixed to the ship's deck. The traversing platform is fitted to the bolster, and rests on the roller path. The frame consists of two cheeks which carry the gun and pivot round a centre on the platform; on these cheeks are fixed the recoil brake and the cylinder-rod for replacing the gun in position.

The gun is elevated by means of a handwheel, the movement of which raises and lowers the carriage. The training of the gun is effected by a lever, by raising which the action of the brake friction slide on the edge of the bolster is momentarily stopped. The gunner can then move this lever in the direction in which he wants to train the gun. The hydraulic brake consists of a cylinder, with piston and spring recuperator. When the gun recoils, the frame in pivoting round its centre, displaces the piston in the cylinder, and causes compression of the springs. When the recoil is spent, the springs relax and relay the gun. The liquid in the brake cylinder flows slowly through small openings in the piston, and moderates the speed at which the gun is automatically relaid.

10-Centimetre (3.937-In.) Gun. Type 1892 (Figs 595 and 596).—Guns of this type have been supplied to the Haytian Government for arming the gunboats Petion and Capois la Mort.

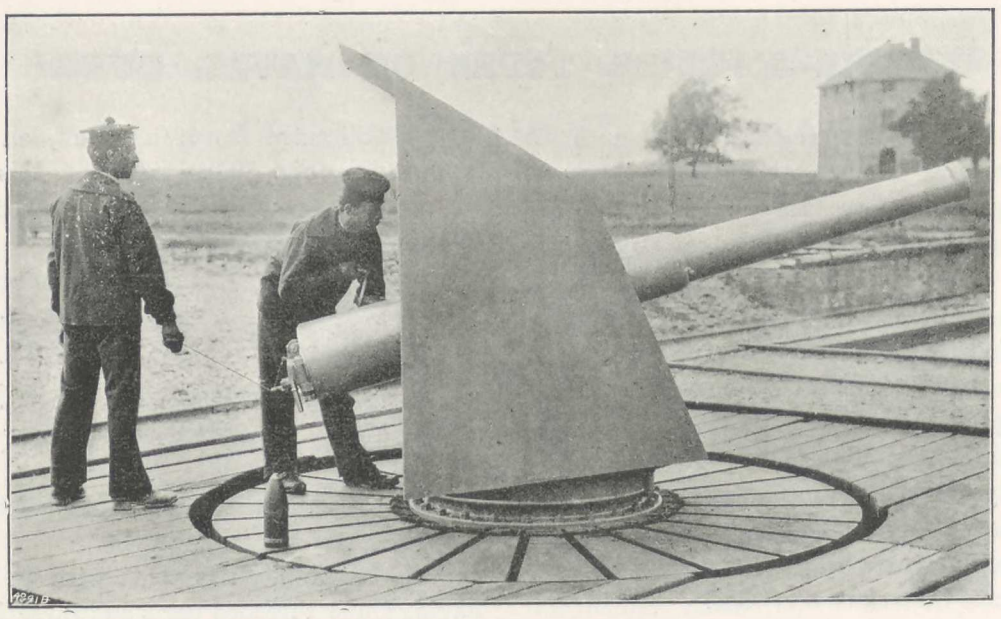


Fig. 595. 10-Centimetre Gun, Mounting and Shield; Side View; Model, 1892.

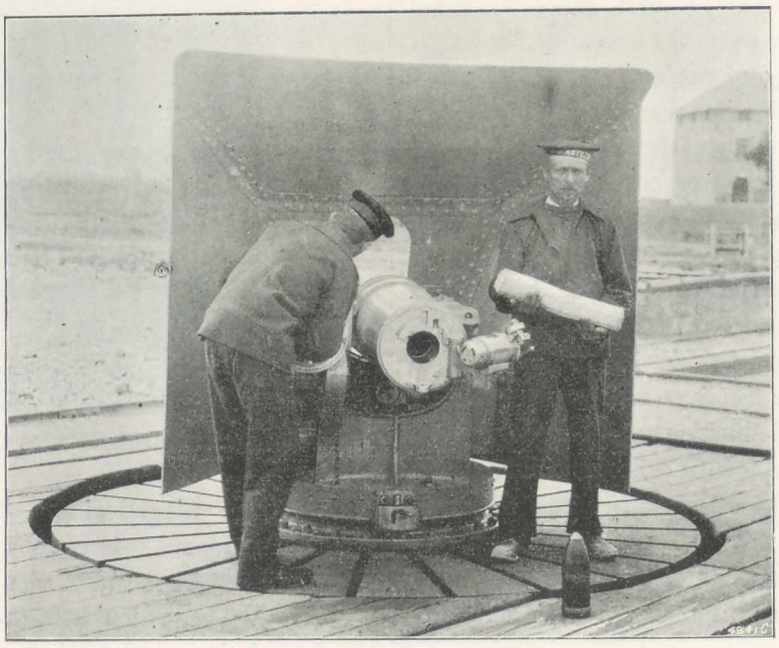


Fig. 596. 10-Centimetre Gun, Mounting and Shield; End View.

Weight of gun	1430 kg.	3146 lb.
,, mounting	1591 kg.	3500 lb.
,, shield	475 kg.	1045 lb.
,, projectile (armour-piercing shell)	12.5 kg.	27.5 lb.
Weight of charge (prismatic brown powder)	5.8 kg.	12.76 lb.
Muzzle velocity	520 m.	1705 ft.
Angles of elevation	25 deg.	10 deg.

The breech-block of this gun is cylindrical, with three threaded sectors; it is worked by means of a lever, the

head of which acts as a cam and prevents any accidental opening of the breech-piece after the charge is inserted. The breech-block is carried by a bracket, that turns round a vertical bolt attached to the back of the gun.

Obturation is insured by a plastic ring placed between the front end of the screw and the movable head.

The gun is fired by means of a percussion bolt that moves between two slides on opening the breech, thus immediately closing the vent. The percussion tube can only be inserted and the trigger worked, when the breech is completely closed.

The central pivot mounting consists of three main parts —the bolster, the slide, and the gun-carriage. The bolster is fixed to the deck, and is fitted with a roller path and central pivot; the slide rests on the roller path, and so as to maintain a practically uniform pressure in the cylinder. Buffers regulate the travel of the gun-carriage during its automatic return.

12-Centimetre (4.724-In.) Gun. Type 1885 (Fig. 597). —Guns of this type have been supplied to the Haytian Government for armament of the despatch boat Toussaint Louverture.

Weight of gun	2000 kg.	4400 lb.
,, mounting	3500 kg.	7700 lb.
,, projectile (armour-piercing shell)	21 kg.	46.2 lb.
Weight of charge (black powder) ...	8.4 kg.	18.5 lb.
Muzzle velocity	565 m.	1853 ft.
Pressure	2400 kg.	15.24 tons per square inch
Angles of elevation	28 deg.	10 deg.

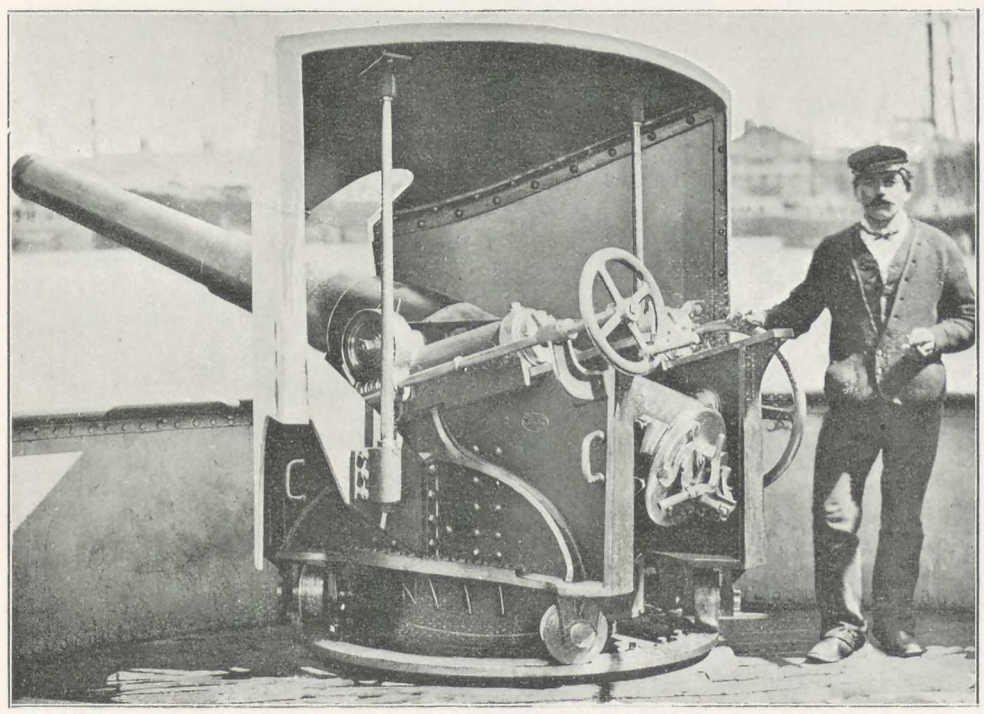


Fig. 597. 12-Centimetre Gun and Mounting; Model, 1885.

consists of two cheeks provided with cross-stays; it comprises also a plate disc into which is fitted the bolster pivot; the gun carriage is made movable in the inclined planes of the slide, and is fitted with the trunnion plate, the front stay carrying the pivots of the recoil piston-rod crosshead.

For elevating, a hand-wheel is provided, which works a toothed sector fixed to the gun by means of a helicoidal screw and pinion.

The gun is trained by means of a pinion gearing in the toothed ring that surrounds the bolster. The pinion itself is worked by a helicoidal wheel, upon which acts a plate chain set in motion by a crank.

The recoil cylinder placed between the cheeks of the slide is fixed; the piston is worked by the action of the recoil, and the liquid in the cylinder passes through lateral ports and an annular space between the edges of the piston and central rod. The sections of this rod are made to vary,

The breech-block is cylindrical, with interrupted screw threads, and slides to-and-fro in guides at the rear of the gun. The opening and closing mechanism is operated by a lever and cam, and a safety device prevents accidental opening of the breech. A plastic obturator is placed between the front end of the breech-block and the movable head. The firing mechanism comprises a percussion bolt, the striker of which can only act on the percussion tube when the breech is completely closed.

The mounting of this gun consists of three main parts, the bolster, the slide, and the gun-carriage proper. On the bolster is attached the roller path and the central pivot, around which the slide turns, on conical rollers. The carriage is fitted with recoil cylinders and elevating gear and it rests on the inclined slides of the frame, guide-blocks being introduced as indicated in the illustration.

A pinion gearing with the toothed sector fixed to the gun, regulates the elevating movement; this pinion is

worked by a helicoidal screw from an hand-wheel. The gun is trained by means of a pinion and toothed ring attached to the bolster, the pinion being actuated by a hand-wheel, a system of gearing, and a chain and helicoidal screw.

The hydraulic recoil cylinders, which form part of the gun-carriage, are provided with rods fixed to the front of the slide. They are in communication with each other by means of two pipes.

12-Centimetre (4.724-In.) Gun. Type 1890 (Figs. 598 and 599).—Guns of this type have been delivered to the Mexican Government for the armament of the training-ship Zaragoza; they have included two series, of different lengths, as shown below:

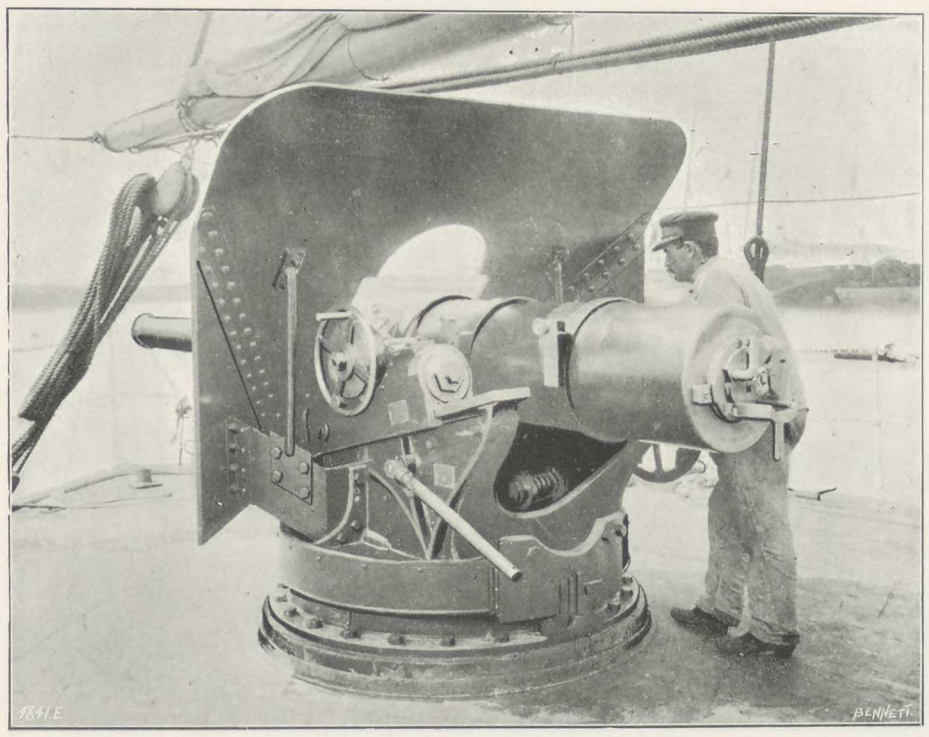


Fig. 598. 12-Centimetre Gun and Mounting (26 Calibre); Model, 1890.

—	26 Calibres Long.	43 Calibres Long.
Weight of gun...	2888 kilogs (6353 lb.)	3428 kilogs. (7541 lb.)
,, mounting	2290 kilogs (5038 lb.)	2290 kilogs. (5038 lb.)
,, shield	625 kilogs (1375 lb.)	625 kilogs. (1375 lb.)
,, projectile (armour-piercing shell)	21 kilogs. (46.2 lb.)	21 kilogs. (46.2 lb.)
Weight of charge (prismatic black powder)	12 kilogs. (26.4 lb.)	12 kilogs. (26.4 lb.)
Pressure	2400 kilogs. (15.24 tons per square inch)	2400 kilogs. (15.24 tons per square inch
Muzzle velocity	660 m. (2165 ft.)	710 m. (2329 ft.)
Angles of elevation	+ 25 deg. − 8 deg.	+ 22 deg. − 8 deg.

The breech mechanism is the same for both guns; it consists of the breech-block with interrupted screw, carried by a slide bracket which pivots on a vertical hinge at the back of the gun. The block is operated by a lever provided with a cam that enters a mortice only when the breech is completely closed, thus acting as a safety block. This cam serves also, in case of need. to disengage the obturator from the walls of the gun chamber, when the lever is brought down after having disengaged the threads of the breech-screw.

The obturator consists of special-shaped plastic disc placed between the movable ring and the front end of the breech-screw. A bolt contains the firing device, which works by percussion. The vent remains closed as long as the breech is not locked, thus preventing premature firing as the percussion tube cannot be placed in the vent until the closing of the breech is complete. The striker is worked by a trigger and a line.

The central pivot mounting consists of a circular bolster fixed to the deck and roller path; a slide formed of two brackets connected by cross-stays constitutes a platform that surrounds the pivot and bolster; the gun-carriage proper consists of the usual slides and two recoil cylinders that communicate with each other through a pipe and slide on the brackets.

To elevate the gun, a differential device, worked by a handwheel, is provided; it acts through a friction cone on a pinion that gears in a toothed sector fitted to the left of the gun. The gun is trained by another handwheel and a pinion which gears in a circular rack fitted to the bolster.

The recoil cylinders are of the Schneider-Canet type, with central counter-rods. Both the pistons and rods remain fixed during recoil. Each piston is provided with valves that remain open only under the action of the recoil on the liquid contained in the cylinders. Automatic return of the gun takes place with reduced speed in order to reduce shocks.

138.6-Millimetre (5.456-In.) Gun on Muzzle-Pivoted Mounting (Fig. 600).—Guns of this type have been supplied to the French Navy.

Weight of gun	3250 kg.	7150 lb.
,, mounting	2870 kg.	6314 lb.
,, projectile	30 kg.	66 lb.
,, charge (prismatic brown powder)...	12.3 kg.	27 lb.
Muzzle velocity	590 m.	1935 ft.
Angles of elevation	+ 28 deg.	+ 28 deg.
	− 12 deg.	− 12 deg.

slide is formed of two parallel guide beams carried on conical rollers, which run on the roller paths. The gun-carriage proper rests, through cylindrical rollers, on the inclined girders of the slide. Under these is placed the hydraulic recoil cylinder that checks the recoil of the system.

A pinion with helical gearing that works on a toothed sector, fitted to the gun, serves for obtaining the required elevation, while the gun is trained by a handwheel and

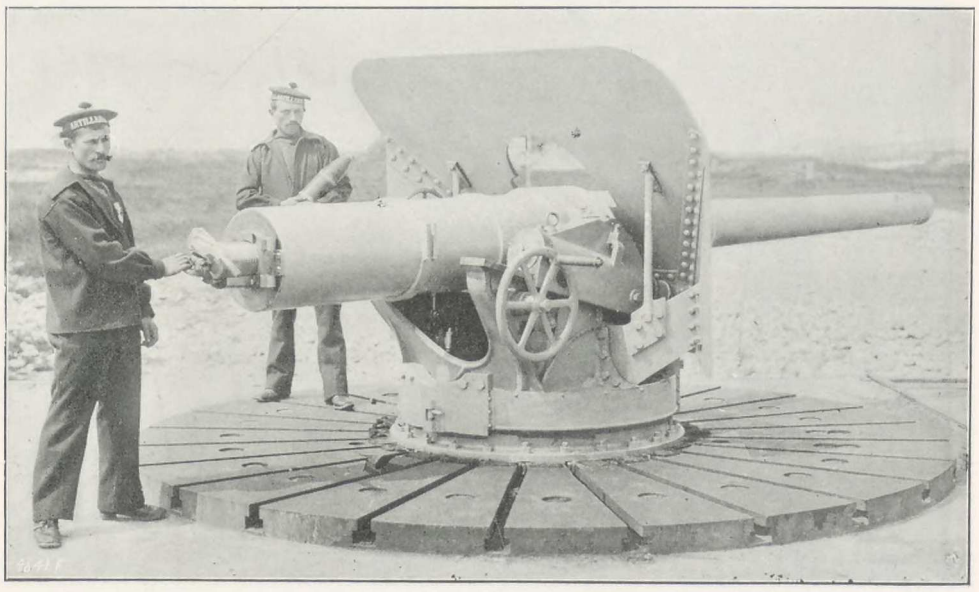


Fig. 599. 12-Centimetre Gun and Mounting (43 Calibre); Model, 1890.

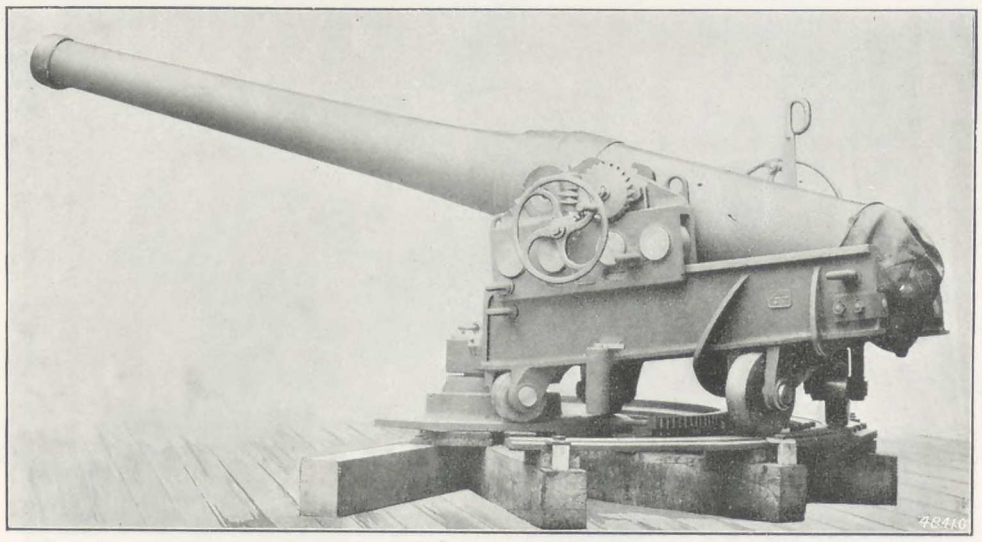


Fig. 600. 138.6-Millimetre Gun and Muzzle-Pivot Mounting.

The breech-block is cylindrical with interrupted threads, and slides in a bracket which turns round a vertical hinge; it is worked by a jointed lever. A plastic obturator is placed between the bulb of the movable head and the front end of the screw. The striker can only act when the breech is completely closed.

The mounting consists of the bolster, the slide, and the carriage. To the bolster are connected the muzzle pivot, and concentric roller paths bolted to the deck. The inclined toothed gearing which acts on a circular rack fitted to the bolster. The recoil cylinder is on the hydraulic system, with constant volume and loaded valves. The force of the recoil is utilised to bring the gun back into battery.

14-Centimetre (5.511-In.) Gun on Central-Pivoting Mounting (Figs. 601 and 602).—Guns of this type have been supplied to the Spanish Navy.

The breech-closing mechanism is essentially similar in

its various parts to that of guns already described, and the systems of obturation and firing are also similar.

The mounting consists of a bolster fixed to the deck and the usual roller path ; an inclined slide, formed of two brackets bolted on a circular platform, rests on the bolster, conical rollers being interposed, and clips which prevent the slides from being displaced. The gun-carriage with two brake cylinders runs freely under the action of recoil on two sets of cylindrical rollers up the two inclined planes of the slide.

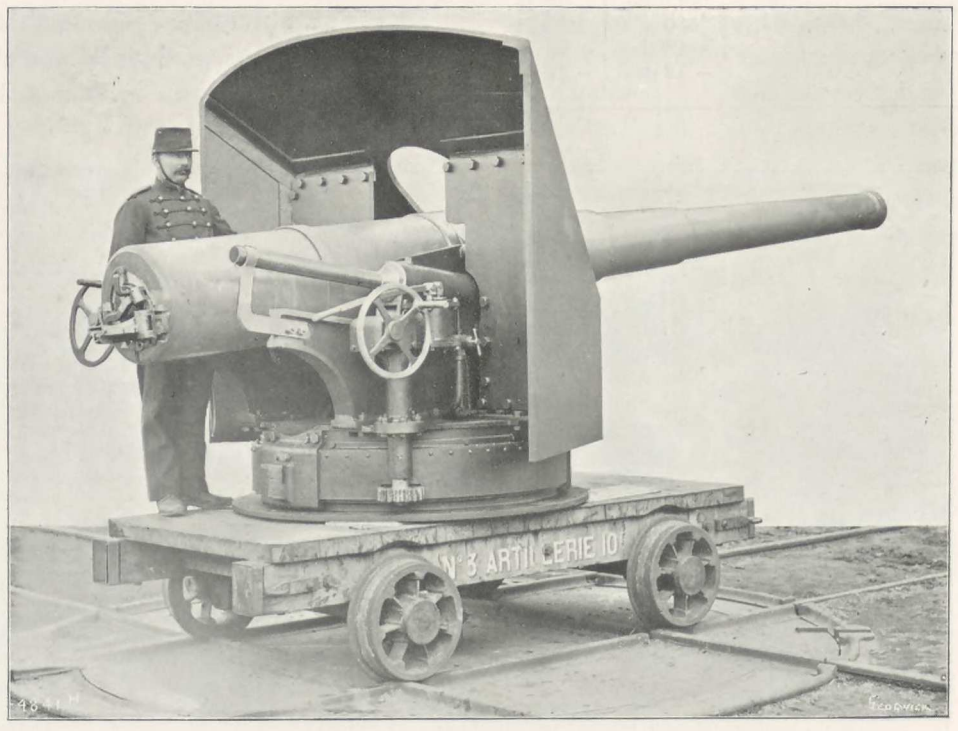


Fig. 601. 14-Centimetre Gun and Central-Pivot Mounting.

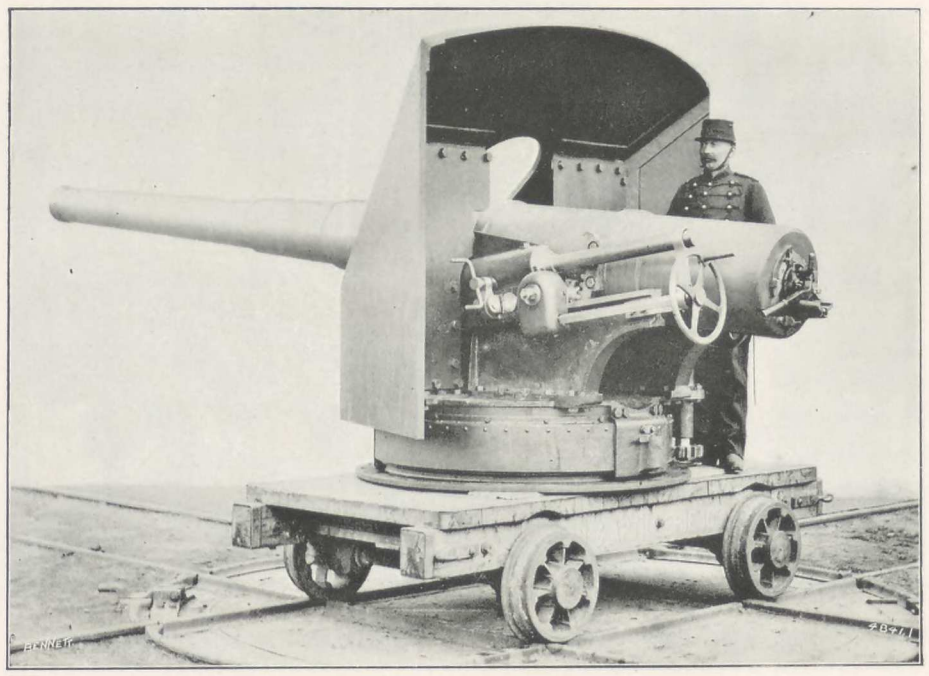


Fig. 602. 14-Centimetre Gun and Central-Pivot Mounting.

Weight of gun	4200 kg.	9240 lb.
,, mounting	3680 kg.	3680 lb.
,, shield	1870 kg.	4111 lb.
,, projectile	40 kg.	88 lb.
,, charge (prismatic brown powder) ...	20 kg.	44 lb.
Muzzle velocity	630 m.	2066 ft.
Angles of elevation	+ 25 deg.	+ 25 deg.
	− 10 deg.	− 10 deg.

For elevating, a handwheel operates a pinion that gears into a toothed sector fitted to the gun. For training, another handwheel is provided that works a pinion acting on a circular rack around the bolster.

The recoil cylinder is hydraulic with constant volume ; the piston-rods are fixed to the front of the slide, and are supported at the back by angle-shaped standards. When

the recoil has ceased, the gun returns automatically into position by its own weight,

14 - Centimetre (5.511 - In.) Gun on Circular Slide (Figs. 603 to 605).

This class of gun has been supplied by Messrs. Schneider and Co. to the French Navy. The following are some particulars:

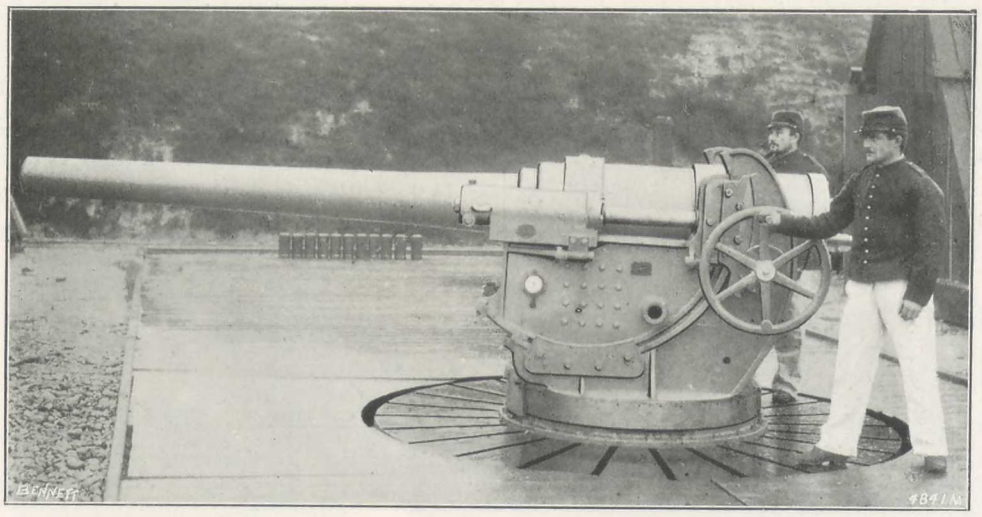
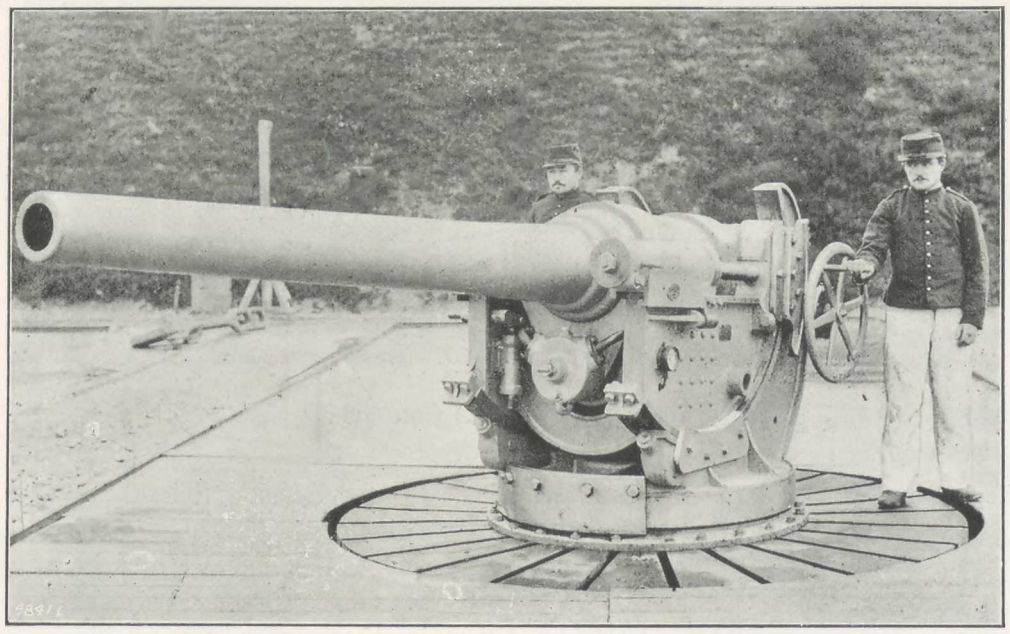


Fig. 603.



Figs. 603 and 604. 14-Centimetre (5.511-in.) Gun and Circular Slide.

Weight of gun	3200 kg.	7040 lb.
,, mounting	3700 kg.	8140 lb.
,, projectile	30 kg.	66 lb.
,, charge (black powder)	13.7 kg.	30.14 lb.
Muzzle Velocity	500 m.	1640 ft.
Pressure	2100 kg.	13.33 tons per sq. in.

The breech mechanism consists of a cylindrical breech-block sliding in a bracket which turns horizontally on a vertical hinge, and worked by a lever. A plastic obturator, specially shaped, is placed between the front end of the screw and the movable head. The bolt for firing acts by percussion, all the necessary means being taken against premature firing.

The mounting consists of the following main parts: A bolster which rests on a fixed platform, the top of which serves as a roller path for the training of the gun. A fixed slide, consisting of two vertical brackets stayed together, rests on the series of rollers on the roller path; the top part being shaped into two circular slide paths, the centres of which coincide with the gun trunnions. An oscillating slide, also consisting of two vertical stayed brackets, the bottom part of which forms slide-blocks of the same shape as the slide-paths; the two latter brackets serve also as slides for the gun-carriage proper. The object of this special type of mounting is to maintain, with all angles of elevation, an exact coincidence of the axis of the recoil cylinders with the line of recoil.

For elevating the gun, the slide is provided with a

circular rack, in which gears a pinion worked by a handwheel. The gun is trained by the combined working of a handwheel with a pinion, a plate-chain, an endless screw, and a helicoidal wheel, the whole setting in motion a pinion that gears in the rack fitted to the platform. The recoil cylinders are carried on the gun-carriage proper; they are on the Schneider-Canet system, with central counter-rod. These cylinders are in connection with an air, or a spring, recuperator placed under the carriage, and which serves to bring the gun into position again after firing.

15-Centimetre (5.905-In.) Gun on Muzzle Pivoting and Central-Pivoting Mounting (Figs. 606 to 609, Plate CX.).

These guns have been supplied to the Greek Admiralty for armament of the battleships "Hydra," "Spetzaï," and "Psara."

Weight of gun	7750 kg.	17,050 lb.
,, mounting (muzzle pivoting) ...	3175 kg.	6,985 lb.
,, ,, (central ,,) ...	3630 kg.	7,986 lb.
,, shield	895 kg.	1,969 lb.
,, projectile (armour-piercing shell) ...	42 kg.	92.4 lb.
,, charge (prismatic brown powder) ...	22.85 kg.	50.27 lb.
Muzzle velocity	650 m.	2,183 ft.
Pressure	2400 kg.	15.24 tons per sq. in.
Angles of elevation	+ 22 deg. − 3 deg.	+ 22 deg. − 3 deg.

The breech mechanism consists of three main parts, a breech-block with movable head and bracket, an obturator and a firing device. The breech-block is cylindrical with interrupted threads, and is carried by the bracket; it is worked by a cam lever which effectually locks the breech when closed; the lever serves, besides, to disengage the obturator on starting the opening motion. The obturator consists of a plastic disc of special shape, placed between the movable head and the front end of the breech. Firing is effected by percussion, the device being so arranged that until the breech is completely closed, the tube cannot be placed home in the vent and the striker armed. The striker is worked by a trigger and a line. Each of the two types of mountings consists of the following main parts: bolster, slide, and carriage.

In the muzzle-pivoting mounting, the bolster is fixed to the deck and is connected with two roller paths, between which is the circular rack for training the gun. The slide is built of two brackets firmly stayed together and finished with sliding paths on the upper surface; below, it bears on cylindrical rollers, the roller paths being held in position by clips. On the left-hand bracket is a glycerine hand pump and tank by which the gun can be run in. The carriage consists of a frame carrying the trunnion bearings and two recoil cylinders of the ordinary kind. In the central-pivoting mounting the bolster is fitted to the deck, its bottom part forming the roller path. The slide rests on the bolster and carries a platform that surrounds the bolster pivot. The gun-carriage proper is similar to the preceding one. A flat-surfaced shield protects the men serving the gun. The gun is elevated by means of a handwheel working through a differential acting device; for horizontal training, a set of gearing is operated by a handwheel and pinion that engages in the circular rack fitted to the bolster.

The recoil cylinders are on the Schneider-Canet system, with central counter-rod, arranged so as to allow automatic running-in under the action of gravity.

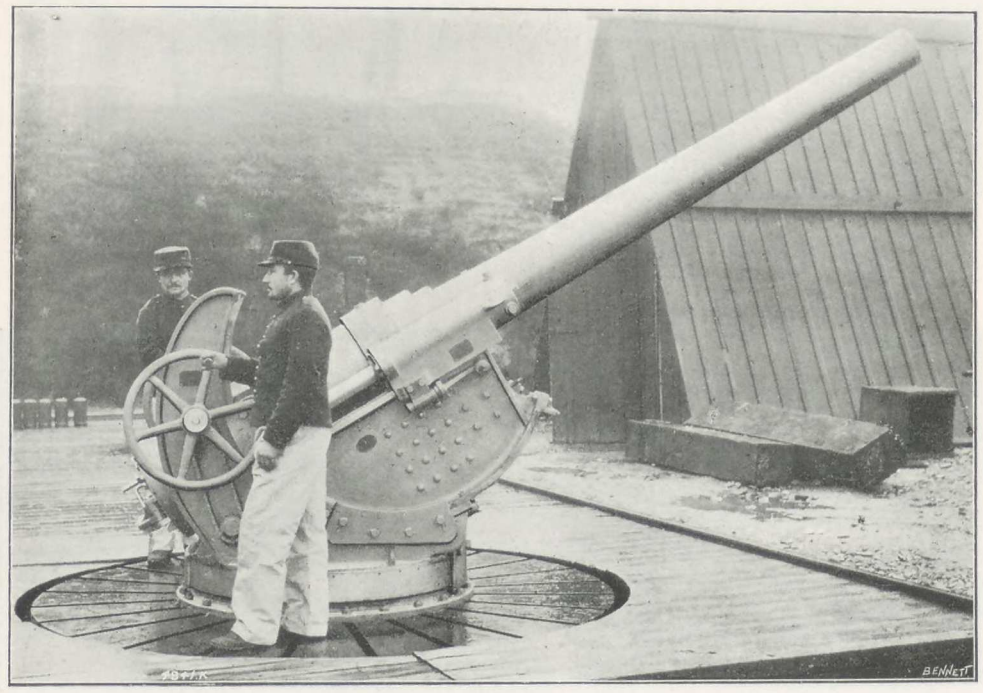


Fig. 605. 14-Centimetre (5.511-in.) Gun and Circular Slide.

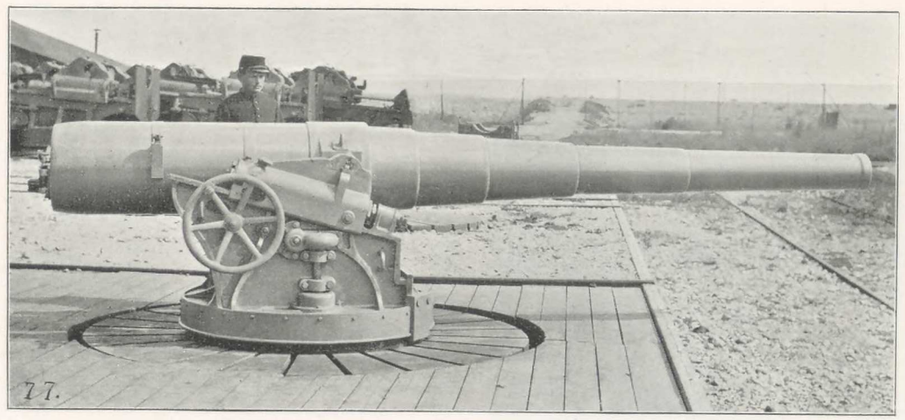


Fig. 606.

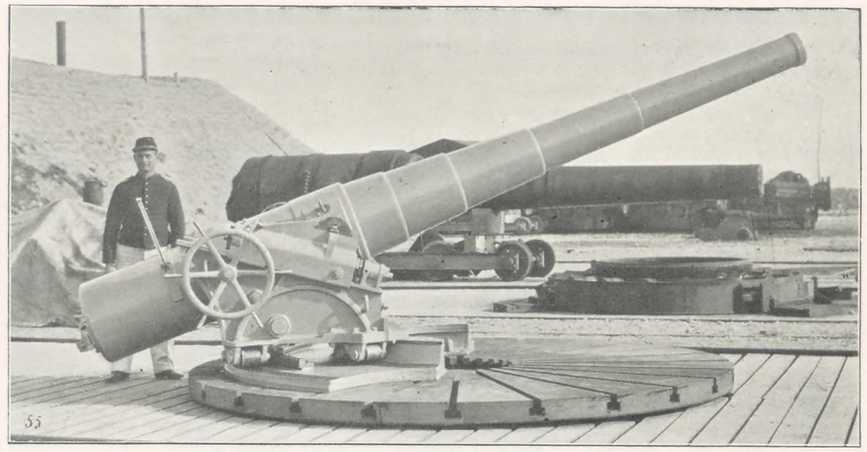


Fig. 607.

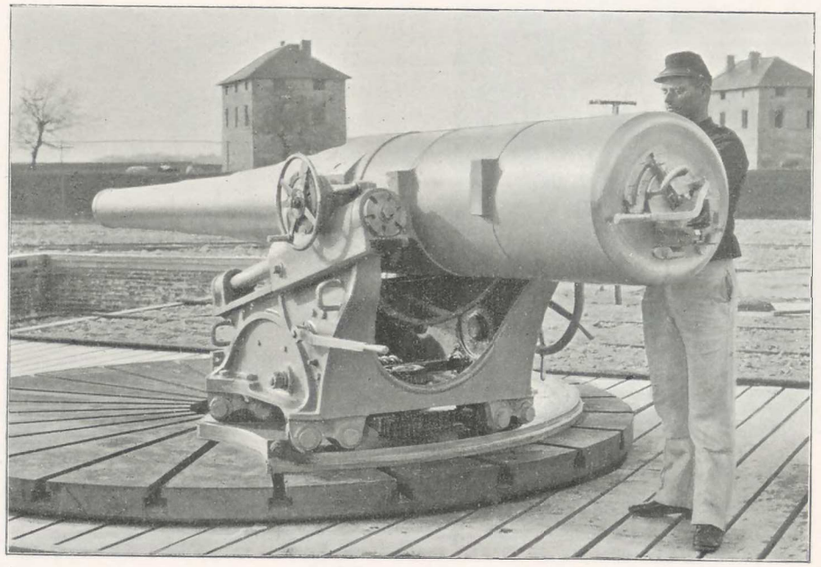


Fig. 608.

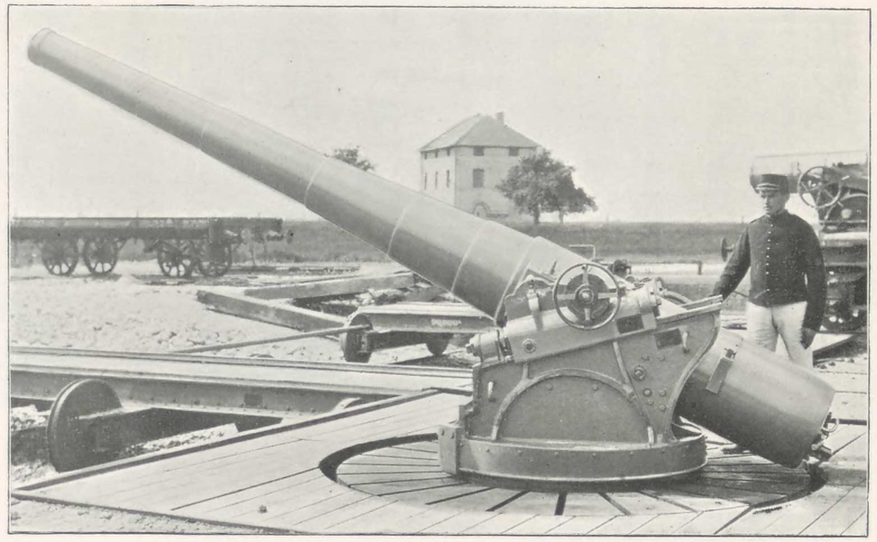


Fig. 609.

15-Centimetre (5.905-in.) Gun and Naval Mounting.

5¾-In. Gun on Muzzle-Pivoting Mounting (Figs. 610 and 611).

The following are some particulars of these guns, which have been delivered to the Brazilian Government:

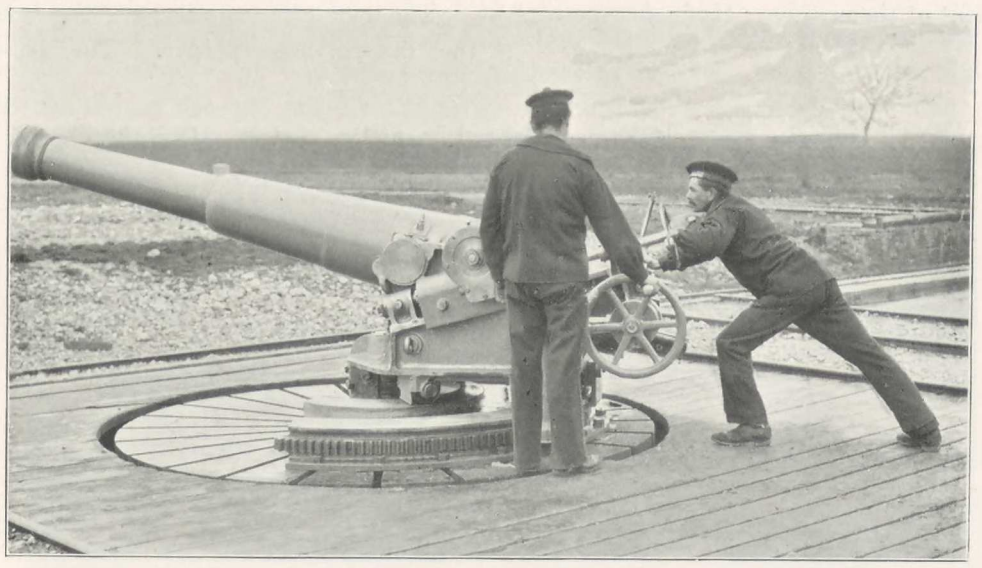


Fig. 610. Naval Gun and Mounting; Side View.

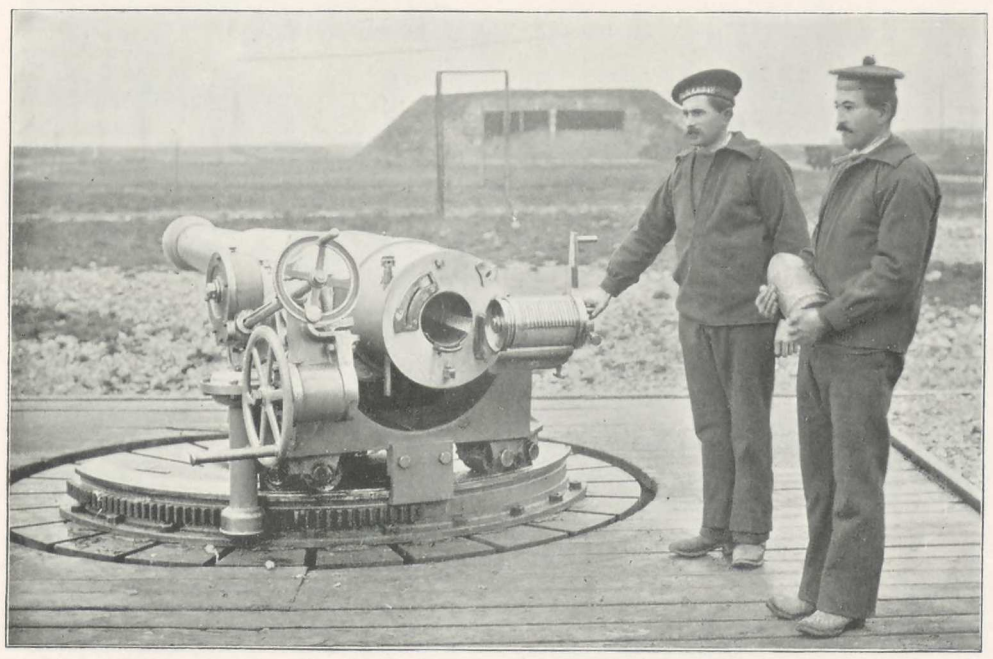


Fig. 611. 5.75-in. Naval Gun and Mounting; End View.

Weight of gun	3050 kg.	6710 lb.
,, mounting	2920 kg.	6424 lb.
,, projectile	36.3 kg.	81.8 lb.
,, charge (prismatic brown powder) ...	13.6 kg.	29.92 lb.
Muzzle velocity	518 m.	1699 ft.
Pressure	2000 kg.	12.70 tons per sq. in.

The breech-closing mechanism and firing device of these guns are very similar to those last described. The bolster, bolted on the deck, forms a circular sector in the centre of which is a pivot around which runs the mounting for training the gun. There are two concentric roller paths. The slide rests on the bolster through the interposition of a series of truncated conical rollers. Steel clamps hold the slide to the bolster, and prevent it from rising during firing. The gun-carriage consists of the ordinary supports placed in guides on the slide; two recoil cylinders, communicating with each other, form part of the gun-carriage.

A pinion that gears in a curved rack fixed to the gun serves to elevate it; a set of gearing working a pinion which engages a rack fitted round the bolster serves for training.

The recoil cylinder is hydraulic, on the Schneider-Canet system, with central counter-rod. The piston is drilled with radiating holes, which allow the liquid to pass from one end of the cylinder to the other. These holes are closed by loaded valves. Vents of small diameter are

provided in the valve to insure the return of the gun to firing position.

27-Centimetre (10.630-In.) Gun on Central-Pivoting Mounting (Figs. 612 and 613).

Guns of this type have been supplied to the Greek Navy for the armament of the cruisers "Hydra," "Spetzaï," and "Psara."

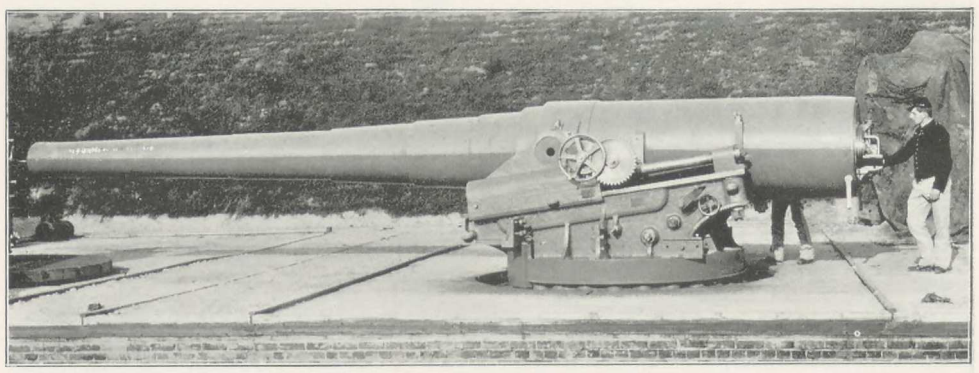


Fig. 612. 27-Centimetre (10.630-in.) Gun and Mounting.

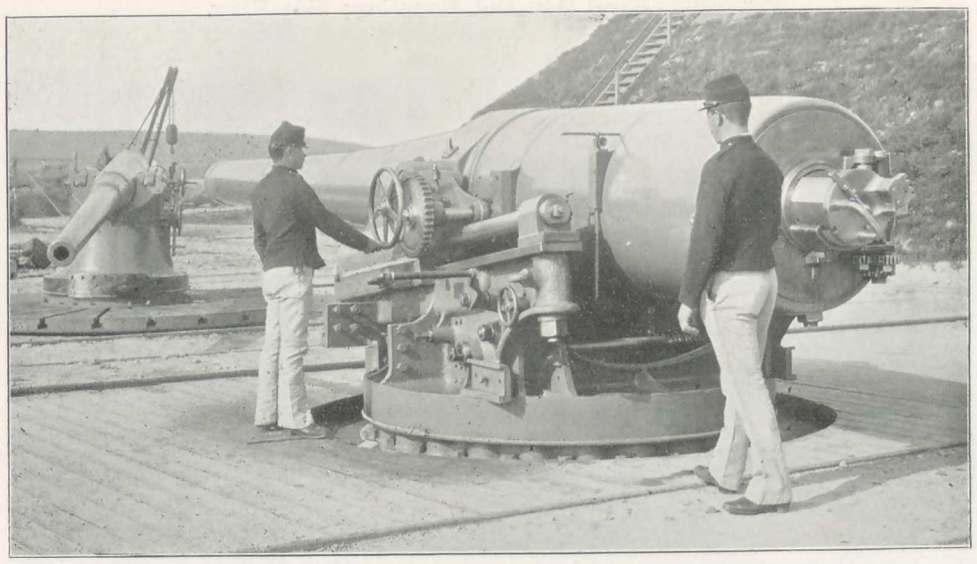


Fig. 613. 27-Centimetre (10.630-in.) Gun and Mounting.

Weight of gun	35,900 kg.	78,980 lb.
,, mounting	16,420 kg.	35,728 lb.
,, shield	1,450 kg.	3,190 lb.
,, projectile (armour-piercing shell) ...	250 kg.	550 lb.
,, charge (prismatic brown powder) ...	165 kg	363 lb.
Muzzle velocity	665 m.	2182 ft.
Pressure	2,400 kg.	15.24 tons per sq. in.
Angles of elevation	+ 15 deg. − 5 deg.	+ 15 deg. − 5 deg.

The breech mechanism consists of three main parts—the breech-block with supporting slide, the obturator, and the firing device. The block is cylindrical, with four plain and four threaded divisions; it is carried on a supporting slide which pivots round a vertical bolt. The mechanism is worked by a crank and toothed gearing. One man can easily open or close the breech, though the mechanism weighs approximately 520 kilogrammes (1144 lb.). The obturator consists of a plastic disc placed between the front end of the screw and the movable head. Firing is effected by means of a bolt that acts by percussion. The vent is masked by the bolt, and the striker cannot act until the breech is completely closed.

The mounting consists of the bolster, the slide, and the gun-carriage proper. The bolster rests, through two bearing rings, on a wrought-iron bed. On the roller path are arranged twenty-four truncated conical rollers, maintained in position by guides. The slide is formed of two brackets stayed together; it rests on the rollers, and is held in place by clamps. On the left bracket is the mechanism for hauling in the gun. The gun-carriage proper rests on blocks on the slide; it carries two recoil cylinders united together by a stay-piece, which forms the gun rest, and there are also two compensating cylinders. A shield, fitted to the front of the slide, protects the piece and the gunners.

To elevate the gun there is provided a differential device with toothed-wheel gearing and friction cones, working a curved rack fixed to the gun, which is trained by a set of toothed-wheel gearing, worked by hand or by steam power.

The hydraulic recoil cylinders are provided with central counter-rods on the "Schneider-Canet" system, and with compensating cylinders. The cylinder piston-rods are fixed to the rear end of the slide paths, while those of the compensating cylinders form one piece with the front cross-stay of the slide. The running out of the gun can be controlled or stopped at will by operating a valve that controls the action of the compensating cylinders.

The gun is made throughout of steel, and is built up in jackets to the muzzle; it is held in the carriage proper by means of a grooved jacket. The breech mechanism consists of a breech-block with supporting slide, an obturator, and the firing device. The breech-block is cylindrical, with four plain and four threaded parts; it is carried on a supporting slide. It is worked mechanically by means of a crank and toothed gearing which successively turns the block in its seating, withdraws it, and moves its support

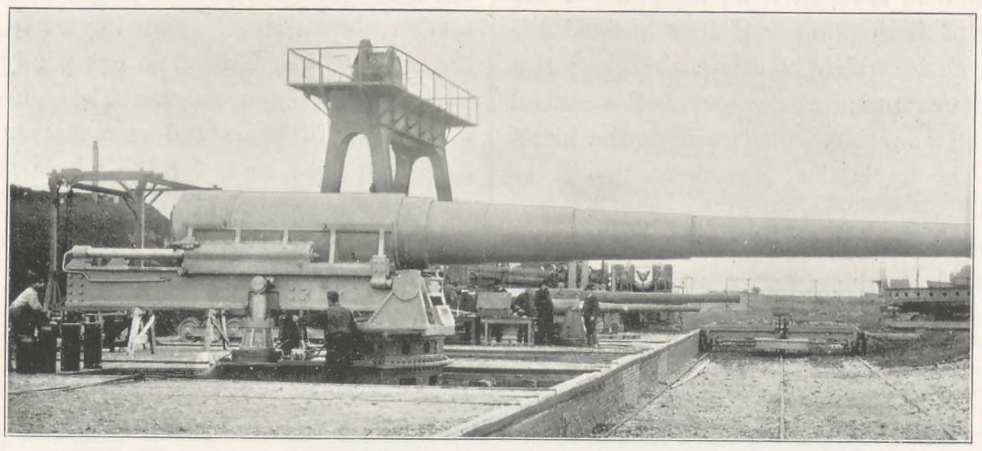
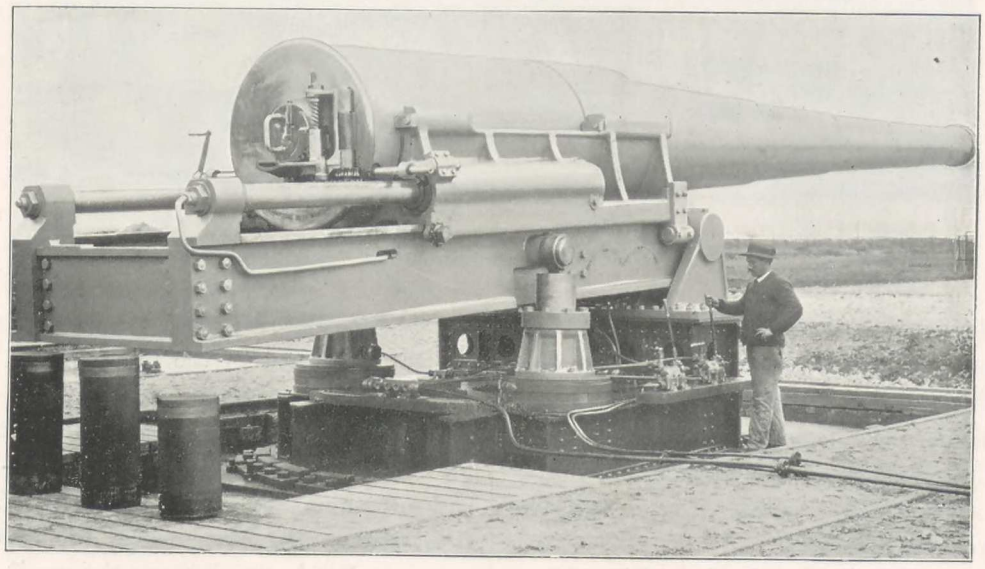


Fig. 614.



Figs. 614 and 615. 32-Centimetre (12.598-in.) Gun and Mounting.

32-Centimetre (12.598-In.) Gun, 40 Calibres in Length (Figs. 614 and 615).—Guns of this type have been supplied to the Japanese Government for armament of the coast-guard ships Itsukushima, Matsushima, and Hashidate.

Weight of gun	66,000 kg.	66 tons
,, projectile	450 kg.	990 lb.
,, charge (prismatic brown powder	240 kg.	528 lb.
Muzzle velocity	700 m.	2296 ft.
Pressure	2,400 kg.	15.24 tons per sq. in.
Angles of elevation	+ 10 deg. − 4 deg.	+ 10 deg. − 4 deg.

round the vertical hinge bolt. The obturator is plastic, and is situated between the front end of the screw and the movable head. The firing device consists of a bolt which acts by percussion. As long as the breech is not completely closed, the bolt that slides in the rear end of the breech-screw masks the vent, and prevents the introduction of a percussion tube; at the same time the striker cannot act, thus doing away with all risk of premature fire.

The mounting consists of bearing-blocks, a slide and a gun-carriage proper. The bearing-blocks are two in number; they are fixed symmetrically to the platform, with the interposition of a sole-plate; clamps prevent all

rising of the gun supports. The slide consists of two beams stayed together, their upper surfaces forming slide paths; the front end is provided with trunnions, and the rear ends with blocks in which are fixed the recoil cylinder piston-rods. The gun-carriage proper is semi-cylindrical in shape, and rests on the path of the slide; the recoil cylinders and compensating cylinder are cast in one piece with it.

For training the gun, hydraulic pressure is necessary, owing to the heavy weights that have to be moved, and for this purpose cylinders are placed on each side of the slide. To the head of both plunger pistons is fixed the end of the pitched chain which traverses the gun; this chain takes a half turn round the racer of the central tube which carries the mounting. For training, the hand-wheel that governs the mechanism is made to turn in the direction towards which the gun is to be moved. The levers and handwheels are all within reach of the gunner.

bolted a rack; this works through toothed gearing and a shaft, the rotation of which effects the opening and closing of the breech. The working of this mechanism is very simple; the piston remaining stationary, it is only necessary to admit water under pressure to the right or left of the piston in order to cause the cylinder to move and bring the rack in the required position.

The mounting consists of three main parts; the gun-carriage proper, in which the gun is fitted; an oscillating slide, and the foundation. The gun is without trunnions, but it is held by a series of rings which fit in grooves in a semicircular carriage. Four keys, two in front and two in the rear, are lodged in slots cut partly in the carriage and partly in the gun rings. The gun is, therefore, held throughout in place and cannot turn round. The gun-carriage proper rests for the whole of its length on the slides; a system of clamps prevents it from getting displaced laterally. The gun-carriage slide-blocks are of gun-

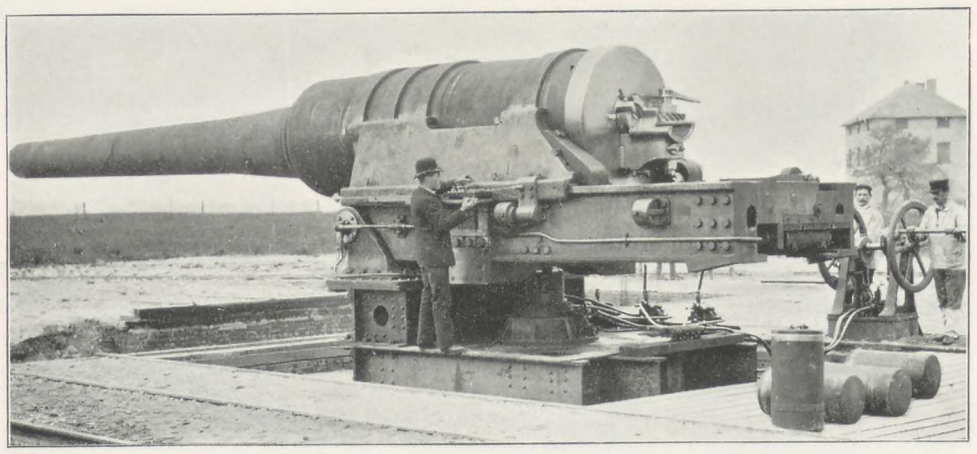


Fig. 616. 34-Centimetre (13.386-in.) Naval Gun and Mounting.

The recoil cylinders are on the Schneider-Canet system, with central counter-rod. They communicate with each other by a pipe which carries a valve-box fitted to the rear of the intermediate compensating cylinder. This arrangement gives full control in the operation of running out and hauling in of the gun. A slide valve governs the distribution in the various cylinders.

34-Centimetre (13.386-In.) Naval Gun (Fig. 616).—Guns of this type have been supplied for the armament of the first-class cruiser Marceau.

Weight of gun	51,250 kg.	51.25 tons
,, projectile	420 kg.	924 lb.
,, charge	195 kg.	429 lb.
Muzzle velocity	625 m.	2050 ft.
Angles of elevation	+ 11 deg.	+ 11 deg.
	− 5 deg.	− 5 deg.

The gun is of steel throughout, and is held to the gun-carriage proper by grooved jackets.

The breech mechanism consists of a breech-block, an obturator, and a percussion firing device. The breech is opened and closed automatically by means of a movable cylinder placed in the rear of the slide, and on which is

metal, the sliding surfaces being fitted with lubricators. Buffers are fitted to the gun-carriage guide; this carries also a specially shaped slide-bar, which operates a pin that regulates the circulation of liquid in the recoil cylinders. The body of the slide consists of two I-beams, in the front end of which are fitted trunnions. Two cross-stays, in front and in the rear, insure the perfect stiffness of the system. Inside the slide are the recoil cylinders placed on the right and on the left, and the distribution box; the cylinder for working the breech mechanism is in the rear; on the sides are two fixed buffers, which correspond to those fitted to the gun-carriage guide. The slide also carries the support for the regulating pin. The two foundation supports are symmetrical, and are fixed to the platform, with the interposition of a sole-plate, which holds them together in front, and constitutes, at the same time, a clamp to prevent any rising.

The hydraulic press for elevating the gun is bolted to the turret platform. It consists of a cylinder and a hollow piston with a socket containing the spherical head of the connecting-rod, which is joined by a trunnion to the frame. The piston is raised when water under pressure is caused

to act under the plunger. For lowering, it is sufficient to cause the water under the plunger to escape. The central supporting tube is fitted under the armoured deck, with a circular rack for traversing the gun. On each side of this tube, and in the same plane with the circular rack, are placed two small hydraulic cylinders. On the lugs cast on the cylinders are fixed the ends of a pitched chain, which passes round the head pulleys of the large pistons; the cylinders, in which the pressure remains constant, maintain the chain taut. It suffices, therefore, to send water under pressure in one or the other of the cylinders to cause the turret to turn one way or the other.

The hydraulic recoil system consists of two lateral cylinders and of an intermediate distribution chamber; the cylinders are of equal diameter. The distribution chamber is provided with a valve loaded by Belleville springs, and with a regulating pin. The system works as follows: During recoil, the gun draws back the gun-carriage, and with it the pin-slide which regulates the circulation in the recoil cylinders. The liquid passes from the rear to the front of the pistons by lifting the distribution valve, and penetrating through an annular opening situated between the walls of the distribution box and the regulating pin. The flow of liquid is regulated by the specially shaped rod, the section of which varies in such a way as to maintain a tolerably constant pressure in the cylinder during the whole time the recoil lasts. When the recoil is spent, the loaded valve falls on its seat, and shuts off all further communication between the front and the rear of the cylinders, the gun remaining hauled in. To run it out again, it is only necessary to admit water under pressure to the rear of the pistons, the liquid in front being allowed to escape.

In the above brief notices only a small number of the older types made by Messrs. Schneider and Co. have been described in order to give a general history of the principal natures of "Schneider-Canet" naval guns, manufactured previous to the adoption of quick-firing ordnance. Had every type been considered separately, a whole series of descriptions would have to be given, bearing on questions of detail, many of them now obsolete, and on the many improvements made every year in designing war material. The main object being to give an idea of the Schneider-Canet system as a whole, it was not necessary to enter into more detail in this part of the subject. Besides, owing to the importance now acquired by quick-firing guns, the types that were built even ten years ago, are chiefly of retrospective interest.

XXVIII.—QUICK-FIRING GUNS.

THE first carefully conducted, and conclusive trials, made, with medium-calibre quick-firing naval guns, date back to 1887, when the 15-centimetre (5.905-in.) calibre was the largest to which it was deemed advisable to adapt quick-firing mechanism. Since then, however, Messrs. Schneider and Co. and Mr. Canet, have greatly improved this type of naval gun, in all the most important parts, until to-day the Schneider-Canet quick-firing guns, with calibres ranging from 37 millimetres (1.456 in.) to 24 centimetres (9.449 in.) inclusive, constitute a complete series of ordnance. The special features which go to form the most recent types of Schneider-Canet quick-firing guns, can be applied to the largest calibres; owing, however, to the heavy weights that have to be moved when the calibre exceeds 24 centimetres (9.449 in.), and also because of the more complicated mechanism required for these heavier weights, the larger-calibre guns—those above 24 centimetres—of the most improved type, while not belonging strictly to the quick-firing class, are arranged for a sufficiently rapid fire to justify their classification under the name of "Matériel à tir accéléré."

As the use of quick-firing guns for modern naval armaments is becoming yearly of greater importance, we propose to describe in detail the "Schneider-Canet" guns of this system, and to review briefly the history of their development. A full consideration of the subject naturally falls under the following headings: 1. The gun tube proper. 2. The breech mechanism. 3. The mounting and its various accessories.

Materials and Tubes.—Schneider metal, specially made for this purpose at the Creusot Steel Works, is exclusively used for the manufacture of the Schneider-Canet quick-firing guns. A detailed description has already been given of the steel plant where the material is made, in an earlier part of this volume. From what we have already said, it will have been noticed that Messrs. Schneider and Co. possess the most modern and powerful appliances for the production of gun steel, and that they are able, according to the requirements of various Governments, to supply guns made from steel ingots forged under a steam hammer, or from compressed-steel ingots worked up under a forging press. It is worth mentioning that the French Government does not manufacture steel gun forgings, but orders from Messrs. Schneider and Co. a considerable number of such pieces every year, the complete gun being built up in the State gun factories.

Series of severe tests for ascertaining the quality of the metal, and securing its uniformity, are regularly carried out both at Creusot and at Havre. Messrs. Schneider and Co. also manufacture a particular quality of gun steel, containing varying percentages of nickel and other metals and alloys. The process of manufacturing this particular quality is, however, a secret one.

Design and Manufacture.—The Schneider-Canet quick-firing guns are characterised by great simplicity of design and by the small number of pieces of which they are constituted. As a rule they consist of a thick tube, strengthened by two jackets, as illustrated in Fig. 617, which shows the longitudinal section of a 15-centimetre (5.905-in.) 50-calibre gun. By inspection of this section, it will be seen that the three pieces forming the gun are of very simple and regular shape. It

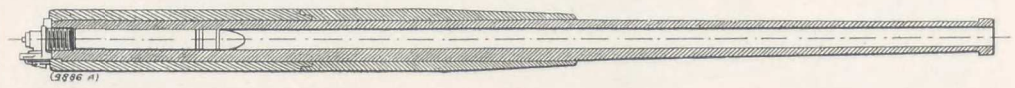


Fig. 617.

follows therefore that the forging, and more especially the tempering, operations, which affect the quality of the metal to a marked degree, can be carried out under the most favourable conditions; as a consequence the metal of the gun leaves nothing to be desired as regards regularity in quality and homogeneity. Besides, and this is very important, as there are no complicated forms, the process of building up the gun is completed with less chance of errors in workmanship, and errors are always to be feared in this class of work, whatever be the skill of the men, and the excellence of the plant. A large experience has proved that the construction of Schneider-Canet guns is reliable throughout, in consequence of the design which has been finally adopted, and the system employed in manufacture.

The section (Fig. 617) shows also that the strains due to firing are judiciously divided between the elements that constitute the gun, and especially between the tube and the rear jacket, while in most other systems the longitudinal strains are thrown on the jacket, the tube having only to bear the transverse strain due to the explosion of the charge. In the Schneider-Canet guns—apart from those fitted with a concentric-threaded breech-block, which is of a special type—these two elements of the gun are

so arranged that they act together in resisting both these strains, the breech-screw being fitted in the tube itself. There is, therefore, between the various parts constituting the gun, as perfect a distribution of material as it is possible to obtain, the strains when developed by firing being taken up by all the elements together.

This principle is not wholly in accord with pure theory, which does not consider the necessities of manufacture, and which would point to multiplying the number of jackets placed one over the other. It has, notwithstanding, been endorsed in the manufacture of Schneider-Canet quick-firing guns, by a long and repeated practice. Among the large number of guns of this system now in regular service all over the world, not a single one has shown any weakness under fire in the elements that constitute it. On the contrary, the records of many of these guns indicate that they have sustained, without undue wear, firing at exceptional pressures, reaching as much as 4800 kilogrammes per square centimetre (30.477 tons per square inch), a strain equal to double the normal pressure in service.

Out of a large number of Schneider-Canet quick-firing guns, 10 centimetre (3.937 in.) and 55 calibres in length, built for the French Navy, the Admiralty inspector selected one at random, with which to make a large number of extreme practice firing trials. The gun and its mounting were placed on board the French training ship Couronne, and it has undergone regular service for the last six years. Up to a recent date, this gun has fired no less than 4000 rounds, besides being used for training drill; it has done, therefore, an exceptional amount of work, and is nevertheless still in excellent condition. Such an experience is a sufficient answer to the well-known allegation that quick-firing guns wear rapidly. Many other examples of the strength and endurance of Schneider-Canet quick-firing guns might be given to disprove this statement.

From the first introduction of quick-firing ordnance, the Schneider-Canet guns were noted for their great power. In 1892-3, the muzzle velocity of these guns was 800 and even 880 metres, while the muzzle velocity generally obtained in service was 680 to 700 metres as a maximum. In order to obtain these very high results, which were considered exceptional at the time, the Schneider-Canet guns had been most carefully designed and were made of exceptional length. It is almost superfluous to-day to insist upon the advantages that arise from high muzzle velocities, both for firing on board ship and on land; the time when this was questioned has long gone by, and the universal practice of to-day always tends to obtain still higher velocities. This was not the case, however, when the early types of Schneider-Canet quick-firing high-velocity guns were introduced, and which were made the subject of much hostile criticism. The long lengths of bore were particularly objected to, chiefly on the ground that such long guns were not capable of giving an effective service on board ship, and that they required mountings of exaggerated dimensions. In spite of these criticisms—which were to be disproved by future experience—Messrs. Schneider and Canet increased the length of their guns successively to 45, 58, 50, and even 55 calibres. Guns of these, at that time exceptional, proportions were manufactured in considerable numbers for various Governments; and the results obtained, both as regards efficiency and durability, have been eminently satisfactory.

Messrs. Schneider and Canet then proceeded to build 100-millimetre (3.937-in.) and 57-millimetre (2.244-in.) guns, 80 calibres in length; these formed the most advanced series of quick-firing Schneider-Canet guns at the time. They gave, in regular firing service, muzzle velocities of 1,015 and 1,025 metres, the firing mechanism being also extra rapid. They were, therefore, of exceptional power, and as their trajectories were remarkably flat, they gave results which could not be attained by any other quick-firing guns of the same calibres. They were distinguished also by the ease with which the loading, training, and firing operations were carried out.

Similar velocities (exceeding 1,000 metres) were obtained at a somewhat later date in several countries, not with service guns, but with tubes fixed end to end, and giving a total length of approximately 100 calibres, special means being taken to insure the stability of the arrangement. Such trials amounted simply to proving-ground firing experiments. The 80-calibre Schneider-Canet guns, were from the first tested to the utmost, and their efficiency never left anything to be desired. They were afterwards inspected by a special Naval Commission appointed by the Ministry of Marine, which decided to purchase them.

Since that time the development of the Schneider-Canet system has steadily progressed, thanks to the lessons taught by actual warfare, to the accumulated experience of the proving-ground, and to improvements in material and design; so that at the present time it deservedly occupies a front rank in modern armaments throughout the world.

The Schneider-Canet quick-firing guns are now manufactured of various lengths, from 40 to 80 calibres, according to the power required, and the varied conditions of service.

This brief review, completed by some detailed descriptions, will give a clear idea of the characteristics of the Schneider-Canet quick-firing guns, and the important part played by the manufacturers in the progress made in the construction of ordnance, more especially, perhaps, as regards high velocities, one of the principal requirements of the present day.

XXIX.—BREECH MECHANISM FOR QUICK-FIRING GUNS.

THE Schneider-Canet breech-closing devices, though comprising a large number of types, embody general characteristics common to all of them. They all have been thoroughly tested, and the various types are adapted to fulfil the different conditions required for naval and land service. The designs of the breech mechanisms having been carried out simultaneously with that of the whole material, it is necessary, in order to form an idea of the important progress made, to pass in review successively the various typical patterns that have been manufactured and put into service.

Until 1895 the Schneider-Canet guns were exclusively fitted with breech-blocks having interrupted screws. This system, and its many undoubted advantages over the wedge-closing devices, are now well known, and we shall not enter into details on this point. It will suffice to remark in passing that every nation has now adopted the breech-screw mechanism.

Since 1895, Messrs. Schneider and Co. have put into service, after protracted experiments, an entirely new type of breech-closing arrangement, which is known as the "concentric threaded breech-piece;" this combines the good qualities of the wedge and screw systems, without any of their disadvantages, In its most modern form, which has been evolved from experience gained during the last twelve years, the Schneider-Canet breech mechanism combines the following advantages:

Ease and rapidity in working.

Excellence in the design of the various parts composing the mechanism, and facility with which it is taken apart.

Complete safety during all the various phases of service.

In the following descriptions we shall consider the principal types that embody special features separately, classifying them, for greater convenience, according to the number of motions required to operate the complete opening of the breech. This will lead to an approximately chronological enumeration of the various types, corresponding generally to the dates of trial and adoption in service. The arrangement will, better than any other classification, enable our readers to follow the steady progress made in the Schneider-Canet quick-firing system with regard to the breech mechanism.

The classification will therefore be as follows:

1. Three-motion types.
2. Two-motion types.
3. One-motion types.
4. Concentric threaded types.

1. THREE-MOTION BREECH MECHANISM.

We shall only describe a few specimens of the first type, as it was first adopted several years ago, and being now antiquated is only used for new guns when expressly specified, or when it is a question of completing existing armaments in a uniform manner. The various breech-pieces of this type differ one from the other in a few accessory details, the main parts being practically all similar. They have been applied to guns of all calibres, including those of 27 centimetres (10.530 in.), and in working they invariably gave satisfaction. One of the delicate parts of this class of breech, the plastic obturator, has been carefully improved by Messrs. Schneider and Co., in order to insure its satisfactory action under the various conditions of service. The practical result has been a composite elastic obturator, which does away with all the difficulties that attended the use of those of the ordinary kind.

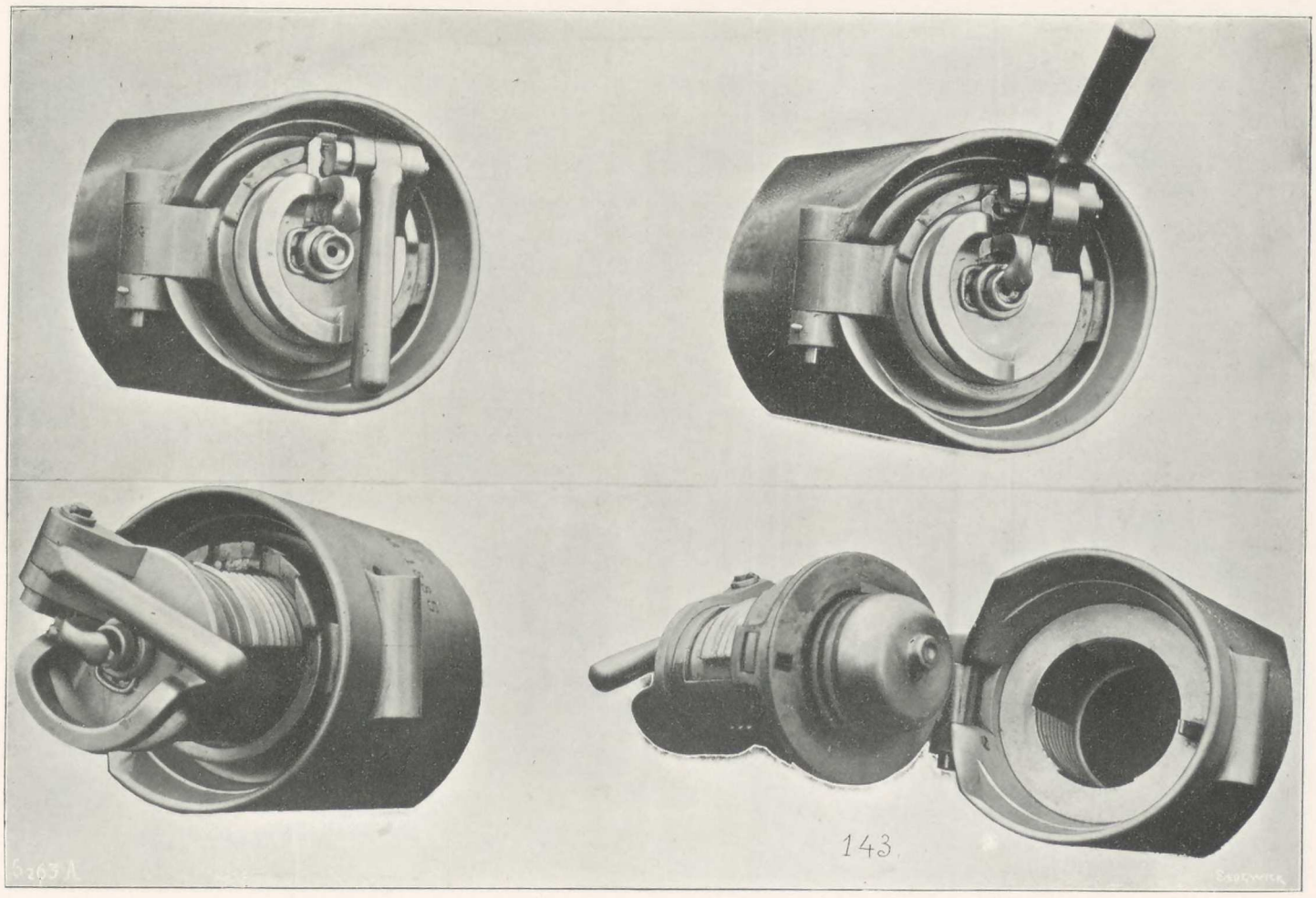
The five types illustrated by Figs. 618 to 634, Plates CXI., CXII., and CXIII., consist each of a breech-block with interrupted screw, an obturator, and the firing device. The breech-block is made in three threaded parts and three interruptions; it is carried on a bracket which pivots round a vertical hinge bolt. The obturator consists of a plastic elastic disc, placed between the movable head and the rear end of the breech-screw.

To open the breech it is necessary (1) to lift the hand-lever in order to disengage the cam, and to give to the breech-piece one-sixth of a revolution with the help of the same hand-lever; (2) to lower the lever in order to disengage the obturator and to pull the block from the breech by taking hold of the fixed handle; and (3) to turn it back to the side on the vertical hinge-bolt. To close the breech, the same motions are repeated in inverse order. During these various operations a special slide-bolt, not fitted with springs, but acting on two combined inclined planes, unites the breech-screw to its support and the support to the gun alternately. The views we give reproduce the successive phases of opening the breech; they show:

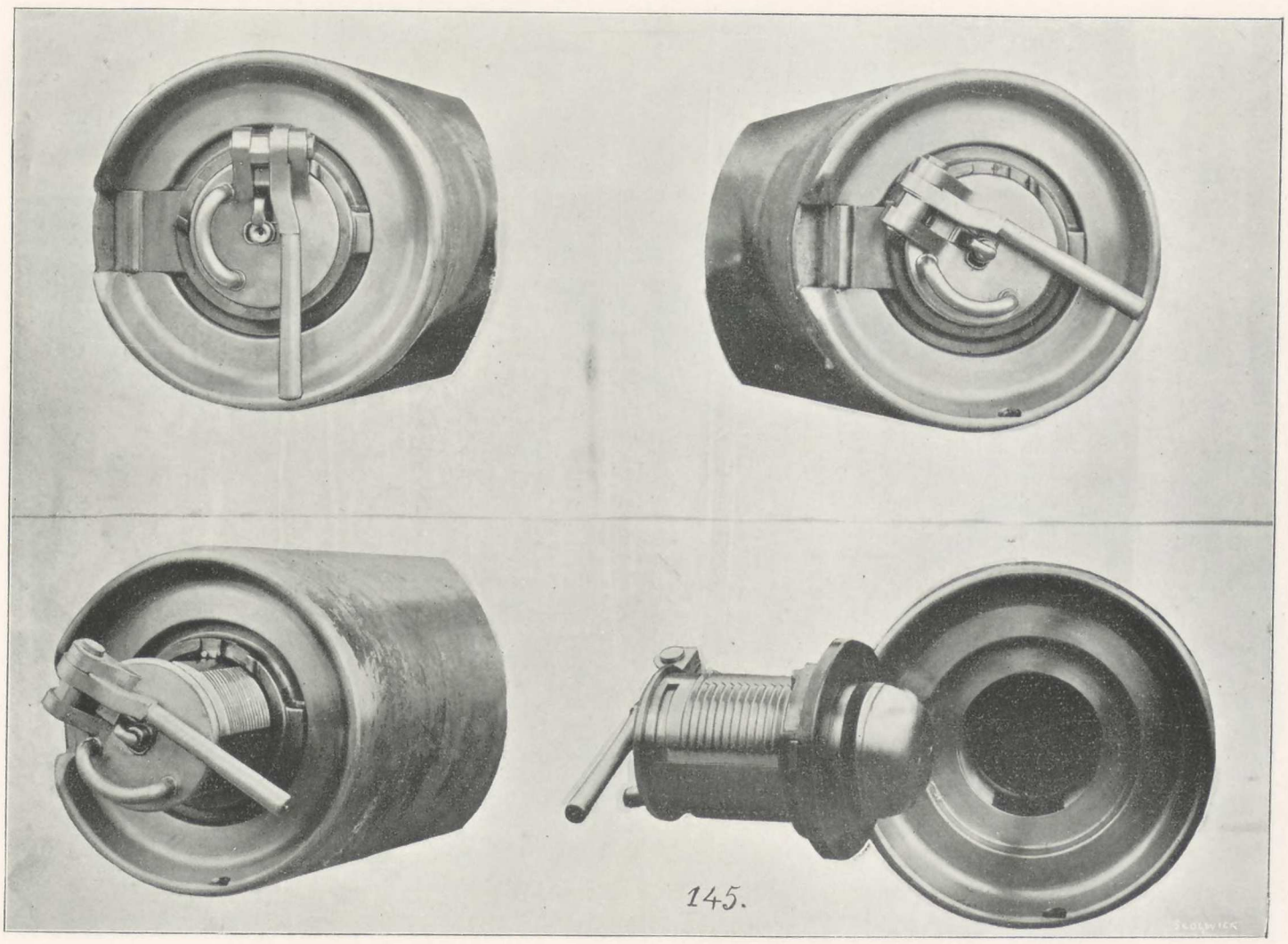
1. Breech closed.
2. Breech-block disengaged, lever brought down.
3. Extraction of breech-block.
4. Swinging of breech-block to the side.

Type 1 (Figs. 618 to 621, Plate CXI.).—This breech-piece contains the following accessory devices: Firing is obtained by means of a friction fuse. During the opening motions, a finger worked by a cam, which forms one piece with the hand-lever, masks the vent until the breech is

BREECH-MECHANISM FOR QUICK-FIRING GUNS.

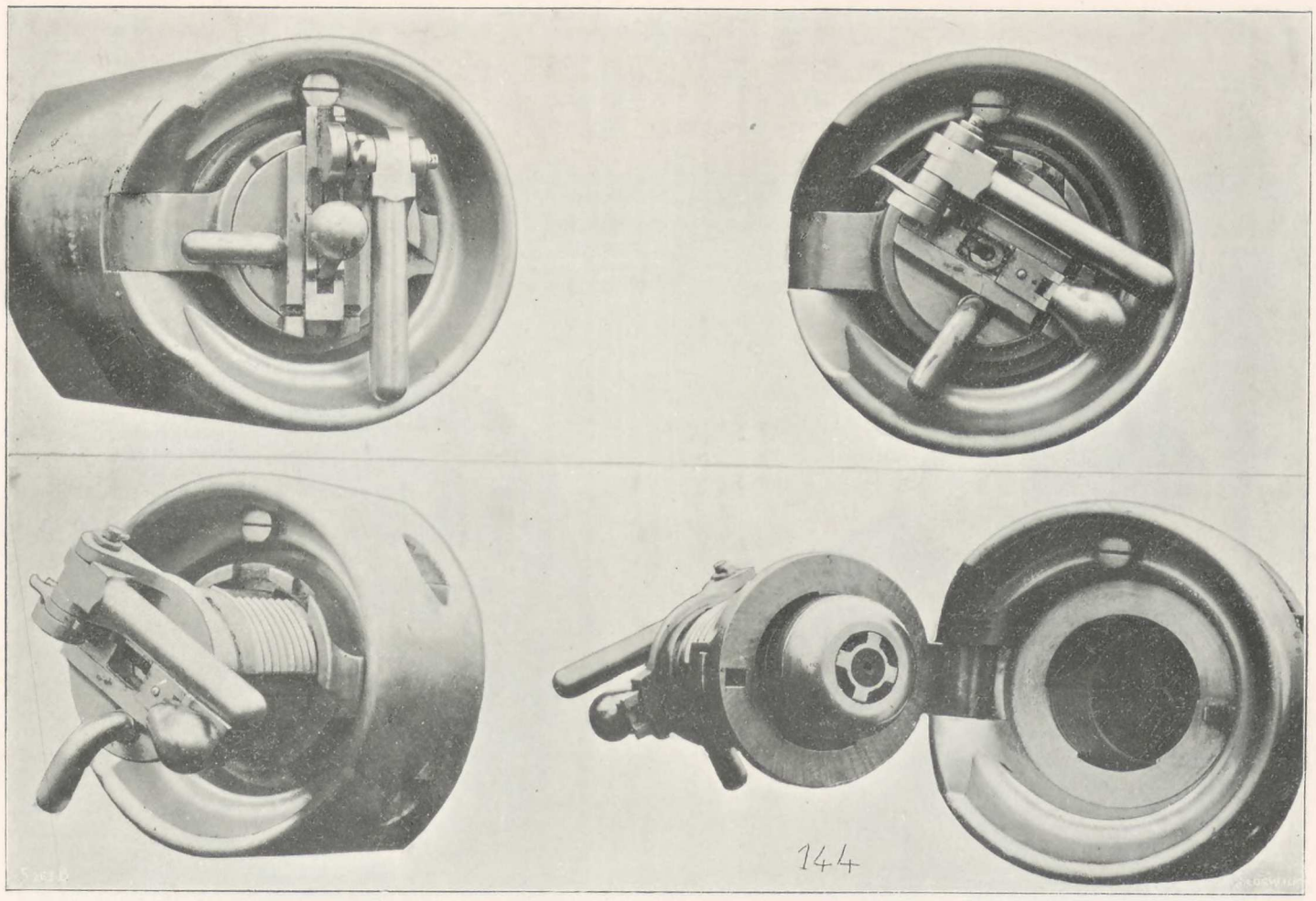


Figs. 618 to 621. Four Positions of Breech-Mechanism, Type 1.

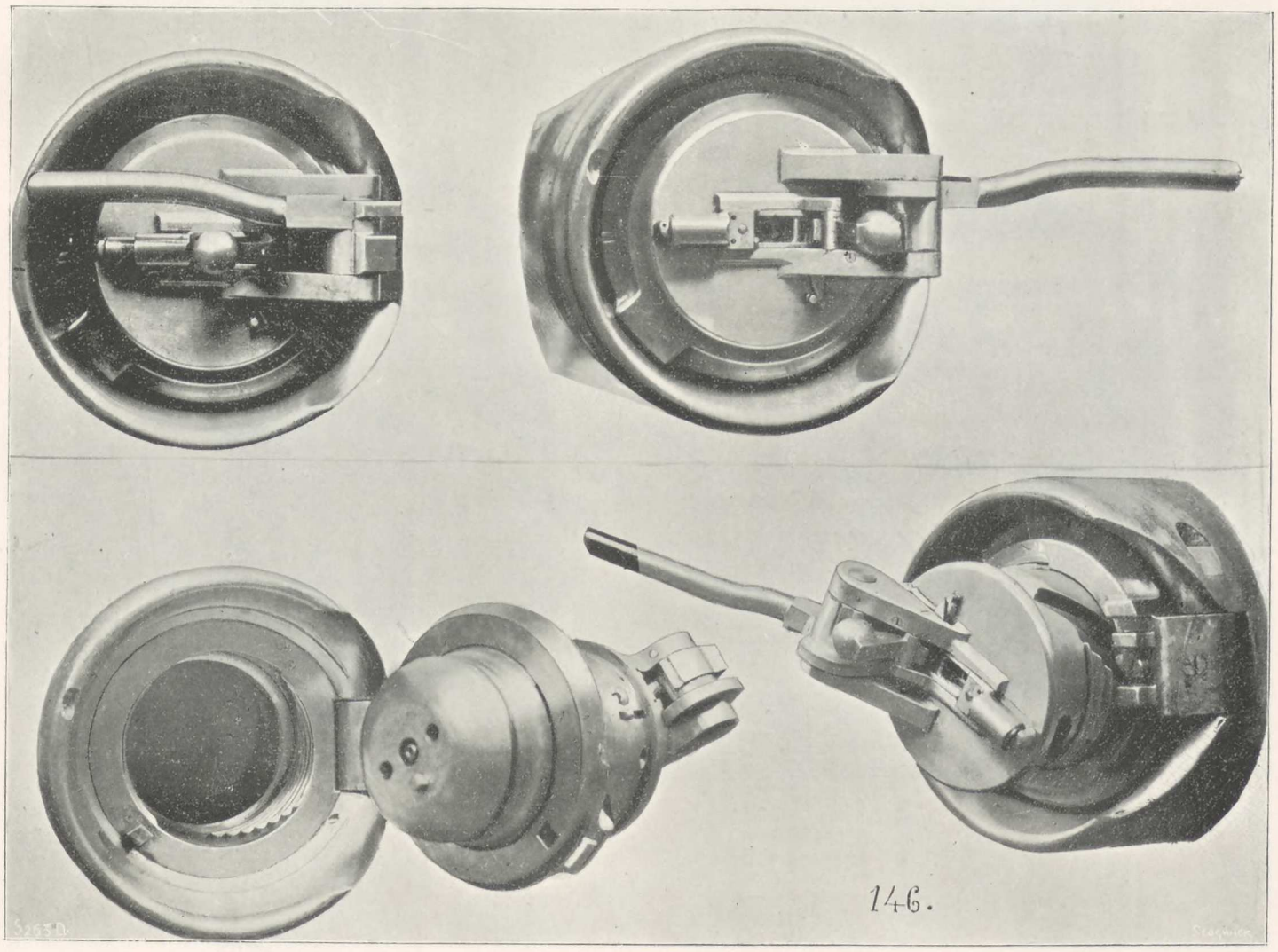


Figs. 622 to 625. Four Positions of Breech-Mechanism, Type 3.

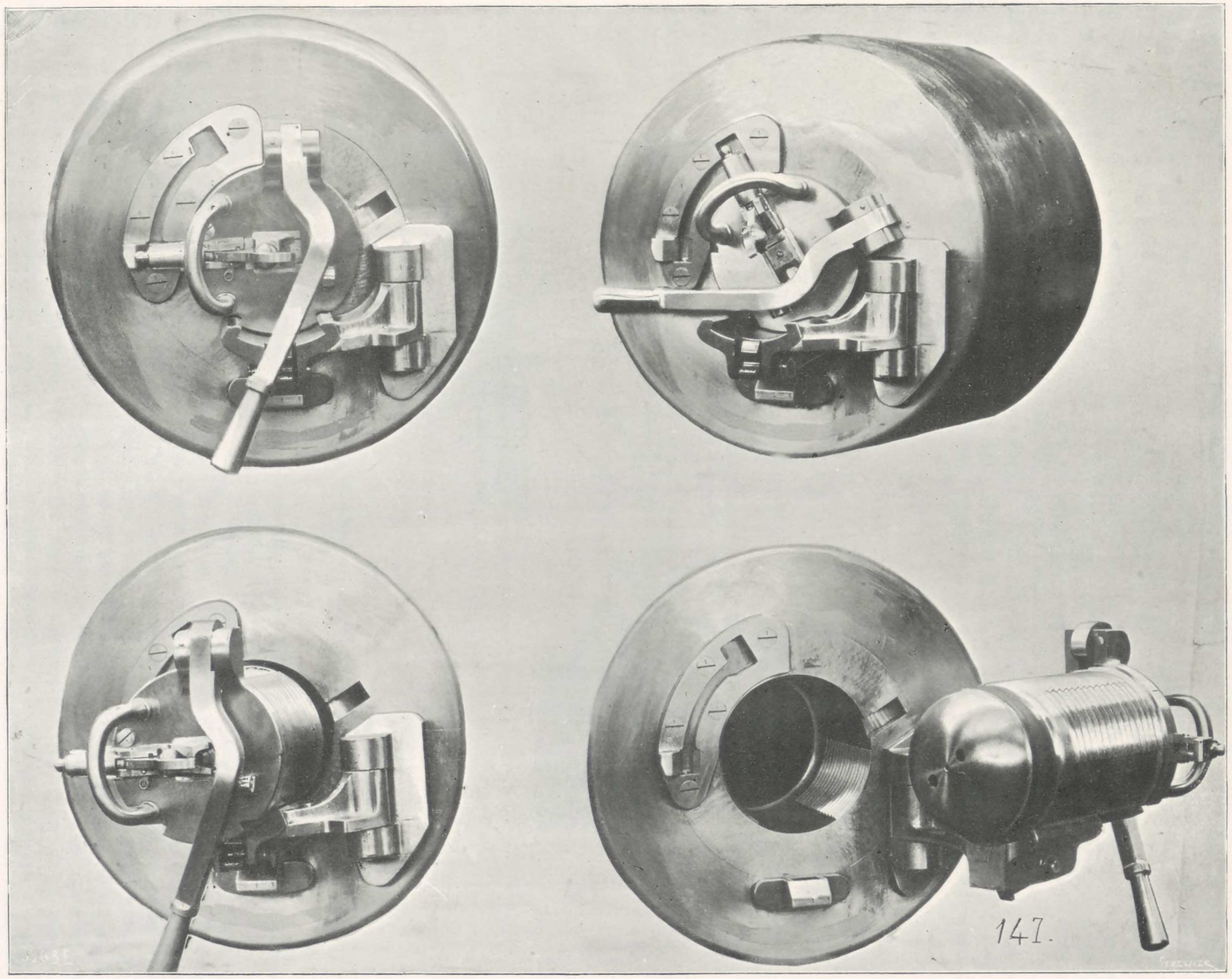
BREECH-MECHANISM FOR QUICK-FIRING GUNS.



Figs. 626 to 629. Four Positions of Breech-Mechanism, Type 2.



Figs. 630 to 633. Four Positions of Breech-Mechanism, Special Type.

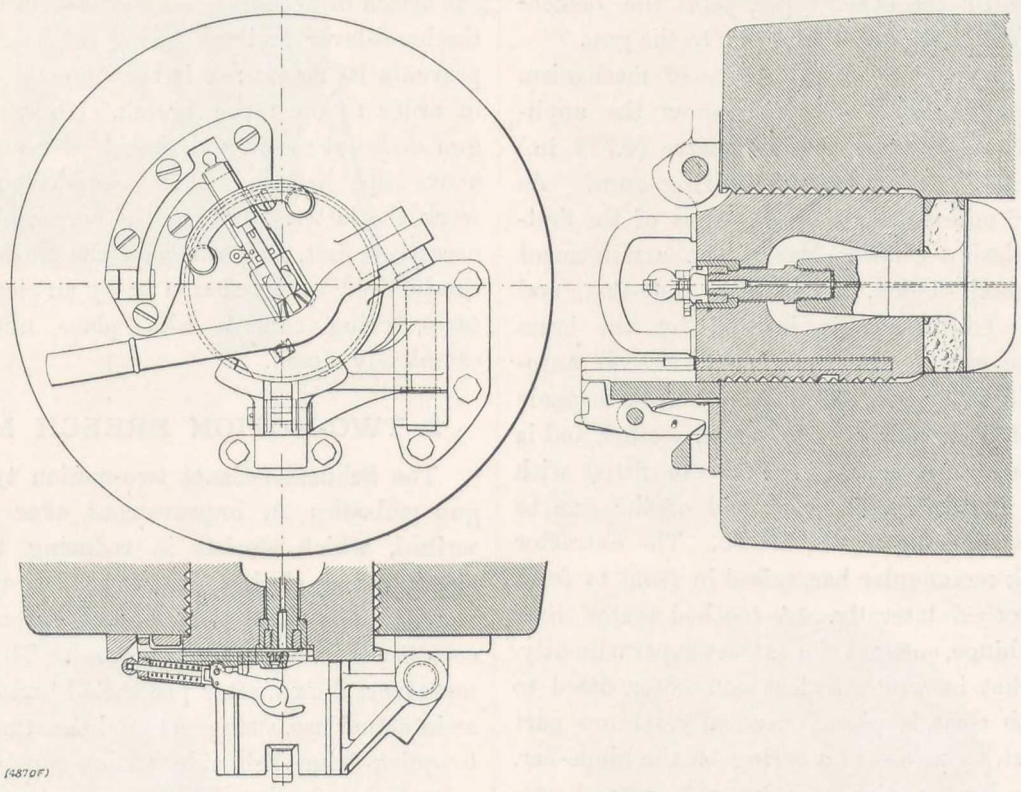


Figs. 634 to 637. Four Positions of Breech-Mechanism, Type 4.

completely closed. To prevent all backward movement of the breech-block, the hand-lever is provided with a cam, which on closing the breech, fits in a mortice. As the vent remains masked until the breech is completely closed, there is no risk whatever of premature fire.

Type 2 (Figs. 626 to 629, Plate CXII.).—In this type, firing is effected by a slide-bolt, which acts by percussion, by means of a line. No springs are used, and the striker is free only when the breech is completely closed. The percussion fuse is on the Schneider-Canet system, and is ejected automatically from the block in starting the opening motion of the breech. To prevent accidental opening of the breech-block, the lever is made with a cam, which fits in a mortice when the breech is completely placed in the vent. The striker is set by hand, and acts by means of a firing line. The lever is provided with a cam that fits in a mortice when the breech is completely closed, thus preventing the throwing back of the breech-block. The vent being closed as soon as the operation of opening is commenced, and the striker being opposite the fuze only when the breech is closed, there is no risk of premature fire. The gun can be fired both by percussion and with friction fuze. In this type only a few slight alterations would be required to use metallic cartridge-cases instead of the plastic obturator.

The above brief descriptions explain the chief characteristics of the earlier types of this system of breech mechanism; and it will be seen that these characteristics



Figs. 638 to 640. Sections of Breech Mechanism, Type 4.

closed. The gun is secure against premature firing, as the striker can only act also when the breech is completely closed.

Type 3 (Figs. 622 to 625, Plate CXI.).—This arrangement is practically similiar to the preceding one, but is used for larger calibre guns. The various parts of the mechanism have been simplified and hidden as much as possible in the breech itself.

Type 4 (Figs. 634 to 637, Plate CXIII., and Figs. 638 to 640).—In this type the gun is fired by means of a bolt that slides in the breech-piece and acts by percussion. On starting the opening of the breech, the bolt, being no longer opposite a rectangular space cut in a circular groove on the rear end of the gun, the vent cannot be freed; moreover, as the striker is maintained slightly lifted, it would not be opposite to the fuse had this already been are still more defined in the patterns that have been manufactured subsequently.

Special Type.—We now pass to a further development, illustrated by Figs. 630 to 633, Plate CXII. In this, the three movements are still effected successively, but they are continuous, so that practically they are reduced to one operation. The breech-piece consists of a cylindrical screw, but the threads are set out as on a helicoidal surface; there are two threaded parts and two interruptions. The block is carried by a bracket which pivots round a vertical hinge-bolt. The obturator consists of a plastic elastic disc of special shape, placed between the movable head and the front end of the breech-piece; or metallic cartridges may be used. Firing is effected by a sliding bolt fitted with a striker, that acts by percussion through a spring pressing against a tappet on the rear end

of the breech-block. A trigger keeps the gun cocked, and it is fired by pulling on the firing line only when the breech is completely closed. The lever is provided with a cam which, when the breech is closed, fits in a mortice in the slide-rest of the breech-screw, and prevents all accidental back movement. Until the breech is closed, the striker is not opposite the vent; besides this, the striker can only act when the breech is locked, thus preventing all accidental firing.

To open the breech, the hand-lever is brought from left to right, to disengage the cam; then the breech-block is turned round; this first disengages the threads and brings out the breech-screw to the side of the gun. The breech is closed by repeating these motions inversely.

In this type of breech, a special bolt of the same pattern as that employed in the other types, joins the breech-block alternately to the slide-rest, and this to the gun.

A good idea of the three-motion type of mechanism is given in Figs. 641 to 644, which show the application to the Schneider-Canet 12-centimetre (4.724 in.) and 138.6 millimetre (5.456 in.) quick-firing guns. As fitted to the 138.6 millimetre (5.456 in.) guns of the first-class French battleship Charles Martel, the arrangement consists of a breech-block, a pivoting slide-rest, and a double latch. Obturation is insured by the brass cartridge-case, the empty case leaving the breech automatically when it is opened. The breech-block is made with 15 interrupted threads, on four equal sectors, and is worked by means of a hand-lever; a cam fitted with a spring fits in a mortice on the rear end of the gun to prevent accidental opening of the breech. The extractor consists of a thick rectangular bar, raised in front to form a clutch and toothed laterally. A toothed sector that turns freely on a hinge, engages the extractor permanently, and forms a socket in which a cleat can enter, fitted to the bracket. The cleat is placed vertically, its top part being made to rest, by means of a spring, on the hinge-bar.

To open the breech, the hand-lever is turned one-eighth round, the small lever that works the spring cam being taken hold of at the same time, as the latter then gets disengaged from the gun, and permits the hand-lever to act freely. The screw-block is then pulled out, guided by the bracket clutches; when clear, it strikes against the butt end of the clutches, the shock causing the head of the bracket double-latch to be freed from its catch, while the heel of the latch engages in a groove made in the screw, the cleat being in the hollow made for it in the toothed sector. On pulling the hand-lever sharply, the bracket and breech-block turn round on the hinge; shortly after the turning motion has begun, the cleat strikes the toothed sector of the extractor, the shock freeing the brass cartridge-case. The rotation of the bracket in its motion to the rear, moves the toothed sector, the extractor-rod and the empty case; at the same time the hinge-bar causes the cleat head to rise, the cleat becoming disengaged from the toothed sector previous to the complete rotation of the bracket. The extractor has then been brought back to such an extent that the cartridge-case has advanced several centimetres from the rear end of the gun, and can be removed by hand. By working rapidly, the empty case would be thrown right out. On introducing a fresh cartridge, the flange on the base of the cartridge-case brings the extractor and toothed sector to their first positions. To close the breech, the usual movements are executed: the hand-lever is replaced in position, and the spring cam fits in its groove to prevent all accidental opening of the breech.

When the breech is closed, a small block worked by a spring, and arranged on the rear end of the gun, extends over the hand-lever to prevent it from moving; it is fitted laterally with a spring catch. When the gun is fired and during recoil, the block by its own weight, and under the action of recoil, enters a groove in the gun, disengages the hand-lever. and the spring catch enters a notch which prevents its return; it is then possible to work the lever in order to open the breech. In case of miss-fire, the gun does not recoil, and the block remains in its position above the hand-lever, thus rendering it impossible to work the latter. To open the breech-block it is therefore necessary, first, to push back the safety block. The gun can be fired by percussion or by an electric fuze. In both cases, firing cannot take place until the breech is completely closed.

2. TWO-MOTION BREECH MECHANISM.

The Schneider-Canet two-motion type of quick-firing gun embodies an improvement over those already described, which consists in reducing the operations for opening and closing the breech, to two distinct movements. The smaller number of parts in the mechanism constitutes another improvement. The arrangement has, moreover, shown, after protracted and severe tests, as well as in actual use, such good qualities, that it has been fitted to quick-firing Schneider-Canet guns of the most recent manufacture, and which, owing to the conditions required in service, have to undergo rough handling. Breech-blocks of this model have been fitted to guns of calibres from 75 millimetres (2.952 in.) to 15 centimetres (5.905 in.) inclusive, the latter calibre not being regarded as a maximum, as the system is well adapted for application to larger sizes. With this type, either fixed obturators or brass cartridge-cases can be used; and the mechanism lends itself therefore equally well to firing by friction, by percussion, or by electricity. The following examples, chosen among many others, will serve to illustrate the system.

Two-Motion Mechanism with Repeating Firing Device (Figs. 645 to 648).—This consists of the breech-block, the breech-block carrying device, and the firing mechanism. The hand-lever is in one piece with the rear disc of the block, which is made with two threaded parts and two interruptions; it is therefore necessary to turn this starting lever only a quarter round to disengage it; the shape and dimensions are so calculated that the breech-block need not be pulled back to cause it to leave the gun

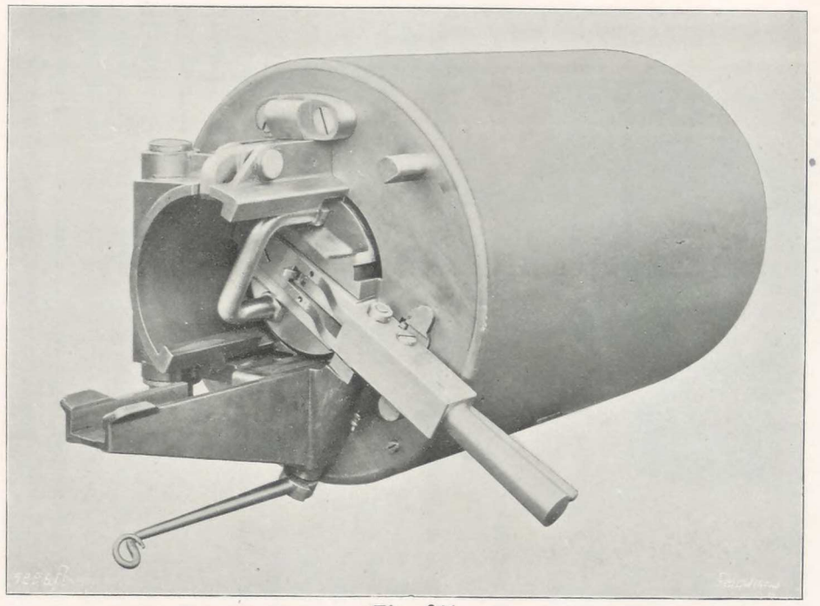


Fig. 641.

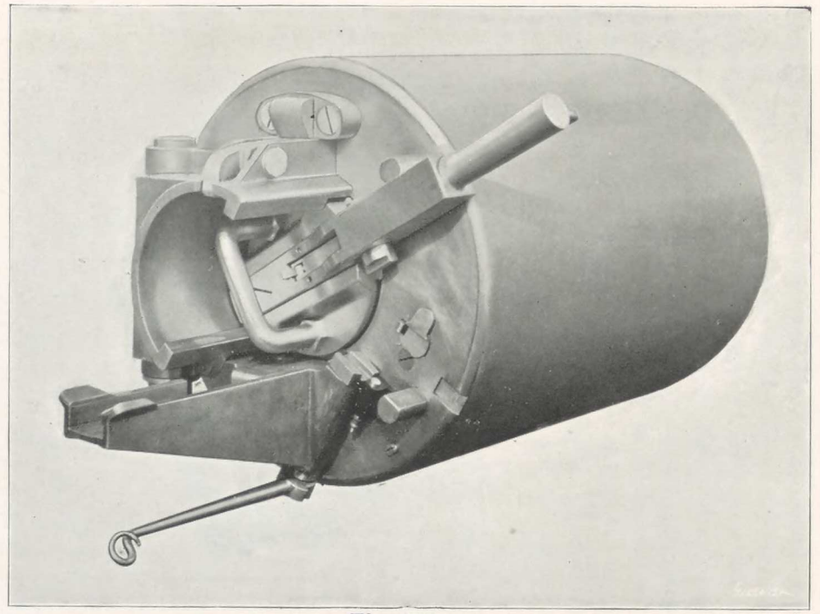


Fig. 642.

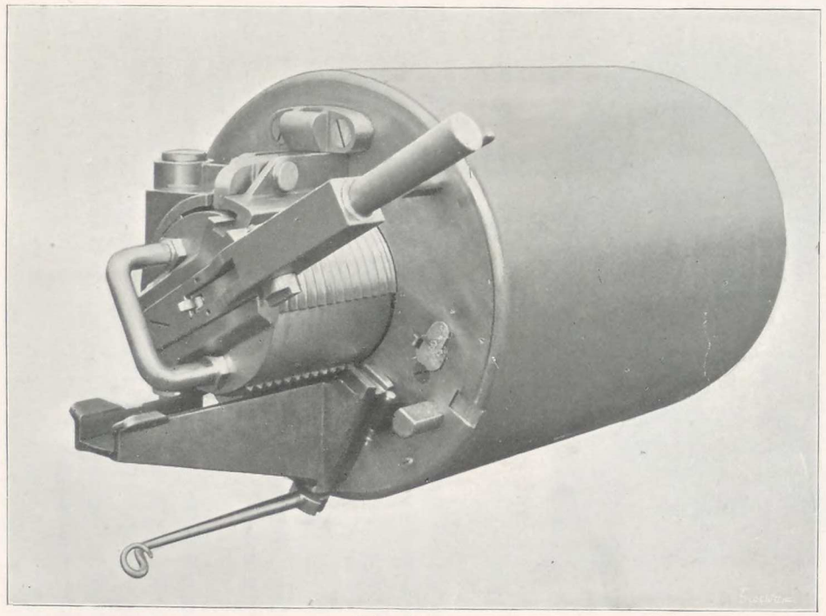


Fig. 643.

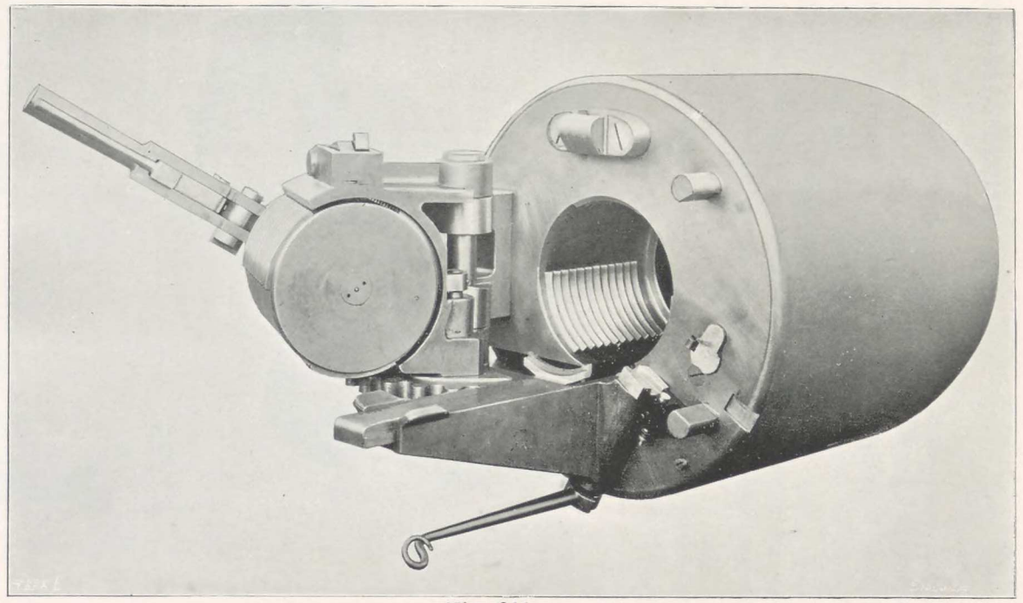


Fig. 644.

Three-Motion Breech-Mechanism for 12-Centimetre and 138.6 Millimetre Quick-Firing Guns.

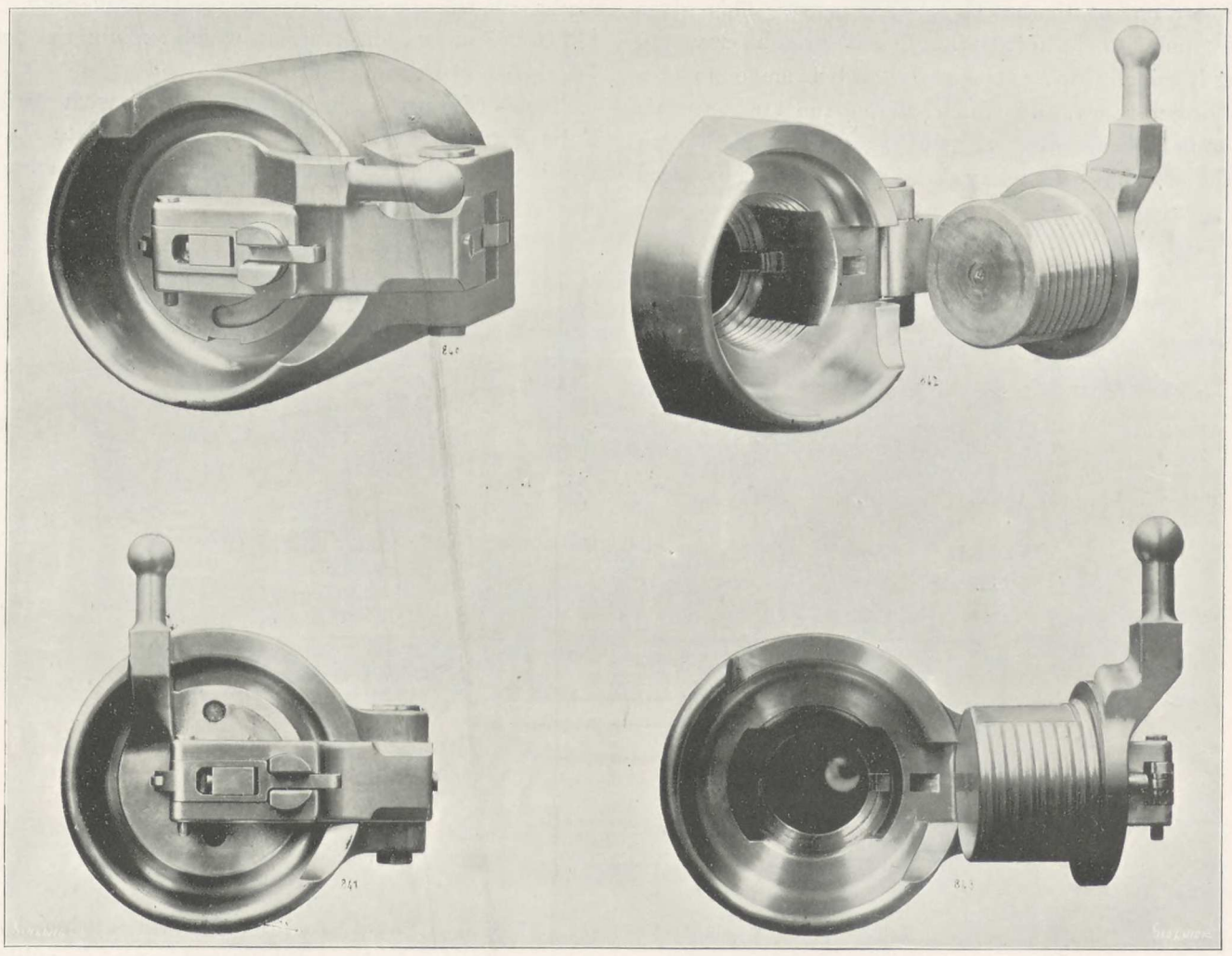
as it turns round laterally as soon as it is unscrewed. The breech-block carrying device consists of a horizontal extension hinged to the projections on the side of the gun; this extension is provided with a screwed end, on which the block is fixed by means of a bayonet joint, and it is made with a groove in which the firing striker acts; the safety arrangement against missfires is placed in this same groove. The firing device consists of a pointed striker, the trigger acting in the body and head of the striker; the arrangement, as a whole, is similar to that which will be described hereafter as fitted to the breech-pieces which open in one action.

In firing the gun, the trigger is worked by a line, the striker is drawn back, the action pressing down a spring; the trigger then frees itself, and the striker is thrown forward against the fuse. This operation can be renewed as many times as necessary without touching the breech-piece.

As a security against premature fire, the end of the trigger lever presses, through the interposition of a friction roller, on a spring bolt, which slides in a suitable latch fitted to the rear end of the breech-block. If the end of the trigger is not exactly opposite the bolt—in other words, if the breech is not completely closed—the trigger has not a sufficient range to operate the striker, and there is therefore, no risk of premature fire. When the gun is fired, the spring bolt falls down in the latch; if there is a miss-fire, the gun does not recoil, the bolt remains in place, and the breech cannot be opened.

The extractor is placed in a groove made in the wall of the breech end of the gun; the breech-block operates it in swinging round.

To open the breech, the lever is given a quarter-turn from right to left to disengage the threads; the breech-block then pivots round the hinge, and when it has turned completely, it acts on the extractor, and the cartridge-case is ejected. To close the breech, the two actions are repeated inversely.



Figs. 645 to 648. Two-Motion Breech-Mechanism, with Repeating Device.

In these actions a special spring latch unites the breech-block carrier to the block-screw and to the gun. Figs. 645 to 648 show the breech locked, the breech-block unscrewed, and the breech opened.

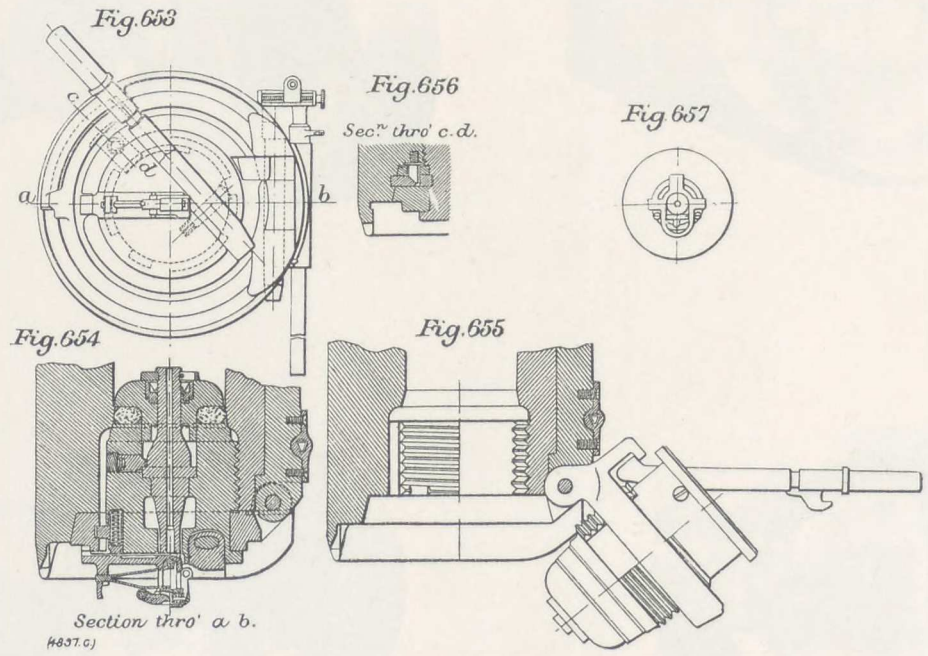
Two-Motion Breech Mechanism, with Plastic Obturator and Percussion Firing Device (Figs. 649 to 652, Plate CXV., and Figs. 653 to 657).—This type consists of a breech-screw, with obturator and movable head; of its support, and of the firing arrangement. The breech-block is in the shape of a truncated cone

with three threaded parts and three interruptions. The obturator consists of a Schneider-Canet composite plastic elastic disc placed between the movable head and the front end of the breech-screw. The breech-block support is mounted on a vertical hinge, and it carries the block in its action. The hand-lever is jointed on the rear end of the breech-screw, and when the breech is completely closed, it fits in a hollow, as shown in Fig. 649. The end of the lever opposite from the handle is finished with a projection (Fig. 655), which, when the breech-block is unscrewed, lodges in a suitably-shaped catch, on the rear end of the breech-screw support. This gives a bearing point to aid in withdrawing the breech-screw and pushing it aside. Firing is insured by a bolt made movable in the breech-screw, and which carries the striker; this works under the action of a catch-spring. To fire the gun when the breech is completely closed, the trigger is operated by means of a line, the striker being driven forward by the working of the spring. A latch made with inclined planes, similar to that already mentioned in connection with the preceding type, serves to connect the support to the block, and to the gun.

While the breech remains completely closed, a pawl which forms part of the movable hand-lever is maintained by a spring in a notch made in the part that covers the breech, thus preventing all accidental opening. When the unscrewing motion has commenced, the heel of the firing latch slides on an inclined guide cut in the breech support; the percussion lock is consequently removed from the vent as long as the breech is not completely closed, thus doing away with all risk of premature fire.

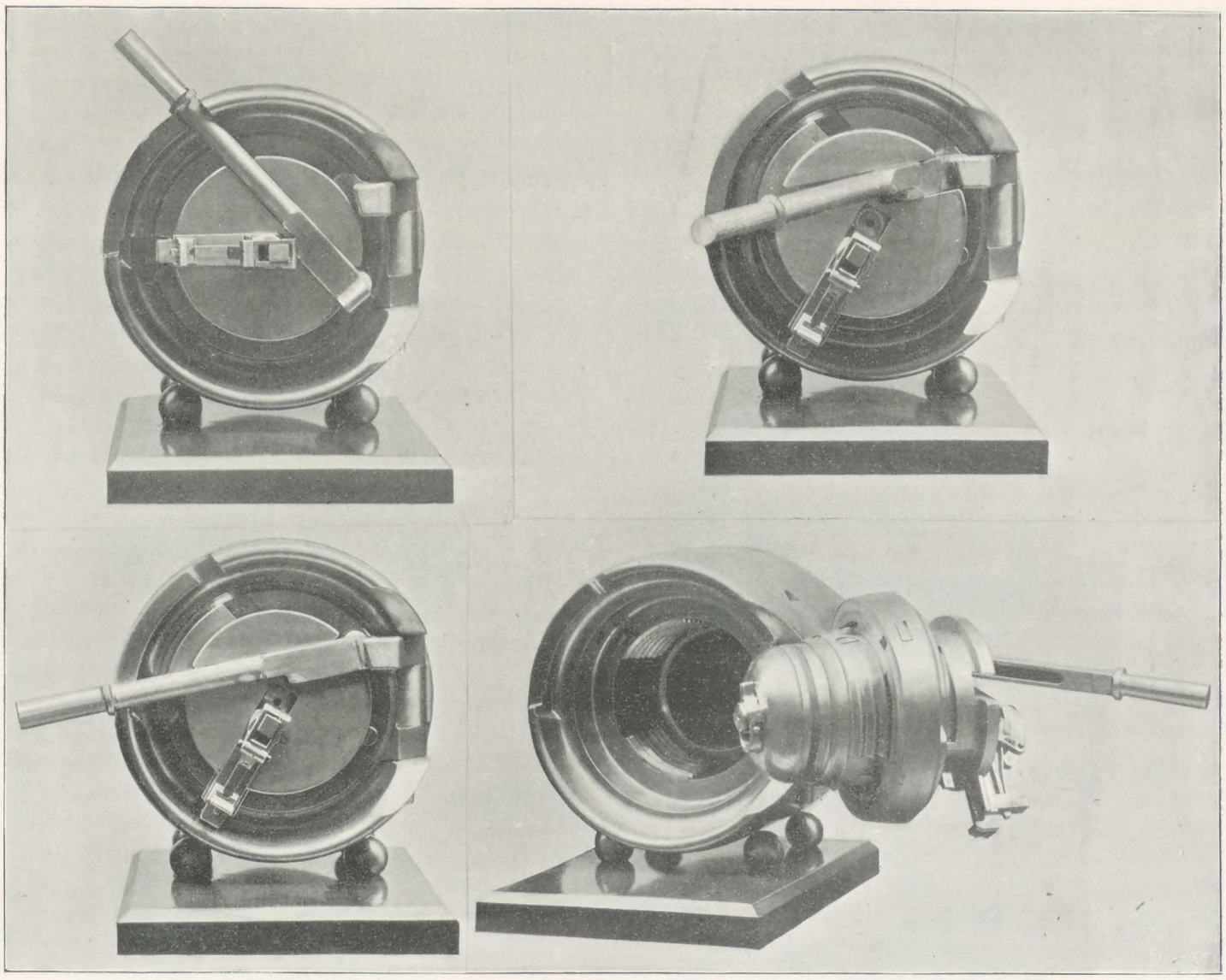
To open the breech, the hand-lever is pushed on its hinge, to press down the inside spring and disengage the pawl from the notch above referred to. The lever is then turned round 60 degrees on a plane normal with the centre line of the gun, during which time the pawl of the hand-lever slides in the groove made on the lower part of the rear end of the gun. When the unscrewing is completed, the jointed heel of the hand-lever is placed in the socket on the breech-screw support. The breech-screw can then be pulled back by means of the hand-lever, the joint of this bearing in the socket of the breech-block support, one of the clutch bolts becoming disengaged from the body of the gun, the other entering the breech-block. The mechanism can then be made to pivot to the side round the vertical hinge-bolt. To close the breech, the above actions are repeated inversely. Figs. 653 to 657 are various sections which explain the detailed description of this mechanism.

Two-Motion Breech Mechanism, with Friction-Tube Firing Device (Figs. 658 and 659, Plate CXV.).—This breech-piece is of more recent application than the preceding one; it is based on the same principles, but is of a simpler design. The breech-screw is cylindrical, and firing is effected by friction. A description of it is given, in order to point out the progress made since the date when this type of breech was first manufactured. The breech-block is provided with two threaded parts and two interruptions. The obturator consists of a plastic elastic composite disc, placed between the front end of the breech-screw and the movable head; the latter is in one piece with its shank, the vent being in the centre and ending in the rear in a socket, in which is screwed the friction tube, a safety device preventing the insertion of the tube until the breech is completely closed. The breech-block is carried by a jointed support, which pivots round a hinge bolt placed to the left of the gun, the dimensions of the various parts being such that the pivoting to the side of the breech mechanism can take place without it being necessary to draw the

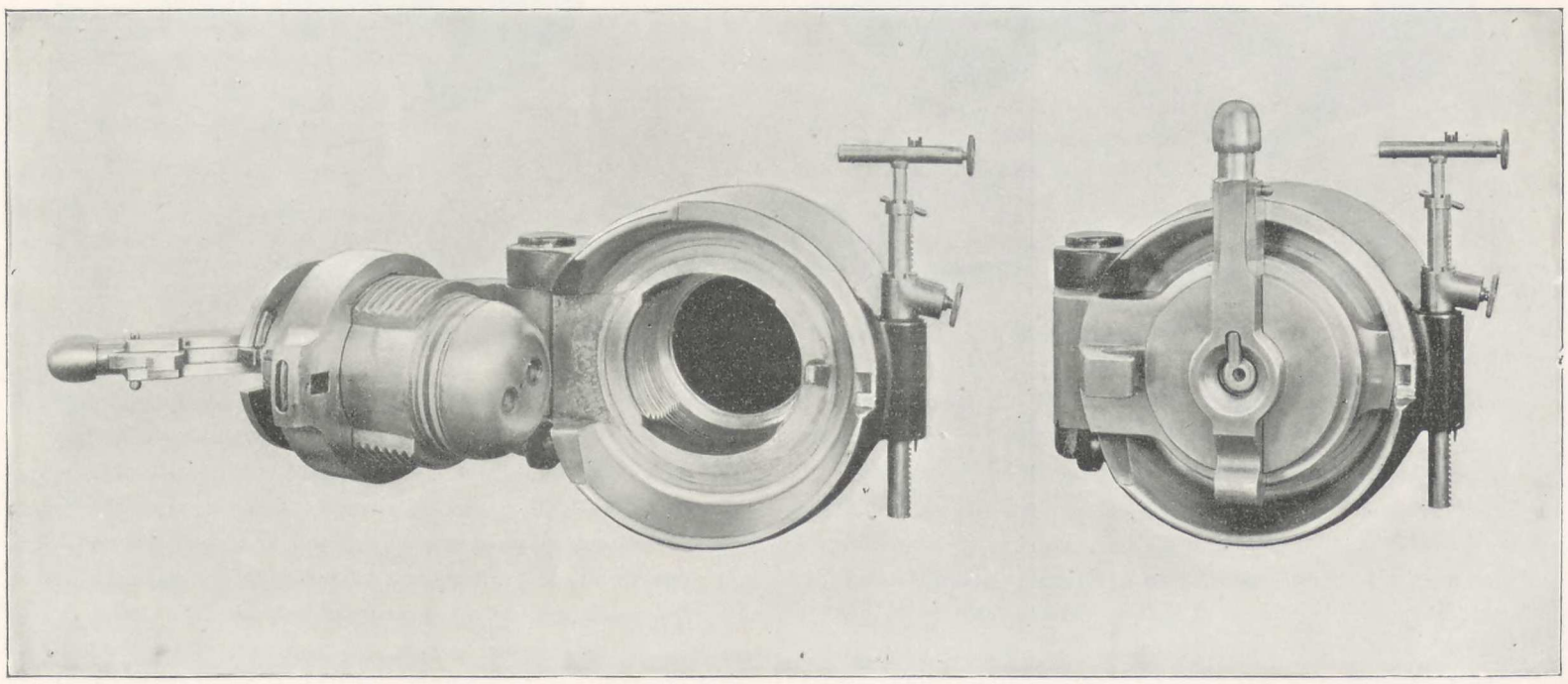


Figs. 653 to 657.

BREECH-MECHANISM FOR QUICK-FIRING GUNS.



Figs. 649 to 652. Two-Motion Breech-Mechanism, with Percussion Firing Device.



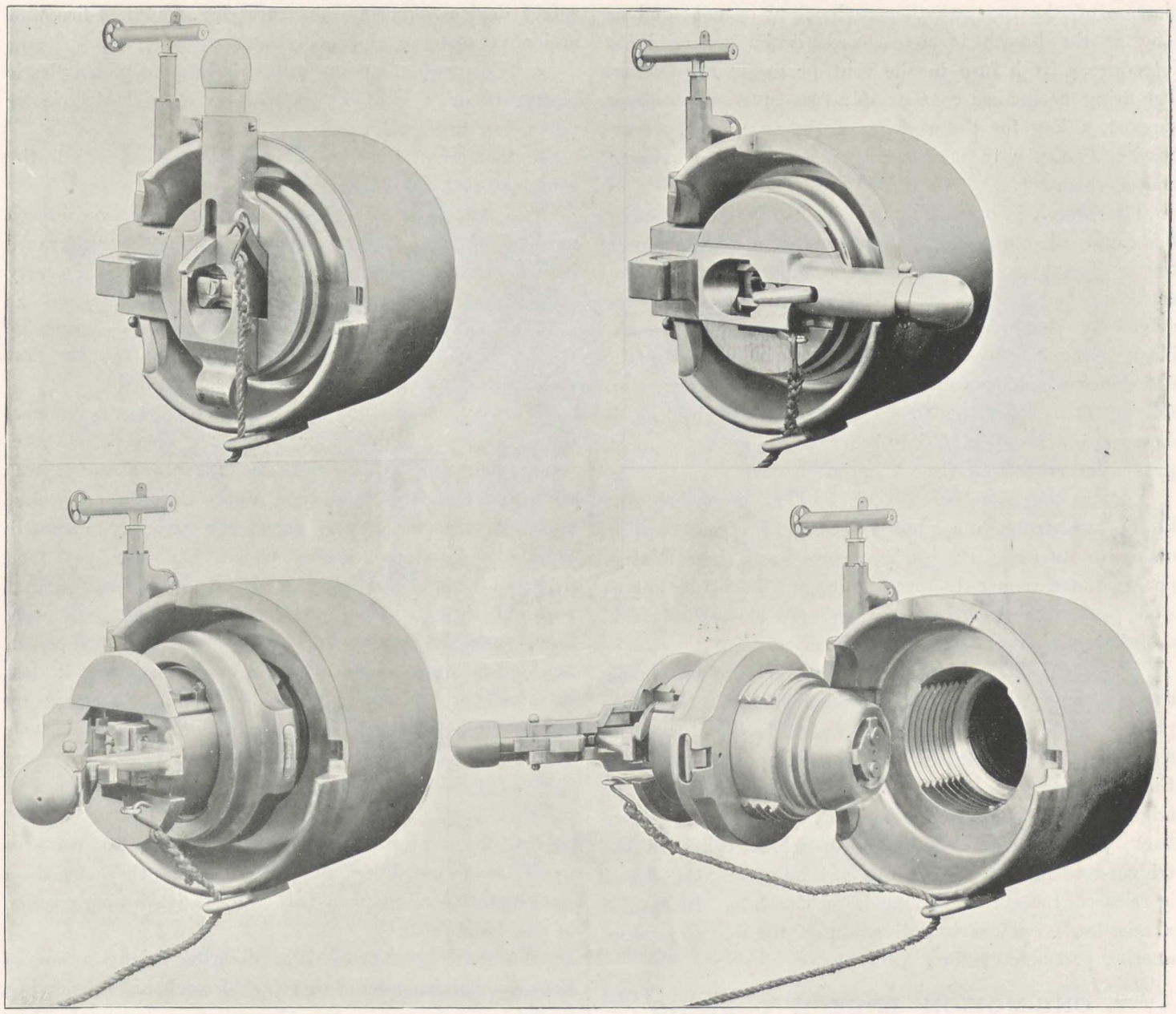
Figs. 658 and 659. Two-Motion Breech-Mechanism, with Friction-Tube Firing Device.

breech-screw completely back in the support; the travel of the block for extraction is very much reduced, which enables the breech to be opened in two actions only.

The head of the hand-lever is slotted, and is in one piece with a double latch; it is governed in its sliding action by an inside spring. The lever is, moreover, fitted with a joint, which, after the unscrewing of the breech-piece, lodges in a socket which forms part of the breech-

of the heads of the latch holds the lever to the gun when the breech is closed, the other head leaves the vent free only when the breech-block is placed completely home.

To open the breech-block, the hand-lever is brought to the right to disengage the breech-screw; the lever is then pulled back, thus withdrawing the breech-screw in its support, and causing the whole of the mechanism



Figs. 660 to 663. Two-Motion Breech-Mechanism, with Percussion Fuse.

screw support. Firing is effected by means of a line that causes the friction tube to act.

An automatic double-ended latch on the right hand of the breech-block support, serves to fix this to the gun when the breech is closed, and also to hold the breech-screw to the carrying ring during the opening of the breech.

The head of the hand-lever, in conjunction with the double latch above referred to, constitutes the means that prevent the accidental opening of the breech while affording complete safety against premature fire; one

to turn round on the vertical hinge-bolt. To close the breech, these movements are repeated inversely.

This breech-closing arrangement is characterised by great simplicity and by a small number of parts; it is therefore easily worked and kept in order.

Two-Motion Breech Mechanism, with Percussion Firing (Figs. 660 to 663).—This type differs from the preceding one (see Figs. 658 and 659) only as regards the firing device, which is specially arranged for a percussion fuse. Percussion is effected direct, with repeating action, the

fired fuse being ejected automatically; the whole of the device is placed in the breech-block. All the pieces are so arranged that they can be fitted together separately from the gun, so as to form a whole block, which can be placed on the end of the movable head shank before attaching the lever, the latter holding the whole mechanism in place.

The gun is absolutely safe against premature fire, for the action of opening the breech causes the automatic ejection of the fuse, whether it be fired or not; and as long as the breech is not closed, it is impossible to introduce a fresh fuse in the vent, or to set the striker. The firing mechanism consists of a fuse-cover, a fuse-cover support, a key for the working of the fuse-cover, a percussion frame, with main-spring and needle; a trigger, and an extractor.

The breech is opened by pressing on the lever handle; this causes the clutch to leave the socket made in the gun, the lever is then turned a quarter round to the right, disengaging the breech-screw. In this action the working key driven by the breech-block, and bearing on the breech-block support, turns round on its centre and lifts the fuse-cover which acts on the heel of the extractor, thus forcing it to eject the fuse, When the breech-block is disengaged, the working key bears on the block support, preventing all action of the firing mechanism.

On drawing the breech-block out of the breech, the key is withdrawn also, but is prevented from turning owing to its heel; the various parts keep their relative positions, and render the introduction of a fresh fuse impossible, thus insuring complete safety. To close the breech, the above actions are repeated inversely.

When the breech-block is completely screwed home, the key, under the action of the fixed handle, returns into position with the fuse-cover and frame. The fuse can then be placed in the vent after raising the fuse-cover. Firing is effected by means of a line attached to the trigger-lever. The percussion frame, on being drawn back, presses on the main spring which bears on the trigger-return device; after a certain travel, the frame is released, the spring driving it on the fuse. In case of a missfire, it suffices to pull again on the line to produce another percussion action.

3. ONE-MOTION BREECH OPENING MECHANISM.

The Schneider-Canet guns were the first to be fitted with this type of screw breech mechanism; they were quick-firing guns of 57 millimetres (2.244 in.), 65 millimetres (2.559 in.), 10 centimetres (3.937 in.), 12 centimetres, (4.724 in.), and 15 centimetres (5.905 in.) in calibre.

From the commencement, the details of the various types of Schneider-Canet guns, designed with a view to obtain rapid firing, did not refer chiefly to the various parts of the carriage, but to the breech mechanism. The principal considerations which served as a basis in the calculation of this all-important part were the following:

a. The reduction to a minimum of the necessary operations for opening, closing, and firing.

b. Complete safety afforded to the *personnel*, so that the attention of the men serving the gun might be concentrated upon the rapid manœuvres required; and this state of safety results from, (1) the automatic succession in the positions of the breech-block, which does away with all hesitation as regards the order in which the various actions should be effected; and, (2) providing safety devices against premature fire, hanging fire, and accidental opening of the breech.

c. The possibility of using indifferently a plastic obturator or a metallic cartridge-case, and electric or percussion firing devices.

d. Reduction in the effort necessary to effect the complete opening of the breech.

The first type of Schneider-Canet one-action breech mechanism fulfilled all these conditions, and its appearance in the service proved a great success. During the early period, and up to the present date, it has undergone—as has, in fact, the whole of the material — successive improvements in the details of the mechanism, the first principle of the system not having been modified.

We have seen that the design of the Schneider-Canet guns of high power, and great length of bore, was very much criticised in the first instance. It was the same with this new type of breech. When it first appeared its value was somewhat strongly disputed, especially by those works which had not yet then departed from the ordinary screw breech mechanism, that required three distinct actions in opening. As soon, however, as the results of trials made with this new breech mechanism were known, the arguments against it lost in intensity; and the principle of opening the breech by one single action of the lever in a horizontal plane, was reproduced and applied by various foreign makers more or less successfully. At the present time the advantages of this type of breech are no longer disputed, and several firms who had criticised it the loudest, use—for every medium-calibre quick-firing gun they build—a breech-closing mechanism that works with a single action of the hand-lever.

We shall now proceed to describe briefly a few of the principal examples of this type of mechanism, following, as far as practicable, the chronological order of their adoption in service.

Cylindrical Breech-Screw, with Repeat-Firing Action (Figs. 664 to 668).—This consists principally of the breech-block, the breech-block support, and the firing device.

The breech-block is cylindrical, with four threaded parts and four interruptions; it is arranged for firing with metallic cartridge-cases, and is provided with two claws in front, which form extractors, and which are so disposed as to take hold of the cartridge-case flange, and withdraw it gradually during the opening of the breech. It is provided in the rear with a toothed sector, in the continuation of which is a longitudinal hollow rack, inside the breech-

block itself and in the direction of its main centre line. The breech support carries the whole of the mechanism in the various positions it takes, and pivots round a vertical bolt held in a lug fitted at the side of the gun; it is provided with the double-acting Schneider-Canet latch, already described in a preceding chapter, and which serves to connect, at the proper moment, the various elements. The hand-lever operates a compound pinion mounted on the pivot of the breech support, and which consists of an endless screw that engages the toothed wheel of the breech-screw rings and a section of wheel with cylindrical teeth that works the longitudinal rack. When the breech is completely closed, the lever enters a notch in the rear, and presses down a tongue spring which secures the system, and prevents the accidental opening of the breech. The firing device is repeating, and embodies the general arrangements previously described with the two-motion breech-blocks, and also their safety appliances.

To open the breech, it is sufficient to turn the hand-lever round in a horizontal plane. During the first period, the endless screw arrangement acts on the toothed wheel, and causes the breech-block to revolve. In the second period, the cylindrical teeth of the pinion engage the rack, and effect the withdrawal of the breech-screw. The continued action of the hand-lever brings the whole of the mechanism to the side, leaving the breech of the gun free. To close the breech, the hand-lever is brought back.

Cylindrical Breech-Block, with Repeat Firing Action (Figs. 669 to 671).—This type contains the same principal elements as the one just described; it differs from it, however, in this detail, that during the opening and closing actions, the breech-block is not shifted with relation to the seating, the swinging of the mechanism to the side taking place immediately after unscrewing.

The block is cylindrical, with two threaded parts and two interruptions; a screwed cylindrical part is cut out centrally in the rear, thus forming a toothed socket for a pivot of equal diameter carried by the breech-screw and the support. On the right the block is fitted with a toothed wheel arrangement, of the same type as that described for the preceding breech-piece; the seating is cut in such a way that the block can enter the gun simply by bringing round the hand-lever, no shifting action being necessary.

The breech-block support is in the form of a disc; it completely closes the gun in the rear, and affords, in consequence, full protection for the various parts of the mechanism. It pivots round a vertical hinge fitted to the right of the breech-end, and carries the block through the screwed socket and pivot mentioned above. It carries also on the right, the socket for the endless screw, which works the pinion that forms part of the breech-screw,

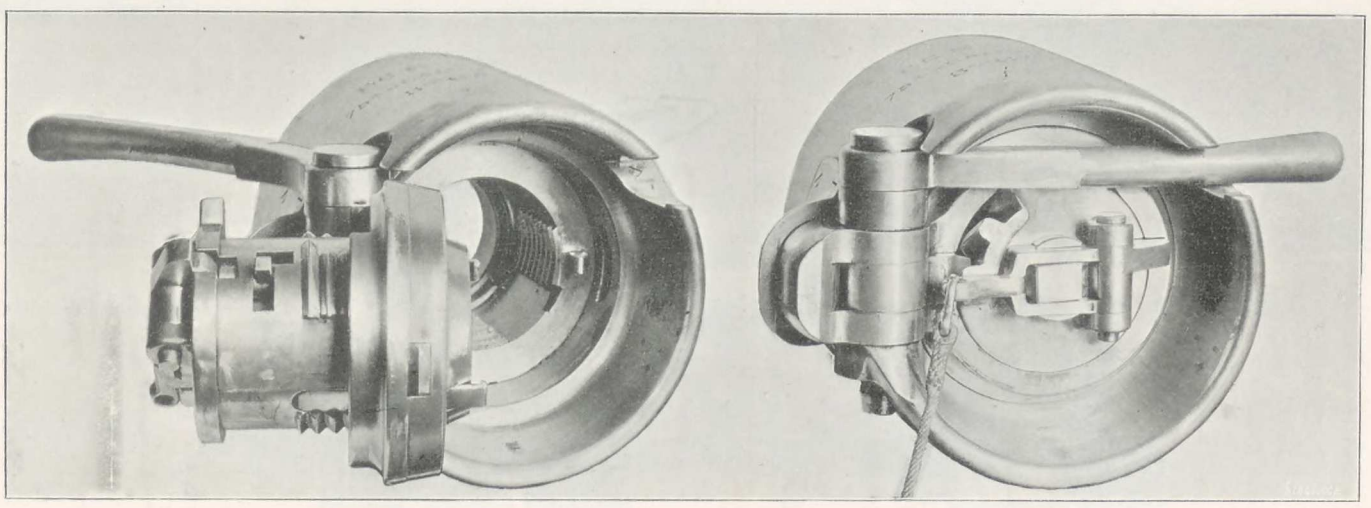


Fig. 664.

Fig. 665.

Fig. 666

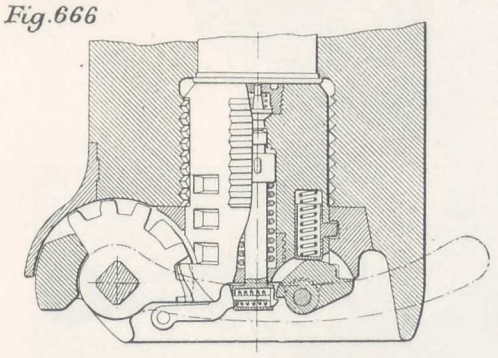


Fig. 667

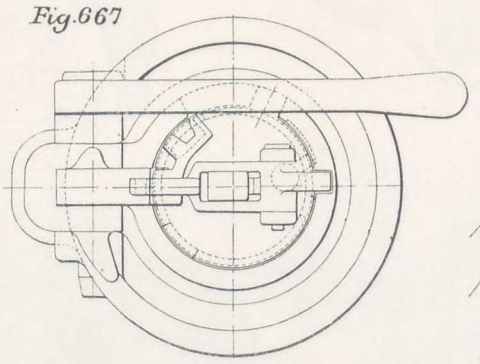
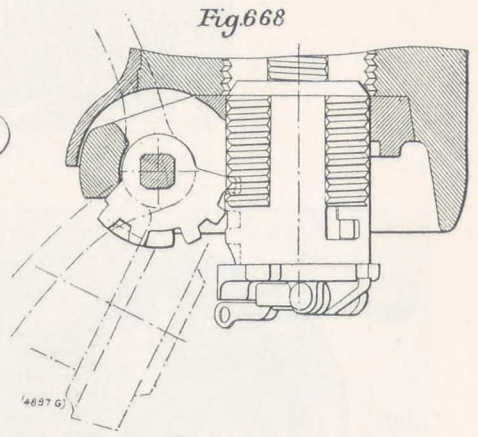
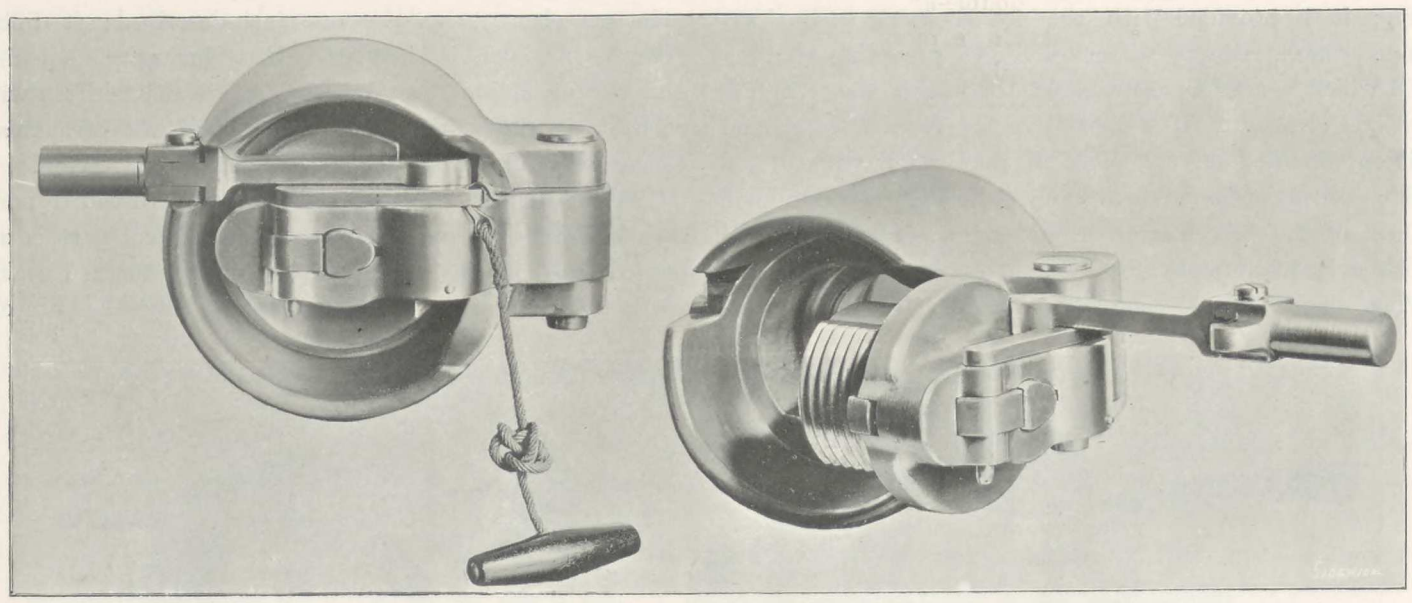


Fig. 668



Figs. 664 to 668. Single-Motion Breech-Mechanism, with Repeating Firing Device.

and on which the hand-lever is fitted. This is provided with a jointed handle fitted with a catch, which prevents the accidental opening of the breech. The repeat firing



Figs. 669 and 670. Single-Motion Breech-Mechanism for Quick-Firing Guns, with Repeat-Firing Action.

Fig. 671

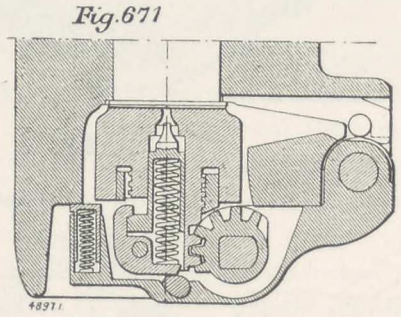
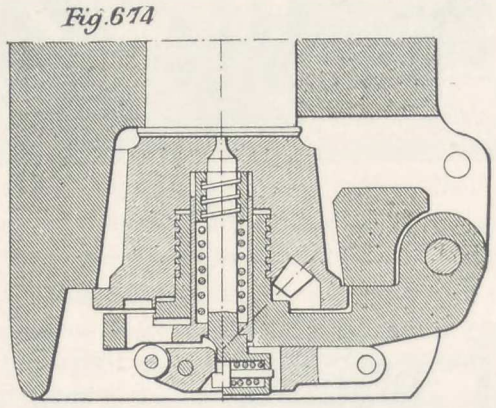
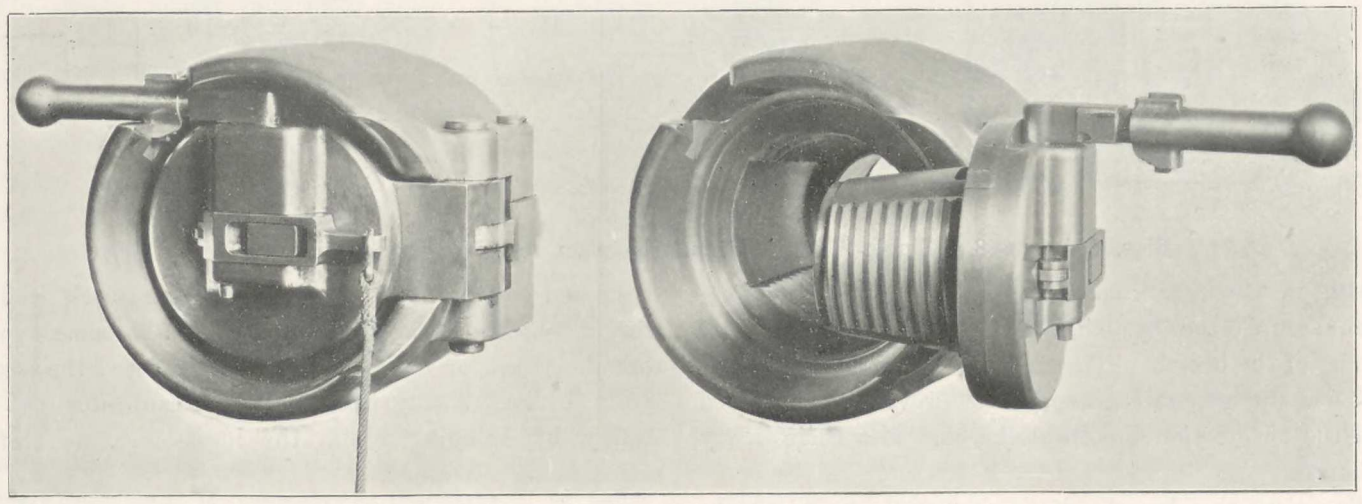


Fig. 674





Figs. 672 and 673. Single-Motion Breech-Mechanism for Quick-Firing Guns, with Conical Block.

action is of the type already described; it is worked by a horizontal lever placed immediately below the hand-lever, and is fitted with the required safety devices. A double-ended extractor is lodged in the gun, and oscillates freely to eject the empty cartridge-cases; it is worked by the butt-end of the breech-block support, which bears on it when the screw is made to swing completely to the side. A spring latch, which serves solely to fix the screw on its axis as soon as the swinging to the side has commenced, is provided on the left side of the screw support. When the latter comes in contact with the rear-end of the female screw, this connection ceases.

To open the breech, the hand lever is brought round

from left to right; during the first period the catch leaves the gun, and the lever, on getting away from the breech-block support, works the endless screw, which produces the release of the block. In the second period, the whole of the mechanism, drawn by the hand-lever, pivots round the vertical hinge, until the breech of the gun is completely freed, the latch fixing the block on its axis; when the swinging round is complete, the mechanism bears on the heel of the extractor, which effects the ejection of the cartridge-case.

to the centre line of the gun. It is united to the support by a screwed joint of the type described for the preceding breech-piece. The breech-block support consists of a circular disc, which pivots round a vertical hinge on the right hand of the gun; it carries all the mechanism. In its central plane is the socket for the conical pinion fitted to the hand-lever. The lower part of the breech-block is fitted with a pinion of the same shape, the two pinions, by acting on the hand-lever, screwing or unscrewing the breech-block in its seat.

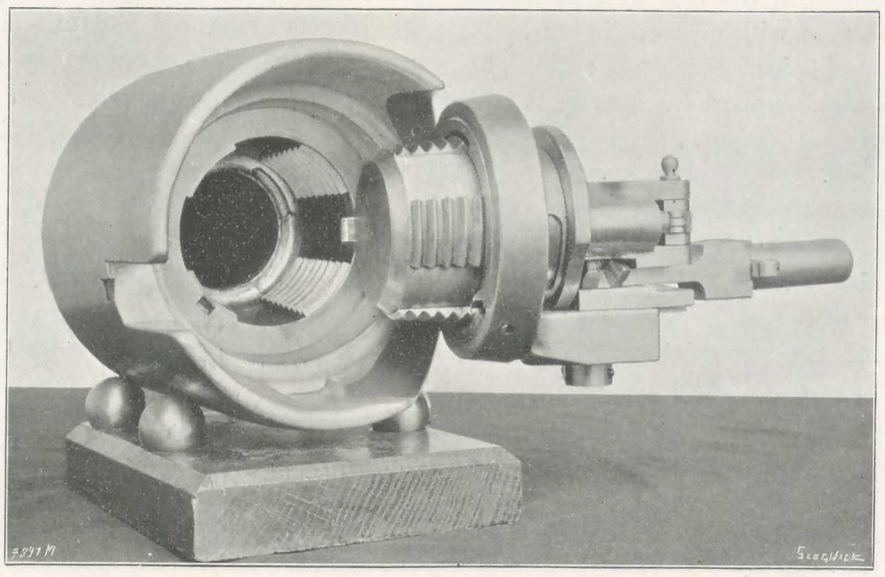


Fig. 675.

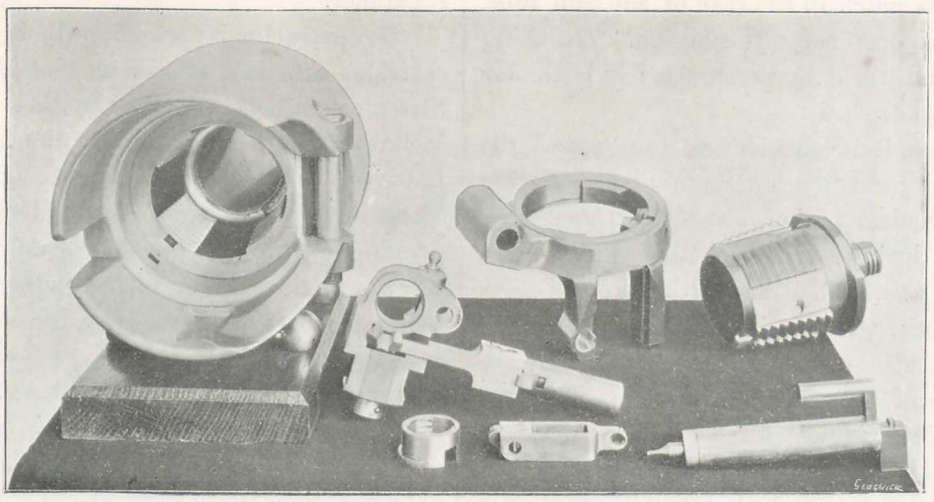


Fig. 676. Single-Motion Breech-Mechanism for Quick-Firing Guns, with Conical Block.

To close the breech, the action is repeated inversely. When the breech is closed, it is sufficient to pull the firing-line to fire the gun; the firing device cannot act until the breech is completely closed.

Conical Breech-Block, with Repeat Firing Action (Figs. 672 to 674).—This type is very similar to the preceding one, though the breech-block is conical, and the working mechanism consists of conical pinion gearing.

The block has two threaded parts and two interruptions; swinging to the side takes place immediately after unscrewing, the block not being shifted with regard

The hand-lever is provided with a spiral spring, the object of which is to ensure the locking of the system when the breech is completely closed. The extractor, latch, firing device, and general working of all the various parts are similar to those described with the preceding breech-piece.

Conical Breech-Block, with Shifting Action (Figs. 675 and 676).—This differs from the preceding type, as the block is slightly shifted in its support; moreover, the working lever is fitted to the lower part of the breech-block. The latter is slightly conical, and has four threaded

parts and four interruptions; there is only one clutch ejector, of the type already described. On the rear is a conical toothed arrangement that gears into a pinion worked by the lever; this produces the necessary partial revolution of the breech-screw. On the continuation of the breech-block and on its centre-line, is a pivot threaded on its outside circumference on two sectors, there being also two interruptions. When the breech is closed, the block support lodges in a rabbet in the rear-end of the gun.

This support is continued in the rear by a horizontal frame that forms a slide; as will be seen in Fig. 676, which shows the breech mechanism taken apart; the right-hand side of the breech-block support frame is made with a circular groove on its lower surface, the groove ending in a semi-cylindrical bearing.

The mechanism is carried entirely on the supporting frame, and consists of the conical gearing mentioned above, and of the jointed hand-lever. On the first arm of the lever is a slide that carries the pinion centre, and which fits to the breech through a bayonet-joint, of which the breech-block rear pivot forms one of the elements. The second arm ends in a roller, which, during the operation, moves in the lower groove of the support above referred to, and, by bearing on the bottom of the groove, insures the removal of the breech-block from the breech and its swinging to the side of the system.

The working lever is fitted with a jointed handle provided with a catch; this, when the breech is completely closed, enters a notch in the rear of the gun tube, and prevents accidental opening of the breech. The firing device is repeating, and works by percussion; it is similar to the one previously described.

To open the breech, it is sufficient to turn round the hand-lever from left to right in a horizontal plane. During the first period the conical pinion effects the unscrewing of the breech-block; during the second, the roller on the smaller arm bearing at the bottom of the groove helps to withdraw the block, which slides on the horizontal frame. The action continues without interruption by the swinging to the side of the whole mechanism. To close the breech, the hand-lever is turned from right to left.

Cylindrical Breech-Block, with Automatic Trigger-setting Action (Figs. 677 to 679, Plate CXVI.).—In certain cases the method of working by conical pinions or endless screws, described for preceding types, is replaced by a rack which acts direct on cylindrical toothed gearing in the rear part of the breech-block. A large number of quick-firing Schneider-Canet guns in service at the present time are fitted with this type of breech-closing arrangement. They have given the best results.

The breech-block has two threaded parts and two interruptions. Its shape and dimensions are such that it is not necessary to draw it back to disengage it from the seat; once turned, it is immediately withdrawn by its support. This pivots round a vertical hinge; it contains a holding and guiding gear for the block, and sockets for the various parts of the mechanism and firing device. The working gear proper consists of a hand-lever, a rack, and the toothed part cut in the rear of the breech-block. The lever is in one piece with the hinge-bolt, and is fitted with a pivot that works the rack, and a heel that effects the swinging round of the breech-block support. The rack is guided throughout in the support, and engages the teeth of the block; on the other end is a socket in which fits the hand-lever pivot.

The percussion piece is made with two helicoidal curved planes, cut symmetrically one with the other; on opening the breech, these ascend two similar planes cut in the breech-block. The main spring rests on a ribbed tube which butts on the breech-block, and cannot follow the longitudinal action of the percussion piece. A pin, which runs through the block support and the percussion piece, prevents the latter from turning round, while it permits the cocking of the system on opening the breech. Firing can also be effected by electricity, in replacing the percussion piece by a contact pin.

The electric-firing device has a single pin, which, under the action of a spring, extends slightly beyond the front of the breech-block, and which touches, when the breech is closed, the centre of the electric fuse, screwed in the bottom of the cartridge-case. An insulated wire unites this pin to a switch. The operator fires the gun by closing the circuit. To prevent missfires or delays in firing, all the contacts are covered with silver, and a few seconds before it is required, the battery is worked on a high shunt-resistance.

The extractor is fork-shaped; it disengages the empty cartridge-case and effects its ejection. To this end it is fitted on a bolt provided with a stud, moving in an incline cut in a tube fitted to the hinge-bolt. When the breech is completely closed, the hand-lever clutches the block-support automatically, and prevents all accidental opening of the breech. The catch being in the breech-screw and the trigger in the breech support—the trigger being, moreover, governed by the end of the firing-lever placed on the rear end of the gun—the gun cannot be fired until the breech is completely closed.

To open the breech, it is sufficient to press on the handle to disengage the clutch at the heel, and to bring the lever, in one action, from left to right. In doing this, the lever withdraws the rack, and the breech-block becoming disengaged, pushes back the percussion-piece and sets its spring. When the breech-block is thrown back, the catch engages under a shoulder made on the rear of the percussion-piece, and keeps it cocked. When the block is quite unscrewed, the driving heel bears on the block support, and brings it to the side, while the latch bolt, pushed by its spring, engages in the rack and fixes the block in its support; the extractor then disengages the empty cartridge-case and throws it back. To close the breech, this action is repeated inversely.

To complete our review of the various Schneider-Canet systems of breech mechanism for quick-firing guns of

BREECH-MECHANISM FOR QUICK-FIRING GUNS.

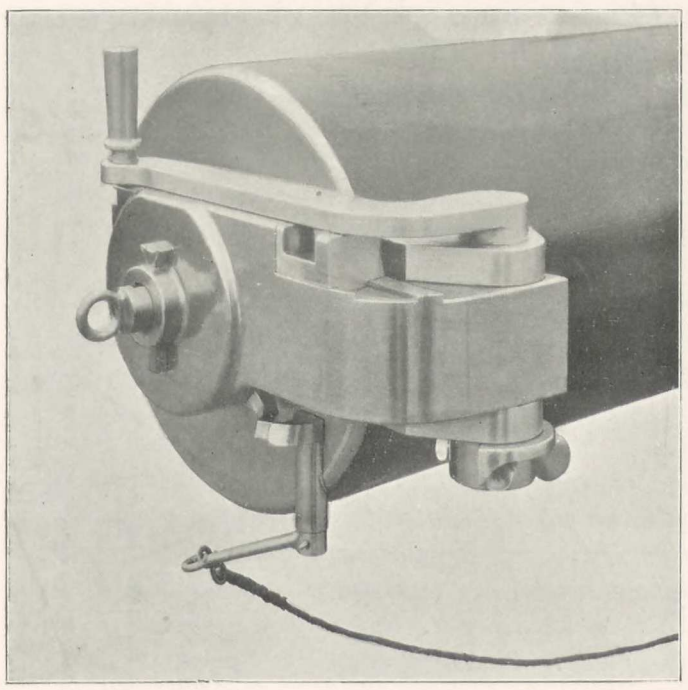


Fig. 677.

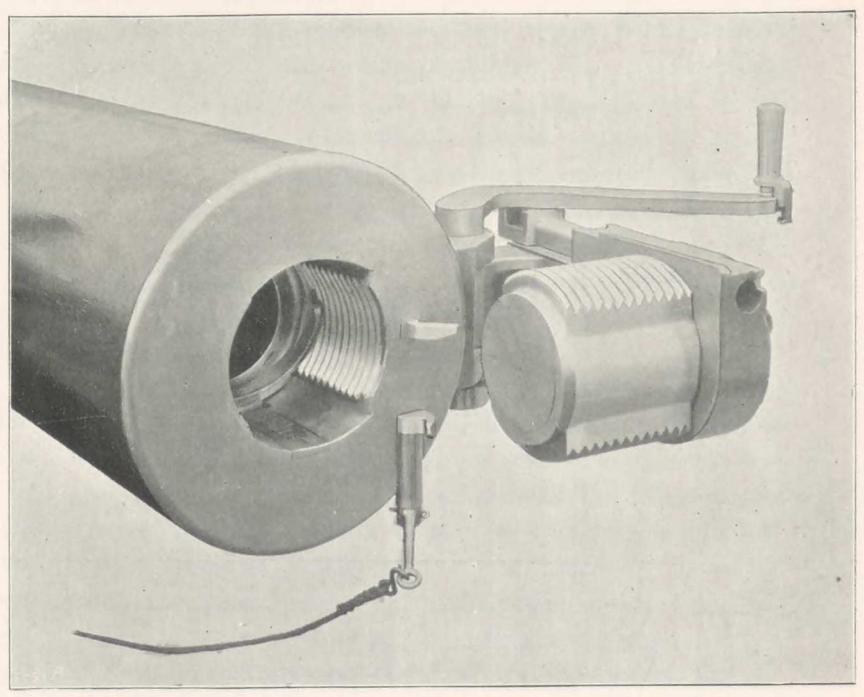


Fig. 678.

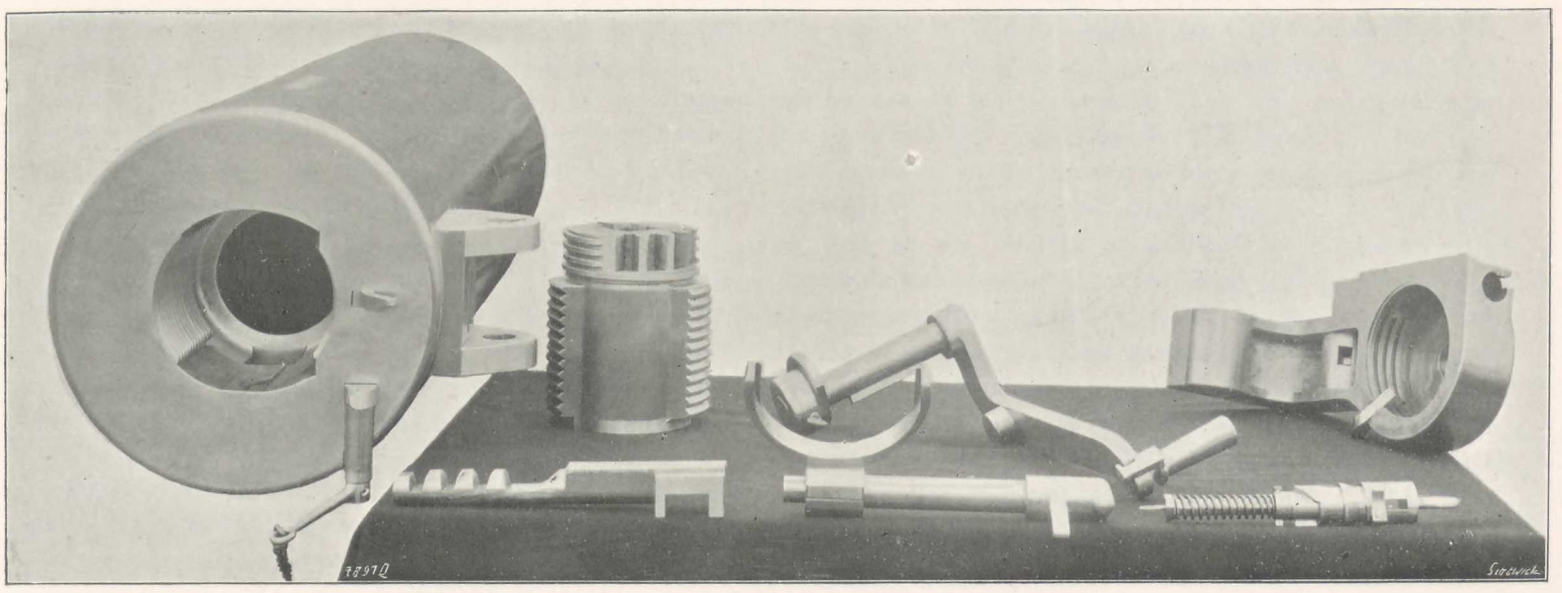


Fig. 679. Single-Motion Breech-Mechanism for Quick-Firing Guns, with Cylindrical Block and Automatic Firing Device.

medium calibre, we will add particulars of a one-motion type which, at the present time, is being fitted to a large number of guns in course of construction for various Governments at Creusot and at Hâvre. The engravings illustrating this description are reproduced from photographs, typical examples of the various calibres having been selected.

Cylindrical Breech-Screw, with Repeat-Firing Action, Operated Laterally (Figs. 680 to 682, Plate CXVII.).—In this mechanism several features of the breech-pieces already described are reproduced, but with the important improvement of a special device by which a handle is placed within easy reach of the man training the gun, and by which, without being obliged to take his eye off the tangent sights, he can fire immediately the aim comes in the line of sight.

The main parts of this mechanism are the breech-block and support, the operating details, the extractor, the firing device and controller, and the safety arrangement.

The breech-block is cylindrical, with four threaded parts and four interruptions. At the rear it ends in a flange which checks its travel in the supporting ring; in this flange is placed a conical toothed ring which operates the screwing and unscrewing of the block. The two clutches that form the extractor are jointed opposite each other in front of the block. The middle of the breech-block is extended at the rear by a hollow cylinder of small diameter, the surface of which is formed with two threaded parts and two interruptions; this constitutes the pivot around which the breech-block turns in its angular movements in the seating of the gun.

The ring supporting the block is lodged in a recess made in the rear of the gun, the support consisting of a frame perpendicular to the face of the breech. This support carries the block and the whole of the mechanism during the periods of opening and closing, and it pivots round a vertical hinge-bolt. The two sides of the support form a path for the slide that carries the operating apparatus, the left side ending in a sector in the lower surface of which a circular groove is cut.

The operating device consists of:

1. The working lever formed of two horizontal arms, the longer one ending in a vertical handle; at the end of the smaller arm and on a vertical axis is a roller which, travelling in the circular groove above mentioned, allows the breech-block to be removed from the seating when it has been turned through 45 deg.

2. Of a pair of bevel-toothed wheels arranged so as to cause the breech-block to turn until the threads are all disengaged; this gear consists of a pinion keyed on a vertical axis fitted to the working lever, and a conical toothed ring fitted in the flange of the breech-block.

3. Of a brass guide-block formed by the junction of two hollow cylinders, the centre lines of which meet at 90 deg.

The vertical cylinder which receives the axis mounted on the working lever is fitted at its lower part with slide-blocks which move in the slides of the support frame; the horizontal cylinder, through the centre of which the firing device passes, is connected to the breech-block by a bayonet joint, one of the elements of which projects beyond its rear face. This arrangement, which leaves the mechanism free for the unscrewing of the breech-block, also allows it to be removed from the seating by acting on the working lever.

The extractor consists of two clutch levers carried in the breech, and which withdraw the cartridge-case during the removal of the block. These levers which, when the breech is completely closed, engage the flange of the cartridge-case, fit in grooves of suitable shape, cut in the thickness of metal at the rear of the gun. In order to keep clear of the flange during the closing action of the breech, these levers oscillate round a centre fixed tangentially with the breech-block, their smaller arm being permanently pressed outwards by a spring.

The repeat-firing action is composed of the following parts: the striker, the catch, and the control device. The striker consists of three principal parts: (*a*) the striker proper, with a pin that is driven against the fuse; (*b*) the percussion hammer, consisting of a cylinder of sufficient size to transmit to the striker the necessary force for firing the fuse, and on which the firing spring acts, this spring being relaxed when the gun is not cocked; (*c*) the trigger, formed like a hollow prism, the centre line of which is normal to that of the whole mechanism in the rear of the hammer. This prism contains a small cylinder ending in an abutment, and which can be moved to and fro in a straight line, under the action of a spiral spring surrounding it.

The striker is lodged in the centre of the body of the breech-block, and as long as the catch is left undisturbed, the pin is withdrawn within the front surface of the block. The catch consists of a rectangular frame, one of the sides of which forms a hinge with a vertical axis fixed in two projections on the slide-block. This hinge carries on its inner surface a finger which engages the butt-end of the trigger, and enables this to be drawn back, as well as the hammer to which it is connected, this operation also pressing down the firing spring. A working arm projects from the catch, and is turned to the right, ending in an abutment disc on which the transmission-rod acts, and of which the butt in the hand of the gunner forms part. The front end of this working arm bears against the spring piston of the device for safety against premature fire. The opposite side of the catch frame ends in a lever provided with a ring, to which the firing line is tied when the gun is trained and fired by two men. In this case, the lateral working arm is not used.

A mechanical training device, on the Schneider-Canet system, enables the man training the gun to fire immediately the target appears in the line of sight. This is most important for naval service, owing to the mobility of the aim and of the firing platform. In such cases, it is very desirable that the gunner who has charge of training the

gun should, while keeping his eye on the sights, himself fire at the precise moment. This special apparatus consists of two bars fitted end to end to the side of the gun, and sliding in bearings joined to the fixed slide in which the gun recoils, and to the jacket that holds the recoil checks. The front bar can be brought back by means of a lever, and can resume its normal position by a spring, when the action of the lever is removed; it carries in the rear a transverse piston with counteracting spring that can be made to disappear, or to engage in a notch on the side of the jacket above referred to, and it works the rear bar which acts direct on the butt of the firing lever. By manipulating the working lever, the gun is fired and the breech safety piston enters its socket in the breech-block; at the same time the transverse piston of the front bar is driven by its spring into the notch prepared for it in the jacket.

When the charge is fired in the ordinary manner, the gun recoils and liberates the transverse piston from the front bar, the various springs restoring all the parts to their first positions, so that when the gun is relaid the firing device is again ready for action, and the breech can be opened freely.

When the gun hangs fire no recoil takes place, and the front bar, held firm by its lateral piston, remains in an extreme rear position, as well as the rear bar; the safety piston stops in its socket in the breech-block, and keeps it from moving. Under these conditions the breech cannot be opened; and if the gunners have not been able to ascertain whether the gun has been fired (which may be difficult in action, owing to the report of several guns firing simultaneously), they are warned, by the resistance encountered in trying to open the breech, that something unusual has happened, and that it may be dangerous to proceed. When in such a case it is desired to open the breech after a few minutes' delay, it is sufficient to disengage the transverse piston from the front bar, by drawing it sideways by means of its stud; the various parts then take up their first position automatically, and the breech mechanism is set free.

The gun can be fired electrically by operating the firing switch; the circuit is completed by the receiving line, the terminal on the breech-block support and its abutment, the jacket-rod, the striker proper, the fuse, the body of the gun, the mounting, and the return line.

A Schneider-Canet double latch, of the same type as those already described for the two- and three-motion breech-blocks, joins the breech-block to its support, and latter to the gun, alternately and at the right moment.

The arm working the catch bears, as above mentioned, on a piston fitted with a counteracting spring which, when the catch is set for striking, is driven forwards, and engages in a groove of suitable section cut in the breech-block, when complete closing is effected. This, of course, is only possible when the piston is exactly opposite its housing in the block; therefore, if the breech is not completely closed and locked, the catch is masked by the safety piston, and has not a sufficient travel for cocking the striker and firing the fuse, thus doing away with all risk of premature fire. This device works automatically, and is quite reliable. To prevent accidental opening of the breech-block, the working lever is locked to the rear of the gun in such a manner that it cannot be set free without the intervention of the gunner, the general manœuvres not being delayed nor complicated thereby. In the rear face of the gun is screwed a stud made with an incline and a notch in which fits the end of an oscillating lever, worked direct by the handle of this main lever. This additional lever is recessed into the thickness of the working lever, and oscillates in the vertical plane of the latter round a fixed centre. It is provided with a counteracting spring, which insures locking as soon as the gunner releases the handle after having closed the breech. To open the breech, it is necessary, therefore, to disengage the end of this supplementary lever from its socket, by bearing vertically on the working handle before withdrawing it. This is practically an instinctive action, as the gunners have a natural tendency to press on the handle when they take hold of it to open the breech.

The gun is secure against hanging fire, owing to the device described above.

It may happen that the cartridge-case becomes set in the chamber. In such a case the opening of the breech is rendered difficult, and the clutches of the extractor are liable to damage. It is then necessary to resort to the rod provided for lifting the extractor. This is a thin round rod, which is introduced in a passage made flush with the rear end of the gun, and which leads above the small arm of the lever that carries the extractor clutch; the clutch can thus be freed from the flange of the case, and the breech opened. A specially-shaped wrench, which forms part of the accessory gear, is then used to pull out the case, the rammer not being resorted to at all. There is thus no risk of striking the fuse, and of causing accidental explosions.

To open the breech, the gunner presses on the handle, and turns the working lever in one motion from right to left, until the breech is completely opened, and the block swung to the side. During the first part of this action the end of the clutch lever is freed from its notch, and the conical pinion mounted on the spindle of the lever causes the breech-screw to turn in the seating; then the vertical roller fitted to the end of the small arm of the working lever, engages the circular groove cut in the lower surface on the left side of the bracket. The breech-block is then completely unscrewed, and the roller, bearing in the end of the groove, effects the withdrawal of the breech-block from the seating. The whole of the mechanism then swings to the side by turning on its hinge. As soon as the block begins to leave its seat, the extractor clutches withdraw the cartridge-case; when the block is completely withdrawn, the double latch fixes it to the support. To close the breech, the working lever is brought back in one action. When the breech-block arrives in contact with

BREECH-MECHANISM FOR QUICK-FIRING GUNS.

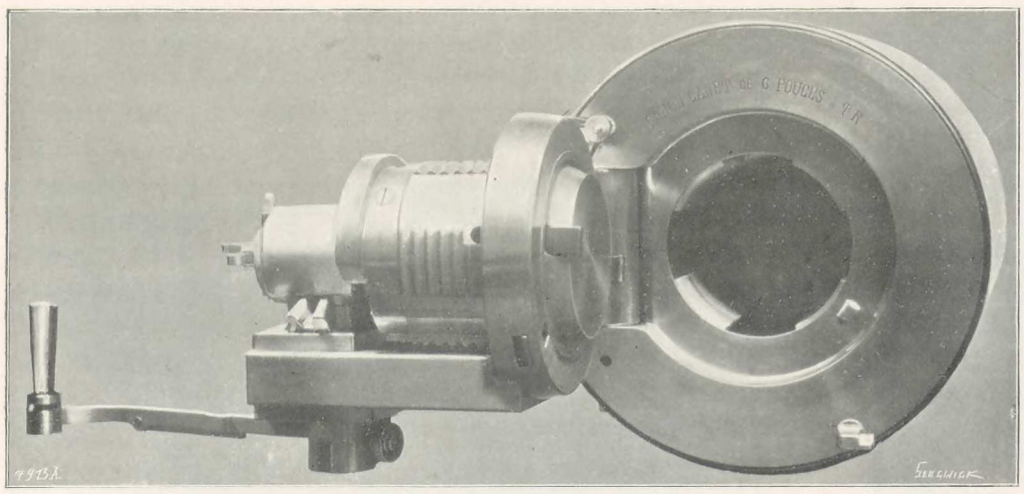


Fig. 680. Single-Motion Breech-Mechanism, Latest Type.

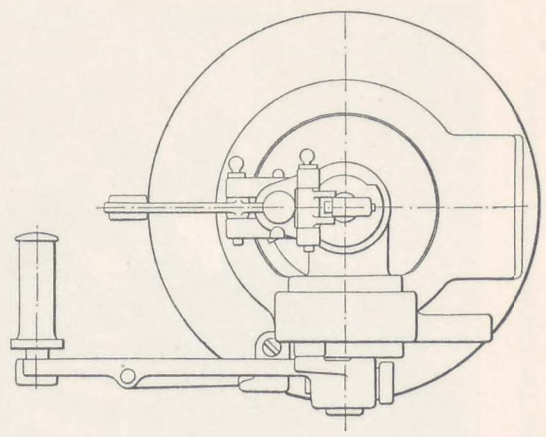


Fig. 681.

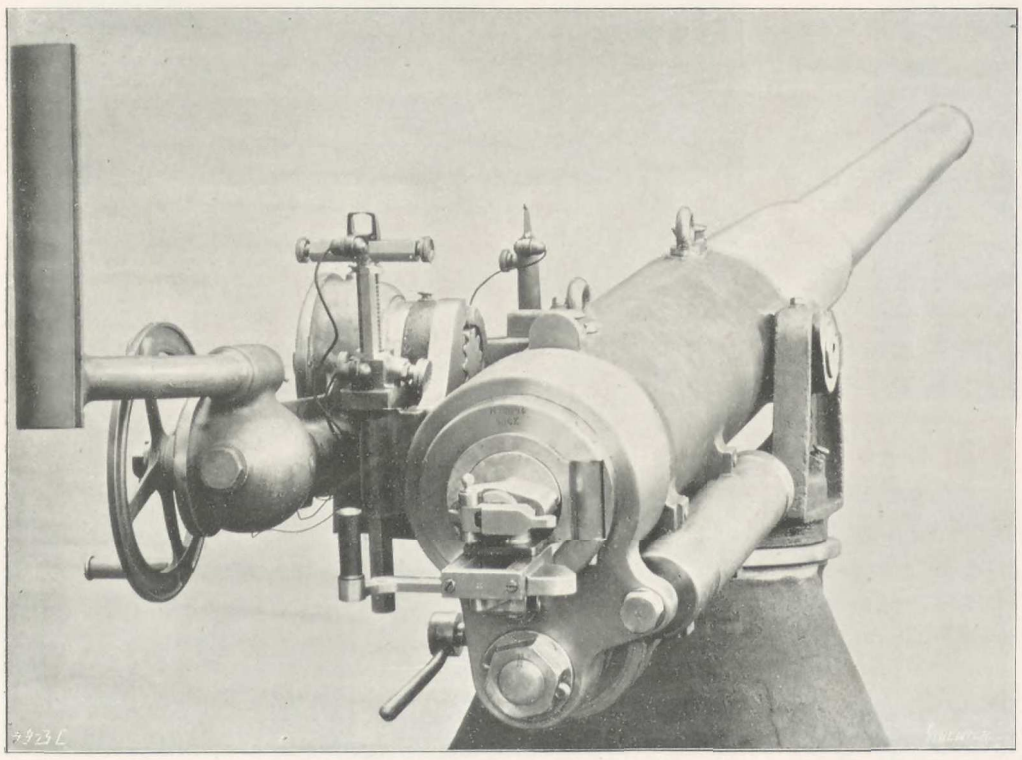


Fig. 683.

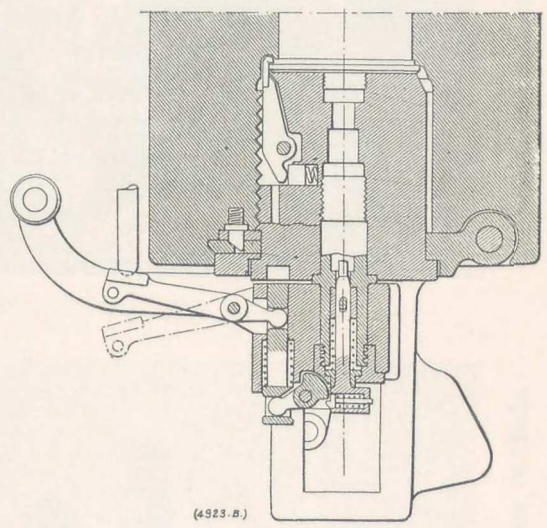


Fig. 682.

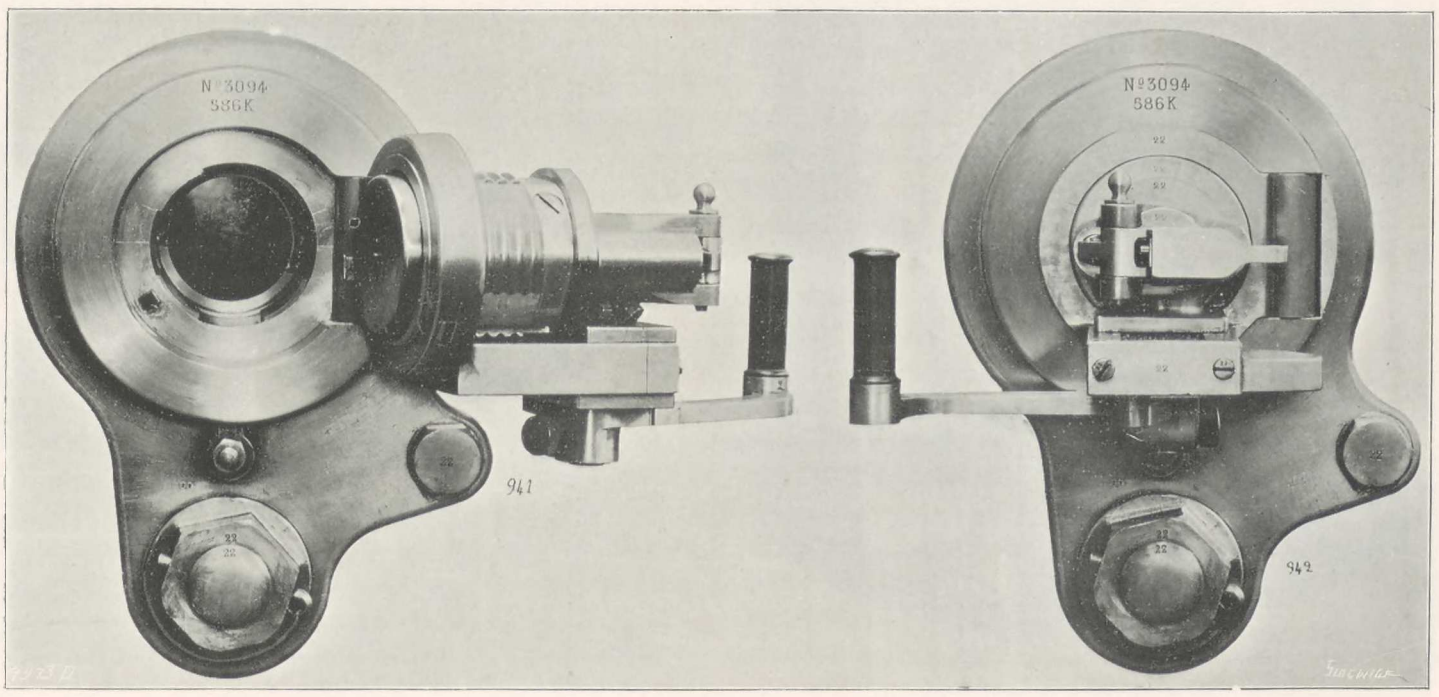


Fig. 684. Fig. 685.

Figs. 683 to 685. Single-Motion Breech-Mechanism for 65-Millimetre (2.599-in.) Quick-Firing Guns.

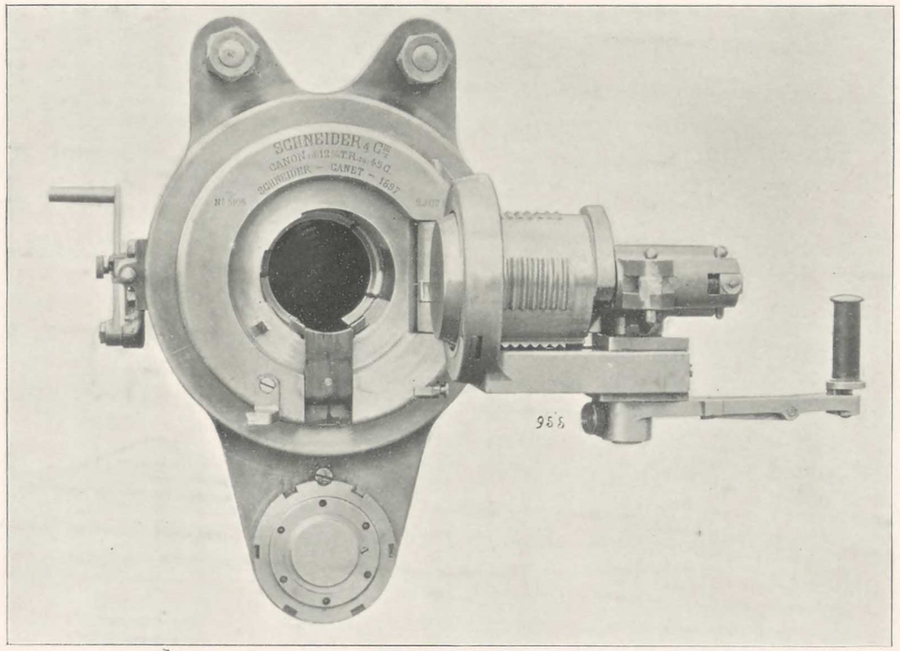


Fig. 686.

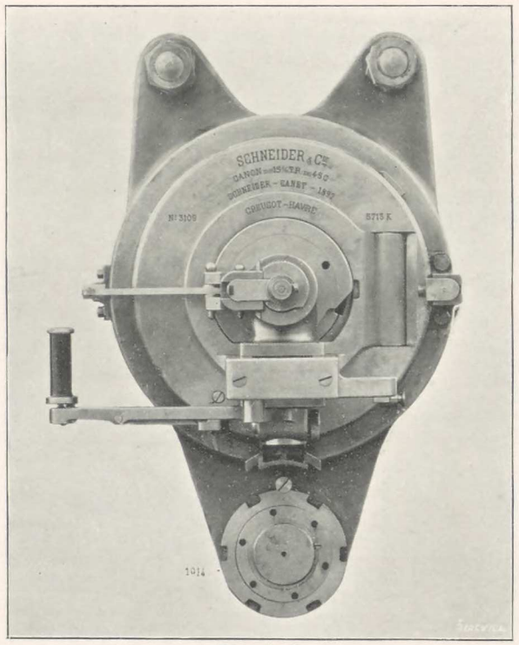
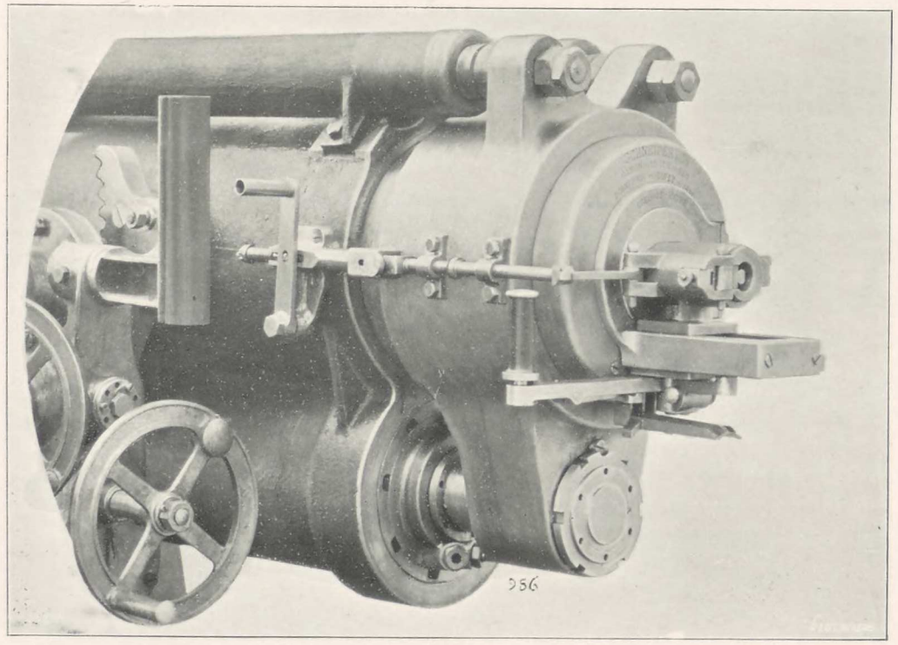
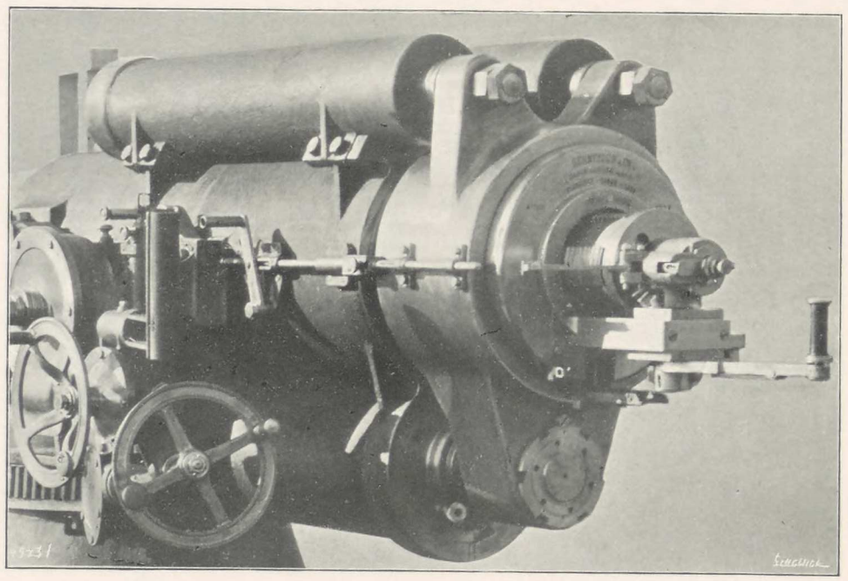


Fig. 688.



Figs. 686 and 687. Single-Motion Breech-Mechanism for 12-Centimetre (4.724-in.) Quick-Firing Guns.



Figs. 688 and 689. Breech-Mechanism for 15-Centimetre (5.905-in.) Quick-Firing Guns.

the cartridge-case, the extractor clutches pivot round their centres, and embrace the flange. The closing is complete only when the end of the supplementary lever worked by the handle has been placed in the notch of the stud screwed in the rear of the gun.

To operate the firing device, it is sufficient to pull the straight arm of the catch by means of the firing line, or to act on the small firing lever held by the pointer. The finger of the catch turns round to the rear, and by acting on the butt-end of the trigger and on the hammer, which can only move in a straight line, the firing spring is pressed down; escapement then takes place, and the hammer being freed is thrown forward under the action of its spring, and drives the striker against the fuse. At the same time, the working arm of the catch, by bearing against the piston of the safety device, drives it home by pressing down the counteracting spring. When the catch is released, it has a tendency to resume its first position under the action of the safety piston; it acts, therefore, owing to its projection, on the butt-end of the movable cylinder of the trigger. The latter is withdrawn, but is thrust out again immediately under the action of its spring, the two pieces again engaging each other. The device is then ready to repeat the firing action. Figs. 681 and 682 show in detail the shape of the various parts, and the way in which they act. Fig. 680 is reproduced from a photograph of breech-blocks of this type for the current calibres of quick-firing Schneider-Canet guns of recent manufacture.

Breech-Block for 65-Millimetre (2.559-In.), 50-Calibre Quick-Firing Schneider-Canet Gun (Figs. 683 to 685, Plate CXVII.).—In this breech-closing arrangement, the clutch device for the working lever and the lateral rod for firing are not used, owing to the dimensions of the gun, which is fired solely by the firing line.

Breech-Block for 10-Centimetre (3.937-In.), 50-Calibre Quick-Firing Schneider-Canet Gun.—This mechanism contains the clutch device for the working lever and the lateral firing lever.

Breech-Block for 12-Centimetre (4.724-In.), 50-Calibre Quick-Firing Schneider-Canet Gun (Figs. 686 and 687, Plate CXVIII.).—Besides the various parts described above, this breech-block is provided with a charging plate, jointed on a hinge fitted to the rear end of the gun. In Fig. 687 this plate is shown brought down, under the breech-block bracket. In Fig. 686 it is shown brought up, flush with the lower part of the bore, to facilitate the quick introduction of the cartridges.

Breech-Block for 15-Centimetre (5.905-In.), 50-Calibre Quick-Firing Schneider-Canet Gun (Figs. 688 and 689, Plate CXVIII.).—This mechanism is similar to the preceding one, but is of larger dimensions, corresponding to the increase in the calibre.

XXX.—BREECH-BLOCKS FOR LARGE-CALIBRE GUNS.

THE classification of breech-blocks for rapid-firing large-calibre guns under a separate heading is justified by the special arrangements required for manœuvring the heavy parts that constitute the mechanism. In the Schneider-Canet types of heavy breech-blocks, mechanism is used which the gunner can either control by direct action or the gearing of which contains a more or less intricate series of transmissions that reduce the effort to be exerted within the limits of hand-power. This subdivision of large-calibre breech-blocks corresponds roughly to quick-firing guns and accelerated firing guns respectively. When the sizes of the parts to be operated make it expedient to have recourse to mechanical motors, the work of the *personnel* is replaced by a steam, hydraulic, or electric motor, that generally forms part of the ship's machinery; in some installations accumulators are used, which absorb a more or less important part of the total power produced by the recoil of the gun. In such cases, the gunners have only to manœuvre a distributor that acts upon a set of valves; hand levers are nevertheless provided, to be used for working the breech-block, should the motors fail to act. The following Schneider-Canet breech-blocks may be used with any type of obturator, whether plastic disc, metallic ring or cup, movable bottom or whole cartridge-case.

Direct-Acting One-Motion Breech-Block for 20, 22, and 24-Centimetre (7.874, 8.661, and 9.449-In.) (Figs. 690 to 695, Plate CXIX.).—The same type of breech-block is applied to the three calibres. It contains generally the same mechanism as the breech-blocks for medium-calibre guns already described. The general views and details illustrate the working parts, which are so arranged that, by one single action of the hand lever, breech-blocks up to 9.449-in. calibre are quickly opened or closed. Section Fig. 690 shows the breech-closing device for a 20-centimetre (9.449-in.), 45-calibre Schneider-Canet quick-firing gun. It is designed for firing with a plastic obturator and by electricity. A bracket in the rear of the gun, which can be raised and lowered, facilitates charging (see Figs. 694 and 695, Plate CXIX.).

Two-Action Breech-Block, with Firing Device for Friction Fuse (Figs. 696 to 698, Plate CXX.). — This illustrates the class of Schneider-Canet breech-blocks, for the opening of which several distinct actions are necessary. This mechanism comprises the breech-block with obturator and movable head, its bracket with the working mechanism, and the firing device. The breech-block is made with three threaded parts and three interruptions; the obturator consists of a metallic disc centred on the movable head.

The bracket consists of a horizontal plate, projections in which guide the breech-block in its longitudinal travel. This plate is in one piece with the part that passes over the hinge-bolt round which the whole system turns. The working gear is used specially for unscrewing the breech-block; it consists of a pinion fitted to the end of the lever, forged in one piece with the rear disc of the breech-block. This pinion engages in a circular rack fitted to the rear end of the gun. A handle fixed to the pinion axis serves to turn round the lever, operating the breech-block which is thus unscrewed. In the lower part of the lever is a groove in which travels, guided by a spring, a small tongue plate that masks the vent as soon as the opening action is started. A fixed traction handle on the rear breech-block disc serves to withdraw the block, when it is unscrewed. A special double latch unites the bracket to the breech-block and to the gun alternately. Firing is obtained by means of friction fuses placed in the vent. The tongue plate masks the vent so long as the breech is not completely closed, it is then impossible to insert the fuse, so there is therefore no risk of premature fire; besides, as it is necessary, in the event of a miss-fire, to lower the tongue plate, and consequently to previously remove the fuse from the vent, there is no risk of accidental firing.

To open the breech, the tongue plate being lowered, the lever handle is turned until the breech-block has travelled through 60 deg., when the threads being disengaged, the block can be withdrawn and swung to the side by pulling on the fixed traction handle. When the breech-block is completely swung back, the bracket latch engages a hook fitted to the rear end of the gun, and is held firm whatever be the incline taken by the gun, owing to the rolling of the ship or to any other cause. An emergency mechanism, operated by a separate handle placed under the bracket, serves to insure regular working should it be found difficult to withdraw the breech-block from the seating. To close the breech, the latch is released by hand, and the above actions are repeated inversely.

Figs. 696 to 698, Plate CXX., show the breech closed, the breech-block unscrewed, and the block withdrawn from the breech.

Three-Motion Breech-Block, with Percussion Firing (Figs. 699 to 702, Plates CXX. and CXXI.).—This differs from the preceding type, in that the block is swung to the side by means of a special mechanism. It consists of

BREECH-BLOCKS FOR LARGE-CALIBRE GUNS.

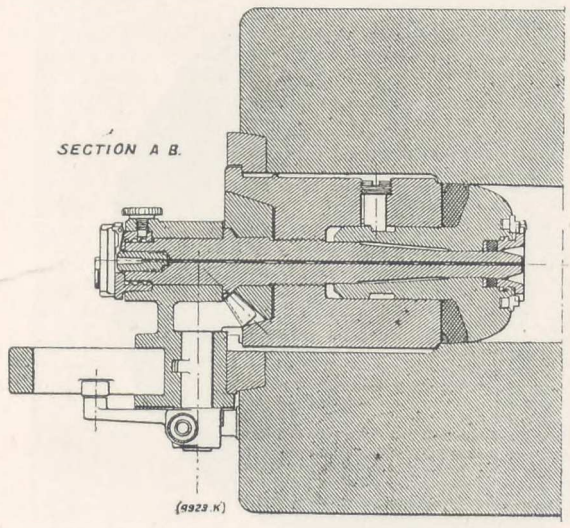


Fig. 690.

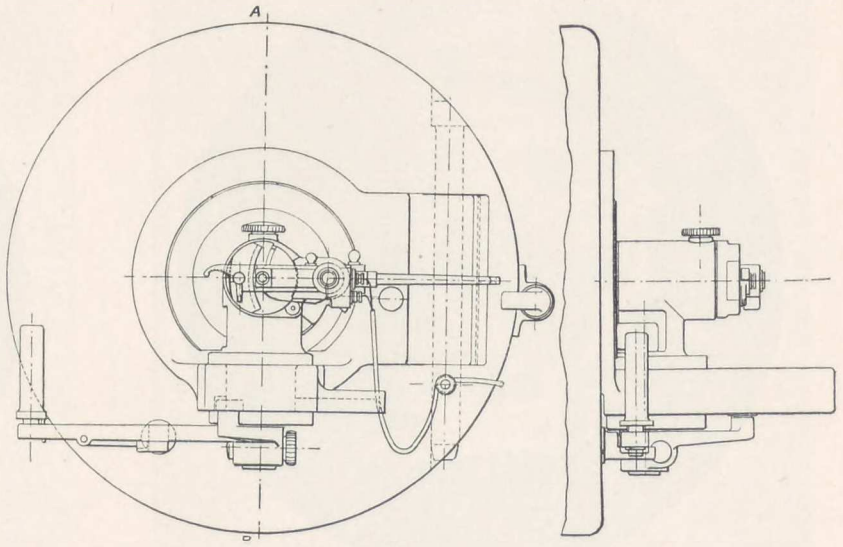


Fig. 691.

Fig. 692.

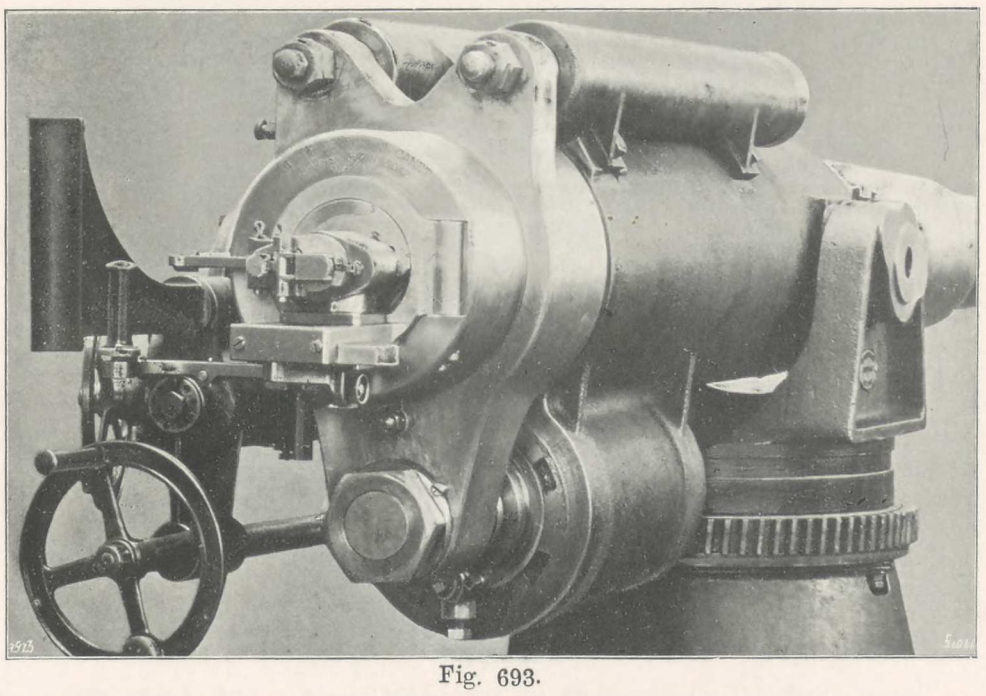


Fig. 693.

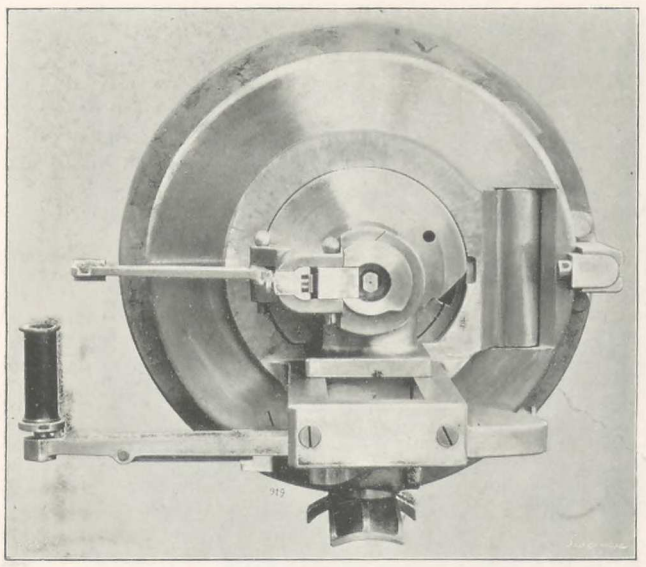


Fig. 694.

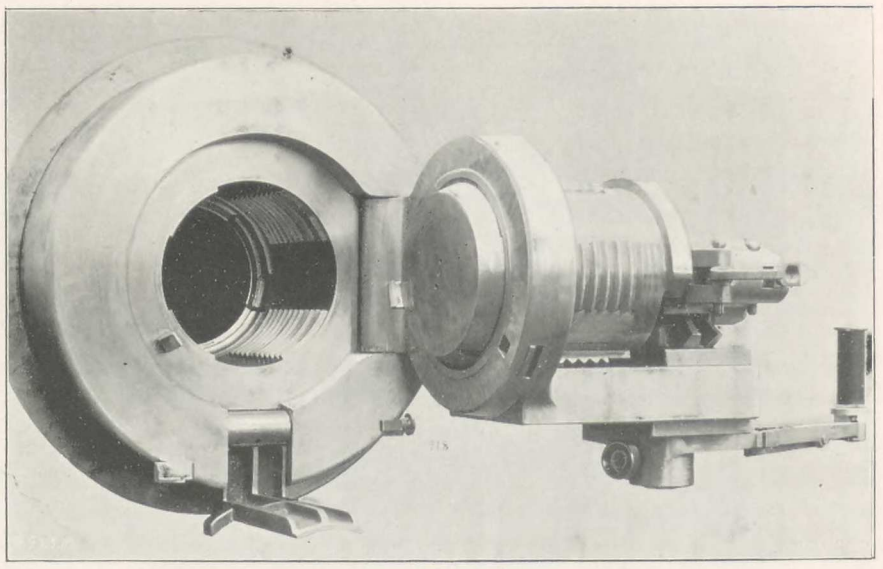
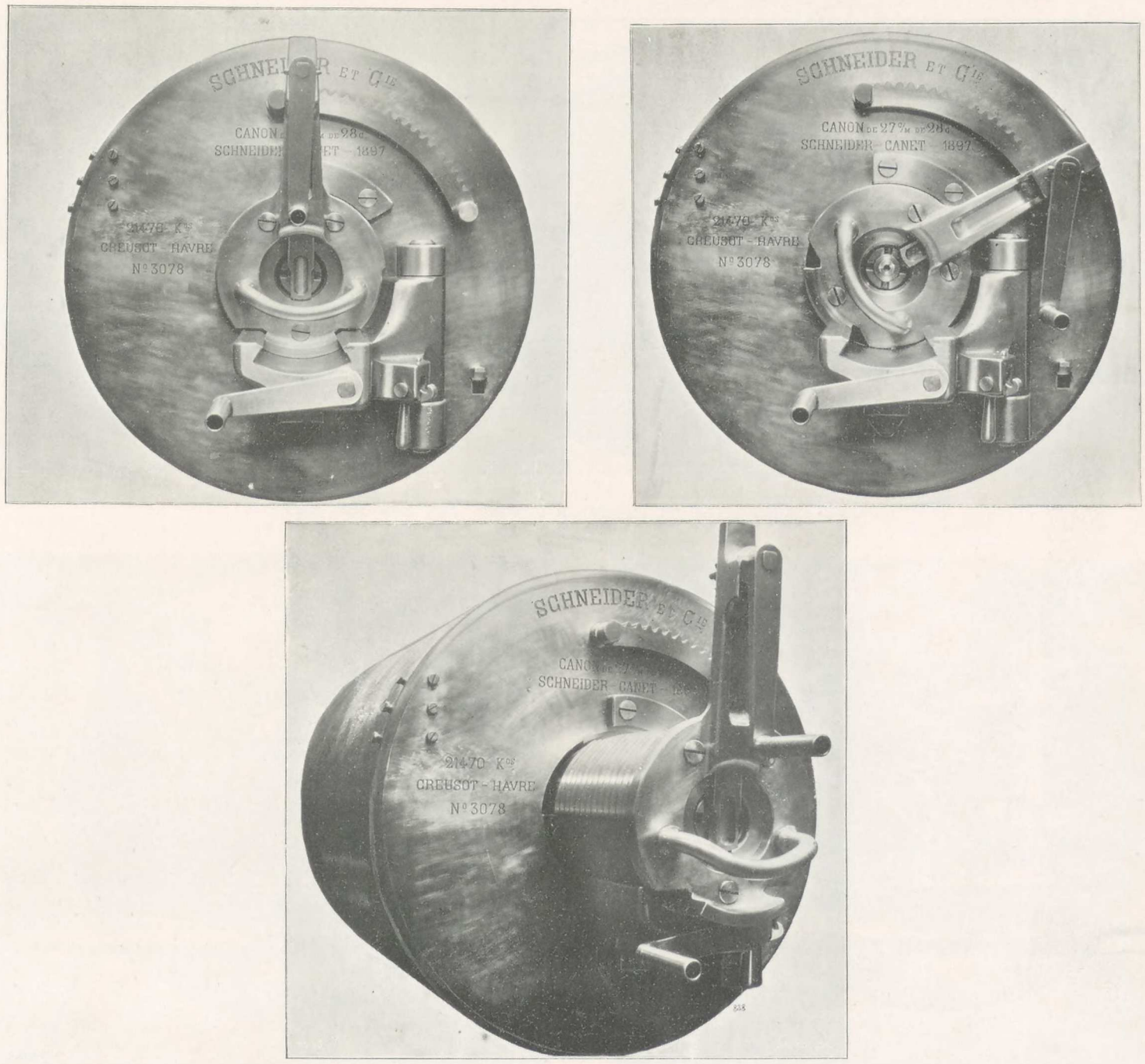


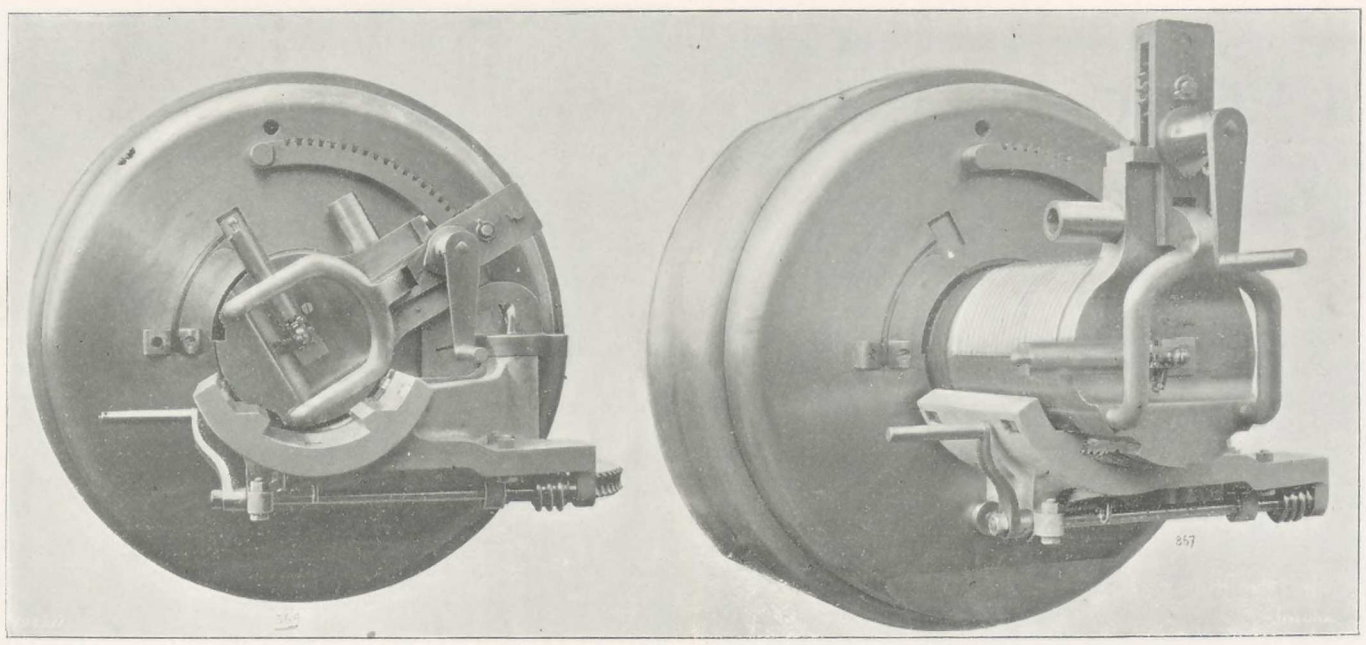
Fig. 695.

Figs. 690 to 695. Breech-Mechanism for 20-Centimetre (9.449-in.) Quick-Firing Guns.

BREECH-BLOCKS FOR LARGE-CALIBRE GUNS.

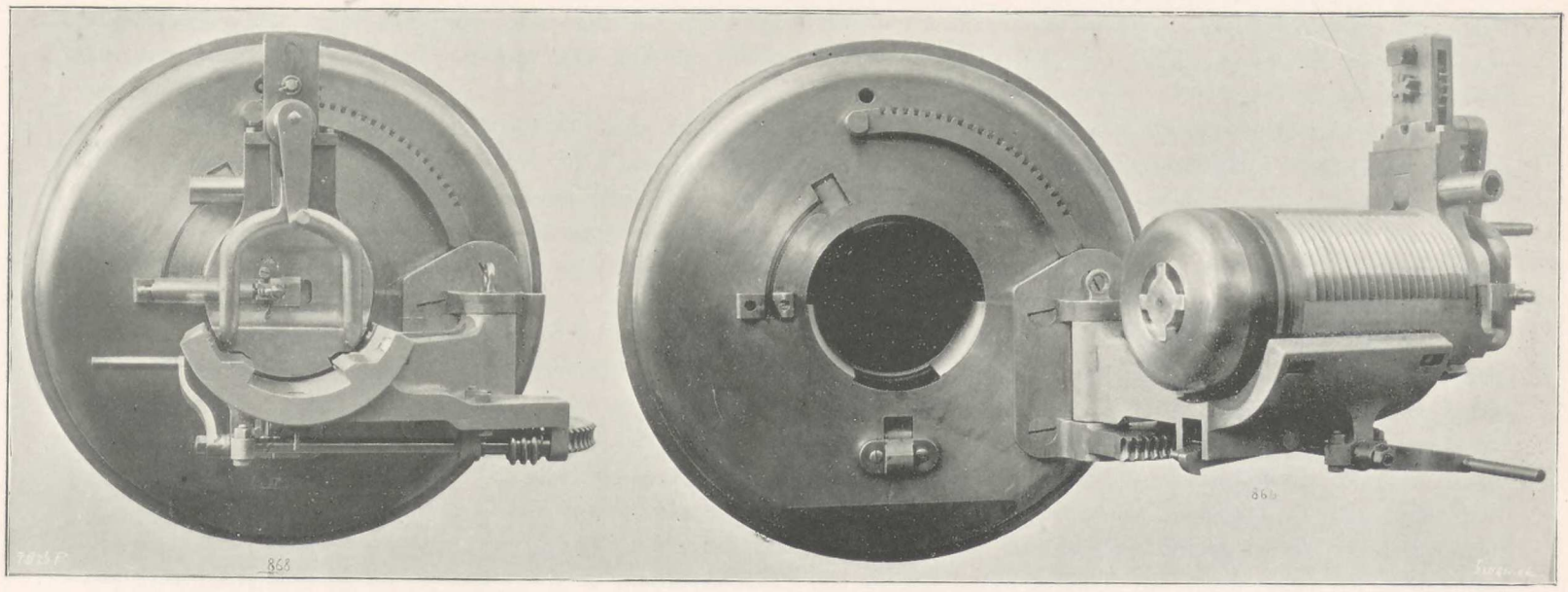


Figs. 696 to 698. Breech-Mechanism for 28-Centimetre (11.02-in.) Guns.

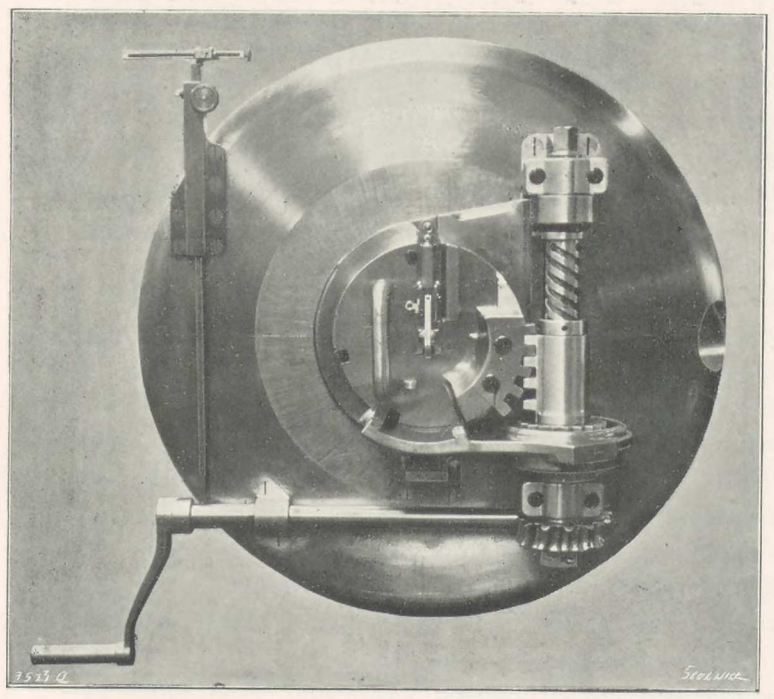


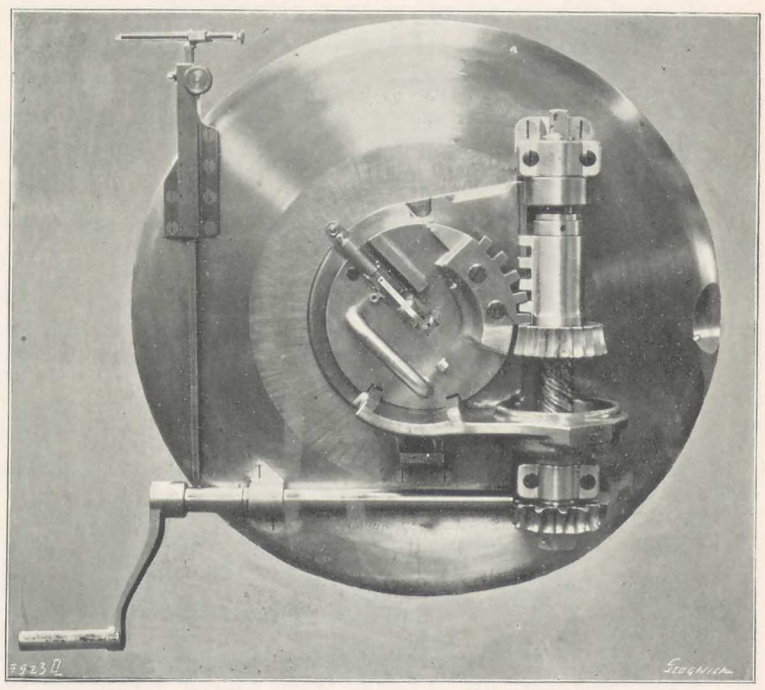
Figs. 699 and 700. Breech-Mechanism for Large-Calibre Guns.

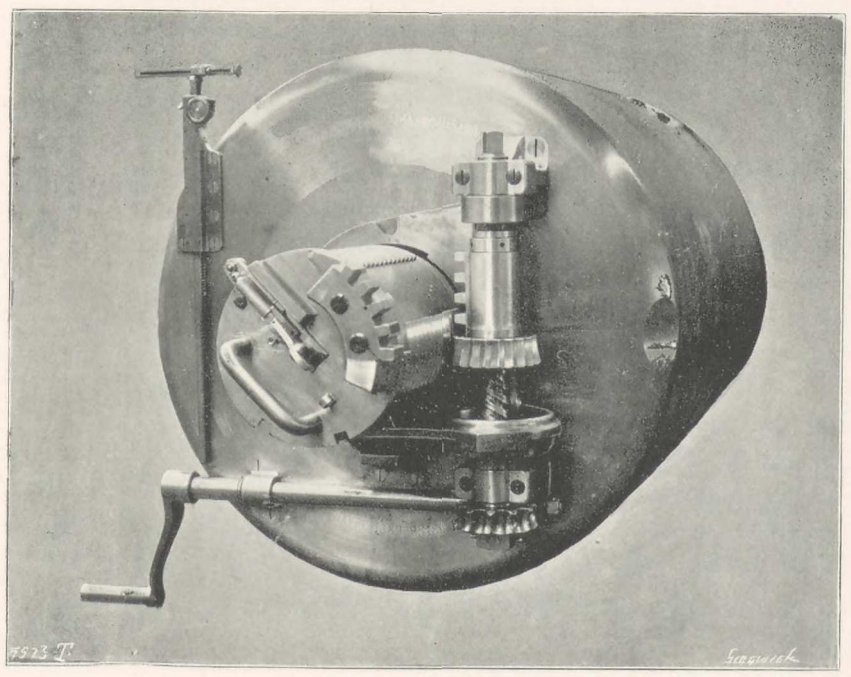
BREECH-BLOCKS FOR LARGE-CALIBRE GUNS.

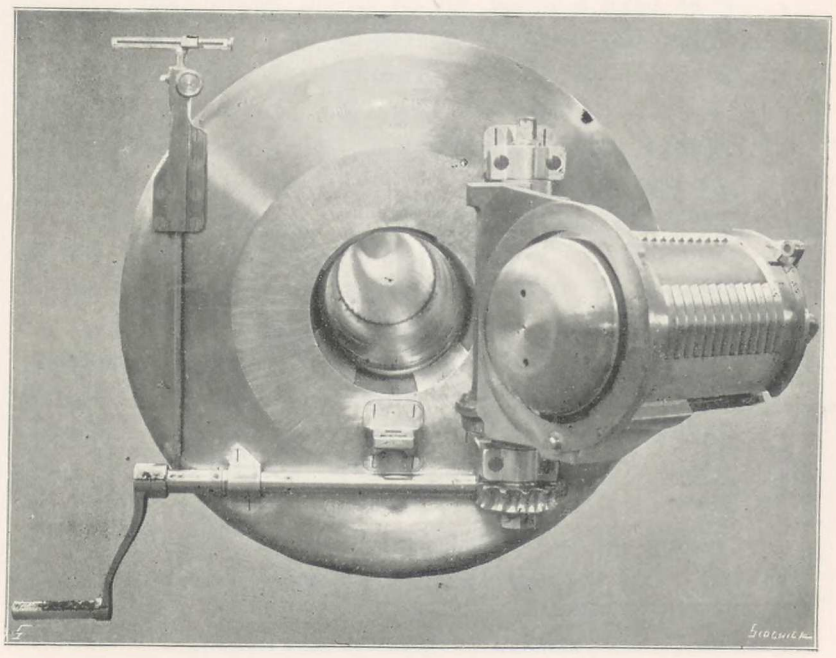


Figs. 701 and 702. Breech-Mechanism for Large-Calibre Guns.









Figs. 703 to 706. Schneider-Canet Breech-Mechanism for Large-Calibre Guns.

the breech-screw, with obturator and movable head, the supporting bracket, with the working gear, and the firing device.

The breech-block has three threaded parts and three interruptions. The obturator consists of a plastic elastic disc placed between the movable head and the front end of the breech-screw. The vent goes through the movable head-bar, the rear end being fitted with a brass bush, in which the fuse is placed.

The supporting bracket consists of a curved plate, projections on which guide the breech-screw in its longitudinal travel. This plate is in one piece with the hinge that surrounds the vertical bolt, round which the whole of the system is made to turn. The working gear consists of the mechanism which produces the unscrewing of the breech-block, and the swinging of the system to the side of the gun. The disc of the breech-block is extended, and forms a lever, at the end of which is fitted a set of toothed gearing, working a pinion that engages a circular rack fitted to the rear end of the gun. The mechanism is operated by a handle keyed to the small pinion axle. A spring latch at the end of the lever blocks the mechanism, and holds the gearing fast as long as the breech-screw is not driven completely home; this is to prevent any accidental displacement of the breech-screw during the manœuvres which follow the unscrewing.

To withdraw the breech-block when it is unscrewed, the gunner acts on the jointed hand-lever by raising its two arms. In so doing, a cam at the top part of the lever bears on the rear end of the breech, and facilitates the release of the obturator; then, by pulling the whole of the system to the rear, the breech-block is withdrawn from the seat; anti-friction rollers are placed on the guides to facilitate the movement of the block. The bracket is turned round to the side of the gun by acting on the lower handle, which works a spindle passing under the bracket, the spindle being fitted with an endless screw that engages a helicoidal sector fixed to the gun. A swinging latch unites the bracket to the breech-block and to the gun alternately.

A latch bolt is used for percussion firing; this contains a hammer worked by a spring, and which moves in a groove transversal to the breech-block disc. As soon as the opening motion is started, the end of the bolt which, when the breech is closed is situated in a slot cut in the rear surface of the gun, rises up the incline on the left-hand side of the slot, and travels in the circular groove with which the slot is connected; the hammer-spring is thus set, and the hammer is brought out of the centre of the vent. Premature firing is thus rendered impossible.

To open the breech, the block is turned round 60 deg. by working the upper handle; this disengages the threads, and the breech-block can be withdrawn by acting on the jointed handle; the obturator being previously released, the lower handle is then turned to cause the whole of the system to swing round to the side. For closing the breech, the above actions are repeated inversely. Figs. 699 to 702, Plates CXX. and CXXI., show the breech closed, the breech-block unscrewed, the breech-block withdrawn from the seating, and the breech completely open.

Breech Screw with Percussion Firing (Figs. 703 to 706, Plate CXXI.).—This example has been chosen to illustrate the types of Schneider-Canet breech-blocks, the closing and opening of which are effected mechanically throughout, by turning the crank handle always in one direction. The mechanism comprises the breech-block, its plastic obturator and movable head, the bracket with the working gear, and the firing device. The breech-block is made with four threaded parts and four interruptions. The obturator consists of a plastic elastic composite disc, specially shaped, and placed between the movable head and the front end of the breech-screw. On the rear end of the latter is fixed the tooth sector by which the block is turned.

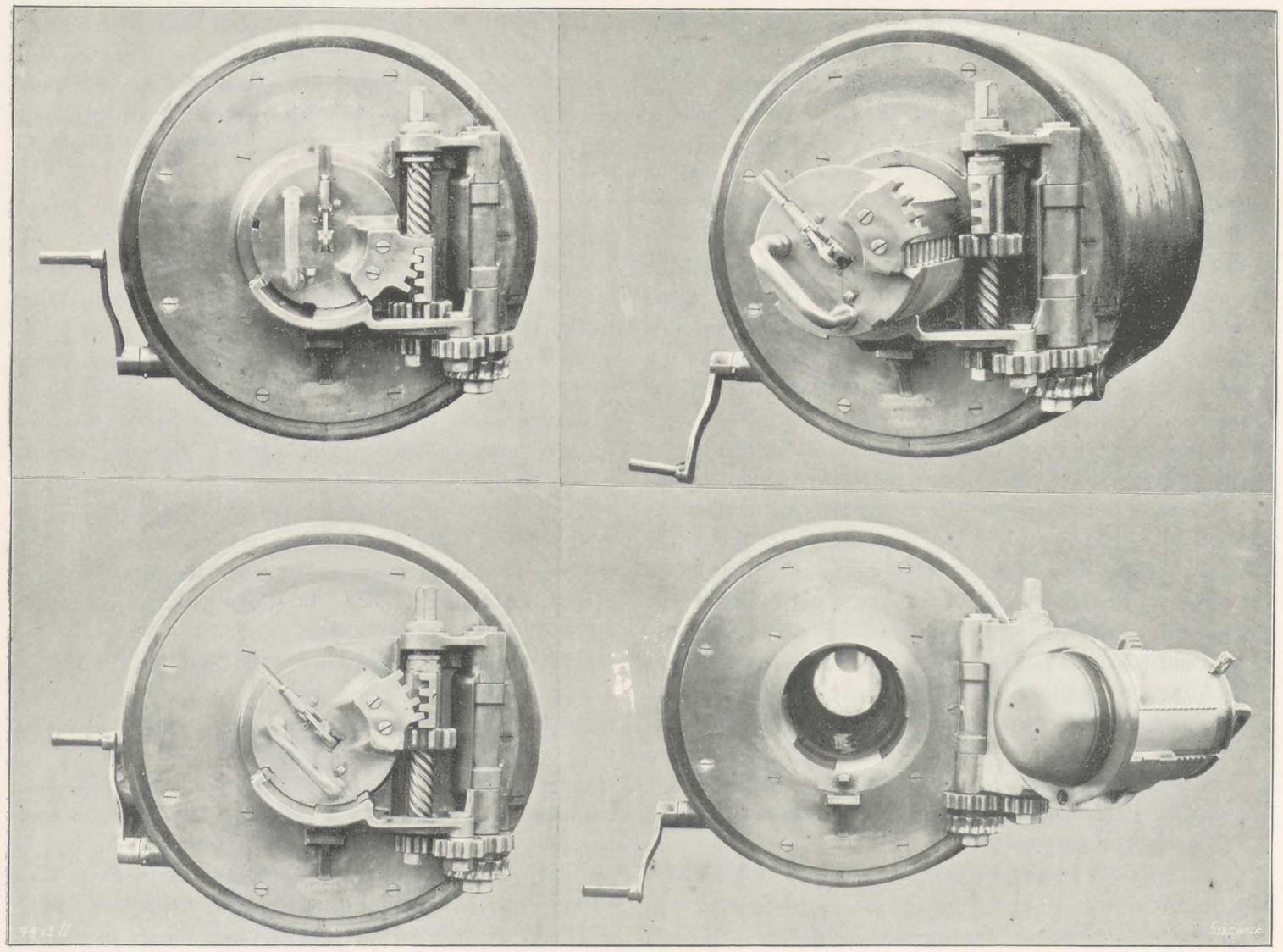
The bracket consists of the support and the breech mechanism. The support carries the breech-block as it is displaced, and is made to turn round a vertical hinge bolt. The breech mechanism comprises the crank that works the horizontal spindle of the driving screw; the latter engages direct with a toothed wheel fitted to the vertical hinge bolt, and effects all the opening motions. The hinge bolt consists of an endless screw mounted in two bearings on the rear end of the gun, and on which travels a rack made to slide, in the rear, in two vertical slots which prevent it from turning round. The rack is fitted at its lower part with a pinion which, when the breech-block is unscrewed, engages the threads of one of the toothed sectors, and effects the withdrawal of the breech-block from the seating.

The percussion firing mechanism consists mainly of a hammer worked by a spring. When the opening action is started, the tenon fitted to the bolt (and which, when the breech is closed, lodges in a notch cut in the support), rises up the inclined plane to the left; this sets the firing spring, and removes the hammer from the vent. At the same time, the safety key engages in its slot, and, driven by its spring, becomes fixed in a socket provided for it in the bolt. When the breech is closed, the rim of the breech-block comes in contact with the support, the bolt key engages in its slot, and leaves the bolt free to slide in its groove. As the hammer cannot be set free, and as the striker is not opposite the vent, so long as the breech is not completely closed, all risk of accidental firing is avoided.

To open the breech by turning the crank, the vertical endless screw is set in motion, the rack rises and engages the toothed sector fitted to the rear of the breech-block, the latter becoming unscrewed. When the rack is at the top of the endless screw it is made to revolve, the pinion with which it is fitted engages the threads of the breech-block, and brings this back until the bracket guides cause it to stop. On continuing to turn the crank, the whole system swings to the side of the gun. To

close the breech, the crank is turned round inversely. A special latch, governed by a spring, alternately joins the support to the breech-block and to the gun. Figs. 703 to 706, Plate CXXI., show the breech closed, the block unscrewed, withdrawn, and the breech opened.

Figs. 707 to 710 illustrate another type of Schneider-Canet breech-blocks for large-calibre guns; the general arrangement is similar to that just described; but besides the endless screw and the rack gear for turning the breech-block, there is a separate bolt which forms a hinge for swinging it to the side. A set of gearing interruptions; it is fitted at the back with a toothed sector for turning, and with a longitudinal rack for withdrawing, the block. It is guided in a bracket provided with a closing disc, and which can turn round a hinge supported on steel lugs. The hinge bolt is fitted with two pinions of different diameter; one of these engages a double-toothed rack that can slide horizontally in a groove on the rear end of the gun to effect the turning; the second set of teeth is arranged to engage the toothed sector fitted to the breech-block; the other pinion works the longitudinal rack when the turning



Figs. 707 to 710. Schneider-Canet Breech-Mechanism for Large-Calibre Guns.

placed under the bracket puts the endless screw in motion, and insures the opening and closing of the breech. The mechanism for percussion firing and the safety device, are similar to the corresponding parts of the preceding breech-block.

In another modification, the continuous action of a crank also produces the opening and closing of the breech. The opening action consists of turning, withdrawing, and swinging the breech-block to the side by means of pinions and racks; but in this type all the toothed wheels are covered, which insures greater safety in service.

The breech-block has four threaded parts and four is completed, and withdraws the breech. The action of the crank is transferred to the two pinions through an endless screw and a suitably-geared wheel. A double-latch bolt fitted in the bracket fixes it to the breech, and the block to the bracket, so that the three motions of unscrewing, withdrawal, and swinging to the side, always follow in the required succession. A small cam on the hinge bolt fixes the unscrewing rack during the withdrawal of the breech-block and its swinging to the side. The teeth of the pinions and rack are so shaped that the breech-block is never abandoned when one action ceases to give place to another.

XXXI.—CONCENTRIC-THREADED BREECH-BLOCKS.

IN a distinctive class of breech mechanism adapted to the Schneider-Canet quick-firing guns, the block is made with concentric threads.

The main feature of this new type consists in the adaptation to the gun of a block with a spherically-shaped face, the two sides having parallel plane surfaces, with the rear hollowed out. The block thus formed fits in a suitable socket cut in the rear of the gun. By this arrangement, it will be seen that a rotary motion opens or closes the bore by a single action; in this respect the arrangement fulfils in the simplest manner the conditions required of breech mechanism. The displacement of the breech-block is effected round a centre line, which may be set at any desired angle. A series of concentric threads, of equal section, cut in the breech-block cheeks, fit into corresponding grooves made in the seating, and insure the close connection of the block with the gun in the various positions the former is required to take. Figs. 719 to 721, Plate CXXII., show the principle of this class of breech-blocks.

Besides the principal characteristic of this type, there are special points connected with the particular arrangements adopted for its manipulation, firing, &c. We shall review in the following descriptions the various types that have been put into service, those for small and medium-calibre guns and those for large guns, first giving a description of the Schneider-Canet spherical breech-block, from which the concentric-threaded type has been evolved.

Schneider-Canet Spherical Breech-Block for Quick-Firing Guns (Figs. 711 to 715, Plate CXXII.).—This type consists of a complete sphere made to turn in a spherical seat in the enlarged rear of the gun. It is held in position by a screwed ring at the back of the block, and the arrangement is completed by special mechanism for firing and extraction. In the centre of the sphere a hole is drilled, of the same diameter as the bore of the gun, so that the charge can be easily introduced. When the breech is open, the bore in the sphere corresponds exactly with that of the gun, while to close the breech it is sufficient to turn the block through 90 deg.: that is to say, into a vertical position (see Fig. 713).

The device consists mainly of the following parts: (*a*) the breech-block, with threaded ring in the rear; (*b*) the working lever, in which part of the firing mechanism is fitted; (*c*) the extractor.

The ring, which bears against the back of the block, is of hardened steel, and is screwed into the rear end of the gun, the threads on the ring being either continuous or interrupted, as in ordinary breech-blocks. The spherical block is maintained in position by the smaller arm of the working lever, which contains a cylindrical extension forming a trunnion. When the lever is fitted in the breech-block, the latter can only turn round the axis of this trunnion, the rotary travel being limited by a stop provided in the swell of the gun, and by the smaller branch of the extractor, which the block meets when the opening motion is complete. The working lever is the only mechanism visible when the breech is fitted up ready for service, either when the breech is open or closed (see Figs. 711 and 712).

Firing is obtained by a striker that acts direct on the fuse; it is worked by a two-armed lever that oscillates in the body of the spherical block. One of the arms of this lever is governed by a hammer and a spring fitted to a cylinder placed in the centre line of the smaller arm of the working lever, which is grooved out to receive it. When the hammer is drawn back, the firing spring is pressed down by a cam trigger of the same type as that described for the one-motion breech-blocks for 6-in. quick-firing guns. The trigger is fitted completely in the thickness of the working lever. To cause the fuse to act, it is sufficient to pull, by means of the firing line, on the lever fitted with the cam, until the latter escapes the corresponding tooth fitted to the hammer; when the hammer is freed, it returns with a shock and acts on the two-armed lever that drives the striker against the fuse.

The extractor consists of a round horizontal rod guided in a groove cut in the bore, and on which are jointed two clutches that act on the cartridge-case flange. The case is ejected when the horizontal rod is driven forward by the spherical block, as the opening action is completed; the extractor works as a lever, and the clutches are driven backwards and draw out the case, the extractor resuming its position on the introduction of a cartridge-case. Its operation is insured by a stud that forms the head of a spring fitted in the thickness of the block, and which comes in contact with the horizontal rod, thus shifting it when the opening motion is completed and clearing it immediately afterwards. To prevent accidental opening of the breech, the working lever is provided with a movable handle fitted with a spring, and in the continuation of which is a lateral catch; when the breech is closed and the gunner releases the handle, the catch is driven into a projection on the gun, and the breech-block is thus held in position.

Until the breech is completely closed, the striker, which moves with the spherical block, is not opposite the

fuse, so that all accidental firing is rendered impossible; in addition, the working lever is fitted with a second catch that holds the trigger cam fast during the period of opening, releasing it only when the breech is completely locked. To open the breech, the gunner presses on the working lever handle to disengage the catch, and turns the lever through 90 deg. backward in one action. When a fresh cartridge-case is introduced the extractor is brought back to its normal position, and to close the breech it is sufficient to turn the working lever forward through 90 deg. If the cartridge-case has not been pushed quite home by hand it is driven into the correct position by the spherical block, owing to the two inclined planes with which the latter is provided for the purpose.

Concentric-Threaded Breech-Blocks for Small and Medium-Calibre Guns (Figs. 716 to 722, Plates CXXII. and CXXIII.).—The first breech-block of this type designed and manufactured by Messrs. Schneider and Co. was fitted to a 75-millimetre (2,952 in.) quick-firing gun. As will readily be seen, this arrangement is a natural development of the spherical block just described. The working lever for opening and closing the breech is on the right-hand side of the gun, and is joined to the breech-block by a semi-cylindrical arm forming a trunnion that rests in a bearing of similar section cut in the rear of the gun. The lever is provided with a movable handle, fitted with a projection which, when the breech is closed, engages in a recess cut in the thickness of the metal at the breech end of the gun. An inside spring presses the projection to the bottom of its socket, and fixes the block when the breech is closed.

The firing device consists of three parts all enclosed within the breech-block (see Fig. 722). The catch, formed of a working arm and a cam joined together by a round pin, acts on the movable trigger fitted to the striker and on the smaller arm of the V-shaped firing spring; the working arm is made with an eye to which the firing line is attached; it is placed on one side of the breech-block, in a groove made in the concentric threads. When the firing line is pulled, the catch of the cam draws the striker to the rear by bearing on the trigger until it escapes the latter. The striker is then under the action of the firing spring, which drives it against the fuse.

All danger of premature fire is done away with, as the space cut out of the concentric threads is shaped in such a way that the catch cannot move until the breech is completely closed and locked. The ejection of empty cartridge-cases is insured by a two-branched extractor, provided in the rear with a horizontal arm on which the whole weight of the block acts when the opening motion is completed. The travel of the breech-block is limited by a regulating screw, which fits in a socket cut in the thickness of metal of the working lever, and which, when it is at the bottom of its socket, projects from the inner surface of the lever and runs in a circular groove cut in the gun breech. The development given to this groove regulates the travel of the breech-block. To take the mechanism apart, it is sufficient to slacken the regulating screw by a few turns, and bring the working lever back far enough to disengage the threads.

Concentric Threaded Breech-Block with Repeat and Automatic Firing Action (Figs. 723 to 726, Plate CXXIII.).—The second type of breech-block contains the principal parts already referred to; the firing device, however, is fitted on the left-hand side of the gun, the working lever, alone, remaining on the right-hand side, and the concentric threads are not cut out for the firing mechanism, which can be made repeating or with automatic action, at will.

The striker is cylindrical, and ends in front in a point which strikes against the fuse; in the rear it is divided into two U-shaped branches. In its lower central part, a slot is cut to receive the V-shaped spring. The right-hand branch of the striker carries a projection on which the heel of the hand lever acts direct, while the other is fitted with a stop against which the cam of the governing apparatus presses. The latter consists of a cylindrical pin of varying diameters, fitted in a socket of the same shape cut in the rear of the gun, and surrounded by a spring which acts both by torsion and compression; this pin ends in a plate of larger diameter, in which is cut the cam for cocking the striker. On the other end is keyed the catch lever fitted with a tooth which, during the working of the firing system, runs in a groove cut in the thickness of the breech end of the gun on the left-hand side. This groove, which extends through an angle of 120 deg., is made at one end with an incline, up which rises the corresponding inclined surface of the tooth when the gun is fired.

The working lever is recessed as in the case of the mechanism last described, and contains a hollow rod free to slide, and kept in position by a spiral spring. This rod is fitted on the end opposite to the handle with two heels (or projections), one of which acts on the projection on the right-hand branch of the striker, the other constituting a latch bolt which enters a mortice in the gun when the breach is completely closed.

In order to operate the striker, it is sufficient to cause the catch lever to turn through 120 deg. by means of a firing line; during this action the cam causes the stop on the left-hand branch of the striker to recede progressively, by bending the firing spring until the instant when the tooth on the catch lever, having concluded its rising action on the incline, forces the cam to move to the left and release the striker, which is driven against the fuse under the action of its spring. From the arrangement of the various parts, it will readily be seen that this action can be repeated as many times as is necessary (in the event of a hang-fire), without having to interfere in any way with the breech.

To cock the gun automatically, it is sufficient to adjust the catch lever nearly to the firing position by means of a screw with which it is fitted for this purpose, the end of the screw being made to run in a groove in the breech of

SPHERICAL AND CONCENTRIC-THREADED BREECH-BLOCKS.

Fig 713

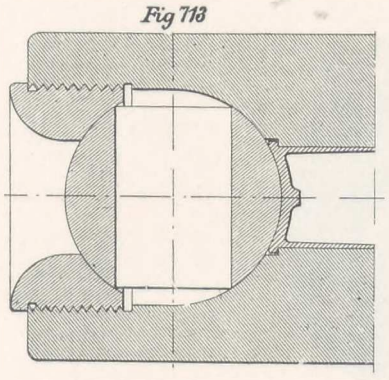
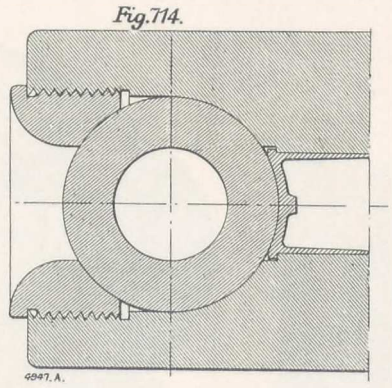
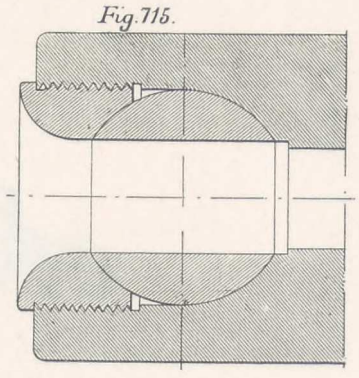


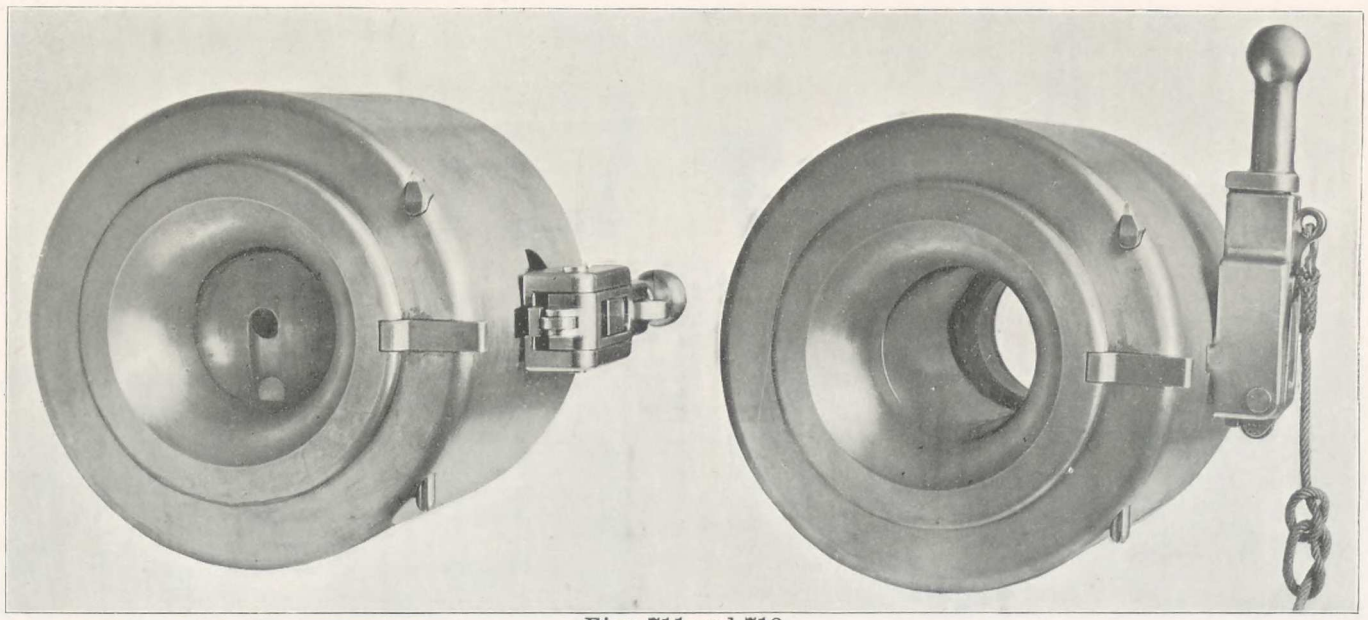
Fig.714.



4847. A.

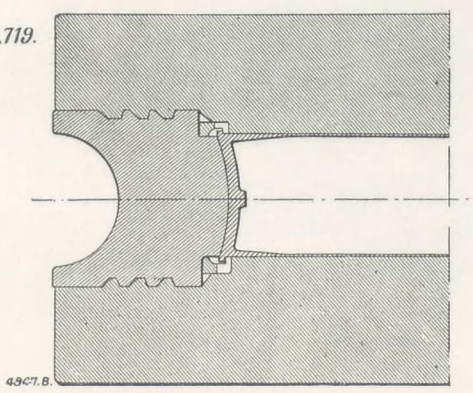
Fig.715.





Figs. 711 and 712.

Fig.719.



4967. B.

Fig.720.

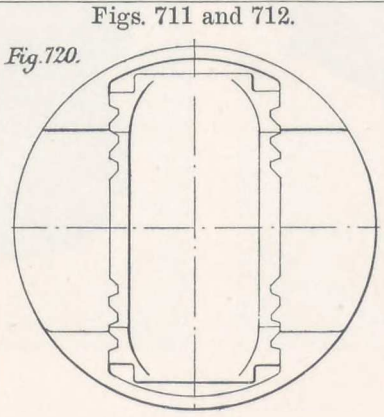
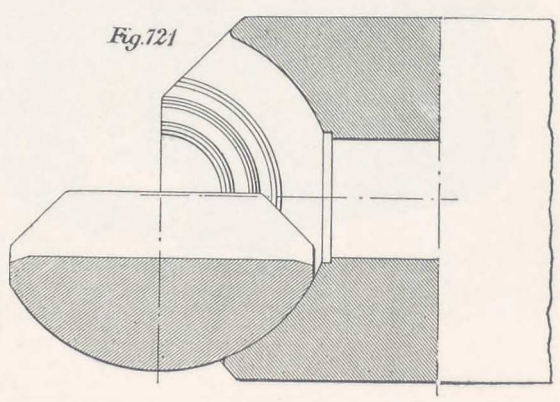
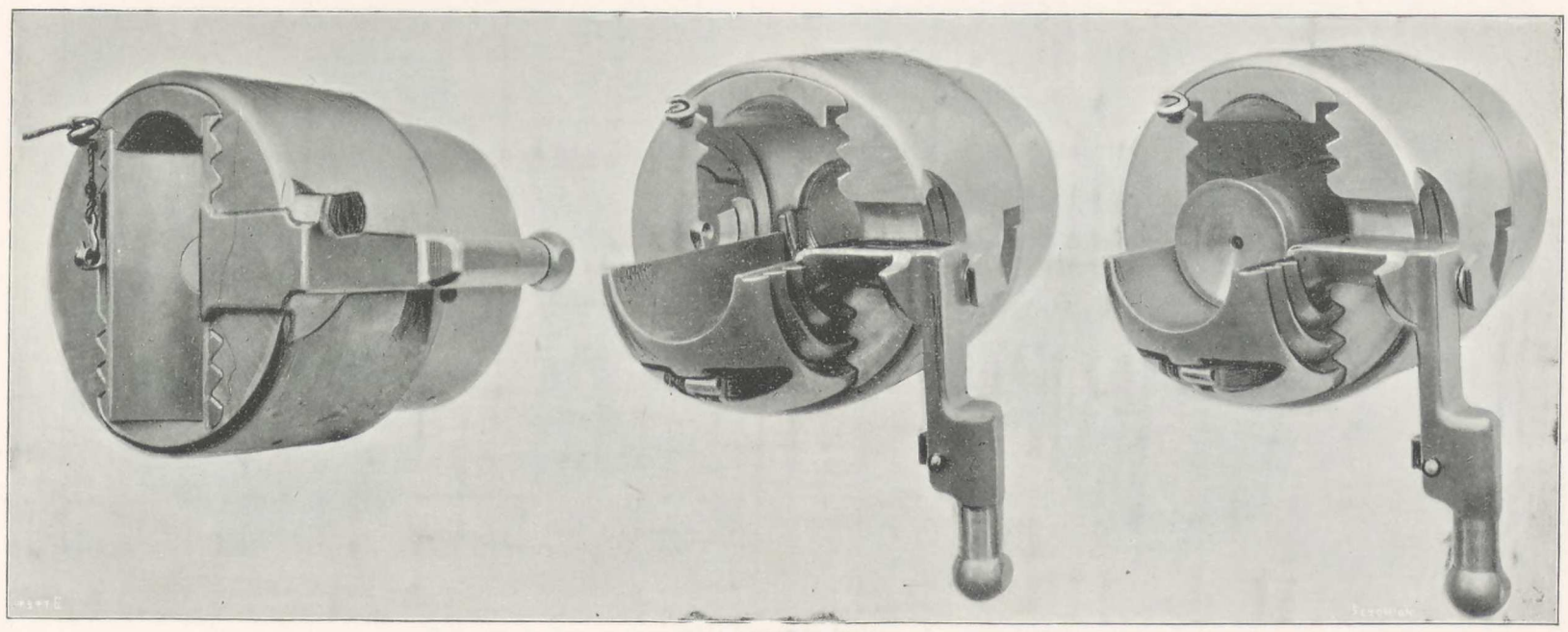


Fig.721





Figs. 716 to 718.

Figs. 711 to 721. Spherical and Concentric-Screw Breechloading Mechanism for Quick-Firing Guns.

CONCENTRIC-THREADED BREECH-BLOCKS.

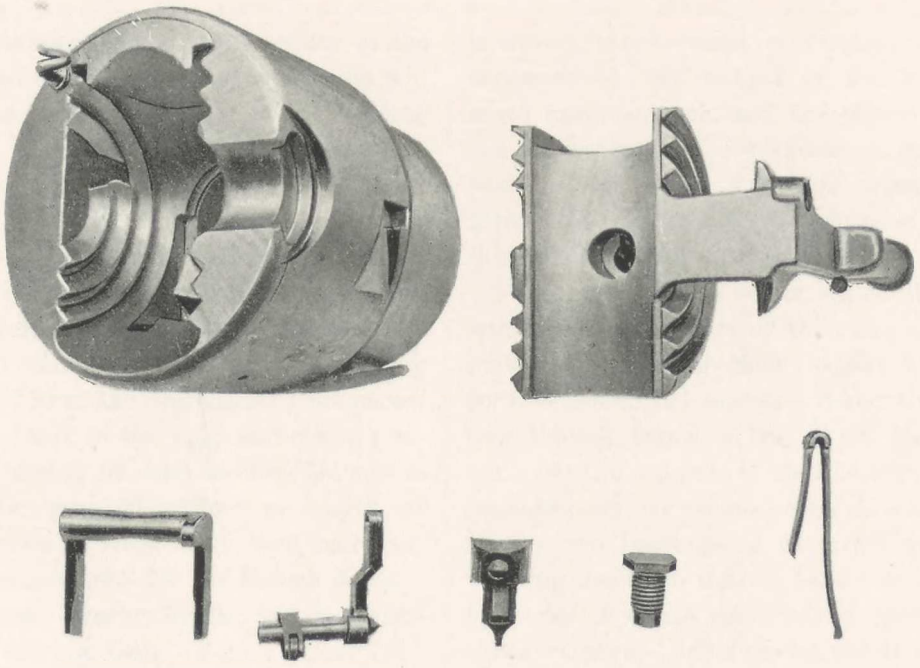


Fig. 722.

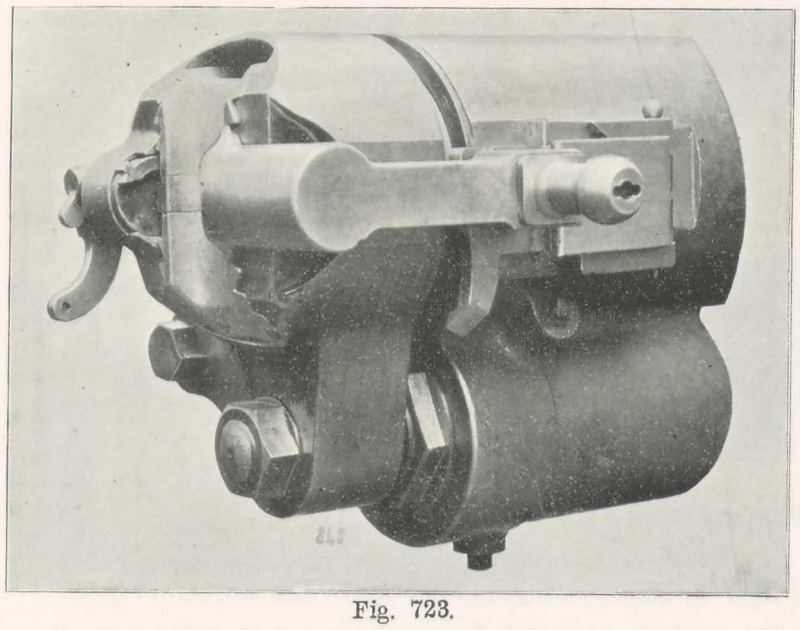


Fig. 723.

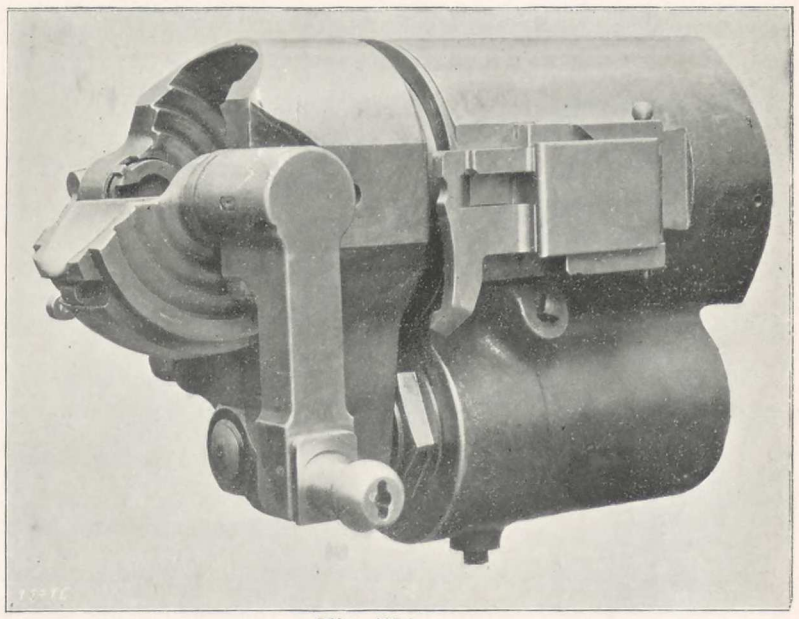


Fig. 724.

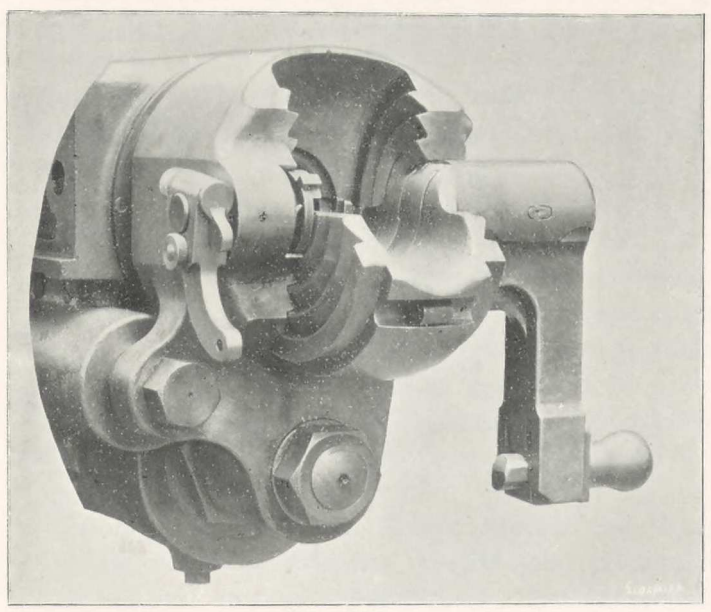


Fig. 725.

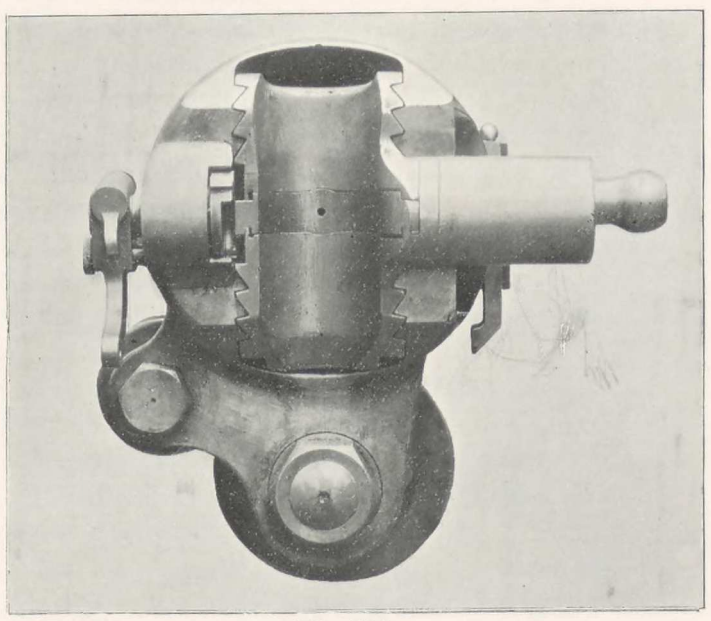


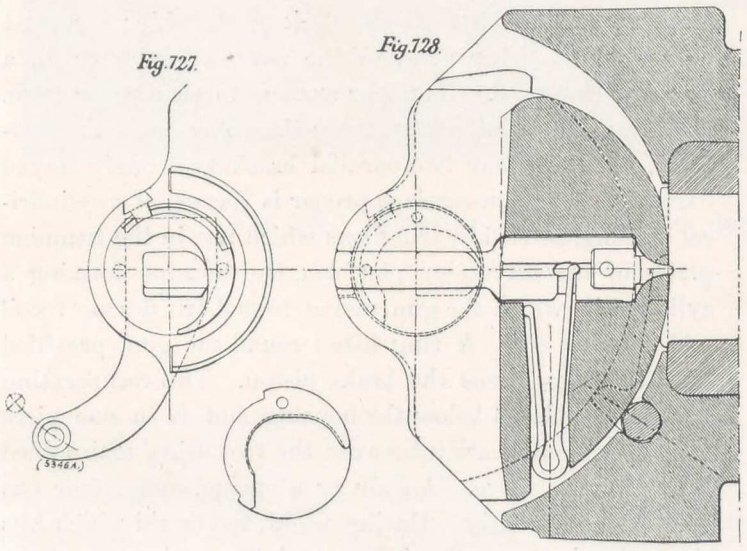
Fig. 726.

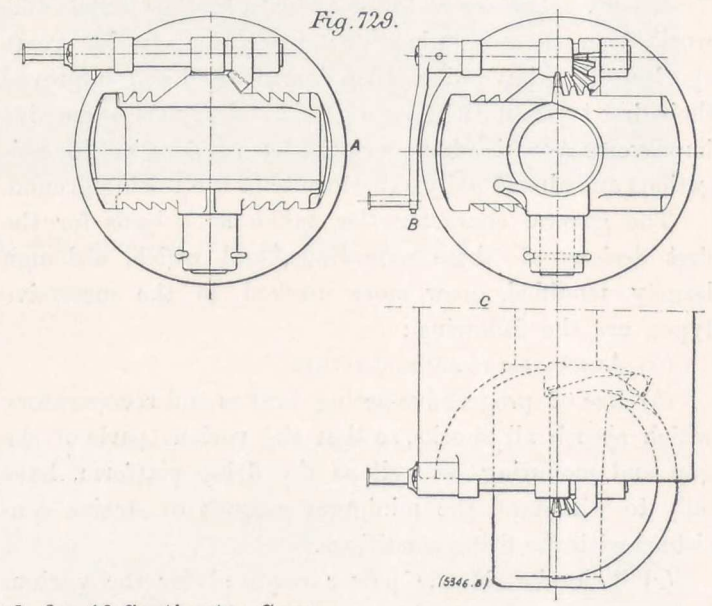
Concentric-Screw Breechloading Mechanism for Quick-Firing Guns.

the gun. In this way, as soon as the closing motion of the breech is commenced, and during this motion, the cam will act on the stock of the striker, driving it back and bending its spring. To fire the fuse, it will suffice to displace the lever catch slightly, thus setting the striker free.

Premature firing is impossible in both cases, for as soon as the handle of the lever is started to open the breech, the heel of the inside rod engages a projection on the right-hand branch of the striker, and prevents all forward motion of the latter. Figs. 727 and 728 show the type of firing mechanism; whilst Figs. 723 to 726, reproduced from photographs, show the breech-block in the open and closed positions; the example illustrating this breech-block belongs to a 47-millimetre (1.850 in.) gun, 60 calibres in length, of high power. Several series of these have been manufactured for various Governments and for the French Navy.

Concentric Threaded Breech-Block for 10-Centimetre (3.937-in.) Quick-Firing Gun (Figs. 727 and 728).





Concentric-Threaded Breech-Block for 10-Centimetre Gun.

—These are views of a breech-block of this type, fitted to a 10-centimetre (3.937-in.) quick-firing gun of high power. The working parts and firing mechanism are similar to those for the 47-millimetre (1.850-in.) guns above described. The catch lever, however, is not fitted with a tooth, but the cylindrical axis of the working crank is provided in the part inside the breech-block mortice with a bevel-shaped stop catch. One of the concentric threads is also bevelled, so that at the end of the travel of the catch lever, the cam is driven to the left, and frees the striker as previously described.

Numerous other examples could be given of concentric-threaded breech-blocks, for small and medium-calibre guns, which differ from the above only in the accessory gear, and especially in that of the firing device. A few words should, however, be added with reference to the manner in which the concentric screw has been applied to the breech mechanism of large-calibre guns.

Concentric-Threaded Breech-Blocks for Large-Calibre Guns (Fig. 729, A, B, C).—The same principle has been adapted to large-calibre guns. The breech-block, however, turns round a vertical axis; owing to this arrangement, the weight of the block does not cause much inconvenience, and the efforts required for working the mechanism are not excessive, or beyond the manual power of the men. The type selected for description is fitted with intermediate transmission, though in most cases this can be dispensed with.

The vertical axis round which the block turns corresponds with the centre of the gun; consequently, the concentric threads and their depths in the breech are in parallel horizontal planes. When the breech is open the breech-block forms a lip, which facilitates charging the gun. At the top part is fitted a segment of a pinion that engages a similar pinion keyed on a horizontal shaft, turning in two bearings at the rear end of the gun. The working crank, on the left-hand side, is keyed on this shaft, by means of which the shaft is opened and closed. The accessory parts—firing device, safety arrangements, locking gear—are of the same type as those previously referred to. Several other examples could be described, but this one will give an exact idea of the remarkable qualities of this new type of breech-block.

The advantages claimed for the concentric-threaded system are the following:

1. Extremely rapid manipulation.
2. Complete ejection of the cartridge-cases.
3. Absolute safety against premature firing, accidental opening, or hanging fire.
4. Facility in taking apart and refitting the breech-block and mechanism.
5. Easy inspection of the threads and of other wearing parts.
6. Utilising the block itself as a charging table.
7. Removal of all risk of wedging and shearing, should the case not be placed quite home in the chamber.
8. Fewness and simplicity of parts, and their complete protection in all positions.
9. The use of cartridge-cases with a concave bottom, which reduces risks of accidental explosion during handling.

XXXII.—NAVAL MOUNTINGS FOR QUICK-FIRING GUNS.

THE construction of naval mountings for quick-firing guns is almost as complex a problem as that of breech mechanism; and the complete solution of the question, as illustrated by the most modern types, has been gradual, though always steadily advancing. The conditions to be dealt with are very varied, as they differ with the calibres that range from the 37- and 47-millimetre (1.456 in. and 1.850 in.) guns, to those of medium and large calibres up to the 24-centimetre (9.449 in.).

Messrs. Schneider and Canet took a leading part in this work from the beginning, now more than twelve years ago, and they have since then transformed and improved their first types, until those of 1898 embody the successive improvements which have resulted from theoretical investigations and almost daily experiments in the testing ground.

The general characteristics, taken as a basis for the first designs of these mountings, and which, although largely modified, grow more marked in the successive types, are the following:

(*a*) Automatic recoil and return.

(*b*) Use of progressive-acting brakes and recuperators, which absorb all shocks, so that the various parts of the gun and mounting, as well as the firing platform, have only to withstand the minimum amount of strains consistent with the firing conditions.

(*c*) Reduction in the power required for the various manœuvres; and grouping together, within easy reach of the gunner, the laying and training hand-wheels.

(*d*) Reduction to a minimum of weight and bulk, resulting in greater facility for inspection, dismounting, and maintenance.

In order to give a means of comparison and an illustration of the progress achieved, we have selected some of the earliest types for illustration and description.

1. Mounting with Brake Cylinder as Gun-Housing (Fig. 730, Plate CXXIV.).—In this type the brake cylinder forms the housing which surrounds and supports the gun, the latter being fitted with a ring that acts as a plunger or piston; a spring recuperator compressed by the action of the brake completes the system. The type illustrated shows a 10-centimetre (3.937 in.) mounting of this type, the principal data of which are as follow:

Weight of gun	1980 kg.	4364 lb.
,, mounting	1900 kg.	4188 lb.
,, projectile	13 kg.	29 lb.
,, service charge (smokeless powder)	3.5 kg.	7.7 lb.
Muzzle velocity in service	720 m.	2428 ft.

This may be considered a gun of medium power. The various parts and the gunners can be protected by a shield of suitable shape and dimensions, that vary according to whether the gun is for service on board ship or for coast defence. It should be mentioned that, by means of a special device, the breech can be opened and closed automatically during the running out of the gun.

The mounting consists of the three following main parts: the gun carriage, the traversing platform, and the bolster or fixed support. For naval mountings, this is circular, and is bolted to the deck of the ship; for coast defence, it is either fixed to the masonry-work or on a wrought-iron base. Its upper surface forms a roller path. The traversing platform rests on the rollers and the bed-plate, and consists of two parallel brackets strongly stayed together. The gun-carriage proper is formed of a cylindrical housing, carried by trunnions which rest in the trunnion plates of the traversing platform, the housing forming a cylinder, in which the gun moves to-and-fro during recoil and running out. A ring fitted round the gun, provided with openings, forms the brake piston. The recuperating cylinder is placed below the housing, and is in one piece with it, communication between the two being maintained by a pipe and valve. An air, or a spring, compressor can be used indifferently. During recoil, the liquid which fills the space between the jacket and the gun passes from the rear to the front of the brake piston. The diameter of the gun being larger in the front than in the rear of this piston, the liquid displaced is forced through the connecting pipe, lifts the valve, and enters the recuperator, where, acting on a piston, it compresses the air or springs. When the recoil is finished, the liquid is forced back into the jacket through a narrow passage, and runs out the gun.

For elevating the gun, a shaft with a hand-wheel is provided, mounted on a bracket fitted to the left side of the carriage; this works a pinion through a set of toothed gearing, which engages a toothed sector fixed to the jacket, and the centre of which corresponds with the axis of the trunnion. For lateral training, either direct action or transmission gearing can be employed. In the first case, the gunner acts on a jointed lever on the left side of the mounting, and by working it to the right or to the left, he causes the mounting to turn round on its rollers; previously, however, he slightly presses down the lever, in order to disengage a bar which fixes the system in the firing position. In the second case, the lever is replaced by a hand-wheel, which works a pinion through a set of

NAVAL MOUNTINGS FOR QUICK-FIRING GUNS.

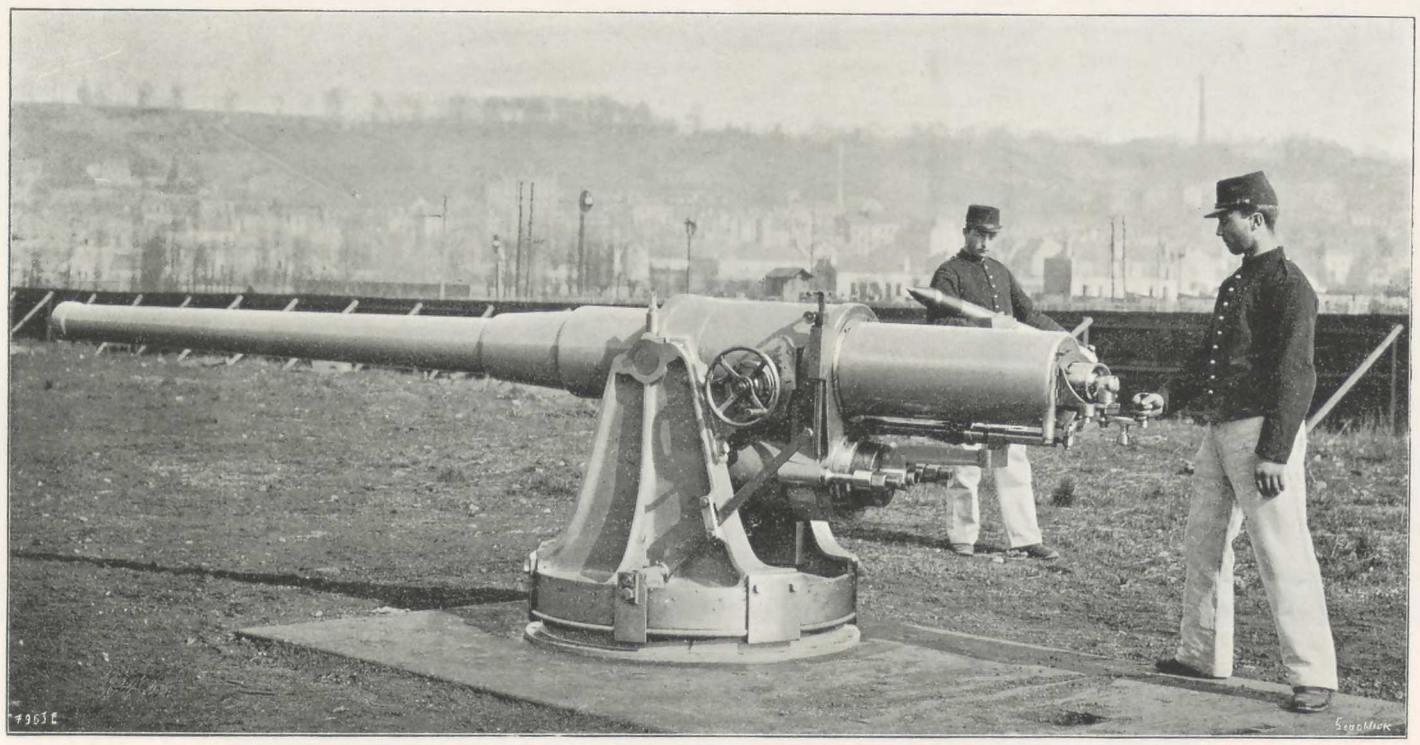


Fig. 730. Mounting for 10-Centimetre Gun, with Housing used as Brake Cylinder.

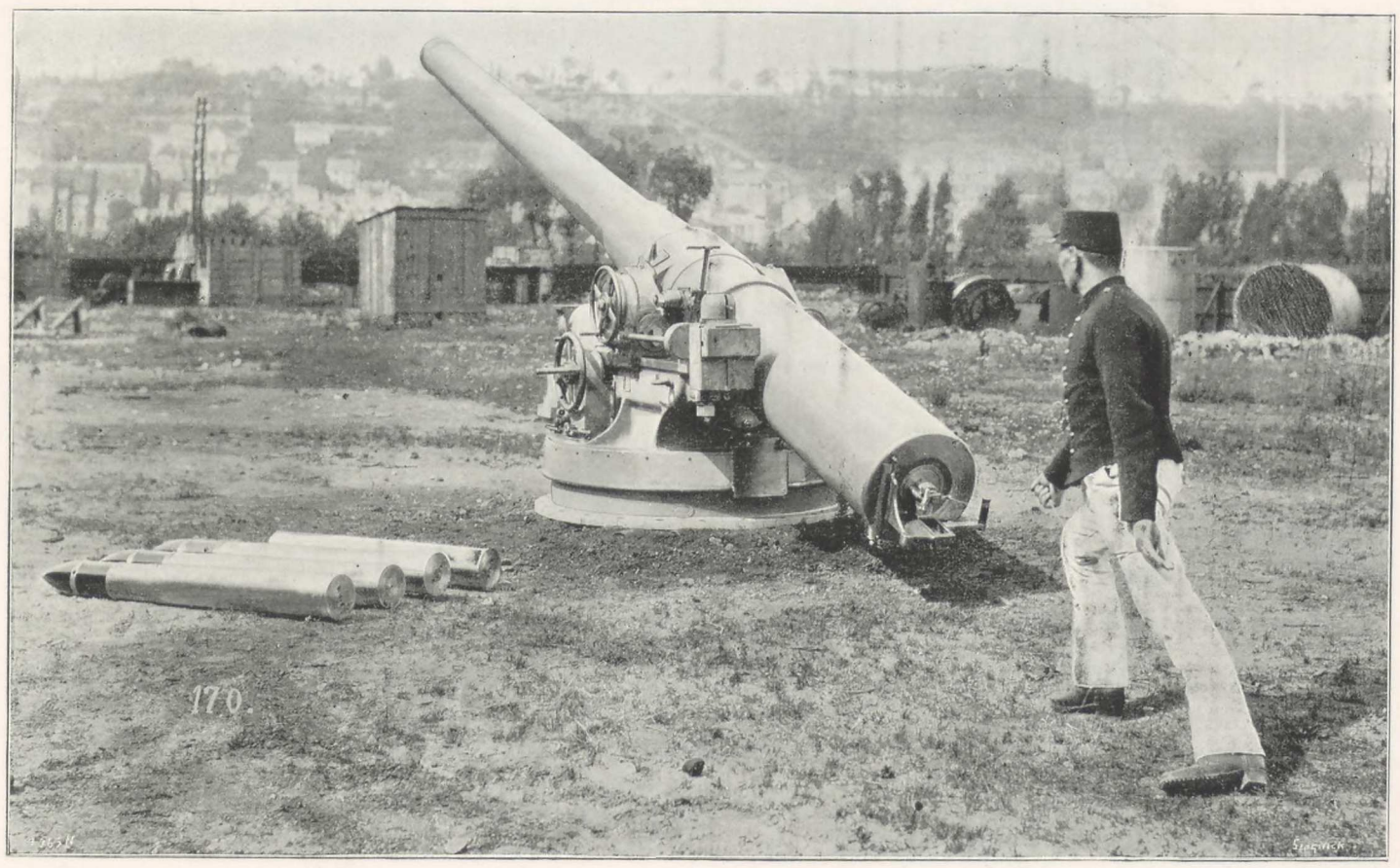


Fig. 734. Mounting for 15-Centimetre Gun with Horizontal Slide.



NAVAL MOUNTING FOR QUICK-FIRING GUNS.

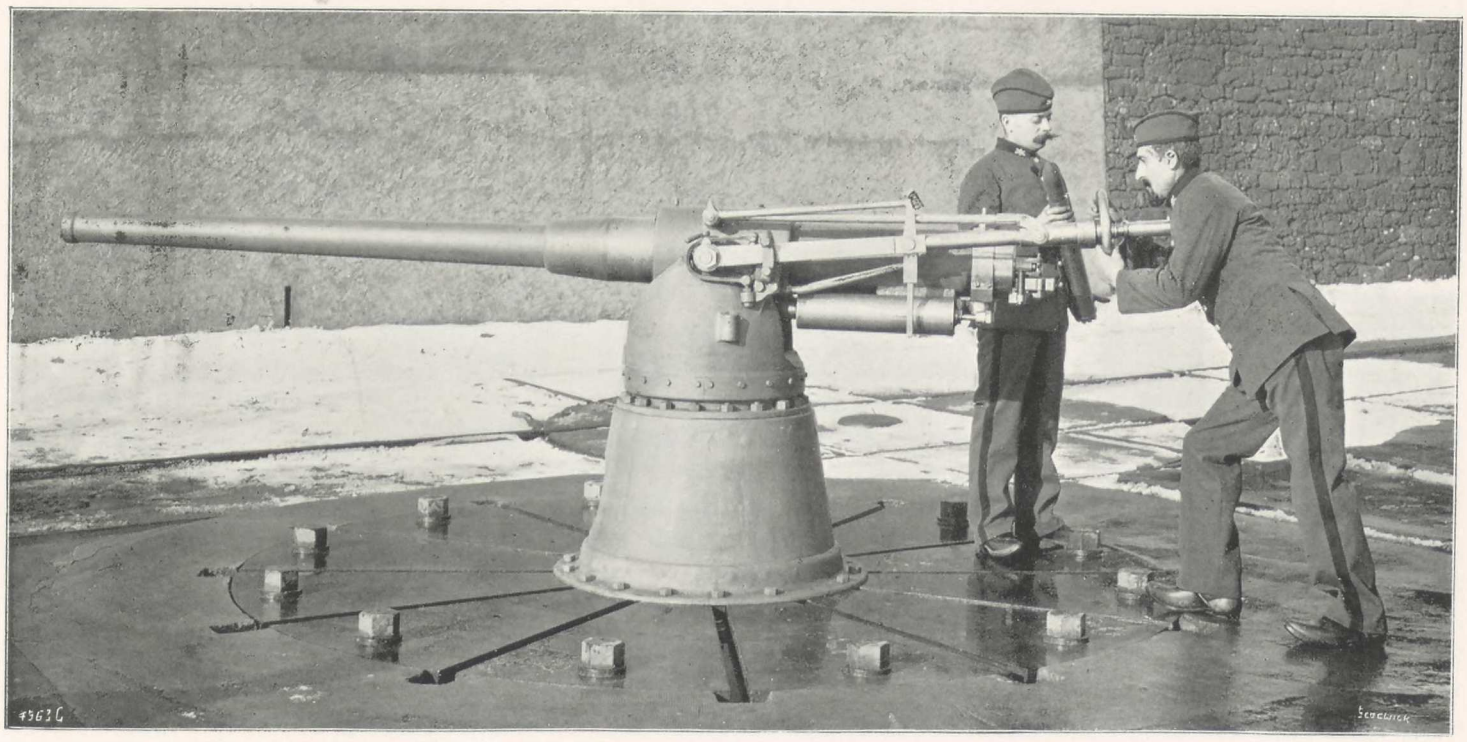


Fig. 731.



Fig. 732.

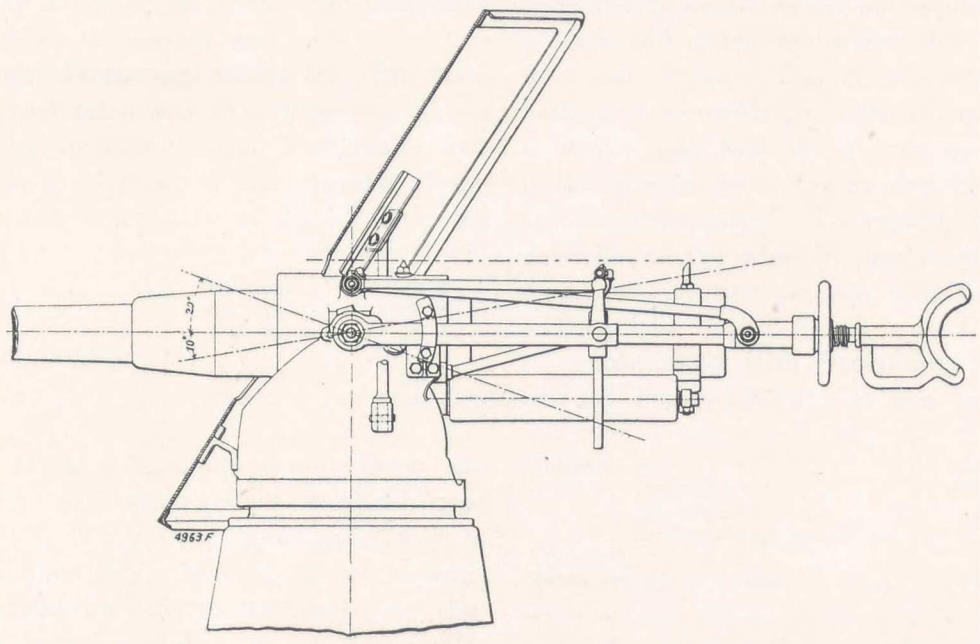


Fig. 733.

Mounting and Training Gear for 65-Millimetre 50-Calibre Gun.

gearing that engages a circular rack on the bolster. In this type of mounting, the lateral sights are fixed to the housing and are not affected by the recoil; the gunner can, therefore, constantly follow the aim during the whole of the service operations, including firing, recoil, and running out.

Figs. 731 to 733, Plate CXXV., illustrate a modification of this type of mounting for a 65-millimetre (2.559-in.) 50-calibre quick-firing gun; the slide and bolster are, however, of a particular shape, and there is a special system for elevating the gun.

The base of the mounting has the form of a truncated cone, bolted on the deck; the top forms the circular path for the slide, while in the base is the pivot in which the steel pivoting screw rests that supports the slide, which is guided by a friction ring.

The slide is of cast steel, with two brackets joined at the bottom by a circular plate, and carefully stayed. It is extended downwards by an inverted cone, terminating in a wrought-steel bearing which rests on the rounded head of the pivoting screw; brass friction rings are fitted on all the parts that undergo friction. Side openings, usually closed, are cut in the walls of the bolster, to facilitate inspection of the pivot.

The gun is trained by the shoulder pressing on the butt rest, which is fixed rigidly to the slide; part of the length is screwed and is provided with a box nut, to which is fitted the working hand-wheel; a hollow cylinder surrounds the butt-rod, and slides on it governed by the box-nut; it is joined to the gun-housing by a bar which ends above the left trunnion The whole of this mechanism, under the action of the hand-wheel, causes the gun-housing to turn round on the trunnions, thus giving the required elevation. The system is completed by a sight bracket fixed to the housing, and by a jointed bar which unites the head of the sight to the axis on which the longitudinal bar acts that unites the hand-wheel to the gun-housing.

The gunners and the various parts of the mechanism can be protected by a shield, the shape and dimensions of which vary according to requirements.

2. Mounting with Horizontal Slides (Fig. 734, Plate CXXIV.).—This type is fitted with fixed horizontal slides; the tangent scale recoils with the gun horizontally, and sighting requires the co-operation of two gunners. These arrangements are not completely in accord with the present description applies to 15-centimetre (5.905-in.) guns, shown in Fig. 734, Plate CXXIV.

Weight of gun	6300 kg.	13,885 lb.
,, mounting	4650 kg.	10,248 lb.
,, projectile	40 kg.	88 lb.
,, service charge (smokeless powder)	10.5 kg.	23 lb.
Muzzle velocity in service	740 m.	2428 ft.

general conditions of the programme already given, and according to which quick-firing Schneider-Canet guns are usually mounted. They have been reproduced in a small number of guns only. In this type of carriage, elevation and training are effected exclusively by electricity, the motor being controlled by one lever. The

A suitable shield is made for naval and coast-defence guns.

The mounting consists of the three main parts, as usual. The upper face of the traversing platform is made with two horizontal bearing surfaces, on which travel the horizontal slides. These are provided with rollers, to facilitate the displacement of the cradle during the recoil and running out of the gun. The cradle contains the lateral brake cylinders, and also the recuperator placed below, and in the centre line of, the system. The brakes have central counter-rods, and carry the trunnion-plates in which the gun trunnions are placed. The piston-rods are fitted in the front of the travelling platform. The recuperator cylinder is provided with lugs in front, to which are fastened the spring bars. A piston, the rod of which is fixed to the front of the traversing platform, moves in this cylinder during recoil, the cylinder being closed at the opposite end by a movable bottom, on which are bolted the bars that run in the centre of the set of springs. When the gun is fired, the carriage proper runs on the rollers, which are placed slightly above the top surface of the horizontal slides, and the brake cylinders act in the usual way to absorb part of the recoil energy.

The mounting is provided with two sets of gear for elevating and for training the gun, which can be worked by electricity or by hand. For elevating by hand, the device comprises a hand-wheel placed at the rear part of the housing, which works through differential gearing, a pinion that engages a rack fitted to the gun. For training, a hand-wheel is placed in the middle of the left cheek, which works through a set of toothed wheels, a pinion that gears in the circular rack placed inside the traversing platform.

Two small electric motors are provided for driving the elevating and training mechanism; but, as working by hand and by electricity are not required at the same time, a lever and clutch are added that throw one or other in or out of gear. The electric motors are driven by a battery of accumulators. The commutators are arranged in such a way that the gunner, by acting on the lever in the direction he wishes to give the gun, obtains exactly the position required. The rapidity of the motion is proportional to the angle of displacement of the lever from its original position, the gun being fixed immediately it is suitably laid.

3. Mounting with Oscillating Slides (Figs. 735, 740, and 741, Plate CXXVI.).—In this type, the slides can be inclined according to the degree of elevation required

Weight of gun	3130 kg.	6898 lb.
,, mounting	3150 kg.	6942 lb.
,, projectile	21 kg.	46 lb.
,, service charge (smokeless powder)	6 kg.	11 lb.
Muzzle velocity in service	740 m.	2428 ft.

of the gun. The illustrations show a mounting of this class for a 12-centimetre (4.724-in.) quick-firing gun.

A shield of suitable shape may be adapted to the gun.

In this mounting, the bedplate is bolted to the deck as usual, and forms a path for the live ring. The traversing platform carries the trunnion standards, to which are fitted the joints of the movable slides; these bear on two circular racks, jointed to the lower part of the traversing platform. The gun-carriage proper consists of a semicircular cradle, in which the gun rests; it also comprises the two lateral brake cylinders, the blocks of which run on the movable slides. The piston-rods are in the front part of these slides. The recuperator is in one piece with the gun-carriage proper, and consists of a cylinder inside which is a fixed plunger joined to the rear stay of the slides. At the opposite end is a fixed plunger, fitted with a ring on which are joined two rods that carry the sets of springs. These rods are guided, with but slight friction, in the ring of the recuperator cylinder. During recoil, the gun, carried in its housing, travels on the slides; the two lateral brakes, with central counter-rods, act in the usual way to absorb part of the force due to the recoil. At the same time, the fixed plunger enters the recuperator cylinder and displaces the movable end opposite; this acts on the two sets of springs, which are compressed by bearing against the ring of the recuperator cylinder. When the recoil is exhausted, the stored-up energy in the springs runs out the gun.

To vary the inclination of the gun, the housing is moved by means of the two oscillating arcs at the lower part of the traversing platform, which travel freely in two guides at the rear of the slides. The latter are cast with bearings for a horizontal shaft, provided with two pinions that engage the movable racks. When, therefore, the pinions are made to travel up or down the racks, the gun is given a corresponding inclination; the gunner can produce these displacements by means of gearing. The gun is trained horizontally by a lateral wheel that works a pinion through an endless screw, and a helicoidal wheel, the pinion gearing into the circular rack on the bolster. The sights are fitted on the left trunnion of the housing, and on the rear of the corresponding side; the gunner can, therefore, keep his eye constantly to the firing line, including the period of recoil and of running out.

4. Mounting with Independent Recuperator and Guiding Transom (Figs. 736 to 739, page 217, are views of a mounting for a 65-millimetre 50-calibre quick-firing gun.

Weight of projectile	4 kg.	8.8 lb.
,, charge BM^3	1.660 kg.	3.65 lb.
Initial velocity	750 m.	2460 ft.
Weight of gun	510 kg.	1122 lb.
,, mounting and shield ...	910 kg.	2002 lb.

The arrangements of this mounting are clearly shown in the illustrations; they include brake cylinders and spring recuperators, the rods of both being attached to a crosshead ring fastened on the gun.

The mounting is central pivoting, with hydraulic brake and reduced recoil, the running out being effected by the recuperator; the angles of elevation vary from − 10 deg. to + 25 deg. The gun recoils in a cradle with trunnions, the brake cylinders being attached to the cradle. The transom frame turns round a central pivot that rests on a bearing fitted to the bedplate, the base of which is large enough to insure suitable stability to the system. A holding ring that runs on the whole circumference of the transom frame, prevents the shifting of the system during firing; it is also fitted with a latch to fix the mounting. All the larger parts of the mounting are of cast-steel. The gun during the recoil, slides on gun-metal shoes fitted inside the cradle, ribs being provided to prevent the system from turning. The brake cylinders, cast in one piece with the housing, are placed vertically, so as to reduce as much as possible the width of the mounting; they have gun-metal linings, in which grooves of different sections are cut for the passage of the liquid. The piston plungers are attached by a bayonet joint to a ring shrunk on the gun. The recuperator for running out the gun consists of two series of spiral springs which bear on lugs on the housing, and are compressed by two screwed rods fixed to the gun ring. The springs are so set that they can run the gun out under the greatest angle of elevation. The gun is but little displaced during recoil, as the resistance of the brakes produces a resultant in the centre line of the gun which is in direct opposition to the pressure on the bottom of the bore. Leather plugs placed between the gun ring and the brake cylinders limit the running back of the gun. The housing, transom frame, and bolster are on the same pattern as those of the numerous other mountings built by Messrs. Schneider and Co. for the French Admiralty, as well as for foreign Governments.

The gun is trained vertically by a handwheel and gearing, which works the rack fitted to the housing through a set of pinions; the effort required is only that necessary to overcome friction, as the whole of the oscillating weight is accurately balanced on the housing trunnions. The gunner trains the gun by horizontally pressing with his right shoulder on the butt; and while he sights the target, he works the elevating handwheel with his left hand, and draws the firing line with his right. The sight and scale are fitted to that part of the housing which oscillates without recoiling; the pointer can, therefore, when necessary, roughly sight the gun during loading, sighting it finally as he fires.

To dismount the gun, all that is necessary is to detach the piston plungers from the brake cylinders, and to take the rods from the recuperators, the gun being then made to slide in the housing from the front to the rear. The ring holding the brake and the recuperator is then taken off by disengaging it from its lugs, by turning it a quarter round. All the parts of the mechanism, as well as the recuperator springs, can be taken to pieces with great facility.

NAVAL MOUNTINGS FOR QUICK-FIRING GUNS.

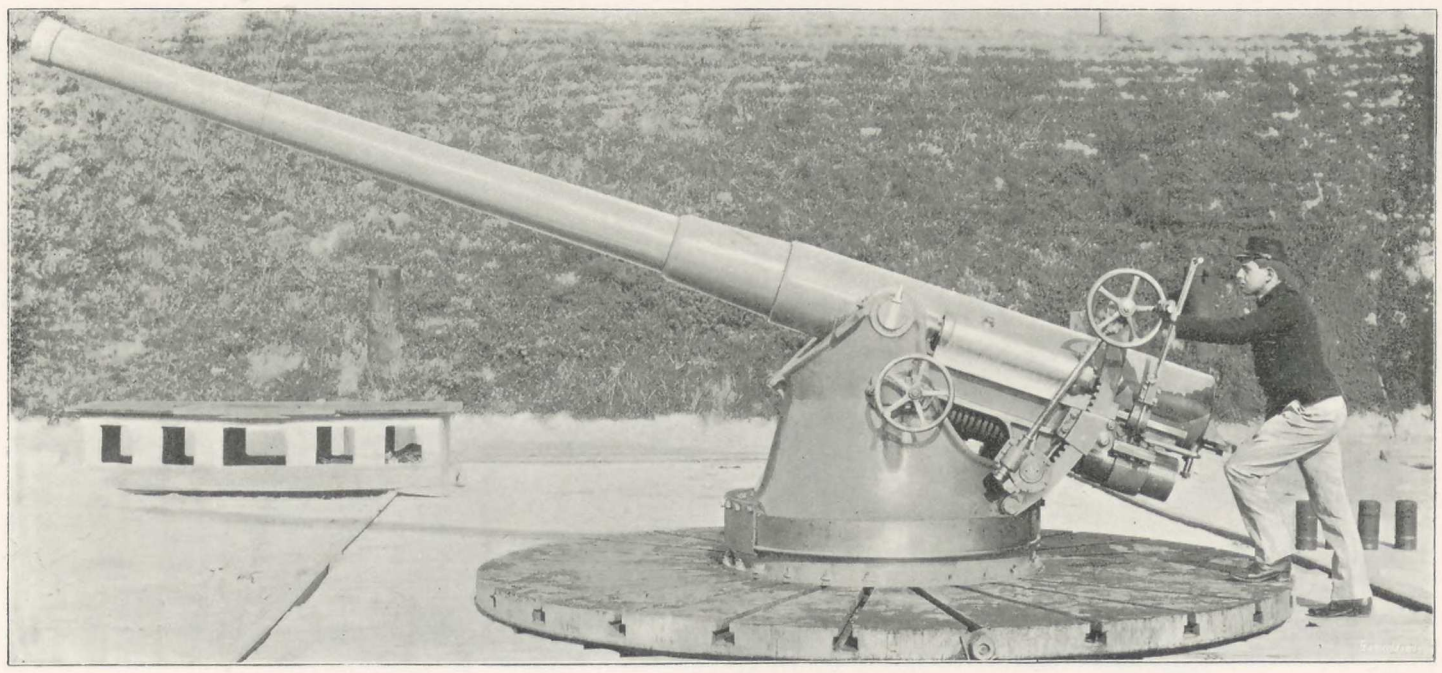


Fig. 735.

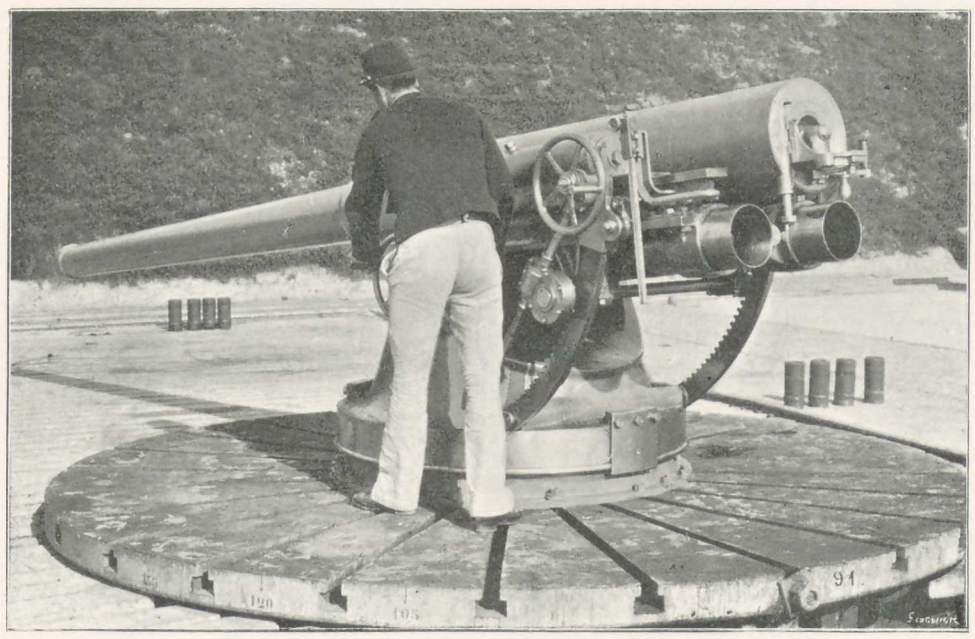


Fig. 740.

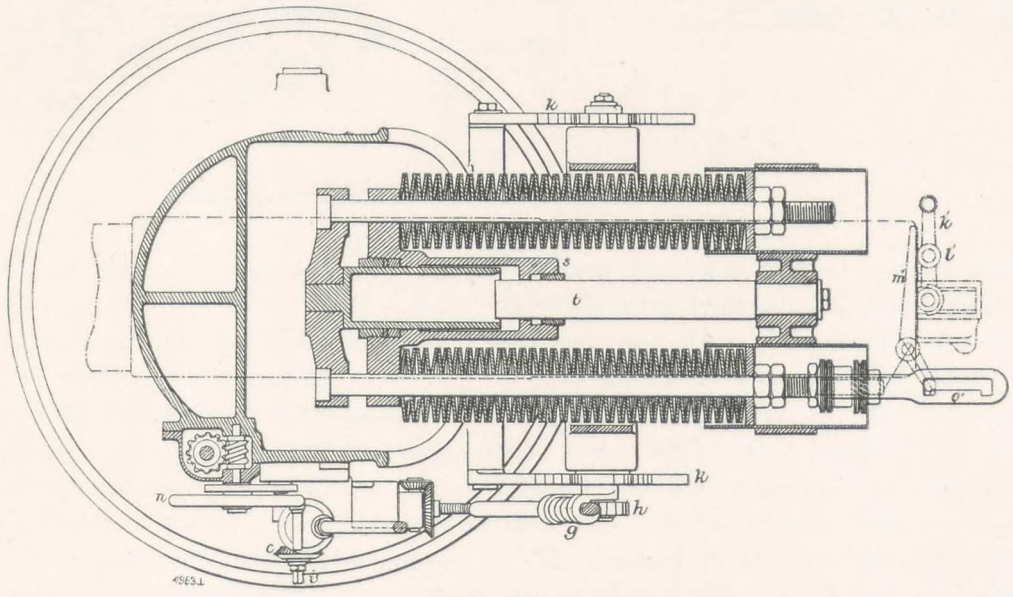


Fig. 741.
Mounting with Oscillating Slides for 12-Centimetre Quick-Firing Gun.

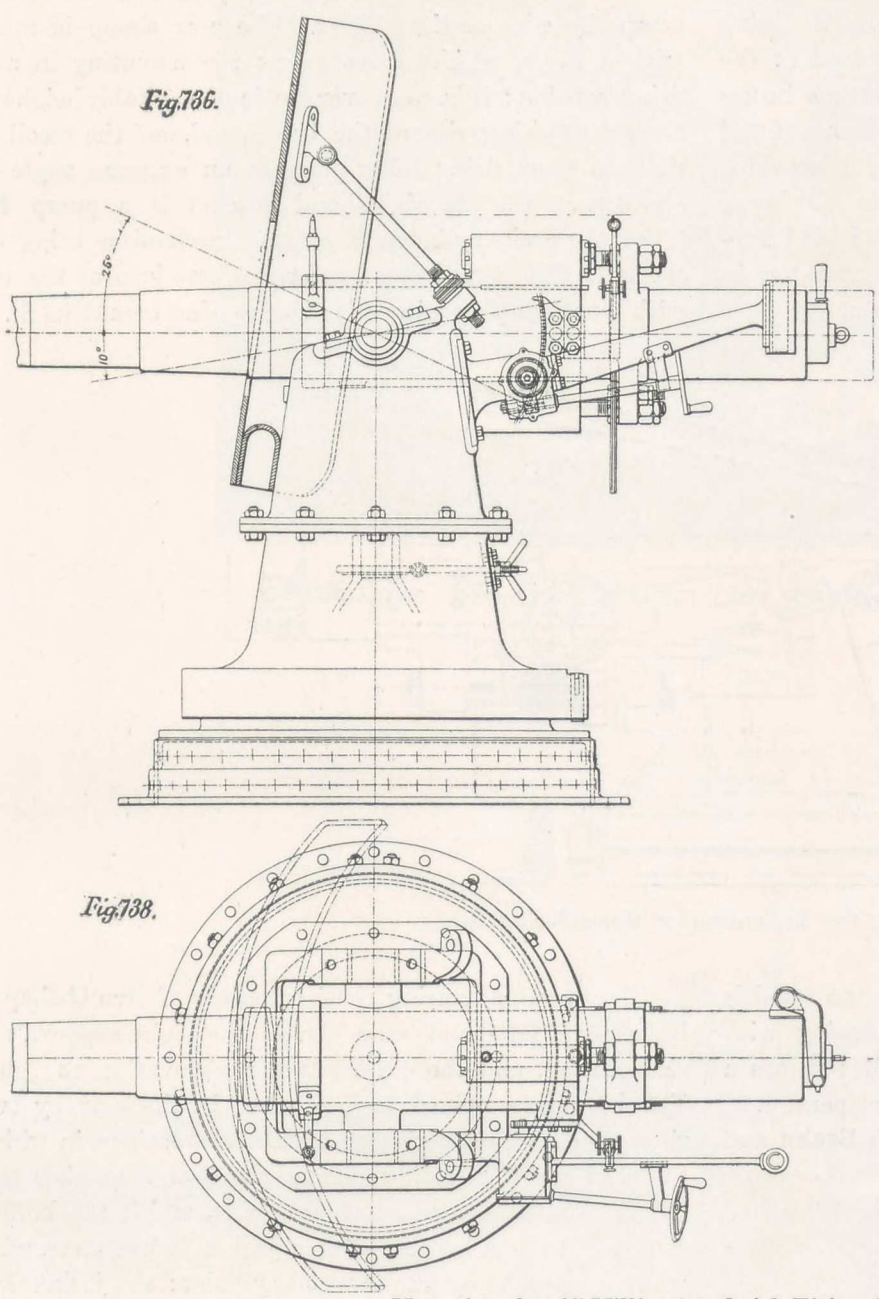
A circular shield protects the gunners and the mounting against grape shot; it is fixed to the transom frame by means of two stays and braces. To work the gun, the following *personnel* is required: One pointer who fires the gun, one gunner at the breech, and one to keep the gun supplied with ammunition.

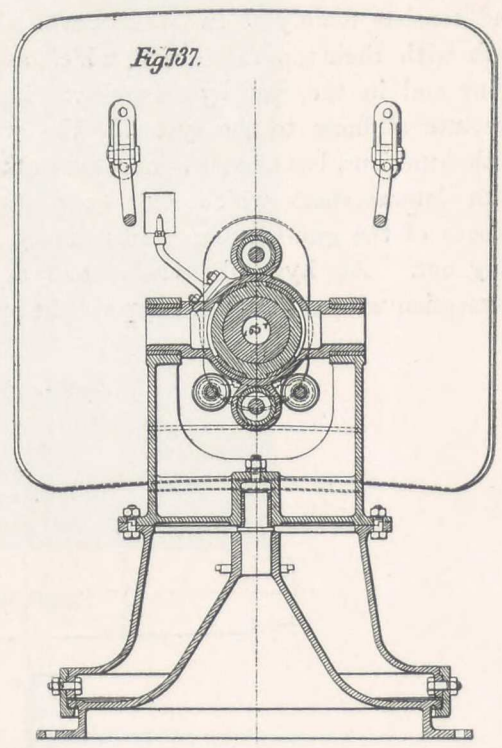
In order to give a complete idea of the importance and number of tests of all kinds that were made during several years in the Creusot and Havre Works and Proving Grounds, with a view to establish the bases for the construction of new quick-firing guns, it would be necessary to speak further and in detail of a numerous series of accessory gear relating to the various parts of the material, and which were manufactured and tried at the same time as the mountings, the principal types of which we have just described. Such a description would, however, carry us too far. These various experiments were witnessed at the time with great attention by commissions appointed by the French Admiralty and by foreign Governments; and they resulted in important orders being given for Schneider-Canet quick-firing guns.

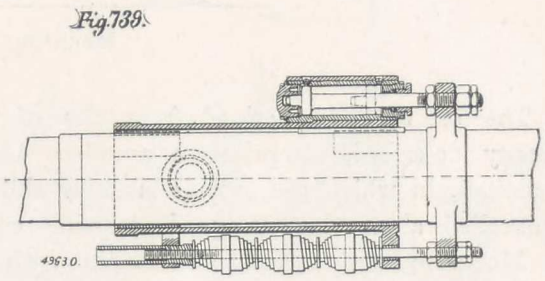
SCHNEIDER-CANET QUICK-FIRING NAVAL GUNS, 1888 PATTERN.

Following these experiments, two types of mountings were decided on for the 1888 ordnance. First, that with oscillating slides was chosen; this was fitted to a traversing platform made to slide on balls or rollers, or turning on a standard and pivot. These types were further improved upon, as experience was gained in practice, and the general arrangements, especially the elevating mechanism, were made more simple. The system which embodied a brake separate from the recuperator, and fitted to a frame provided with a guiding transom, was also maintained.

The Schneider-Canet system of gun mounting of 1888 may be taken as the basis of their most advanced practice;







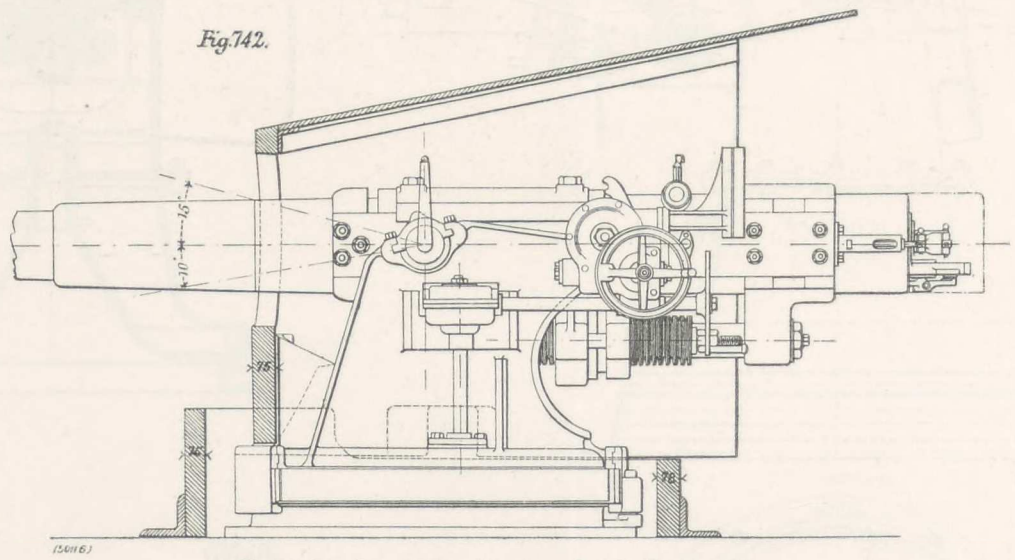
Mounting for 65-Millimetre Quick-Firing Naval Gun.

it comprises a large variety of guns and mountings of the usual calibres, which have been delivered by the Creusot and Havre Works, and placed in regular service in several fleets. The guns themselves are of a uniform type, and have already been described; the breech-blocks work by one action, with the interposition of toothed pinions or of a rack.

The mountings are of two principal types: The first, developed from the model with oscillating slides, is characterised by a movable gun-housing fitted with the trunnions, and consists mainly of two beams which form a sliding path with their top flange, and which are joined at the front and in the rear by two short rings which insure absolute stiffness to the system. The gun is not fitted with trunnions, but carries a jacket shrunk on it, provided with lateral shoes which slide on the upper and lower flanges of the gun-housing beams during recoil and running out. An hydraulic brake and a recuperator, in connection with each other, complete the system.

top surface forming a roller path; it is also fitted with the circular rack for the training. The traversing platform consists mainly of a lower bed, in continuation of which are two brackets, made almost vertical and suitably stayed; the central part contains the vertical pivot ring. The lower surface of the bed is trough-shaped where it rests on the roller balls. The whole system is held down during firing by two clamps, fixed, one in the front and one in the rear of the traversing platform, and which grasp the edge of the bolster. The rear clamp is fitted with a catch, which serves to fix the mounting in any firing position; it is, moreover, made of a suitable height to allow for the lowering of the breech end, and the recoil of the gun when firing takes place at an extreme angle of elevation. On the right-hand bracket is a pump for filling the brake cylinders, the firing mechanism being on the left. The traversing platform is provided at the top with trunnion-plates, in which the housing trunnions fit.

Fig. 742.



Mounting for 10-Centimetre Quick-Firing Gun.

The second type, derived from one of the models already described, comprises a complete housing with trunnions, in which the gun is made to slide; it has a hydraulic brake, and an independent spring-recuperator.

Mounting with Lateral Beams and with Brake and Recuperator Connected (Fig. 742).—A typical example of this mounting is that for 10-centimetre (3.937 in.) 55-calibre Schneider-Canet guns; it is of small dimensions compared with the *vis viva* of the gun.

Weight of gun	2200 kg.	4848 lb.
,, mounting	3740 kg.	8242 lb.
,, shield	2450 kg.	5400 lb.
,, projectile	14 kg.	31 lb.
,, service charge (smokeless powder)	3.4 kg.	7½ lb.
Muzzle velocity	780 m.	2559 lb.
Elevation	+ 15 deg.	+ 15 deg.
	− 10 deg.	- 10 deg.
Training	360 deg.	360 deg.

The bolster is circular, and is bolted direct on the firing platform. It is fitted around its circumference with a ring which holds the traversing platform clamps, the

The movable housing consists mainly of two U-shaped beams; the left-hand beam carries the sight support, the scale casing, and the curved rack for elevating the gun. The beams are joined in front and in the rear by two rings lined inside with gun-metal for bearings, in which the gun slides smoothly during recoil and running out. On the front ring are the stops against which the buffers strike. The gun is made with a jacket, in one piece, with which is cast the hydraulic recoil cylinder; the jacket has slides on each side, which clasp the top and bottom flanges of the beams, along which they travel during recoil and running out. The gun, therefore, slides along the beams of the housing during firing, while the housing can only turn on its trunnions during the action of elevating or lowering the gun. On the top part of the jacket are the rings for lifting the gun in and out, and the slide lubricators. The brake cylinder placed below is provided with two projections, which form abutments for the Belleville springs of the recuperator. In front of the cylinder is the piece which carries the guide of the recuperator bars. The hydraulic brake is on the

MOUNTINGS FOR SCHNEIDER-CANET QUICK-FIRING GUNS.

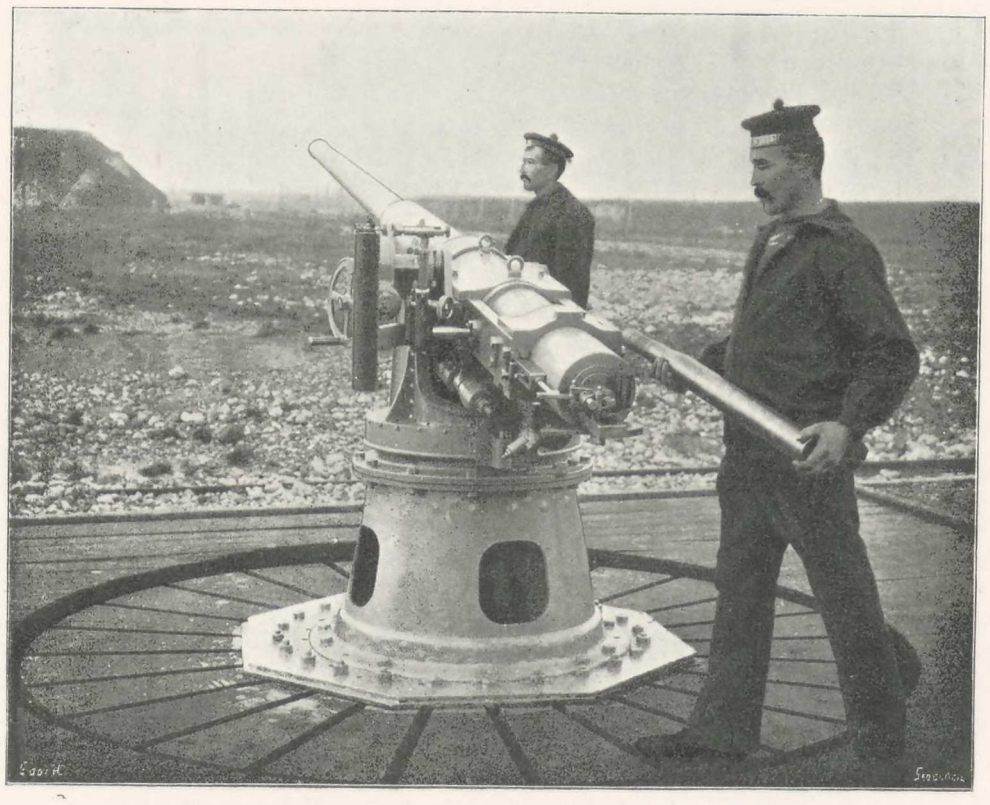


Fig. 743. Mounting for 57-Millimetre Quick-Firing Gun.

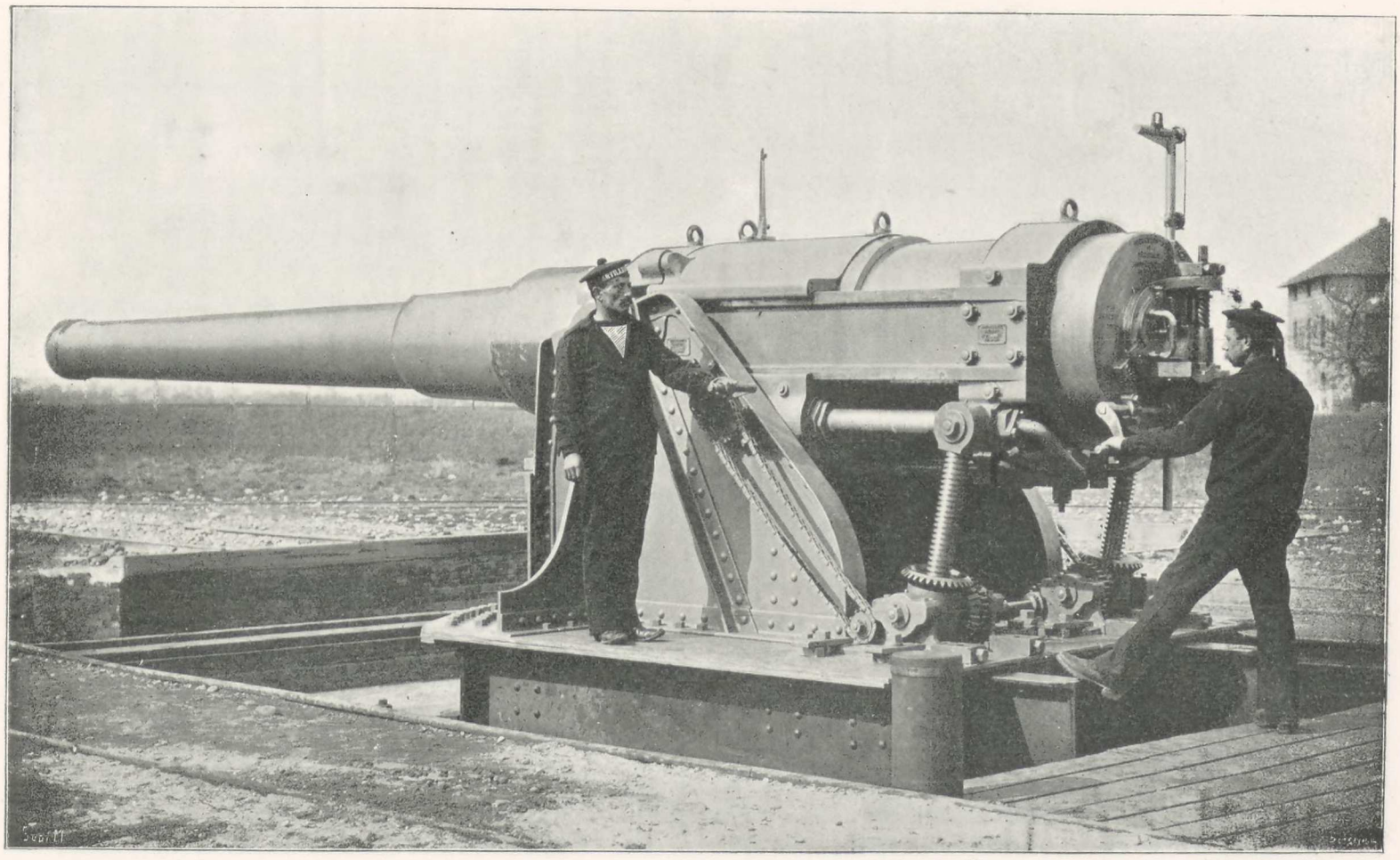
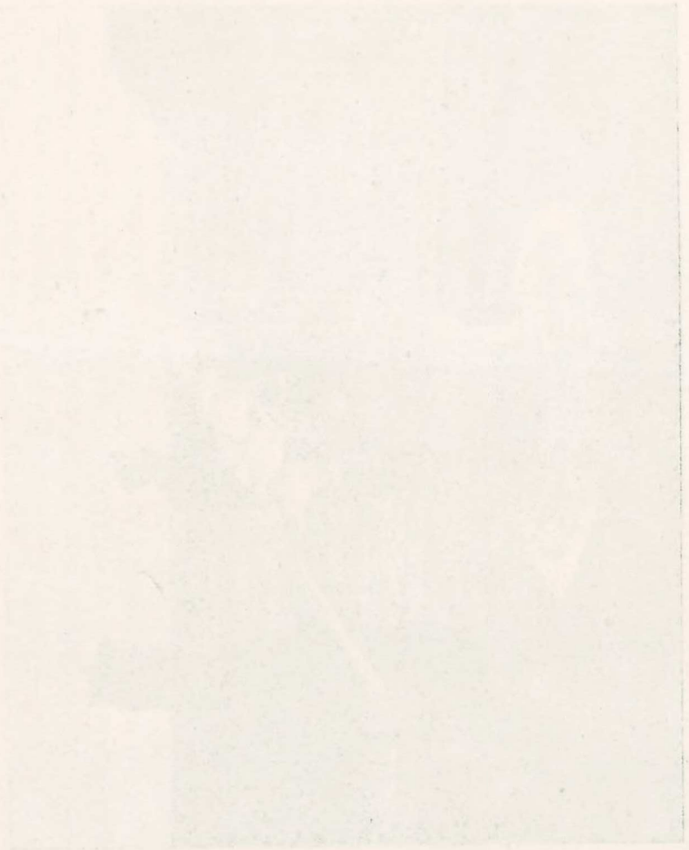
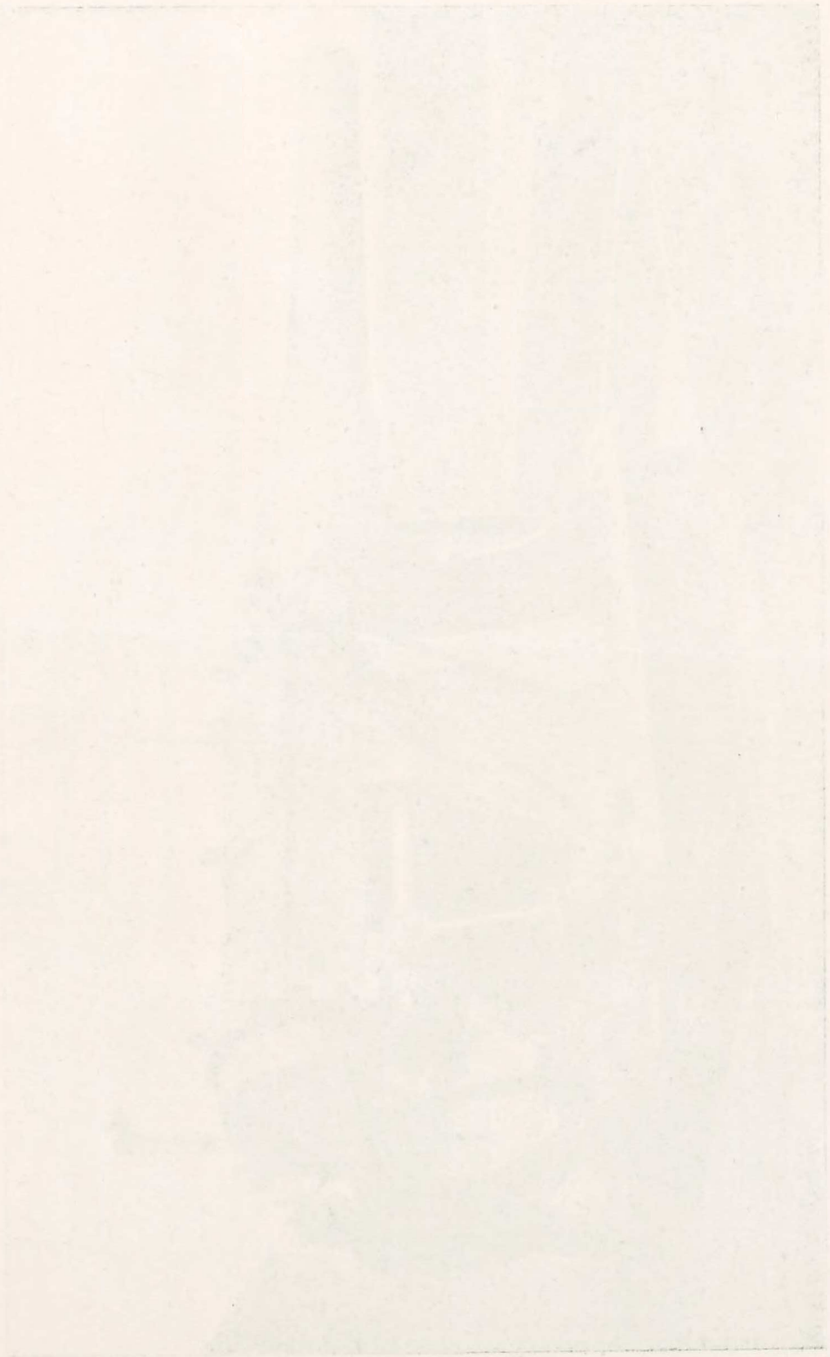


Fig. 748B. Mounting for 24-Centimetre 23-Ton Quick-Firing Gun.


CH3-CH2-CH2-COOH



Schneider-Canet type, with central equalising rod; the cylinder is closed in the rear by a plunger, which bears against the crosspiece forming an abutment for the Belleville springs.

During recoil, the brake piston remaining fixed, the gun draws the cylinder along with it; the liquid is compelled to pass through the annular vent made between the central counter-rod and the edges of the grooving in the piston, by raising the valve. As the diameter of the counter-rod is smaller than that of the piston-rod, the liquid drives the movable end of the brake-cylinder before it as well as the rear crosspiece, thus compressing the Belleville springs of the recuperator. When the recoil is ended, the springs relax and drive back the crosspiece and the movable end of the cylinder, the liquid returning to the space it originally occupied by passing through the narrow vents made in the valve seat, the valve falling back on the seat immediately recoil ceases. The flow of the liquid thus takes place slowly, and the running out of the gun is effected progressively and without shocks.

The gunner, by bearing with his left shoulder against the butt-rest, has the two hand-wheels within easy reach; he is thus enabled to place the gun in all the positions required. The elevating mechanism consists of the hand-wheel with the shaft, which works, through an endless screw and a toothed wheel, a pinion that engages the circular rack fitted to the rear of the movable housing. The training of the gun is insured by a mechanism with toothed wheel and endless screw, working a vertical pinion that engages a circular rack forming part of the fixed bolster. The gun can, therefore, be trained and elevated simultaneously as may be required.

The mounting can be fitted with a shield, shaped according to the requirements of the service. The shields are balanced on their supports so as not to interfere with the working of the mounting, to which they are joined by elastic couplings.

Fig. 742 illustrates a 10-centimetre (3.937-in.) 55-calibre gun and mounting; a large number of this type has been manufactured in the course of the last few years,

Mounting for 57-Millimetre (2.244-In.) 80-Calibre Quick-Firing Guns (Fig. 743, Plate CXXVII.).—These guns have already been referred to several times, owing to their remarkable qualities as regards power, combined with the ease with which they are worked, a general characteristic of the Schneider-Canet ordnance. The following are some data:

Weight of gun	810 kg.	1785 lb.
,, mounting	700 kg.	1542 lb.
,, projectile	2.7 kg.	6 lb.
,, service charge (smokeless powder)	1.9 kg.	4.18 lb.
Muzzle velocity in service	1000 m.	3280 ft.
Elevation	+ 15 deg.	+ 15 deg.
	− 15 deg.	− 15 deg.
Training	360 deg.	360 deg.

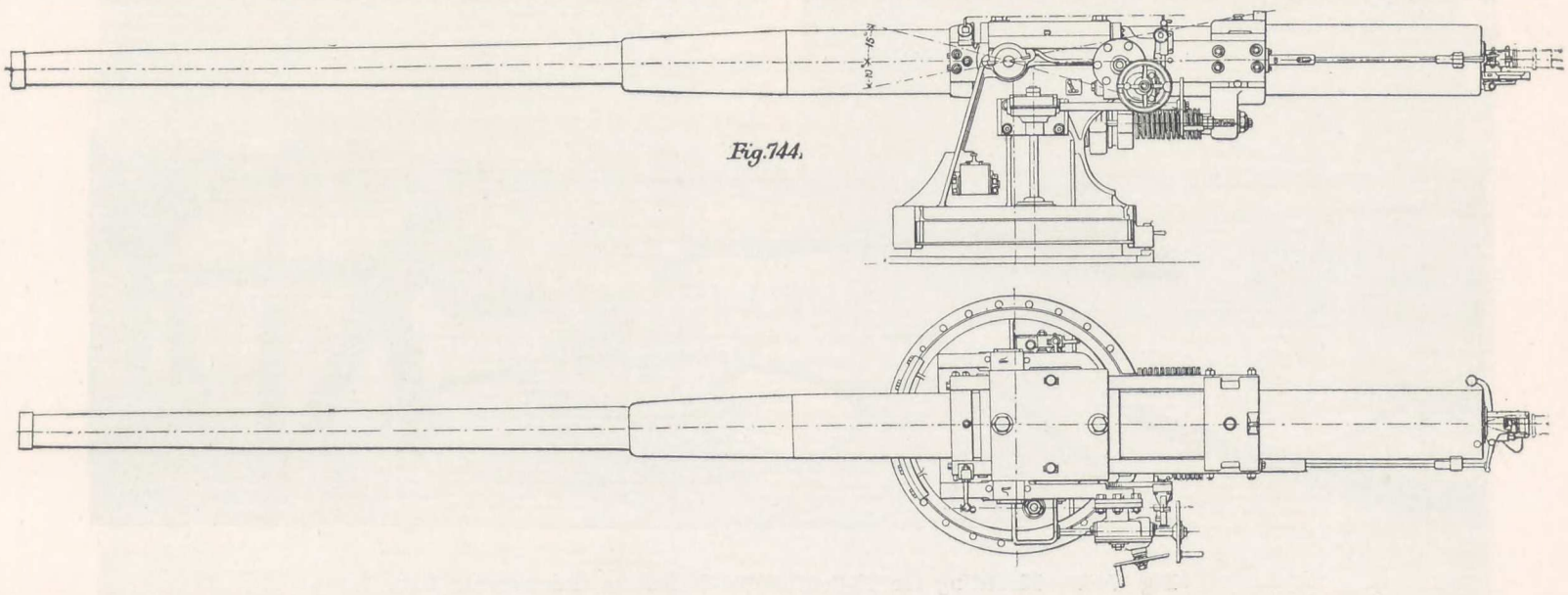


Fig. 744.

Mounting for 10-Centimetre 80-Calibre Quick-Firing Gun.

The gun is 80 calibres in length, of the design generally followed by Messrs. Schneider and Co. for their quick-firing guns. This is not merely a proving-yard gun, to be used only for ballistic experiments, but a serviceable weapon embodying all the necessary conditions required of war material, and which forms a powerful unit in the armament of ships. The first gun built of this type has through several years, undergone a great amount of service in the Hoc Proving Ground, and inspection of the various parts reveals no undue wear and tear. The breech-block is on the Schneider-Canet system, worked by one action of the lever; the gun is fired by percussion, either with the firing line or through the action of a lateral rod combined with a mechanical disengaging device.

The mounting is of the type with lateral slides, already described, and is remarkable for its small dimensions compared with the considerable power of the gun. The balancing of the various movable parts enables the gun to be trained by the gunner, who acts with his shoulder on

the butt-end. Elevation is effected by a handwheel, and the same class of mechanism as that for the 10-centimetre (3.937-in.) 50-calibre guns.

10-Centimetre (3.937-In.) 80-Calibre Quick-Firing Guns (Figs. 744 and 745).—This type reproduces the principal arrangements of the 10-centimetre (3.937 in.) 55-calibre guns already described. The first gun of this type was built at the same time as that of 57 millimetres (2.244 in.) 80 calibres in length. Both embody in every respect all the qualities required of war material. The mounting is of a very small size in comparison with the power of the gun, and the small reactions developed during firing allow it to be used for service on board light-draught ships, the decks of which are not suited for the carrying out of exceptional stiffening methods.

Weight of gun	4050 kg.	8926 lb.
,, mounting	3750 kg.	8265 lb.
,, projectile	13 kg.	28½ lb.
,, service charge (smokeless powder)	6 kg.	13¼ lb.
Muzzle velocity in service	1025 m.	3362 ft.
Elevation	+ 15 deg. − 10 deg.	+ 15 deg. − 10 deg.
Training	360 deg.	360 deg.

The first Schneider-Canet long guns which were put in service attracted much criticism; bending at the chase was considered as almost certain, and special steps were taken at the Hoc Proving Ground in order to ascertain exactly, by means of registering apparatus, the importance of the phenomena that was predicted. It was found that the vibrations at the chase of these long guns did not exceed, to any marked degree, those produced in the current types of guns of the period, and that therefore no trouble need be feared under this head in their service on board ship. Moreover, the tests of all descriptions that were carried out—tests to prove the resisting power of the guns, precision trials, quick-firing salutes, &c., gave place to no untoward incident, and the French Navy deemed the results sufficiently conclusive to adopt the long Schneider-Canet guns in service.

The firing tests carried out at the Hoc Proving Grounds (Fig. 746), for precision firing with a moving gun at a moving target or at a fixed target, are interesting. The target carries two series of distinct objectives, namely, three white panels on the right and two on the left, at different heights. The quick-firing test is effected by firing alternately against a right-hand panel and a left one, the succession in the rounds being so set that it is necessary to change, after each round, the elevation and training of the gun. The gunner has, therefore, to face the same difficulties he would encounter in firing against a moving target, as for each round he has to alter the angles of elevation and training.

Mounting for 12-Centimetre (4.724-In.) 45-Calibre Guns (Figs. 747 and 748, Plate CXXVIII.).—Guns of this type have been manufactured for the French, Russian, Japanese and Chilian Governments; apart from the sighting mechanisms, which are modified, they embody the general characteristics of the gun already described.

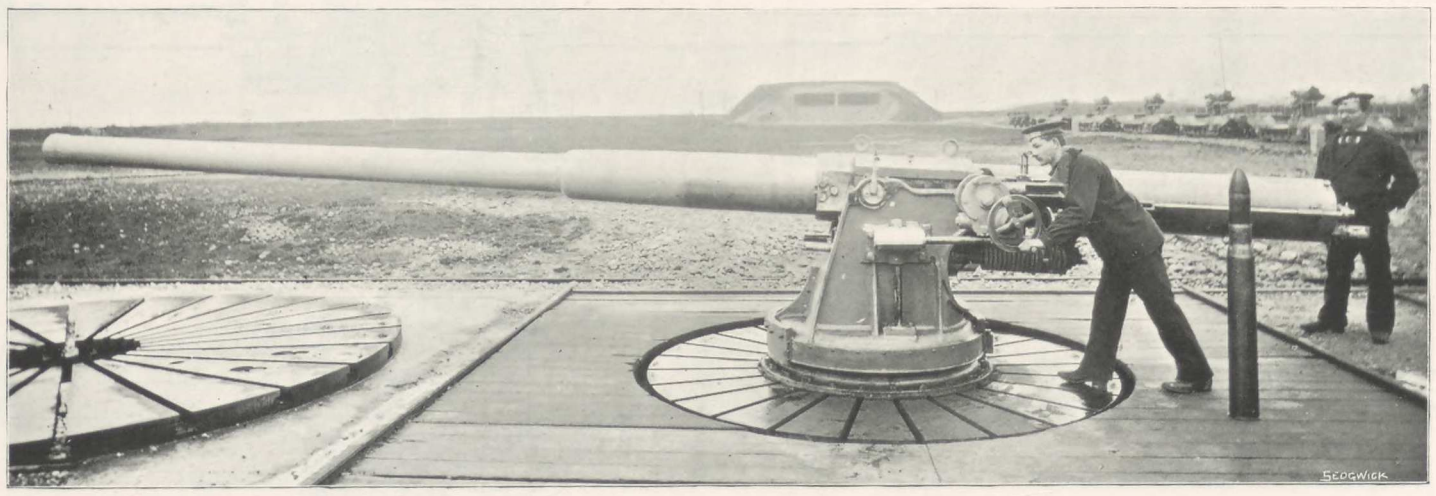


Fig 745. Mounting for 10-Centimetre 80-Calibre Quick-Firing Gun.

Weight of gun	2970 kg.	6545 lb.
,, mounting	3750 kg.	8265 lb.
,, shield	888 kg.	1957 lb.
,, projectile	21 kg.	46 lb.
,, service charge (smokeless powder)	4.8 kg.	10½ lb.
Muzzle velocity in service	680 m.	2230 ft.
Elevation	+ 20 deg. − 7 deg.	+ 20 deg. − 7 deg.
Training	360 deg.	360 deg.

The gun is trained and elevated by the action of a single handwheel, a lever being provided for connecting and disconnecting the handwheel shaft with either one of the mechanisms alternately. The gunner, resting his shoulder on the butt-rest, has under his right hand the wheel handle, and under his left the disconnecting lever The handwheel is invariably fitted to a horizontal shaft, which rests in bearings fixed to the left cheek of the mounting. The disconnecting lever works a coupling-block to and fro, which slides on the shaft, but revolves with it. Threaded sleeves are fitted loose on the main shaft, on each side of the coupling-block, and can be made

fast with the latter by means of locking grooves, so as to revolve with the main shaft. It will be seen, therefore, that by acting on the handwheel and the disconnecting lever, the gunner can set the gun as required for firing, as both the threaded sleeves are set in motion alternately to drive their corresponding gear.

This mechanism can also be worked by electricity. For this purpose the training shaft is provided at its front end with a conical pinion, which gears into another pinion fitted to the vertical shaft of a dynamo placed on the left cheek of the mounting, and worked either from a battery or with electric current taken from the main transmission wheel, the shaft of which can be connected or disconnected with either gear by the action of a lever.

Weight of gun	5740 kg.	12,651 lb.
,, mounting	5340 kg.	11,769 lb.
,, shield	980 kg.	2160 lb.
,, projectile	40 kg.	88 lb.
,, service charge (smokeless powder)	9.7 kg.	21 lb.
Muzzle velocity in service	680 m.	2230 ft.
Elevation	+ 20 deg.	+ 20 deg.
	— 6 deg.	— 6 deg.
Training	360 deg.	360 deg.

Mounting for 16-Centimetre (6.299 In.) Quick-Firing Guns (Fig. 750, Plate CXXIX.).—These reproduce

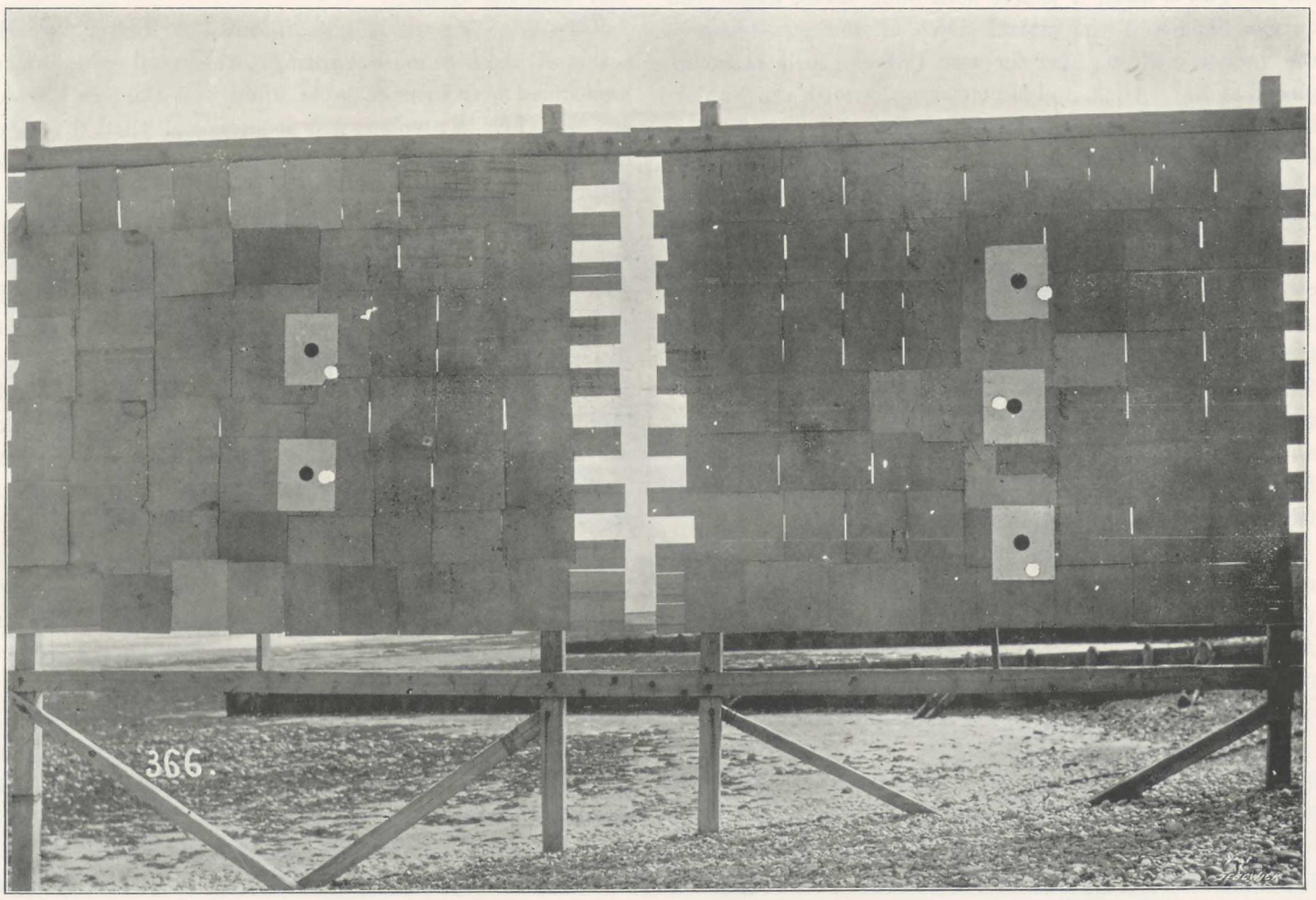


Fig. 746. Firing Tests at the Hoc Proving Grounds.

of the ship. When it is required to work the gun thus, the two conical pinions are put into gear, and the handwheel is drawn back. The gunner has then only to operate the disconnecting lever in order to train the gun. When the gun is pointed, he fixes the coupling-block in an intermediate position, the main shaft turns free, the two sleeves remaining loose.

Mounting for 15-Centimetre (5.905-In.) 45-Calibre Quick-Firing Guns (Fig. 749, Plate CXXIX.).—This type is a reproduction of the preceding one, but of larger dimensions. It contains similar mechanism for closing the breech, firing and training by hand and by electricity. Training and elevating are controlled by the same hand-

all the characteristics of the 10-centimetre (3.937-in.) 50-calibre guns, but on a correspondingly larger scale. A great number of these guns have been built at Messrs. Schneider and Co.'s Havre Works.

Weight of gun	6730 kg.	14,833 lb.
,, mounting	7230 kg.	15,935 lb.
,, projectile	45 kg.	99 lb.
Elevation	+ 15 deg.	+ 15 deg.
	— 8 deg.	— 8 deg.
Training	360 deg.	360 deg.

Mounting for 24-Centimetre (9.449-In.) Quick-Firing Guns (Fig. 748B, Plate CXXVII.).—This type of mounting contains practically the same principal elements

as those already described for medium-calibre guns. The example shown applies to 24-centimetre guns in turrets.

Weight of gun	23,000 kg.	50,692 lb.
,, slide and movable housing	6500 kg.	14,326 lb.
,, projectile	170 kg.	374 lb.
,, service charge (smokeless powder)	90 kg.	198 lb.
Muzzle velocity in service	680 m.	2230 ft.
Elevation	+ 15 deg.	+ 15 deg.
	— 5 deg.	— 5 deg.
Training	270 deg.	270 deg.

The mounting consists of a gun-housing carrying a slide with the elevating mechanism, a movable housing with hydraulic brake, and a compressed-air recuperator. On the gun is fitted a jacket with slide shoes, which run on the flanges of the lateral slides of the gun-housing; the jacket contains also the two lateral recoil cylinders placed at the bottom, and is fitted besides with the buffers, lubricators, and controlling pistons. The carrying slide is formed of two vertical wrought-iron cheeks, fitted with trunnion-plates, and bolted on a revolving platform that forms part of the turret; they carry the transmission mechanism for elevating the gun. The movable housing consists of two lateral beams, joined together in the front and in the rear by stay rings. It is made to oscillate on two trunnions placed at the front. To the rear ring are fixed the rods of the hydraulic-brake cylinders, and the trunnions of the elevating screw shells; the elevating screws are worked by conical pinions and endless screws from a horizontal shaft, worked by hand or by electricity.

The compressed-air recuperator consists of a gun-metal cylinder joined by a wrought-steel tube to a valve chest, which communicates with the hydraulic brake cylinders. A conical-shaped rod fitted to the valve chest and worked from the outside enables the communication between the valve chest and the recuperator to be interrupted at will.

During recoil the plunger pistons, by sliding in their cylinder, displace a certain quantity of liquid, which lifts the valve fitted to the communication tube, and acts on the separator piston of the recuperator cylinder by compressing the air it contains. When recoil is spent, the valve falls back on its seat, and the liquid driven by the water can only fill the space it occupied previously, by passing through a narrow vent made in the valve; the gun thus runs out again progressively, and the buffers meet without shocks. This takes place automatically throughout, and under the best conditions of rapidity.

12-Centimetre (4.724-In.) 50-Calibre Quick-Firing Guns (Fig. 751, Plate CXXX.).

Weight of gun...	3300 kg.	7273 lb.
,, projectile	22 kg.	48½ lb.
,, charge (smokeless powder)	8.250 kg.	18⅛ lb.
Muzzle velocity	810 m.	2657 ft.
Weight of mounting	2850 kg.	6282 lb.
,, shield	3850 kg.	8485 lb.
Elevation	+ 20 deg.	+ 20 deg.
	— 5 deg.	— 5 deg.

The mounting is central pivoting, with a limited recoil and automatic return. It consists mainly of an oscillating housing, two slides or recoil cylinders, a pivot transom, and a bedplate. This type of mounting fulfils the following conditions:

It allows the gun a very limited recoil, and insures quick and automatic return; it does away with the percussion efforts, whatever be the position of the gun, which recoils along its axis, and meeting the action of the brake direct. The effects due to firing are divided over a large number of points, thus reducing the wear and tear on the various parts. It allows the gunner to elevate, train, and fire the gun direct, without having to interfere in any way with the loading.

The gun is constantly maintained in battery by the action of the running-out springs; the recoil cylinders are kept filled with incongealable liquid, and the joints, which are very few in number, are so arranged that they keep tight. The mounting is, therefore, always ready for firing.

The mounting body is of cast steel; it consists of a housing in two parts firmly bolted together in the middle, and provided with trunnions which fit in the sides of the slide, and which carry the gun, the slides, and the gun-carriage proper. The two slide-shoes, of forged steel, are placed symmetrically, and are uniform in their working. Each one fits in the grooves made in the gun, and are provided in front and in the rear with cylindrical seatings of equal diameter and length, which constitute the recoil cylinders,

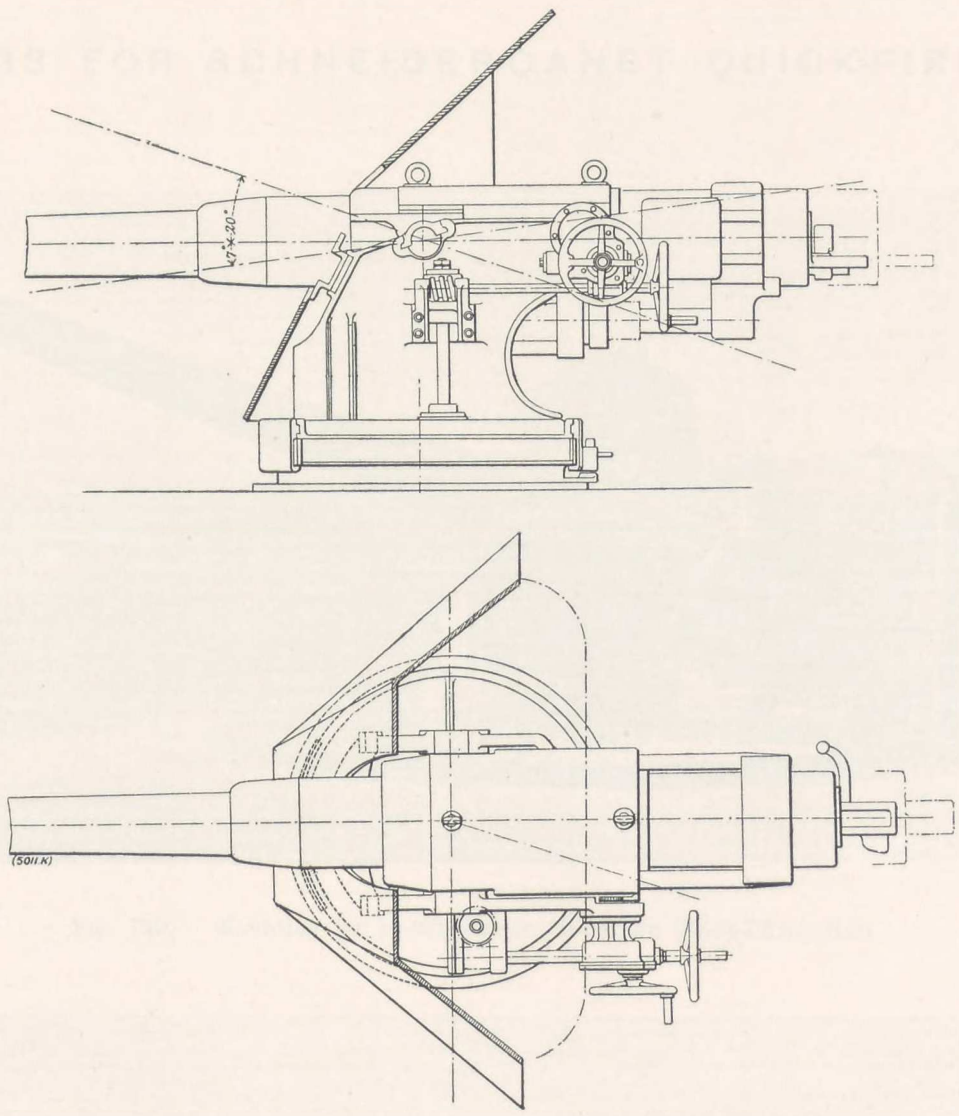
When the gun, during recoil, drives back the slide-shoes, or, in other words, the recoil cylinders—the pistons remaining fixed—the liquid which is in front of the pistons is driven violently back, and flows through the grooves of various sections cut in the cylinders. The section of these grooves is so designed as to offer a constant resistance on the whole length of the recoil, which extends over 200 millimetres (7⅞ in.) as a maximum. Return is effected automatically by a recuperator formed of two sets of direct-acting springs.

To elevate the gun a handwheel is provided, which works, through an endless screw gearing, a pinion that engages a circular rack fitted on the left side of the gun-carriage. The endless screw wheel is fitted by friction, to allow, if necessary, of a slight displacement during firing. The gun is trained by means of a handwheel, through an endless screw, a helicoidal wheel, and a vertical pinion which engages a circular rack surrounding the bolster.

15-Centimetre (5.905-In.) 50-Calibre Quick-Firing Guns (Fig. 752, Plate CXXX.).

The gun slides in a housing which is of uniform type whatever be the style of mounting used. It consists of a cylindrical body, fitted with the trunnions and the recoil cylinders; the latter afford a constant resistance, owing to the variations in the dimensions of the vents. Each cylinder is formed of a chest, with two reglets of varying

MOUNTINGS FOR SCHNEIDER-CANET QUICK-FIRING GUNS.



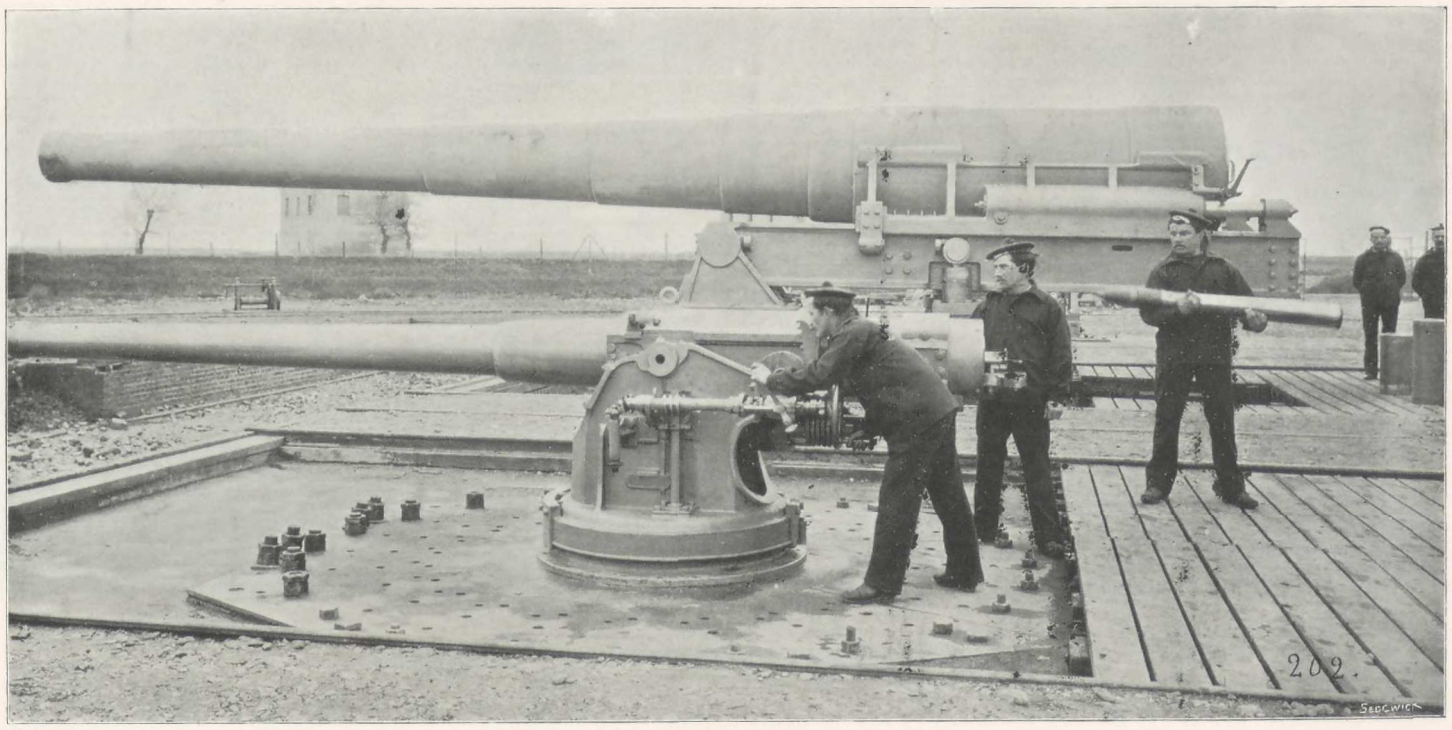


Fig. 747 and 748. Mounting for 12-Centimetre 45-Calibre Quick-Firing Gun.

MOUNTINGS FOR SCHNEIDER-CANET QUICK-FIRING GUNS.

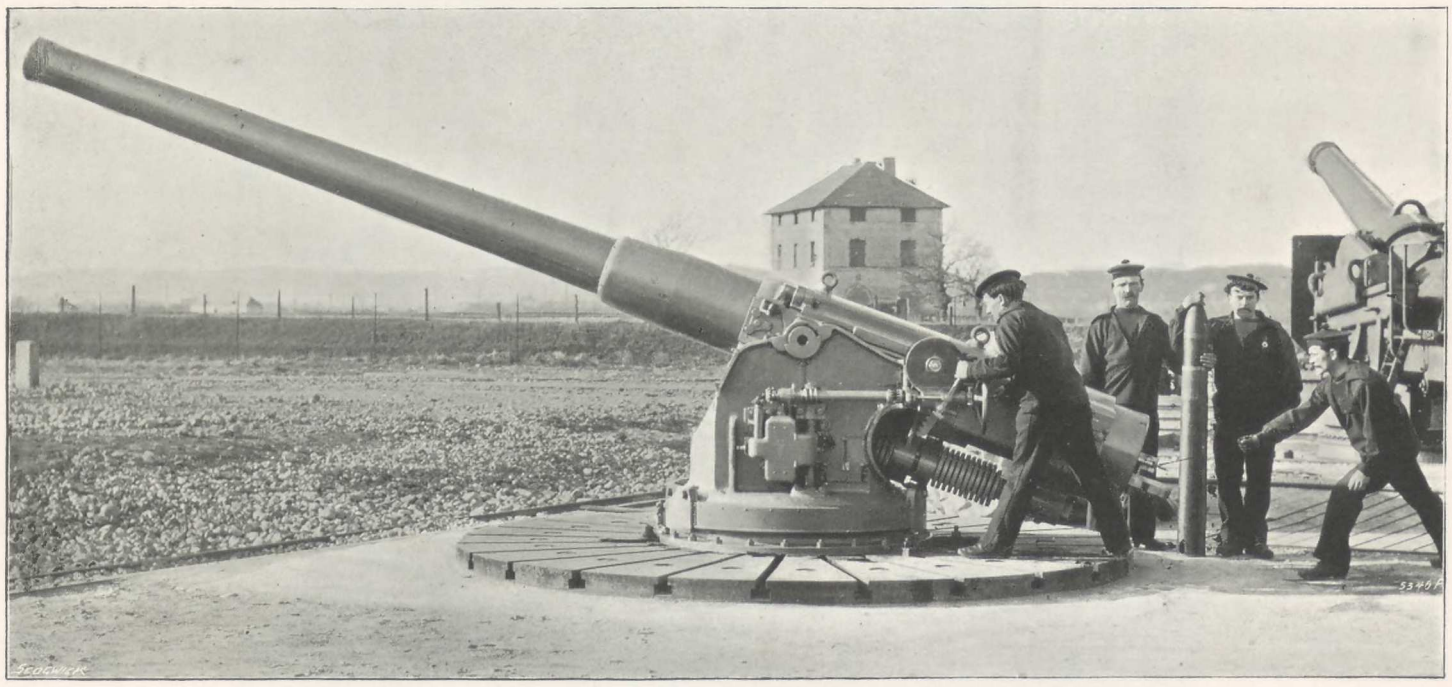


Fig. 749. Mounting for 15-Centimetre 45-Calibre Quick-Firing Gun.

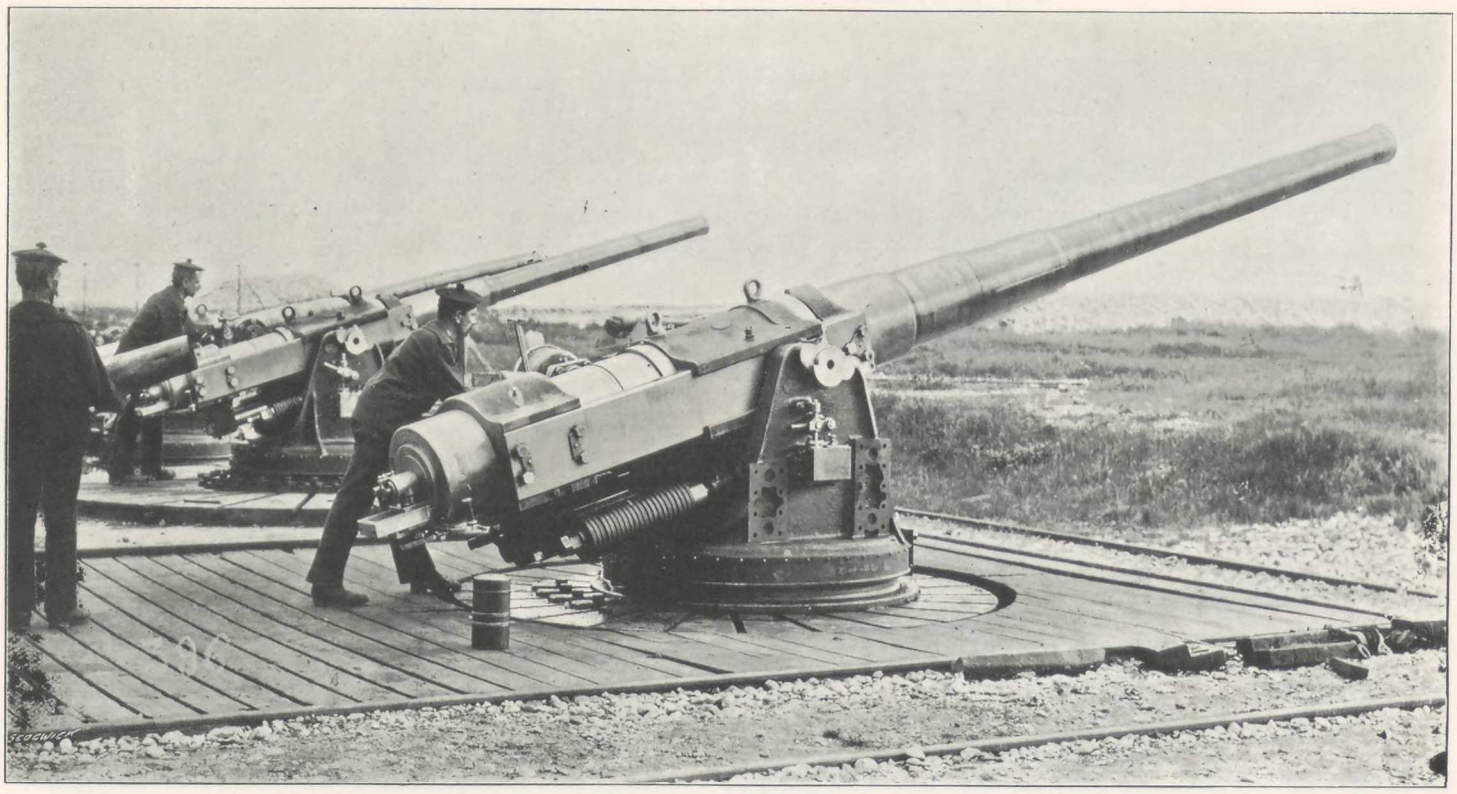


Fig. 750. Mounting for 16-Centimetre Quick-Firing Gun.

MOUNTINGS FOR QUICK-FIRING GUNS.



Fig. 751. 12-Centimetre 50-Calibre Quick-Firing Gun.

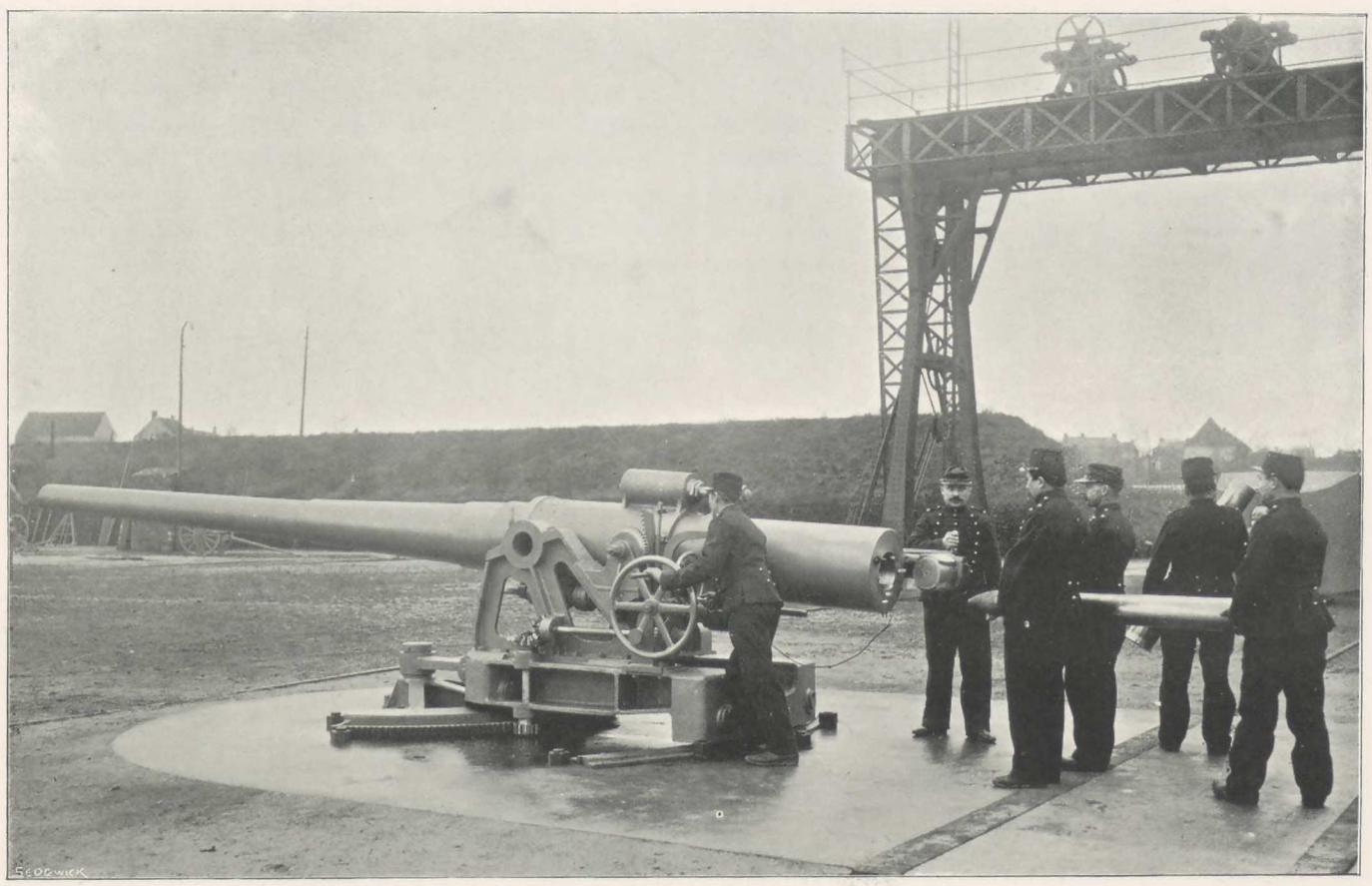


Fig. 752. 15-Centimetre 50-Calibre Quick-Firing Gun.

section, a plug, and a gland. The pistons are provided in front with a projection that forms a hydraulic buffer for automatic return, and end in the rear in a screwed part for fitting to the gun. The spring recuperator is independent of the brake, and consists of two series of spiral springs, which bear on the housing, and work by traction on the rods fixed to the gun.

Weight of gun	6250 kg.	13,775 lb.
,, central-pivoting mounting, with shield	7990 kg.	17,610 lb.
Weight of muzzle-pivoting mounting	5650 kg.	12,452 lb.
Elevation	+ 18 deg.	+ 18 deg.
	− 5 deg.	− 5 deg.
Weight of light armour-piercing projectile	40 kg.	88 lb.
Weight of charge, smokeless powder	13 kg.	28⅔ lb.
Muzzle velocity...	820 m.	2690 ft.
Weight of heavy armour-piercing projectile	50 kg.	110 lb.
Weight of charge, smokeless powder	12¼ kg.	27 lb.
Muzzle velocity...	730 m.	2395 lb.

The central-pivoting mounting consists of a movable part, slide and transom, made to turn, by the interposition of rollers, on the bedplate fitted to the deck. A wrought-steel shield is fixed to the movable part, with elastic couplings. The gunner bears on the butt, and points the gun by acting on two handwheels, the right-hand one for elevating, and the left-hand one for training the gun.

The muzzle-pivoting mounting consists of a movable part, slide and transom, made to turn round a front roller path fitted to the bedplate, and round a racer in the rear, bolted to the deck. The gun is also elevated and trained by means of two handwheels.

The gun is set by a scale and a foresight fitted to the housing, and the angle is unaffected by the recoil. The muzzle-pivoting mounting has two lines of sight, one on the right and one on the left.

For night service a breech-sight is added to the scale, and on the foresight a point, both being provided with a small incandescent lamp. The rays of light in the scale fall on silver foil, while the lamp, combined with the foresight, lights a crystal cone fitted to the end of the point. The amount of light is regulated by rheostats placed on the accumulator chests; the lamp connected with the scale may be detached to be used in the same way as a hand-lamp.

This closes the description of the Schneider-Canet longitudinal slide mountings; a larger number of examples might be mentioned; the types we have chosen will, however, suffice to illustrate the class.

To complete this review of quick-firing Schneider-Canet mountings, developed from the 1888 pattern, it is necessary to add that, from their first appearance in service, the guns and carriages gave proofs of remarkable qualities as regards quick-firing and perfect working of the various parts. They were adopted for regular service by various Governments, for the arming of fleets and for coast defence works. At the present time, orders are in course of completion in Messrs. Schneider and Co.'s works, for mountings differing from the earlier types in matters of detail only.

It must be remarked, however, that the 1888 pattern, while fulfilling the conditions now demanded of quick-firing naval ordnance in current service, requires a slow and complicated process of manufacture which it is almost impossible to hurry, whatever be the power and completeness of the plant used. Besides, as ships are now built in a much shorter time than was the case ten years ago, their armament is wanted much more promptly.

To meet this particular difficulty, Messrs. Schneider and Co., shortly after the designing of the 1888 pattern, were led to consider in what manner they could modify their first designs, in order to reduce the time taken in building up the ordnance to a minimum. This has led to a simplified type of mounting, which has been supplied with the most recent armaments they have executed, or have now in course of completion at their works.

XXXIII.—SCHNEIDER-CANET QUICK-FIRING GUNS AND MOUNTINGS (MODERN TYPES).

Recent Types of Quick-Firing Schneider-Canet Guns.—These are based on the 1888 pattern, and also for certain parts, on the earlier types previously described. The gun itself, as a rule, is the same, with the exception that in certain cases the one-motion cylindrical breech-block has been replaced by the concentric-threaded type. The mounting reproduces certain primary arrangements of the 1888 pattern, and to a certain extent, the design of slide and bolster of the 65-millimetre (2.559 in.) 50-calibre gun mounting, mentioned in the descriptions of the first quick-firing Schneider-Canet guns. We propose, as we have already done for the 1888 pattern, to give a complete description of each type of mounting.

47-Millimetre (1.850-In.) 60-Calibre High-Power Quick-Firing Guns (Fig. 753, and Fig. 754, Plate CXXXI.).

The gun is of steel throughout, and consists of four parts: *a*. The inside tube that runs the whole length of the bore, and bears in the rear against a projection of the jacket. *b*. The jacket, in which is cut the breech seating, and which is provided in the rear with a coil made with lugs for fixing the brake and recuperator rods. *c*. The front coil, which joins the gun tube to the jacket. *d*. The breech mechanism, of the concentric-threaded type, with extra quick-opening action, already described.

The mounting consists of the bedplate bolted on the deck; the movable slide that rests on the bedplate, with the interposition of a pivot; the oscillating housing, or jacket, which carries the gun, and rests in the slide. The slide, housing, and gun, turn in two guiding collars with a vertical axis, for training the gun. The housing and gun oscillate round the housing trunnions, for obtaining the required elevation.

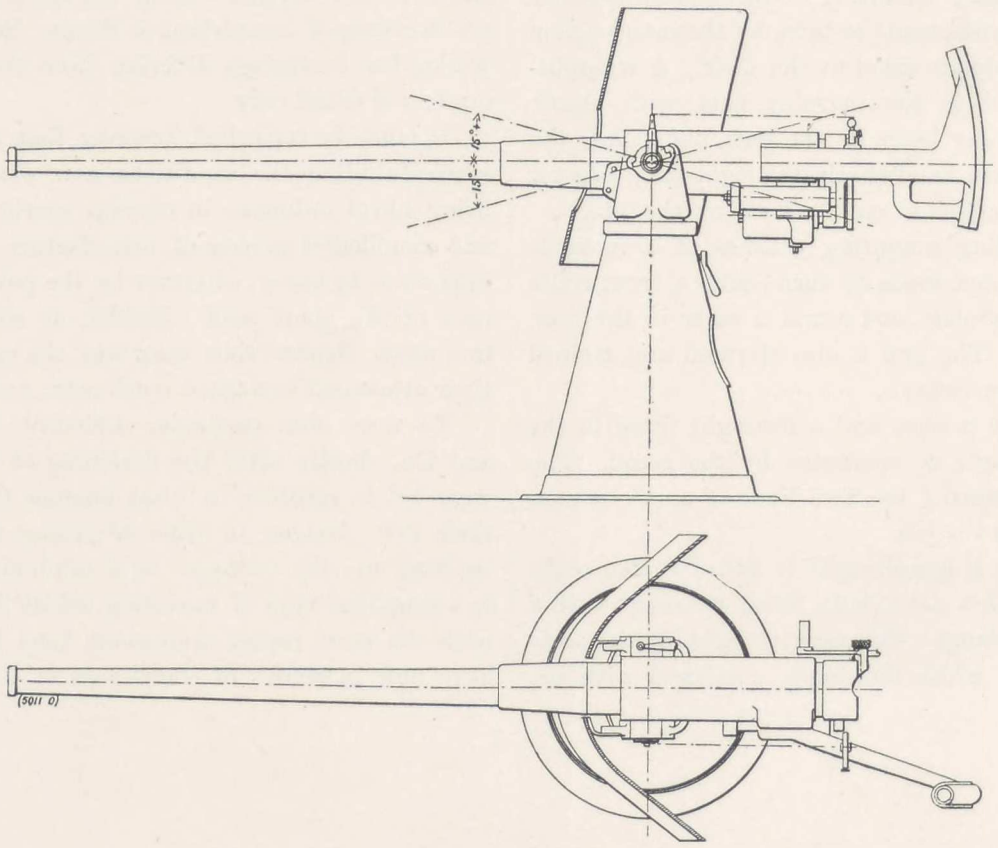


Fig. 753. Mounting for 47-Millimetre Quick-Firing Gun.

Weight of gun	270 kg.	595 lb.
Length in calibres	60	60
Weight of mounting	450 kg.	992 lb.
,, shield	50 kg.	110 lb.
Elevation	+ 15 deg.	+ 15 deg.
	− 15 deg.	− 15 deg.
Weight of projectile	1.5 kg.	3.30 lb.
Muzzle velocity in service ...	880 m.	2887 ft.

The bedplate is in the shape of a truncated cone, and consists of the outside envelope of wrought steel, fitted at

its lower part with an angle forming a flange, by which the cone is bolted to the firing platform; of the inside gun-metal body, on which are fitted: (*a*) The top plate, which carries part of the weight of the mechanism; and (*b*) the two guide collars of the slide pivot, joined together by a piece in the shape of a truncated cone, provided with stiffening ribs.

The slide is in one piece, and rests on the bedplate. It consists of: (*a*) Two parallel cheeks with trunnion plates that receive the trunnions of the gun-housing; on one side is a projection in which engages a square-headed bolt that serves to fix the trunnion at any required elevation. (*b*) A disc which joins the two cheeks at their lower part, and carries the buffers that limit the degree of elevation of the gun. (*c*) The central pivot, formed of two cylindrical parts, joined together by a truncated cone. At the lower part of the pivot is a bolt provided with a catch. When the slide is in its place, a nut is screwed on the bolt, which bears on the bottom of the pivot and prevents all raising during firing. Besides this, a hand-screw goes through the shell of the bedplate, and by bearing against the body of the pivot, allows of fixing the gun in any position.

The housing is cylindrical, and surrounds the gun so as to form a slide during recoil and running out. It consists of: (*a*) A jacket with trunnions, and fitted at the ends with gun-metal rings to insure perfect guiding. (*b*) A recoil cylinder in one piece with the jacket, and on one of the ends of which is screwed the central counter-rod. On the left side of the housing, are two bearings on which are bolted the flanges that hold the recuperator and the butt-end for the training of the gun. The hydraulic recoil cylinder is on the Schneider-Canet system, with central counter-rod; its rod is held by a nut in the lower projection of the recoil rear jacket. The recuperator consists of a cylindrical chest containing a series of spiral springs; its governing rod is fixed to the second projection of the recoil rear jacket, and is provided with a bearing ring which weighs on the set of springs. The working of the recoil cylinder is therefore quite independent of that of the recuperator, as these elements are without inside communication from one to the other; they act separately during recoil, the recuperator alone effecting the running out of the gun.

The various parts of the mounting being of comparatively small weight, and the shifting of the movable parts requiring but little effort, training and elevation

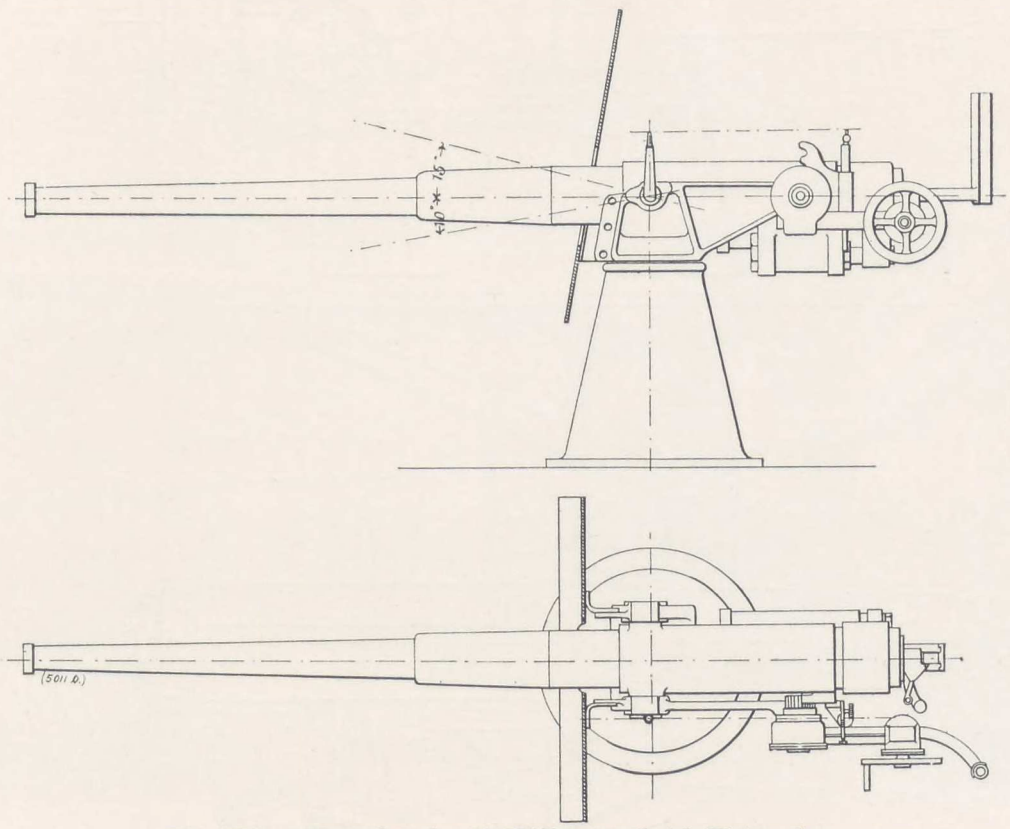


Fig. 755. **Mounting for 65-Millimetre Quick-Firing Gun.**

are secured by the gunner bearing with his shoulder on the butt. By taking hold of a suitable handle in one piece with the butt, the gunner has no difficulty in sighting the target accurately.

When a quick-firing salute is to be effected without any modification in the sighting of the gun, it suffices to set the screw on the right-hand trunnion and that which goes through the shell of the bedplate, in order to fix the gun in the required position. The scale is carried in a slide which forms part of the jacket, and the sight is on the left trunnion. A suitable shield serves to protect the gunners and the working parts of the gun.

These guns are characterised by their very great power compared with their calibre, and by the flatness of the trajectories, which renders the firing point-blank up to a distance of 1,000 metres quite practicable. They are, therefore, suitable for naval service on board ships of

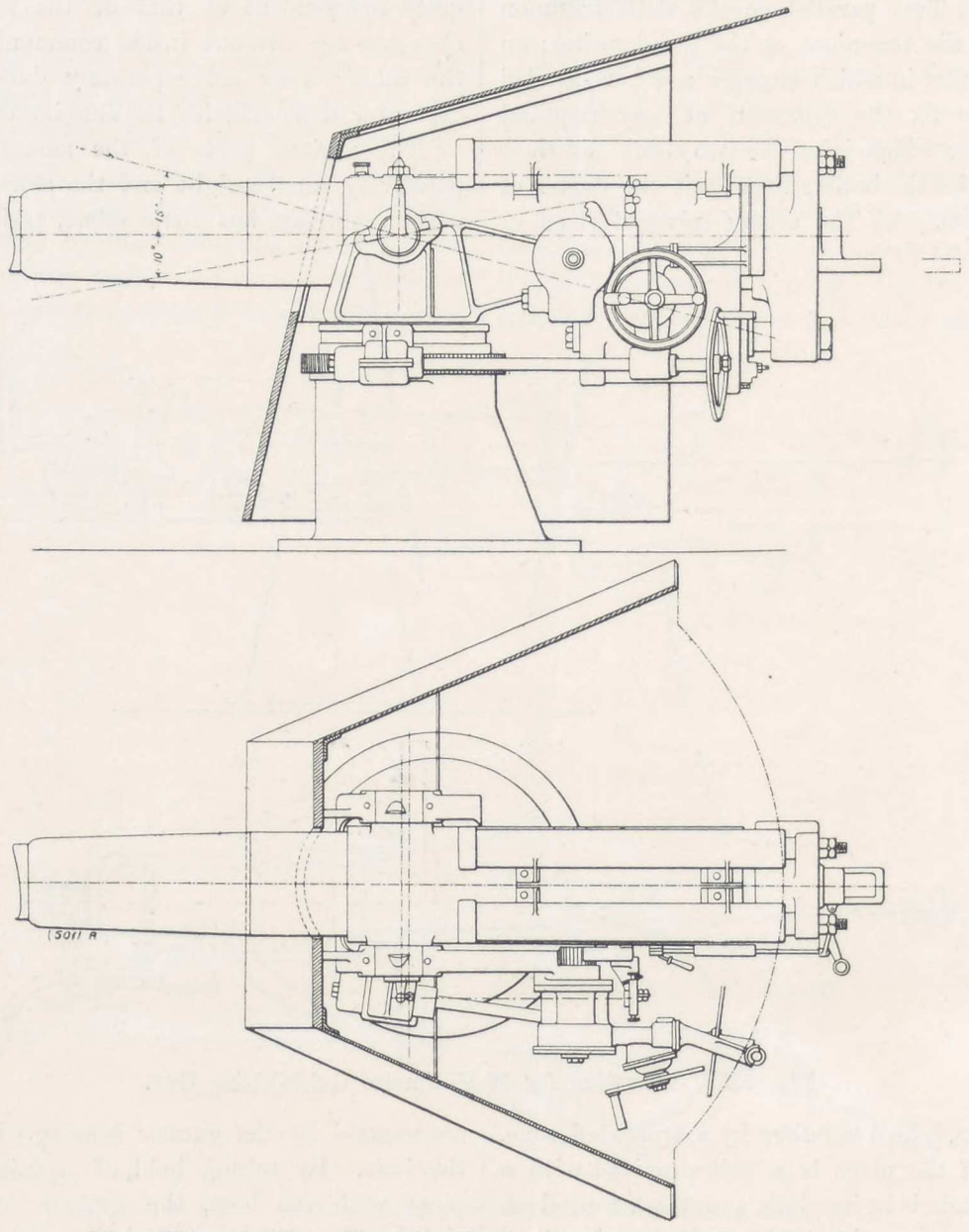
limited tonnage, designed for pursuing similar ships scantily protected, but capable of developing a high speed. They can be worked ultra-rapidly, the breech-block being almost instantaneous in its action.

65-Millimetre (2.559-In.) 50-Calibre Guns (Fig. 755).—These guns, as a whole, embody the same general arrangements as those of 47-millimetre 60 calibres in length, just described. They differ, however, in the addition of an elevating mechanism and in the details of the slide pivot.

Weight of gun...	550 kg.	1212 lb.
Length in calibres	50	50
Weight of mounting	600 kg.	1322 lb.
,, shield	180 kg.	396 lb.
Maximum angles of elevation ...	+ 15 deg.	+ 15 deg.
	− 10 deg.	− 10 deg.
Weight of projectile	4 kg.	$8\frac{4}{5}$ lb.
Muzzle velocity in service	740 m.	2428 ft.

The elevating mechanism is on the left side of the slide; it consists of a shaft fitted with a toothed pinion and worked by a handwheel; this shaft works a second spindle parallel with the mounting bracket, and fitted with an endless screw that engages a helicoidal wheel mounted on the same axis as the cylindrical pinion that engages the toothed sector fitted to the jacket, and transmits to the gun the required oscillations. As regards the inside pivot arrangements, these guns are very similar to those of 10, 12, and 15 centimetres described hereafter.

10-Centimetre (3.937-In.) 45-Calibre Quick-Firing Guns (Figs. 756 and 757; and 758 and 759, Plate CXXXI.).—Guns of this type have been manufactured lately by Messrs. Schneider and Co. in large numbers.



Figs. 756 and 757. Mounting for 10-Centimetre Quick-Firing Gun.

The mounting is generally similar to that for the 47- and 65-millimetre guns already described, but it embodies a special mechanism for the training of the gun. In this and the larger calibres, the inertia of the movable parts is too great for it to be possible to insure their working with the required rapidity, by simply acting on the butt-end of the gun.

The base is of cast steel, in one piece, its lower flange being bolted on the deck. Its central part forms the

seating of the fixed pivot; this is of steel, and its height can be varied at will, owing to the outside threads cut on it. This pivot bears part of the weight of the slide, and insures besides the perfect centring of the system. On the top part of the base is a horizontal ring, which is continued on the inside by a vertical cylindrical bearing; this is provided with a gun-metal lining. The whole arrangement is suitably stiffened. The slide is of the same shape as those of the 47-millimetre and 65-millimetre mountings; its bottom part ends in a step-bearing lined with gun-metal, which clasps the fixed pivot of the base. The brake, with central counter-rod, is placed under the gun-housing; on the top part of the latter are the two cylindrical envelopes that contain the recuperator set of springs. The mechanism for training the gun consists of: (*a*) A horizontal shaft slightly inclined with regard to the axis of the slide; it is provided with an endless screw worked through a set of conical pinions, one pinion being keyed on the handwheel shaft, (*b*) A circular rack which runs round the baseplate; an elastic coupling is used to control the speed of the various parts in the training operations. The endless screw and the circular rack are surrounded by an airtight envelope, easily removable, to preserve them. The elevating mechanism, apart from the dimensions, is the same as that for the 65-millimetre guns. All the movable parts are fitted with an airtight cover provided with a lubricator. The gun-housing is fitted with a butt-end, against which rests the gunner during the service.

12-Centimetre (4.724-In.) 45-Calibre Quick-Firing Guns (Fig. 760).—These guns and mountings are generally similar to the 10-centimetre types already described. The gun is of the type adopted by the Portuguese Government for the armament of their new cruisers, the length being 45 calibres. These guns have, however, been manufactured up to 80 calibres in length, the power thus obtained being considerable for the bore.

Weight of gun	2800 kg.	6171 lb.
,, mounting	2750 kg.	6061 lb.
,, shield	900 kg.	1983 lb.
Elevation	+ 15 deg.	+ 15 deg.
	− 10 deg.	− 10 deg.
Weight of projectile	21.5 kg.	47⅓ lb.
Muzzle velocity in service	720 m.	2362 ft.

14-Centimetre (5.511-In.) 45-Calibre Guns (Fig. 761, Plate CXXXII.).—These form part of the recent types built by Messrs Schneider and Co., and adopted, among other Governments, for the Spanish Navy. Owing to delay, these guns were not used in active service during the American-Spanish war, and they will form an excellent basis for the reconstruction of the Spanish Fleet. They contain the main characteristics of the preceding calibres. Fig. 762 shows one of these guns and carriages, of which particulars are added:

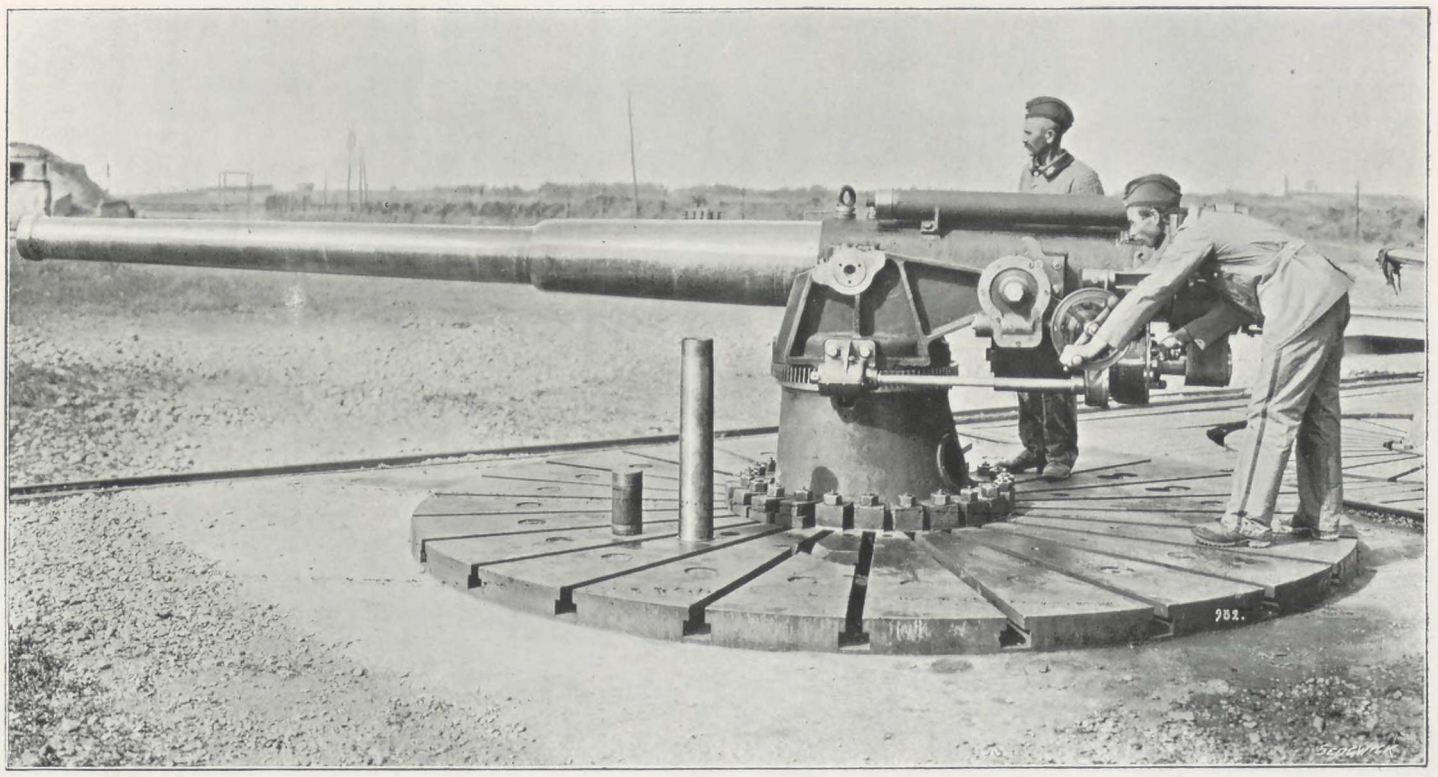


Fig. 760. 12-Centimetre 45-Calibre Quick-Firing Gun.

Weight of gun	4800 kg.	10,579 lb.
,, mounting	4100 kg.	9,036 lb.
,, shield	1200 kg.	2,644 lb.
Elevation	+ 20 deg.	+ 20 deg.
	− 5 deg.	− 5 deg.
Weight of projectile	40 kg.	88 lb.
Muzzle velocity in service	700 m.	2296 ft.

15-Centimetre (5.905-In.) 45-Calibre Quick-Firing Gun (Fig. 763, page 228). — These guns and mountings have been adopted, among others, by the Portuguese

Government for the armament of cruisers of recent construction. They contain all the improvements carried out for the Schneider-Canet quick-firing naval guns, and allow of extra rapid action. The various manœuvres and the firing are effected by a single gunner, who has within easy reach all the various parts of the mechanism.

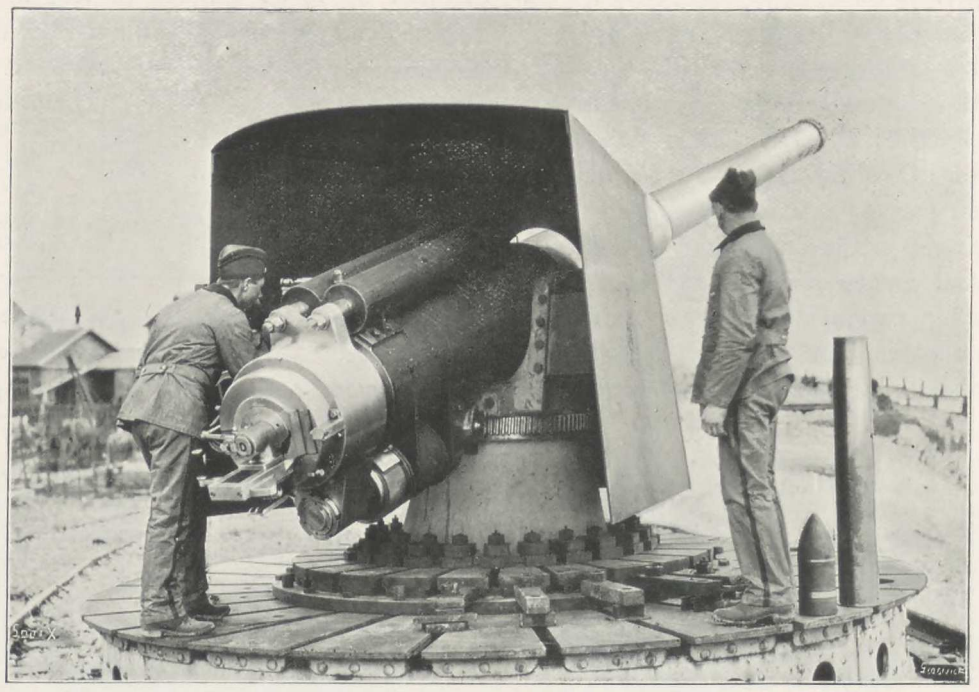


Fig. 762. Mounting for 14-Centimetre Quick-Firing Gun.

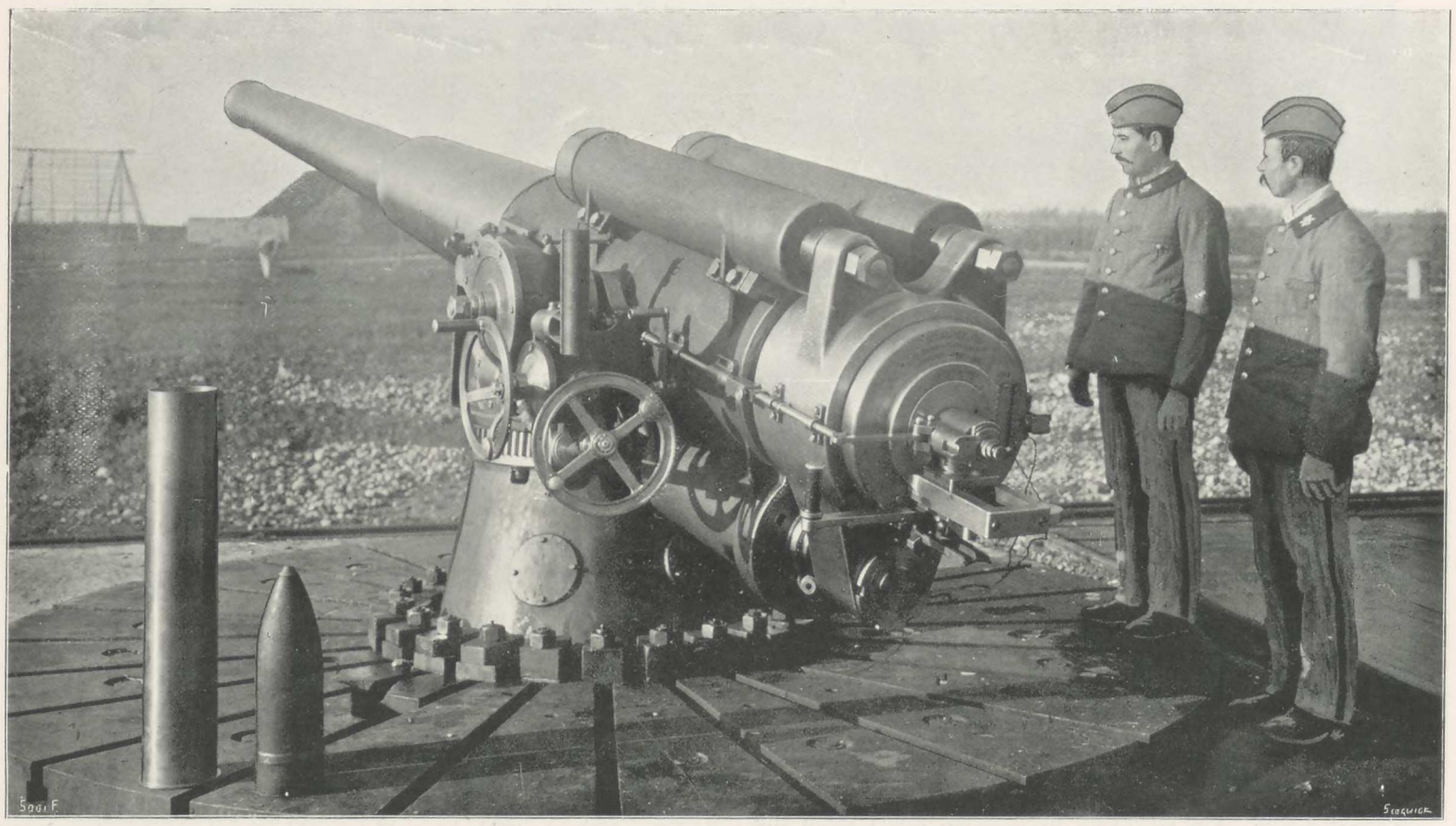


Fig. 763. Central Pivoting Mounting for 15-Centimetre 45-Calibre Quick-Firing Gun.

Weight of gun	5700 kg.	12,562 lb.
,, mounting	4500 kg.	9,918 lb.
,, shield	1200 kg.	2,644 lb.
Elevation	+ 15 deg.	+ 15 deg.
	− 10 deg.	− 10 deg.
Weight of projectile	40 kg.	88 lb.
Muzzle velocity in service	720 m.	2362 ft.

The line of sight is lighted by electricity for night service, and the fuse can be fired either by percussion or by electricity. The guns were built according to a specification which provided that they had to fire a projectile isolated from the cartridge-case, in order to facilitate loading and handling in the magazines.

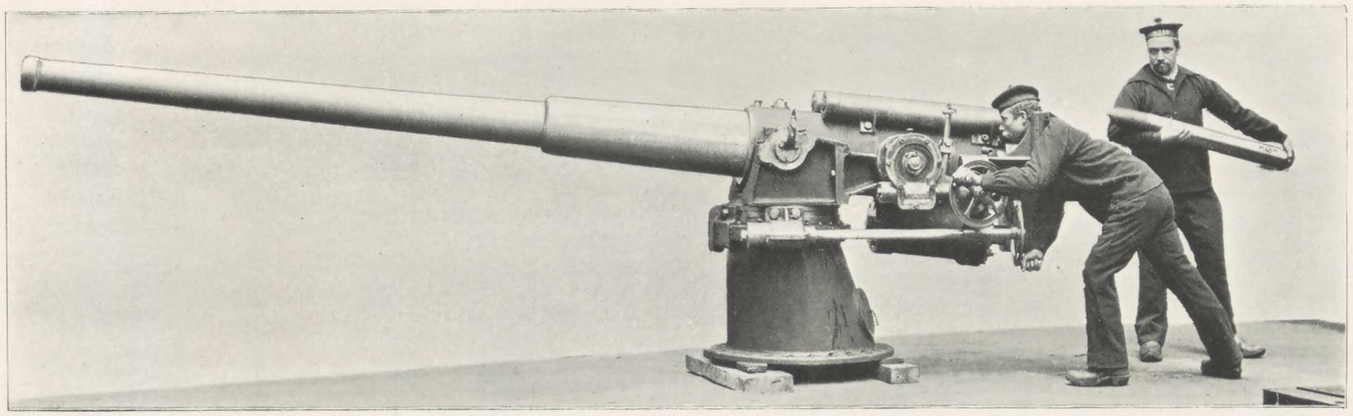


Fig. 758. Mounting for 10-Centimetre Quick-Firing Gun.



Fig. 754. Mounting for 47-Millimetre Quick-Firing Gun.

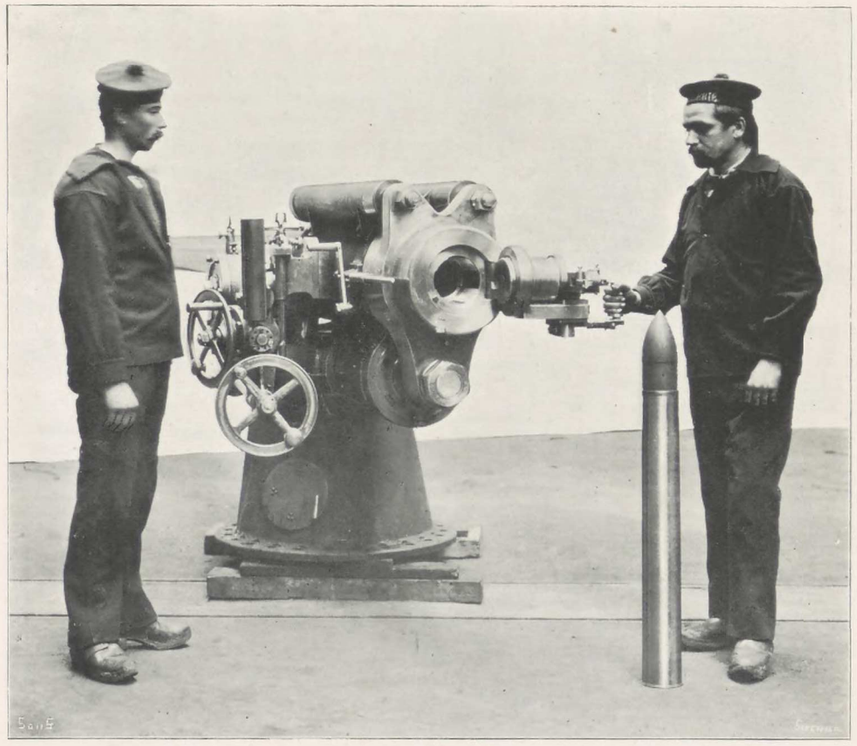


Fig. 759. Mounting for 10-Centimetre Quick-Firing Gun.

ARMAMENT OF LIGHT-DRAUGHT SHIPS.

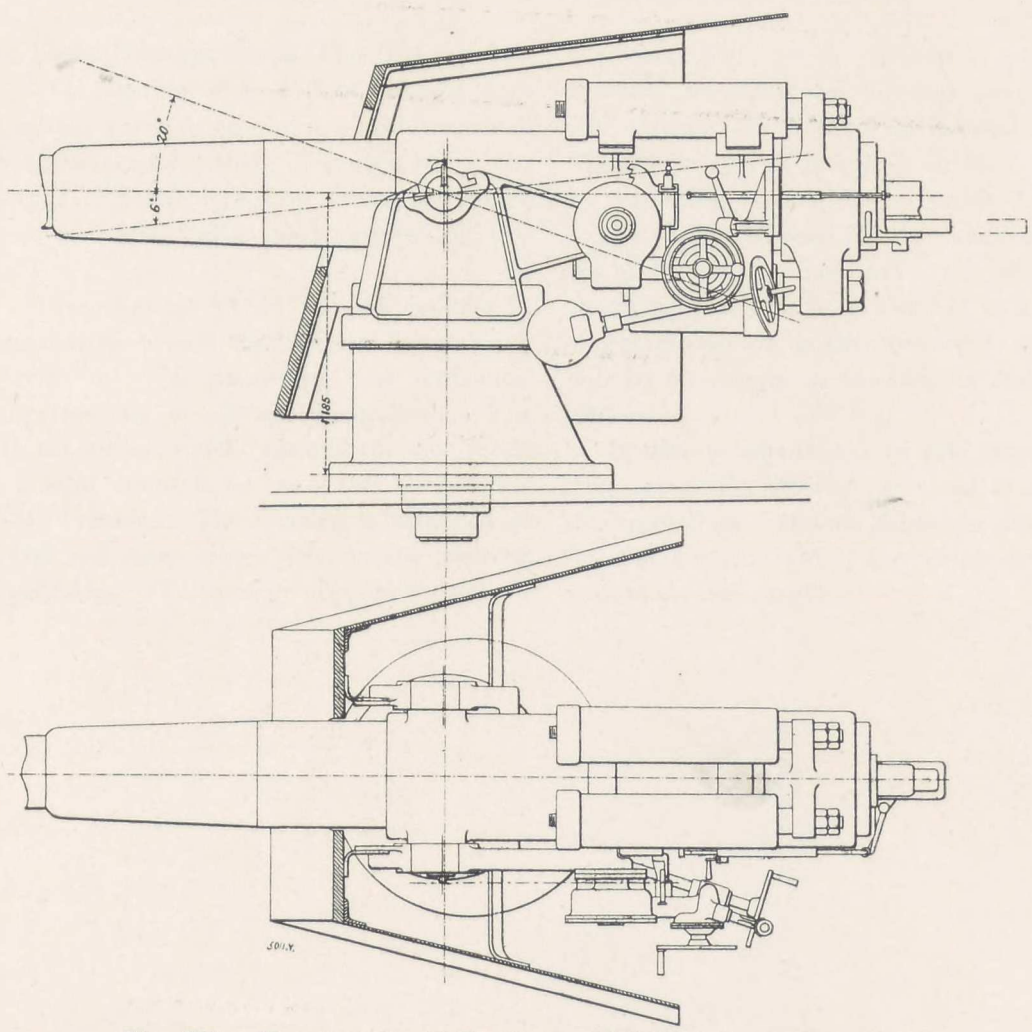


Fig. 761. Mounting for 14-Centimetre 45-Calibre Quick-Firing Gun.

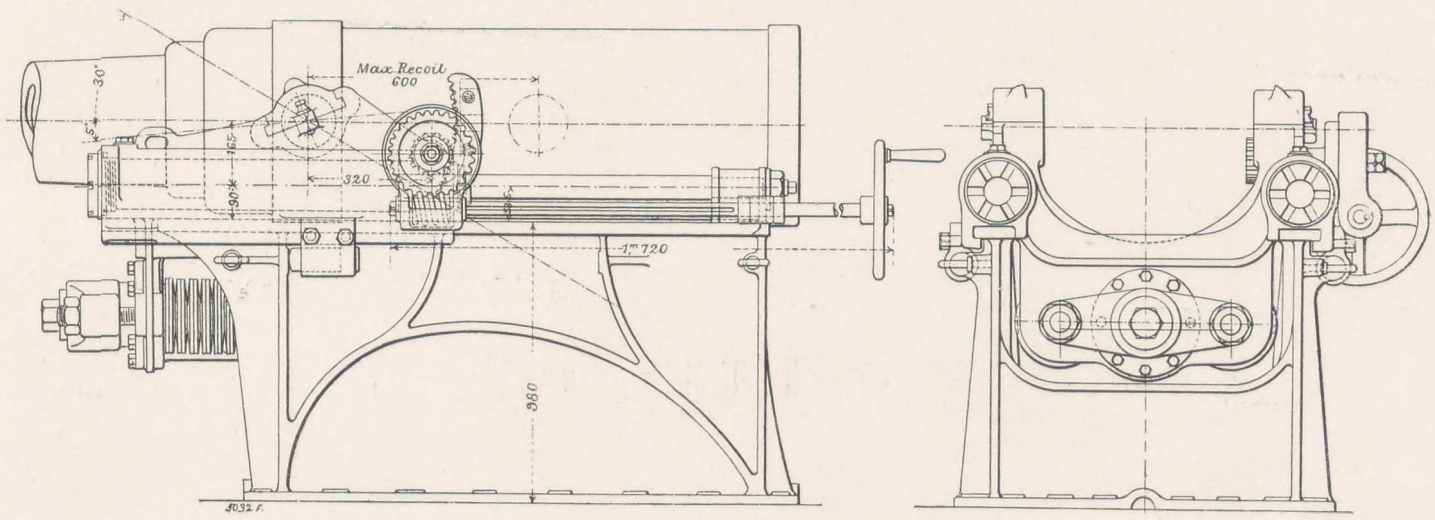


Fig. 764.

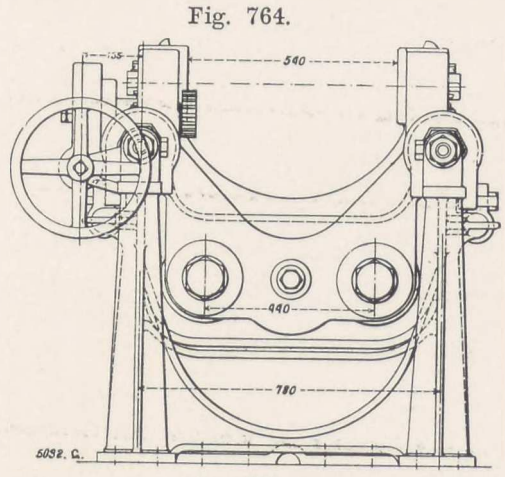


Fig. 765.

Horizontal Mounting for 14-Centimetre Gun.

Armament of Light-Draught Ships (Figs. 764 and 765, Plate CXXXII.).—The arming of very light-draught ships with a medium-calibre quick-firing gun is a problem which has often been under consideration. We give below the description of a type of Schneider-Canet armament, which has been designed and tried with good results for this special use.

The gun is a 14-centimetre (5.511 in.), 45 calibres in length, with one-motion breech mechanism, firing being effected by percussion. The mounting has horizontal slides, with compressed-air or spring- recuperator. The gun is carried in a housing, which contains the two recoil cylinders with central counter-rod, and the recuperator placed between the brackets. The housing is provided at its lower part with two shoes, which slide on the paths of the traversing platform. The carriage support consists of a circular platform, on the top of which are two parallel brackets, the upper one forming the horizontal-slide paths. Rollers may also be used for facilitating recoil and return. The whole system is bolted on deck. The gun is trained by displacing the ship in the required direction.

The design followed for the mounting, and especially the use of horizontal slides, cause the efforts of percussion on the firing platform to be reduced to a marked degree; the efforts of traction on the piston-rods can also be reduced at will by alterations in the interior design of the hydraulic brake.

It may be mentioned, in this respect, that the circular slide mounting, already described, is also very suitable for this special use. Messrs. Schneider and Co. have built one for the French Navy, for firing trials on board ship against moving targets.

XXXIV.—MORTARS AND HOWITZERS FOR NAVAL SERVICE.

THE details of modern naval armaments frequently comprise a certain number of guns of the howitzer and mortar types, for firing projectiles charged with high explosives under great angles. Such pieces are specially designed for the attack on armoured decks which, while forming one of the vulnerable parts of modern men-of-war, usually escape owing to the flat trajectories of quick-firing guns. On the other hand, trials have been made for arming light-draught ships with a single-quick firing gun of medium calibre and high power. In both cases, special arrangements are necessary, so that the shock resulting from firing these guns may not be a cause of injury to the decks and their framing. It might be possible, it is true, by placing suitable stiffening pieces directly below the gun, to employ mountings of the usual type for this service; but in many cases this would not meet a large number of conditions that have to be taken into account when designing the internal arrangements of warships. It was, therefore, most important to be able to rely on a type of armament successfully designed to meet these particular requirements.

The problem presented itself several years ago, in connection with the Schneider-Canet guns, and was solved by placing in service a series of various types, each one corresponding to a distinct purpose. Their main characteristic is the reduction, by means of special arrangements, of the percussion produced by firing, the shock being reduced to a proportion consistent with the normal resistance of the deck to which the armament is attached.

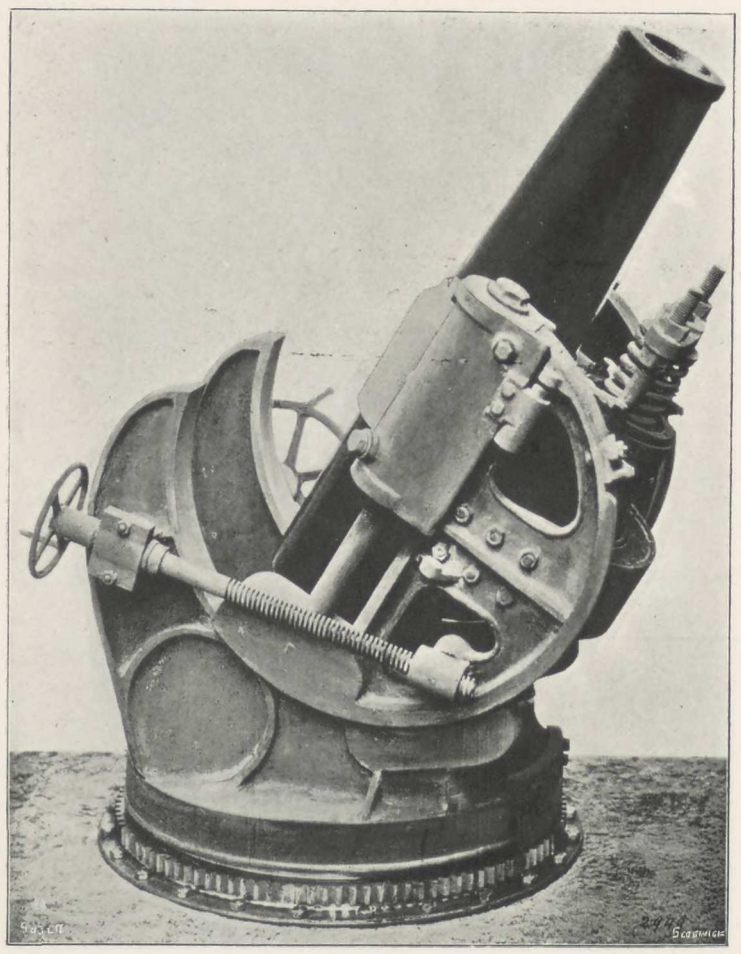


Fig. 766. Mountings for Mortars and Howitzers.

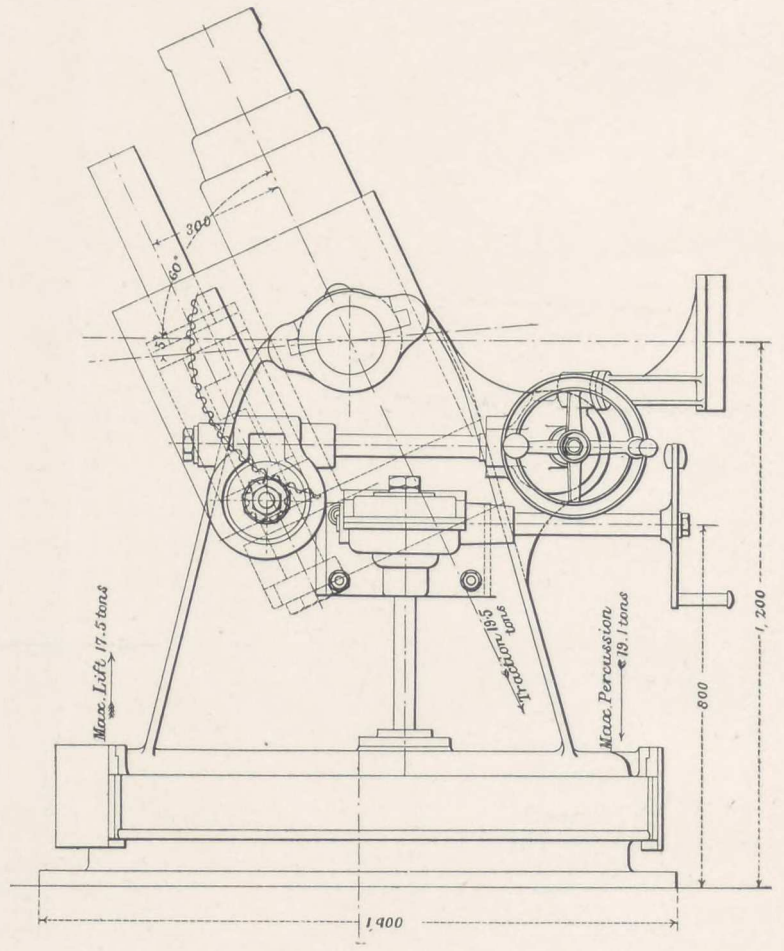


Fig. 767.

These mortars and howitzers, as regards their design and their breech-closing arrangements, form part of the Schneider-Canet current series. The mountings can be divided into two main classes:

1. **Beam Mountings.**—In this type, an oscillating slide is used, which is made to turn round horizontal trunnions; as it recoils during firing, it operates a hydraulic brake and recuperator, which run out the piece to its

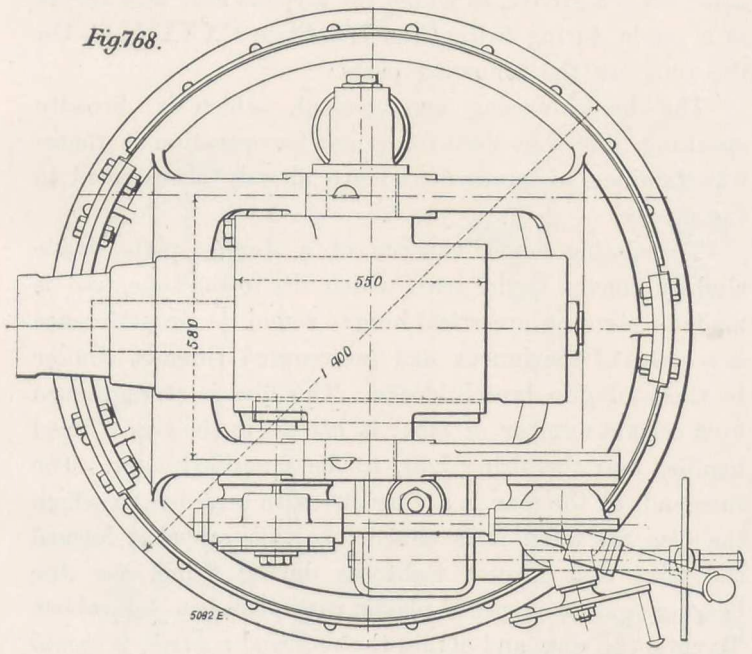
original position. This type will be described in a separate section, which deals with disappearing gun carriages.

2. Circular Slide Mountings.—These are made with a traversing platform embodying circular vertical slides, the centre of which coincides with the axis of the trunnion. By this arrangement, whatever be the angles of elevation, the axis of the hydraulic cylinders follows the direction of the firing line, thus reducing the effort of percussion. A complete description of a mounting of this type has been given in a preceding section, in connection with an ordinary 14-centimetre gun. Fig. 766 shows a 22-centimetre (8.661-in.) howitzer on a mounting with circular traversing platform.

Weight of howitzer	3,500 kg.	7,714 lb.
,, mounting	11,600 kg.	25,566 lb.
,, projectile	116 kg.	255 lb.
Muzzle velocity in service	300 m.	984 ft.
Elevation	- 5 deg.	− 5 deg.
	+ 60 deg.	+ 60 deg.
Training	360 deg.	360 deg.

15-Centimetre Quick-Firing Mortar (Figs. 767 and 768).—The principal parts of this are the following: The mortar, with its breech-closing arrangement; the housing; the slide and the bedplate.

Fig.768.



Plan of 15-Centimetre Howitzer and Mounting.

The mortar is furnished with a breech mechanism of the two-action type. To the rear is screwed a recoil jacket, to which is fixed the head of the hydraulic recoil piston. The housing is provided with trunnions, and consists of a cylindrical body in which the mortar slides, and of an hydraulic recoil cylinder with constant resistance. The piston is held by the recoil jacket, and a counter-rod is provided of a slightly larger diameter, which, by penetrating the cylinder during recoil, forces part of the liquid to flow into the recuperator. This is placed outside the right bracket of the slide, and consists of a vertical cylinder in which moves a double diaphragm, combined with a set of springs. Communication is established between the recoil cylinder and the recuperator by a pipe which passes through the centre of the right trunnion of the housing; a loaded valve placed on the circuit followed by the liquid, is raised during recoil, and falls back on its seat when the recoil is spent. The liquid can only return by flowing through small vents cut in the valve seat; the mortar then runs out slowly under the relaxing of the recuperator springs. On the left side of the recoil cylinder is the circular rack for elevating the mortar.

The slide consists of two brackets, made with stiffening ribs, and strongly stayed together. Its lower part forms a circular plate, round which is the racer that carries the balls for facilitating the rotary movement; in its centre, the plate is in the shape of a vertical cylinder, which fits on the fixed pivot of the bedplate. The slide is, moreover, provided with the necessary lugs and projections for the fixing of the setting mechanisms. Two clasps, one in front and one in the rear, prevent all raising of the system.

The bedplate on which the slide rests is fitted with a circular rack for training the mortar, and with a ring plate, in the holes of which the foundation bolts are placed. Its central part forms the fixed pivot.

The required elevation is obtained by operating the handwheel placed on the left of the slide. This works through two conical pinions, an endless screw and a set of differential gearing, the right-hand pinion which engages the fixed toothed sector, which is on the left side of the housing.

The mortar is trained by turning a second handwheel placed slightly to the rear of the preceding one. It works, through an endless screw and a helicoidal wheel, a vertical pinion gearing with the circular rack on the bolster.

To train the mortar by means of these two handwheels, the gunner rests his shoulder on the butt-end, which is so placed that he can immediately cast his eye on the line of sight.

This mounting takes up but little room, and is suitable for large-calibre guns, without any extra provision for stiffening the decks of ships being required.

The following are particulars of the 15-centimetre (5.905-in.) quick-firing mortar, on central-pivoting mounting:

Weight of mortar	480 kg.	1058 lb.
,, mounting	2700 kg.	5950 lb.
,, projectile	40 kg.	88 lb.
Muzzle velocity in service	200 m.	656 ft.
Elevation	− 5 deg.	− 5 deg.
	+ 60 deg.	+ 60 deg.
Training	360 deg.	360 deg.

The above brief data will show that the Schneider-Canet material solves this particular problem, as regards the use of mortars and howitzers on board battleships and cruisers.

XXXV.—TORPEDO-LAUNCHING TUBES.

THE Schneider-Canet system of artillery includes a series of torpedo-launching tubes, of various patterns, fulfilling the numerous conditions required in service in modern fleets. A special section of the artillery department is reserved for this work.

The tubes are of gun-metal or of steel, as may be found expedient, and they can be adapted for launching any type of torpedo now in service in various countries. The series may be divided into two principal classes:

1. SCHNEIDER-CANET TUBES ABOVE WATER-LINE.

The large number of patterns of this class differ one from the other only in their mountings, which vary in design, according to the conditions of service and the type of ship on which they are fitted. They can, moreover, be extended in front by a spoon-shaped guide, which insures the horizontal position of the torpedo being retained when it penetrates the water after launching. The following details are common to all the types:

(*a*) The delicate mechanism carried by the torpedo itself, and especially the screw which propels it, are secured against all damage that might be caused either by the sudden influx of compressed air or by the deflagration of powder gases.

(*b*) The device for closing the rear of the tubes. This is of a special design, resembling the interrupted threads of a breech-block; a progressive turning of the closing arrangement insures a tightness of the joint under the pressure at which firing takes place. Some of these devices are closed mechanically, reducing the efforts to be developed on the governing crank. Figs. 770 and 771, Plate CXXXIII.

(*c*) For the tubes supplied with compressed air-firing device, the mechanism for launching with powder is also delivered, unless otherwise stipulated.

(*d*) Smokeless powder can be used when required, so as to prevent an enemy from noticing the exact instant a torpedo is fired, and from aiming at a dangerous part of the ship.

(*e*) Firing can be effected by a percussion, or an electric, fuse, and the firing device can be worked mechanically or by electricity at will.

(*f*) The Schneider-Canet tubes are provided with automatic apparatus which render impossible, in current manœuvres, any mistake in the order of succession of the various actions.

(*g*) The tubes are fitted with luminous sights which render night service possible; the deviations resulting from the speed of the target, and the ship itself, being corrected automatically.

From the above remarks, it will be seen that it will prove sufficient, to obtain a clear idea of the Schneider-Canet system, to give the details of one tube, a special description being added of each of the principal types of mountings.

FIXED TUBES.

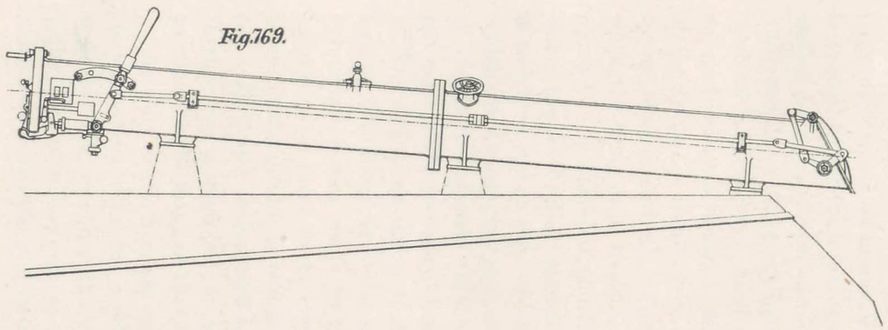
(a) **Fixed Tube on Deck in the Bow of Torpedo-Boats.**—The tube may be made of gun-metal or of steel, the thickness of the walls, and consequently the total weight, varying according to the metal used. It consists of two cylindrical rings, the length and inside diameter of which depend upon the type of torpedo to be used, and which are fitted together by means of flanges and bolts. The top centre line on the inside surface is made with a groove, in which the torpedo fits; this serves as a guide during firing (Fig. 772, Plate CXXXIII.). On the tube are the following parts:

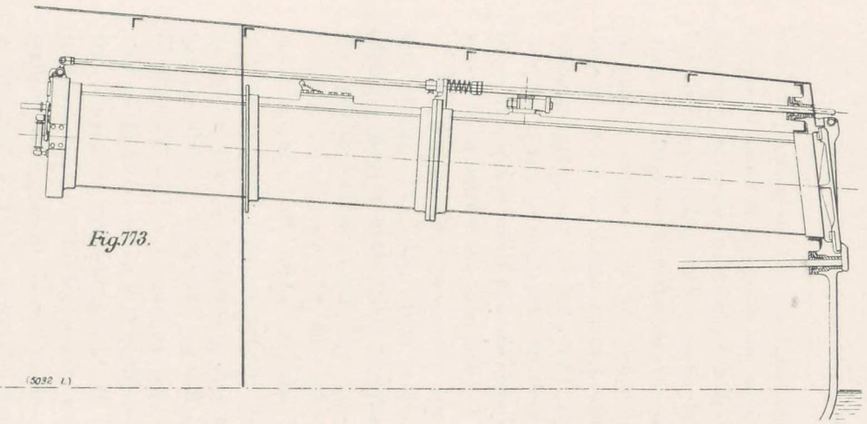
The breech-closing arrangement, which is, broadly speaking, like that used for guns; its operation is therefore familiar to gunners who are already accustomed to the service.

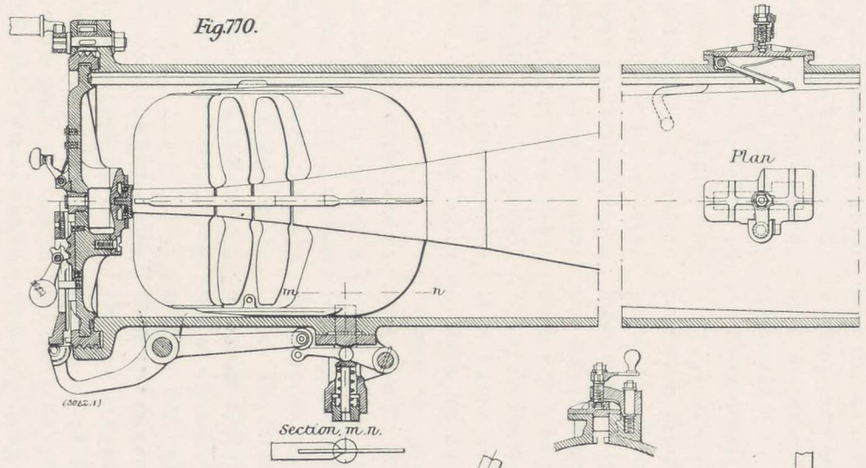
The closing device consists of a circular plate, made slightly convex to the rear, which fits to the tube, and is made to pivot on a vertical hinge; round its circumference is a series of continuous and interrupted threads, similar to those of gun breech-blocks. This disc is strengthened by a certain number of ribs; it carries in the rear a fixed handle, and the firing bolt, to be described later. The tube ends at the rear in a ring cut with a rabbet, in which the disc fits when it is closed. In this rabbet is formed the joint that insures tightness during firing, the disc bearing against a special plastic ring placed in the rabbet. To close the disc and obtain the required contact, a round ferrule is screwed in the projection of the rabbet, and is made to turn round its centre; on its inside are cut a series of continuous and interrupted threads, which correspond exactly to those on the disc, in such a manner that it is sufficient, in order to fix the disc to the tube when it is at the bottom of the rabbet, to turn the ferrule to a degree corresponding with the pitch of the continuous threads, this action being transmitted by a toothed sector fitted to the outside of the ferrure, and by a pinion placed in the thickness of the ring in the rear of the tube. The whole system is worked by a crank.

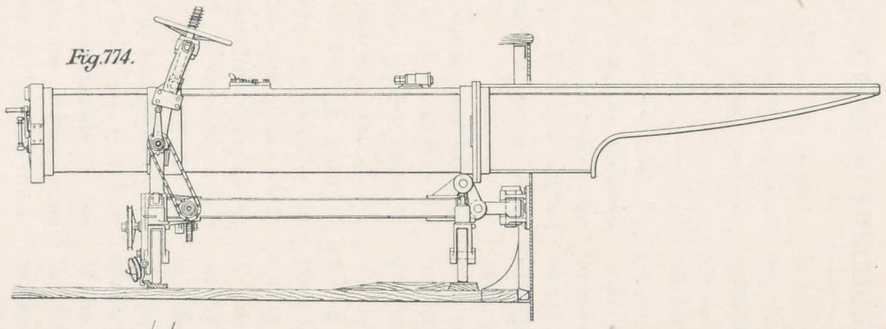
To open the disc, the crank is turned round to disengage the continuous threads, the disc being then brought to the

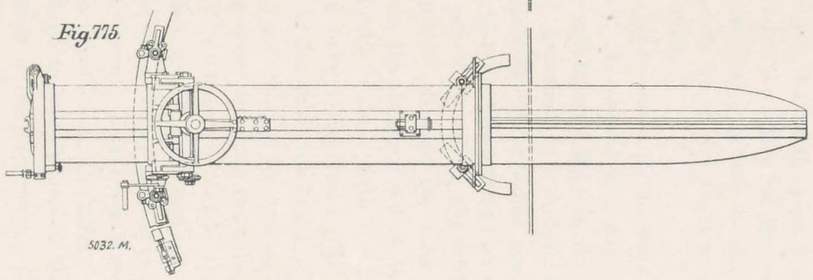
TORPEDO-LAUNCHING TUBES.

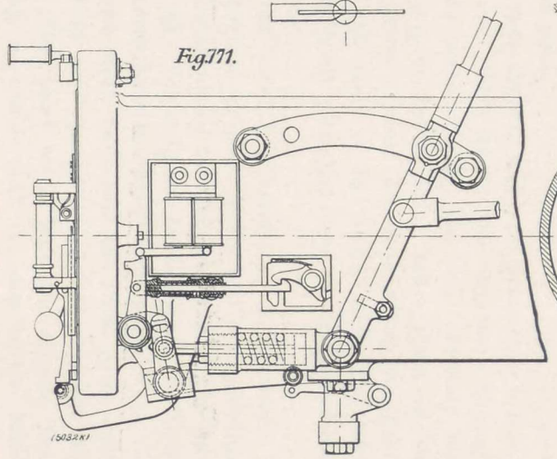


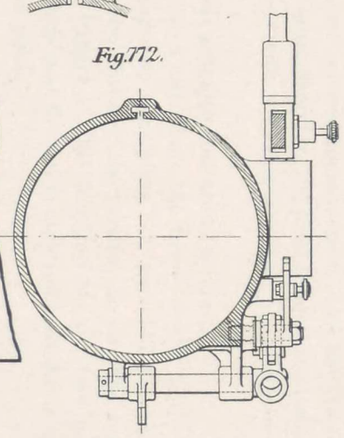












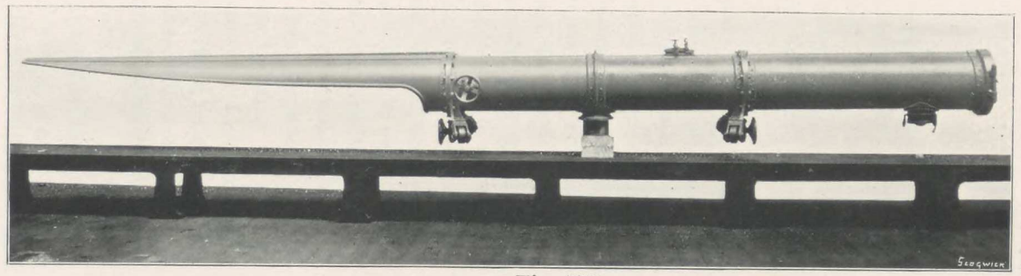


Fig. 776.

Details of Schneider-Canet Torpedo-Launching Tubes.

side by drawing on the fixed handle. When the torpedo is placed home in the tube, the same motions are repeated inversely to close the disc. On its inner concave surface the disc is provided with a recess in which the charge is placed. The gases flow through the tube by vents, arranged in such a manner that the propelling machinery of the torpedo is not in direct contact with them, the pressure rising progressively in the tube. The vent in which the fuse fits is cut through the centre of the disc, and ends in the centre of the small powder chamber. A spring ejector serves to withdraw the fired fuse.

The firing device consists of the bolt and the working mechanism. The bolt, which is similar to those used for guns, is made movable in a longitudinal groove fitted to the outside surface of the disc, the bottom of the groove forming a fixed rack. On the bolt is fitted the centre of the joint of a ball-hammer, on the hinge of which is cut a series of teeth that engage the fixed rack. The whole is put together in such a way that when the bolt is at the extreme limit of its travel, the ball of the hammer, which is provided with a percussion pin, is in contact with the rear of the fuse; when it is at the lowest part of its travel, the hammer is brought down. It is sufficient, therefore, to move the bolt in its groove to communicate to the striker, the required *vis viva* to fire the fuse. This action is imparted to the bolt by the firing device, the disengaging of which can be controlled either by hand or by electricity.

The firing device acts on the bolt to bring it up to the limit of its travel by means of a two-branched lever, which is jointed under the lower rear end of the tube, and controlled by a horizontal piston worked by a spiral spring contained in a fixed cylinder. A vertical disengaging mechanism, held by a pawl mounted on the armature of an electromagnet, keeps it in position. The disengaging of the system is obtained in lifting the pawl by hand or by an electric current. The two-armed lever can then work the firing bolt freely. To bend the main-spring, a round rod is operated, which is placed in a socket at the end of the shaft which carries the firing lever. This socket is provided with a cam which, when the lever is operated, causes the disengaging gear to turn until it grips the pawl of the electromagnet. When this is effected, the rod is put back in the accessory chest.

The stop-latch serves to fix the torpedo in the tube as long as the firing device is not worked. It consists of a cylindrical piston, made to enter the tube for a certain length, and is fitted to the lower part near the rear. A slit is cut in the piston in which the lower fin of the torpedo fits. This latch is governed by a spring; and, as mentioned further on, is arranged so as to leave the torpedo free previous to the firing of the charge.

As long as the torpedo remains motionless in the tube, its mechanism does not work, the compressed air in the reservoir not reaching the cylinders that work the propeller. As soon, however, as firing takes place, the torpedo advances in the tube, and immediately this forward motion is started, the valve opens which admits the compressed air, under the action of the starting finger that projects from the inside surface of the tube at the spot chosen for the lever, which works this valve, and which is fitted to the torpedo.

A brake serves to fix the torpedo in the tube until it is fired. It consists of a piston, which may project on the inside and bear on the torpedo under the action of a spiral spring, contained in a suitably-shaped casing. It can only act when the torpedo has been placed completely home; until then it is maintained on the outside. To this effect, it is provided with a threaded rod, to which is fitted a handwheel. During the time the charging of the tube goes on, the threaded rod is brought down in its nut, and the brake is flush with the inside wall of the tube, its spring being compressed. As soon as the torpedo is in place in the tube, the brake is made to bear on it and its spring gets relaxed by turning round the handwheel.

In order to close the tube when it is not required in service, to keep the inside free from sea-water, a cover is fitted to the front end and made to swing on a hinge, the joint not being tight as is the case for the rear closing arrangement. This cover is worked by a series of levers of the usual kind; the safety devices, however, vary with the shape and dimensions of the tube, and with the accommodation on the manœuvring platform.

In torpedo-firing service, it is absolutely necessary that the succession in the operations of charging and firing be effected in a uniform order, as the least mistake might give rise to most serious consequences. All the various working parts must, therefore, be joined together mechanically or united with clutches, so that all mistakes be impossible.

These special arrangements are as follows:

(*a*) A system which fixes the firing device until the time when firing is to take place. A movable pin can be placed so as to go through the vertical arm of the firing lever and the trigger. This junction of the two parts prevents all action, and the pin is only removed the instant firing is to take place.

(*b*) On the same shaft to which the firing lever is fitted, is a second one which works the stop-latch through a finger which penetrates it. The latch forcibly disengages the torpedo before firing takes place, as the striker only drives against the fuse when the firing lever reaches the limit of its travel, while the latch runs down completely when the lever has performed half of its travel only.

(*c*) The front cover is governed by a bar which is connected through a series of levers and a longitudinal rod, to a hand-lever placed on the right side of the tube near the rear end. Perpendicular to the axis of this hand-lever, and near its joint, is a round stop which, when the lever is brought right back and the front cover open, acts on a spring pawl placed in a frame on the side of the tube. This pawl holds back the trigger, thus rendering firing impossible until the stop on the hand-

lever disengages it. Firing can therefore only take place when the front end cover is opened out.

(*d*) A projecting flange on the lower part of the rear ring unites the breech cover to the tube when it is closed. This flange hides the end of the longer lever branch of the firing device, as long as the tube is not completely closed: until then the latch cannot work.

Such are briefly the principal safety arrangements of the Schneider-Canet tubes. They may vary, in matters of detail, shape, and position on the tube, from one pattern to another; the principle, however, remains the same.

It is not necessary to describe here the mechanism for governing torpedoes at a distance, which in certain cases is found necessary; such mechanism form more especially part of the ship's gear.

(b) **Fixed Mounting** (Fig. 769, Plate CXXXIII.).—In this pattern, the mounting consists of a plain support which serves to fix the tube to the deck. The required training is obtained by the steering of the ship, the tube always firing direct forward; no special methods of fixing the tube are required, apart from those which result from the ship's outfit: it being well understood, however, that nothing must interfere with the manœuvres and the various launching operations.

(c) **Fixed Tube in the Bow of Torpedo-Boats.**—This tube, shown in Fig. 773, Plate CXXXIII., is fixed, and is placed under the deck in the ship's bow. It differs from the preceding in matters of detail only. It consists of two cylindrical parts, joined together by flanges and bolts. The tube is fitted with the breech-closing cover, and with electric firing device, the starting finger, and the automatic stop-latch of the torpedo. The front end cover is kept in place by a latch fitted to the end of a long rod that allows fastening from the rear; a safety-bar on the top part of the tube, constantly drawn forward by a spiral spring, prevents, as long as the front end cover is closed, the placing of a fuse in the vent, thus insuring complete safety against premature firing. The torpedoes are always fired direct forward, and the required direction is given by the steering of the ship.

MOVABLE TUBES.

Torpedo-Launching Tube on Central-Pivoting Mounting, Without Elevating Gear (Fig. 776, Plate CXXXIII., and Fig. 777, Plate CXXXIV.).—This type of tube, with spoon-shaped extension, is fitted on deck, and made to fire from both sides of the ship. The tube is steel, in two parts, and is provided in front with a spoon-shaped guide. It contains the various mechanical details already described. The spoon-shaped guide begins with a cylindrical neck, cut out at its lower part. The groove is continued in it without interruption, so that when the T-shaped support reaches the end, the torpedo enters the water horizontally; thus doing away with all lateral deviations, and insuring a greater precision in the launching than would be the case were the torpedo to plunge point foremost.

The central pivoting mounting consists of the ring in which fits the pivot placed under the centre of gravity of the tube; the support bolted on the deck and carrying the pivot; the racer round which the whole system is made to turn on four rollers placed under the joint rings. These rings are made arc-shaped underneath the tube, and carry the roller axles; they are each provided with a clutch-brake to fix the system in any required position. The brake is worked by means of a handwheel fitted to a screw.

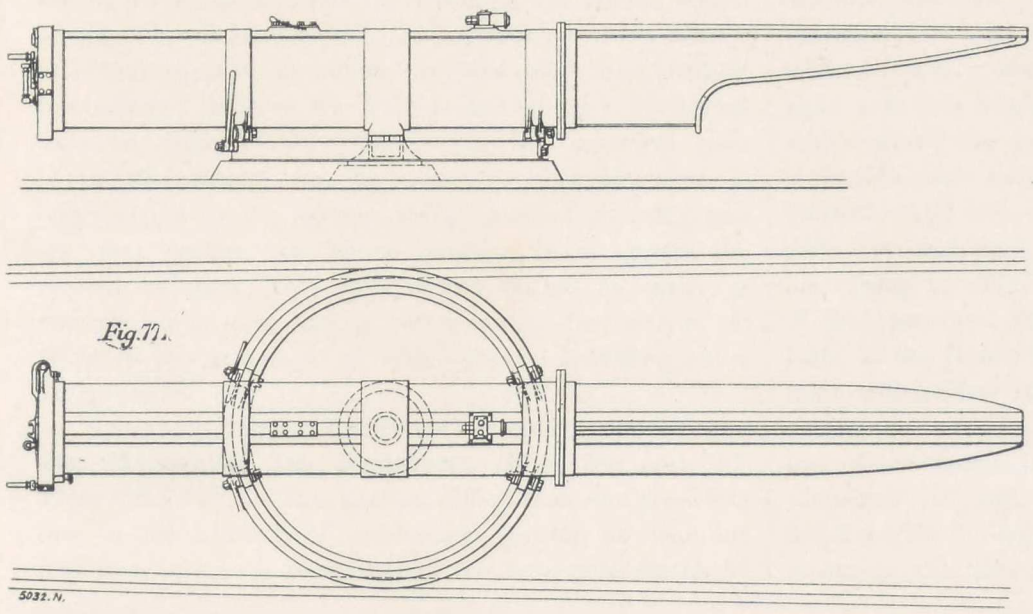
Torpedo-Launching Tubes for Service on Deck of Destroyers (Fig. 779, Plate CXXXIV.). — These tubes, with spoon-shaped extensions, are designed for the armament of destroyers. The "Chishima Kan," built for Japanese Navy, is provided with this type of tube. They fire from both sides of the ship, the deck being provided to that end with straight and circular racers. The tube proper is in one piece, the spoon-shaped extension being made to turn up and down round a hinge-bolt. The accessory fittings are similar to those of the preceding types, namely, the closing cover, the firing device, the stop-latch, the starting finger, besides the support and joint of the spoon-shaped extension.

The mounting consists of a frame, fitted in the rear with two circular arms joined to the top part by a horizontal stay. The middle of this stay is made with a nut, in which a square-threaded screw turns, worked by a handwheel and jointed to the tube. It suffices to act on this handwheel, to give to the tube the required elevation. At the lower part of the frame are placed the sockets in which the rollers fit; there are on a vertical axle, and can be made to turn in the required direction.

In the centre of the ship are two concentric racers, formed of two flat strips, round which the rollers turn when their surface is more or less parallel with the end bars of the frame. When the tube is not in service, and when it is loaded, it rests on these racers, its axis being parallel with that of the ship. When loading is completed, the tube is turned round normally to its first position; and the rollers having been moved through 90 deg., are placed on the two rails across the deck, the tube being rolled to the side on which firing is to be effected. On both sides of the ship are half racers, as shown in Fig. 778, Plate CXXXIV. The tubes can fire round 50 deg. fore and aft. This arrangement enables the firing under a maximum range with one single tube. The manœuvres are very simple, and quickly effected.

Tubes with Spherical Joint for Destroyers (Fig. 782, Plate CXXXIV.).—Tubes of this type have been supplied to the Japanese Navy, and, as is the case with the preceding type, the whole of the system is movable on deck; the angle of elevation is 8 deg., and the training range 33 deg., on each side. The tube is generally similar to the preceding one, and contains the same kind of fittings. It differs, however, in the spherical shape given to the part in the rear of the spoon-shaped extension, and which fits in a seating provided in the sides of the ship. The spoon is fitted to the tube by a

TORPEDO-LAUNCHING TUBES.



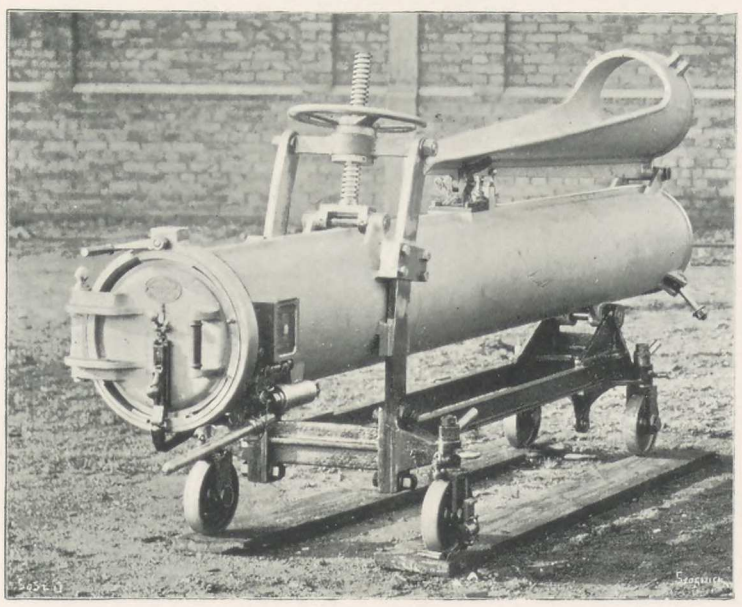
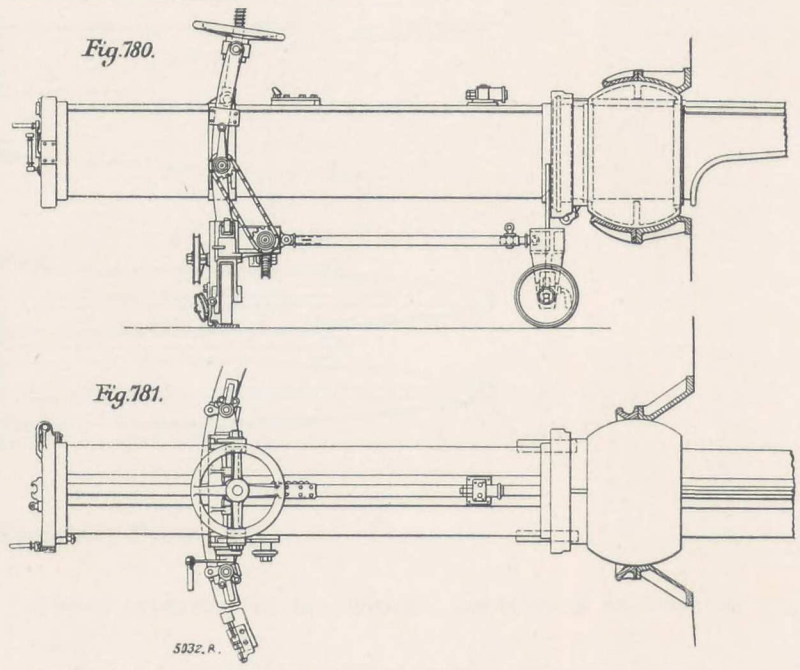


Fig. 779.



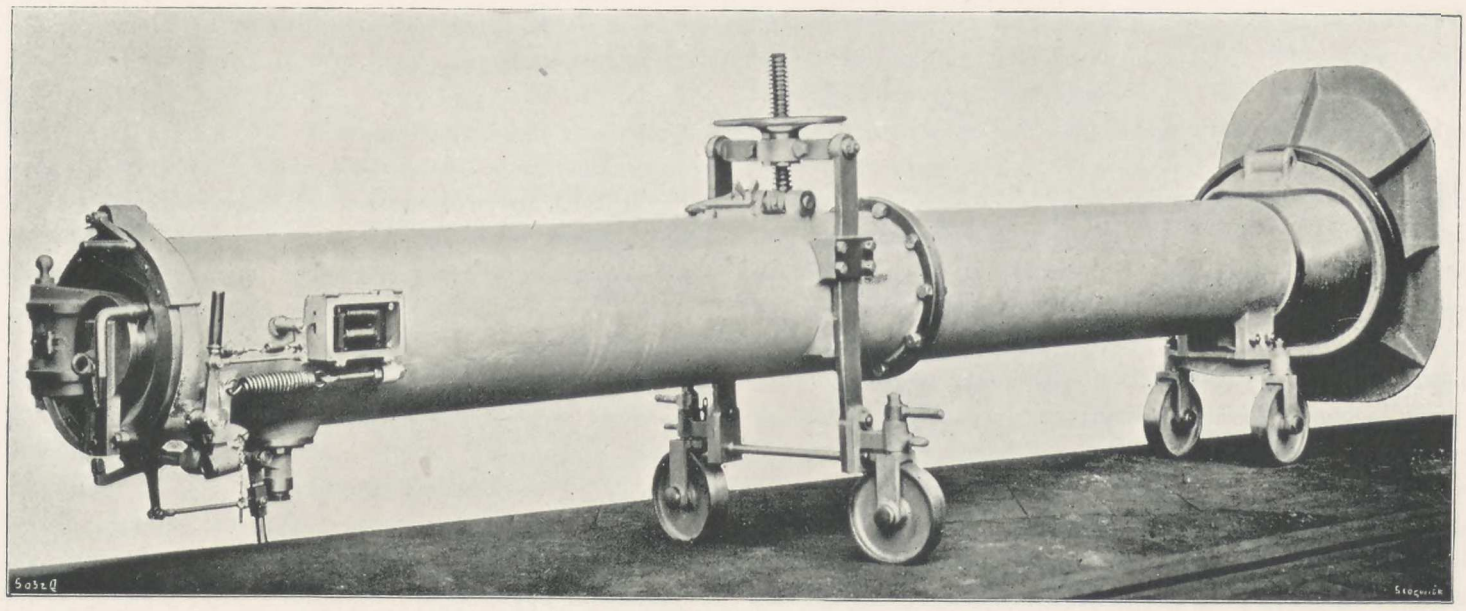


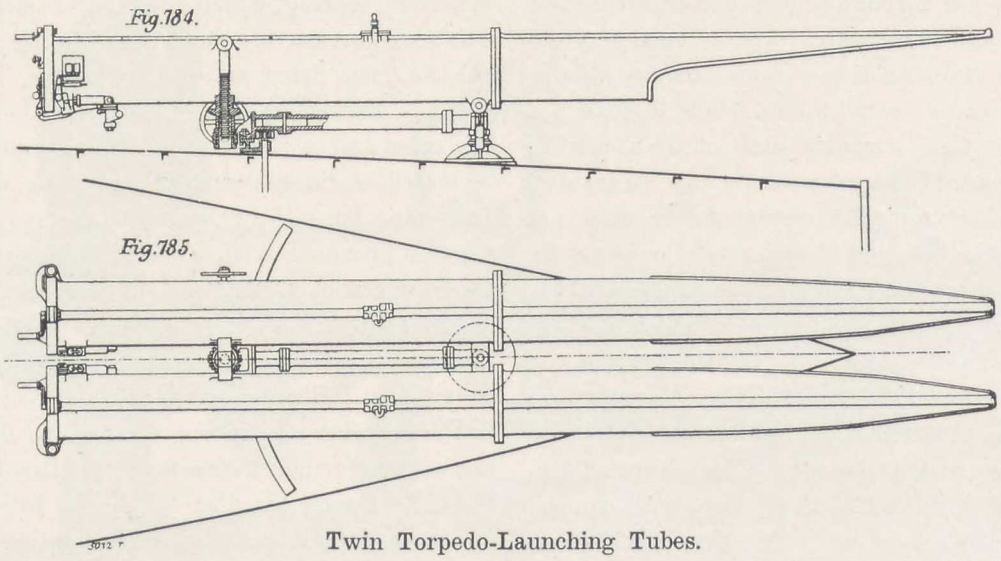
Fig. 782.

Schneider-Canet Fixed and Movable Torpedo-Launching Tubes.

bayonet-joint. The system is so arranged that the tube can be moved as required, for obtaining the desired angles of elevation and training. The mounting consists mainly of a rear support on rollers, provided with the elevating mechanism; in front the tube is carried on a horizontal axle on two rollers, which, when the spherical part is in its seating, can be raised so that the tube is only carried by the seating in the side of the ship and the rear rollers, in which position it is given the desired training. This type is not shifted as easily as the preceding one, and is better suited for service on ships, in the armament of which several launching-tubes are provided.

Spherical-Jointed Tubes with Elevating and Training Mechanism for Destroyers (Figs. 780 and 781, Plate CXXXIV.).—This pattern differs from the preceding one in the addition of mechanical gearing for training. The front truck is connected to the rear roller-frame by a jointed stay. The system contains two tension rollers, placed at one end of the rear racer; a vertical grooved pulley in the rear of the frame, with guide-rollers; a flexible cable, that surrounds the rollers and pulley, and enables the mounting to be drawn to one side or the other, according to the way the grooved pulley is made to turn. The pulley is worked by a transmission, comprising a helicoidal wheel and an endless screw on the axle of a toothed wheel. This wheel is set in motion by a plate chain, worked by a similar wheel, the centre of which is on the right-hand circular arm. A hand-crank completes the system. The other manœuvres are executed, as is the case for the preceding pattern.

Tubes for the Armament of Cruisers, with Elevating and Training Mechanism (Figs. 774 and 775, Plate CXXXIII.).—Tubes of this type have been built in large numbers, and, among other ships, for the Brazilian cruiser "Almirante Tamandare." The tube proper contains the arrangements previously described; it is provided with a spoon-shaped guide, fixed with a bayonet-joint, but without a hinge. The mounting is muzzle-pivoting, and consists of a horizontal frame, formed, in its central part, of an I-bar, in the rear of which oscillate the two jointed circular arms which serve as bearings for obtaining the required elevation, in the manner already described for preceding types. On the right arm is a winch for training the tube, with a crank, which allows the displacing of the system, by acting on a flexible cable rolled round a series of rollers, and on a toothed wheel; the two ends of this cable are fixed to the deck. At each angle of the frame are the rollers, the rear ones being provided with clutches made to clasp the edge of the rear racer fixed to the deck. In front, the tube rests on the frame, with the interposition of a horizontal joint, which allows the required vertical displacements for obtaining the desired elevation. Moreover, the front end of the frame is made with a lug, which may be connected, through a jointed bar, to a vertical pivot fitted to the bulwark of the ship. A suitable opening is cut in the bulwark, to give free space to the spoon-shaped extension in the various positions it is made to take.



Twin Torpedo-Launching Tubes.

Special Elevating Mechanism (Fig. 783, Plate CXXXV.).—In certain cases the Schneider-Canet tubes rest at the rear, on an elevating screw similar to that used with some types of field gun carriages. This does away with the two oscillating arms which form part of the tube mountings already described. The whole of the system is thus much simplified.

The cross-piece which forms the body of the rear support, and which rests at its two ends on the rollers, is provided at its centre with a nut that can turn in its socket under the action of a handwheel. In the nut fits the elevating screw, the head of which is jointed in a lug provided at the lower part of the tube; the screw is raised or lowered by acting on the handwheel. During firing, the mounting is held firm by means of tackle fixed to eye-bolts fitted in the bulwarks. The rollers serve to set the tube in the required direction; they can be turned in such a manner as to draw the tube on deck when not required for service. The desired training is obtained by moving the tube itself.

Tubes on Double Mountings with Elevating and Training Gear for Torpedo-Boat Armament (Figs. 784 and 785).—These figures show twin tubes on a double muzzle-pivoting mounting. The tubes have spoon-shaped extensions, and are arranged for firing forward. The mounting consists of a rear support, which forms the circular rack of the training mechanism, and which carries the elevating mechanism. The support is joined to the front pivot by a stiff bar. The lower surface of the rack rests on the fixed circular racer, bolted on deck, and slides on it during lateral training, no rollers being used in this type of mounting. The front pivot consists of a vertical cylinder hinged on the bottom part of the tube, and resting in a socket carried by a footplate bolted on deck. The tubes are elevated by a mechanism worked by a crank placed on the left-hand side, and containing the gear already described, namely, a screw, the head of which is hinged on a horizontal cross-bar that joins the two tubes in the rear; a nut through which passes the screw, made to turn freely and to oscillate, when necessary, round a horizontal axle on the rear of the frame; on the outside surface of the nut is cut a conical pinion, made to gear in a bevel-wheel keyed on the horizontal shaft of the elevating handwheel. The required lateral training can be insured by gear set in motion from the inside of the ship. It consists of the rack which carries the whole of the elevating gear, and which rests on the fixed circular racer, suitable clutches holding these two pieces together, and a vertical bar that goes through the deck, and is fitted at the top with a pinion which gears in the rack. This rod in turning communicates to the system the required action.

Tubes for Firing with Powder Charge or Compressed Air.—Fig. 786, Plate CXXXV., reproduced from a photograph, shows a deck tube, with elevating mechanism, training device, and spherical joint, generally similar to those previously described. Compressed air or gunpowder can, however, be used at will for launching the torpedoes. To this effect a compressed air reservoir is provided at the lower part of the tube, and follows it in all its actions. A bent tube of large diameter unites the reservoir to the rear end of the tube. A valve with which the tube is provided governs the admission of air in the tube.

Tubes Carried under Deck Beams.—These tubes are required in some cases, owing to the design followed in the construction of the ship; they are characterised by the special shape of their supporting gear. They are carried by the upper deck beams, leaving the firing quarters entirely free. The tubes are generally similar to those previously described.

Jointed Tube, with Spoon-Shaped Guide, and Training and Elevating Mechanisms.—Fig. 787, Plate CXXXVI., shows a side elevation and section of a tube of this type. The tube frame is hinged to a vertical pivot which forms part of the spherical joint support, the axis of the support corresponding with the centre of the joint. The frame rests at the rear on a truck, made to turn round a circular track fitted under the deck beams. The tube, when in firing position, is carried in front in a spherical socket, and is provided with a spoon-shaped guide. In the rear it bears on the head of an elevating screw, two lugs being made to move in two circular grooves cut in the lateral vertical supports of the screw; the centre of the grooves corresponds with that of the spherical joint. Lateral training is obtained by the action of a winch, mounted on a roller truck that rests on the rear of the frame. The tube can be drawn in through a special truck, mounted on the U-section bar, on which it is carried by four rollers. This truck is joined to the tube at a point slightly in the rear of its spherical swell, which can be made to leave its socket, and the whole system drawn back, the port being closed by a cover.

Tube with Spherical Bearing, for Compressed Air and Gunpowder Discharge.—The tube shown in Figs. 788 and 789, Plates CXXXV. and CXXXVI., is in two parts bolted together. The front part is made with the spherical bearing, which fits in the bulwarks of the ship. The rear part carries the breech-closing cover, the powder-chamber, the firing and safety devices. The front closing cover is worked by a rod placed on the top centre line of the tube, and a handwheel. The compressed air chamber is bolted to flanges, cast in one piece with the tube. A bent pipe joins this chamber to the rear of the tube; the pipe is provided with a valve, which is connected with the launching mechanism in such a manner that the compressed air cannot be delivered in the tube, unless the breech-closing cover be completely locked, and the front cover open. Two pressure gauges record the air pressure in the chamber and in the tube. The electric disengaging mechanism for percussion-firing is fitted in the usual place; the firing device can also be worked by hand. The whole of the system is carried on a mounting suspended under the deck beams, generally as described for preceding patterns. It can be drawn in during the navigation of the ship. Fig. 788 shows the arrangement, the breech-cover open and a torpedo in the tube.

Schneider-Canet Tube, with Intermediate Expansion Chest.—In closing this brief review of the Schneider-Canet tubes for launching torpedoes above the water line we may give a description of a special arrangement, with expansion chest, adapted fer certain particular cases. Fig. 790 shows the arrangement in question, the advantages of which are the following:

(*a*) It enables quick ignition powders to be used, without damage to the torpedo-propelling meehanism.

(*b*) It allows the production in advance, when necessary and with the use of explosives, of the compressed fluid required, which is introduced in the tube only at the instant of firing.

(*c*) It combines all the advantages that result from the use of compressed air and powder charges.

To obtain this result, and to enable the gases to expand fully, the powder charge is ignited in an auxilary receiver (*a*) of suitable volume, fixed to flanges (*b*) cast in one piece with the tube. One end of the receiver is closed by a screwed

TORPEDO-LAUNCHING TUBES.

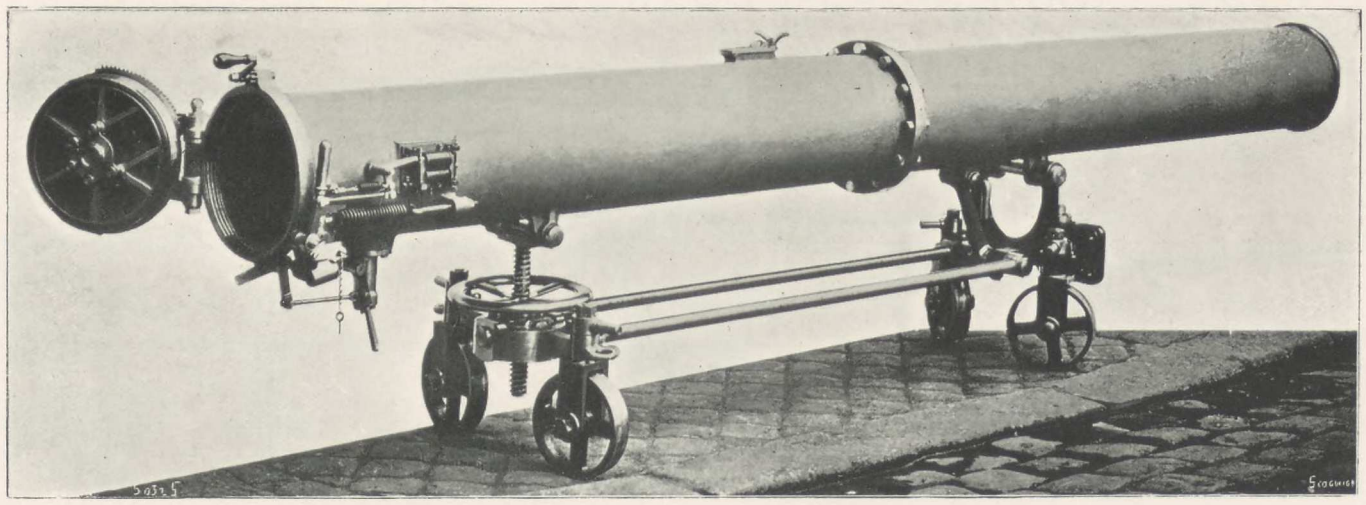


Fig. 783. Deck Torpedo Tube with Screw Elevating Gear.

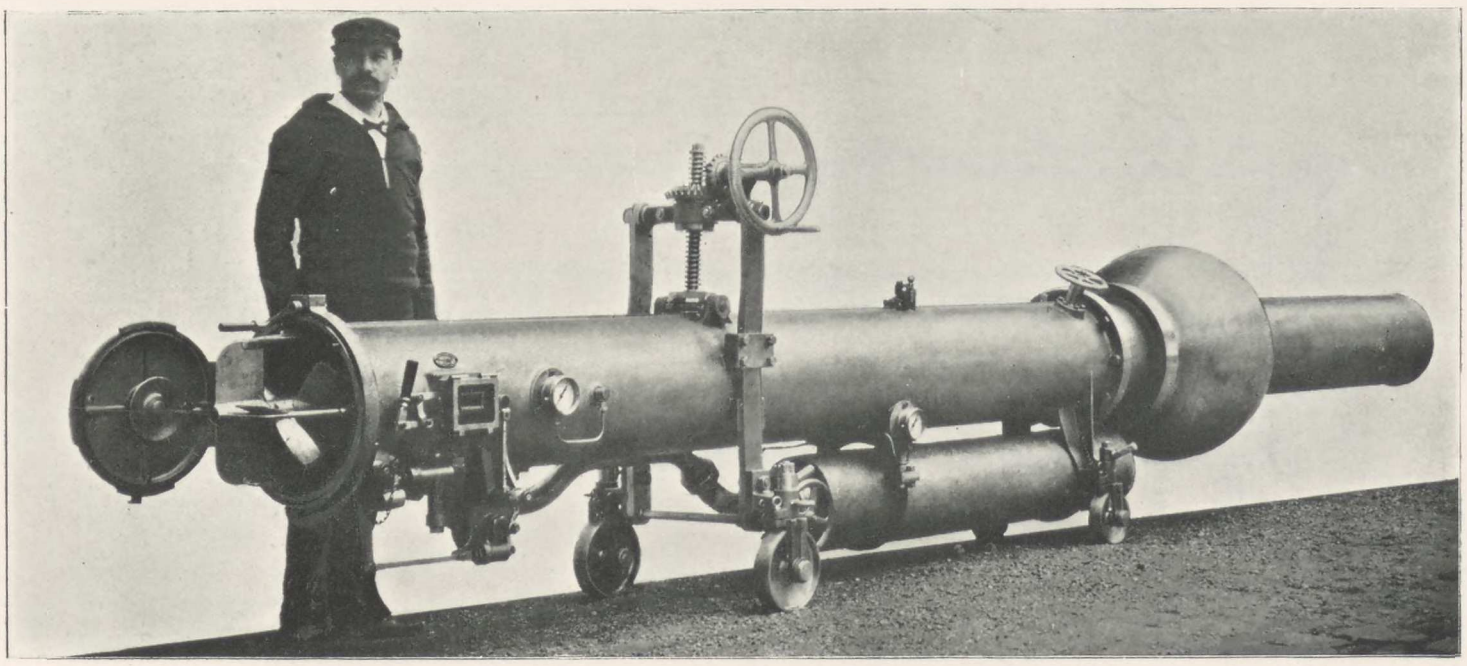


Fig. 786. Torpedo Tube for Firing with Compressed Air or Powder.

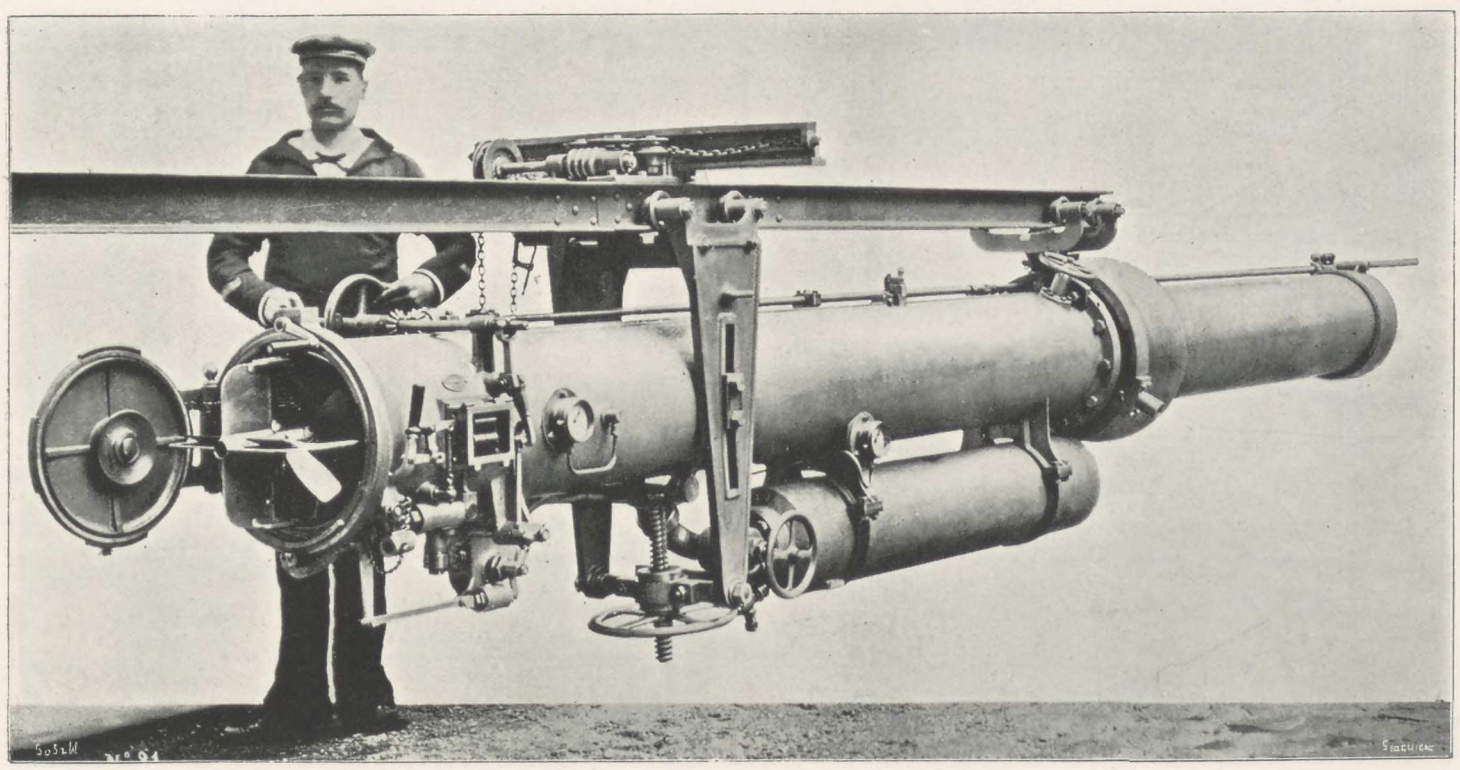
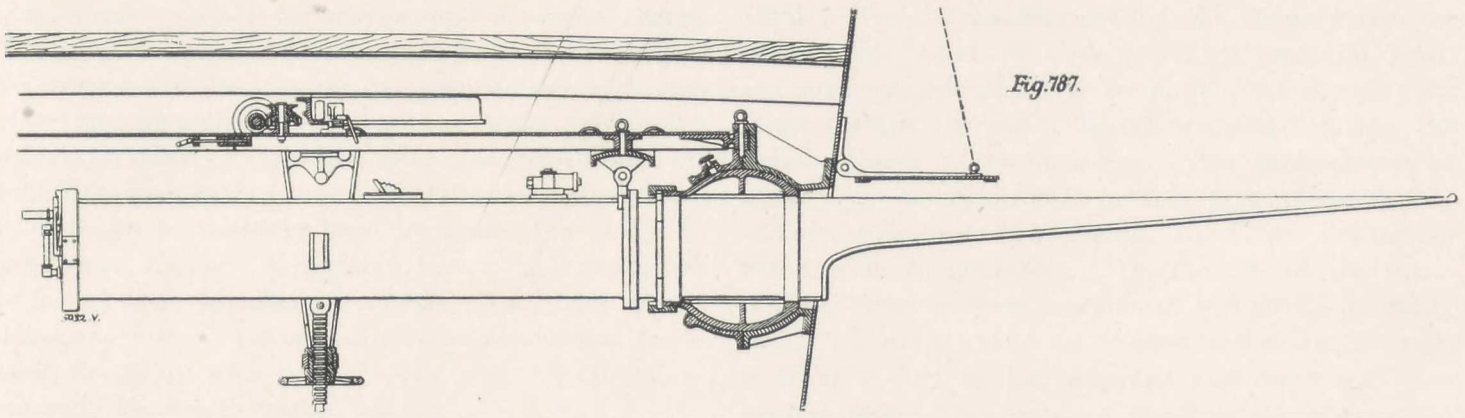
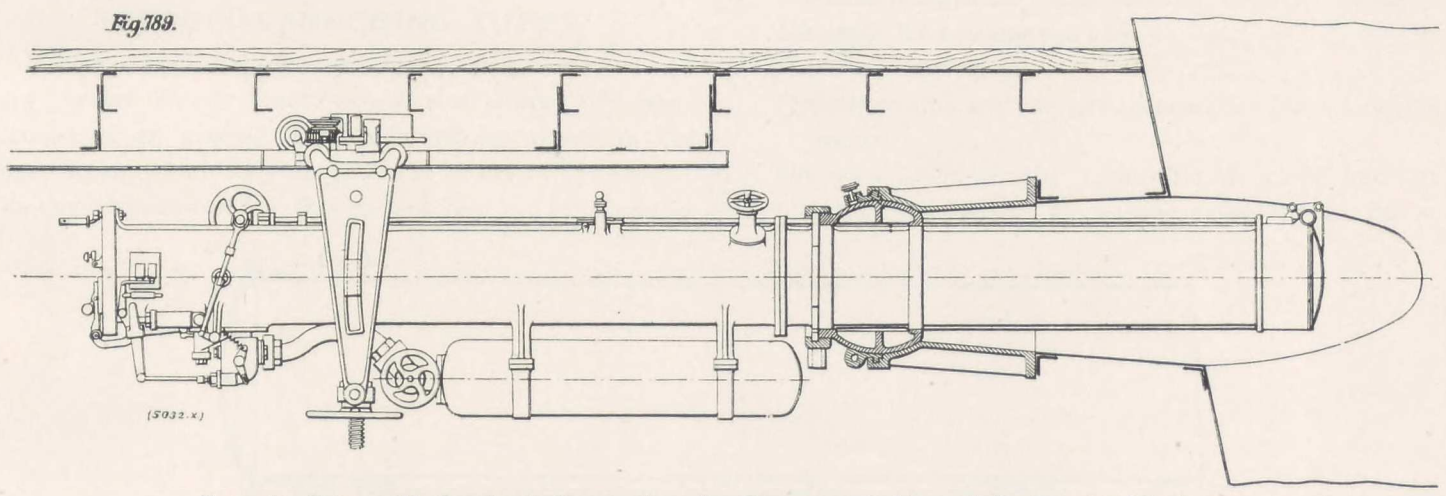


Fig. 788. Torpedo Tube with Overhead Suspension, for Compressed Air and Gunpowder Discharge.

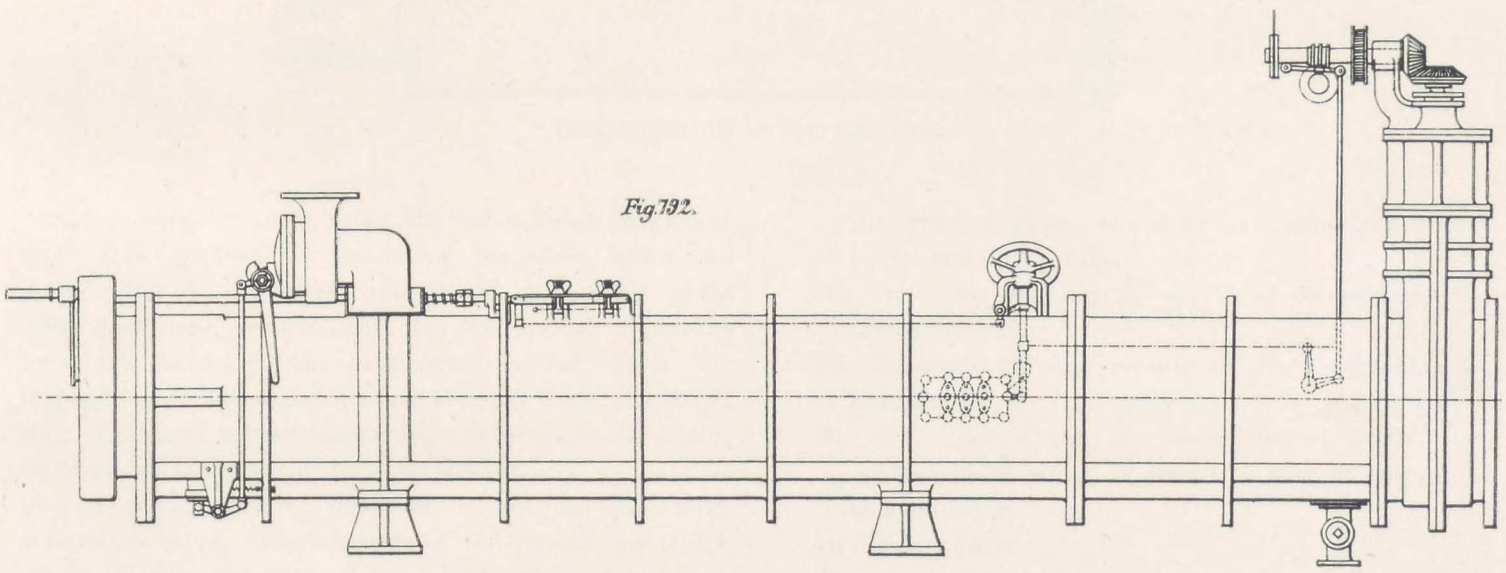
SCHNEIDER-CANET TORPEDO-LAUNCHING TUBES.

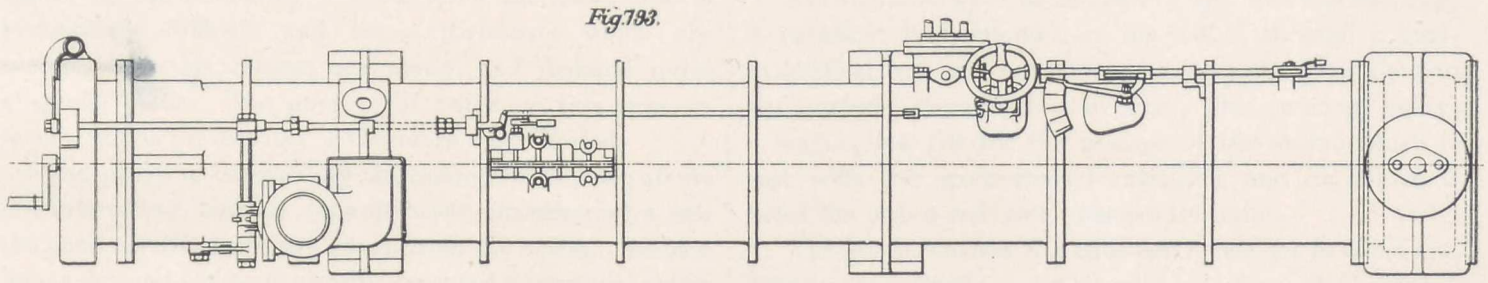


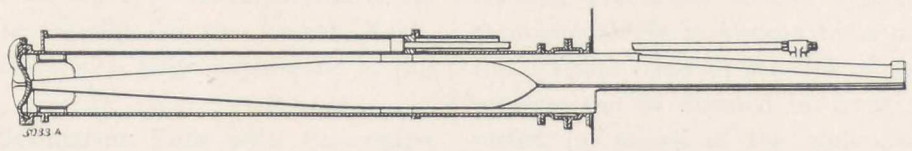
Torpedo with Overhead Suspension.



Torpedo Tube with Overhead Suspension, for Compressed Air and Gunpowder Discharge.







plug, which is movable for introducing the powder charge. The firing device is one of the types previously described; the receiver and the tube are in communication with each other through a pipe provided with a loaded valve. The valve (*e*) is raised by the action of the gases which enter the tube (*d*) as soon as they have reached the required pressure; it may also be raised by hand by means of a lever. In some cases, the valve is replaced by a conical tap, which is turned when launching is to take place. This system does away with all piping and air compressors, and facilitates the firing with powder even when the tubes are normally filled with water.

2. SCHNEIDER-CANET SUBMARINE TORPEDO-LAUNCHING TUBES.

Recent naval engagements have demonstrated the very grave danger that exists, for ships of large dimensions, in placing torpedo-launching tubes on the upper decks, where they are liable to be hit by the enemy. The experience gained in this respect has led, for ships of recent construction, to placing the tubes below the water line. The problem of launching torpedoes below the water line is, however, surrounded by many great difficulties, and renders the use of special apparatus necessary, owing to the very great lateral efforts the torpedo has to withstand when it emerges from the ship's side. Ordinary torpedo-launching tubes might be manufactured at the present time by almost any works that own a suitable plant; but such is not the case with submarine tubes. The analysis of the phenomena which appear at the launching of tubes below the water line is particularly difficult, and the experiments which are necessary in this respect are costly, and demand quite a special plant. The number of tubes of this type in service at the present day is therefore very limited.

The patterns covered by the Schneider-Canet patents are interesting, both as regards their characteristics and the good results they have given from the outset. Messrs. Schneider and Co. have already executed important orders for tubes of this type, chiefly for the French Navy; they have, therefore, acquired a large experience in this speciality.

Schneider-Canet Submarine Tube with Concentric Guide.—This is characterised by the shape given the spoon guide, which is made concentric with the tube; the arrangement allows a favourable division of the strains which the guide has to withstand during the various phases of the launching. The tube proper, or shell, is of gun-metal, made in four parts placed end to end and stiffened by ribs; the rear end carries the closing cover, with its mechanism. On the side of the intermediate rings is fixed a cylinder screwed in a strong socket. There is a cover for opening and closing the tube in front, worked mechanically, and kept watertight, preventing water from entering the tube so long as the breech-cover is not closed.

The tube is fitted with the following external fittings:

The latch for holding the torpedo fast.

The launching valve.

The cam casing and an arrangement for inspecting the valves.

The stop-latch of the spoon-shaped guide and its safety rod, in two pieces, one extending as far as the cam casing, and the other extending from there to the end of the tube.

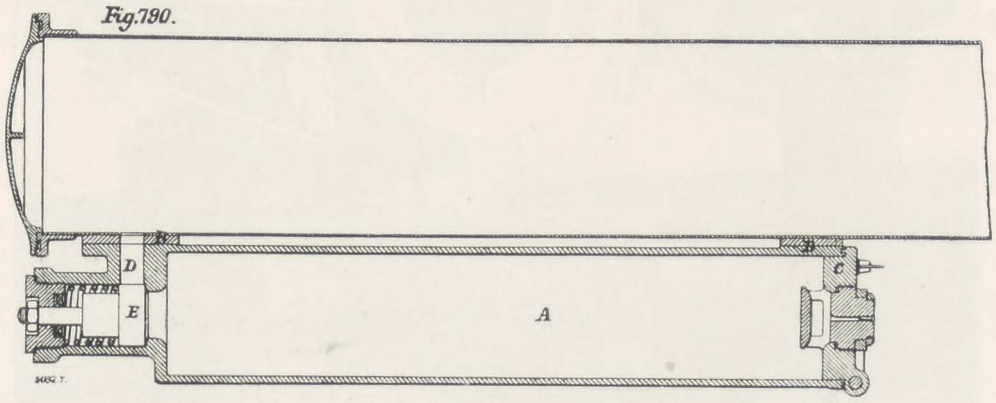
The finger for opening the air valve connected with the safety rod.

The indicator for the placing of the spoon-shaped guide.

The slide that works the spoon-shaped guide, the mechanism of which is joined to that of the valve and indicator.

An exhaust valve.

Fig. 790.



Compressed Air or Gas Chamber.

The cylinder fixed to the side of the intermediate rings is extended in front and on the valve, through a semi-cylindrical cast-iron envelope, jointed to the tube by two flat surfaces strengthened by ribs. This envelope covers a longitudinal slit for the passage of the socket which is cast with the spoon-shaped extension, and on which is fitted the piston-rod which insures its action.

The guide consists of a tube partly cut out in front, and forming practically a solid cylinder of equal resistance throughout. It is worked by a piston which travels in the cylinder fixed to the side of the tube. Water under pressure can be directed in front or at the rear of the piston, by means of the slide above referred to. The

guide fits in the tube over a sufficient length, to withstand the considerable pressure of water when the vessel is moving at a high speed. Two grooves are cut inside the tube, and at the two ends of the vertical diameter in which fit the torpedo guides.

When a torpedo is placed in the tube and the breech-valve is not completely closed, and to prevent launching the torpedo until the guide is in place. The tube can be made in such a manner that the above operations follow each other automatically, and to obtain this but few alterations in the accessory gear are necessary. In this case, the launching of the torpedo is effected by simply

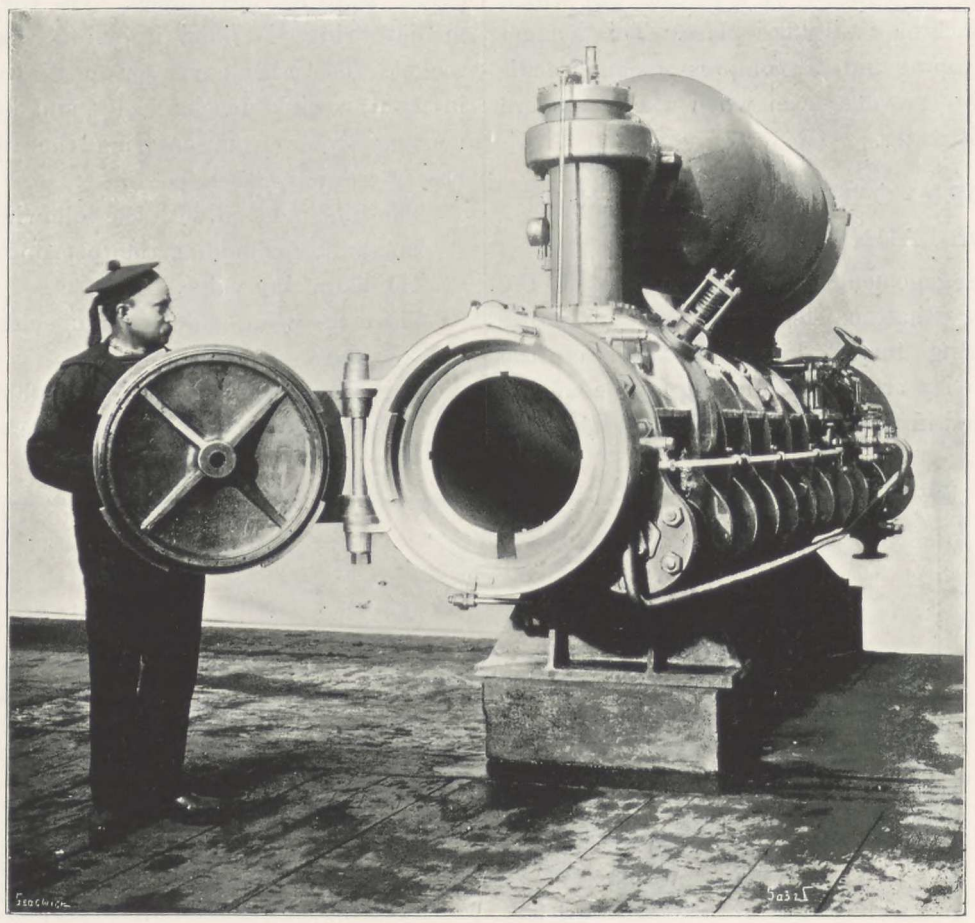
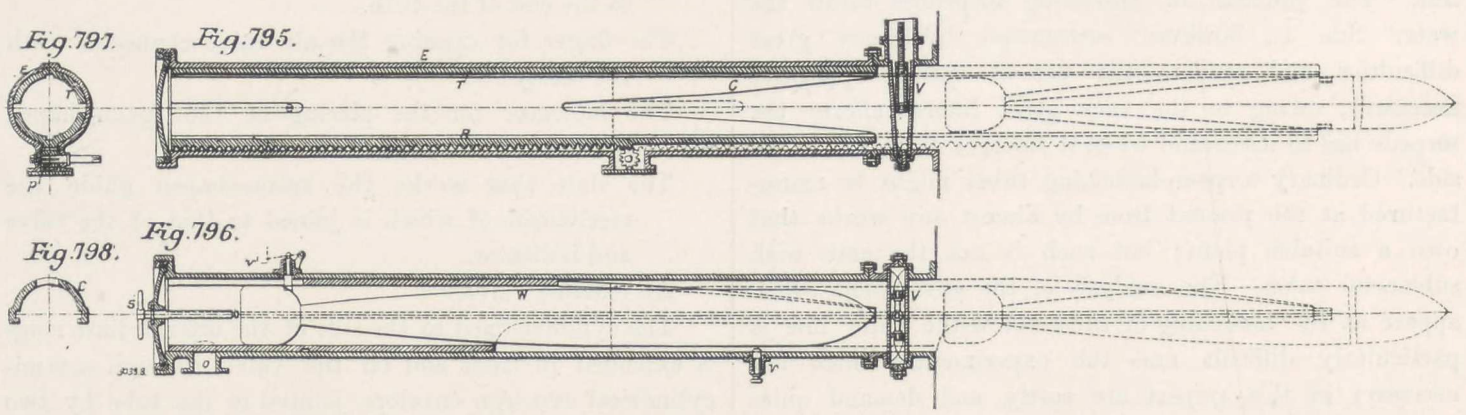


Fig. 791. Torpedo Tube for Firing Below Water Line.



Schneider-Canet Submarine Tubes.

cover is closed, the valve is opened by acting on the working lever; the guide is placed in its position by introducing water under pressure in the cylinder in the rear of the piston. When the torpedo is launched, these operations are repeated inversely and the valve closed. Safety devices are provided to prevent the opening of the valve as long as the breech-cover is not closed, and to stop all forward motion of the guide as long as the acting on a suitably-designed lever. The necessary water under pressure for working the guide can be supplied by a special pump or by accumulators, in which compressed air from the torpedo compressors is allowed to expand. The air which serves to launch the torpedoes is held in a reservoir placed at the top part of the tube, and provided in the rear with a bent pipe which extends to the rear of the tube.

Fig. 791, and Figs. 792 to 794, Plate CXXXVI., show one of these installations complete. It contains a large number of special piping and fittings, the principal ones only having been referred to.

Schneider-Canet Submarine Tube, with Mechanical Working Guide (Figs. 795 to 798).—In this pattern the guide is worked mechanically, no hydraulic machinery being resorted to. When the ship is being navigated, the tube contains the guide; this is provided with two grooves, which are extended in the thickness of the tube walls, and serve as slides for the tenons on the torpedo. The spoon-shaped extension is provided at its lower part with a rack, in which a pinion engages, worked either by hand or mechanically, the pinion being placed in a recess on the tube. The principal fittings are the following: The front closing valve V, the breech-cover, two automatic working latches, one to limit the forward travel of the tube, the other holding the torpedo in the tube when it has been placed ready for firing; the torpedo is held besides by a screwed plug that goes through the breech-cover. The mechanism is the same as that of the preceding pattern.

When the torpedo is in place and the breech-door closed, water enters the tube as soon as the valve V is opened. The extension guide is then released to the limit of its travel, by turning the pinion which gears in its rack. When the accumulator is connected with the rear of the tube, the latch that holds the torpedo is disengaged automatically, and the torpedo is driven forward. When launched, the extension guide is brought back in the tube, the front valve is closed, and the tube is emptied, ready for another operation.

XXXVI.—SCHNEIDER-CANET NAVAL TURRETS.

THIS is an important branch of the Schneider-Canet system of armament, both as regards the improvements carried out in successive turrets built, and the large number, adapted for all calibres of guns, that have been supplied to the French and various foreign Governments. The Schneider-Canet system was the first to combine balanced turrets with a central tube, and worked either by electricity or by hand. The present section is, therefore, of special interest, and we shall classify it, in order to facilitate the description of the various types, under the three following heads:

1. Hydraulic, non-balanced turrets, for loading in all positions.

2. Hydraulic, balanced turrets, with central tube, for loading in all positions.

3. Electrically-working turrets.

1. HYDRAULIC, NON-BALANCED TURRETS, FOR LOADING IN ALL POSITIONS.

As a type of this, the Schneider-Canet turrets for 138.6-millimetre (5.456-in.) guns may be taken.

The turret consists of a platform with a conical wrought-steel socket; the gun mounting; a hoist with loading platform; a means for the discharge of empty cartridge-cases; and the mechanism for lateral training and elevation of the gun. One side of the turret space is set aside for delivery of ammunition to the gun and the discharge of empty cartridge-cases, the other side being reserved for operating the breech-block, and the elevating and training mechanism. Ammunition from the magazines is placed in the hoist on the orlop deck.

The platform consists of two longitudinal and six transverse beams built up of plates and angles, and strongly fitted together with wrought-steel flooring plates; it carries the gun and its mounting with the interposition of a cast-steel bearing, in the sides of which the trunnions are placed. Angles fitted to the ends of the beams round the flooring plates, serve to fix the armour and backing to the platform. The turret is 1.800 metres (5 ft. 10$\frac{7}{8}$ in.) high to the springing of the top plates. The conical socket consists of two 12-millimetre (.472-in.) steel plates lap-jointed together; the upper part enters a steel casting which connects the socket with the platform, and the lower part is closed by another steel casting forming the pivot support, which is of forged steel; it turns on a bush of hard gun-metal placed inside a gun-metal step bearing, bolted to a cast-steel foundation plate. The rotation of the bearing allows the height of the turret to vary by a few centimetres. The pivot, the step bearing, and the foundation plate, are recessed in the centre to receive the pipe that delivers water under pressure. The turret is guided in a cast-steel ring fixed to a guide plate, the joint between the socket and the platform being lined with gun-metal friction ring, which turns inside the cast-steel ring.

The gun mounting is arranged with limited recoil and automatic return; it consists of a trunnion carriage, two recoil slides, and a spring recuperator. The centres of the carriage trunnions and those of the recoil slides are in the same plane, the spring recuperator being placed underneath the carriage. The carriage is of cast steel, in two similar parts, connected vertically in front and at the rear. On the sides are the trunnions on which it is carried, and the slides for the slide-blocks. The jointed parts in front and in the rear, form two jackets, placed as far apart as possible; these serve as guides for the gun. They are lined with gun metal, as also are the lateral slides, in order to reduce friction during recoil and return. The slide-blocks are rectangular, and are placed symmetrically; they contain the brake cylinders; two half rings welded to the blocks unite them together in a vertical plane. These half rings are made with projections which fit in grooves cut in the gun, thus causing the slide-blocks to follow all the motions of the gun. Recoil is absorbed by the two recoil cylinders. The piston-rods in front of the carriage pass through the cylinders from one end to the other, the volume in the brake therefore remaining constant. Grooves of varying sections are cut inside the cylinders to allow the liquid to flow from one side to the pistons to the other; they are calculated in such a way as to offer a practically constant resistance through 250 millimetres (9.842 in.), which is the length of the recoil. The recuperator consists of two sets of spiral springs, symmetrical with the gun, and bearing on the rear end of two rods, the front ends being fixed to the front of the mounting. The springs are compressed during recoil, through a forged steel crosspiece fixed to the half rings of the slide-block. When the recoil is spent, the reaction of the springs, runs out the slide-blocks and the gun. The springs can be easily and quickly replaced. Return to firing position is controlled by the brake during the greater part of the travel, and afterwards by a hydraulic buffer.

The gun is supplied with ammunition by means of a hydraulic hoist and loading platform. The hoist consists of a tube with a lateral opening, which serves as a guide for the ammunition, and of an endless chain, fitted at

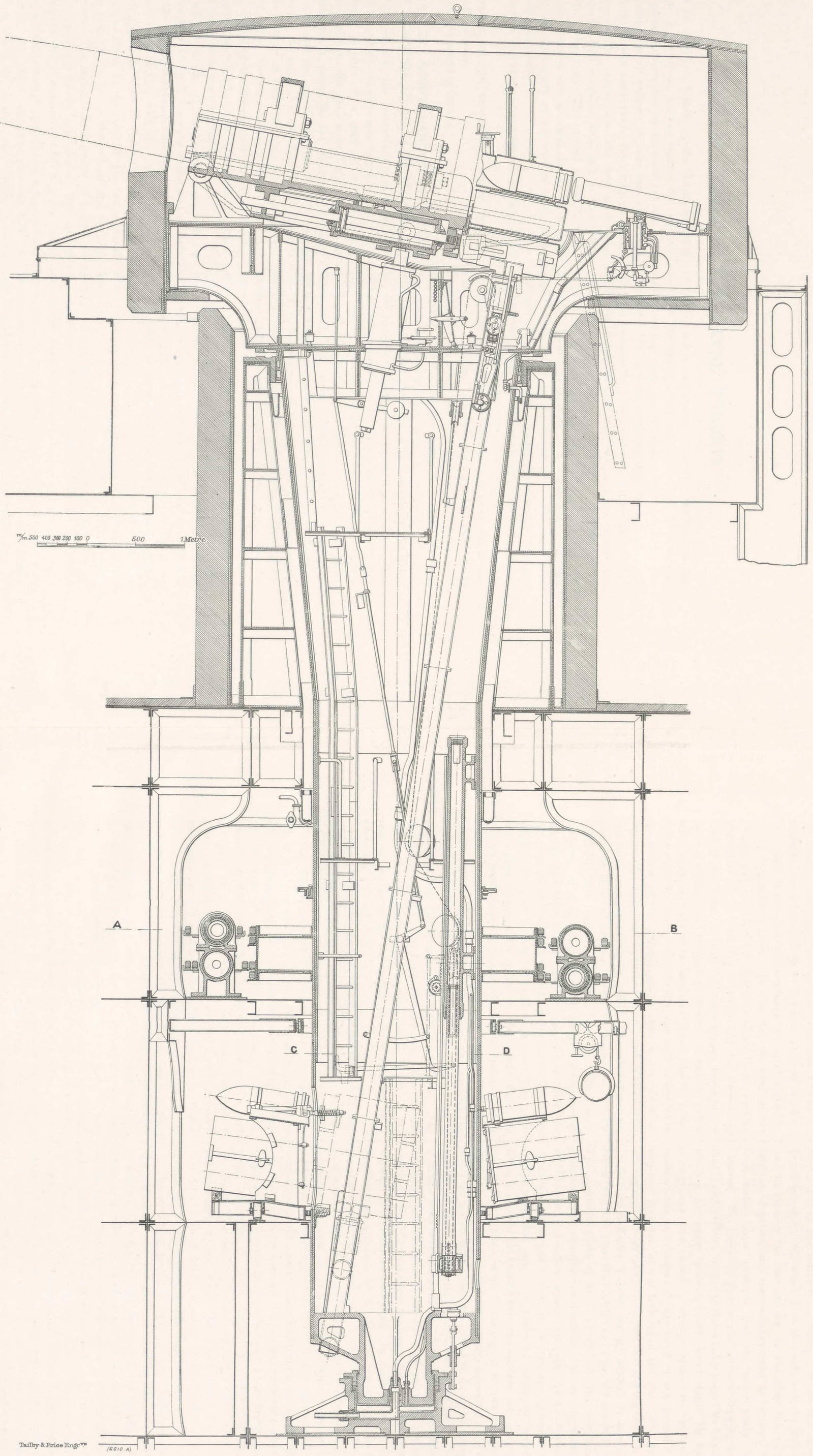


Fig. 799. Turret, Gun Mounting, and Ammunition Hoist for 274.4 Millimetres and 305 Millimetres Naval Guns.

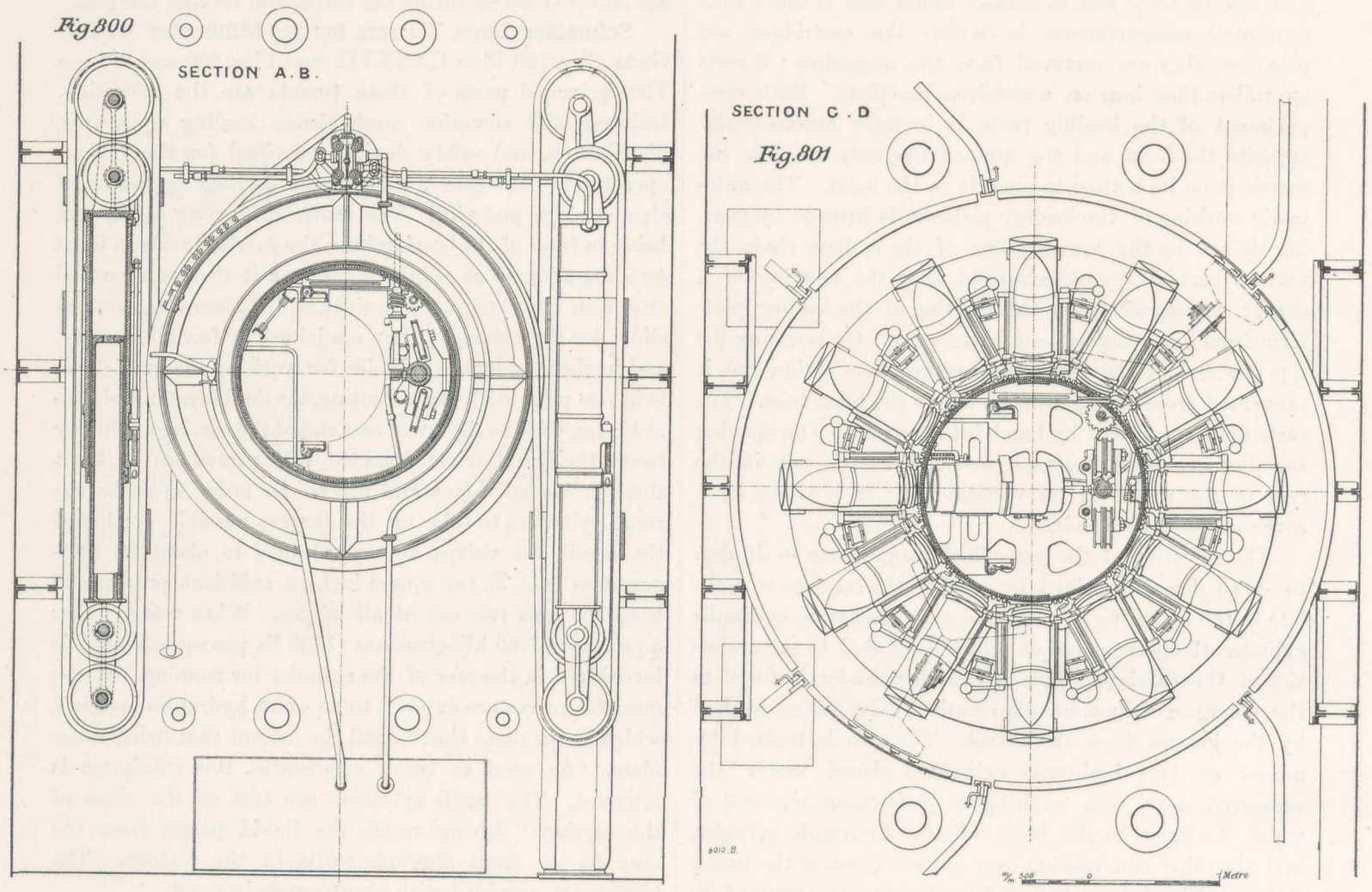
intervals with cleats or brackets that carry the cartridges. By working the chain, ammunition is delivered from the magazine on a lower deck to the gun, as it is required. The chain is operated by the plunger piston of a double-acting hydraulic cylinder. To this end, the head of the plunger piston is provided with two jointed levers, bearing alternately on the spindles of the rising and descending sides of the chain, so that the latter always turns in the same direction round the pulleys whichever way the piston acts. A spring cleat at the bottom of the hydraulic cylinder engages the chain automatically, and holds it fast when the motion of the plunger piston changes its direction. The loading table can be turned round, and is fitted with concentric compartments, in which the cartridges are placed as they are removed from the magazines; it rests on rollers that bear on a cast-iron baseplate. Each compartment of the loading table is brought automatically opposite the hoist, and the gunner has only to slide the cartridge on its bottom to place it on the hoist. The automatic working of the loading platform is insured by gearing driven by the lower pulley of the endless chain, the various parts being so arranged that the hoisting of a charge corresponds with the shifting of the loading platform from one compartment to the next. On reaching the top, one end of the cartridge engages in a guide, and is prevented from falling when it leaves the hoist tube. The cartridges are placed by hand into the gun. The opening for discharging the empty cartridge-cases is cut in the rear of the turret in its vertical wall; it is closed by a cover and a double bolt.

The elevation of the gun, which ranges from — 10 deg. to + 15 deg., is obtained by causing the carriage to oscillate in the mounting by means of a double-acting hydraulic cylinder, the plunger rod of which is jointed to the underside of the carriage. This hydraulic cylinder is fitted to the mounting frame, its distribution valve being worked by the gunner from the turret. The gun is trained by means of two hydraulic cylinders. placed under the armoured deck, each working a plate-chain, one end of which is fixed to the body of the hydraulic cylinder, and the other end passing over a drum fixed to the turret socket. The lateral training mechanism is arranged so as to work the turret when the ship has a list of 5 deg., and to hold it fast under an angle of 15 deg. The delivery and exhaust of water under pressure take place through a valve at the bottom of the cylinders; this valve is loaded at 10 kilogrammes (142 lb. per square inch), in order to keep the chain taut and to fix the turret should the pipes leak or burst. The distribution gear of the lateral training cylinders is placed on the orlop deck, in the cylinder space; but it is worked from the firing platform by means of a geared transmission, placed in the turret; while in the pit, on a level with the distributor, are a wheel and an endless screw, working a gun-metal disc to fix the system; this disc is made with two concentric grooves connected by an incline, and in which a roller travels fitted to the distribution valve-rod. The difference between the radius of the concentric parts of the grooves corresponds with the travel of the distribution valve. When the turret is not in service, the roller is in the middle of the incline, and by turning the disc one way or the other, the valve becomes displaced and causes one cylinder to be supplied with water under pressure, and the other ready for exhaust. The turret is thus caused to turn, drawing the disc round with it; when the latter has resumed its former position, the valve closes and the turret stops. By this arrangement the turret is always under the gunner's control; the valve ports are calculated so as to insure the required precision in the training of the gun. Six men are required for operating the turret and serving the gun.

Schneider-Canet Turrets for 305-Millimetre (12-In.) Guns (Fig. 799, Plate CXXXVII., and Figs. 800 and 801).—The principal parts of these turrets are the mounting, training, and elevation mechanisms, loading apparatus, distributors, and safety devices, provided for the various operations. The gun is held on the carriage by means of clamps, rings, and pins. The centre of gravity of the gun being in front of the bearing base, the carriage rests in front on a trunnion block, while in the rear it throws a vertical strain on the clamps. The sides of the mounting serve as slides for the carriage; they are joined in front by a stay, and in the rear by the cylinder for working the gun. This is in one piece with the mounting, the double-acting piston-rod being fixed to the lower rear end of the carriage. During recoil, the liquid driven from the rear passes to the front through loaded valves and pipes. In order to cause the recoil cylinders to take up the largest possible portion of the recoil, the valves are only loaded to about 32 kilogrammes (455 lb. per square inch), a sufficient pressure to keep the gun run out at all angles. When water under a pressure of 80 kilogrammes (1138 lb. per square inch) is introduced in the rear of the cylinder for running out the gun, the valves are exposed to an extra hydraulic pressure, which keeps them closed until the instant that firing takes place. As soon as recoil commences, this surcharge is removed. The recoil cylinders are cast on the sides of the carriage; during recoil, the liquid passes from the rear to the front through vents in the pistons. The pistons are provided with counter-rods in front.

The revolving platform, built of steel plates, carries the mounting and the gun, as well as the protective armour; it is bolted to the top part of the socket. The latter transmits the whole weight of the movable turret to the ship's framings; on the top is a gun-metal ring which slides inside the circular guide, and ends at its lower part with the hydraulic pivot. This can travel vertically over 40 millimetres (1.575 in.) in a step bearing, the travel being regulated by an automatic valve mounted on the pivot, the rod of which is joined to the step bearing in such a way that the admission of water under pressure beneath the pivot, is closed by the turret itself when it reaches the firing position, and opened if the turret has a tendency to get lowered. Special latch-bolts on the platform lock the turret when it is not in service; these

bolts are set under the action of springs, and are pushed back when the water under pressure acts underneath the plunger pistons. A safety device prevents setting the bolt-valve for water admission, and the turret cannot be freed for lateral training, if the pivot valve has not been adjusted previously for admission. A finger joined to the pivot valve prevents it being set for exhaust, if the latch-bolts are not home in their catches. The hydraulic cylinders for elevation are placed on the lower part of the platform; they each contain a double-acting piston, the top of the rod forming a sheath in which is a connecting-rod jointed at one end to the mounting frame, and to the piston at the other end. The connecting-rod heads are provided with spherical bushes which allow a certain lateral motion of the mounting frame. Single-acting horizontal hydraulic cylinders, placed transversely on the orlop deck, two in front and two in the rear, regulate the horizontal training by means of plate chains and pulleys. The plungers are guided by slides fixed at one end to the sides of the ship. Handwheels for horizontal training are placed in the turret; they are turned in the same direction as the turret. Ammunition is supplied to the gun by a special hoist, suitably arranged and provided with devices for insuring safe working.



Sections of Gun Turrets.

Turrets for 274.4-Millimetre (10.790-In.) Guns.—The illustrated description of the turrets for 305-millimetre (12-in.) guns, given above, applies to those for 274.4-millimetre (10.790-in.) guns, especially as regards the method of working. The differences in their construction are wholly in points of detail.

2. HYDRAULIC BALANCED TURRETS, WITH CENTRAL TUBE FOR LOADING IN ALL POSITIONS.

In the earlier days of turret-protected guns, a large number of ship turrets of various systems presented two disadvantages which, in certain cases, rendered their working a rather delicate matter, and prevented the guns from being fired at their maximum power. The ammunition was, as a rule, delivered into the turret through an opening on the circumference of the platform, corresponding with a single fixed passage leading either direct to the magazine or to an intermediate staging. To supply the gun with ammunition during firing, it was therefore necessary to bring the opening in the movable platform over the mouth of the ammunition passage, which involved an extra manœuvre of varied duration. Besides this, the centre of gravity of the whole of the movable system was not on the vertical axis of rotation of the turret; it was, indeed, in not a few instances, far from it. Therefore, a slight inclination of

the platform caused a tendency to revolve, owing to the eccentricity of the movable mass. This effect varied, of course, with the extent to which the ship rolled. The result was a considerable difficulty in producing lateral displacements for training the gun, or even a temporary immobility of the system. As the deck of a ship at sea is in a state of constant oscillation, the various mechanisms gave more or less trouble, producing uncertainty in the firing manœuvres. Hydraulic brakes were then little known and seldom resorted to, and the mountings which were placed in the turrets were much longer than those now used, thus leading to the adoption of protective armour of large diameter and considerable weight. The consequences of the earlier mode of construction and working such turrets may be briefly stated as follow: Firing was comparatively slow, as after each round the turret had to be turned for a new supply of ammunition. Effects due to the eccentricity of the system either produced sudden movements, or, offering considerable resistance, deranged the operations of training the gun or even stopped them at times; in extreme cases, the transmissions became totally disorganised. The working gear had consequently to be strengthened owing to these various strains, and the power of the engines had to be increased above that acually required, in order to counteract the tendency to revolve, due to the oscillations of the platform. The armour had also to be made of dimensions and weights excessive in proportion to the offensive power of the gun it protected. It is easy to see, therefore, that under such conditions the working of the various parts was difficult, requiring a trained and cool-headed *personnel;* indeed, under the best conditions the power of the guns could only be utilised to a limited extent. At the same time, turrets did not play the important part in the armament of ships which they do now, owing to the great improvements that have been introduced.

Schneider-Canet Barbette-Turret for 27-Centimetre (10.630-In.) Gun (Figs. 803 to 807, Plate CXXXVIII.).—This type of turret has been supplied to the Greek Admiralty for the armament of the cruisers "Psara," "Hydra," and "Spetzaï." Each turret was delivered complete, with gun, mounting and frame, revolving and training mechanism, hoist, &c.

The trunnions of the gun rest in the trunnion-plates

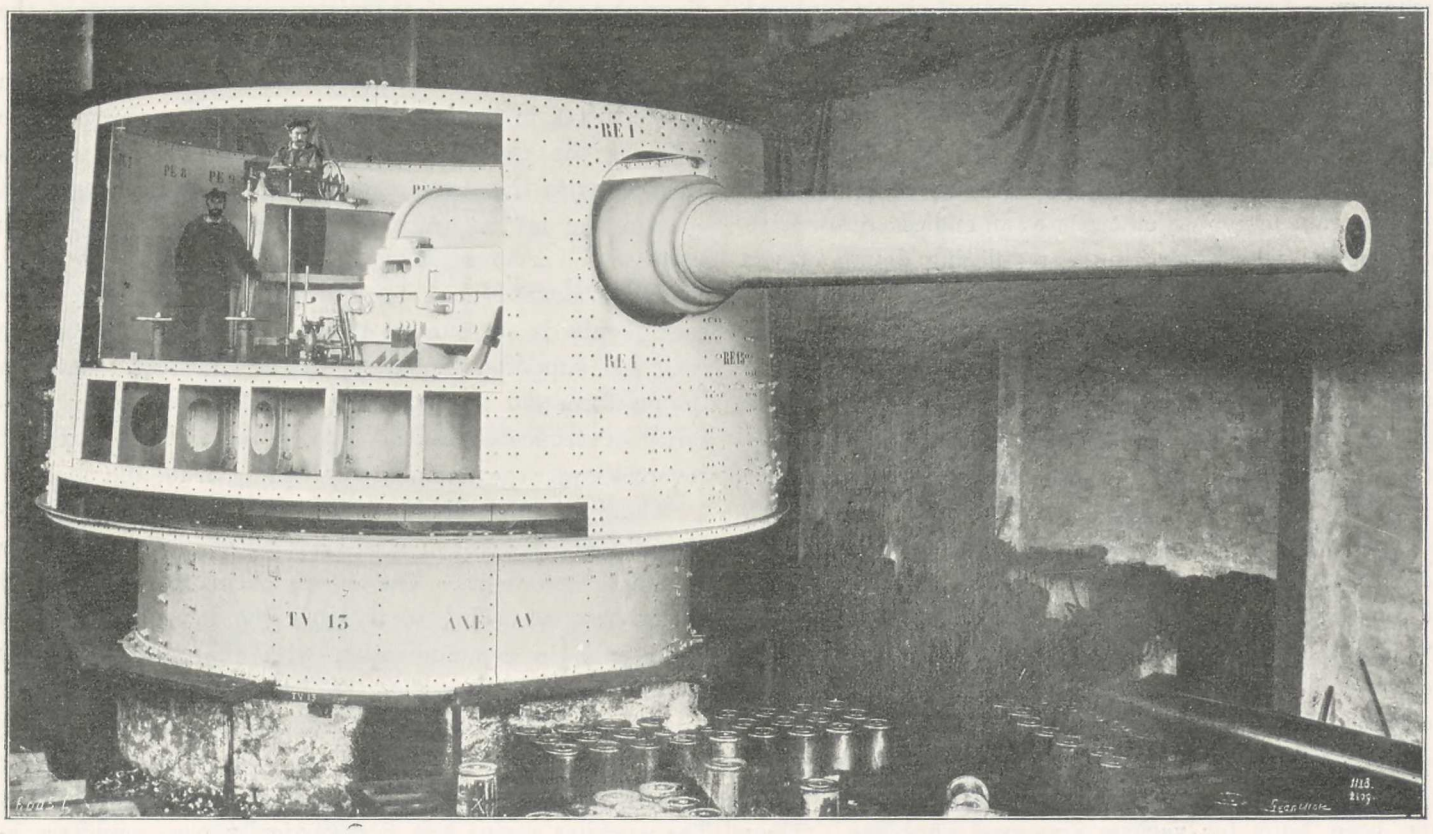


Fig. 802. Closed Turret and Mounting for 27-Centimetre Gun.

cast with the carriage; this consists mainly of the two recoil cylinders, with slides and clamps. Inside are two compensating cylinders, joined to the recoil cylinders by pipes. The mounting consists of two cheeks, the top surfaces of which form the slide paths. Rollers facilitate the travel of the carriage.

On the front cross-stay are butts corresponding with the buffers on the carriage. The recoil piston-rods are fixed to the rear end of the slides; those of the compensating cylinders are attached to the front stay of the carriage. When the gun is fired, the liquid, which is compressed in the front of the recoil cylinders, flows to the rear, whence it is driven into the compensating cylinders the dimensions of which are carefully calculated. When the recoil is complete, the intermediate valves fall back on their seats, and the mounting remains run in, until com-

munication is re-established by hand, through a vent made in the thickness of the valve-chest, when it runs out again by gravity. The whole of the system comprising the gun, the mounting and its frame, is fitted to a bolster, which rests on the platform, with the interposition of a series of coned rollers. The bolster supports the tube for the passage of ammunition, as well as the movable shell of the turret. A circular casing of armour fitted to the deck, and a space which surrounds the central tube, complete the protective part of the installation. Elevation is given by a crank which gears the pinion that works a toothed sector fitted to the left cheek of the carriage. The mechanism is completed by a set of holding-back toothed wheels, worked by the crank, and which set in motion the small pinion of the elevating mechanism. Lateral training is obtained either by hand or by power, by means of a pinion which engages in the circular rack fixed on the upper deck. This pinion is set in motion either by a set of gearing worked by a pinion keyed on a horizontal shaft which goes through the cheeks of the mounting and carries the working cranks, or by a steam motor which actuates an endless screw with an helicoidal wheel, carrying a regulating device of the type provided for the elevating mechanism. The hoist is made with three compartments; it is guided by rollers which travel inside the central tube, and there are two chains mounted on drums, that are turned by hand or power. In the former case, the drums are operated by means of cranks, plate chains, and gearing; when a motor is used, the transmission consists of an endless screw with helicoidal wheel and gearing keyed on the endless screw-shaft, that work the toothed wheel of the drum. When the top staging is reached, the half-cartridges are removed by hand, the projectile being raised to the height of the breech by a winch fixed to the roof of the inner shell of the turret.

Closed Turret for 270-Millimetre (10.630-In.) Gun. — Turrets of this type (see Fig. 802, on page 243), have been built for various armoured gunboats. They consist of the mounting with its slide, the turret, the training mechanism, and the ammunition hoist. In order to obtain the necessary elevation, the gun is mounted on a carriage which travels on a slide, turning around horizontal trunnions in brackets carried by the movable platform. The carriage is provided with buffers, and is guided in its slides by lateral clamps; the gun is held in the carriage by grooves and pins. The slide consists of beams stayed together, and between them are placed the two recoil cylinders. An intermediate stay, which rests on the piston-rod of the training press, carries the mechanism that regulates the recoil as well as the running out and in of the gun. The hydraulic brake consists of two lateral cylinders bolted to the slide, the piston-rods of which have a constant diameter on their whole length and extend on both sides of the piston. There is in connection with these cylinders an intermediate distribution chest, fitted with a loaded valve, and to which are brought the conduits that are connected with the pipes extending to the front and rear of the recoil cylinders. A regulating rod completes the system, which works as follows: When the gun is fired, it draws back with it the carriage and piston-rods, which are fixed to its rear cross-beam, the liquid flowing to the front end of the cylinder after lifting the valve of the distribution chest. The rapidity in flow of the liquid is governed by the regulating rod, which is controlled by a suitable sliding link placed under the carriage; this maintains a practically uniform pressure in the recoil cylinders during the whole period of recoil. When the recoil ceases, the valve falls on its seat and interrupts all communication between the front and the rear of the cylinders, the gun remaining run in. To run it out ready for firing, the water under pressure is directed to the rear of the pistons, the front part of the cylinders being exhausted.

The carriage and slide rest on the movable platform of the turret, in the centre of which is the opening of the tube for the passage of ammunition. The platform is provided with the drum round which the chains pass that operate the lateral training. To the platform is also attached the armour-plating of the turret, with its roofing, and an armoured hood for protecting the gunner. The central tube is surrounded by a casing that rests on the deck and supports the fixed protective armour. Between the platform and the supporting framework is placed the series of truncated conical rollers, on which the turret revolves under the action of the turning drum and chain.

The hydraulic cylinder for elevating the gun is double-acting. The piston-rod extends on both sides, and is made with spherical joints. The breech end of the gun is raised or lowered, according to whether the lower part of the cylinder is in communication with the inlet or outlet of water under pressure. A bolt, worked by a lever is provided, with the object of fixing the gun in its loading position. For lateral training, two sets of hydraulic gear are arranged horizontally on the lower part of the system. The working chains rise first vertically, pass round transmission pulleys, and then round the drum fixed underneath the platform, and referred to above; they then return to the hydraulic cylinders. The motion is obtained by placing one or other of these cylinders in communication with the accumulator. The valve distribution chest is within easy reach of the gunner. A set of fixed and loose toothed wheels produces more or less rotation one way or the other, or an instantaneous stoppage of the system. A special brake holds the turret fast at the position chosen for firing.

Ammunition is raised from the magazines to the breech by means of an hydraulic hoist, provided with three stagings that can hold a projectile and two half-cartridges. The ammunition tray, mounted on a roller truck, rests on a plate which is raised by means of a telescopic apparatus; it is guided by two shoes, which move in the slides carried by the tube. On reaching the upper end of the travel, the rollers of the truck

SCHNEIDER-CANET NAVAL TURRETS.

Fig.803

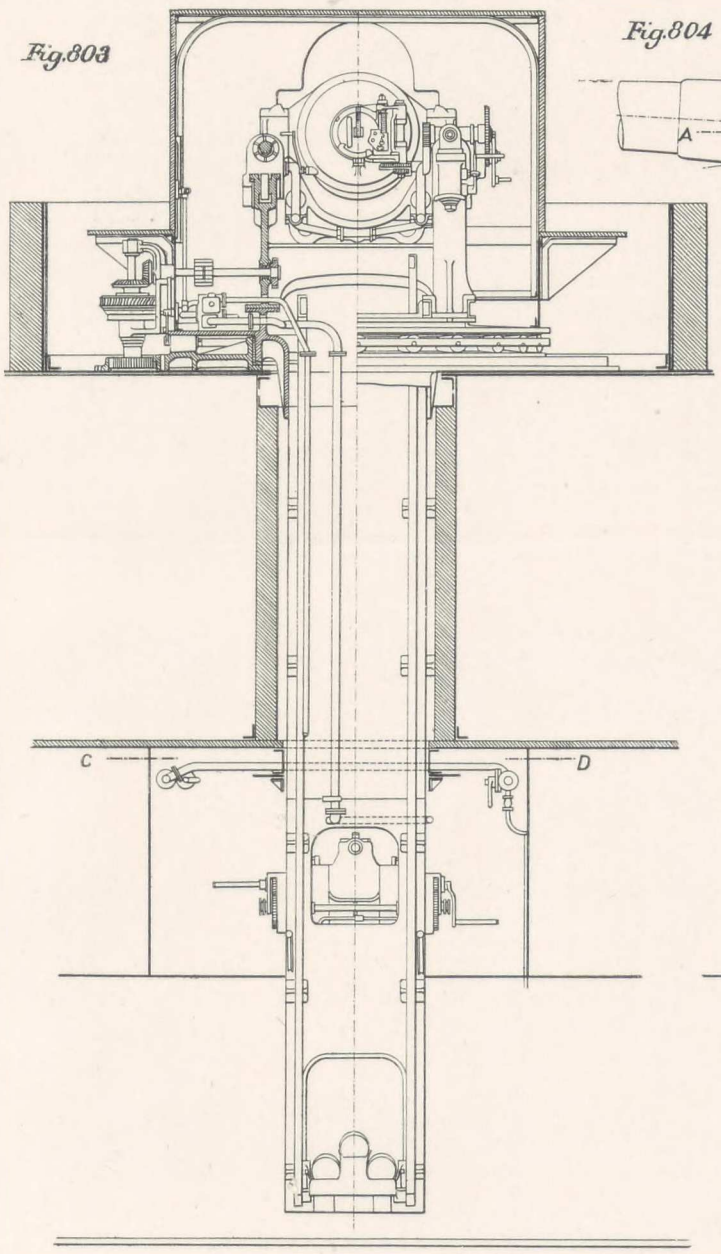


Fig.804

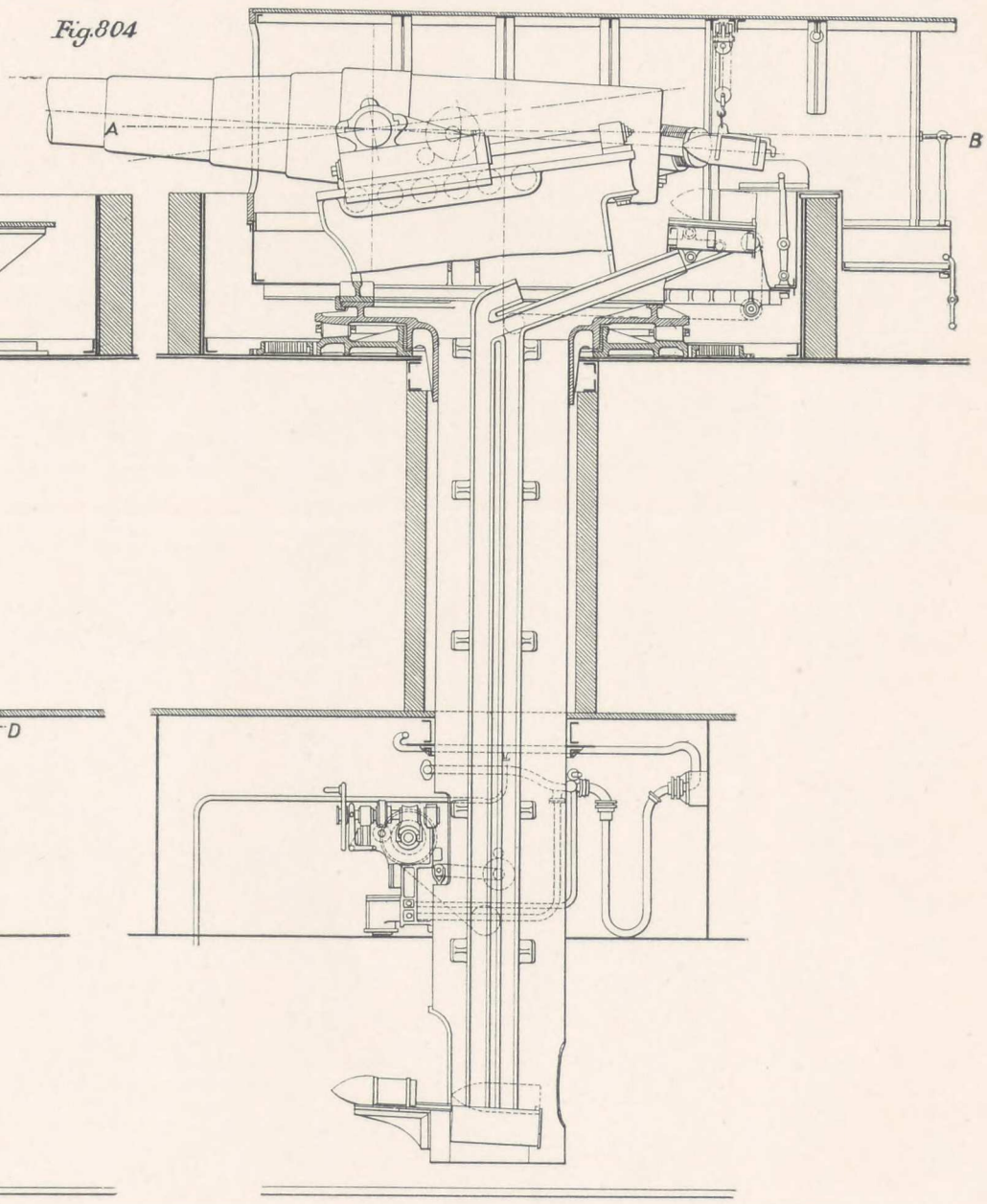


Fig 806
Section C D.

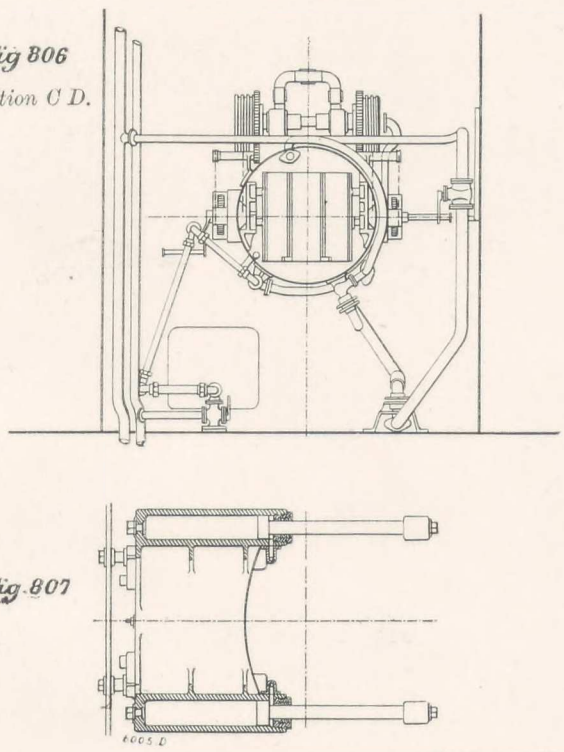
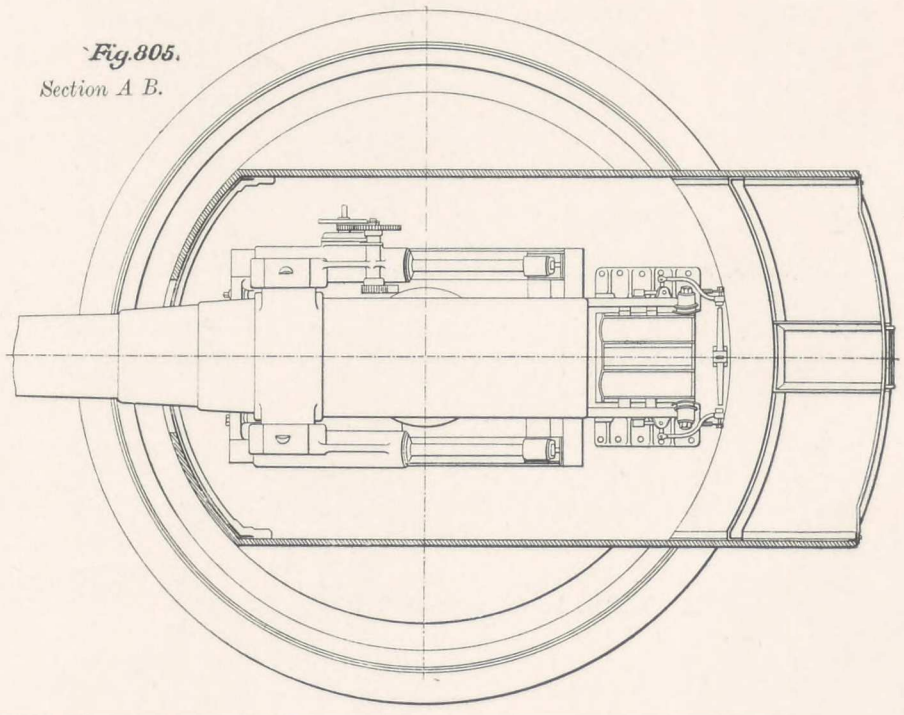
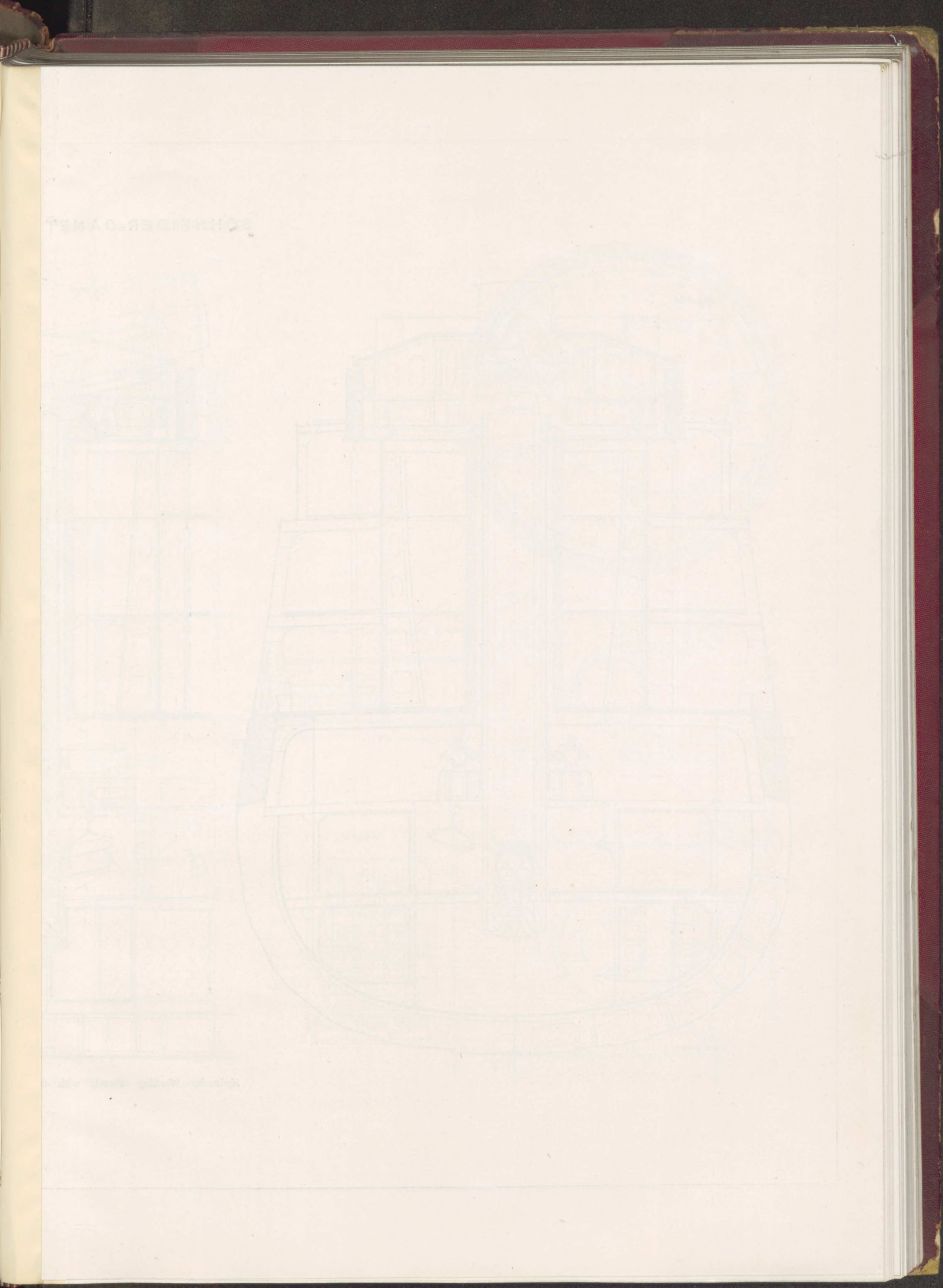


Fig.807

Fig.805.
Section A B.



Barbette Turret and Mounting for 27-Centimetre Gun.



SCHNEIDER-CANET NAVAL TURRETS.

Fig. 808

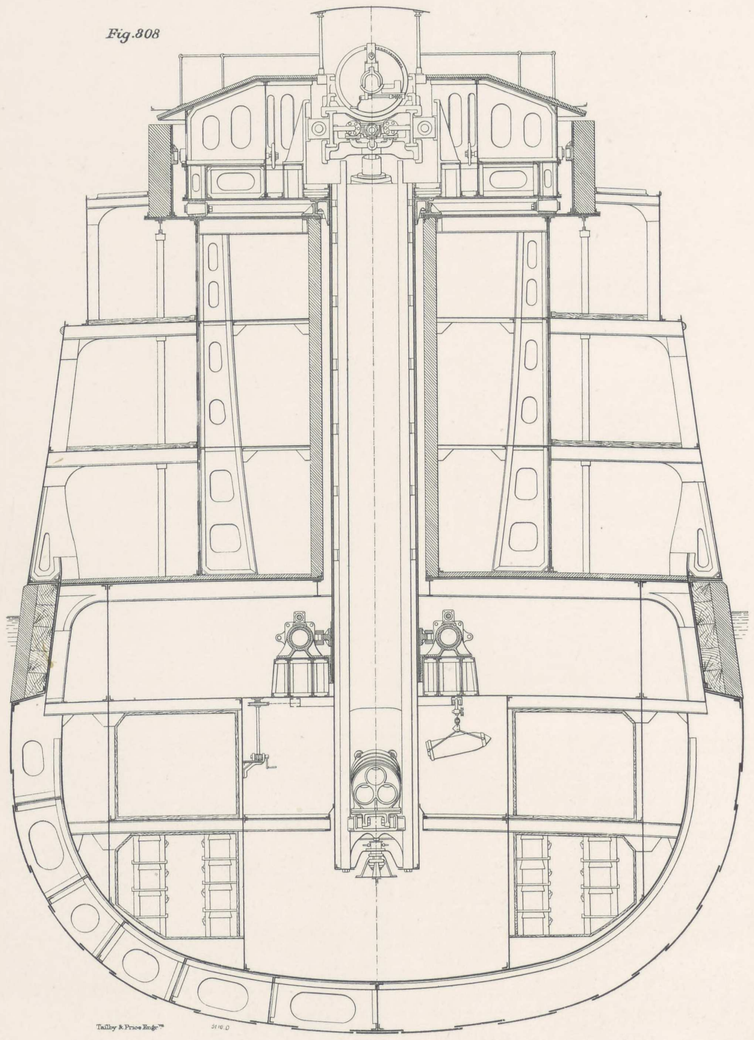
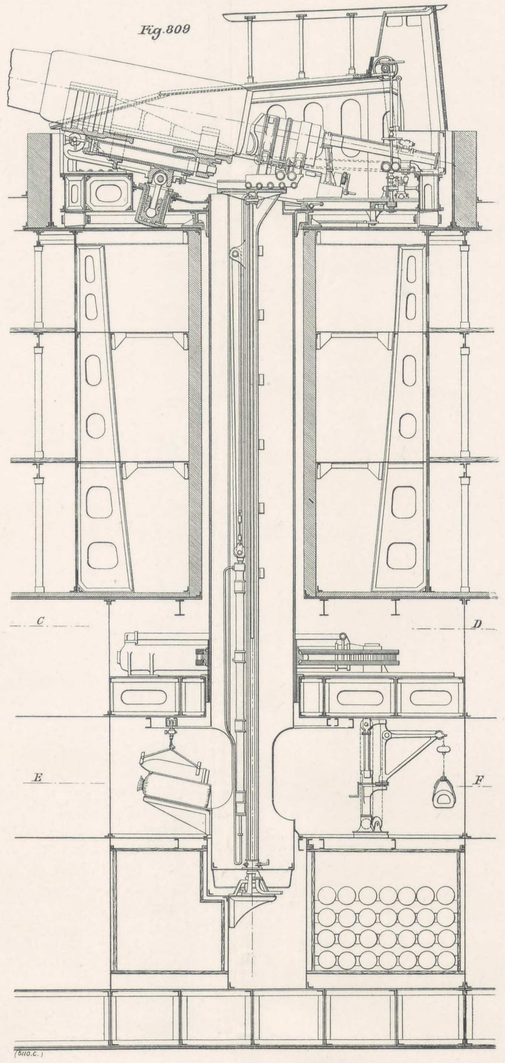


Fig. 809



Hydraulic Working Turret, with Central Tube for 32-Centimetre Gun.

Fig. 810

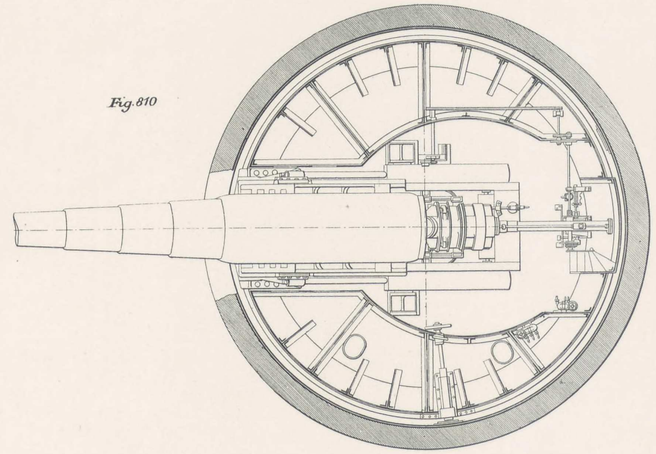


Fig. 811 *Section thro' Hydraulic Brake.*

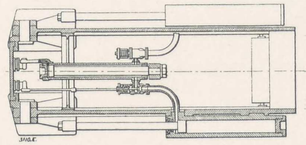


Fig. 812 *Section C. D.*

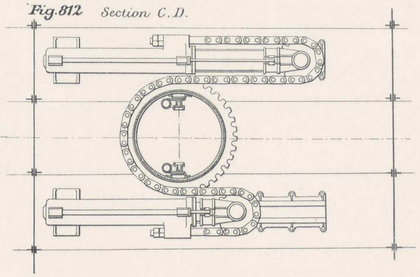
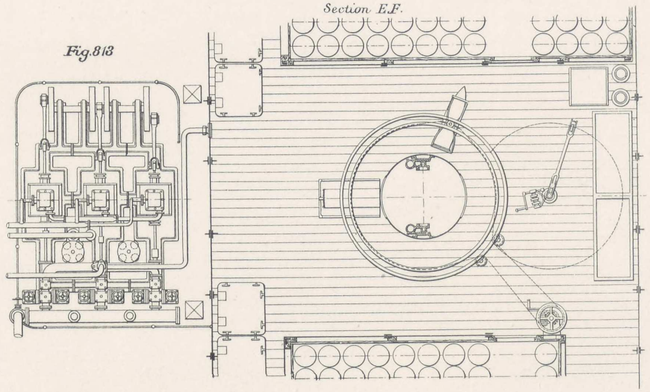


Fig. 813

Section E.F.



BARBETTE TURRET, AMMUNITION HOIST, AND MOUNTING FOR 340-MILLIMETRE (13.386-IN.) GUN.

Fig. 814

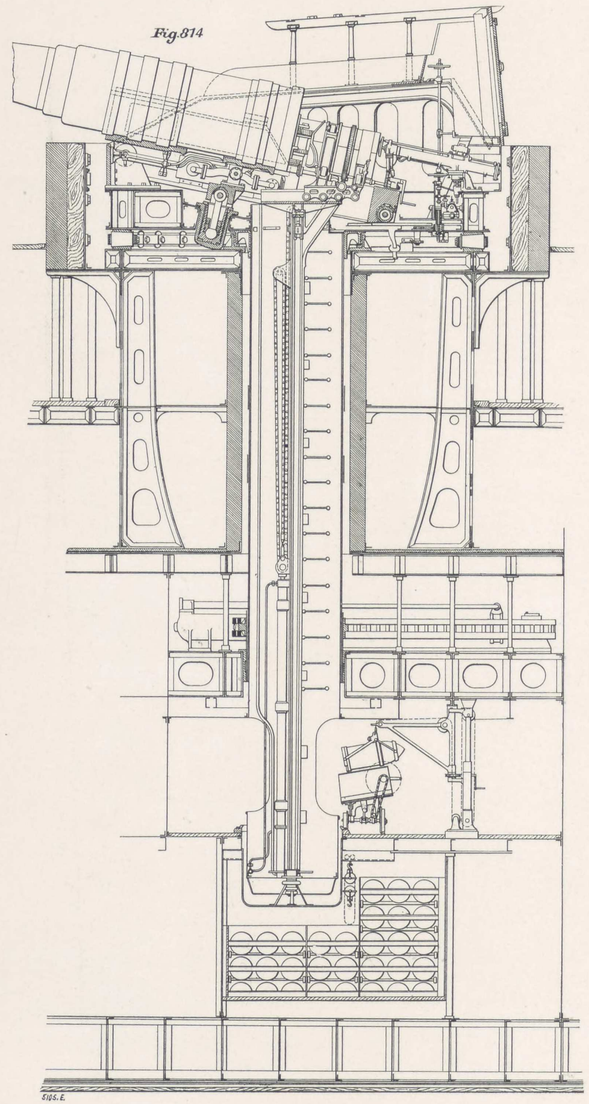


Fig. 815

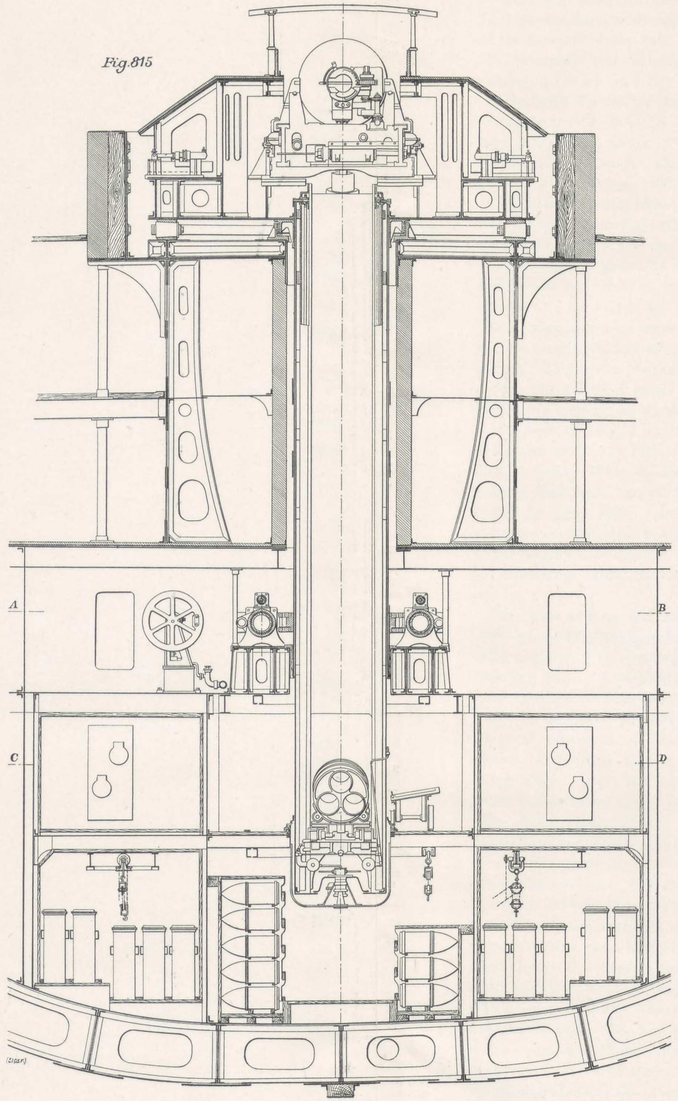


Fig. 816

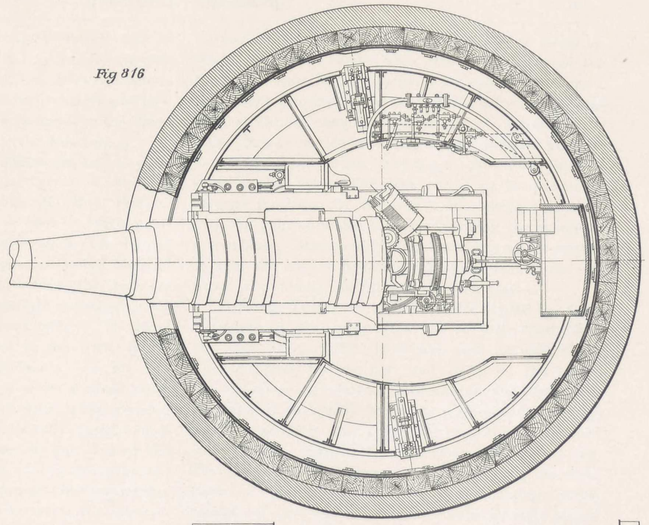


Fig. 817

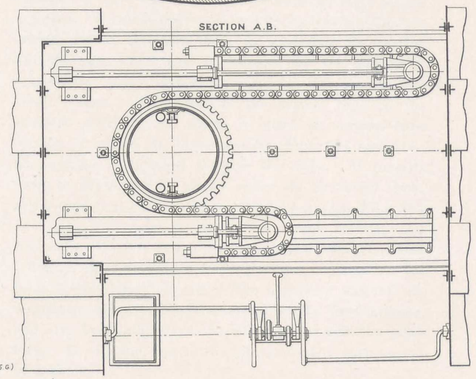
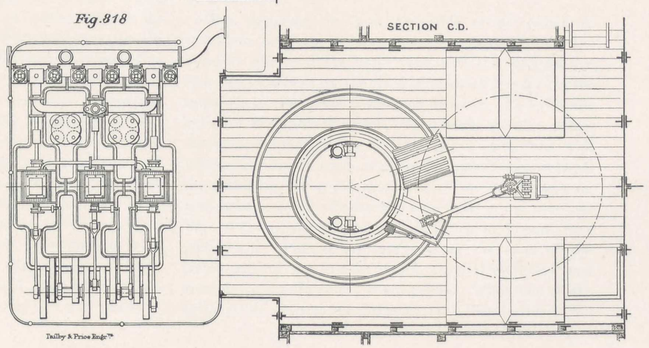


Fig. 818



engage in a part of the slides that are turned over at an angle, and bring the ammunition tray into the required position for loading or unloading. A latch-bolt allows of the apparatus being held fast at both extreme positions. The projectiles and cartridges are brought to the lower staging in a truck, on a line fixed to the deck beams.

Barbette Turret for 32-Centimetre (12.598-In.) Gun (Figs. 808 to 813, Plate CXXXIX.).—Turrets of this type have been built, among other ships, for the "Pelayo," of the Spanish Navy. The gun is held by tongues and grooves in a carriage, which travels on a slide formed of two beams pivoting round horizontal trunnions, attached forward to the floor of the platform; between the beams are the recoil cylinders and the intermediate compensator, the system being completed by clamps and buffers. The recoil piston-rods are fitted to two lugs in the front of the carriage; in the rear is the intermediate piston-rod. The intermediate piston is made with a series of small vents, and the recoil cylinders are provided with reglets of varied section, calculated to maintain a practically constant effort during the period of recoil. When the gun is fired, the carriage in recoiling moves the piston-rods in the cylinders; this causes the liquid to flow through the rectangular vents, and to lift the valves until it reaches the intermediate cylinder. When the recoil is complete, the valves fall back on their seats, and the gun remains run in. To run it out for firing anew, water under pressure is delivered through a special pipe to another cylinder, and the front of the intermediate cylinder is connected with the exhaust. In conducting operations inversely, the gun would be run in.

The gun, carriage, and mounting rest on the movable platform, which consists of two beams joined by a circular built-up girder. The framing of the turret is stiffened by radiating stays. A staging of plates and angles in front, carries the hydraulic cylinder for elevating the gun. The whole of the platform rests, with the interposition of a series of rollers, on a ring bolted to the deck. The central ammunition tube is provided at the top with a ring, which insures the accurate guiding of the system. Below the armoured deck is fixed a lateral training circular piece, which surmounts the guiding socket fixed to the frame that carries the hydraulic cylinders. Inside the tube are the guides, hydraulic cylinders, and gear for the working of the hoist. The gun is elevated by means of an hydraulic cylinder, the piston-rod of which, acting on the underside of the carriage, causes the latter to oscillate round its trunnions. Lateral training is obtained by connected hydraulic cylinders, placed underneath the armoured deck; the piston-heads of these carry each a pulley round which passes a plate-chain that surrounds the rack fixed to the tube. The two ends of the chain being fixed to the hydraulic cylinders, it is sufficient, in order to train the gun, to put one of these cylinders in connection with the accumulator and the other with the exhaust. The distribution valves are worked by a small hand-wheel within easy reach of the gunner. For loading, the gun has to be elevated to its maximum angle. Ammunition is raised by means of a drum carrier with three compartments; the working is controlled by the hydraulic cylinders and gear a hydraulic automatic brake controls the delivery from the hoist at the top staging. The carrier is mounted on a roller truck, which by travelling in the slides is brought to the rear of the breech; it is free to turn round its axle, so as to place successively each one of its compartments opposite the bore. To the rear is the telescope rammer, with the help of which each part forming the charge is driven home. Manœuvres on the lower staging are carried on with the help of hydraulic cranes and tackle, made to travel on a circular line fitted to the deck-beams.

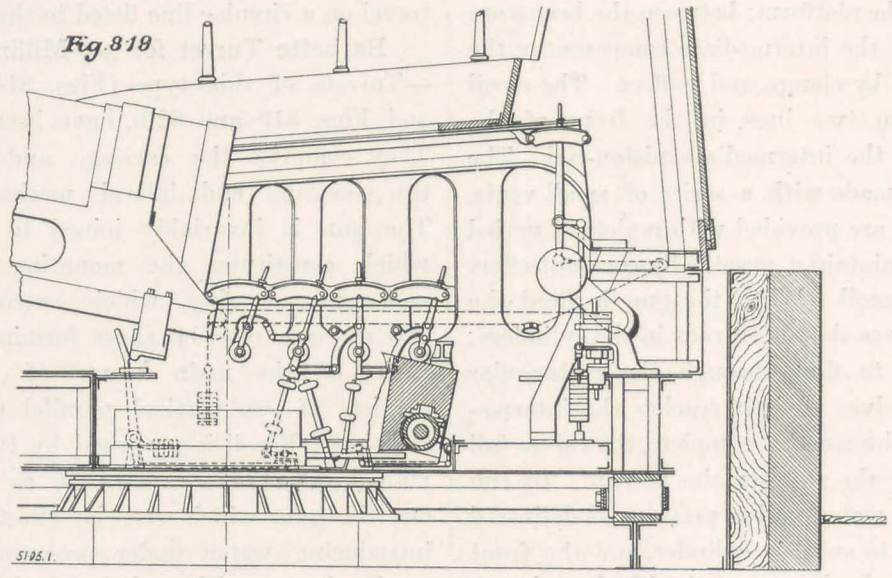
Barbette Turret for 340-Millimetre (13.386-In.) Gun.—Turrets of this type (Figs. 814 to 818, Plate CXL., and Figs. 819 and 820), have been built for battleships. They comprise the carriage and its slide, the turret, the elevating and lateral mechanisms and the hoist. The gun is invariably joined to the movable carriage which constitutes the mounting proper, by a tongued and grooved ring which surrounds the breech-end. The carriage rests on shoes forming clamps on the slide-paths of the main beams of the mounting, which consists of two vertical parallel cheeks strongly stayed together. Recoil is governed by two hydraulic cylinders, which act at the same time as controllers in running out the gun, which can be effected at all angles by introducing water under pressure to the rear of the recoil pistons. The whole of the system rests on the movable platform, to which is fitted a vertical tube formed of plates, as illustrated by Figs. 814 and 815; ammunition is supplied through this tube. It extends down to the magazines placed under the armoured deck, and is guided at both ends; as will be seen from Figs. 815 and 818, it is used to rotate the turret, through the hydraulic cylinders and chain on a lower deck. The distribution chest for water under pressure is placed at the level of the lower staging. The mounting and all its mechanism are completely protected by the fixed armour, and also by a light structure which turns with the platform. In the the rear is the gunner's stage, surmounted by a shield.

For elevating the gun, the slide pivots round its trunnions in front, the trunnion plates being fixed to the movable platform; the latter rests, with the interposition of a ring of rollers, on the fixed circular path bolted to the upper deck. Elevation is obtained by means of a hydraulic cylinder, the piston of which, placed under the slide, causes the whole of the mounting to rise or fall; a valve-chest, with a lever within easy reach of the gunner, is suitably arranged for obtaining the required actions. The lateral training mechanism consists of a toothed ring fixed on the tube (see Fig. 817), and surrounded on half its circumference by a plate-chain. Pulleys are mounted on the ends of the piston-rods of the two hydraulic parallel cylinders, and around these pulleys the chain passes. When one of the cylinders is open to the pressure, the other is free to the

exhaust; so that when one ram is protruded, the other is withdrawn to an equal amount. Lateral training, therefore, is obtained by putting one or the other of the two cylinders in connection with the accumulator, according to the direction of rotation required. The valves are worked by a handwheel controlled by the gunner; a special mechanism operated by the same handwheel causes a continuous revolution, more or less rapid, one way or the other; the rotating movement stops when the handwheel is released.

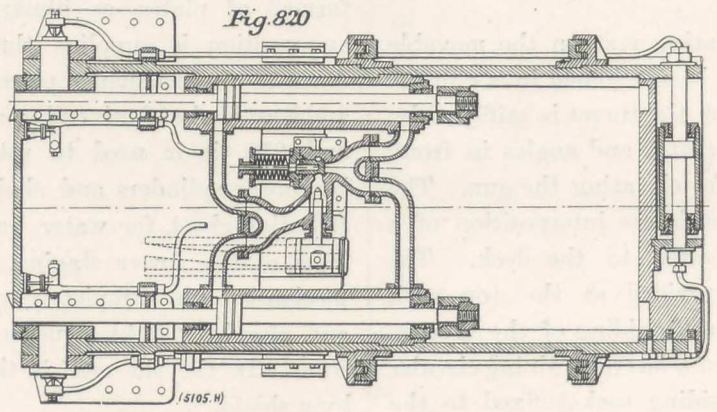
For loading, the gun is elevated to its highest angle. In this position its centre line corresponds to that of a hydraulic rammer, with a telescopic ram carried on the turret platform; this rammer serves to drive home the projectile and the two half-cartridges. The charge-holder is of the same form as that already described; it has three tubes mounted on an axle, placed, when in position for loading, at the same angle as the gun; a partial rotation through 120 deg. brings the projectile and the two half-cartridges successively opposite the breech; an automatic latch-bolt fixes the barrel in the required positions. The charge-holder is worked by two hydraulic pistons, the cylinders of which are placed vertically in the tube, near the guiding slides. The two plate-chains are fixed at one end to the head of the piston-rods, and at the other to the plate which supports the charge-holder. The plate is also guided by two slide shoes, which travel in the slides fitted to the tube. The charge-holder is mounted on a truck, which renders it movable in its support, and which is fitted with two rollers that travel in vertical slides; these are made to branch off at their top part. This arrangement forces the truck to travel first vertically, and when it nears the breech, to slide back, so as to take up a suitable position for the loading of the gun. At the lower staging, the operations follow each other thus: Cranes raise the projectiles and half-cartridges to the height of the lower deck, from where they are taken by a set of tackle that travels on a circular line, made concentric with the ammunition tube. The tackle discharges in a cradle fitted to the lower part of the tube; the charges have then only to be slid in their compartments in the barrel. The gun can be loaded, whatever be the position of the firing platform.

Fig. 819



Platform with Starting and Controlling Mechanism.

Fig. 820



Hydraulic Brake for 340-Millimetre Gun.

3. SHIP TURRETS WORKED BY ELECTRICITY AND BY HAND POWER, WITH CENTRAL AMMUNITION TUBE.

The Schneider-Canet system of electric turrets has been largely supplied for various ships; they are now generally preferred to hydraulic turrets.

The increasing importance given to the application of electrical energy on board modern ships, was a sure sign that this comparatively new source of power would find its place in the working of turrets. It was first applied in various forms in the Schneider-Canet system of ordnance, for working hoists, for the elevation and lateral training of guns, opening out of the breech, firing the guns, night sights, &c. The marked preference given to the new system is, moreover, fully justified, for the working of such installations by means of a liquid under pressure is an incomplete and not a satisfactory solution of the difficulties encountered, notwithstanding the degree of perfection to which the hydraulic system has been carried after many years of experimenting with progressive designs. The main difficulties with the hydraulic system lie in the defects of principle that surround the applying of a hydraulic motor for this special use; among the most serious may be mentioned:

1. The system involves the use of a large number of pipes, the rapid repair of which is often impossible.

2. The influence which great variations in temperature may have on the general working of the system.

Fig. 821

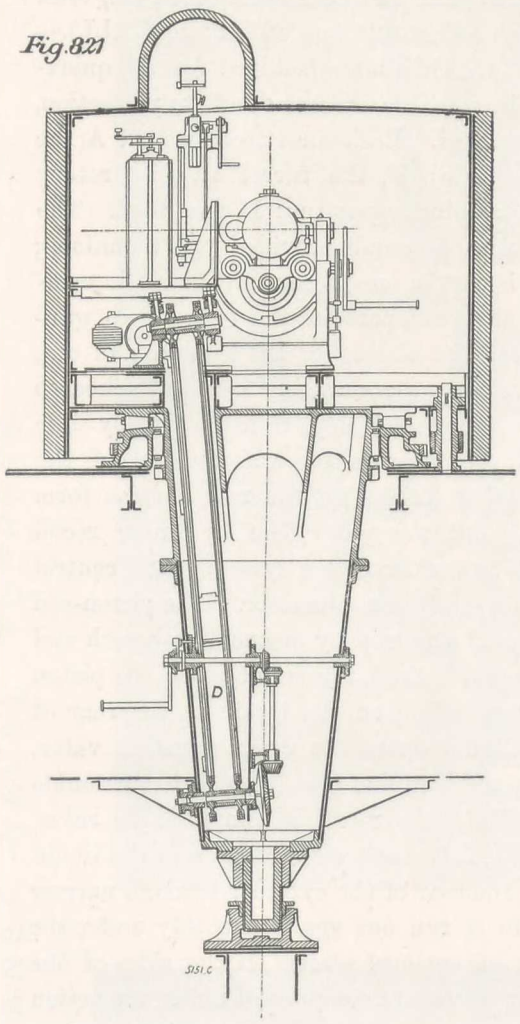


Fig. 822

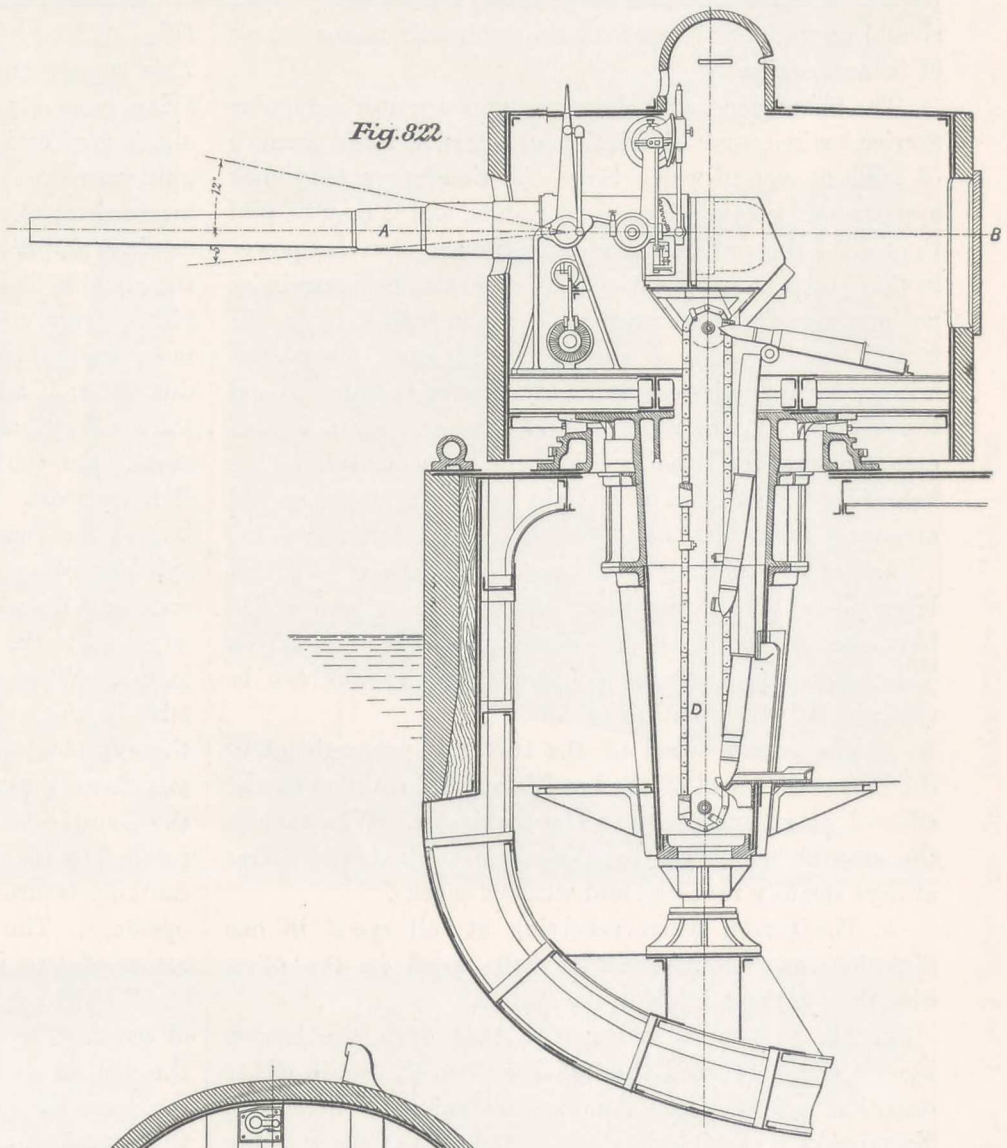
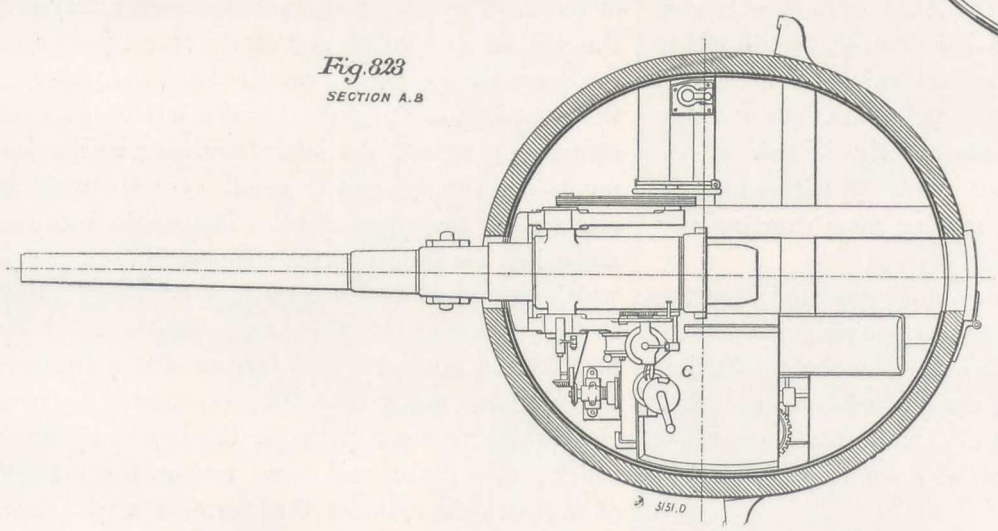


Fig. 823
SECTION A.B



Electrically-Worked Turret for Two 12-Centimetre Guns.

3. The difficulty of training the gun accurately and rapidly, with a *personnel* that has not been previously fully trained to the work.

4. The practical impossibility of arranging the various parts in a suitable manner for working the turret by hand, should an accident happen to the hydraulic motor or any of its accessories.

The Schneider-Canet electric turrets are now in regular service, or in course of erection, on board a large number of modern men-of-war. Since the time when they first appeared they have given good results, and it may be said they solve the problem of electric transmission and power in this particular application. The general characteristics we have already enumerated are common both to hydraulic turrets and to those of similar design, worked by electricity, for in both designs the system is balanced round the vertical axis of rotation, and both embody a central arrangement for loading the gun; in addition, the Schneider-Canet type of electric turrets contains special arrangements, which may be summed up as follows:

1. Lateral training is insured by means of a hand-lever placed within easy reach of the gunner, and which he moves in the direction he wishes to give the turret. This manœuvre is of the simplest character, and can be carried out by any untrained hand.

2. The rotary speed of the turret is proportional to the extent of travel of the hand-lever, and training can be effected at all speeds up to the maximum. Whatever be the rate at which the hand-lever is worked, the turret always steadily revolves, and without shocks.

3. The turret, when revolving at full speed in one direction, can be reversed at full speed in the other direction, without injuring the system.

4. The system is so sensitive that even the largest turrets can be turned through less than $\frac{1}{20}$ deg. in either direction, and to effect this no special training is necessary. No mistake is possible in the manipulation of the working devices, and the gun can always be exactly sighted.

5. The turret can be stopped suddenly, without shock, and without the weight of the moving mass exerting any local injurious strain.

6. If, through mistake, the gunner does not stop the turret before the extreme limit for training is reached, that is to say, before it strikes against the mechanical buffers, the system comes in contact with an electrical switch that stops it automatically, while the connections return to zero under the action of a counteracting spiral spring.

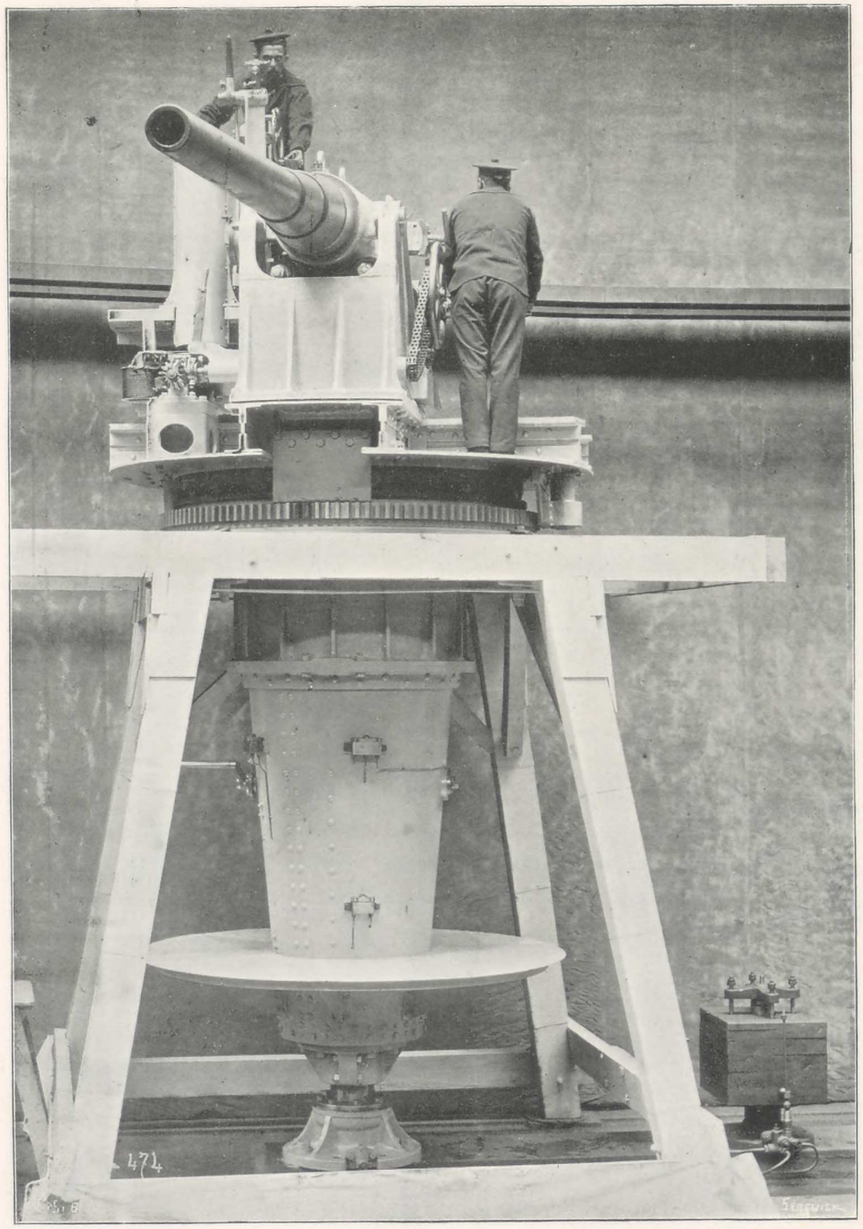
7. The working apparatus proper, placed in the turret, takes up but little room, thus giving more space for the *personnel*; all the inside connections being prepared separately, the apparatus is easily put in place, and should it get injured in any way, it can be replaced by a duplicate, making the connections taking but little time.

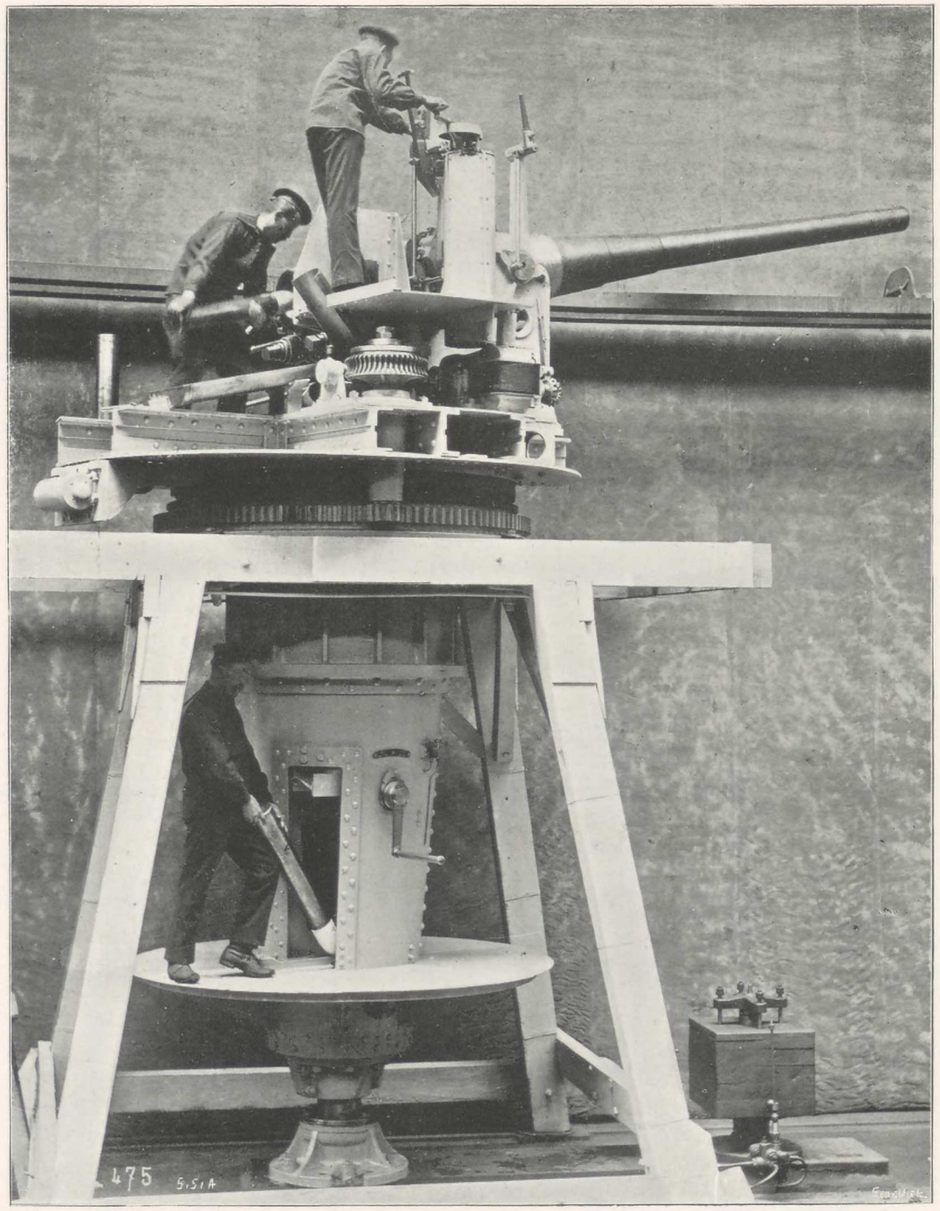
8. All the Schneider-Canet electric turrets are so arranged that, if for any reason the electric motor is not used for the various operations, the training and the elevating of the gun, and the hoisting of the ammunition, can be performed by hand-worked direct-acting cranks.

We will now describe a few types of turrets, making a selection among those for guns of the usual calibres.

Closed Turret for One 12-Centimetre (4.724-In.) Gun (Figs. 821 to 823, and Figs. 824 and 825, Plate CXLI.).—This type of turret, which is manufactured for all quick-firing guns of medium calibre, insures complete protection, and is very easily worked. Each turret consists of: A, the gun, carriage, and slide; B, the turret and its rotary mechanism; C, the training apparatus; D, the hoist. The carriage proper consists of a cradle provided with trunnions; the recoil cylinder is cast in one piece with it, and it completely surrounds the rear part of the gun. Two gun-metal rings facilitate the sliding of the gun in and out, during recoil and return; the elevating arc is attached to the recoil cylinder. The gun is kept from turning by slide shoes. On the left trunnion is screwed the rod of the sight support. Leather linings on the rear surface form buffers for running out the gun. The hydraulic recoil cylinder is on the Schneider-Canet system, with central counter-rod and independent recuperator. The piston-rod is joined to the rear of the gun by means of a breech-end jacket. When the gun is fired, the recoil draws the piston with it, the pressure acting on the liquid in the rear of the cylinder; the liquid opens the communication valve, and flows through the annular opening which surrounds the counter-rod. When the recoil is complete, the valve, pressed by its spring, falls back on its seat, and the liquid can only return to the rear of the cylinder through narrow openings. The gun is run out again smoothly under the action of two sets of springs, placed on the sides of the recoil cylinder, and which are compressed under the action of recoil. The slide consists of two cheeks, stayed together, the soleplates of which rest on the turret platform; at the top parts of the cheeks are the trunnion plates, in which the trunnions are placed. On the left cheek is fixed the elevating gear and the lateral training mechanism. The pump for supplying the recoil cylinder with liquid is attached to the right cheek. The whole, comprising the mounting, the slide, and the armour, rests on the platform, which consists of plates carried on two longitudinal beams strongly braced; the platform is continued at the lower part by the central socket formed like a truncated cone, the platform and socket being connected by a cast-steel ring, which forms a path for the horizontal and vertical rollers. The socket and turret rest on the plunger piston of a hydraulic cylinder that forms a step bearing; the hydraulic cylinder is fixed to the bottom frames of the ship, and is connected with an accumulator fed by a pump. This arrangement allows the movable part to be raised, in order to free the horizontal rollers and inspect and repair the various parts on which the system rotates.

The device for elevating the gun is placed within easy reach of the gunner, and consists of a handwheel on a shaft, upon which are keyed two pinions that transmit motion through an endless screw, and a set of gearing to



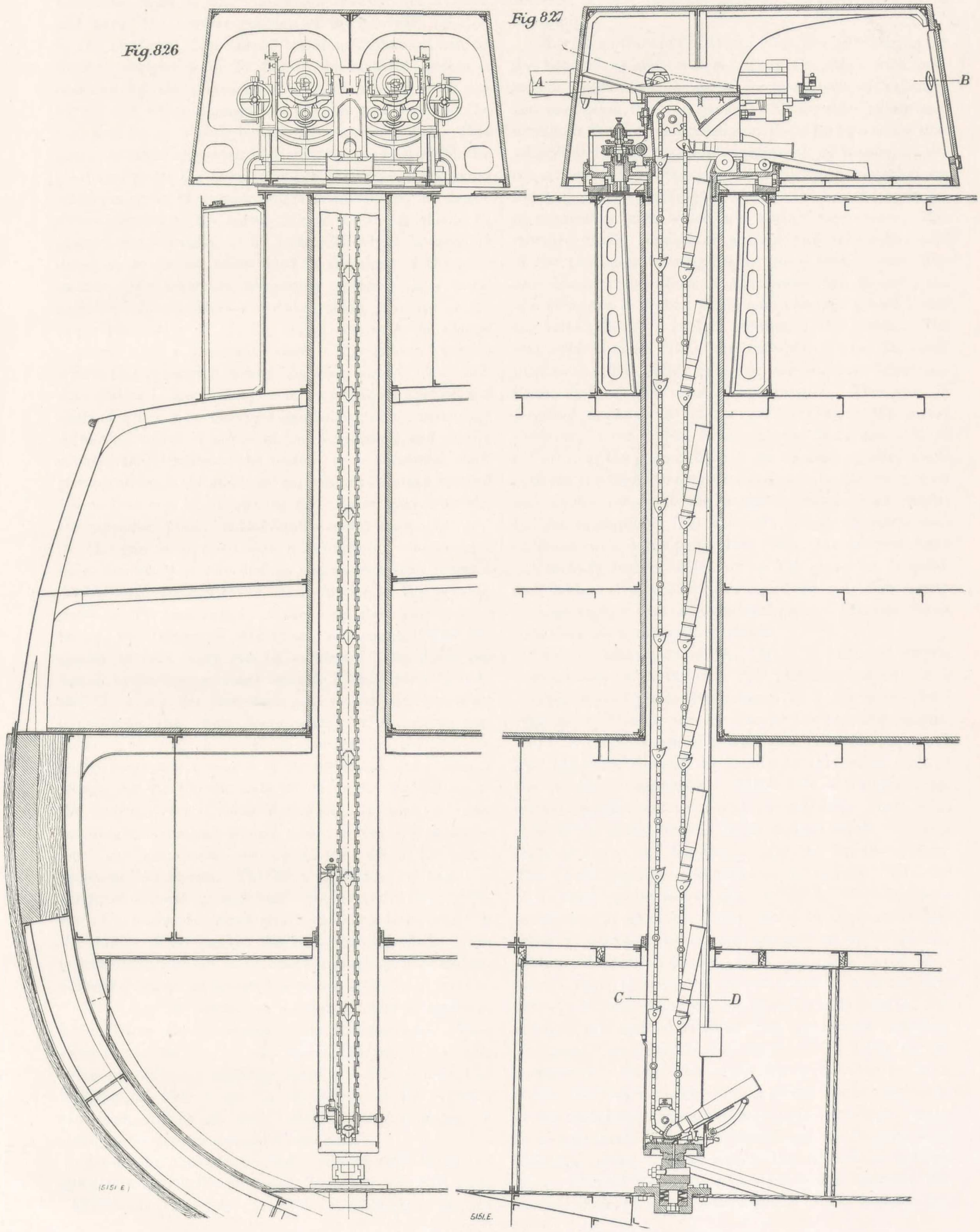


Figs. 824 and 825. Closed Turret for One 12-Centimetre (4.724-in.) Gun.

SCHNEIDER-CANET NAVAL TURRETS.

Fig. 826

Fig 827



Electrically-Worked Turret for Two 12-Centimetre Guns.

the elevating arc fixed to the gun. An index fitted to the horizontal shaft of this mechanism travels over a scale, and marks the angular position of the gun with relation to the platform. The lateral training mechanism can be worked electrically or by hand; the required motion is obtained by the rotation of a pinion moving with the turret, and which engages the circular rack fixed to the ring that forms a path for the two sets of rollers. This pinion is keyed on a vertical shaft that passes through the platform, above the level of which it carries a helicoidal wheel; a series of friction rings is introduced to absorb the momentum of the turret, in case the motor should be stopped too abruptly. The helicoidal wheel is actuated direct by an endless screw fixed to the shaft of the same motor. The latter is completely enclosed in a metal cylinder. It comprises a working shaft, provided at the upper part with a handle, which the man in charge displaces over a graduated scale. The general way in which this apparatus works has been already described. The system is operated by hand by acting on a wheel, the shaft of which is on the right-hand cheek of the mounting. A toothed wheel is keyed on the handwheel, and carries a chain that transmits the motion to a horizontal shaft passing through the slide, and carrying at its end a toothed wheel that can be thrown in and out of gear with the corresponding pinion on the electric motor shaft.

The gun is supplied with ammunition by means of a hoist consisting of two endless chains that turn round a double-toothed wheel below, set in motion by the working parts of the mechanism; at the top they pass over a pulley, the frames of which are so arranged that the tension of each chain can be regulated. The chains are united by bucket-cup rings movable round horizontal rods, and in which the cartridges are placed, the projectile downwards, the point being placed in a smaller cup. When a cartridge is placed in this position, the first cup partly surrounds the head of the projectile, and draws it along. At the top the slide which guides the bottom of the cartridge-case is rounded, and slightly enlarged before reaching the inclined trough that receives the cartridge when the latter turns over round the axis of the corresponding bucket-cup. The hoist is worked by hand, by means of a crank placed inside the central socket, at the end of a horizontal shaft which carries a bevel wheel in the middle of its length; the rotary motion of the latter is transmitted to the wheel shaft through an intermediate vertical shaft, on which are keyed two other bevel wheels.

The sight and scale are carried in jointed supports, which follow the mounting in its displacements. They extend over the roof of the turret, the top of the scale being opposite the sighting opening. The gunner has, therefore, a wide range for executing all the sighting operations, and he can even follow a movable target. A sliding door closes the turret in the rear.

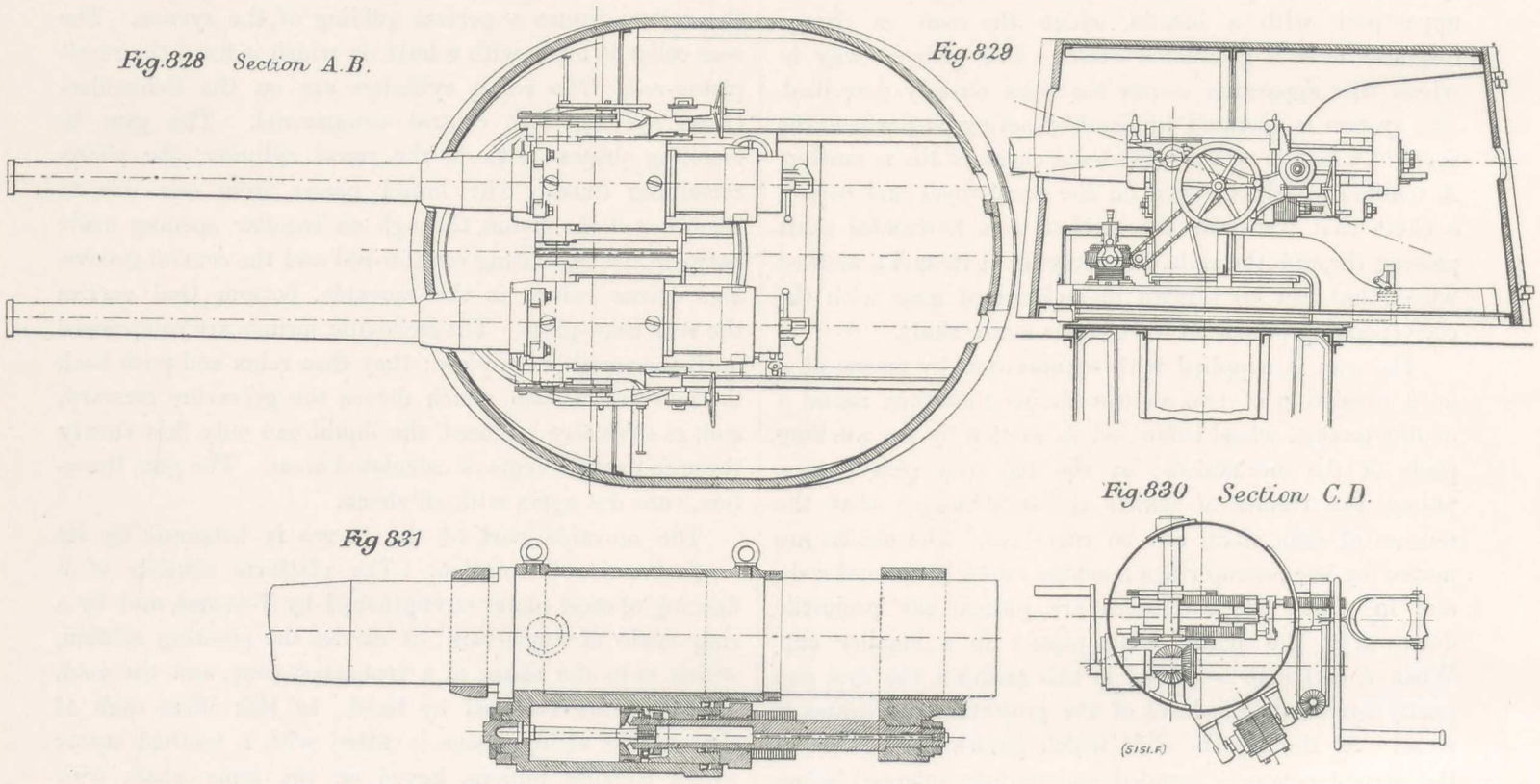
Closed-In Turret for Two 12-Centimetre (4.724-In.) 45-Calibre Quick-Firing Guns (Figs. 826 and 827, Plate CXLII., and Figs. 828 to 831).—A description of this type is of special interest, and the turret we shall here describe is one forming part of the armament of a battleship.

The 12-centimetre (4.724-in.) guns are quick-firing, of the Schneider-Canet system. They are fitted with one-motion breech-blocks, arranged for firing both with electric and percussion fuse. A jacket, with shoulder extensions, surrounds the gun, and carries on the sides two slides that support and guide the gun during recoil by bearing on the top surface of the string-beams. In front of the jacket are the buffers, and underneath is placed the recoil cylinder, in connection with which is a spring recuperator. The movable cradle consists of a front and rear collar, and of the two lateral string-beams which unite them. The gun during recoil slides in the frame thus formed; the trunnions are in front. Gun-metal bearings, placed inside the collars, insure a perfect guiding of the system. The rear collar is made with a butt, on which is fixed the recoil piston-rod. The recoil cylinders are on the Schneider-Canet system, with central counter-rod. The gun in recoiling draws with it the recoil cylinder, the piston remaining fixed. The liquid passes from one side to the other of the piston, through an annular opening made between the regulating counter-rod and the central groove, and drives before it the movable bottom that carries the rear cross-piece. The Belleville springs are compressed until the recoil is complete; they then relax and push back the movable bottom, which drives the glycerine forward, and, as the valve is closed, the liquid can only flow slowly through narrow vents of calculated areas. The gun, therefore, runs out again without shock.

The movable part of the turret is balanced on its vertical axis of rotation. The platform consists of a flooring of steel plates strengthened by T-beams, and by a ring made of angle-bars; it carries the pivoting column, which is in the shape of a truncated cone, and the roof. The guns are elevated by hand; to this effect each of the outside string-beams is fitted with a toothed sector which engages pinions keyed on the same shaft with a helicoidal wheel worked by an endless screw. On this shaft is keyed the handwheel operated by the gunner. The lateral training mechanism is worked by electricity or by hand; in the former case the motor, which is placed in the front part of the turret, drives, through an endless screw, a helicoidal wheel, that operates an inside gearing with a differential motion. This gearing is keyed on a vertical shaft, at the lower end of which is a pinion that gears with two other pinions placed symmetrically, and engages the toothed circular rack for lateral training. The gunner regulates the training at will by acting on the commutator. In the device for lateral training by hand power, the men work two cranks placed one on each side of the mountings; these transmit power through a chain to a shaft fitted with an endless screw, which gears in a helicoidal wheel that surrounds the differential gearing above referred to. The helicoidal wheel operates the vertical shaft provided with a pinion which engages the

circular rack for lateral training. The two mechanisms are absolutely independent one from the other.

Ammunition is raised to the top platform by means of a hoist placed in the central tube. The hoist consists of two endless chains, between which are held the buckets which contain the cartridges. During the raising motion the cartridges are guided by gun-metal slides, placed on the whole height of the tube; the chains are, moreover, provided with cross-pieces placed at the height of the cartridge-cases. The chains in descending are also guided in a brass tube; the buckets are thus kept in position, and remain always suitably placed for receiving the cartridges to be raised. The automatic feed of the hoist is insured by a device worked by the chains, and on which the men deposit the cartridges. For working the device, the a roller suitably placed for this purpose; it then pivots round the bucket trunnions until it slides by gravity in the trough prepared to receive it. As soon as the cartridge has left the bucket, the bottom end of the latter strikes against a fixed butt which places it straight again, ready to follow the guide that surrounds the descending chain. The electric motor for working the hoist is joined to the central tube below the armoured deck. It works a shaft through an endless screw and a helicoidal wheel that surrounds a set of differential gearing; this drives a shaft arranged to work another spindle placed at the lower end of the tube, and on which are keyed the pinions that drive the hoist. For operating the hoist by hand power, it suffices to turn the central shaft by two cranks, the gearing above referred to transmitting the motion.



Schneider-Canet Electrically-Worked Turret for Two 12-Centimetre Guns.

chains are provided with suitable catches, which act on a horizontal rack that sets in motion a pinion keyed on the shaft of the hauling-in arm; the latter consists of a forked-shaped lever, which receives the cartridges in such a way that the bottom of the cartridge-case rests first on a small roller placed between the branches of the fork, the point of the projectile bearing against a catch at the opposite end; this catch disappears when the fork-shaped lever is raised, and the cartridge takes a vertical position; it then slides down, and rests in the bucket which is ready to receive it. The hauling-in device holds the cartridge until the bottom of the cartridge-case enters the guiding tube; it then falls back to its original position, to take up a fresh charge. When it has reached the top part of the tube, the cartridge is inclined while it passes through the opening provided between the mountings, by bearing on

Closed-In Turret for One 15-Centimetre (5.91-In.) Gun (Figs. 832 to 837, Plate CXLIII., and Figs. 838 and 839).—In the turrets of this type, the gun is mounted on a carriage consisting of two beams, at the front end of which the trunnions are placed. These beams are joined in the rear by a jacket in which the gun slides during recoil and return. The recoil cylinder, placed on the axis of the gun, is cast in one piece with the jacket. The piston-rod is keyed on the breech end coil, the lateral surfaces of which form slides during the travel of the gun. The slide consists of two wrought-steel cheeks, strengthened by flanges and stayed together. The recoil cylinder is on the Schneider-Canet system, with central counter-rod; two sets of springs placed on the sides insure by reaction the running out of the gun. The general arrangements for working are similar to those described in a previous

SCHNEIDER-CANET NAVAL TURRETS.

Fig.832

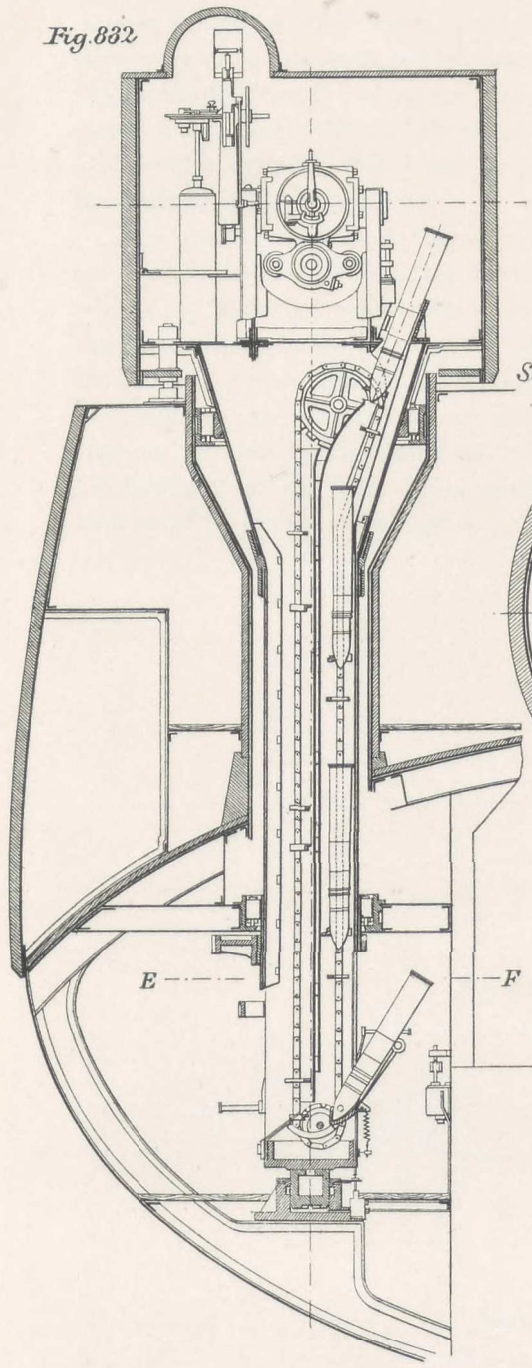


Fig.833.

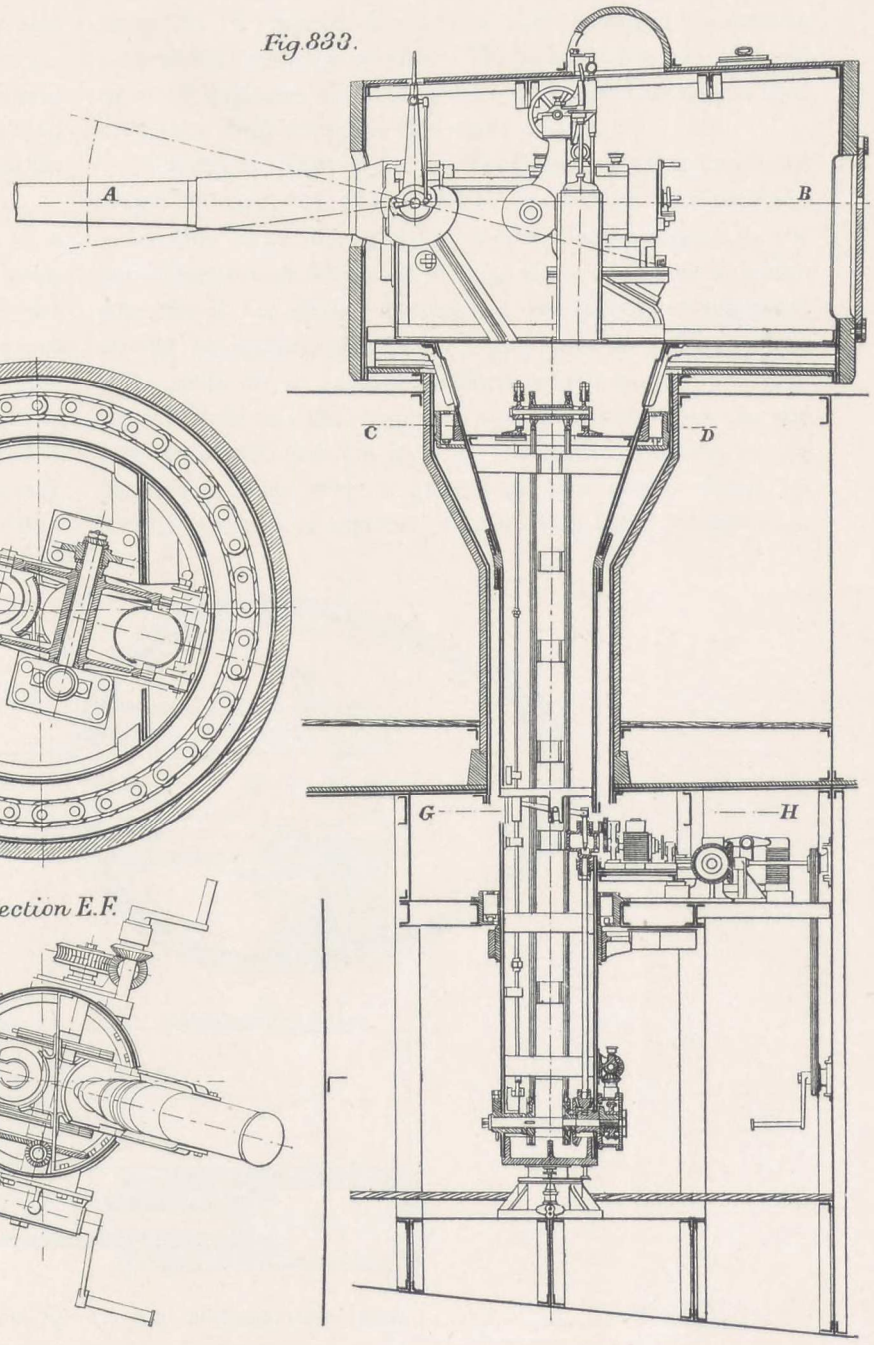


Fig.835
Section C.D

Fig.836 Section E.F.

Fig.837 Plan G.H.

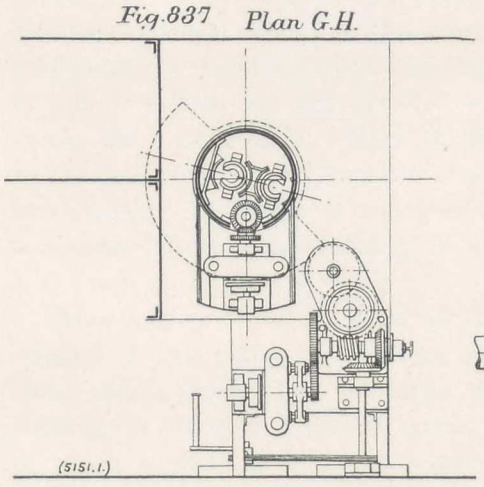
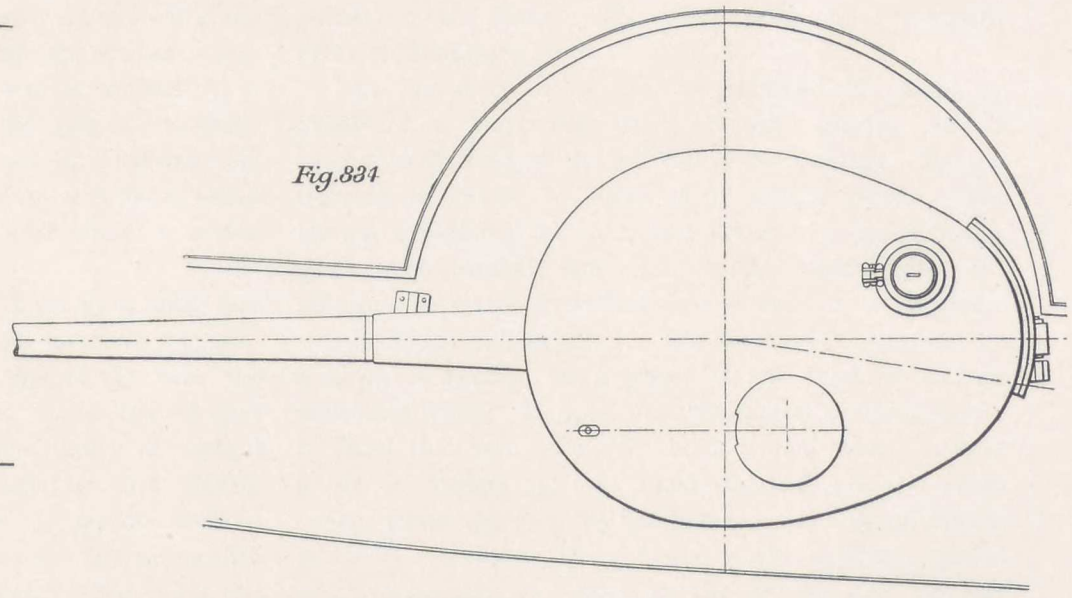


Fig.834



Schneider-Canet Turret for 15-Centimetre Gun.

section for the 12-centimetre guns. The mounting and slide rest on a platform, which also carries the armour. Under the platform is bolted the ring, to which the central socket is attached. The whole of the turret is carried on a hydraulic cylinder, that forms a pivot, and is fixed to the bottom frames of the ship.

The gun is elevated by hand power, by means of a crank and a pinion ; the latter works, through two bevel wheels, a helicoidal wheel, and an endless screw the shaft, on which is keyed a square pinion which engages the toothed sector fixed to the carriage. A jointed sight-line follows the gun in all its displacements. Lateral training is obtained by hand or by electric power, the displacement of the gun being produced by the rotary motion of a pinion which gears in a toothed ring fitted

therefore be stopped during the time required for taking a cartridge from the carrier. The hoist is worked by hand or electric power through pinion and bevel wheels, which drive the shaft carrying the chain wheels.

Closed-In Turret for 20-Centimetre (7.874-In.) Gun (Figs. 840 and 841, Plate CXLIV., and Figs. 842 to 845). —In this type the gun is mounted on a carriage, the arrangements of which, as well as those of the slide which supports it, are similar to those of the corresponding parts of the 15-centimetre (5.91-in.) gun just described. The slide rests on a turning platform which carries the protective armour ; the top part of the central tube for the passage of ammunition ends on the right-hand side of the platform. The tube is guided at two points along its height by rings of vertical rollers. It is fitted outside with

Fig.838. Section A.B.

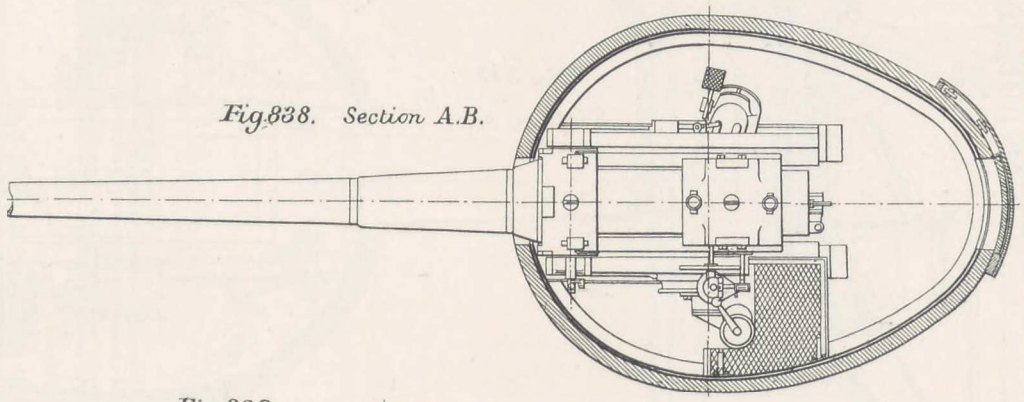
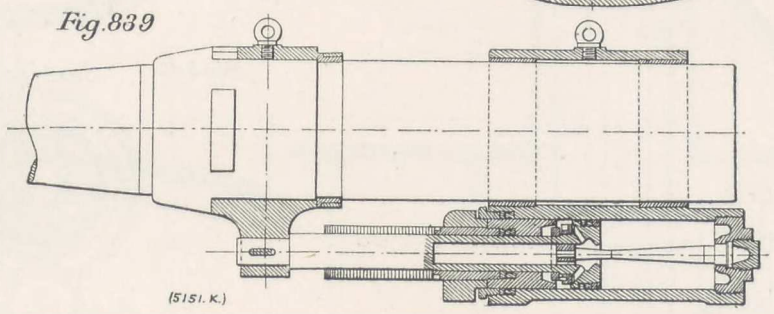


Fig.839



(5151. K.)

Schneider-Canet Turrets for 15- and 20-Centimetre Guns.

round the central socket, the pinion being worked by a helicoidal wheel and an endless screw. In operating the mechanism by hand, the shaft carrying the endless screw is put in motion by two bevelled wheels worked by a crank and a plate-chain. When electric power is resorted to, the helicoidal wheel is worked direct by a dynamo and two pinions. The motor is controlled by a cylinder called *cartouche électrique*, the working lever of which is within easy reach of the gunner.

Ammunition is raised to the platform by a hoist that consists of two plate-chains, united at intervals by gun-metal saddle-pieces. At the lower end of the tube the cartridge is placed in a special carrier, in the bottom part of which is fitted a lever; this moves under the action of the saddle-piece, lifting up the cartridge and placing it ready for hoisting up the tube. A treadle worked by the gunner on the top platform throws the mechanism of the hoist out of gear when necessary ; the hoist can

a circular rack for lateral training, and inside with the guides for the hoist. The whole rests on a hydraulic cylinder, forming a pivot.

The elevating mechanism is governed by hand, by means of a handwheel, that actuates gearing, and a toothed rack fixed on the left side of the carriage. Lateral training is effected by hand, or by electric power. The motion is obtained by the rotary action of a pinion which gears in the circular rack fitted to the central tube ; the pinion is keyed on a vertical axle worked by a helicoidal wheel and an endless screw. The mechanism is driven by a series of friction rings placed in the thickness of the helicoidal wheel. In operating the lateral training device by hand, the shaft on which the helicoidal wheel is fitted is set in motion by two square-toothed pinions which engage those keyed on the handwheel axles. When electric power is resorted to, the dynamo works a square pinion which transmits its motion to the driving axle through

one of the toothed wheels that form part of the hand-working device for training the gun. By means of a lever and clutch, the hand and power transmissions can be thrown in and out of gear.

The hoist consists of a carrier with two compartments one above the other. The carrier is raised from the magazines to the platform, by a chain set in motion either direct, by means of a crank and a set of conical gear, or through a dynamo fixed to the central tube below the armoured deck, the dynamo transmitting its motion to the lower mechanism of the chain by a vertical shaft placed inside the tube. A disengaging lever makes it possible to render these two mechanisms independent of each other. The carrier for hoisting the charges is guided in its travel by rollers which turn in the slides fixed within the ammunition tube. When the charge has reached the platform, it is received by an oscillating table carried by a horizontal frame. A lever placed within reach of the gunner on the platform enables him to check the chain at the moment when the hoisting of the holder carrying the charge is completed.

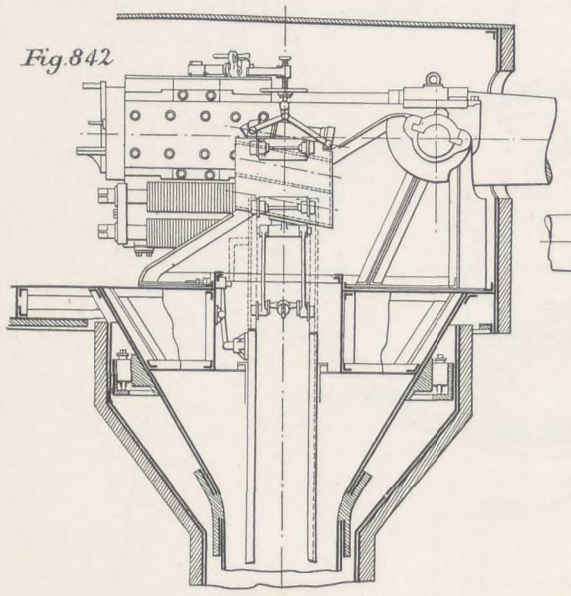


Fig. 842

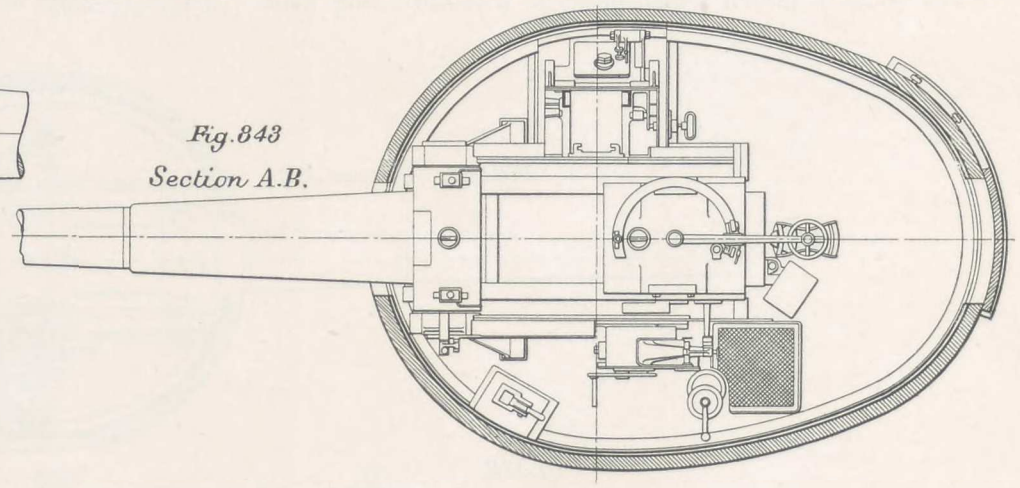


Fig. 843 Section A.B.

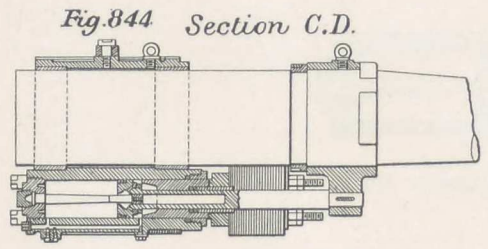


Fig. 844 Section C.D.

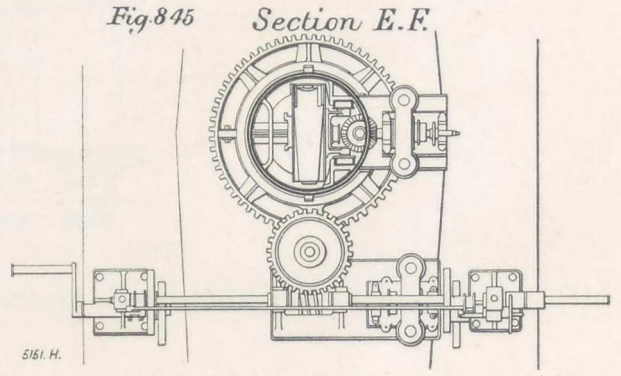


Fig. 845 Section E.F.

5151. H.

Schneider-Canet Turrets for 15- and 20-Centimetre Guns.

Closed-In Turret for 24-Centimetre (9.449-In.) Gun (Figs. 846 to 851, Plates CXLV. and CXLVI.).—The turret to be now referred to is a type which Messrs. Schneider and Co. have designed especially for the armament of protected coastguard ships. It contains four main parts, namely: the mounting and its slide; the turret and its mechanism; the training apparatus; and the hoists.

The mounting consists of a carriage formed of a recoil cylinder, and provided with the trunnion plates. The lower part of the cylinder is fitted with slides having outside clamps and inside guides; front buffers limit the travel of the carriage. The slides are made with two cheeks; these have a soleplate bolted to the turret platform, the top flanges constituting slide-paths in which seatings are cut for the rollers that facilitate the travel of the carriage during recoil and running out. The right-hand cheek carries the side support, the sight-line not being affected by the recoil. The recoil-cylinders are on the Schneider-Canet system, with central counter-rod; the pipe which unites the two cylinders ends on one side at the rear of the right-hand cylinder, and on the other in a valve on the cover of the left-hand cylinder. The liquid flows from right to left by lifting the intermediate valve; this falls back on its seat when recoil is spent, and the flow of the liquid ceases. The gun remains run in, until a valve placed on a pipe that establishes communication from one cylinder to the other, is turned by hand, when the gun runs out again under the action of gravity. The turret is arranged for central charging, and consists of:

(*a*) The movable platform, with two longitudinal beams placed underneath the mounting cheeks.

(*b*) The path on which horizontal rollers turn, placed at the top of a frame formed like a truncated cone, which surrounds the central tube; this frame is made with a roller path for the vertical rollers.

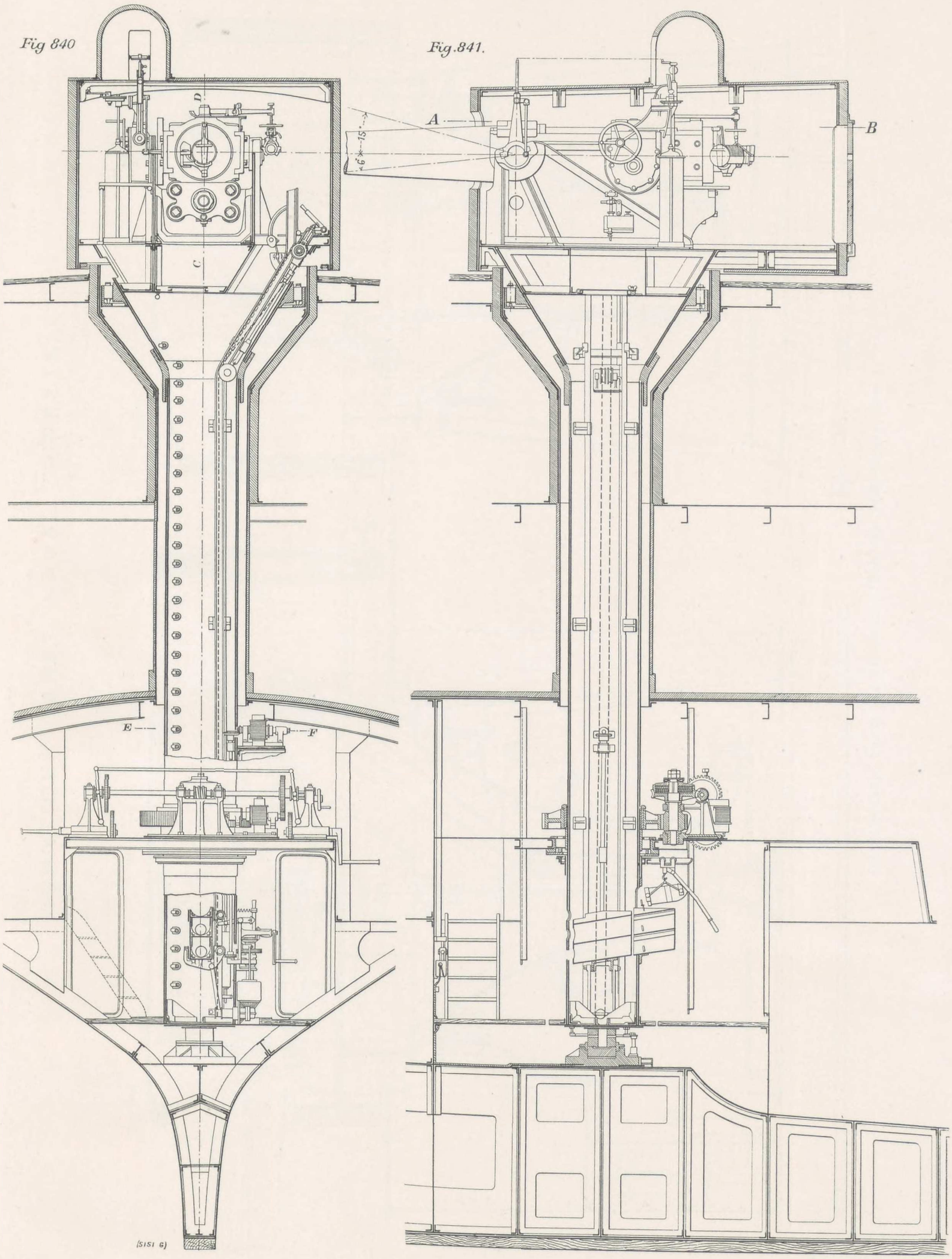
(*c*) The central tube, made in two parts joined by a piece which serves also as a support for a circular line for the ammunition service.

(*d*) The hydraulic cylinder, which acts as a pivot

SCHNEIDER-CANET NAVAL TURRETS.

Fig 840

Fig.841.



Schneider-Canet Turret for 20-Centimetre Gun.

Fig 846

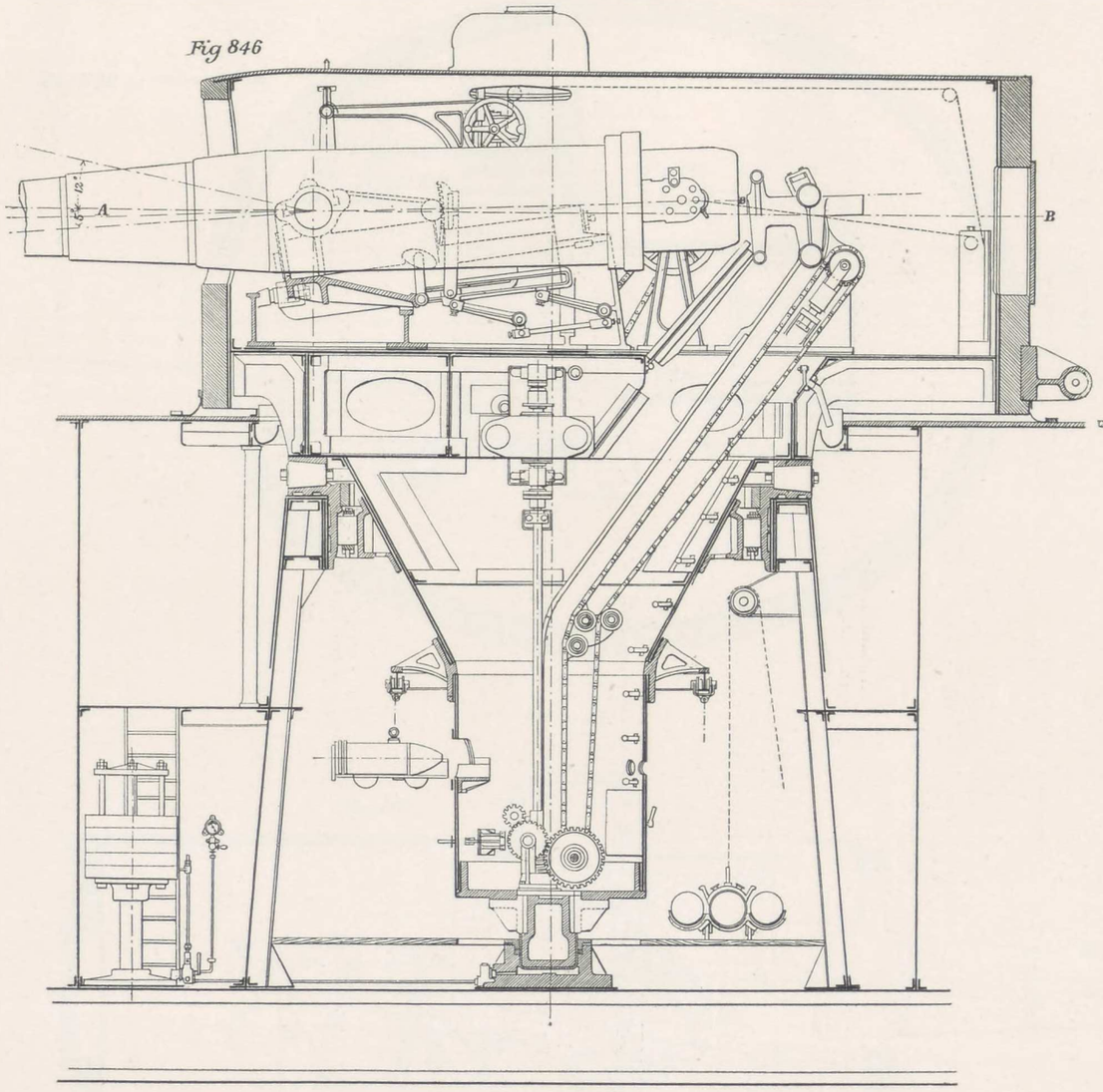
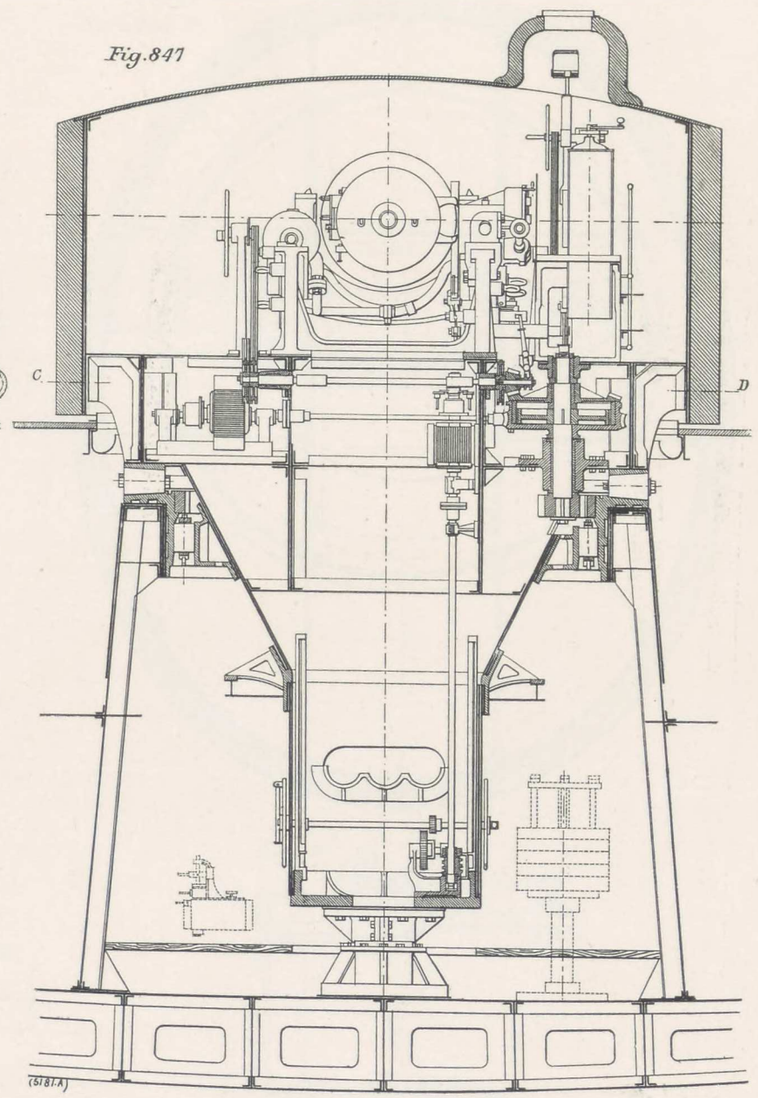


Fig.847



Schneider-Canet Turret and Ammunition Hoist for 24-Centimetre Gun.

Fig.848 *Section A.B.*

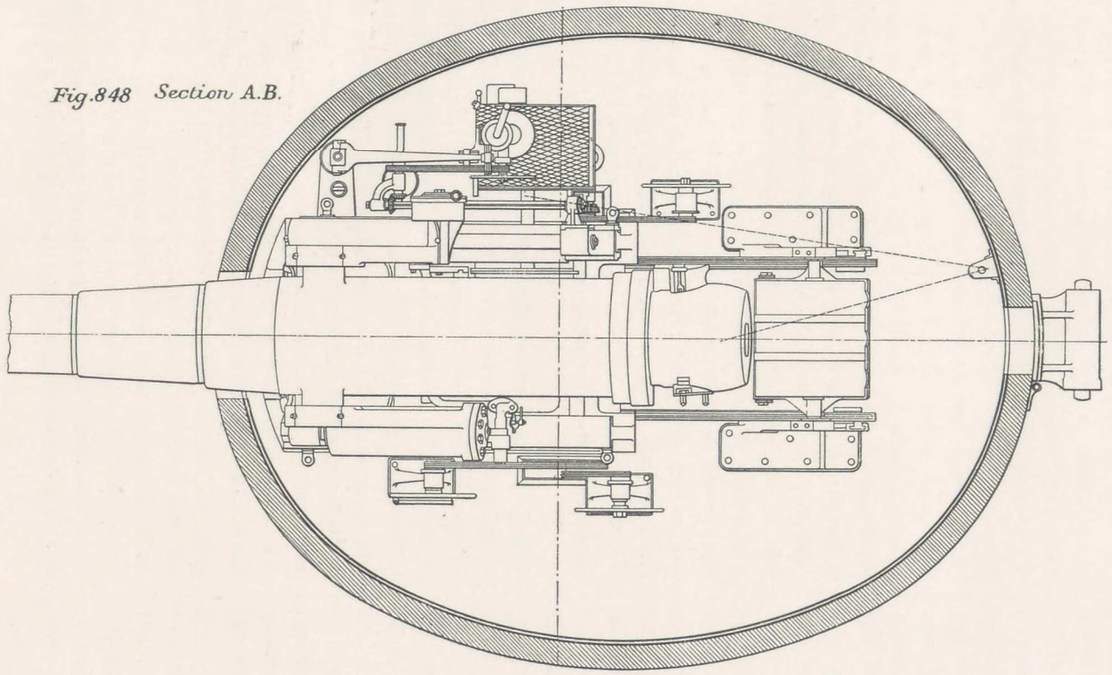


Fig.849
Section C.D.

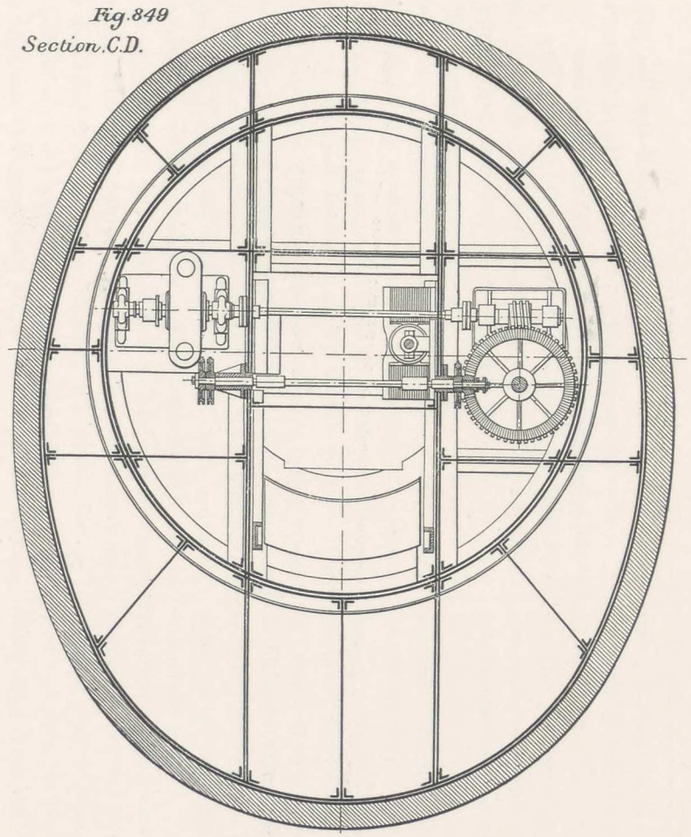


Fig.850

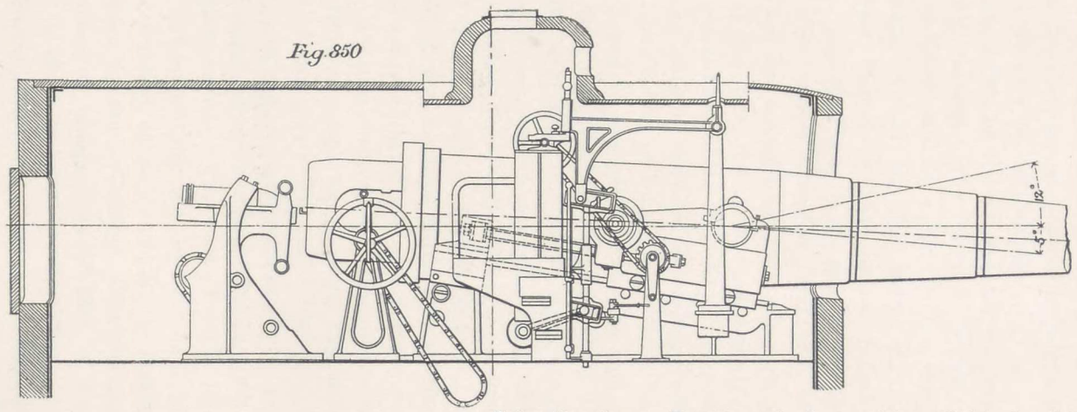
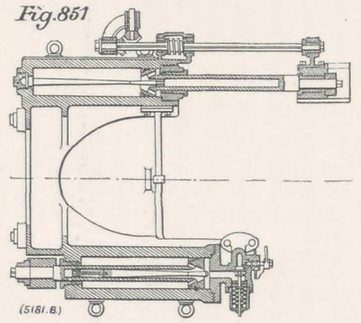


Fig.851



Schneider-Canet Turret and Ammunition Hoist for 24-Centimetre Gun.

bearing, and which carries most of the revolving weight; it serves also to lift the turret for inspecting the rollers.

The mechanism for elevating the gun comprises a handwheel and two bevel pinions which work a helicoidal screw; the latter drives the gearing, on the axis of which is a pinion that engages a toothed sector fitted to the gun. As the helicoidal screw recoils with the gun, it is made to move on a square shaft parallel with the slides. This mechanism can be worked direct by the gunner who stands in the hood, or by his assistant from the platform. Lateral training is obtained by hand, or by electric power. The required motion is given by the rotation of a pinion which gears in the toothed circular rack fixed to the part forming a roller path. This pinion is keyed on a shaft guided by collars fixed on the flooring; it is joined to a helicoidal wheel by an elastic coupling. The helicoidal wheel is driven by an endless screw fitted to the motor shaft. Lateral training is obtained by acting on the handwheel placed on the left side of the mounting; this works, through a cogwheel and a plate chain, the horizontal shaft fitted with a pinion that gears in a wheel keyed on the vertical axle working the rack. A disengaging lever serves to isolate one set of mechanism from the other.

Ammunition is raised to the gun in a carrier made with three compartments placed side by side, its lower part being fitted with a lever provided with rollers that travel in the guides inside the central tube. The carrier is raised by a chain that turns round a toothed wheel below, and on a tension pulley above. The motor is placed between the two floors of the platform; it sets in motion a vertical shaft, at the lower end of which is keyed an endless screw working a helicoidal wheel; the latter is joined to the chain-wheel shaft by an elastic coupling. Two commutators serve, one for raising the system, and the other for lowering it. The hoist can be worked by hand, by means of two cranks placed outside the system and keyed on a horizontal shaft; this also carries the pinion which works the toothed wheel on the cogwheel shaft. The pinion can be shifted to the side of the toothed wheel, thus disengaging the hand-working mechanism.

Barbette Turret for 24-Centimetre (9.449-In.) 42.5-Calibre Gun.—Turrets of this type have been supplied to the Spanish Navy, for the armoured cruisers Princesa de Asturias, Cardenal Cisneros, and Cataluña. The principal characteristics of this type are the following: The whole of the revolving part rests both on a hydraulic pivot and also on a series of horizontal rollers, the latter arranged on the top deck; at the lower part it is guided by the pivot, and at the upper part by a series of vertical rollers. The mounting has an oscillating carriage, with hydraulic recoil cylinders and air recuperators for running out the gun. The gun and mounting are entirely balanced on the trunnions, thus allowing rapid elevation by means of an ordinary winch worked by hand-power, or by an electric motor. The gun can be charged at any horizontal angle and up to a certain vertical angle, the ammunition service being direct to the breech. The gun is held in the carriage by tongues and grooves; the breech end is entirely cylindrical.

The platform is circular in shape; it consists of two longitudinal beams, two transverse stay-girders, and six lateral radiating girders, all strongly connected and fixed to a flooring made of steel plates. On the top flanges is another flooring, strengthened in front where the gun mounting rests. A circular vertical plate, held in place by angles fixed to the ends of the beams, and by six vertical uprights, carries the turret frame. The cylindrical socket is formed of two plates butt-jointed together; its top part is placed within a drum built up of plates, which joins it to the platform, the lower part being closed by a cast-steel piece which constitutes a hydraulic pivot on which rests the whole system. The pivot has a gun-metal lining, and revolves inside a cast-steel hydraulic cylinder. The water required for working the hydraulic pivot is delivered by a small pump, placed near the cylinder and worked by hand or electric power. The fixed roller paths for the horizontal and the vertical rollers are provided in one single cast-steel ring, fixed to the upper deck. The socket is fitted with a drum, placed at a suitable height, round which turn the chains for lateral training.

The mounting consists of the coil around the gun, and of the oscillating carriage. The latter is formed of a trunnion ring in front, and of a rear jacket joined to the ring by means of four cast-steel string beams, the rear jacket being formed by two lateral forged-steel blocks, and two cast-steel stay bars; the blocks contain the recoil cylinders and recuperators, and each of the cast-steel stay bars has seatings for two rollers, on which the rear end of the gun rests. As has already been mentioned, the gun is fixed to the encircling coil by tongue and groove joints; the gun rests on the carriage with the interposition of four rollers of forged steel placed in two lateral cheeks forged in one piece with the coil. The gun is thus always supported by the four front rollers of the coil and the eight rollers of the carriage, the efforts for the running in and out of the gun being thereby reduced to a minimum. The recoil cylinders are bored in the forged-steel lateral blocks; their centres, and those of the gun and of the carriage trunnions, are in one plane; this does away with all effect of percussion, and the system has only to withstand, during firing, the efforts of the recoil cylinders, which are in direct opposition to the recoil force of the gun. The piston-rods are fixed, in front, to the encircling coil, and continued in the rear as counter-rods of equal diameter, thus forming hydraulic brakes of constant volume. The vents for the flow of the liquid are determined by the ballistic data of the gun, and are calculated so as to obtain a practically constant resistance in the cylinders. The working of the recoil cylinders is independent of that of the recuperators, but in order to simplify the system, and to reduce to a minimum the number of joints, the recuperators have been placed in the same blocks with the hydraulic

recoil cylinders, the counter-rods on their leaving the recoil cylinders being utilised for forcing liquid into the air receivers. When the recoil is complete, the air expands and forces back the liquid, which, in its turn, drives back the counter-rods of the recoil cylinders, thus running out the gun again. An air compressor is placed in the turret, and in this an initial compression of 15 kilogrammes (213 lb. per square inch) is obtained. This is sufficient to run out the gun under an angle of 15 deg. A small hand pump placed under the carriage provides for the running in of the gun when necessary. The recoil cylinders and air receivers have no piping, and as they are bored in forged-steel blocks, they offer a great resisting power and are perfectly tight. The carriage trunnions are placed exactly in the centre of gravity of the oscillating system; they are covered with a gun-metal lining, and rest in suitable bearings in two cast-steel supports strongly bolted to the platform.

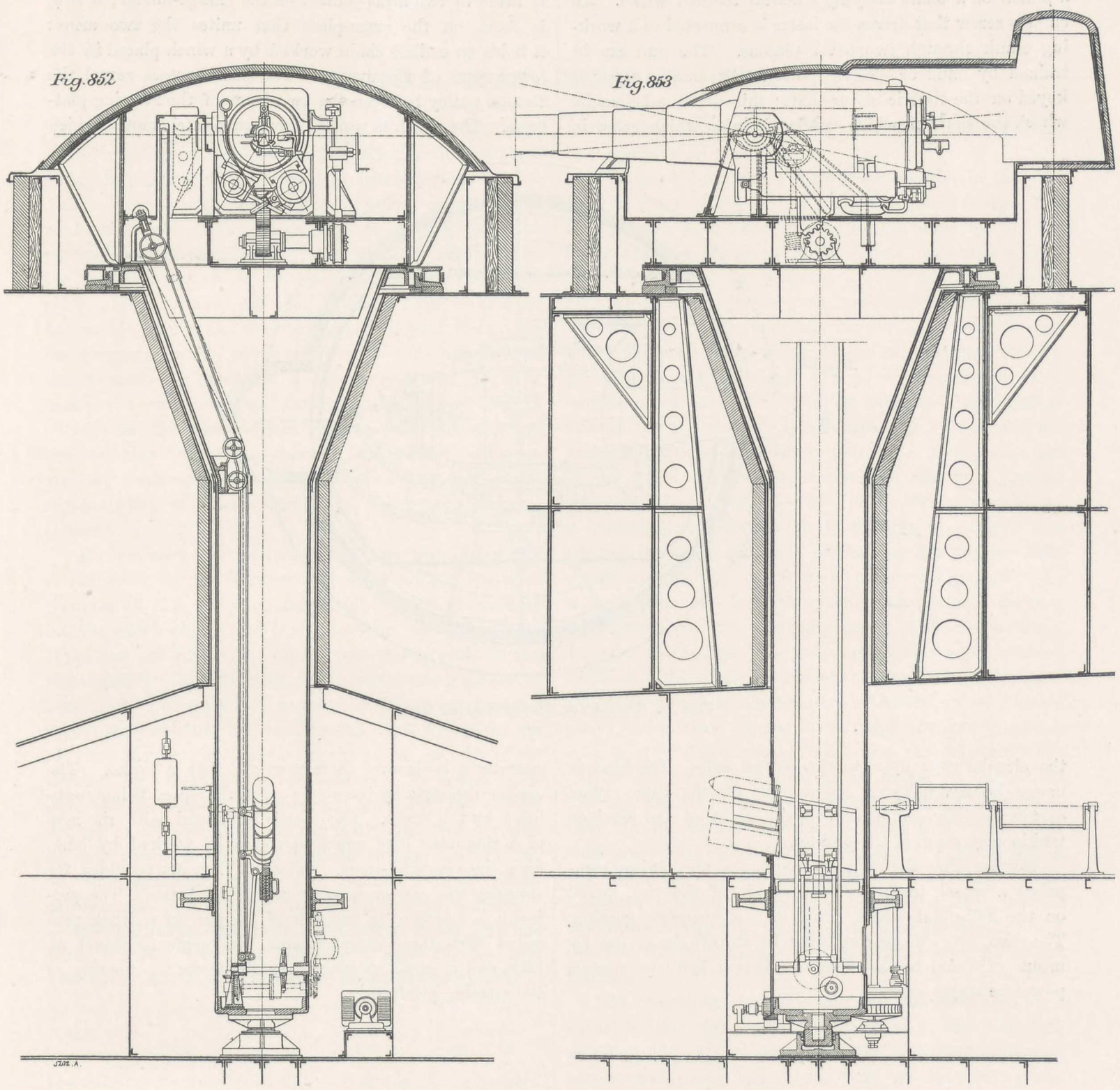
The required elevation for the gun is obtained by the displacement of two racks fitted under the carriage, and guided by rollers. These racks engage two square pinions keyed on the same shaft as a helicoidal wheel; a crank drives the endless screw which works the helicoidal wheel through two bevel pinions. Two men working the crank can elevate the gun from — 5 deg. to + 15 deg. in 30 seconds. A dynamo can also be employed for turning the endless screw shaft by a double set of gearing, and the time required is only 12 seconds. Should the gun not run in, the angular displacement of the carriage could be effected by hand-power by means of a ratchet lever acting on the end of the dynamo shaft. The lateral training mechanism contains two plate chains, two hand winches, and two dynamos. The chains that surround the drum on the socket are worked by two pinions keyed on the same axles as two helicoidal wheels. Lateral training is obtained by the revolution of the helicoidal wheels; the latter are worked by two dynamos which drive direct the endless screws that gear in them, or by hand-power through cranks and winches; clutches enable the dynamos to be disengaged from the winches. The helicoidal wheels are joined to their shafts by means of friction clutches, which serve to limit the efforts on the transmission gear which result from a sudden stoppage of the turret. A speaking-tube establishes communication with the gunner to the men who work the cranks on the orlop deck. The gunner works the dynamos for lateral training direct by acting on a hand-lever placed in the turret. Lateral training has a limit of 240 deg.; when the ship is on a level keel this movement takes, by hand, 1 minute 35 seconds, and by electric power 35 seconds.

The device for supplying ammunition consists of a carrier which can hold the projectile and the two cartridges forming the powder charge; and a winch fitted to the socket worked by hand or by electric power, to raise the carrier up to the firing platform at the rear of the gun. Guides are provided for the carrier, and the apparatus is completed by a hand rammer. The carrier consists of a case suspended on two roller pivots; the projectile is placed in the middle, and the powder charge in the two lateral movable charge-holders. When the carrier is at the lowest part of its travel, it arrives automatically opposite a charging table, and the projectile and powder charge are slid into it by hand, the charging table being suitably inclined for the purpose. The winch which works the hoisting chains is then set in motion; as soon as the hoisting operation starts, the carrier straightens and rises vertically until it reaches the turret, when it follows the incline of the guides; near the end of its travel it arrives in a horizontal position at the rear of the gun. The angle given to the carrier at the end of the lift is obtained automatically by means of two racks fixed to the guides, and two pinions which form part of the carrier, which turn when they meet the fixed racks on the guides in raising or lowering motion. The hoisting apparatus contains all the necessary devices for safe working.

The electrical plant comprises one dynamo for elevating the gun, two dynamos for lateral training, one for the hoist and one for the pivot compressor, besides the electric machines referred to in the preceding description. The auxiliary apparatus consists of a hand-pump for running in the gun; a hand-worked compressor for starting the air recuperators; and a pump worked by hand or by electric power, to maintain the required pressure under the step bearing of the turret.

Closed Turret, Worked by Hand or Electric Power, for 28-Centimetre (11.023-In.) Gun (Figs. 852 to 854).— This installation comprises the following principal parts: The carriage and slide; the turret and its rotary mechanism; the training mechanism and the hoist. The carriage proper consists of a jacket provided with trunnions, with the recoil cylinder and the collars that hold the compressed air recuperator; it is fitted inside with gun-metal rings which guide the gun during recoil. At the lower part, a shoe is provided on which is the sector for elevating the gun. The slide consists of two cheeks, of plates and angles, which rest on a soleplate fixed to the top flooring of the turret, and which carry the trunnion plates that receive the trunnions of the jacket. To facilitate the elevation of the gun and jacket, the trunnions are surrounded by a ring of anti-friction rollers. The right-hand cheek is made with a bracket for the elevating mechanism. The recoil cylinder is on the Schneider-Canet system, with central counter-rod; it is joined to the compressed air recuperator placed under the jacket, through a pipe that opens on the front part of the cylinder, as well as through a small branch on the pipe, and ending at the rear of the cylinder in a gun-metal chest which contains the valve that controls the running in of the gun. When recoil takes place, the piston-rod enters the cylinder, and drives out a quantity of liquid equal to its volume; this acts on one of the sides of the recuperator piston, the latter serving as a compressor for the air; the expansion of which, during the return of the gun, causes the liquid to resume its original place.

The turret is fitted with a central ammunition hoist, and consists of the rotating turret platform, made of two floorings of plates joined together by a circular vertical beam in a line beneath the roller path, and by two longitudinal ones under the slide cheeks. The top flooring is fitted with a steel plate caisson, which forms the inside of the turret, and carries the rotating shell and its plating. The central tube is formed of steel plates, partly cylindrical and partly in the shape of a truncated cone, protected by armour; the two parts being joined together by a cast-steel angle-ring. The top part of the tube is connected to the lower flooring of the platform by a circular caisson of cast steel, the inside surface of which forms a roller path for the set of vertical rollers. The cylindrical part of the tube is fitted with the circular rack for lateral training.



Schneider-Canet Turret and Ammunition Hoist for 28-Centimetre Gun.

The hydraulic cylinder at the foot of the central tube forms a pivot on which the greater part of the revolving weight rests, and which enables the turret to be raised for inspection of the rollers. The rotating mechanism contains the set of conical horizontal rollers on which rests part of the weight of the platform, and the set of cylindrical vertical rollers which insures the centring of the system.

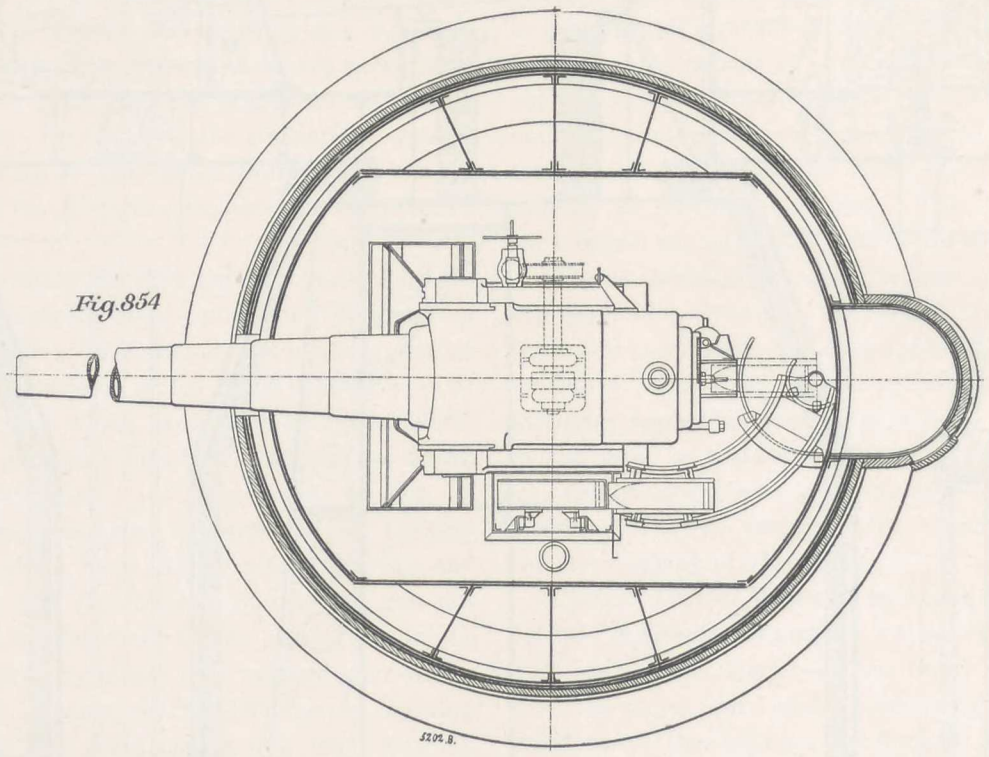
A latch-bolt is introduced for fixing the turret when at sea.

The mechanism for elevating the gun consists of a toothed rack placed under the jacket, and which gears with a pinion on a shaft carrying a helical toothed wheel. An endless screw that drives the latter is connected to a working crank through two bevel pinions. The gun can be trained by hand or electric power. An endless screw is keyed on the electric motor shaft; this drives a helicoidal wheel, the shaft of which carries a pinion which gears in the circular rack fitted to the central tube. The electric motor is driven by a commutator of the type styled *cartouche électrique*, placed on the right of the carriage within easy reach of the gunner.

For training the gun by hand, the mechanism comprises a wheel, toothed on the inside of the rim, keyed on the helicoidal wheel shaft, and a suitable gearing. The two sets of gearing may be thrown in or out by means of a clutch, according to whether hand or electric power be employed.

The gun is supplied with ammunition by means of a carrier containing three compartments placed side by side, fitted with three pairs of rollers that travel in the guides placed inside the central tube. The lower pair of rollers is fitted to two arms jointed on the charge-holder; a ring is fixed on the cross-piece that unites the two arms; it holds an endless chain worked by a winch placed in the lower part of the system. The chain passes round the tension pulley between the two floors of the rotating platform. The winch is worked from an electric motor, which operates a horizontal shaft provided with a brake. The carrier descends by its own weight, the speed being regulated by the brake. The motor is started with the help of a rheostat. The winch can also be worked by hand from the charging-room. Safety devices are provided for stopping the carrier at both ends of its travel. The projectile is brought to the rear of the gun in a truck provided with three compartments, and made to travel on rails, and a small turntable, placed on the top flooring of the rotating platform.

Fig.854



Plan of Turret for 28-Centimetre Gun.

XXXVII.—COAST-DEFENCE GUNS.

A CERTAIN number of types of Schneider-Canet naval guns described in preceding sections, possess details in common with the artillery specially designed for coast defence; such details are, however, more or less modified in some of the latter guns, in order to meet the particular requirements they have to fulfil. As regards, for instance, mountings for quick-firing guns of equal calibre, those for coast defence frequently differ from those for naval guns, in the arrangements provided for giving the former a greater range of elevation. To obtain this, the bedplate is fitted to a special platform, or to a masonry foundation, thus insuring the required height of soleplate for coast-defence batteries. Notwithstanding the fact that both these types of quick-firing ordnance are very similar, we shall describe some examples of coast-defence guns, in order to point out their special characteristics.

The ordinary class of non-quick-firing material, which is still used for the armament of coast-defence batteries, includes all the series of large-calibre guns of medium lengths which are derived from the older non-quick-firing types, but are improved. Such a *matériel* is quite in the right place in coast defences, for it constitutes a powerful armament, and does not require, in time of peace, a numerous *personnel* for maintenance. All the parts are of very simple construction, designed so as not to be affected by variations in temperature. In action these guns can be worked by untrained men, and the careful drilling of the *personnel* is not difficult, and does not take up much time. In order to fulfil the various requirements of this particular service, the Schneider-Canet coast-defence armament includes guns, howitzers, and mortars.

27-Centimetre (10.630-In.) 28-Calibre Coast Defence Gun (Fig. 855).—A large number of guns of this type have been built, especially for the Japanese Government.

Weight of gun	25,890 kg.	57,060 lb.
,, mounting	35,720 kg.	78,727 lb.
,, projectile	216 kg.	476 lb.
Elevation	+ 20 deg.	+ 20 deg.
	− 20 deg.	− 20 deg.
Training	270 deg.	270 deg.
Muzzle Velocity with prismatic brown powder	570 m.	1870 ft.

The gun is built throughout of steel; it consists of a thick tube which runs the whole length of the gun, and is strengthened by sets of coils. It is provided with a two-motion breech-block, of the type described in a preceding section dealing with large-calibre breech-blocks; friction fuses are used for firing, obturation being insured by a special steel cup.

The mounting consists of three main parts, the bedplate fixed to the platform, the slide, and the gun-carriage. The bedplate acts as a fixed support for the movable slide, the latter revolves round its vertical axis on coned rollers. The lower part of the bedplate is made with a horizontal ring, which forms a roller-path, and is strengthened by ribs where required; the upper part contains a vertical cylinder, which fits in a corresponding one on the slide, and forms a pivot for lateral training. The slide is made with two vertical cheeks on the top, part of which bear the carriage slide shoes; the cheeks are strengthened by ribs, and are joined together at their lower part by a domed cap cast in one piece with them; inside the cap is a vertical cylinder which completes the pivot above referred to. A horizontal ring, formed by the bending up of the lower edge of the dome, acts as a bearing surface for the slide on the rollers. The slide contains the elevating mechanism, with a platform for the gunner, the lateral training mechanism, and the charging cradle with its platform. In order to facilitate the running out of the gun without increasing the angle of incline of the slides, cylindrical rollers are provided, the top part of which project slightly above the surface of the slides; the carriage, therefore, rolls on the slides during recoil and running out. The cheeks are made in front with an excess of metal, for holding the recoil cylinder piston. When the carriage runs out, the buffers bear on the front stay of the slide, thus preventing a too sudden stoppage. Four clamps at the lower part of the slide hold the lower edge of the bedplate, and set up to offer together a large vertical resistance during fire; at the same time the arrangement provides for the necessary angular displacement for lateral training.

The mechanism for elevating the gun is placed in a chest on the right cheek, and works in the following manner: The gun is provided with a toothed sector, on which acts a pinion keyed on a shaft, the latter being also fitted with a helicoidal wheel worked by an endless screw. The crank acts on a pair of bevel wheels, one of which is on the endless screw shaft. The platform for the gunner is on the right cheek. Lateral training is obtained by a chain placed in a recess round the circumference of the bedplate. It is guided by two friction rollers, and passes on a grooved pulley cast in one piece with a helicoidal wheel; the latter is worked by an endless screw. The endless screw is keyed on a shaft provided at both ends

with a toothed wheel; two other shafts placed in front of the mounting, work the toothed wheels, and transmit the motion to all the system. The various parts being embodied with the slide, this gets displaced on the bedplate immediately the grooved pulley is made to draw on the chain.

A charging cradle is used for raising the projectile from the ground level to the rear of the gun; it is placed at the end of a lever which revolves round a horizontal axle carried in bushes in the rear of the slide. On this same axle are keyed: (*a*) a cam, on the circumference of which is a chain, the other end of this chain is attached to a spring recuperator; and (*b*) part of a helicoidal wheel. This is moved by an endless screw which in its turn is worked by a set of pinions, these being driven by a crank. The spring recuperator to which the chain is fitted, consists of a piston, the rear surface of which bears on a series of Belleville springs contained in a fixed cylindrical chest. This arrangement renders the efforts for raising the cradle containing the projectile, and the lowering of the empty cradle, practically equal. When the lowering of the empty cradle takes place, the Belleville springs are pressed down through the traction of the chain which is drawn by the crank, the relaxing of the springs taking place during the hoisting of the cradle loaded with a projectile. The charging platform is in the rear of the slide, two ladders giving access to it.

The gun-carriage proper is in the shape of a cradle; it contains the two recoil cylinders, which end at their lower part in two shoes that travel on the rollers of the slide, and form clamps which prevent all raising of the system when the gun is fired. There are two ribs through one of which the two conduits of the recoil cylinders pass; the ribs insure the stiffness of the whole arrangement. The trunnion bearings are on the top of the recoil cylinders; they are kept in place by means of top trunnion plates and screws. Lugs on the outside of the cylinders serve for taking the material to pieces and for its re-erection.

The hydraulic recoil cylinders are fitted with central counter-rods, on the Schneider-Canet system; the pressure inside the cylinder is constant during the time the recoil lasts. The pistons are joined to the slide; when a round is fired, the gun draws back the mounting, and the glycerine contained in the recoil cylinders is compressed in the cylinders by the pistons; it raises the valves placed in the centre of the pistons, and flows through an annular opening cut round the counter-rod. When recoil is spent, the valves under the action of their springs, fall back on their seats, and the liquid can only return to its former place through the small vents cut in the valve seats.

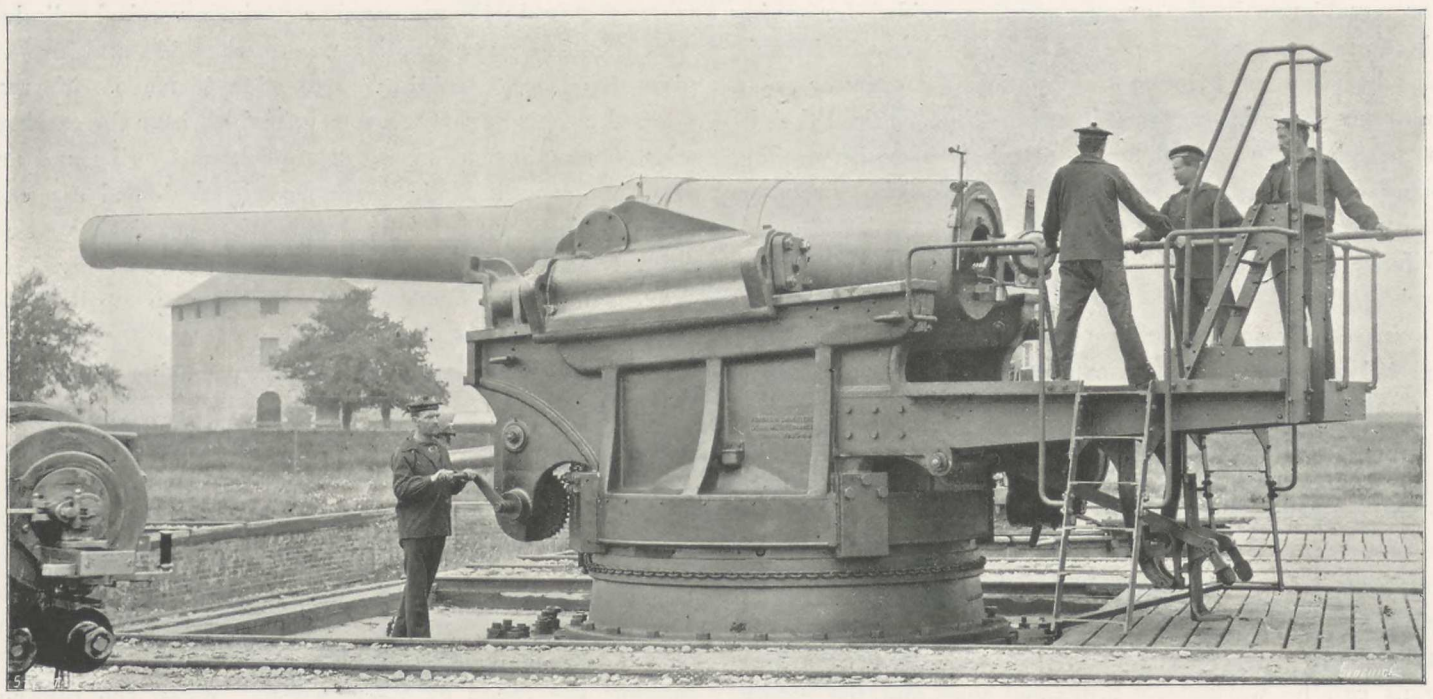


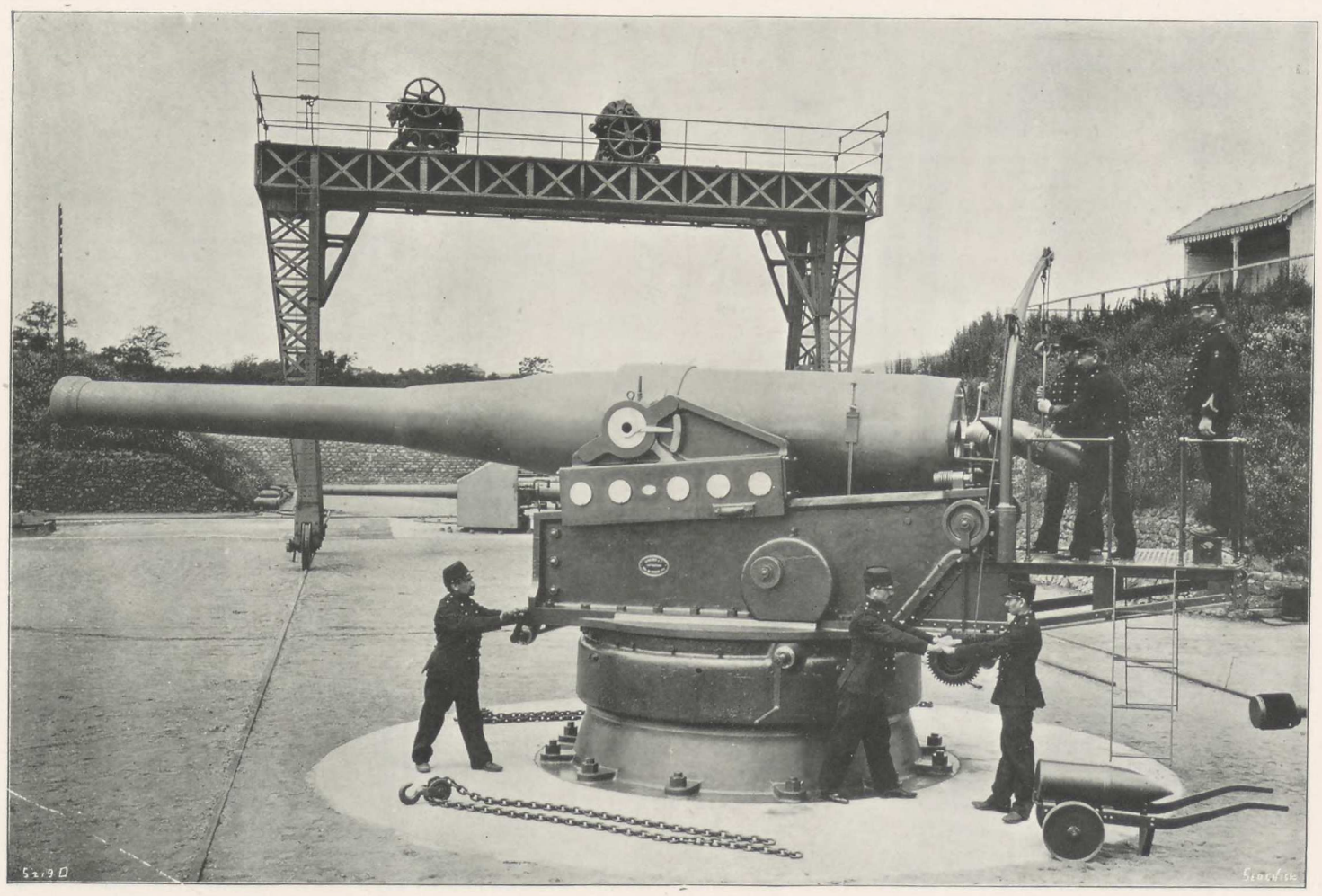
Fig. 855. 27-Centimetre 28-Calibre Coast-Defence Gun and Mounting.

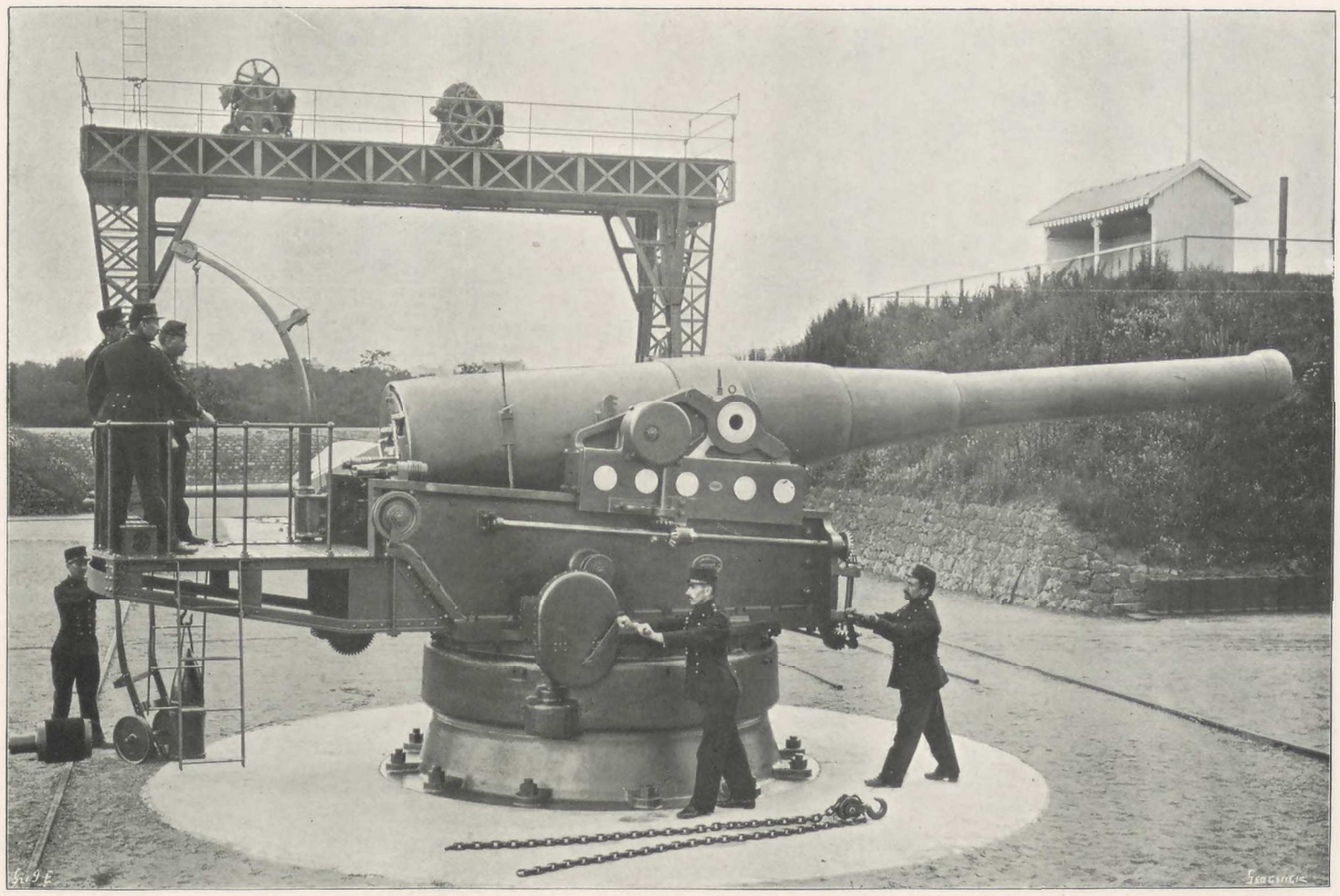
27-Centimetre (10.630-In.) 30-Calibre Coast-Defence Gun, on Central Pivoting Mounting (Figs. 856 to 860, Plates CXLVII. and CXLVIII.).

Weight of gun	26,500 kg.	58,400 lb.
,, mounting	36,500 kg.	80,400 lb.
Angles of elevation	+ 20 deg.	+ 20 deg.
	− 8 deg.	− 8 deg.
Recoil of mounting	1.100 m.	43,307 in.
Weight of powder charge	82 kg.	181 lb.
,, ordinary projectile ...	216 kg.	476 lb.
Muzzle velocity	600 m.	1,970 lb.

The gun consists of a steel tube, strengthened by eight steel hoops. The breech-block is made with three threaded parts and three interruptions, the rear thread being continuous for limiting the travel. The body of the breech-block is made with two grooves for guiding it on the

COAST-DEFENCE GUNS.





Figs. 856 and 857. 27-Centimetre 30-Calibre Coast-Defence Gun and Mounting.

Fig.858

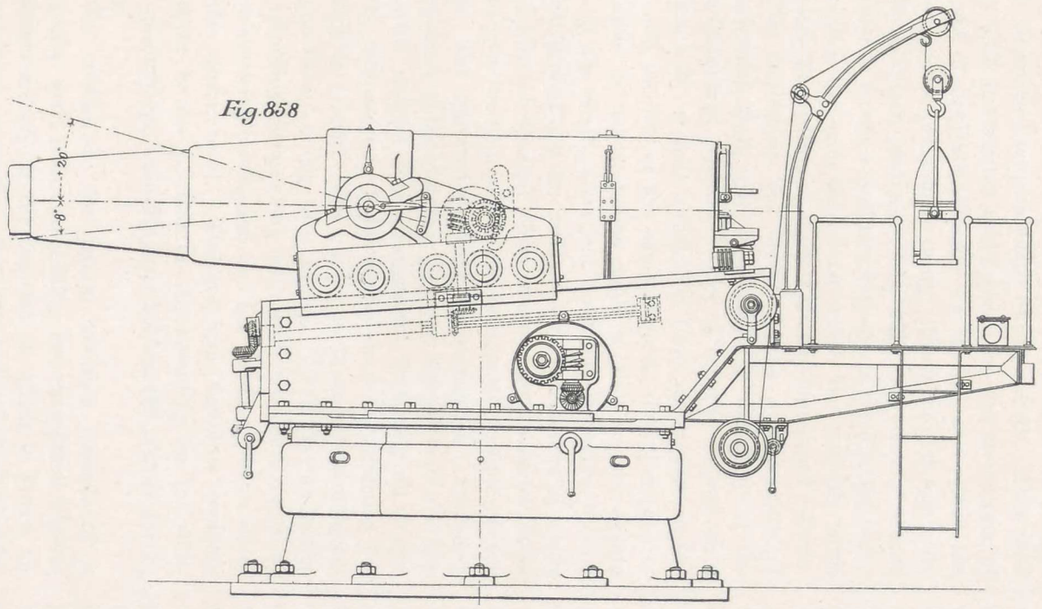


Fig.859

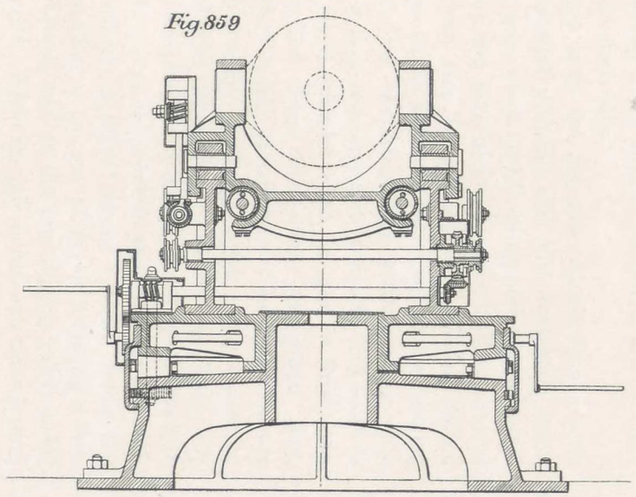


Fig.860

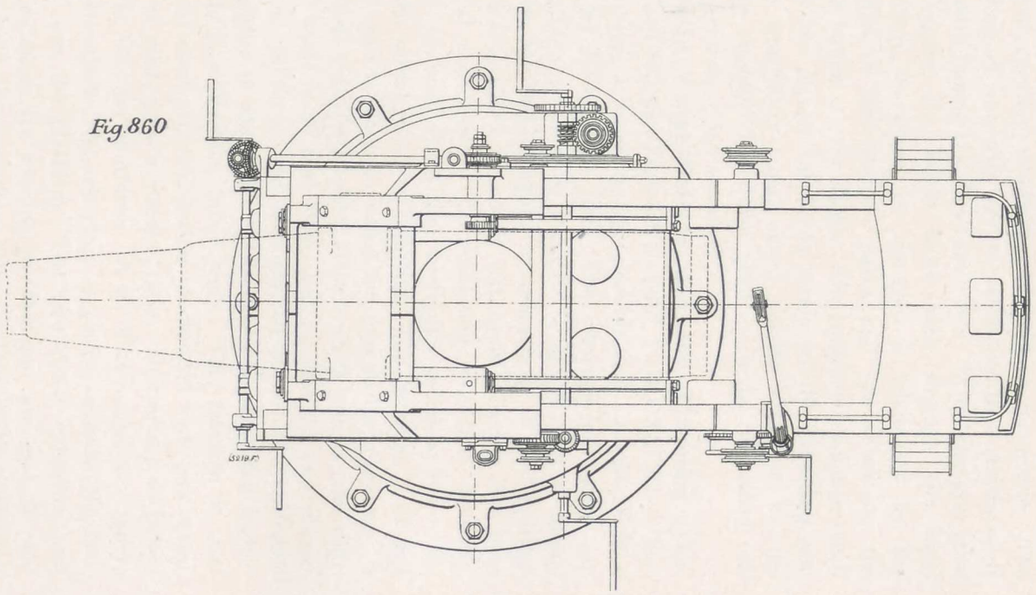


Fig.861

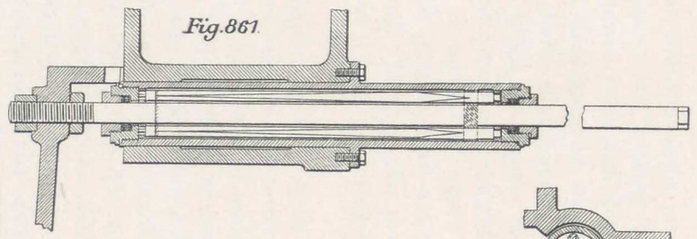


Fig.862

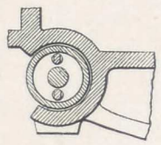
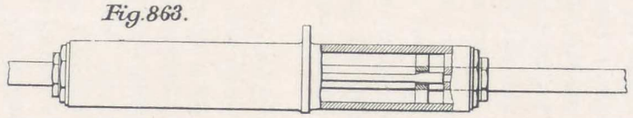


Fig.863.



Schneider-Canet 27-Centimetre 30-Calibre Coast-Defence Gun and Mounting.

supporting bracket. The fuse is threaded, and is fired by friction or by electricity.

The mounting is on the Schneider-Canet system, with inclined slide, central pivoting, and with hydraulic recoil cylinder. The gun, when loaded, being perfectly balanced on its trunnions, one man alone can give it the required elevation. It can also be trained by one man, owing to the care taken in the arrangement of the conical bearing rollers; indeed, for elevating and training, the only effort required is that to compensate friction. No shock is caused in the recoil cylinder when the gun is fired; the rods are protected from the effects of grape shot, and the cylinders being of constant volume, air cannot enter, so they remain perfectly tight. The mounting body is of cast iron; it is made with a large base; the recoil cylinders are placed as near the trunnions as possible, thus reducing to a very large extent the reversing moment. The loading platform is placed about 1 metre below the gun; a wide opening is cut out of it for allowing a free passage to the breech end of the gun during recoil under the greatest angles. When the gun is run out, this opening is covered by the movable flooring joined to the mounting; it is uncovered automatically during recoil. This does away with the trouble that attends the use, at the rear of the gun, of a portable flooring for loading, and which has to be removed previous to firing, Upon the cast-iron body is the cast-iron inclined slide, with two cheeks stayed together in front; a cast-iron transom is fitted to the slide; there is a cast-iron bolster on which the transom turns through the medium of a set of twenty-four coned rollers.

The mechanism for elevating the gun consists of a horizontal shaft with two cranks in the front of the slide, combined with two pairs of bevelled pinions on a vertical axle; a shaft, circular in front and square in the rear, and inclined at the same angle as the roller-path of the slide; a conical pinion made to slide on the square part of the shaft; a vertical shaft on which are fitted a conical pinion and an endless screw; a horizontal shaft fitted with a helicoidal wheel and a pinion; a sector fitted to the gun, the helicoidal wheel being made to slide on the shaft. The required pressure for insuring the necessary compression of the system is given by screwed nuts and two Belleville springs, this arrangement deadening all shocks on the mechanism. Index plates show the direction for turning the cranks. One gunner, in 25 seconds, can elevate the gun from − 8 deg. to + 25 deg. When the gun recoils, the mounting draws along with it all the parts contained in the elevating mechanism, and the bevelled pinion slides on the square shaft. The gun can, therefore, oscillate whatever be the position of the mounting on the slide. The gunners can maintain their hold on the cranks during firing.

The mechanism for lateral training consists of a transverse shaft with two cranks; two cylindrical wheels; a transverse shaft on the transom, on which is keyed an endless screw; a vertical shaft provided with a helicoidal wheel and a pinion; a toothed ring fixed to the bolster; the helicoidal wheel is made to slide on its shaft; the pressure required for insuring the necessary contact is given by screwed nuts with two Belleville springs, this arrangement deadening all shocks on the teeth of the mechanism; index plates are provided for showing the direction in which the cranks have to be turned. One gunner suffices for training the gun through a small angle; for turning it completely round it takes two men five minutes. The gunners need not release the cranks while the gun is fired. There is also a mechanism for running in the gun, but it is only resorted to for maintenance and repair.

The device for checking recoil consists of two forged-steel cylinders cased in the lower part of the mounting, and provided in the middle of their length with a lug for fixing them; they are closed at both ends by covers. The two plunger-rods are fixed to the front stay; the plungers are made with two round holes, through which pass rods of varying sections. (Figs. 861 to 863, Plate CXLVIII.).

When the gun is fired, the mounting recoils and draws back the cylinders. The liquid in the front of the pistons flows to the rear through the openings made between the rods of varying sections and the holes in the piston. The sections of the rods are so calculated that resistance is constant during the time recoil lasts. When the gun runs out again, the liquid flows back through the same openings, the travel of the gun is moderated by the friction of the various parts, and the shock on the front buffers is very slight. The constant resistance recoil cylinders do not cause any strain on the mounting, and give practically equal recoil speeds whatever be the firing angles. The firing platform is in two parts, one fixed and the other movable.

12-In. Coast Defence Gun and Mounting (Figs. 864 and 865, and Figs. 866 and 867, Plate CXLIX.). — This mounting is fitted on an elevator, and disappears in a pit for loading the gun. The disappearing action can only take place when the gun is run in, and a special device has been designed to maintain it in that position after firing, and to run it out again after it has been loaded and raised. The mounting is central pivoting, with inclined slides and hydraulic recoil cylinder, the return taking place by gravity. The carriage is of cast steel, and is made to carry the gun on its trunnions; it is fitted with forged-steel rollers, which run on the slide. The latter is of cast steel, and consists of two cheeks stayed in front and strongly bolted on the cast-steel bedplate; in its centre is the pivot-housing, and underneath is a circular roller path. The transom is also of cast steel, provided with a pivot lined with gun metal, and is made with a circular racer; the transom is bolted on the elevator platform. A set of 24 forged-steel rollers joined together by two rings is placed between the bedplate and the platform. The two recoil cylinders and the cylinder for running in the gun are cast in one piece with the mounting; they are lined with gun metal. The recoil piston-rods are fixed to shoulders in the rear

of the cheeks; the plunger for running in the gun is joined to the slide stay-piece. The recoil cylinders are made with constant resistance. During recoil, the liquid flows from the front to the rear of the piston through two openings, which are partly blocked up by two rods fixed to both ends of the cylinder. The section of these rods at various parts of their length is so designed that the free opening for the flowing of the liquid varies with the recoil speed, the resistance to the flow being constant (Fig. 865). The volume of liquid, which corresponds to that of the rods, when driven from the cylinders, flows through two pipes and a valve chest in the cylinder for running in the gun, and fills exactly the void caused by the withdrawal of the plunger. The valve chest is arranged in such a way that the liquid passes into the running-in cylinder after raising a valve, and can only return in the recoil cylinders through a vent, the opening of which is regulated by a rod which is worked from a handle placed on the side of the mounting. If the rod is driven home in the vent, the gun remains run in, and it runs out quicker the more the rod is raised. The manœuvre for running in the gun is effected by means of a small pump fitted to the bedplate, and worked by two handwheels on each side of the mounting. The pump draws the liquid from the recoil cylinders through a conduit in the rods, and delivers it in the running-in cylinder through a passage in the plunger.

Elevation ranges from — 7 deg. to + 20 deg. A toothed sector fitted to the gun acts in conjunction with a pinion, joined through a friction cone, to an endless screw; Belleville springs allow a certain amount of play between the various parts to counteract violent shocks. The handwheels for giving the required elevation do not follow the recoil, and can act whatever be the position of the gun, by working a square shaft, carried by the mounting, and on which slides a conical pinion. The gun is trained through a pinion fitted to the bedplate, and which engages a circular rack fixed to the transom. The pinion is worked by a set of wheels and an endless screw, the latter being driven by two cranks keyed on the same shaft, and placed near the handwheels for elevating the gun. Cramps in the front and rear of the bedplate clasp

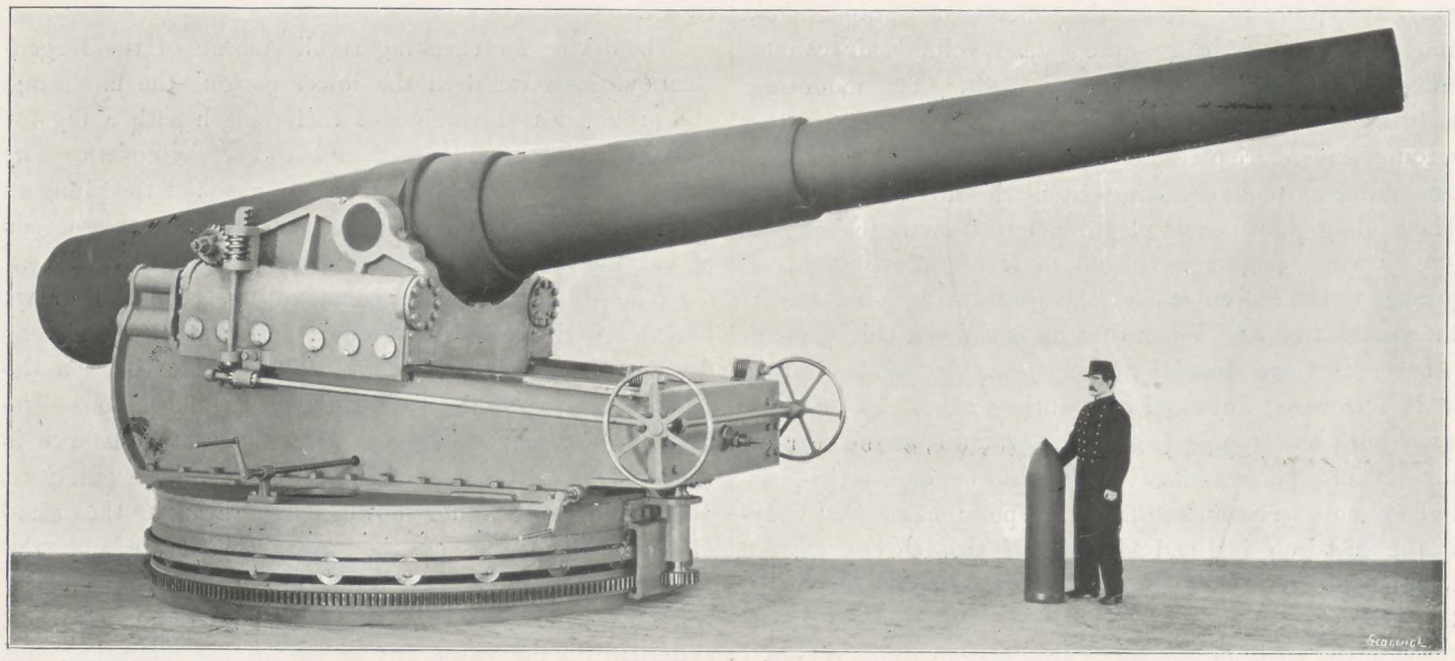


Fig. 864. 12-in. Coast-Defence Gun and Schneider-Canet Mounting.

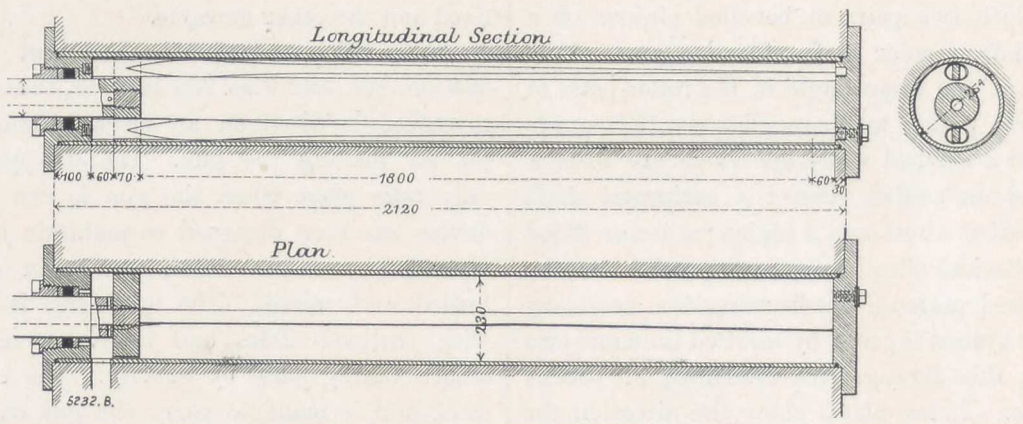
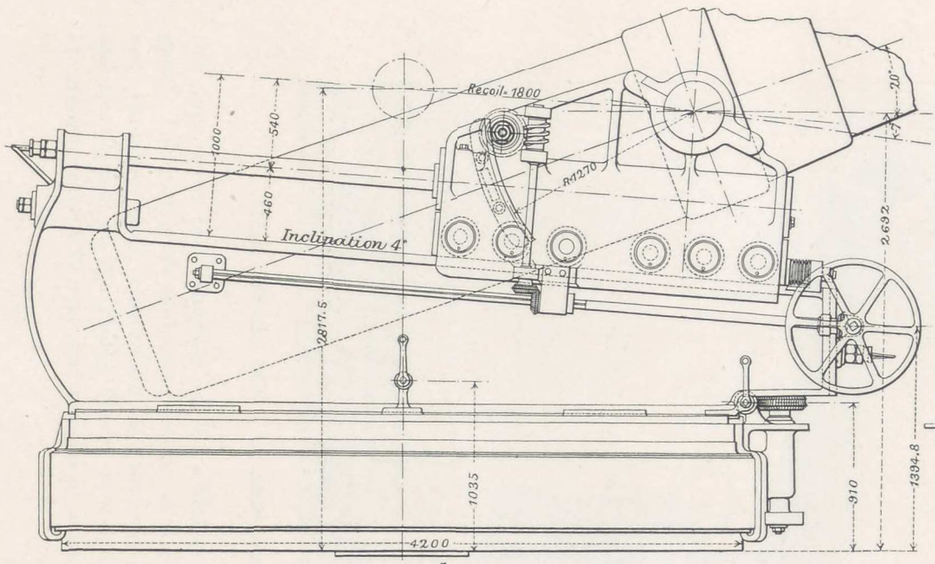
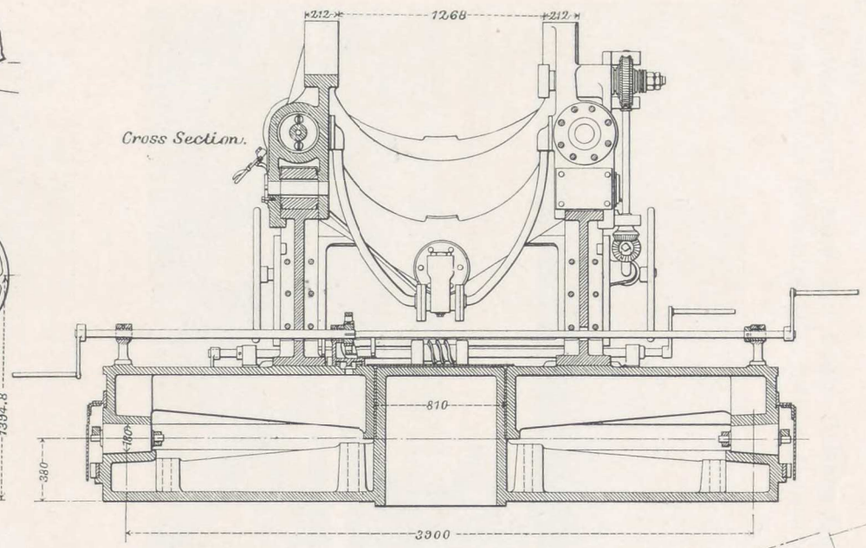
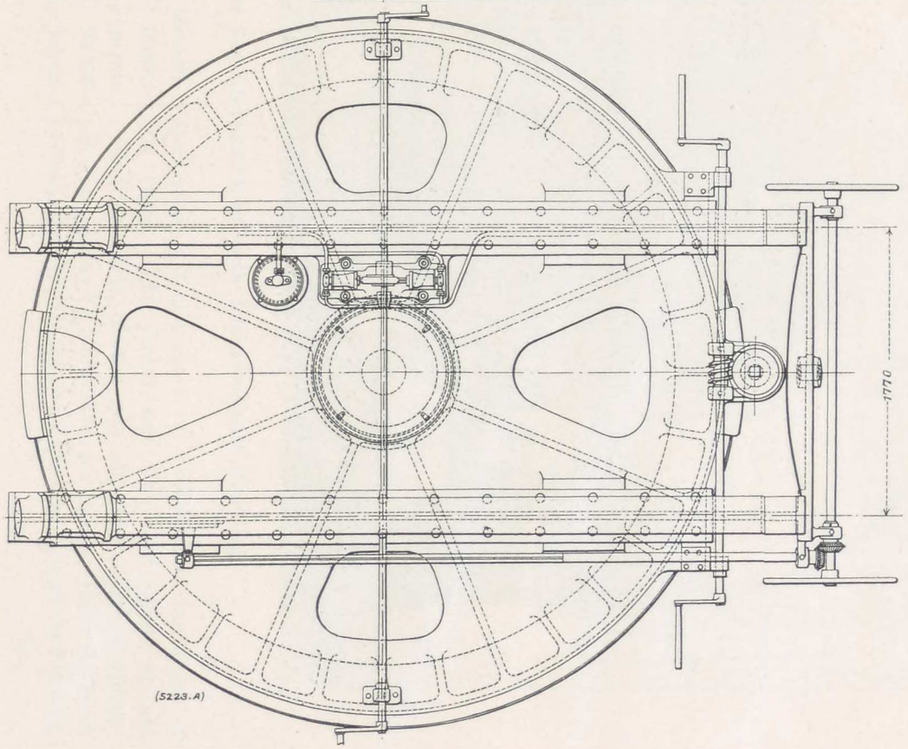


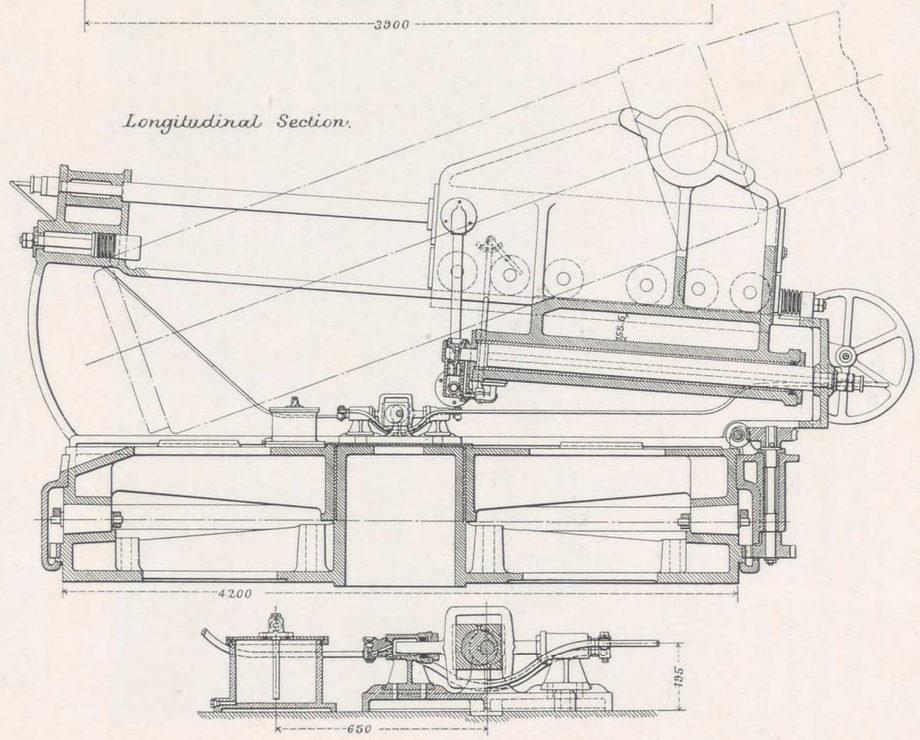
Fig. 865. Section through Brake-Cylinders.

COAST-DEFENCE GUNS.







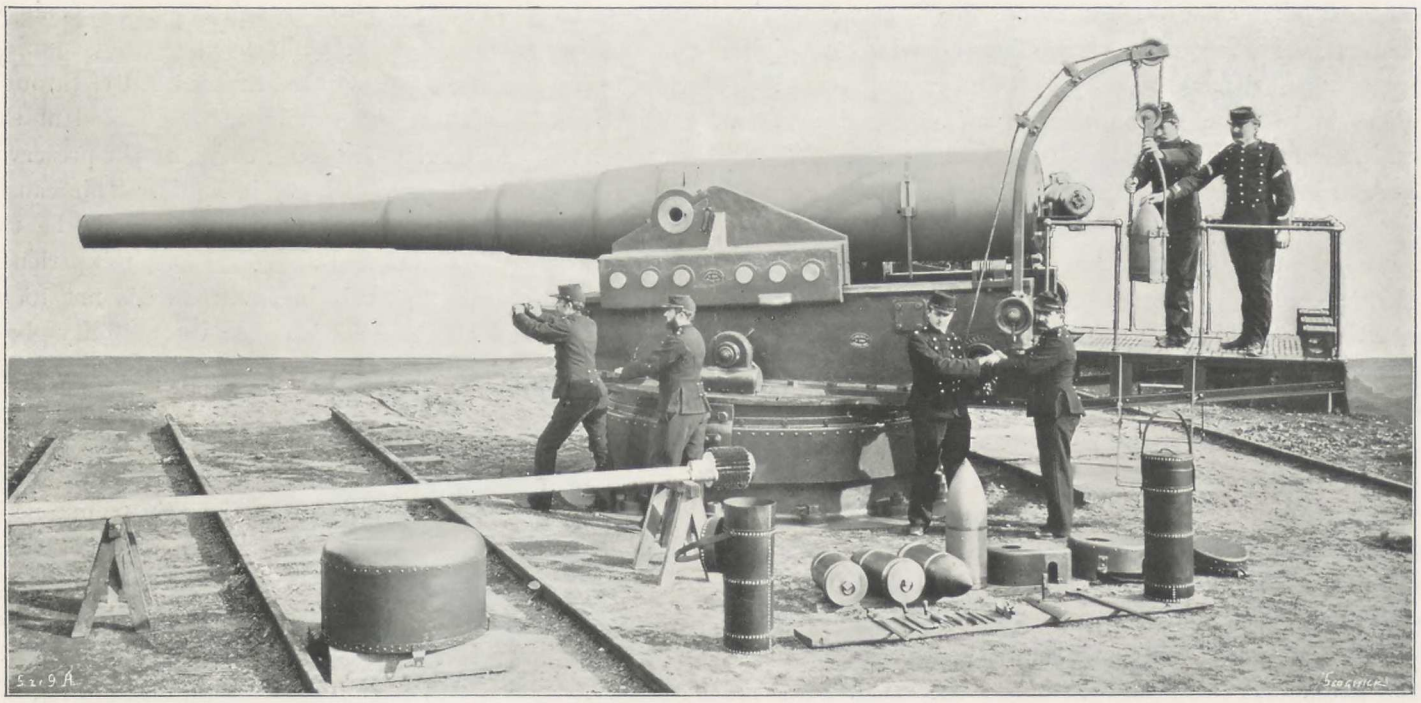


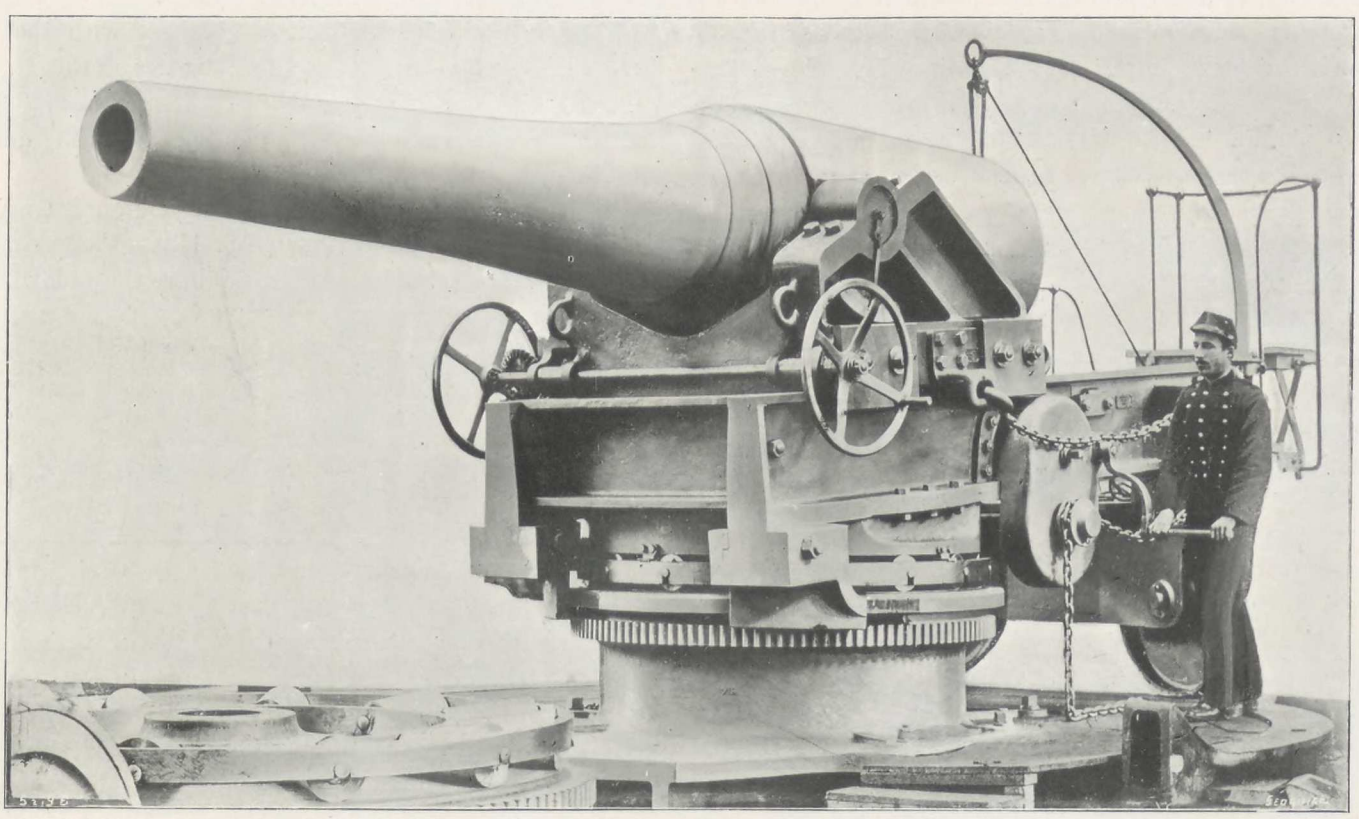
Figs. 866 and 867. 12-in. Coast-Defence Gun and Schneider-Canet Mounting.

PLATE CXLIX.

a ridge on the transom, and prevent the raising of the mounting.

24-Centimetre (9.449-In.) Coast-Defence Gun on Central-Pivoted Mounting (Fig. 868). — Armaments of this type have been supplied to the Chinese Government. The gun is 36 calibres in length; it is of forged and tempered steel, constructed to the requirements and specification of the French Navy; it weighs 20,300 kilogrammes (about 20 tons), and consists of a tube which runs the whole length of the gun, and in which is screwed the breech-block; of a jacket which surrounds the tube from the rear end, to forward of the trunnion-ring; the trunnion-ring; strengthening coils that surround the jacket, and chase-coils on two-thirds of the length of the chase. The jacket and coils are placed on the cylindrical parts of the gun, the diametrical shrinkage allowance being $1\frac{1}{2}$ millimetres per metre. From the front of the jacket, the thickness of the tube is made to diminish





Figs. 868 and 869. 24-Centimetre Coast-Defence Guns, with Schneider-Canet Mounting.

by two steps, the non-reinforced part of the tube being in the shape of a truncated cone. The force of recoil is transmitted direct to the trunnion-ring by the jacket, the latter being made with dovetails, which secure it to the trunnion-ring and to the tube. In order to prevent the sliding of the tube during firing, the bearing of the dovetails is made more secure by allowing a slight longitudinal shrinkage to the jacket and trunnion-ring.

The breech-block is on the Schneider-Canet system, with interrupted screw and composite obturator. All the parts can be put together and taken to pieces without the help of any special tool. The gun can be fired with percussion, or an electric, fuse. It fires ordinary shell, weighing 140 kilogrammes (309 lb.), and armour-piercing projectiles, weighing 164 kilogrammes (362 lb.). The charge consists of prismatic brown powder, and weighs 87 kilogrammes (192 lb.); the corresponding density being .94 (equals weight of powder divided by the capacity of the powder-chamber).

The mounting is central-pivoting, with hydraulic recoil and automatic return by gravity. It consists of a carriage, with slide and transom of cast steel, and a cast-iron bedplate ; it weighs in all 31,200 kilogrammes (31 tons). The trunnion centre is 2,200 metres (86.614 in.) above the floor level. The carriage rests on the slide with the interposition of cylindrical rollers, on which it is guided in its travel, so as to prevent all deviation or raising of the system ; it carries at its lower part two recoil cylinders, each with a piston fitted to the front of the slide. The slide is made with an incline of 4 deg. (7/100), and consists of two parallel cheeks with a cross-beam in front; it is joined to the transom, which turns round a pivot on a set of free rollers kept in place by rings. Cramps fixed to the transom hold a string-piece on the bedplate, and prevent the raising of the slide during recoil. The bedplate forms a pivot, and the string-piece above referred to serves as a circular rack for lateral training. It is bolted on wood beams to a masonry foundation, the weight of which insures the stability of the system. The range of elevation is from — 7 deg. to + 25 deg., and the required elevation is given by cranks working a shaft, and a set of gearing which acts on a toothed sector fitted to the gun. In the arrangement of the gearing, means are taken to insure a smooth working of the gun during elevation, as well as to prevent all shocks on the mechanism when there is preponderance of the muzzle. As the shaft on which the cranks are keyed is fitted to the slide and not to the carriage, the men need not leave the cranks when the gun is fired. For lateral training, the range runs through 360 deg., and this is obtained by cranks working a shaft and a set of gearing that engages the rack on the bedplate ; this same mechanism serves to run in the gun by hand-power, after disengaging a pinion to prevent the mounting from revolving; and for this a set of gearing with plate-chain transmissions is provided.

The recoil cylinders are formed for constant volume, and with loaded valves. They limit the recoil to 1 metre (39⅜ in.) maximum. During recoil, the liquid in the front part of the cylinders acts on the valve and opens it, giving a passage from the front to the rear, a small part of it flowing through two vents in the piston. When the recoil is spent, the valve closes, and the liquid in returning from the rear to the front, passes through the two openings, thus setting up a resistance which controls the running out of the gun, that takes place automatically, through the incline of the slide. The cylinders are placed at the lower part of the carriage, in order to insure the preservation of the rods and prevent losses in liquid. This causes a greater momentum in running out than would be the case were the cylinders placed above the slide ; experience, however, has shown that this inconvenience is not to be feared when, as in the present instance, the stability given to the carriage is properly proportioned to the distance from the cylinders to the trunnions—a distance which has been reduced to a minimum.

The mounting is provided with the following accessory gear : a loading crane, with quick-lowering motion ; a loading platform, from which the gun can also be trained, with hand-rail and steps for sighting at minus angles ; elastic buffers which limit the travel of the carriage on the slide in both directions ; an index for the elevation of the gun, with plates showing the direction for turning the cranks ; sheet-iron covers for protecting the delicate parts of the mechanism from dust and splinters.

The average initial velocities obtained with the gun have varied between 665 and 707 metres (2182 ft. and 2316 ft.), with a powder charge of 87 kilogrammes (192 lb.), and an armour-piercing shell weighing 164 kilogrammes (362 lb.).

24 - Centimetre (9.449 - In.) Coast - Defence Gun, on Muzzle - Pivoting Mounting (Fig. 869).—The principal characteristics of this type of material are the following :

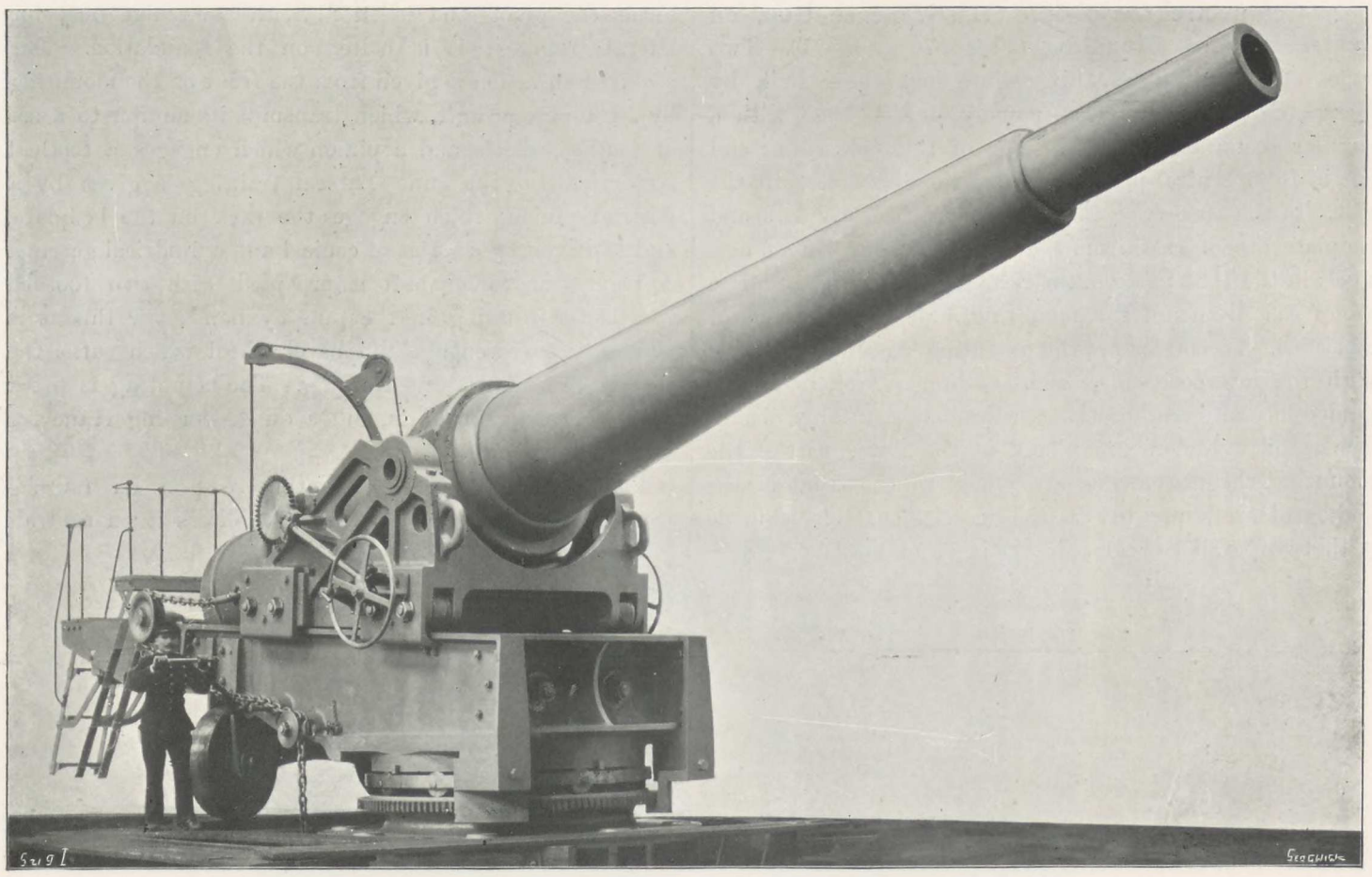
Length of gun...	19 calibres	19 calibres
Weight ,, ...	14,600 kg.	32,178 lb.
,, mounting	27,810 kg.	61,293 lb.
,, armour-piercing shell ...	144 kg.	317 lb.
,, prismatic brown powder...	39 kg.	86 lb.
Muzzle velocity in service	470 m.	1,542 ft.
Angles of elevation	+ 30 deg.	+ 30 deg.
	— 7 deg.	— 7 deg.

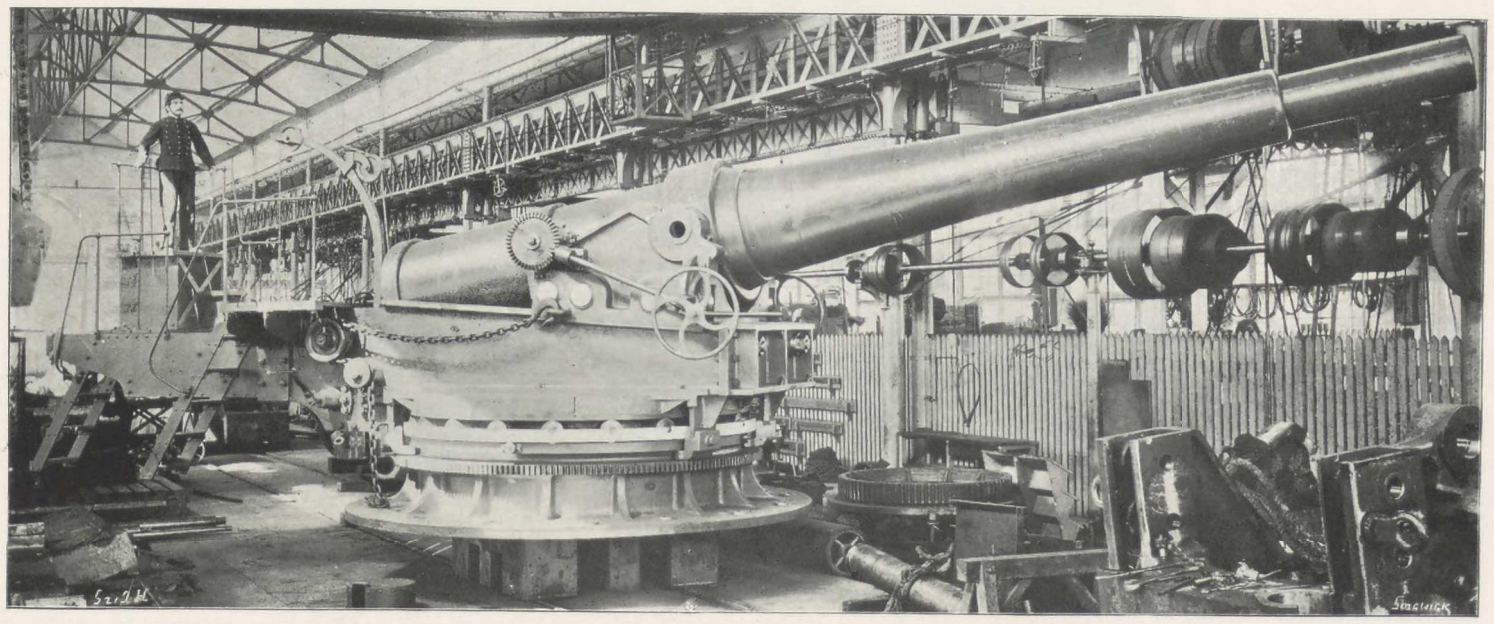
The breech-block is cylindrical, with three threaded parts and three interruptions ; it rests on a bracket which revolves round a vertical hinge-bolt. The obturator consists of a composite elastic disc, which unites the advantages of the Broadwell ring and those of the usual plastic obturator, while allowing the breech to be worked with great facility. It is placed between the movable head and the front surface of the breech-block. Firing is effected with a percussion fuse, by means of a movable bolt, or with an electric fuse, when the bolt is fitted with the necessary terminals for electric connections. The percussion piece is not in the centre of the vent unless the breech be completely closed, thus doing away with all risk of premature fire.

The mounting consists of the bedplate, and the transom,

with slide and carriage. The bedplate is made with a front pivot, and is bolted on a masonry foundation. The transom rests on conical rollers. The slide is fixed on the transom, and consists of two parallel vertical cheeks stayed in front; it is carried in the rear on wheels which turn round a circular path on the platform. The gun is protected by a shield when required.

The required elevation is given by a crank which drives, through a set of pinions, an endless screw and a toothed wheel, the latter engaging direct the toothed sector fitted to the gun. For training the gun, the mechanism consists of a crank, an endless screw, and a pinion, the latter engaging the circular rack of the bedplate.





Figs. 870 and 871. 32-Centimetre Coast-Defence Guns, with Schneider-Canet Mounting.

The hydraulic recoil cylinders are of constant volume; the plunger-rod is fitted to the slide. At the end of the recoil, the valve falls back on its seat, the liquid under

pressure only flowing through small passages; the carriage runs out again smoothly under the action of gravity. In the rear of the carriage is a platform for serving the gun, and a small crane for raising the ammunition.

32-Centimetre (12.598-In.) Coast-Defence Gun, on Central-Pivoting Mounting (Figs. 870 and 871).—Two types of mounting for this calibre have been built by Messrs. Schneider and Co.—namely, one in 1886 with a circular sector on which the rear of the slide rests; and one in 1888, central-pivoting, and without a sector in the rear. In the 1886 type, the mounting, recoil cylinders, and bedplate are of cast iron, the slide and transom of cast steel; in the 1888 pattern, the recoil cylinders and bedplate are of cast iron, and the mounting, slide, and transom of cast steel. In both types the mounting rests on the slide with the interposition of eight cylindrical rollers, and is guided laterally and underneath by clamps suitably placed. The recoil cylinders are placed at the lower part of the mounting, the piston-rods are joined to the front of the slide, and are supported in the rear. The slide is made with two parallel cheeks stayed in front and recessed in the transom. The transom turns round a pivot while resting on the bedplate on a set of conical rollers; the latter are kept apart by two concentric rings. Clamps prevent the slide from rising during firing. The bedplate forms the pivot, and is fitted with a circular rack for lateral training; it is bolted on the foundation. The required elevation is given from the front of the mounting by a transverse shaft, which transmits its motion to a set of toothed wheels, and a pinion which engages a toothed sector fitted to the gun. Lateral training is given by a vertical pinion, which engages the rack on the bedplate, and is driven by a series of conical and cylindrical gearing. A front transverse shaft is provided, with two toothed wheels for running in the gun by hand; for this it is necessary to disengage the bevel wheel which turns the vertical shaft for lateral training. The mounting is fitted with a charging platform, and a quick-working crane for serving the gun.

Fig. 870 shows the 32-centimetre gun on muzzle-pivoting mounting, while Fig. 871 shows it on central-pivoting mounting.

XXXVIII.—MORTARS FOR COAST DEFENCE.

27-Centimetre (10.630-In.) Coast Defence Mortar. (Fig. 872).—Coast-defence mortars of 10.630-in. calibre have been built in large numbers. The following are some leading dimensions:—

Weight of mortar	5,750 kg.	1,267 lb.
,, mounting	19,160 kg.	42,228 lb.
,, projectile	250 kg.	551 lb.
Angles of elevation	– 0 deg. + 60 deg.	– 0 deg. + 60 deg.
Training	through 270 deg.	through 270 deg.
Muzzle velocity, with black powder	275 m.	902 ft.

the chain turns, is set in motion by an endless screw fixed to a shaft, on which are keyed the two working cranks. The elevating mechanism consists of a toothed sector fitted to the mortar, and an endless screw; on the end of the shaft which carries the latter is keyed a square pinion driven by another pinion, on the shaft of which is keyed the working crank.

30-Centimetre (11.811-In.) Muzzle-Loading Rifled Mortar, 1883 Pattern, on Coast-Defence Mounting (Fig. 873).—Mountings of this pattern were built by

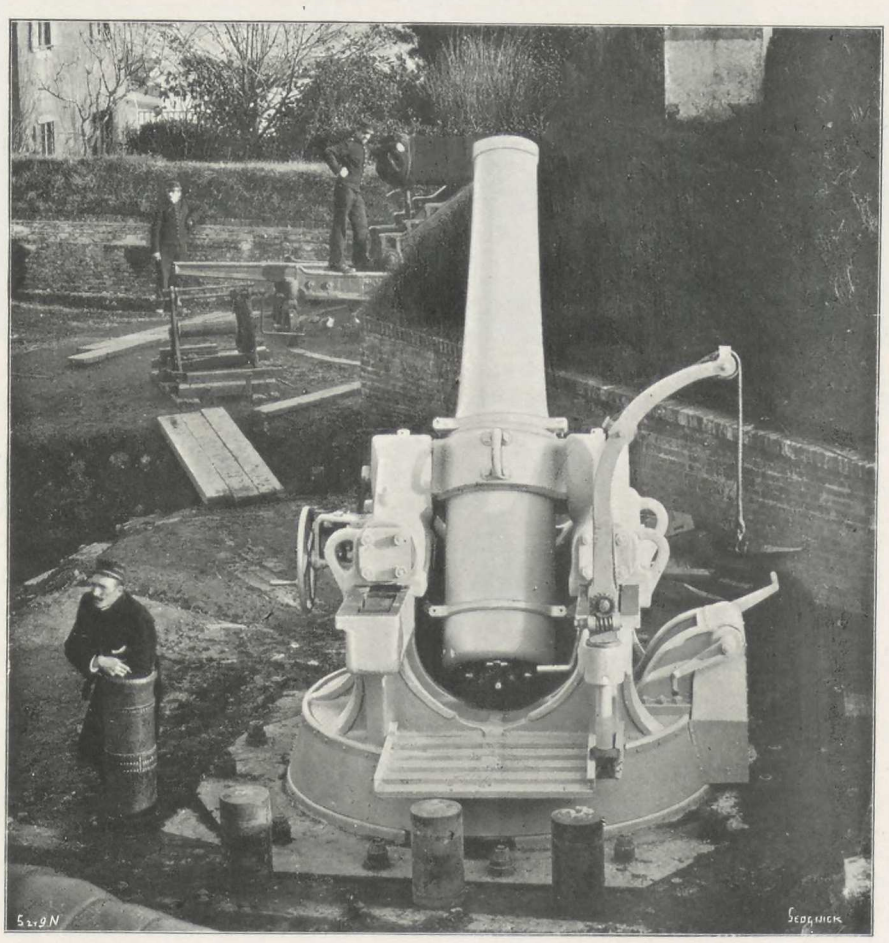


Fig. 872. 27-Centimetre Mortar and Coast-Defence Carriage.

The 10.630-in. mortar illustrated is placed on a mounting, the general arrangements of which are similar to those of the mounting for the same calibre of coast-defence guns already described. In the mortar, however, the height of the trunnions being very much less than in the 10.630-in. guns, the platform for loading and training is not required; the bedplate is fitted with the circular rack and pivot housing, for the pivot on the lower part of the slide. In the lateral training mechanism, the helicoidal wheel, cast in one piece with the grooved pulley on which

Messrs. Schneider and Co. in 1889. They are arranged so as to allow an elevation of from — 5 to + 70 deg., and lateral training through 200 deg. The mounting is built up of steel plates and angles; on the top in front are the trunnion supports, while underneath are two cast-steel frames each containing seven cylindrical rollers, which revolve on the slide. The necessary guiding is secured on the sides and underneath by four clamps of forged steel. A cast-iron recoil cylinder is recessed in the lower part of the mounting, to which it is strongly bolted; the piston-

rod is joined to the front and to the rear of the slide. The slide consists of two I-beams, stayed together in front and in the rear. The slide is fitted, in a line with the mounting trunnions, with a strengthening piece forming a transom. In the rear there is a stay-plate, with two supporting rollers for the mounting trail. The slide is built up of steel plates and angles. The mounting and slide rest in front on a bedplate, and in the rear on a circular segment with the interposition of coned rollers. The bedplate and the rear segment are of cast iron, and rest on oak beams imbedded in the foundation.

The gun is elevated from the front of the mounting by means of a transverse shaft, which works a toothed sector keyed on the left-hand trunnion of the mortar. It is trained from the rear of the slide; a transverse shaft works the pinion which engages the rack of the circular sector, through conical and cylindrical toothed wheels. On the slide is fitted a crane for serving the mortar with ammunition.

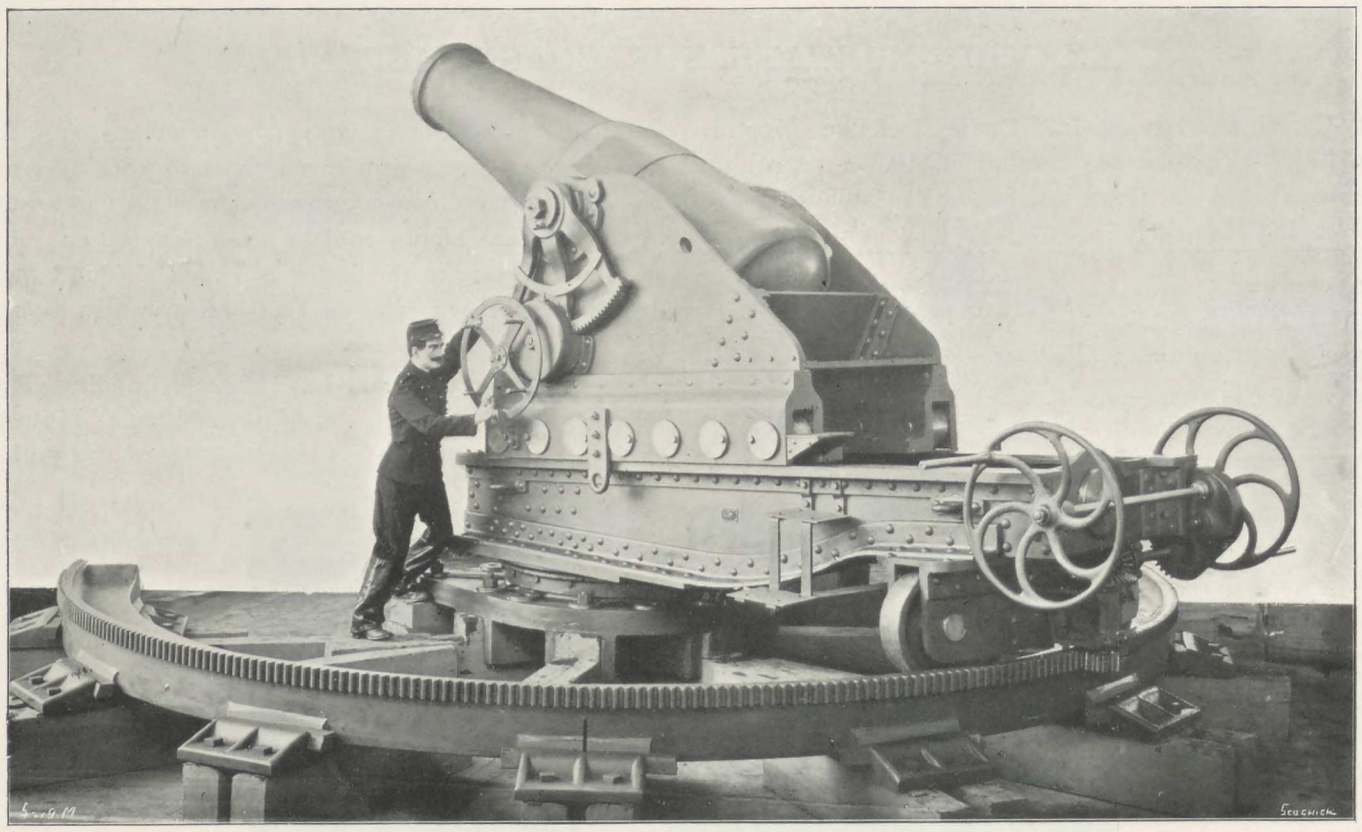


Fig. 873. 30-Centimetre Muzzle-Loading Mortar and Coast-Defence Mounting.

XXXIX.—QUICK-FIRING COAST-DEFENCE GUNS.

A CERTAIN number of points selected for coast defence, and especially for "armour-piercing coast batteries," have to be armed with guns of high power and flat trajectories, permitting a rapid concentration of fire against a target. It is important in many cases that coast-defence batteries should be in a position to compete thoroughly, under conditions approximately equal, with quick-firing naval guns, while it is necessary to take into consideration the ease with which modern fleets can perform their evolutions. A special class of Schneider-Canet quick-firing guns contains a complete series of calibres, from 37 millimetres (1.456 in.) to 24 centimetres (9.449 in.), for carrying out this programme to the best advantage. This class of *matériel* has been adopted for regular service by various Governments, especially by Russia and Japan, the two latter countries having acquired the right to reproduce the type in their own arsenals. As a rule, these guns are similar to those used on board ship, as regards construction and breech-closing devices, but they are frequently of longer calibre, in order to obtain higher muzzle velocities and flatter trajectories. The mountings are also similar to naval mountings; but as coast-defence guns have to fire under great angles, both positive and negative, the mounting is either placed upon a concrete base or upon a cone built up of plates and angles. As the guns of this class are similar, except in dimensions, to the naval guns already described, we shall select for the following descriptions a few only of the most interesting types that embody particular devices, and are placed upon special mountings.

12-Centimetre (4.724-In.) 26-Calibre Quick-Firing Coast-Defence Gun (Fig. 874, Plate CL.).—This has been adopted for regular service in Japanese coast defences. The programme that had to be fulfilled according to the Japanese artillery stipulations, stated that the gun should be of medium power, (muzzle velocity 600 metres only = 1968 ft.), quickly trained and fired by a limited number of men. In connection with this order, the Japanese Government established competitive trials, in which the Schneider-Canet ordnance obtained the first rank, and was definitely adopted. The following are some leading data:

Weight of Gun	1620 kg.	3570 lb.
Length of gun	3.120 m.	10 ft. $2\frac{13}{16}$ in.
Weight of mounting	2780 kg.	6127 lb.
,, base	1800 kg.	3967 lb.
,, shield	1500 kg.	3306 lb.
Maximum angles of elevation ...	− 7 deg. + 20 deg.	− 7 deg. + 20 deg.
Training	through 140 deg.	through 140 deg.
Weight of projectile	18 kg.	40 lb.
,, powder charge, French smokeless powder	2.8 kg.	6 lb.
Muzzle velocity	560 m.	1837 ft.

The mounting is fitted with a shield which protects the working parts and the gunners. The mounting consists of four main parts, namely: The built-up base, in the shape of a truncated cone, stayed inside and bolted to the firing platform, the loading platform being in the rear; the bedplate, fitted to the base and provided with roller balls, the central pivot being joined by ribs to the circular ring; the slide which rests on the bedplate on the balls and consists of two cheeks made practically vertical, the latter being provided with under trunnion plates strengthened in the middle by stays, the cheeks joined together by a stiff plate; the gun carriage, which consists of a cast-steel jacket, in one piece with which is cast the lower part of the hydraulic recoil cylinder; the trunnions are in the front part of the jacket; while inside, gun-metal rings at both ends serve to guide the gun during recoil. At its lower part, over a part of its length, the carriage is made with a gap forming two slide paths to guide the butt end, which draws the recoil piston-rod with it. A transverse bar with buffer is placed in front, to check the travel of the gun when it runs out again.

The recoil cylinder is on the Schneider-Canet system, with central counter-rod. It acts as follows: During recoil the gun draws along with it the recoil piston, its rear surface presses on the glycerine in the cylinder, and forces it to flow through the annular vent cut round the central rod and through the lateral vents cut round the piston. The glycerine flows to the front part, the valve which establishes a communication between the two ends of the cylinder being raised. The inside capacity of the cylinder decreasing by a quantity equal to the volume of the rod which penetrates it, the corresponding excess of liquid moves the bottom of the cylinder, which acts as a plunger; this moves the transverse bar and presses down the recuperating springs. When the recoil is spent, the springs, in relaxing, drive back the transverse bar and the cylinder bottom, thus forcing the glycerine to resume its former position; but as the valve is closed, it can only flow through the narrow vent in the valve seat, the gun returning, therefore, slowly and without shocks.

The training gear, both for vertical and horizontal angles, is of the ordinary type, and so need not be described.

12-Centimetre (4.724-In.) 40-Calibre Quick-Firing Coast-Defence Gun.—This gun is on the same system as the preceding one, but is of a much greater power.

The mounting is provided with a platform, and consists of five main parts:

(*a*) The base, made of plates and angles, carries the firing platform, and contains the roller path. At its

lower part are eight recesses containing rounds of ammunition for insuring rapid firing.

(*b*) The circular bedplate with pivot.

(*c*) The slide which rests on the bedplate through a live ring; it consists of two cheeks stayed together, and is fitted with the trunnion plates.

(*d*) The loading platform on the rear of the slide; it bears on the base with the interposition of rollers.

(*e*) The carriage which carries the gun; this is made with two trunnions that rest in the slide, and is of the same type as that for the preceding gun, as also are the hydraulic recoil cylinder and the recuperator.

Weight of gun...	2650 kg.	5840 lb.
,, mounting	4130 kg.	9102 lb.
,, base	1850 kg.	4077 lb.
,, shield	1650 kg.	3636 lb.
Elevation	– 10 deg. + 15 deg.	– 10 deg. + 15 deg.
Training	through 360 deg.	through 360 deg.
Weight of projectile	21 kg.	46 lb.
Muzzle velocity	650 m.	2132 ft.

6-In. 50-Calibre Quick-Firing Coast-Defence Guns (Fig. 875, Plate CL.).—Guns of this type have been supplied to the Russian Government.

Weight of gun...	6,230 kg.	13,731 lb.
,, mounting	10,400 kg.	22,921 lb.
,, base	3,180 kg.	7,008 lb.
,, shield	1,720 kg.	3,791 lb.
Elevation	– 10 deg. + 30 deg.	– 10 deg. + 30 deg.
Training	through 360 deg.	through 360 deg.
Weight of projectile	43 kg.	95 lb.
Muzzle velocity	720 m.	2362 ft.

The mounting consists of the following main parts:

(*a*) The base, built up of plates and angles, in the shape of a cone, strengthened by gusset plates; the firing platform is bolted to it by means of a circular soleplate.

(*b*) The bedplate, which rests on the cone and is provided with rollers to facilitate rotation. The bedplate is fitted also with the pivot and the circular rack for lateral training.

(*c*) The slide consists of two cheeks with trunnion plates for the carriage trunnions; they are strengthened in front by a rib, and are joined at their lower part by a plate of suitable shape, in which the bedplate pivot fits.

(*d*) The gun carriage consists of a fixed part, and of a movable one which follows the recoil. The fixed part contains two lateral spring beams, a front and a rear collar, and a hydraulic recoil piston. The string beams contain the trunnions, and are bolted at their two ends on the collars. The front collar is provided with a plastic ring, which forms a buffer for the mounting jacket when the gun runs out again. The rear collar is lined inside with gun-metal bushes; it is continued at its lower part, and forms a butt, to which is joined the recoil piston. The movable part contains a jacket, which remains joined to the gun in front by tongues and grooves, and in the rear by two half-rings placed in a groove of the gun; a recoil cylinder cast in one piece with it; two lateral slide shoes, forming clamps which hold on the string beams and support the gun during recoil.

The arrangements of the recoil cylinder and recuperator are the same as those for the 12-centimetre guns, except that the recoil piston-rod is jointed in the rear, and does not follow the recoil. In the case of the present mounting, the cylinder is drawn by the gun, the piston remaining fixed. Moreover, the set of recuperator springs is divided into two parts, and consists of Belleville rings. The slide is continued in the rear by a loading platform. A shield of suitable shape and dimensions protects the whole mechanism.

SCHNEIDER-CANET QUICK-FIRING GUNS FOR COAST-DEFENCE.

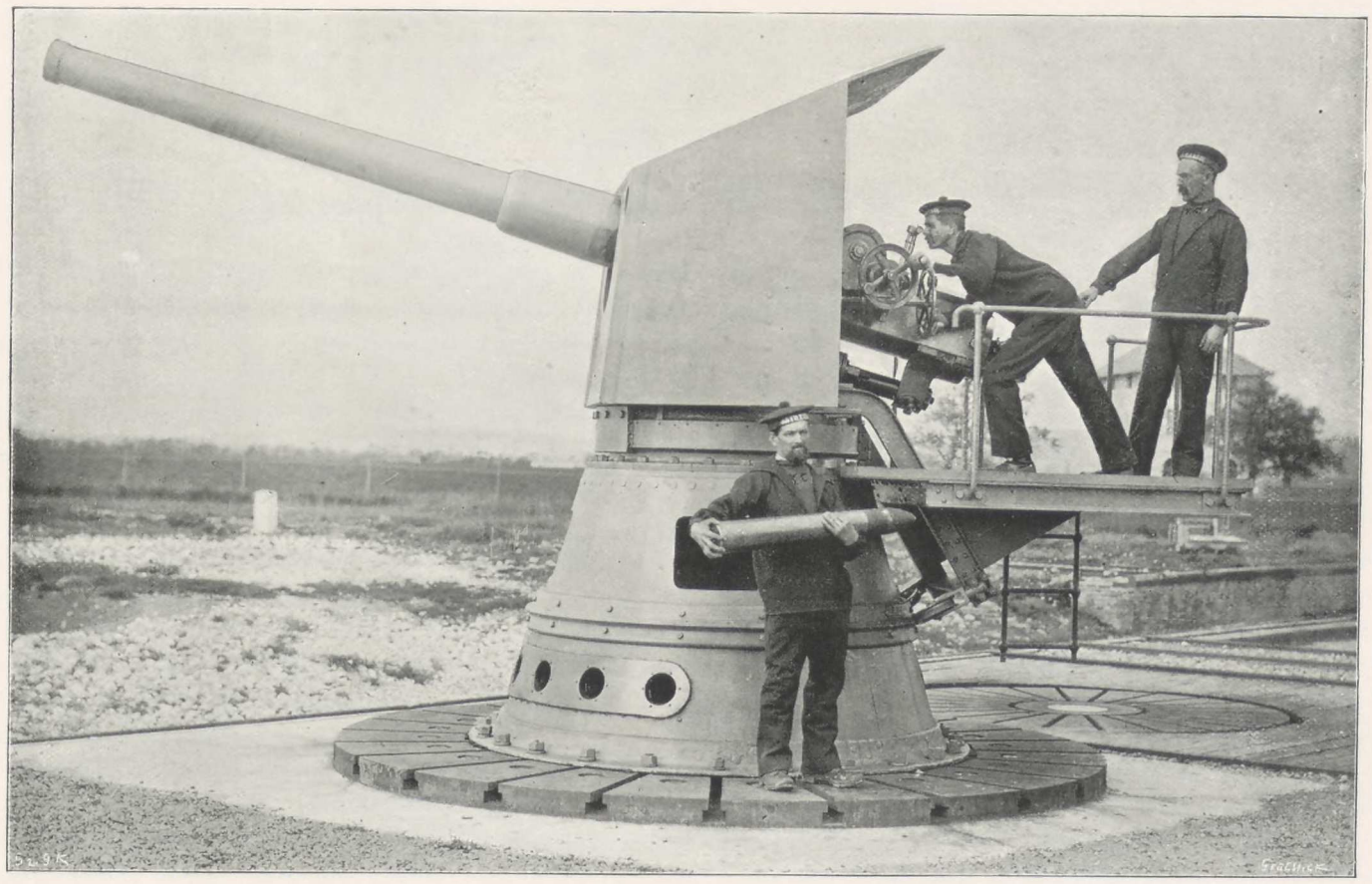


Fig. 874. 12-Centimetre 26-Calibre Quick-Firing Gun and Coast-Defence Mounting.

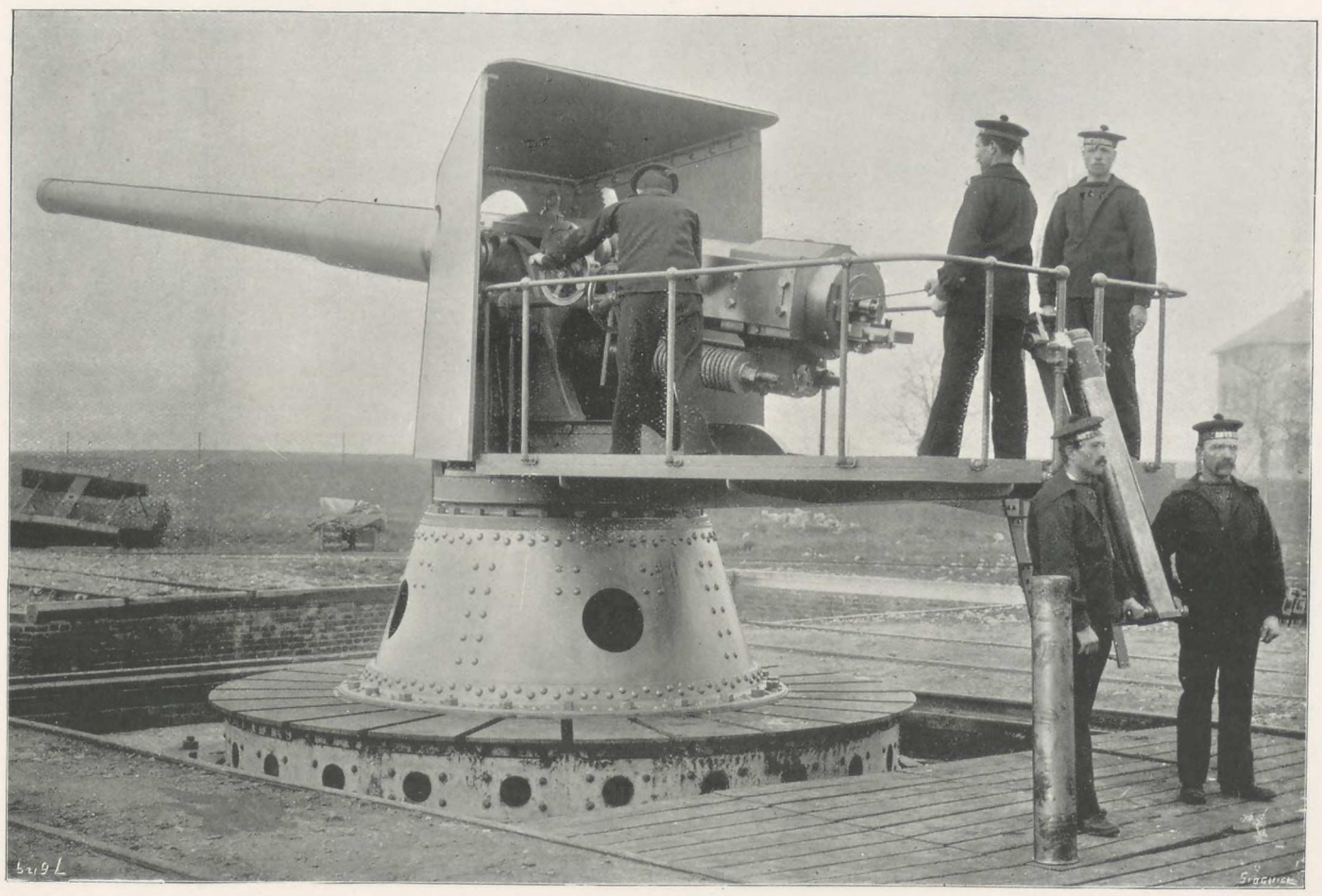


Fig. 875. 6-in. 50-Calibre Quick-Firing Gun and Coast-Defence Mounting.

XL.—DISAPPEARING GUNS AND CARRIAGES.

CLASSIFIED under this general heading are those guns which, when fired, oscillate round movable supports, and thus are caused to disappear; either to be run out again immediately, or only when the operations of reloading and training have been completed. Although mountings of this type are used indifferently for coast defences and for garrison armament, and also in some cases on board ship for mortars and howitzers, it has been found preferable to classify this material separately, and to give the following general data concerning the principal types manufactured and put in service by Messrs. Schneider and Co. As in preceding cases, the principal types only, and those which are of representative calibres, have been selected for description.

75-Millimetre (2.952-In.) Guns on Lever Mountings.—These are used with advantage for the armament of light-draught boats, and were described at the commencement of this series; they are simply mentioned here to make the present section complete. With this mounting the gun does not remain run down; but it rises up again immediately for reloading and training, the lever being short enough to enable the breech to be freely worked.

90-Millimetre (3.543-In.) Gun on Disappearing Carriage, for Coast Defence and Garrison Armament (Figs. 876 to 879, Plate CLI.).—This type is of reduced weight, and, considering its calibre, is of great mobility. It has been designed specially with a view to be easily carried on wheels, and to form the movable armament in a series of distinct positions communicating with each other by a single road; it is, in fact, a highly mobile gun of position. A limited number of such guns is sufficient to defend a largely extended front. The various parts are so arranged that, according to circumstances, firing can be effected while the carriage stands on its wheels, or after placing the gun on a fixed mounting provided in advance at suitable places.

Weight of gun...	530 kg.	1168 lb.
,, carriage	1200 kg.	2645 lb.
,, projectile	8 kg.	17 lb.
Muzzle velocity	460 m.	1508 ft.
Extent of lateral range when the gun is placed on fixed bedplates ...	360 deg.	360 deg.

The carriage consists of the rising and falling arms, the slide, the coupled wheels with bedplate, or the coupled wheels with limber, as the case may be. The arms are formed of two cheeks which carry the trunnion bearings at their top part; in these the gun trunnions are placed. The arms turn round an axle sheathed with india-rubber for deadening as much as possible all shocks on the bedplate during firing. The arms end below in two extensions connected by a rod, on which is jointed the head of the recoil piston-rod. The slide is of plate-iron and angles, and consists of two lateral supports, in which are placed the lever pivots; the supports are joined below on a circular platform, the latter being of the same dimensions as the top of the bedplate, to which it is fixed by a hinged clamp, to prevent shifting. The wheel axle runs through the slide; a roller in a jointed frame is provided, and it can take either of the two positions shown. This slide also carries, the fixed platform for training the gun, and the jointed platform for loading it; the latter is arranged to fall down when the position of the gun is shifted; it is also fitted with the recoil cylinder shaft. The recoil cylinder is fitted with a central counter-rod, of the standard type. The fixed mounting is of cast steel, and is made with a horizontal ring for bolting it to the foundation; this ring is continued by a spherical part ending at the top in another ring, on which is placed the lower portion of the slide.

A toothed sector, fixed to the gun and worked by differential gearing, and by a pinion on a friction cone, is used for elevating; the mechanism is driven by a hand-wheel carried on the left-hand cheek. The toothed sector is made long enough to place the gun in a suitable position for transporting it. Lateral training is obtained by hand action on the rear of the slide; a pointer fitted on the hinged clamp travels over a scale on the bedplate, and shows the angle through which the gun has been trained laterally.

When the gun is on the fixed mounting, as shown in Figs. 876 and 877, Plate CLI., placing in battery is effected by setting the carriage in such a position that the front wheels come opposite two grooves cut in the rim of the bedplate (Fig. 876); in this position, the whole system rests on the top of the bedplate, and the wheels can turn freely round on their axle. The grooves are made perpendicular to the mean firing axis. When the carriage is so placed, and when the bolt is removed which holds the recoil piston-rod to the arms, a shoulder bar is put in the spokes of the wheel, and is made to bear underneath the arms. The wheels are then turned by means of two winches placed on the limber axle and driven by levers, thus causing the cheeks to oscillate and run out the gun. When this is done, the gun is ready for firing, and the junction between the beam and the recoil piston-rod is re-established. The running down of

the gun is effected by an inverse operation, the winch ropes being used only to regulate the lowering motion of the gun. When it is required to fire the gun away from the platform, the limber axle is joined to the slide, and the wheels are wedged by shoe-brakes to limit recoil; in the latter case, the roller is brought up against the lower surface of the slide.

12-Centimetre (4.724-In.) Gun on Disappearing Carriage (Figs. 880 to 884, Plate CLI., and Fig. 885).

Weight of gun	1400 kg.	3086 lb.
,, carriage	4000 kg.	8818 lb.
,, projectile	21 kg.	46 lb.
Muzzle velocity	500 m.	1639 ft.
Training	through 360 deg.	through 360 deg.
Elevation	+ 15 deg. – 5 deg.	+ 15 deg. – 5 deg.

This carriage consists of the swinging beam, the revolving platform, and a bedplate.

The beam is formed of two vertical cheeks firmly stayed together, and which end at the top in trunnion plates that carry the gun trunnions. The beam pivots round an axis carried by the revolving platform, and ends at the lower part in two arms, which act through jointed rods on the head of the recoil piston-rod. The revolving portion is circular in shape, made of cast steel, and has at its top the two brackets which carry the beam trunnions; it rests on a set of rollers on the bedplate, and contains the following parts:

(*a*) The hydraulic recoil cylinder, in the piston of which are cut vents of varying sections. The piston-rod is jointed on a slide shoe, which travels between two horizontal gun-metal slides, and is fixed by a horizontal shaft to the two jointed rods, the other ends of which are fitted to the arms at the lower part of the beam.

(*b*) The spring recuperator, consisting of four cylinders placed in pairs on each side of the carriage, parallel with the recoil cylinder, and in which work plunger pistons loaded with Belleville springs. The first cylinder near the front contains the plunger, and the second one, which is longer, holds the recuperator springs. The arms are fitted loose on the axle that carries the beam, and the ends of these are joined to the lower end of the rods which support the chase of the gun. The gun thus forms the fourth side of a jointed parallelogram. A series of clamps joins the revolving platform to the bedplate, to prevent the shifting of the system. The bedplate is provided with a ring in which are placed the foundation bolts; and besides the roller path it contains a central pivot cased in the revolving platform; the bedplate rests mainly on an iron plate embedded in a concrete foundation.

The required elevation is given by acting on a vertical handwheel on the front of the platform, the shaft of which has an endless screw engaging a toothed wheel keyed on a shaft perpendicular to the carriage cheeks, and driven by two cones. At each end of the latter shaft is keyed a pinion which engages a toothed sector that forms part of one of the arms fitted loose on the beam axle. Under these conditions, the jointed rods give to the gun, by acting on the handwhee the required incline, which can be measured by the levelling instrument placed on the top part of one of the arms. Lateral training is obtained direct, by hand, by means of levers fitted to the platform, and is measured with a pointer which travels on a scale marked on the bedplate.

When the gun is fired, it is thrown to the rear, being held parallel by the two rods, and it draws along with it the beam which pivots round its axis. In this motion the pieces on the lower end of the beam act on the recoil piston and bring it forward. A certain quantity of liquid is thus driven from the recoil cylinder, and flows to the lateral cylinders of the recuperator, through a tube on which is a loaded valve; it drives the plungers to the rear, and causes the set of springs to be pressed down. When recoil is spent, the valve falls back on its seat, and the gun remains run down; it is then loaded afresh. To run it up again, it is sufficient to re-establish a communication between the lateral cylinders and the bottom of the recoil cylinder, and this is obtained by means of a valve worked by a handle placed outside the valve-box. The liquid driven by the relaxing of the Belleville springs acts on the large surface of the piston, and runs up the gun again at a speed that can be regulated at will by controlling the opening of the valve.

All the parts forming this mounting are very simple, and are of easy access for inspection and removal.

15-Centimetre (5.905-in.) Howitzer on Mounting, with Circular Brake (Figs. 886 to 888).

Weight of howitzer ...	820 kg.	1807 lb.
,, mounting ...	2200 kg.	4848 lb.
,, projectile ...	32 kg.	70 lb.
Muzzle velocity (with black powder) ...	300 m.	984 ft.
Angle of elevation ...	from – 0 deg. + 60 deg.	from – 0 deg. + 60 deg.
Training	through 360 deg.	through 360 deg.

The gun is of the Schneider-Canet type already described, with tube, trunnion jacket, and wedge coil, The breech-block has helicoidal segments, and works with one operation. The mounting has been designed specially for plunging fire, and comprises a bedplate, with slide and beam. The top part of the bedplate forms a roller path; its outside rim ends in a ring for the bolting of the system to the firing platform. The slide rests on a set of rollers; two clamps, one in front and one in the rear, prevent the raising of the system. The beam consists of two cast-steel cheeks strengthened with ribs, and ending at their lower part in two trunnions carried in two blocks cast in one piece with the slide; the gun trunnions fit in trunnion plates at the top of the beam. The position of the gun is regulated by two rollers fitted on a rod jointed with the beam. The rod is supported at a point in a line with a roller nearest the breech, by a piston lodged in the beam and made to bear on a spring. Owing to this arrangement, the beam, in oscillating, draws the gun with it smoothly and without any great shocks.

SCHNEIDER-CANET GUNS AND DISAPPEARING CARRIAGES.

Fig. 876

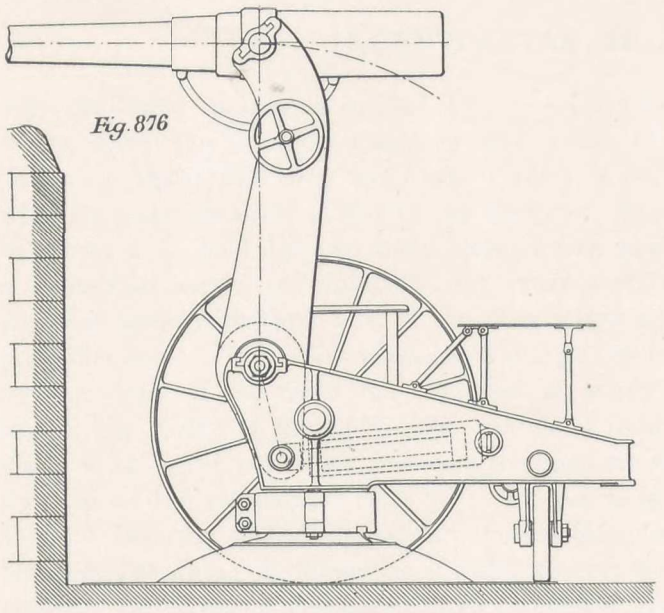


Fig. 877

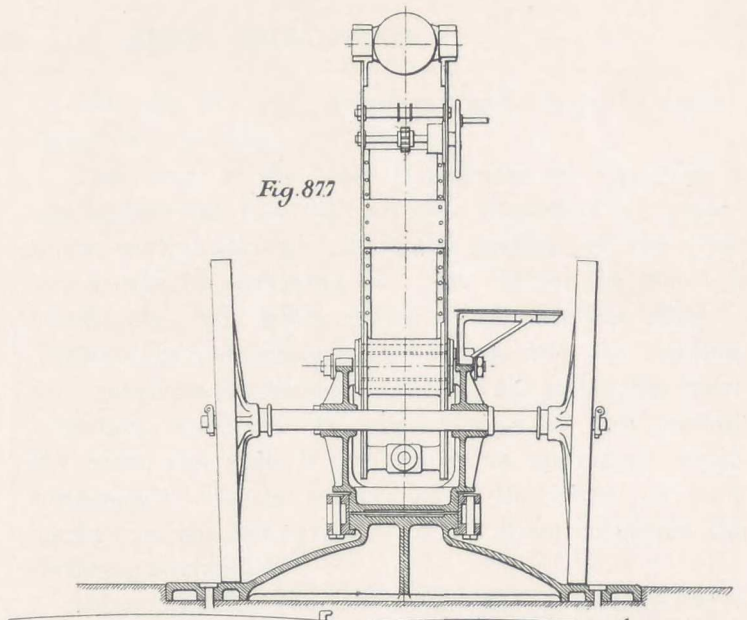


Fig. 878

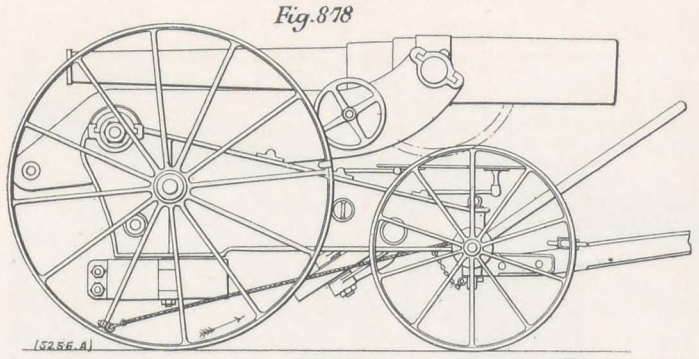
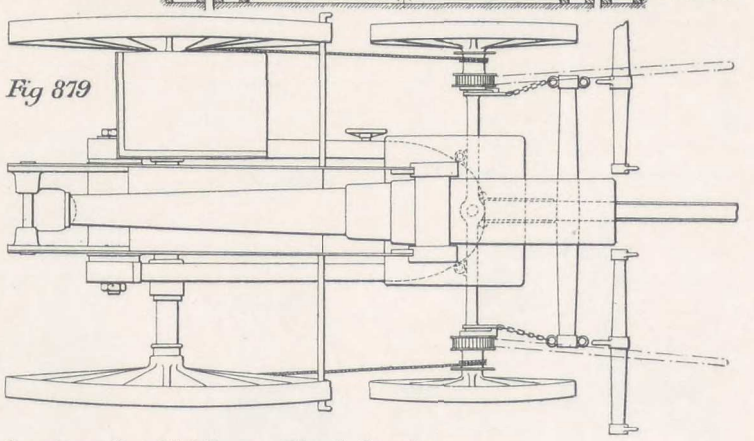


Fig 879



90-Millimetre Gun on Disappearing Carriage for Mobile or Fixed Service.

Fig. 880

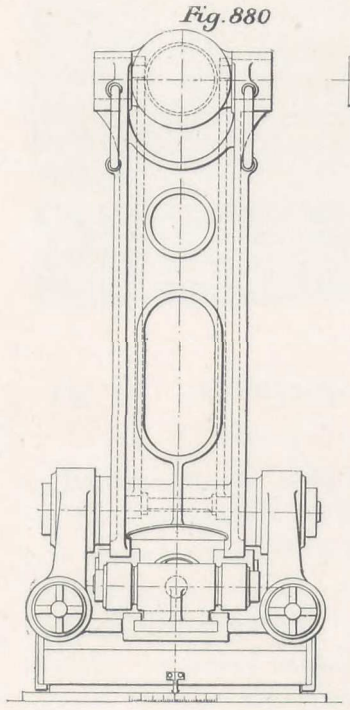


Fig 881.

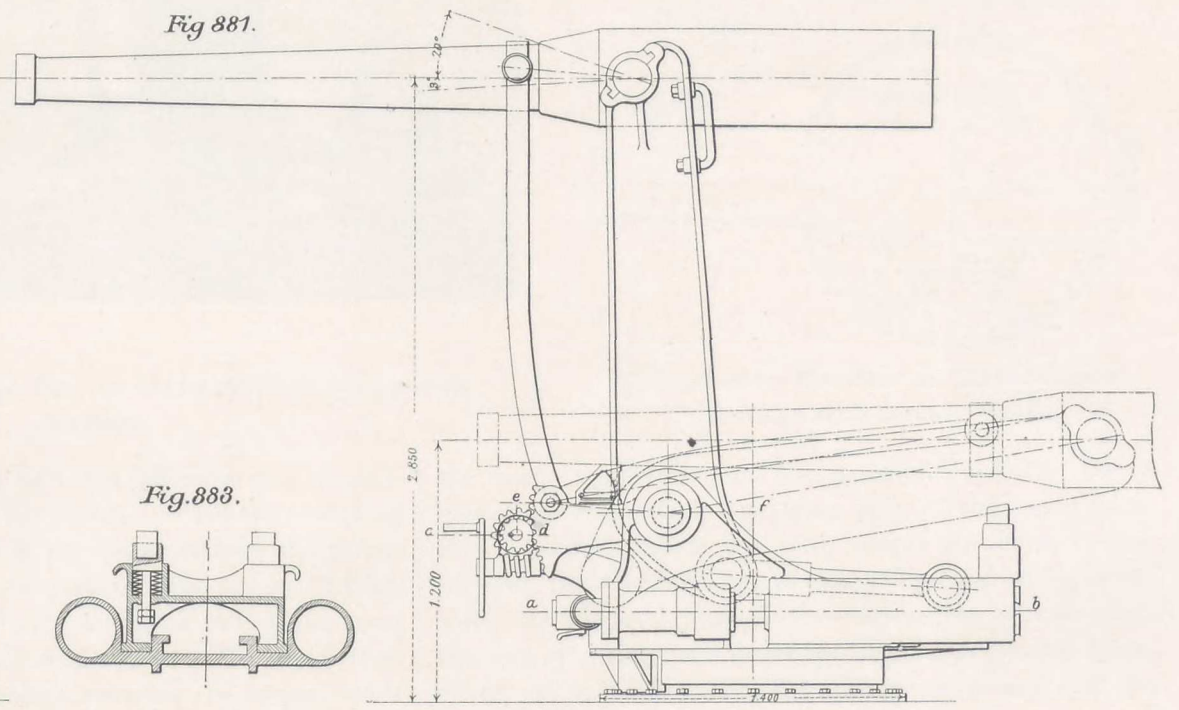


Fig. 883.

Half Section a.b. *Half Section c.d.e.f.*

Fig. 884

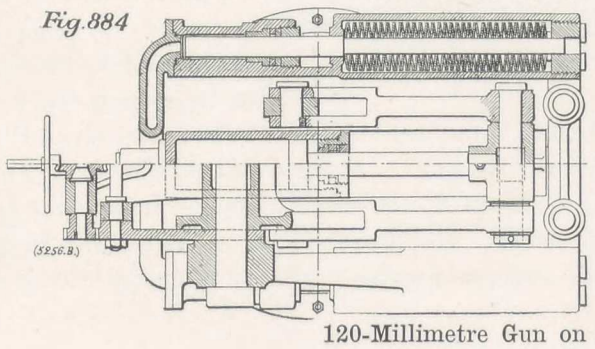
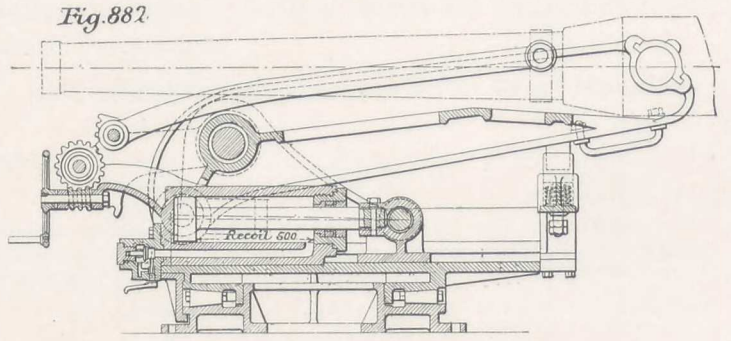


Fig. 882



120-Millimetre Gun on Central-Pivoted Disappearing Carriage.

The oscillating motion is limited by a special type of brake, styled the Schneider-Canet circular brake; it consists of a shaft (Fig. 888) made with three ribs parallel with its centre line and placed in the blocks of the slide, in which it is held by two nuts. Round this shaft is a cylindrical jacket of gun-metal, the inner surface of which is made with three ribs of the same shape as the preceding ones. This jacket is almost entirely surrounded by the drum of the beam, the trunnions of which rest also in the blocks of the slide. The gun-metal jacket is made at its lower part with two lugs, to which are fitted the rods of the recuperator cross-bar; this bar bears on a set of Bellevile springs lodged in a horizontal cylinder bolted on the slide. A sliding piece, which travels on the screw of the elevating mechanism, goes through a groove to disengage the jaw. A scale is traced round the circumference of the slide.

The drum of the beam is provided in front with a semi-cylindrical box, with an axle formed of an endless screw worked through differential gearing, on which the wheel acts for elevating the gun. When the wheel is turned, the slide which moves on the endless screw is displaced in a direction corresponding with the rotation, and travels on the helicoidal slide of the jacket, the latter remaining fixed on its axle. Owing to this motion, the beam, and with it the gun, takes an incline which corresponds with the revolutions of the wheel. A scale marked on the left trunnion of the beam completes the elevating mechanism.

When fired, the gun falls to the rear by turning round

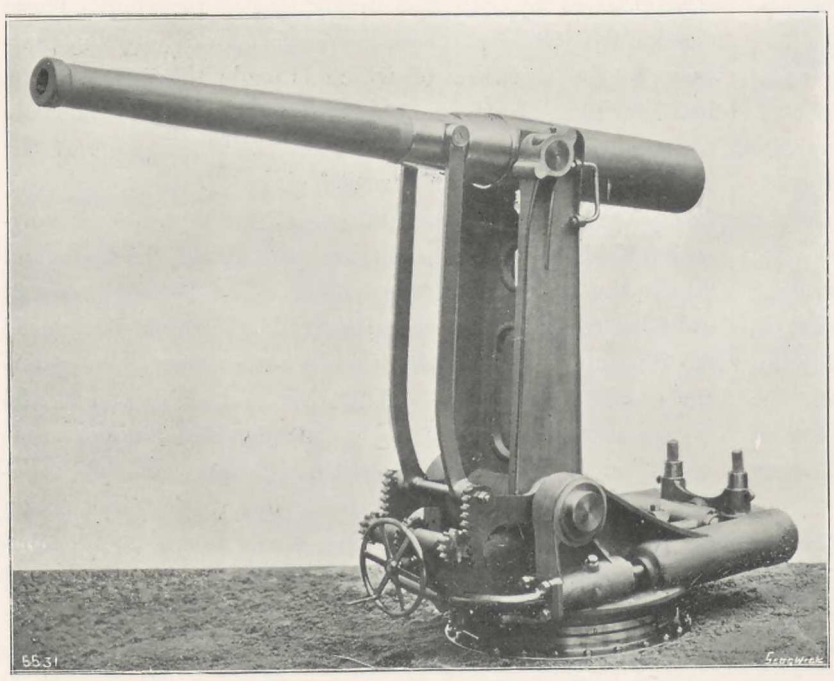
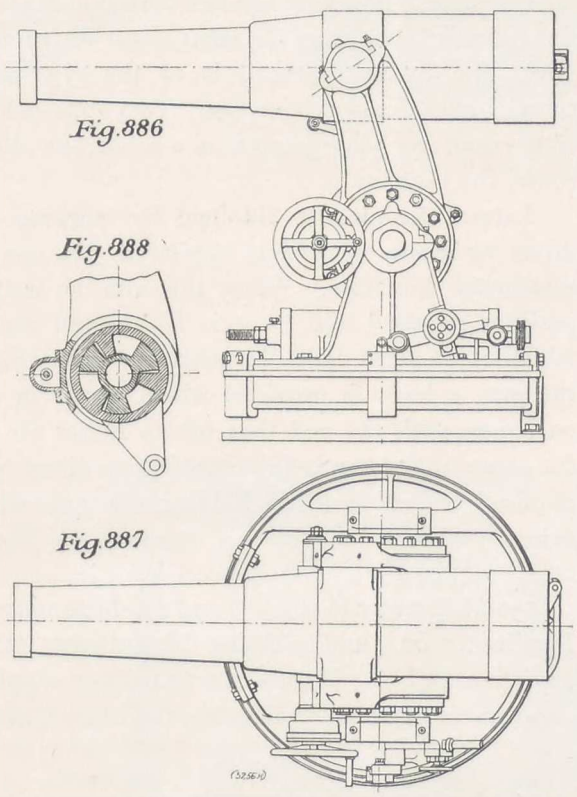


Fig. 885. 120-Millimetre Gun, on Central-Pivoted Disappearing Carriage.



15-Centimetre, Howitzer on Central-Pivoted Carriage with Circular Brake.

on the drum, its end being held in a helicoidal groove made on the circumference of the jacket. When the mounting is in battery, the liquid is in the spaces between the pallets on the shaft and those on the jacket; when the gun is fired, its oscillation round the beam trunnions causes the beam to pivot, the jacket being drawn with it. The liquid then escapes through the openings between the central shaft and the extreme edges of the jacket pallets. The openings are made of a suitable section, in order to ensure a practically constant pressure in the recoil cylinder during the whole time recoil lasts.

The gun is trained by acting direct on a lateral lever, which is carried on the bedplate. The smaller arm of the lever forms a jaw which holds the rim of the slide, and the ring of the bolster to fix the mounting. When the gun has to be trained, it is only necessary to raise the lever to disengage the jaw. When the gun has to be trained, it is only necessary to raise the lever the beam trunnions, and the hydraulic cylinder begins immediately to work, deadening part of the recoil force, this force being made use of to compel the liquid to flow between the extreme edges of the pallets and the opposite wall. At the same time, the two lugs on the jackets cause the sets of springs of the recuperator to be pressed down. When the recoil is spent, the springs relax and run the system out again. All this takes place automatically and without any shocks.

15-Centimetre (5.905-In.) Mortar on Beam Mounting:

Weight of gun	440 kg.	970 lb.
,, mounting	1800 kg.	3967 lb.
,, projectile	32 kg.	70 lb.
Muzzle velocity ...	200 m.	656 ft.
Elevation	from 0 deg. to + 60 deg.	from 0 deg. to + 60 deg.
Training	through 360 deg.	through 360 deg.

This mortar is of similar construction to the howitzer just described. The mounting has been designed specially for plunging fire. It consists of the following main parts; A bedplate with slide and beam. The slide rests on a set of rollers, and is held in place by two clamps that bear on a rim of the bedplate, thus insuring the stability of the system, and preventing it from rising when the gun is fired. The beam consists of two arms strengthened with ribs; in these arms the gun trunnions are fitted; the beam turns round a shaft carried in two blocks, cast in one piece with the slide. Between the shaft and the beam are placed india-rubber sleeves for deadening the shock produced when the gun is fired. The beam arms are continued below the shaft, for making connections with the movable recoil cylinders. The piston is fixed, and its rod is jointed on the slide. A set of springs surrounds this rod inside the cylinder, and forms the recuperator for running out the gun. The hydraulic recoil is of the type with central counter-rod, already described. Two rods hold the chase of the gun, one being jointed on a collar, the other pivoting round the beam axle.

Lateral training is obtained by working the system direct by means of a lever similar to the one for the 15-centimetre howitzer. When the gun is trained in the position required, the lever is let go, and the jaws with which it is fitted hold the platform fast. For elevating the gun, a lever is provided which works in a socket in one piece with the rod that pivots round the beam axle; the chase of the gun is thus acted upon direct to obtain the required incline, a screw holding the gun when it is in firing position. A scale is marked on the left-hand trunnion plate.

150-Millimetre (6.102-In.) and 120-Millimetre (4.724-In.) Howitzers on Double-Brake Mountings (Figs. 889 to 895, Plate CLII.).—These types have been supplied in large numbers to the Russian, Danish, and other Governments.

—	155-Millimetres.	120-Millimetres.
Weight of gun...	1100 kilogs (2425 lb.)	520 kilogs. (1146 lb.)
,, mounting	3000 kilogs (6612 lb.)	2300 kilogs. (5071 lb.)
,, projectile	40 kilogs. (88 lb.)	20 kilogs. (44 lb.)
Muzzle velocity	300 m. (984 ft.)	300 m. (984 ft.)
Elevation	−5 deg. +60 deg.	−5 deg. + 60 deg.
Training, through	360 deg.	360 deg.

The howitzer is of the Schneider-Canet type, already described. The breech-closing mechanism works generally in two actions. The mounting has been specially designed for plunging fire with guns of high power, while reducing as much as possible the shocks caused by the firing, and is characterised by the combination of two distinct hydraulic recoil cylinders. One acts parallel with the direction of the guides of the oscillating slide, and counteracts the force of traction developed by the gun trunnions; while the other serves to deaden the effects of shocks which, in this kind of ordnance, would reach sometimes considerable proportions. Part of the force developed during recoil is taken up by a spring recuperator; it is given back afterwards to insure the automatic running out of the gun. The mounting contains the following main parts: The carriage, the slide, the recoil cylinders and recuperator, and the bedplate. The carriage supports the gun by its trunnions; it consists of a gun-metal cradle, and contains the two traction recoil cylinders. The carriage travels during recoil and return on the oscillating guides, to which it is clamped, to prevent its shifting during firing. The piston-rods are fixed in the front of the guides, and their section is such that the resistance given during recoil to the flowing of the liquid, remains practically constant. The slide is of cast steel, and consists of a movable part, with two oscillating guides which carry the slide-shoes of the carriage, and of the fixed frame, formed of two vertical cheeks strengthened by ribs and firmly stayed together. These cheeks are joined at their lower part by a circular platform, in the thickness of which is made the racer for the ball bearings. In the centre part of the platform is made the vertical cylinder in which fits the fixed pivot of the carriage bedplate; its circumference is provided with clamps that prevent the shifting of the system. A horizontal shaft is placed at the top part of the cheeks, round which the movable slides oscillate. The percussion recoil cylinder contains a piston, the rod of which is jointed at its top part to the middle cross-piece that joins the oscillating guides. When the piston descends, the liquid driven by it, acts on a movable plunger that bears on a cross-piece loaded with two sets of Belleville springs; this takes place when, under the action of firing, the oscillating slide turns down on its horizontal axis. When recoil is spent, and the motion of the guides ends, the recuperator springs relax, and cause the system to rise at a moderate speed; and when the two guides have resumed their normal angle, the carriage resumes the firing position, under the action of gravity. The carriage can also be fixed in any position by means similar to those described for the 15-centimetre howitzers and mortars, namely, by jointed jaws on the rim of the lower platform. A groove is cut round the circumference of the bolster, to form a roller-path for the balls; its central part forms the vertical pivot round which the movable slide revolves. The bedplate is provided with a ring for bolting it to the foundation.

Lateral training is obtained by acting direct on the system, by means of levers that work in sockets forming part of the platform. The position can be regulated during firing, either by sighting a distant point or by means of the scale on the bedplate. In certain cases, the required elevation can be given by acting direct on one of the gun trunnions with a square-studded lever; a screw brake serves to fix the gun when it has been given the required angle. For measuring this the sight scale is used, with movable slide. In cases of masked firing, a mirror placed in front of the sight objective enables the gun to be

SCHNEIDER-CANET 15-CENTIMETRE HOWITZER ON DISAPPEARING CARRIAGE.

Fig.889

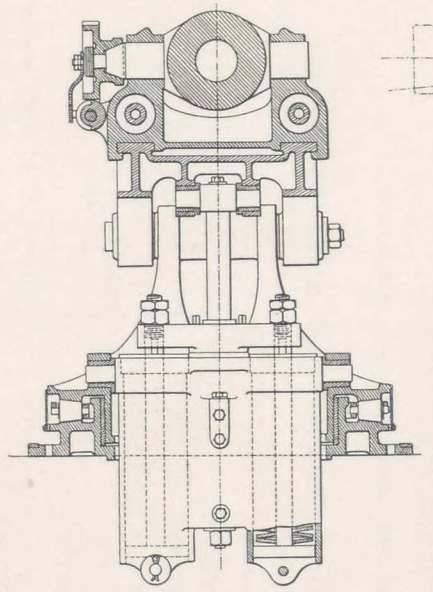


Fig.890

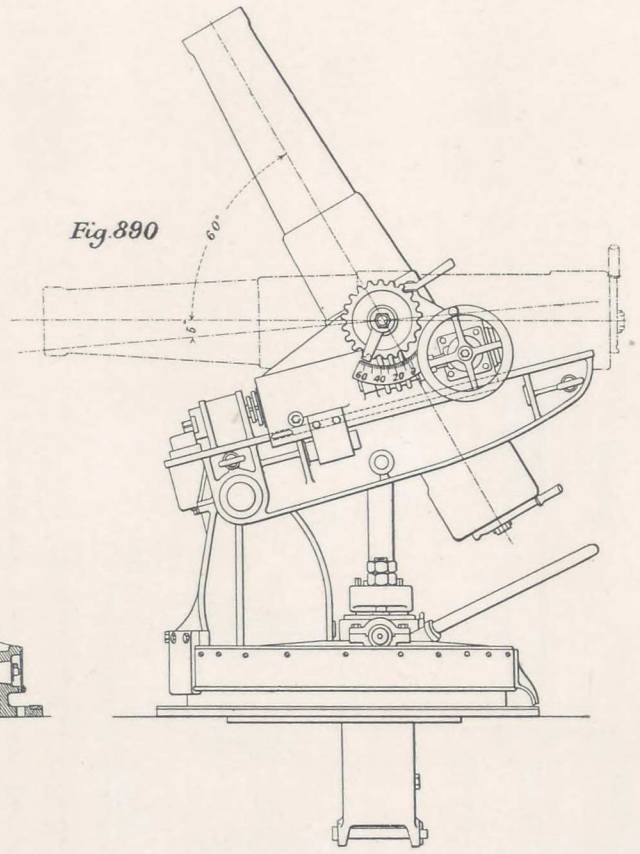


Fig.891

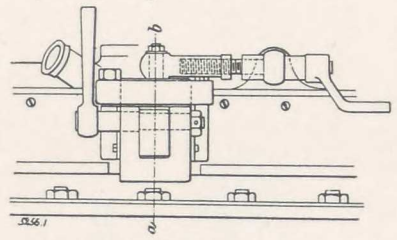


Fig.892

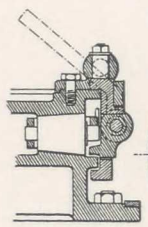
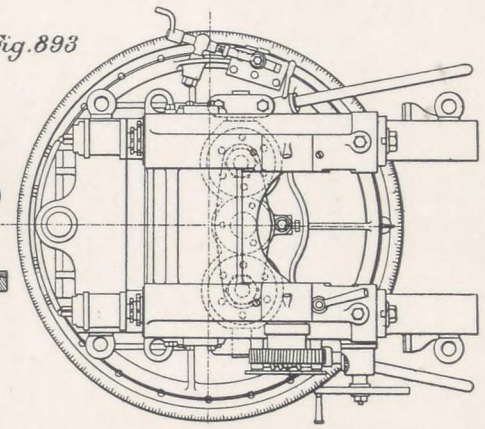


Fig.893



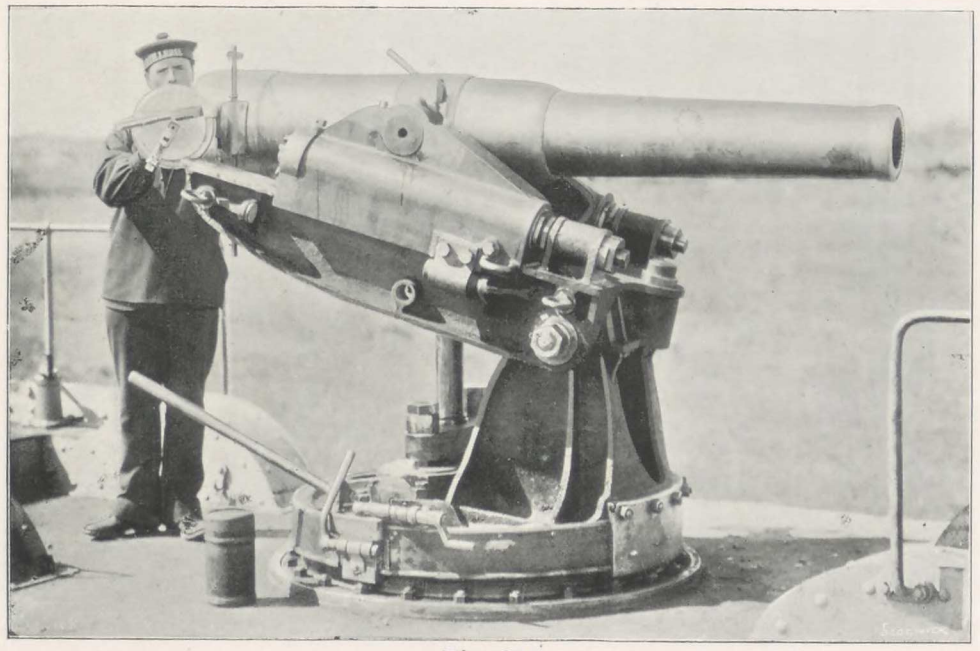


Fig. 894.

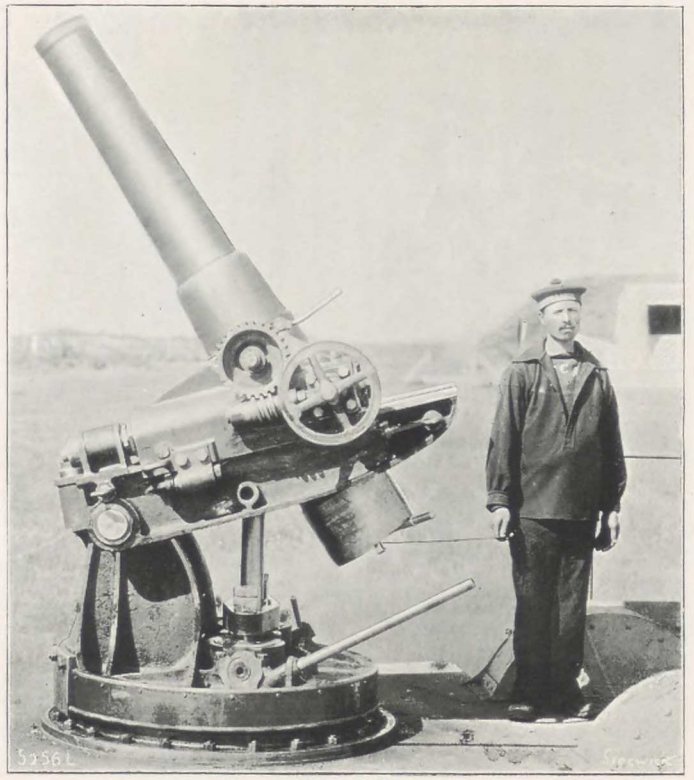


Fig. 895.

correctly trained on an objective chosen at the side. Several pieces of ordnance of this type, built at the Havre Works, are fitted with a special elevating gear, which comprises a crank, a set of conical pinions, and an endless screw, working a toothed wheel that acts on the left trunnion of the howitzer.

actions, and is fitted with a plastic obturator. The bedplate is provided with a roller-path, the balls of which are maintained at a fixed distance apart by a circular plate-ring, in which are cut a series of hollows. It is fitted with a circular disc for fixing it to the foundations. The slide consists mainly of two vertical brackets, joined at their

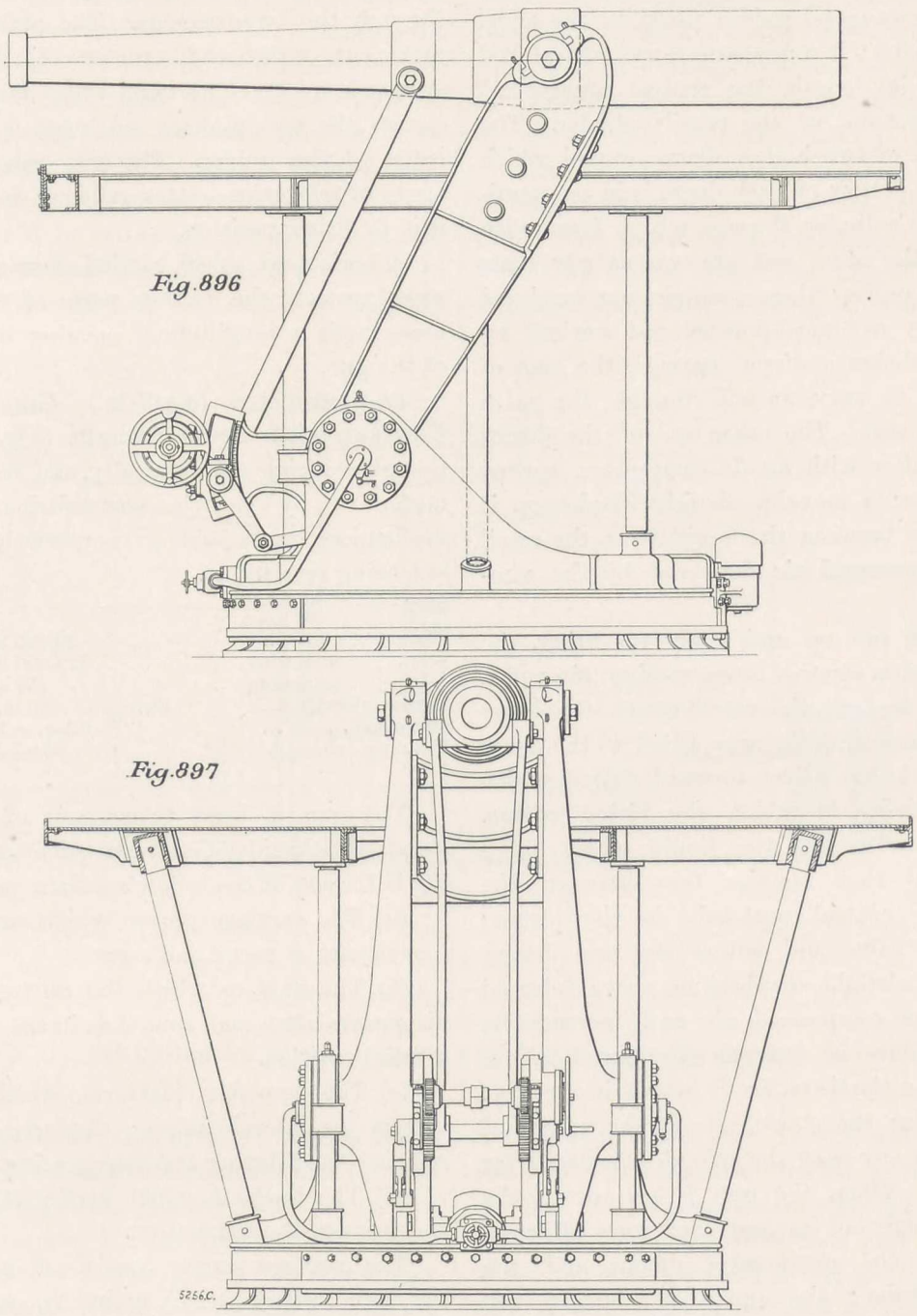


Fig. 896

Fig. 897

5256C.

15-Centimetre Schneider-Canet Gun and Disappearing Carriage.

15-Centimetre (5.905-In.) 26-Calibre Gun, on Disappearing Carriage (Figs. 896 and 897).

Weight of gun	2750 kg.	6,061 lb.
,, mounting	6500 kg.	14,326 lb.
,, projectile	35 kg.	77 lb.
Muzzle velocity with black powder	520 m.	1706 ft.
Elevation	+ 15 deg. – 5 deg.	+ 15 deg. – 5 deg.
Training, through	360 deg.	360 deg.

The gun is a general type of Schneider-Canet ordnance for garrison armament. The breech-block opens in three lower part by a circular platform which revolves on a set of balls on the bedplate. A clamp holds the rim of the latter and the front of the slide, preventing all shifting when the gun is fired. The beam, in which the gun trunnions are placed, consists of two cheeks stayed together at the top; it is movable round a horizontal axis formed by two hollow drums, which oscillate in vertical brackets fixed on the platform of the slide. The gun is, moreover, supported in front of its trunnions by two jointed rods on a collar placed near the wedge coil

The rods oscillate at their lower part on a shaft supported by two sliding shoes, which fit in circular grooves made in the front of the slide brackets. Two smaller rods join the shoes to these arms, in a line with the cheeks, below the drums. The hydraulic recoil cylinder is movable; it is placed horizontally between the brackets, and is provided in front and in the rear with two cross-bars that travel in gun-metal guides fitted to the slide. The piston remains fixed; it consists of a cylindrical rod hollowed out along its length, the central counter-rod being held on the bottom of the recoil cylinder. The recuperator is formed of two hollow drums, round which the beam turns. The bottom of each drum is in communication with the recoil cylinder through a pipe fitted with a loaded valve. In the valve seat are two narrow vents which cross at right angles; these openings can be closed wholly or in part by a conical-pointed rod worked by a screw. This establishes a direct passage, the area of which can be made to vary at will, though the valve be fallen back on its seat. The other end of the drums can be put in connection with an air compressor, worked by hand or by power; a movable airtight diaphragm is put in both cylinders, between the liquid from the recoil cylinder, and the compressed air delivered by the compressor.

When the gun is run up and ready for firing, the pointed regulating rod is screwed down, closing the vents. Then, when the gun is fired, the recoil causes the beam to turn round the drums, and the arms fitted to the lower part of the beam cheeks are driven forward, drawing with them the recoil cylinder in which the piston enters. Pressure is thus exercised on the liquid which flows through the opening that remains free between the counter-rod and the central port-hole in the piston; it raises the loaded valve, and enters the two drums, driving before it the airtight diaphragms above referred to, which act on the compressed air and increase its pressure. This continues as long as the gun has run completely down. An elastic buffer is placed in the rear of the slide, to deaden the shock, should the motion of the system exceed in any way the extent calculated for a normal oscillation. When the gun is run down, the loaded valve falls back on its seat, and cuts off communication between the recuperator drums and the hydraulic recoil cylinder; the gun then remains run down, and can be reloaded and reset. For running it up again, the pointed rod is unscrewed by means of a hand-wheel; the liquid under pressure can thus flow back to the recoil cylinder, which resumes its former position, drawing with it the arms at the lower part of the beam. The running up of the gun can therefore be controlled at will. For rapid firing, the firing device can be arranged to act automatically when the gun has run up in battery, the only stoppage in the action being that for loading and training.

For lateral training it is sufficient to act direct by traction on the movable slide, with the help of one or more levers placed on the circumference of the platform; a scale enables the position of the gun to be noted and maintained. The required elevation is obtained by working the rods jointed on the gun ring; to this effect the slide-shoes, in which is fitted the shaft that joins the two rods at their lower part, extend over the guides in two brackets. A shaft on which two pinions are keyed goes through the two brackets. The pinions gear in circular racks, cut in the outside surface of the fixed guides. The system is worked by a hand-wheel driving the shaft which carries the two pinions. A scale is cut on the outside ledge of the guides. The gun can be set to a given angle of elevation, either when it is run down or when it is in firing position.

A horizontal shield, carried on columns attached to the slide, protects the various parts of the mounting. It is made with a longitudinal opening to admit the passage of the gun.

24-Centimetre (9.448-In.) Gun on Disappearing Carriage with Counterweight (Fig. 898).—This type, though working automatically, can be driven by a steam motor or by electric transmission. It contains only mechanical parts and a counterweight, compressed air not being resorted to.

Weight of gun	22,200 kg.	48,942 lb.
,, mounting	124,000 kg.	273,370 lb.
,, projectile	150 kg.	331 lb.
Muzzle velocity	820 m.	2,688 ft.
Elevation	– 6 deg. + 15 deg.	– 6 deg. + 15 deg.
Training, through	360 deg.	360 deg.

The gun is built throughout of steel, and is of a standard Schneider-Canet coast-defence type. The mounting is formed of the following main parts:

(*a*) The carriage proper, which carries the gun in its movements of recoil and return.

(*b*) The slide, on which the carriage travels; this slide disappears after each round, and runs the gun up again in a firing position.

(*c*) The movable platform, which transmits to the system the lateral training displacements. The platform remains fixed during the disappearing motion of the gun.

(*d*) The bedplate, which carries the whole installation and rests on the foundation.

The carriage proper consists of a cradle; it contains the two lateral recoil cylinders, and an intermediate recuperator placed in the centre line of the system and at the lower part. It is provided with trunnion-plates, in which the gun rests. The lower surface of each of the cylinders forms a slide-shoe, and is provided with a clamp that holds the edges of the slide guides. The recoil cylinders are on the Schneider-Canet system, with central counter-rods. The recuperator communicates with the cylinders through two branched pipes and a valve-chest; it contains a piston, which, on recoil, is driven by the liquid that flows from the recoil cylinder, and presses down two sets of springs parallel with the centre line of the mounting. The slide is formed of two vertical cheeks, the

top part of which constitutes horizontal slides, in which are fitted friction rollers of the type previously described, to facilitate the travel of the cradle. The slide is continued at its lower part by a cylindrical sleeve made of plates, inside which is the hydraulic cylinder used for raising the mounting and regulating the disappearing action. The vertical motion of the sleeve is guided by a set of horizontal rollers, mounted on the vertical pivot of the movable platform. The movable platform carries the horizontal shield, and also the lateral training mechanism. It is circular, and its lower face bears on a series of friction balls; it is fitted with a vertical ring, to which are attached the centring rollers of the sleeve. The platform is guided in its rotary motion by a second series of rollers, the vertical axes of which are fitted to the cylinder that forms part of the cast-iron bedplate running up and down. The cast-iron counterweight consists of a large-diameter ring, guided in its action by a set of horizontal rollers on vertical guides; at a given moment, it can rest completely on a bedplate bolted on the lower part of the movable sleeve, and then the weight of the whole arrangement is sufficient to act against the resisting power of the accumulator. The counterweight can be raised independently of the sleeve, by three plunger pistons contained in vertical hydraulic cylinders, worked simultaneously by the forcing pump. These hydraulic cylinders are embedded in the foundation.

The required elevation is given the gun by a hand-wheel placed in the rear of the left-hand cheek of the slide. The transmission contains a set of square-toothed wheels, an endless screw and differential gearing, working a square pinion that engages the toothed sector fitted on

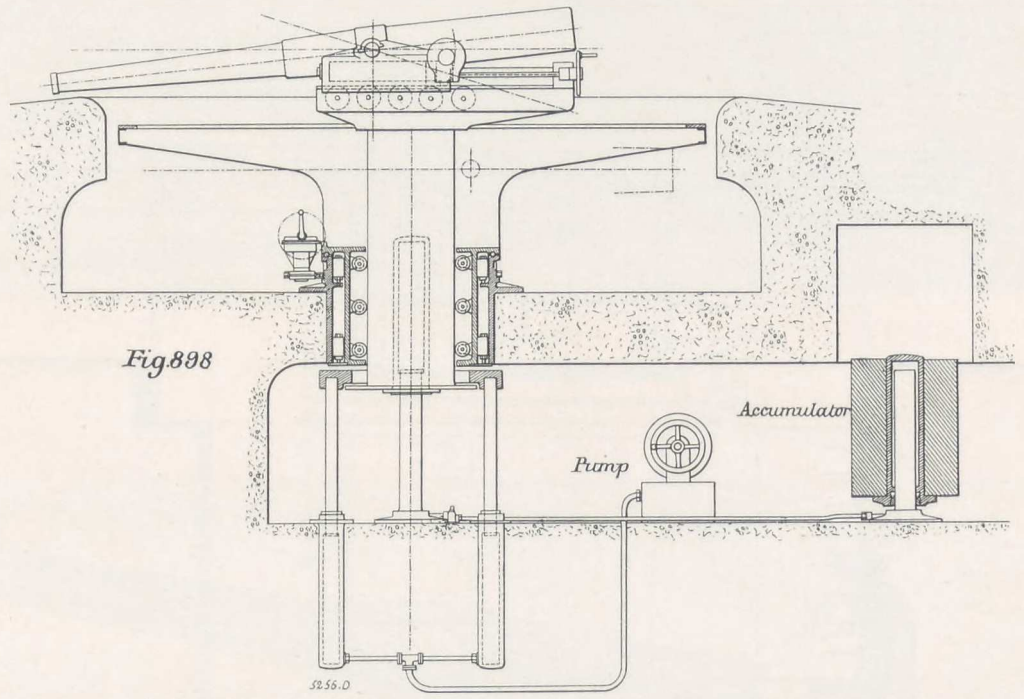


Fig.898

24-Centimetre Schneider-Canet Gun and Disappearing Carriage.

which carries the whole of the system; this bedplate contains a ring that bears on the foundation, and through which run the foundation bolts. Its top part is made with a groove that forms a path for the friction balls. It is strengthened by a series of radiating ribs. Its lower part ends in a vertical cylinder, which rests direct against the cemented wall of the pit, and carries the axles of the guiding rollers of the movable platform. The pit itself communicates with a large-sized room that contains part of the hydraulic mechanism and the counterweight. The room is joined to the battery communications through an underground passage. The fixed plunger that works in the hydraulic cylinder is drilled for its whole length, and parallel with its centre line; the conduit thus established communicates through a tube fitted with regulating valves, with a hydraulic accumulator, designed for storing a power slightly above that required for counterbalancing the weight of the movable mounting during the left side of the gun. Lateral training is obtained with the help of a mechanism similar to that described further on for the 27-centimetre (10.630-in.) gun mountings. The plate chain that surrounds part of the circumference of the movable platform, is driven by a spurwheel keyed on a vertical shaft, which goes through a chest containing the driving mechanism. The gun can be trained direct from the platform with the help of a crank, or through a chain transmission worked by a gunner standing on the shield.

When the gun is in battery, the cast-iron counterweight rests on the lower collar. On firing, when the carriage recoils, it travels on the slide rollers, and the recoil cylinder acts in the same way as that for the types described above. When the recoil is spent, the valve that establishes communication between the recoil cylinder and the recuperator closes and maintains the gun run in. At the same time, the valve which establishes a communication between

the main vertical hydraulic cylinder and the accumulator, opens automatically, allows the flowing out of the liquid, and the gun runs down. It is then reloaded, and reset in position. This effected, and the communication with the accumulator remaining cut off, the ring that forms an additional counterweight is raised, by means of the forcing pump and the three-plunger pistons, to a height that varies according to the angle of elevation under which firing is to be effected. Communication between the hydraulic cylinder and the accumulator is then re-established, and the gun runs up in battery under the action of the accumulator alone. The system is then fixed, and the hydraulic cylinders being turned on the exhaust, the additional counterweight descends, and rests afresh on the caisson collar. A valve placed on the conduit in the thickness of the valve-chest then re-establishes communication from the recoil cylinders to the recuperator, which, in relaxing, place the gun in a firing position.

A circular track, formed of I-bars, is placed below the shield, and allows the working of tackle, the chain of which carries the box for raising the projectile to the breech.

This type of ordnance is simple in design; it contains safety devices that insure a regular succession in the various manœuvres, and it is most suitable for open coast-defence batteries that are so exposed they cannot be protected by artificial means, In the course of firing, a single set of motors is required for manœuvring the additional counterweight, the accumulators being charged before firing commences. The motors are preferably electric motors, and can be supplied with current by underground cables. This type of mounting can be used in conjunction with the largest-calibre guns.

27-Centimetre (10.630-In.) 28-Calibre Gun and Disappearing Carriage (Fig. 899, and Figs. 900 and 901, Plate CLIII.).—This type of gun and mounting has been supplied to the Japan War Department for Tokio Bay, and to other Governments.

Weight of gun	21,720 kg.	47,870 lb.
,, mounting ...	61,300 kg.	135,105 lb.
,, projectile ...	216 kg.	476 lb.
Muzzle velocity	580 m.	1,903 ft.
Elevation	– 5 deg. to + 15 deg.	– 5 deg. to +15 deg.
Training, through	360 deg.	360 deg.

The gun is on the Schneider-Canet system, 28 calibres in length, strengthened by a rear jacket and a set of coils. The breech-block seating is cut in the tube itself. The breech-block is the same as that for 27-centimetre coast-defence guns; it can be fitted with two metallic cup obturators of different diameters, the second acting as a spare one for the first in case of need. The mounting consists of the beam, the slide, platform, and the bed-plate.

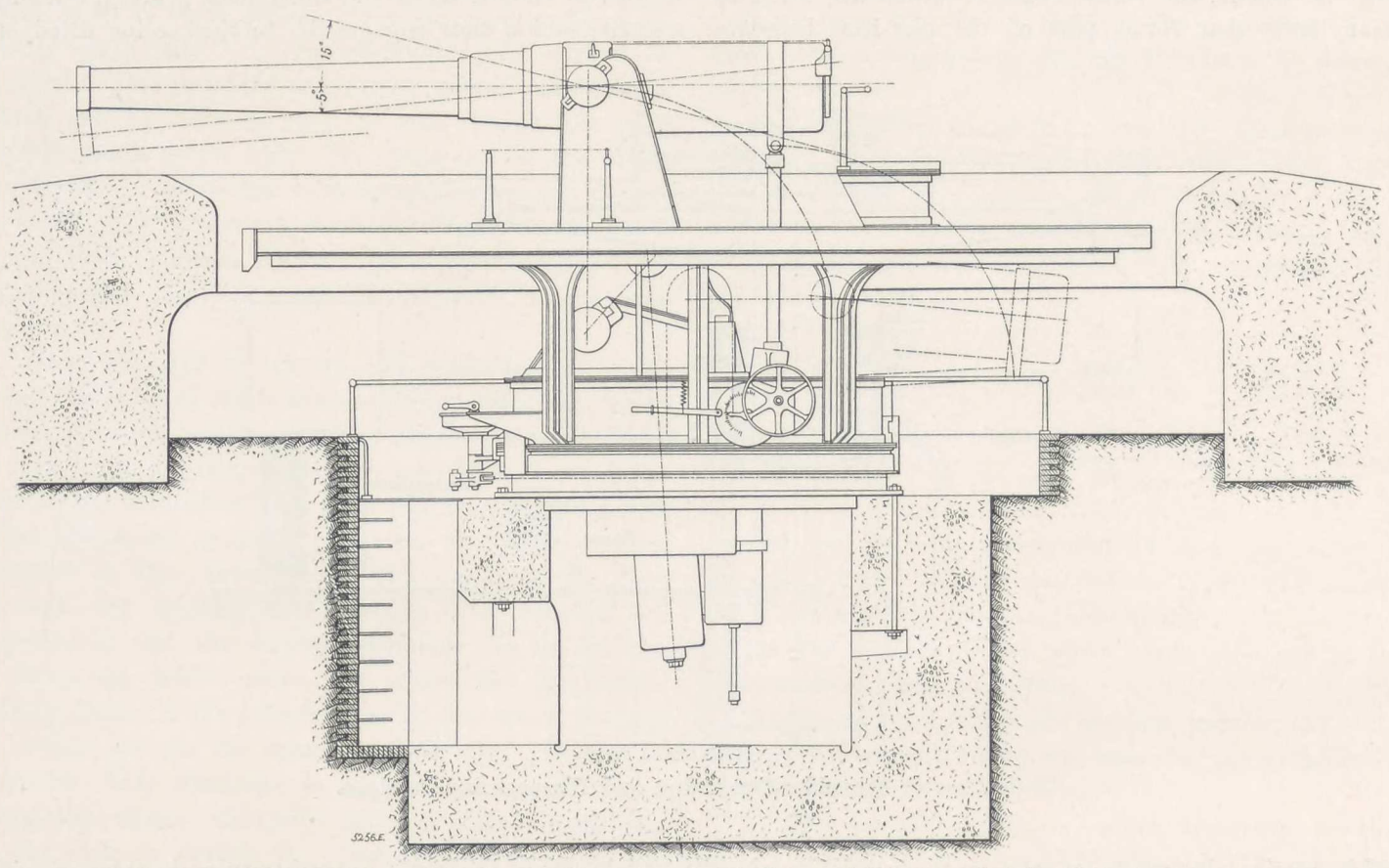
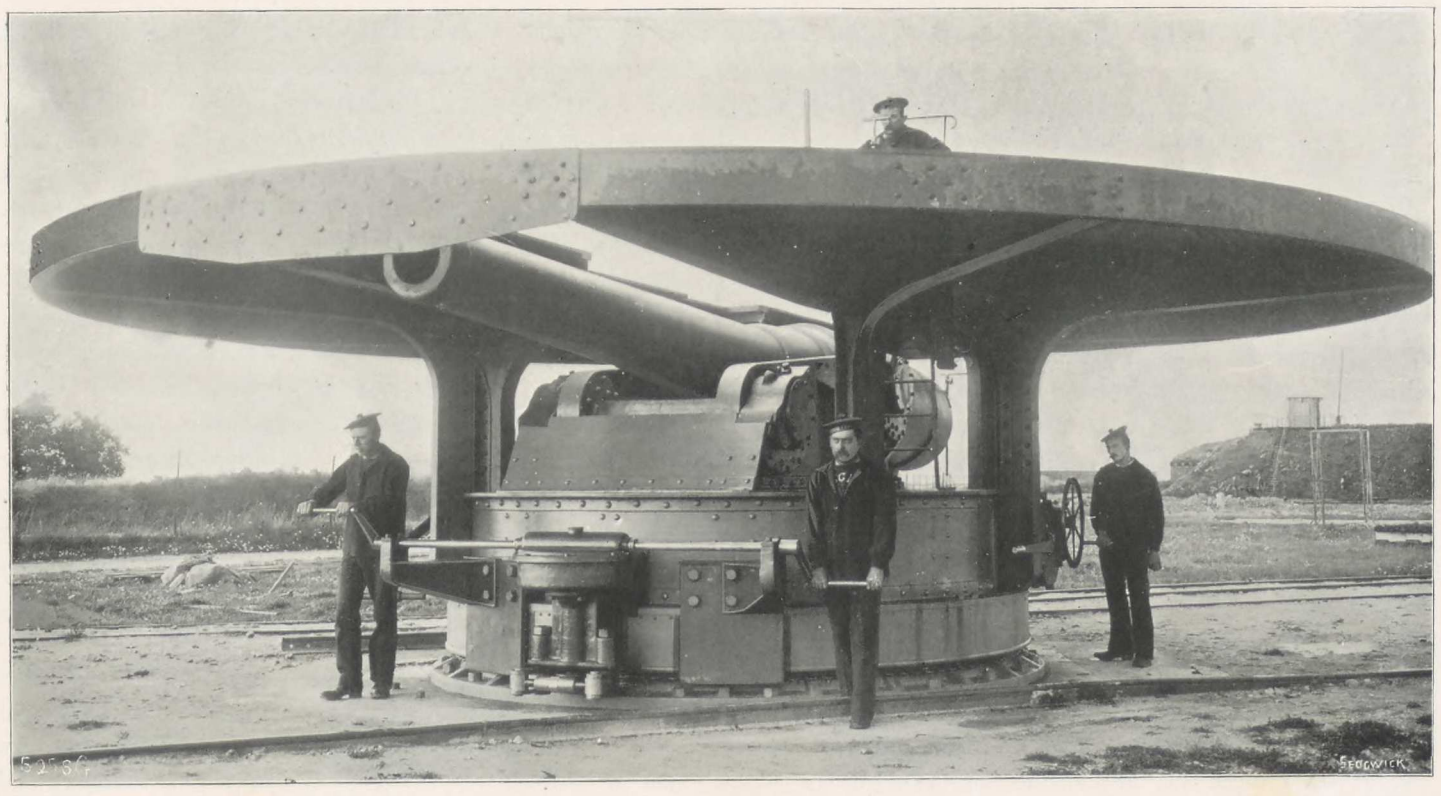


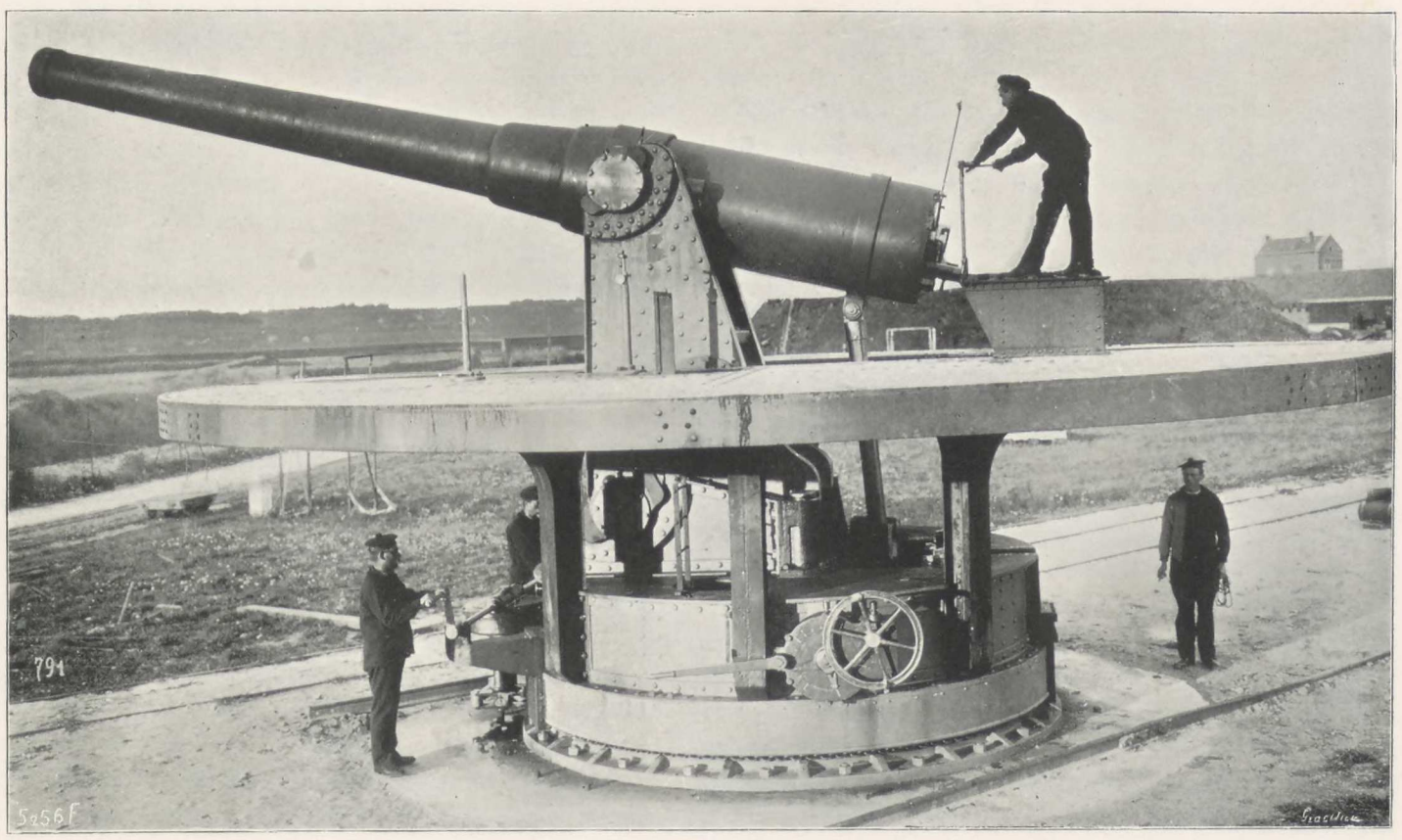
Fig. 899. 27-Centimetre Schneider-Canet Gun and Disappearing Carriage.

The beam is built up of plates, and consists of two cheeks joined by stay bars, and one of these is fitted at its top end with a gun-metal butt to limit the vertical elevation of the gun; the other is provided with a square which, when the gun has run completely down, can connect with the platform and hold the gun, during the necesssry operations for laying and loading it. The beam is fitted:

(*a*) At its lower part, with an axis formed of two

27-CENTIMETRE SCHNEIDER-CANET GUN AND DISAPPEARING CARRIAGE.





Figs. 900 and 901. 27-Centimetre Schneider-Canet Gun and Disappearing Carriage.

trunnions that are carried direct by the brackets of the slide platform.

(*b*) At its top part with cast-steel trunnion plates.

(*c*) With a cross-piece, to which is joined the top of the recoil piston-rod. Both cheeks are, moreover, fitted at their top part with an elastic buffer, which can rest, when the gun is completely run down, on buffers on the platform. The slide platform consists mainly of a plate caisson and two vertical brackets fitted with the trunnion-plates for the beam trunnions. It contains all the parts of the mounting, namely: The recoil cylinder, air recuperator, setting mechanism, pump for running down the gun, and it rests on a set of rollers on the bedplate. It is fitted also with uprights on which is fitted the horizontal shield, circular in shape, and in which is cut a longitudinal opening through which the gun passes in running up and down. The recoil cylinder oscillates round the trunnions carried on the flooring, in two fixed brackets; the flooring is joined to the plate caisson, and is cut out in a suitable way to allow the recoil cylinder free travel in its oscillating movements. The recuperator is in the rear, and is fitted with a collar bolted on the slide platform. Communication between the recoil cylinder and the recuperator is insured through a pipe which ends on one side at the lower part of the recuperator, and on the other, on a valve chest. The hydraulic piston-rod is joined to the beam by a cross-piece with trunnions; the central counter-rod is fixed to the bottom of the recoil cylinder. The air recuperator contains an airtight diaphragm that divides it into two parts—the top division containing compressed air, and the lower one, the liquid brought from the recoil cylinder. Through this diaphragm passes a rod provided with a stop to limit its travel. An air pipe allows the top division to be put in communication with the pressure pump, to run up the gun before firing, should the recuperator have been exhausted.

When the gun is fired, it draws back the beam which turns on its trunnions to the rear, the hydraulic piston descends in the recoil cylinder, and drives the liquid into the bottom of the recuperator; the movable diaphragm is displaced, and compresses the air of the top compartment. When the beam falls back, the air pressure becomes sufficiently high to balance the system, and the valve between the recoil cylinder and the recuperator falls on its seat. During the time the gun runs down, the elevating rod that supports the breech end keeps the gun practically in a horizontal position, and when the motion ceases the gun is placed exactly in the required position for re-loading. The breech is then opened, the projectile and charge are introduced, and the fuse made ready; the gun being given afterwards the required elevation and lateral training, with the help of the scales and marks provided for this purpose. For running up the gun again, the clamp that holds the beam to the slide is removed, and communication is re-established between the recoil cylinder and the recuperator by means of a special lever; the compressed air expands, and drives before it the diaphragm which forces the liquid to return in the recoil cylinder, where it acts on the piston. The gun runs up progressively with a speed in relation to the space left free for the flowing of the liquid; it can be lowered when necessary, with the help of a hand-pump, which serves to force the liquid from the recoil cylinder to the lower compartment of the recuperator.

The gun is given the required elevation by working the rod that supports the breech-end of the gun. The rod is jointed at its top part in a ring in the breech-end of the gun and on its lower end, on the elevating sector worked by a pinion keyed on the working shaft, the latter extending outside the shaft in a box fitted with the working mechanism. This mechanism consists of a set of pinions and endless screws, driven by the shaft of the elevating handwheel. A pointer that travels along a scale shows the exact angle of the gun to the horizontal. Lateral training is given by a chain which surrounds the circumference of the bedplate, and passes round a pulley keyed on a vertical shaft; tension blocks serve to guide the chain. The cranked horizontal shaft drives the chain pulley, and produces the lateral displacements of the slide by tension on the fixed ends of the chain. A scale on the platform marks the extent of the lateral displacements. In normal service, the gun is trained when it is run down and loaded. As it may be necessary, however, to rectify the setting of the gun from time to time, when it is run up in battery, the shield is fitted with a special platform for sighting the gun on the target.

The whole of the mechanism above described rests on rollers on the bedplate, which is bolted on the foundation. When a position has been chosen, the top of the foundation is made with a layer of concrete on which is placed an iron foundation-plate. These arrangements vary according to the nature of the subsoil.

From the number and diversity of types that we have noticed, it will be seen that the Schneider-Canet system contains mountings which can fulfil all the conditions required in service, from those for 75 millimetres (2.952-in.) guns, weighing 100 kilogrammes (2 cwt.) to those for the largest calibres. This section is of special interest, owing to the numerous unsuccessful attempts that have been made in several countries in the adoption of ordnance of this type. The designing of disappearing gun carriages, and their practical working, is a problem difficult to solve, at all events for large-calibre guns. The perfection to which the various types of Schneider-Canet ordnance of this nature have been brought means, therefore, a large amount of calculation, trials, and tests of all kinds, carried through a number of years.

XLI.—FIELD ARTILLERY.

AS in naval armaments, the importance of quick-firing guns has been recognised by their general adoption, increasing calibres, and improved mechanism, so a similar recognition has been given to the value of the same principles, though under widely different conditions, for field artillery. The older types of guns firing from rigid carriages, and with free recoil, will soon be regarded as obsolete, at all events by those nations whose armaments are of the modern type. In treating of this special subject, as elaborated by Messrs. Schneider and Canet, we shall have little to say about the gun itself, which in its design, as well as in the breech mechanism, belongs strictly to the Schneider-Canet system. The principal interest attaches itself to the gradual development of field mountings, which in their most modern types embody the experimental practice of many years.

To deal with the subject fully, we should have to include all the numerous systems which have successively been experimented upon at the Villedieu and Hoc proving grounds, and also the results obtained during the experiments. These have been carried on without interruption in the proving grounds ever since the question of accelerating the fire of field guns first became a practical one. Of course, such an investigation would be of great interest, as it would involve a review in every detail of the constant progress made in the construction of this particular type of ordnance and its mounting. But as this would carry us far beyond available limits, the data we shall give must be limited to a few successive types, with a detailed notice of the 1898 pattern gun and mounting, which embody all the improvements suggested by experiment, and carried out up to that date.

Previous, however, to considering the various systems which Messrs. Schneider and Co. have studied in theory and have experimented upon in practice, it will be well to refer to the conditions they prescribed in undertaking the manufacture of quick-firing field guns and carriages, and towards the complete realisation of which they have never ceased to work. The result, as already stated, is their 1898 pattern, which fulfils all the conditions required up to the present. At the commencement of the quick-firing field artillery development, two different views generally prevailed; and they seem, even now, to divide military experts as regards the conditions which quick-firing field guns should fulfil in service. According to some—and these form to-day the lesser number—the new type of carriage, and especially that part on which most of the changes have been carried out, should not be radically different, when compared to the older rigid types, but be rather an improvement of the latter, such improvements and alterations being mostly in matters of detail, affected, of course, largely by the progress made in the processes of manufacture of different parts, and by the quality of metals now used. This view would bar the possible application, at least to a considerable degree, of the progress made during late years in the construction of quick-firing naval gun mountings, especially as regards hydraulic recoil cylinders, which now work most satisfactorily. It may be remarked here that these same recoil cylinders, when they were first proposed, had been stated by many artillerists to be unfit for naval service.

The greatest concession such theorists are willing to make, is the application to the carriage (which would remain, as in the past, a simple rigid support), of an elastic device, for diminishing recoil, but not absorbing it completely. Sometimes, indeed, this device, which forms the most delicate part of the whole mounting, containing as it does a certain number of springs, is not expected to act, except in special cases, and when the ground on which the gun is fired, is suited for its working. The problem of field gun construction thus interpreted becomes comparatively simple of solution, and it may easily be conceived that the theorists advocating this principle, were readily defended by some manufacturers. Certain writers also have endeavoured to persuade military authorities to accept these same theories; quite recently, indeed, books and pamphlets have been published which claim to prove clearly the utter impossibility of making a field gun-carriage that will remain in position during firing. These claims are not based on theoretical objections, but on the alleged trials and failures of many proposed systems. The objections so made are scarcely worthy of even passing notice; they are one of the phases that always attend on progress, and are only silenced entirely by the indisputable verdict of results. Thus, in the same way, the advocates of breechloading for ordnance were long proved by theorists and faddists to be unpractical and altogether wrong. But the folly of these objectors has been clearly demonstrated, and the arguments in favour of rigid field gun-carriages are equally fallacious.

The main argument used by the advocates of field guns which fulfil their limited programme, and which has been called "accelerated firing," is to the effect that such guns will prove amply sufficient after the firing of a battery has been so regulated, that each gun will fire a maximum of eight rounds per minute. This number of rounds agrees

with the results the same advocates have obtained, and have therefore prescribed as sufficient. Their argument assumes that the firing methods followed with the older type of guns will also be followed with the new types. This is a fallacy, for it is quite certain that the tactics with quick-firing guns will be widely different from those which were deemed the best for guns capable of "accelerated" fire.

It may, we think, be reasonably assumed, all other conditions remaining equal, that a battery, each piece of which will be able to fire on emergency, say, 25 rounds a minute without fatigue to the men or undue wear of mechanism, will undoubtedly have the advantage in all fights against a unit formed of guns, the firing of which is only "accelerated." This cannot be denied, and does not require to be (though it has been) proved in practice.

From the commencement, Messrs. Schneider and Co. took these considerations into account; they attacked the problem in every detail, leaving out none of the difficulties with which it is surrounded, and they quite early defined the problem they meant to solve, and which may be summarised as follows:

To fire with the greatest rapidity possible, and with a maximum of precision; or, in other words, to endeavour to put in a target the largest number of useful shots in a given time, and without excess of fatigue for the gunners or undue wear of material, the ballistic conditions being decided by a majority of members of ordnance technical committees. In carrying out experiments, Messrs. Schneider and Co. found that these objects could only be obtained when they had fulfilled certain conditions, namely:

(*a*) Absence of recoil.

(*b*) Complete stability of the carriage platform.

(*c*) Absence of all necessity for readjusting the elevation and lateral training of the gun during the fire.

(*d*) Making guns and mountings to suit every kind of ground met with in actual service.

The problem thus compressed in a few lines was one of tremendous proportions. How fully it has been solved the following notes will show, as well as by what series of tests and improvements of many kinds, Messrs. Schneider and Co. have produced their 1898 pattern, which fulfils the conditions of this programme, and can really be styled a quick-firing gun.

XLII.—PRINCIPAL TYPES OF MOUNTINGS FOR SCHNEIDER-CANET QUICK-FIRING FIELD GUNS.

IN the following descriptions the systems are grouped together in sets, according to whether they contain characteristics more or less common to each group. This classification, while it facilitates the review of the progress made, does not accord in every case with the chronological order of the various experiments that have been carried out. Such a chronological order would be difficult to follow, for experiments of certain types have frequently been abandoned for a time, and taken up again at a later date, other types having been tested in the interval.

Leaving aside the historical question, this classification will lead in the best way to the desired result, for it will give a clear idea of the designs and tests made by Messrs. Schneider and Co. for establishing a system of field artillery.

The first group contains a series of distinct types, in connection with which mechanical devices were used for limiting recoil, to the exclusion of hydraulic recoil cylinders. Besides, none of these types embodied special appliances to shift the gun on its carriage, over small angles, for adjusting lateral training.

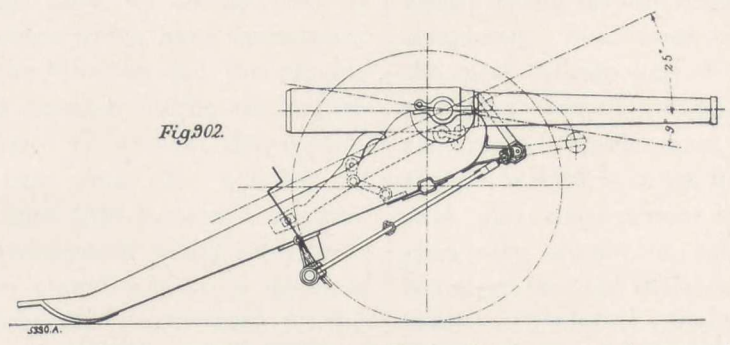
80-Millimetre (3.149-in.) Gun and 75-Millimetre (2.952-in.) Guns on Rigid Carriage Fitted with an Automatic Brake Governed by a Counterweight (Figs. 902 to 906, and Fig. 908).—The following are some general particulars of the 80-millimetre gun:

Weight of gun	425 kg.	936 lb.
,, carriage	495 kg.	1,091 lb.
,, projectile	5.6 kg.	12 lb.
Muzzle velocity	490 m.	1608 ft.
Striking energy of projectile ...	68.5 t.m.	228 foot-tons

This type was manufactured in 1887 from the 1878 pattern of French artillery, in order to devise a system of brake with counterweights, to be used both in the ordinary manner by acting on the carriage wheels, and to check recoil during the firing of the gun. It has been described at length in the *Revue d'Artillerie*. A description of the counterweight brake experimented with is given in the following description of the 75-millimetre gun and mounting on which it was tried. The following are some particulars of this latter gun:

Weight of gun...	322 kg.	710 lb.
,, carriage	448 kg.	987 lb.
,, projectile	5.5 kg.	12 lb.
Muzzle velocity	500 m.	1640 ft.
Striking energy of projectile ...	70 t.-m.	233 foot-tons

The gun is of steel, and consists of a tube of about 32 calibres in length, on which is shrunk a jacket, a trunnion ring, and a wedge coil. The breech-block is made with interrupted screw, and is fitted with a plastic obturator.



75 and 80-Millimetre Field Gun on Rigid Carriage and Automatic Brake.

The carriage is made of steel plates; the head-plate that joins the brackets to the axle is of gun-metal and in one piece. The axle is of steel; its central part is rectangular in section, and it is made with flanges at the angles, which increase its strength. The gun-carriage wheels are similar to those of the limber; they are made of oak, with brass naves and steel tyres. The mechanism for elevating the gun is placed between the brackets; it consists of a hollow screw. The screw penetrates a nut round which is fitted a helicoidal toothed wheel; this engages an endless screw keyed on a shaft which runs through the brackets, and is provided with two handwheels outside the carriage. By acting on either handwheel, the screw is made to turn, thus driving the helicoidal wheel and the nut, giving to the gun the required elevation. A strap joins the gun to the screw head, to prevent a too great preponderance of the muzzle.

The brake, which serves to limit recoil during firing, is arranged in the following manner: A shaft made with threads at two places in its central part, is caused to revolve

in two bushes fixed to the brackets, and is provided with two nuts; the latter are fitted with two arms jointed to a traction-rod fitted with a screw arrangement to regulate the tension of the system. Two tie-bars are fixed at one end to the traction-rod, and at the other to the two ends of a crossbar suspended to the carriage and provided with the counterweight and held by one of the gunners, who thus regulate its action on the wheels.

The gun-limber consists mainly of a frame of steel angles on which the chest is bolted; it is joined to the axle by means of saddle-plates. The gun-carriage is suspended from it.

Fig 903.

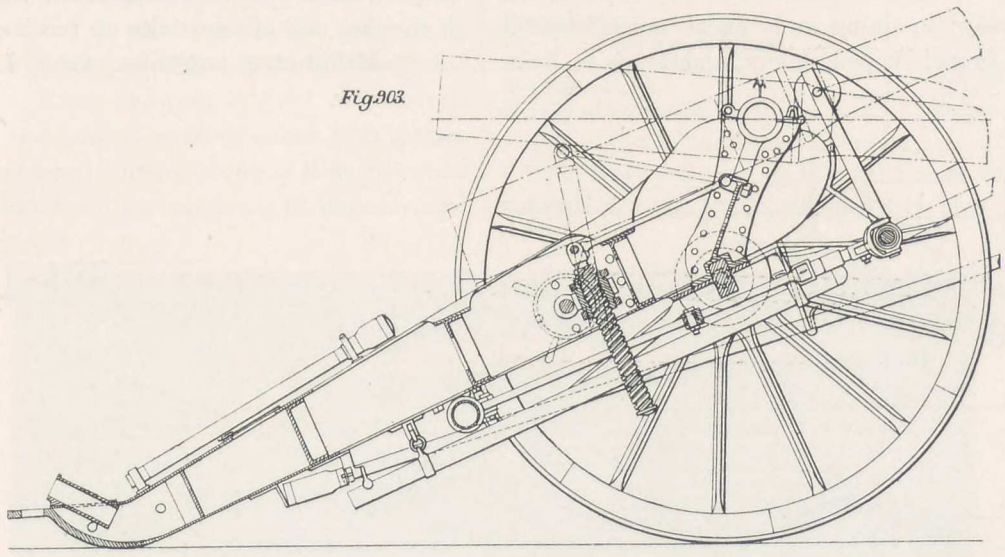
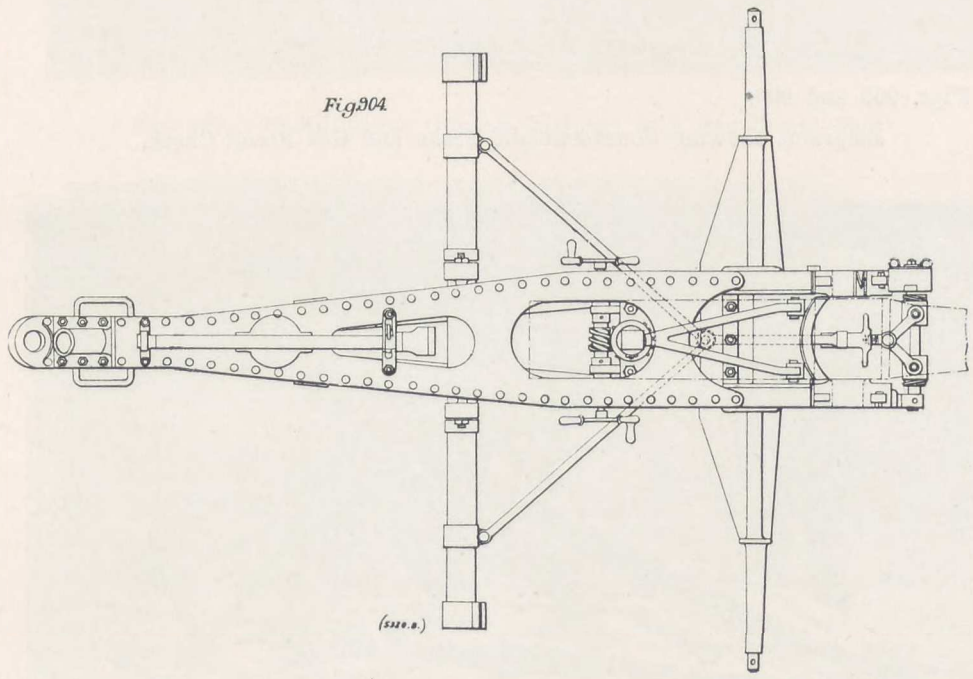


Fig 904.



75 and 80-Millimetre Field Guns on Rigid Carriage and Automatic Brake.

brake shoes. The system is completed by a lever with counterweight, placed on the left-hand side; when the gun is ready for firing, the counterweight is raised against the gun trunnion. When the gun is fired, it falls back and causes the shaft on which it is keyed, to revolve, and in this action the two nuts separate from each other, thus opening the two arms with which they are fitted, and drawing forward the traction-rods and tie-bars, the brake shoes bearing firmly on the wheel tyres. When the round is fired, the lever is brought up again, and the gun can be trained anew. If it is desired to use the brake when the gun is wheeled from one place to another, a rope is tied to

75-Millimetre (2.952-In.) Gun, Long Type, with Gas Recoil-Check, on Mounting Provided with a Trail Spade (Figs. 907 and 909).—The following are some particulars of this gun:

Weight of gun...	360 kg.	793 lb.
,, carriage	540 kg.	1190 lb.
,, projectile	5.2 kg.	11½ lb.
Muzzle velocity	550 m.	1804 ft.
Striking energy of projectile ...	80 t.-m.	266 foot-tons

The gun is fitted with a device called a "gas recoil-check," which utilises some of the propelling force of the gases created by the combustion of the powder charge

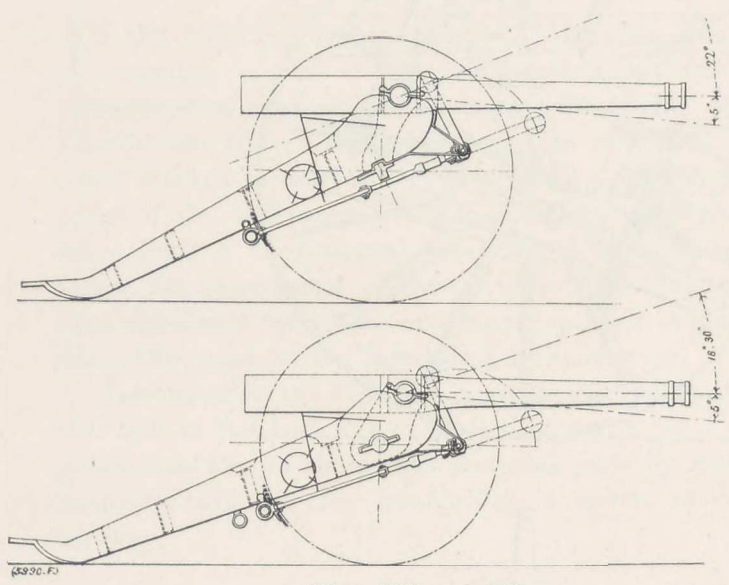
in order to absorb part of the recoil of the gun. This device is funnel-shaped and is fixed to the muzzle; it is made with a hole slightly larger than the projectile, thus allowing the latter to pass through freely. When a round is fired, a wide cone of gas is emitted, the basis of which is in a line with the muzzle end of the gun. The gas strikes against the inside of the recoil check plate, and is forced to the rear; in doing so, it exerts a considerable pressure on the funnel-shaped device, and tends to draw the interposition of Belleville springs; these served to deaden the shocks caused by the firing of the gun.

Experiments made with this gun showed the recoils to be more or less checked by the muzzle device, but the gunners had to stand outside the wheels, not to be inconvenienced by the hot gases that were driven to the rear. Besides, this apparatus alone could not insure the stability of the gun and did not take up recoil completely.

75-Millimetre (2.952-In.) Gun, Long Type, on Carriage with Independent Axle (Fig. 910, and Fig. 912, Plate CLIV.).—The following are particulars of this gun:

Weight of gun	360 kg.	793 lb.
,, carriage	540 kg.	1190 lb.
,, projectile	5.2 kg.	11½ lb.
Muzzle velocity	550 m.	1804 ft.
Striking energy of projectile ...	80 t.-m.	266 foot-tons

The carriage consists of two steel-plate brackets joined together by riveted plates forming transoms; it is supported by the trail which rests on the ground and on an elastic



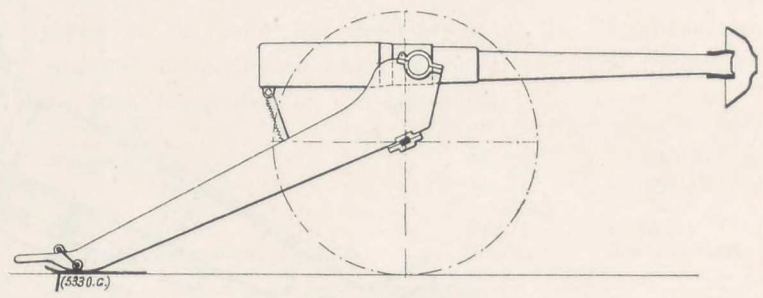


Fig. 907.

Figs. 905 and 906.

Diagrams showing Counterweight Brake and Gas Recoil Check.

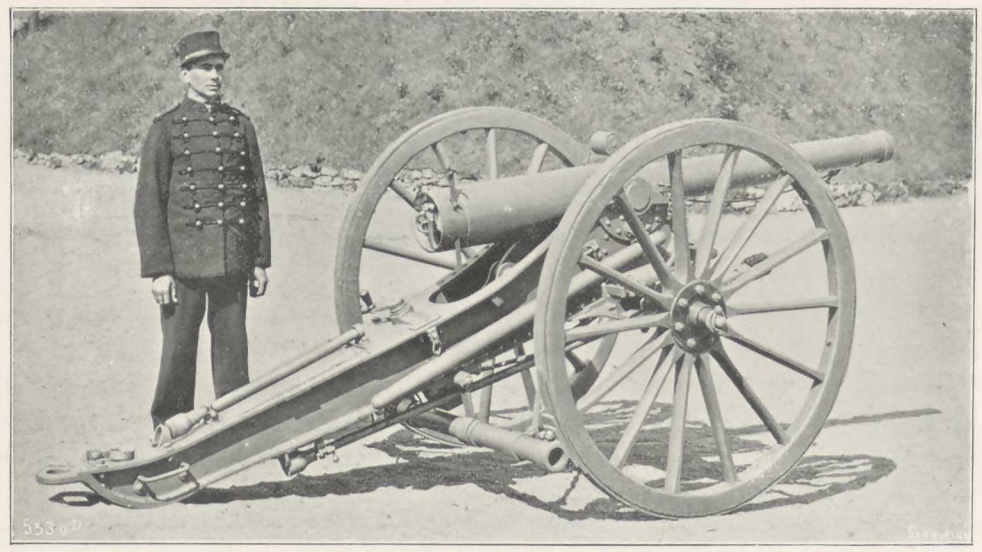


Fig. 908. 75 and 80-Millimetre Field Gun on Rigid Carriage and Automatic Brake.

the gun in the direction of the firing line. This action counteracts that of the recoil and checks it to a certain extent. The carriage is rigid and consists of brackets riveted together; the trail ends in a fixed spade with bearing trail-plate.

The elevating mechanism consists of a jointed rack, fitted in a socket under the breech end of the gun; it gears with a pinion carried by the carriage bar. The pinion is keyed on the same shaft with a helicoidal wheel, the latter driven by an endless screw, fitted on a shaft with

arrangement which connects it with the axle. This arrangement consists of two rods linked to the brackets, the elastic system being in two parts, one jointed on a carriage-bar, formed of a hollow cylinder made to turn round an axle parallel with the carriage-axle; the second consisting of a piston which travels in the cylinder, the piston-rod end being so arranged that it can turn freely round the carriage-axle. A set of Belleville springs is placed on the piston-rod, between the piston and the front end of the cylinder. When the gun is fired, the springs are compressed and the jointed system comes into action. Part of the force developed during firing is thus absorbed by the springs: this eases the various parts of the carriage, and subsequently, the work the gunners had to do to run out the gun afresh, was less than that required for the types of guns and rigid carriages already described.

75-Millimetre (2.952-In.) Gun and Carriage with Anchor Plate beneath Axle (Fig. 913, Plate CLIV.).—The following are particulars:

Weight of gun	360 kg.	793 lb.
,, carriage complete	750 kg.	1256 lb.
,, projectile	5.5 kg.	11½ lb.
Muzzle velocity	550 m.	1084 ft.
Energy of projectile	80 t.-m.	266 foot tons

Several examples of this type were experimented upon successively at the Villedieu and Hoc proving grounds.

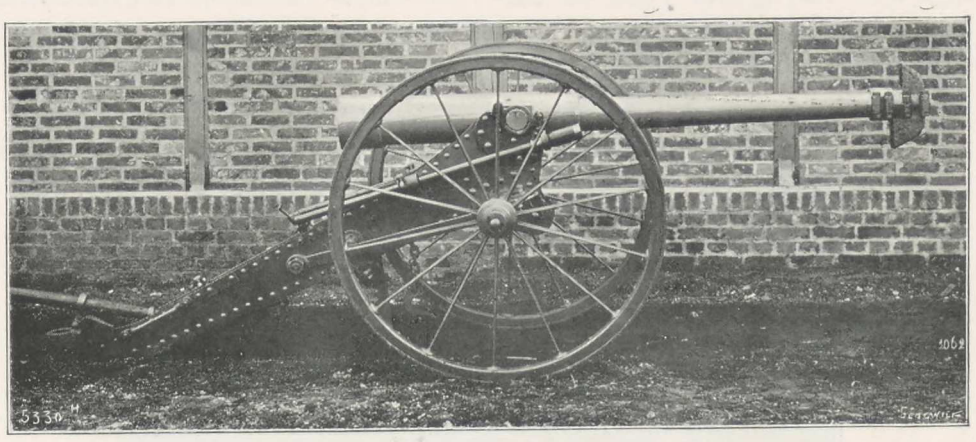


Fig. 909. 75-Millimetre Gun on Carriage with Gas Recoil Check.

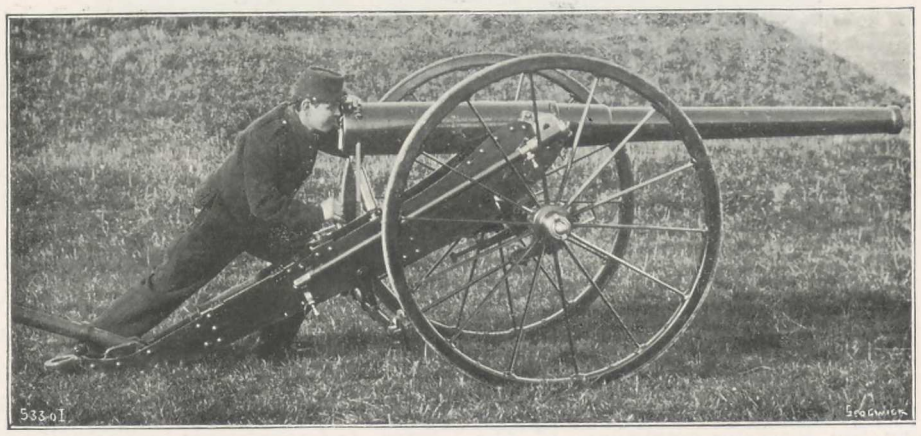


Fig. 910. 75-Millimetre Gun and Carriage with Independent Axle.

so that they can be made lighter in consequence. When the action has attained its height the carriage and the gun resume their respective positions by the relaxing of the springs.

The mechanism for elevating the gun consists mainly of two jointed rods; one linked to the jacket at the breech end of the gun, and the other to a carriage bar. Upon this second rod is fitted a nut which can be displaced over a screw worked by a handwheel. According to the direction in which the handwheel is turned, the nut rises or descends, and gives the required elevation to the gun.

As the trail is not fitted with a spade, the carriage recoils at each round over a length which depends chiefly upon the energy of the projectile. The recoil, however, It was the first of a comparatively large series. The carriage consists of two riveted brackets stayed together by top and bottom trail-plates; at the lower front part are two supports for an axle, on which the spade is jointed. The latter is formed of two vertical arms, the blade being at their lower part and adapted to penetrate the ground. The top part of this anchor is fitted with an inclined plate which throws back the earth when firing takes place in loose ground. The spade is secured to the trail by jointed tie-rods, a set of Belleville springs being placed between the ends of the rods and the vertical arm, to deaden the sudden reactions which might arise during firing. When it is desired to shift the gun, the spade is lifted near the bottom trail-plate.

When a round is fired, the spade is driven in the ground and forms a bearing-point to deaden the force of recoil. The conditions in which this device works vary, however, according to the nature of the ground, and when the latter is not suitable, the gun and carriage are lifted up and may be thrown forward. But when the ground is favourable, the recoil is much less than with the types firing with no recoil checks; on the other hand, the gun often deviates largely, the carriage platform not remaining still. This system nevertheless marked a decided improvement on the preceding ones; it was less fatiguing to work, and the firing speed was a little quicker.

75-Millimetre (2.952-In.) Gun, Heavy Type, on Carriage with Front Spade (Fig. 914, Plate CLIV.). — The following are particulars of this gun:

Weight of gun	360 kg.	793 lb.
,, carriage	580 kg.	1278 lb.
,, projectile	5.2 kg.	11½ lb.
Muzzle velocity	550 m.	1804 ft.
Energy of projectile	80 t.-m.	266 foot-tons

In order to improve the working conditions of the preceding type, a mounting with front spade was made and tested. The joint of the vertical arm was placed at the height of the muzzle by means of two supports fixed at the rear part of the brackets and joined to the axle by stays. To prevent the trail from cutting into the ground, as frequently happened with the preceding type, a plate having a wide bearing surface was bolted to the lower end of the trail. With this arrangement the gun and carriage lifted less than when the spade was placed direct under the axle, but the spade entered the ground to a less depth. The carriage was modified several times with a view of bringing the joint of the spade nearer the vertical of the carriage axle, but without removing the same difficulties, which were, a rising of the whole system, or insufficient penetration of the spade, according as the joint was more or less near the plane of the axle.

75-Millimetre (2.952-In.) Gun, Long Type, on Carriage with Independent Axle, and Spade in Line with the Axle (Fig. 911, and Figs. 915 and 916, Plate CLIV.).—The following are some particulars:

Weight of gun	360 kg.	793 lb.
,, carriage in one case ...	630 kg.	1388 lb.
,, ,, in another case ...	640 kg.	1410 lb.
,, projectile	5.2 kg.	11½ lb.
Muzzle velocity	550 m.	1804 ft.
Energy of projectile	80 t.-m.	266 foot tons

Another type was then tested, which combined the use of a spade placed directly under the axle, but the latter was independent. Two mountings of this kind, with slight variations, were tested. The system of elastic connection between the carriage and the axle remained as in those already described.

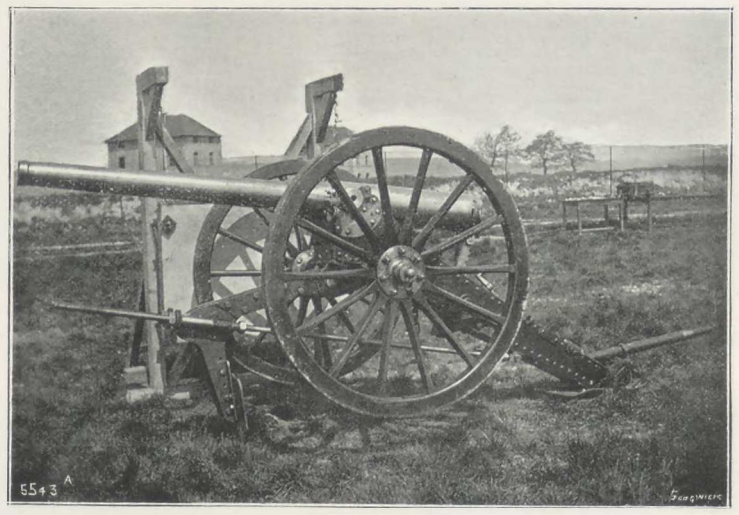


Fig. 911. 75-Millimetre Gun on Carriage, with Anchor Plate in Front of Axle.

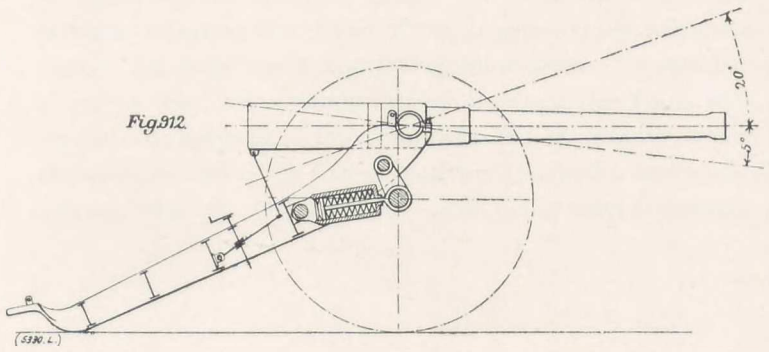
These patterns did not show any marked improvements on the preceding ones, as regards the results obtained separately with a carriage on independent axle and with a carriage, the spade of which is directly beneath the axle. The spade penetrated even less than with the preceding types, and acted very ineffectually when firing took place on hard ground.

75-Millimetre (2.952-In.) Long Type, on Carriage with Inclined Slide and Spade beneath the Axle (Fig. 917, Plate CLIV).—The following are particulars of this gun:

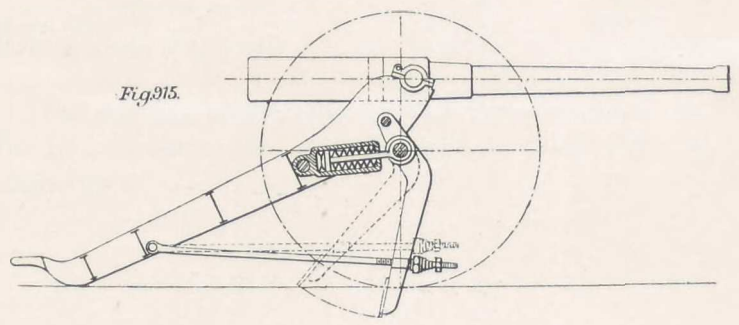
Weight of gun	360 kg.	793 lb.
,, carriage	660 kg.	1454 lb.
,, projectile	5.2 kg.	11½ lb.
Muzzle velocity	550 m.	1804 ft.
Energy of projectile	80 t.-m.	266 foot-tons

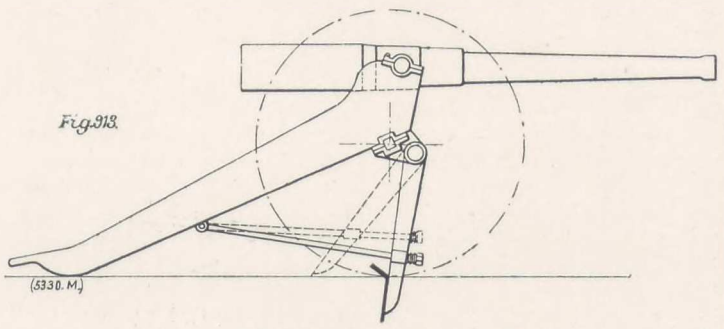
The gun-carriage in this case consists of the brackets with a spade beneath the axle, the slide, and the hydraulic recoil cylinder. The brackets and spade are similar to those already described; a horizontal plate prevents the trail from ploughing up the ground. On the carriage

MOUNTINGS FOR QUICK-FIRING FIELD GUNS.

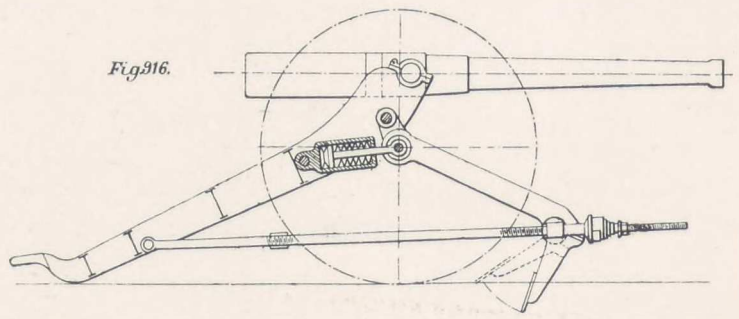


75-Millimetre Gun and Carriage with Independent Axle.

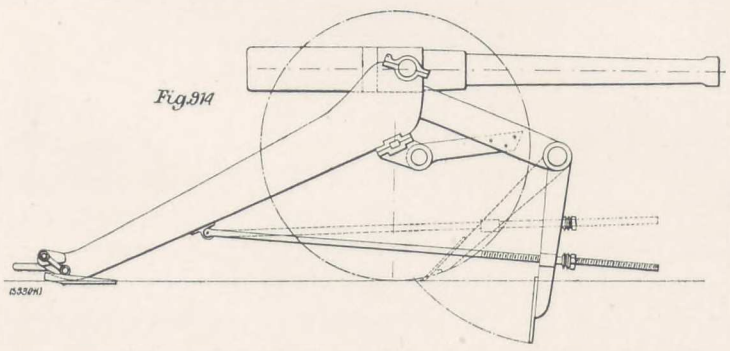




75-Millimetre Gun and Carriage with Anchor-Plate beneath Axle.



Figs. 915 and 916. 75-Millimetre Gun and Carriage, with Independent Axle and Anchor-Plate.



75-Millimetre Gun and Carriage with Anchor-Plate in Front of Axle.

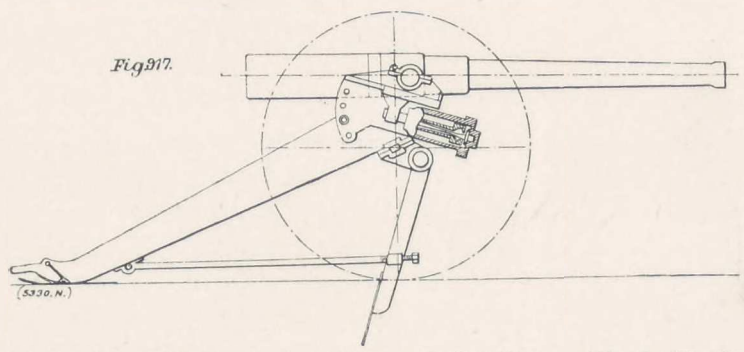


Fig. 917. 75-Millimetre Gun and Carriage, with Inclined Slide and Spade beneath the Axle.

headplate is placed a support which forms the slides, and is provided with the hydraulic recoil cylinder. The support is mounted on a pivot, and can be inclined at various angles. A cast-steel cradle in one piece, with two vertical supports, the top of which forms the trunnion rests, is made to slide on the gun-metal guides, and is held by lateral clamps. In the central part of the cradle is a lug to which is fixed the recoil piston-rod. The recoil cylinder contains a piston, the rod of which is grooved out along its centre, for receiving a regulating counter-rod. A number of ports establish communication between the front and rear of the cylinder. The gun runs out by gravity alone, the slide resuming its former position gradually, and without any shocks. Owing to the spade being placed beneath the carriage axle, the rising of the gun and carriage was still too great. The hydraulic cylinder acted well, but the general working would have been much more satisfactory had the travel of the piston been greater.

80-Millimetre (3.149-In.) Gun on Carriage with Trail-Spade :

Weight of gun	425 kg.	936 lb.
,, carriage	495 kg.	1091 lb.
,, projectile	5.6 kg.	12 lb.
Muzzle velocity	490 m.	1608 ft.
Striking energy of projectile ...	68.5 t.-m.	228 foot-tons

The carriage is the same as that first described—for the 80-millimetre gun—but the trail is fitted with an elastic spade.

XLIII.—SCHNEIDER-CANET CARRIAGES WITH COMPRESSIBLE TRAIL.

ONE of the deductions from the first series of theoretical researches and practical experiments, an abstract of which has been given in the preceeding paragraphs, was that among all the types of mountings tested, not one had the required stability which is essential to modern quick-firing field artillery. Though in the long course of successive experiments, results were obtained which suggested alterations and improvements, so that the series was essentially progressive; and though no definitely satisfactory type was elaborated, the experience gained served as a basis for a new programme for improving ordinary gun-carriages still in service, as well as leading towards a revolution in field armament. Each of the types we have described, when it was fired, recoiled, lifted, and deviated, often to a great extent, behaving, in fact, in quite an unsatisfactory fashion. In some examples, that part which was the main bearing point of the system shifted under fire to a large extent; this often disorganised the trials in a very short time, and caused the gun to trip up suddenly in the course of rapid firing.

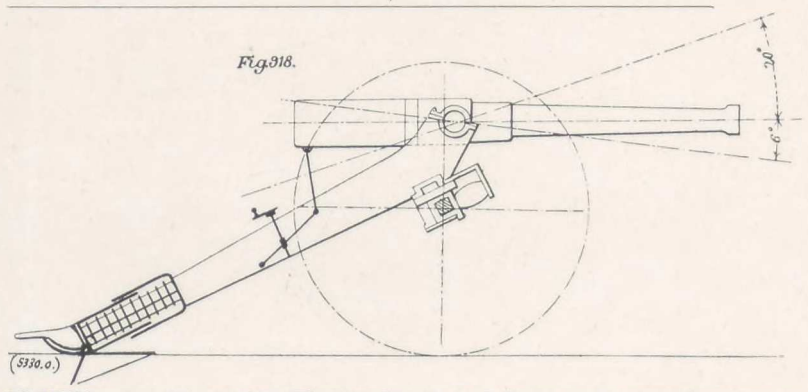
These considerations led Messrs. Schneider and Co., during the first series of tests, to design and experiment with a new type of carriages having an elastic trail. It will be seen hereafter that the extent to which one part of the trail telescoped within the other, was gradually increased; various details were, also, of course, improved progressively. This series of the Schneider-Canet experiments had practical results, and various examples of field gun mountings with elastic trail were manufactured, one important order being executed for Uruguay.

The compressible trail system is one likely to have so wide and important an application that a few words should be given in reference to a controversy of recent date as to the origin of this system; in the controversy referred to it is claimed that the system originated and was first tested in Germany; it will be of interest, therefore to put forward the Schneider-Canet claims in this matter.

It was in France, and in conjunction with the Schneider-Canet type of artillery, that this special kind of trail was first designed and manufactured; it was afterwards improved by Messrs. Schneider and Co., until they felt justified in executing an important order for Uruguay, as above stated. Five complete batteries of guns on this system were put in regular service in that country with complete success, after exhaustive trials had been carried out at the Hoc proving ground, as well as severe cross-country and rolling tests made at Monte Video by a Uruguayan regiment of artillery. It was, moreover, during the experiments carried out in France with this system, that, so it appears, a carriage with a double elastic trail was tested in Germany. It is worthy of comment, that considering the rigid rule in Germany to simplify field artillery and its mountings, that a system should have been designed which embodied not one, but two distinct devices for hydraulic recoil. As a matter of history, the French patent was first applied for in France, then in Germany, and the Berlin Patentamt granted a patent, as is customary, after preliminary researches into the question of priority. Everyone knows the care taken by the German Patent Department before a decision is arrived at, and their having granted these patents appears to settle the discussion in favour of the French manufacturer. With these few words of introduction, we may proceed to consider the second series of experiments.

75-Millimetre (2.952-in.) Short Gun, on Carriage with Elastic Trail and Independent Axle (Figs. 918 and 919).—The following are particulars of the gun:

Weight of gun	620 kg.	573 lb.
,, carriage	410 kg.	903 lb.
,, projectile	4.6 kg.	10 lb.
Muzzle velocity	480 m.	1579 ft.
Energy of projectile	54 t.-m.	180 foot-tons



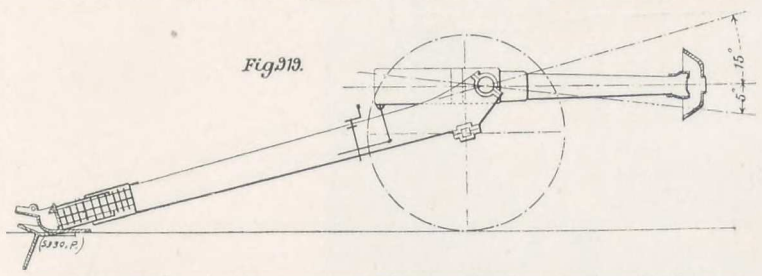
75-Millimetre Gun with Elastic Trail and Independent Axle.

The first carriage of this type was made with a telescopic trail which contained an elastic device, consisting of india-rubber rings placed one over the other; these were compressed when firing took place, returning their energy immediately afterwards. The carriage may be considered to be formed of three main parts: the carriage proper carrying the gun; the spade connected to the carriage; the independent axle and the wheels.

The carriage consists of two steel plate brackets which take the gun trunnions; at the lower part of the brackets, and in front, are soleplates on which slides a saddle-plate carried on the axle. The brackets are joined together in the rear by cylindrical connections formed of two sockets of different diameters made to slide one within the other. These two cylinders are connected by a set of india-rubber rings, which, when the gun is

fired, are compressed, and cause the trail for the moment to decrease in length. The india-rubber rings then relax, and run out the gun again. The bottom of the lower cylinder is made with a circular groove, the centre of which is practically on a vertical line drawn from the centre point of the axle. The trail-spade consists of a steel blade that bears against a horizontal trail-plate. The top surface of the latter is made with a ridge that fits in the circular groove in the lower cylinder, in which it can slide freely, the slide being limited by catches at both ends. With this arrangement, when the spade has been placed in a hollow, or when it has penetrated the ground automatically after firing the first round, the carriage can be shifted over small angles to the right or to the left; the lateral training of the gun can thus be corrected, when only a slight shifting is necessary, without extracting the spade.

In this first type, the axle was independent of the carriage, the following arrangement being adopted: it was fitted with two saddle-plates opposite the soleplates of the brackets; these plates were provided at one end with india-rubber buffers, the other end bearing against angles rivetted to the brackets. When the gun was fired, the brackets, by recoiling, drew back the axle and the wheels,



75-Millimetre Gun with Elastic Trail and Gas Brake.

by pressing down the intermediate buffers. At the same time, the trail cylinders telescoped and compressed the set of india-rubber rings. The trail-spade penetrated the ground more or less deeply, according to the hardness of the soil; it formed the required bearing point to limit recoil, and caused the carriage to run out again by the relaxing of the india-rubber rings. In some experiments the rings were replaced by metallic springs. It will be seen that almost the whole of the system recoiled within the limit allowed by the compression of the elastic column, the *vis-viva* of recoil being greatly reduced.

The results obtained with the first trials of this type were very interesting; the carriage still recoiled and rose when fired, but to a lesser degree; this evil was, in fact, so much reduced that it appeared likely, by improving the various parts, a much greater stability would be obtained than with any of the preceding systems. Numerous other trials were made; among others, some with the gas check at the muzzle, already described. With this appliance, recoil was lessened; but its disadvantages as regards inconvenience to the gunners still existed, and it was finally abandoned.

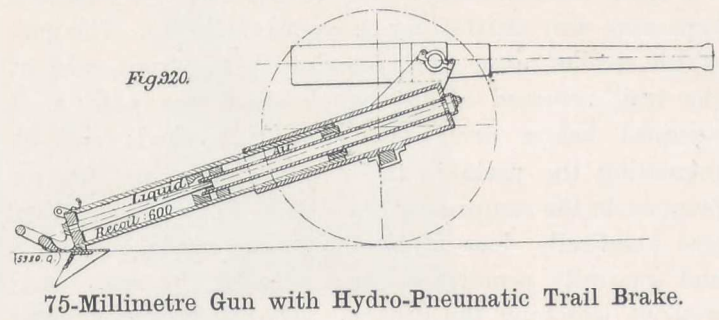
The type which was tried with the gas check at the muzzle is shown in Fig. 919; from this it will be seen that the trail had been lengthened.

75-Millimetre (2.952-In.) Gun, Long Type, on Carriage with Compressible and Hydro-Pneumatic Recoiling Trail (Fig. 920, and Fig. 921, Plate CLV.).—The following are particulars of the gun:

Weight of gun	360 kg.	793 lb.
,, carriage	770 kg.	1697 lb.
,, projectile	5.2 kg.	11½ lb.
Muzzle velocity	590 m.	1936 ft.
Energy of projectile	92 t.-m.	306 foot-tons

The trials which had been made with the first types of carriages with elastic trail, proved the new system to be one of great promise; they also showed that by increasing the length of action of the two parts of the trail, the stability of the system was also increased. It may be mentioned here that all the trials we refer to were carried out in the proving grounds belonging to Messrs. Schneider and Co., with the help of the most perfect measuring and recording instruments, such as crusher gauges, velocimeters. chronographs, &c., with which every action caused by firing was duly analysed; all parts that were found to work unsatisfactorily were, of course, modified immediately.

These trials showed that the working conditions of the



75-Millimetre Gun with Hydro-Pneumatic Trail Brake.

carriage would be further improved if the elastic parts first employed, and which acted simply as buffers, were replaced by a hydraulic brake device, which would constantly offer a resistance directly proportioned to the energy of recoil. If this were obtained, it would check the rising of the gun, and prevent its deviation. A first example of this type of carriage was therefore experimented upon. It consisted mainly of thc carriage proper, the trail-spade, and the hydro-pneumatic recoil trail.

The carriage was formed of two principal parts: one, of cast steel, was a cylindrical tube carrying in front two vertical brackets, in which the gun trunnions are fitted. The tube was closed in front by a cover, in the centre of which was a passage, through which compressed air was introduced in the recuperator; this was closed by a valve. The carriage formed, with the gun, the axle and the wheels, the movable part which recoiled and ran out again. The second part was the trail, which remained fixed during firing; it consisted of a forged-steel tube, which contained the hydro-pneumatic arrangement for checking recoil. It was provided in front with an outside gun-metal lining, which facilitated the sliding of the two parts during recoil and return, the sliding action being, moreover, controlled by lateral guides. A gland, through which ran the tube for the introduction of compressed air,

closed the trail at its front part; it was closed at the rear by a cover, in the centre of which was fixed the central counter-rod. A ring, to which was fitted the trail-lifting lever, was also screwed on the lower end. The spade was attached to the trail with a groove and rib, as described for the preceding type, this arrangement enabling the gun to be trained over small lateral angles. The spade was of steel, and bore against a horizontal trail-plate; it could be easily removed when, for any reason, it was desired to fire with free recoil, as in the old rigid trail system. To obtain this, it sufficed to fix the two tubes one on the other by placing a ring in a groove on the rear tube; the movable tube butted against the ring, and the trail remained rigid.

The hydraulic recoil cylinder and the recuperator were contained in the lower fixed tube. The recoil cylinder was on the Schneider-Canet system, with central counter-rod. The liquid when displaced, acted on an airtight movable diaphragm, which separated the liquid from the air contained in the top part, and the diaphragm compressed the air in front of it. The air by expanding when recoil ceased, caused the liquid to flow back, and the gun ran out again automatically. The results obtained with this type were very satisfactory as regards stability. The gun, which recoiled after each round with the front tube of the trail, returned almost completely to the position it occupied before firing the preceding round; and by regulating the ports in the recoil cylinder and the air pressure in the recuperator, the rising of the whole system was practically done away with. The spade held well, and generally penetrated completely at the first round without loosening the ground. The device for slightly rectifying the lateral training worked satisfactorily, even when covered with earth and mud.

Several specimens of this type, and of various calibres, were manufactured and tested in succession. In some cases the gun rested in a small carriage made to pivot on the carriage proper, a special handwheel being provided for adjusting lateral training. This arrangement also gave satisfaction, and it was chosen by the Uruguayan Government for the ordnance they ordered, and which was manufactured at the Havre Works.

75-Millimetre (2.952-in.) Gun, on Carriage with Compressible Trail Adopted by the Uruguay Government (Fig. 922, and Figs. 923 and 924, Plate CLV.).—The following are particulars of this gun:

Weight of gun	260 kg.	573 lb.
,, carriage	585 kg.	1289 lb.
,, projectile	5 kg.	11 lb.
Muzzle velocity	470 m.	1542 ft.
Energy of projectile	56 t.-m.	186 foot-tons

This type contained, besides those parts mentioned in the preceding description, a small carriage movable on the gun-carriage proper, and which serves for rectifying lateral training. This arrangement necessitates a second handwheel for the lateral training. The small carriage consists of a cast steel circular platform in one piece with two vertical brackets, the gun trunnions fitting in the top part of the latter. The platform is free to turn round a central bearing which forms a vertical pivot; it rests on two circular guides, fitted with gun-metal slide-plates that form part of the gun-carriage proper, clamps in front and in the rear preventing the shifting of the system when the gun is fired. The left-hand bracket is continued at the rear as a support for the gun-training mechanism. The required elevation is obtained by a screw, the head of which bears constantly against the breech end of the gun. It travels in a nut carried on the extension of the small carriage, the rotation of the nut being produced by an endless screw worked by the handwheel. The gun is trained laterally by displacing the small carriage by means of a screw, the nut of which is jointed on the shoe-plate of the gun-carriage proper; the rear end of the screw rests on a second jointed support mounted on the extension of the small carriage. The system is worked by a handwheel. The wheels are of wood with steel centres; the brake used when the ordnance is wheeled from one place to another consists of a circular band that surrounds the nave; it is not used during firing.

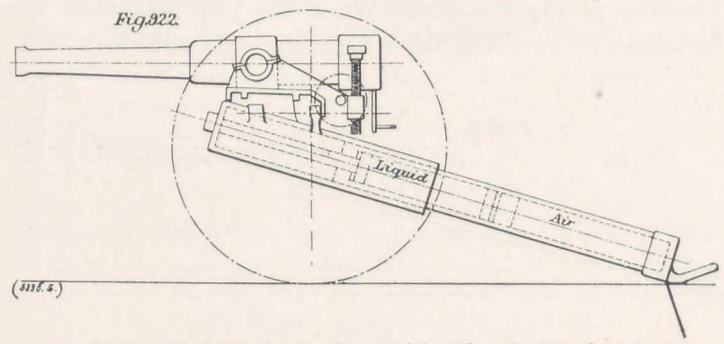


Fig. 922. 75-Millimetre Gun with Elastic Trail for the Uruguay Government.

This description completes the section dealing with elastic trail carriages. This system has been carried by Messrs. Schneider to a high degree of perfection; it allows the firing of 10 and 12 rounds per minute by gunners having no special training. This speed is in excess of what could be obtained at the time with rigid trail carriages, provided with elastic devices for deadening the force of recoil. As has been previously stated, the system works smoothly, and the spade scarcely recoils when the gun has once started regular firing. The rising of the carriage is negligeable. This type is, therefore, suitable to replace the older ones, over which it constitutes a marked improvement.

During firing, however, the gunners are obliged to stand in the rear, or outside the wheels, owing to the backward and forward motion of the latter. The consequence of this is, that the guns cannot be fired with the rapidity now demanded by modern conditions without undue fatigue to the gunners. This led Messrs. Schneider and Co. to design and experiment with another class of gun-carriage for extra rapid firing, in which the wheels remain in place, and by which 20 or even 25 aimed rounds per minute can be fired, without fatigue for the gunners.

SCHNEIDER-CANET SYSTEM OF MOUNTING FIELD ARTILLERY.

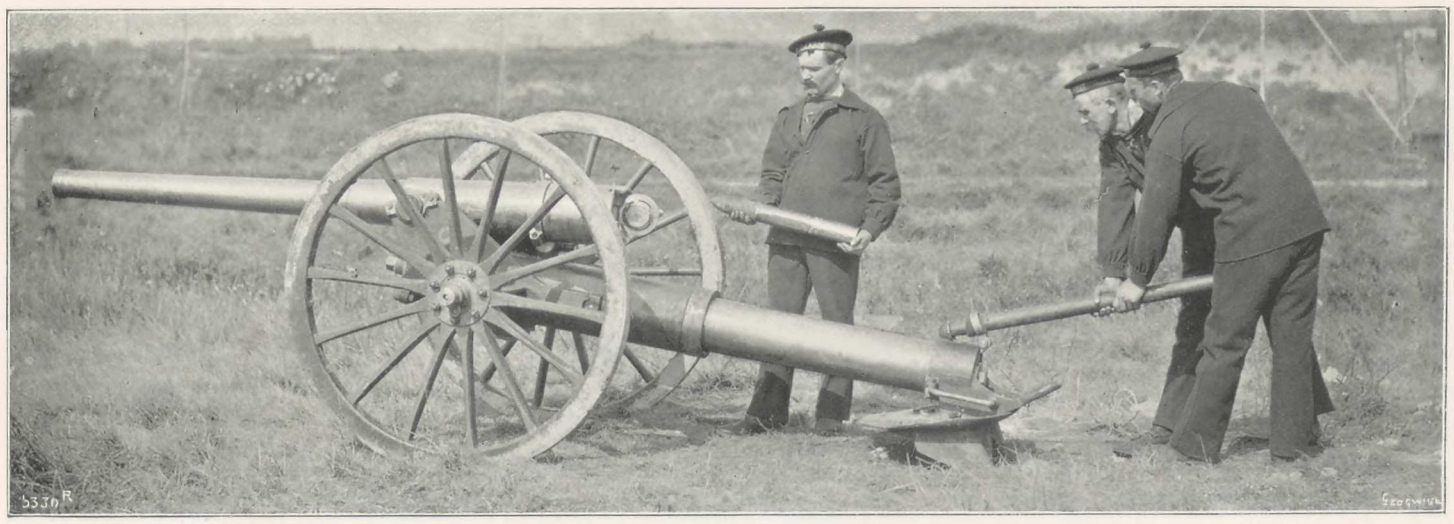


Fig. 921. 75-Millimetre Gun with Hydro-Pneumatic Trail Brake.

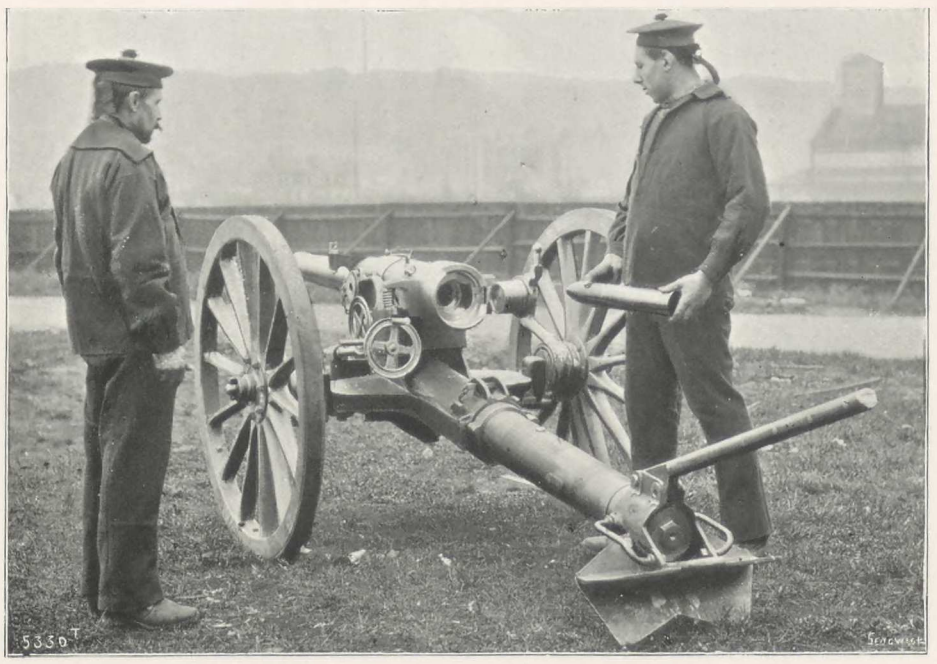


Fig. 923. 75-Millimetre Gun with Elastic Trail for the Uruguay Government.

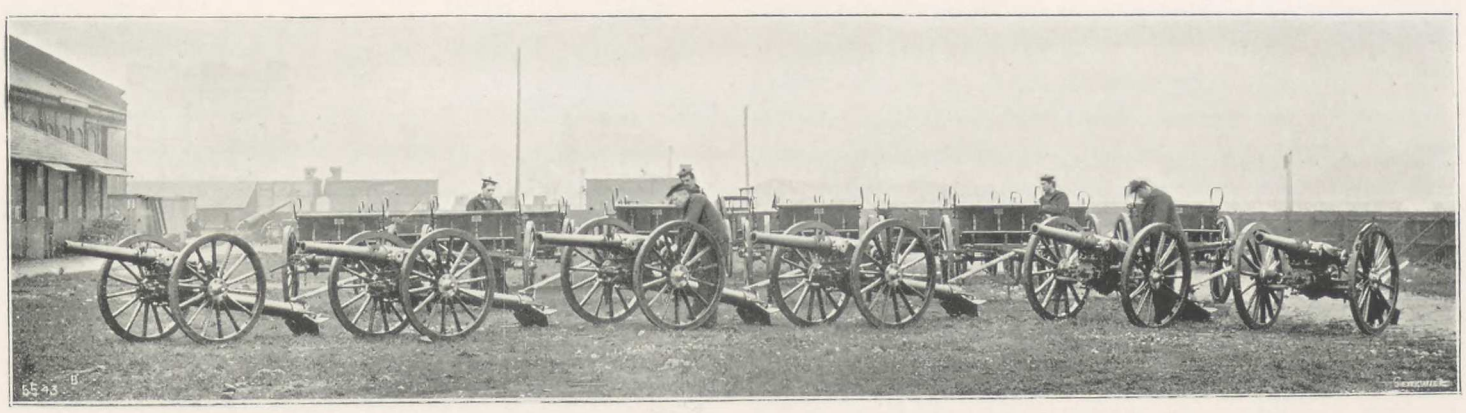


Fig. 924. Battery of 75-Millimetre Guns, on Carriages with Elastic Trail for the Uruguay Government.

XLIV.—FIELD GUN CARRIAGES WITH TELESCOPIC RECOIL CYLINDERS.

THE following section deals with the class designed for extra rapid firing, and especially with the 1898 pattern which, it is claimed, fulfils to a high degree all the conditions embodied in the present programme of the French Ordnance Committees, whose main study is now the transformation of field artillery.

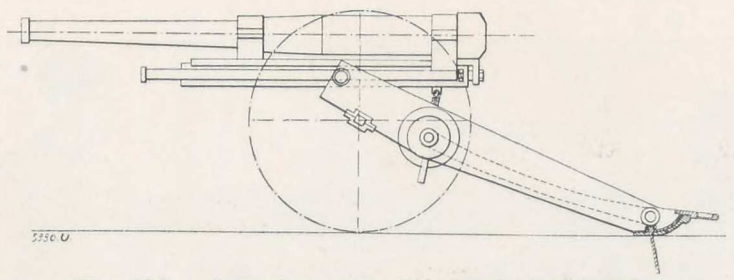


Fig. 925. 3-in. Gun with Telescopic Recoil Brake.

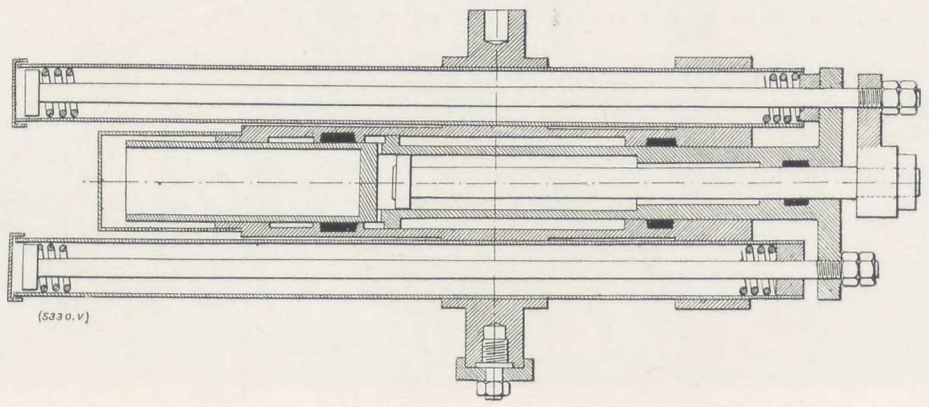


Fig. 926. Section of Telescopic Recoil Brake.

3-In. Gun, Long Type, on Carriage with Telescoping Recoil Cylinder (Figs. 925 to 927).—The following are particulars of this gun:

Weight of gun	430 kg.	948 lb.
,, carriage	870 kg.	1917 lb.
,, projectile	6.2 kg.	13⅔ lb.
Muzzle velocity	610 m.	2001 ft.
Energy of projectile	170 t-m.	390 foot-tons

The carriage may be divided, for purposes of description, into two main parts: the carriage support and the carriage proper. The carriage support consists of two fixed plate brackets; it is joined by a circular rib and slide to a trail-spade, on which it can be displaced to the right or to the left, for regulating the lateral training. The gun rests in two collars placed, one near the reinforce and the other in front of the breech-block; the collars are in one piece with the slide. The latter, during recoil and return, travels in a forged-steel cradle fitted with the excessively. An outside cylinder forms part of the cradle, and remains fixed when the gun recoils; it is fitted in front and in the rear with a gland and two flanges, in which are screwed the tubes that contain the recuperator springs; these tubes are supported near the middle of their length. A piston travels in the outside cylinder, and forms an intermediate recoil cylinder with relation to the piston proper, which is joined to the gun. These concentric cylinders and the piston proper telescope one in the other during recoil and return. A head-piece is screwed on the rear end of the intermediate cylinder; it is fitted with two flanges, against one of which bear the right-hand recuperator springs, the other supports the left-hand recuperator-rod. The gland plug of the recoil piston-rod is screwed in the centre of the head-piece; the piston is made with a port which allows the liquid to flow from one side to the other, a reglet causing the opening of the vent to vary as may be required. The piston-rod is joined

direct to the breech end of the gun; a neck fitted with a valve is placed in the centre of the system, and serves to fill the recoil cylinder. The shoulder-piece, to which the recoil-rod is fixed, is fitted on the right-hand side, with an arm on which the rod of the right-hand recuperator is bolted. The recuperators are formed of sets of springs placed inside the cylindrical tubes fixed to the cradle; these springs are divided by diaphragms, and are placed on a central rod.

The required elevation is obtained by means of a screw jointed on the cradle and which turns in a nut, the latter being worked by two bevel wheels—one keyed on the nut, the other on a hollow horizontal shaft set in motion by a handwheel driven by the gunner. Lateral training is obtained by displacing the trail. To obtain this, the spade is provided with a rack worked from a pinion keyed on a shaft with a pitched wheel driven by a plate-chain. The latter is worked by a pinion keyed on a shaft placed concentric with the hollow shaft for elevating the gun The two handwheels for elevating the gun and for lateral training are therefore on the same centre.

75-Millimetre (2.952-In.) Gun, Long Type, on Carriage with Trail-Spade and Hydraulic Recoil Cylinders (Figs. 928 to 934, and Fig. 937, Plate CLVI., and Figs. 935, 936 and 938).—The following are particulars of the gun:

Weight of gun	355 kg.	782 lb.
,, carriage	635 kg.	1399 lb.
,, projectile	6.5 kg.	14⅓ lb.
Muzzle velocity	500 m.	1640 ft.
Energy of projectile	83 t-m.	276 foot-tons

In a modified type the particulars were:

Weight of gun	348 kg.	769 lb.
,, mounting	638 kg.	1406 lb.
,, projectile	6.5 kg.	14⅓ lb.
Muzzle velocity	500 m.	1903 ft.
Energy of projectile	111.5 t-m.	371 foot-tons

In these models the following properties were shown to exist in a high degree under test:

1. Reduced recoil, allowing continued fire.
2. Rapid and sustained fire at comparatively short range, without re-training the gun.
3. Great stability during recoil on ordinary ground.
4. Very slight deviation of the gun.
5. Strong and absolutely safe breech-closing device.

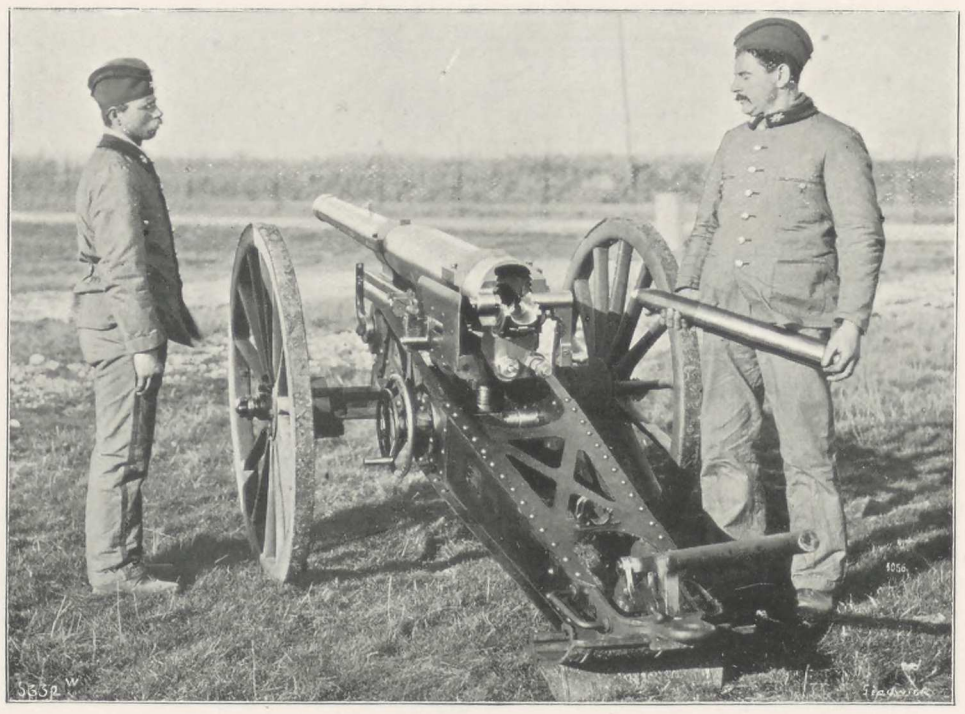
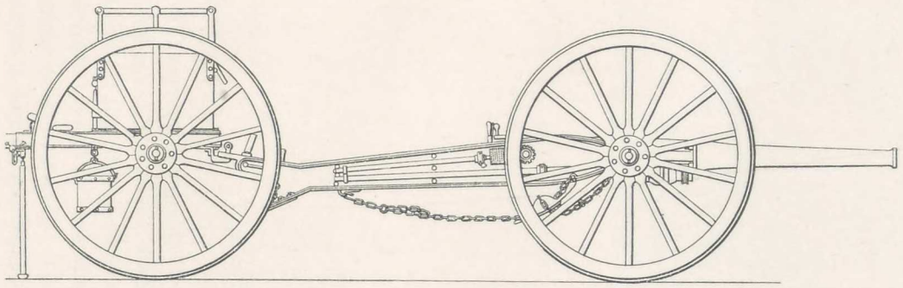


Fig. 927. 3-in. Gun with Telescopic Recoil Brake.

6. High ballistic power compared with the weight of the gun.
7. Complete protection of parts against grape-shot and dust.

The gun is of forged and hardened steel; it is 33.3 calibres in length, and is made in two parts: the tube in which the breech-block is screwed, and the jacket, which covers the tube for a length of 1.210 metres (47.637 in.). The force of recoil is transmitted to the hydraulic recoil cylinders by the jacket, so that the tube has not to withstand any efforts that would tend to affect the breech mechanism. The gun is connected to the recoil cylinders by means of dovetailed flanges, which form a strong attachment, but allow the system to be taken to pieces rapidly. The gun has been designed to take a truncated conical metallic cartridge; it is therefore not fitted with any mechanism for obturation. The breech-block can,

SCHNEIDER-CANET FIELD GUN-CARRIAGE WITH TRAIL SPADE AND HYDRAULIC RECOIL BRAKE.



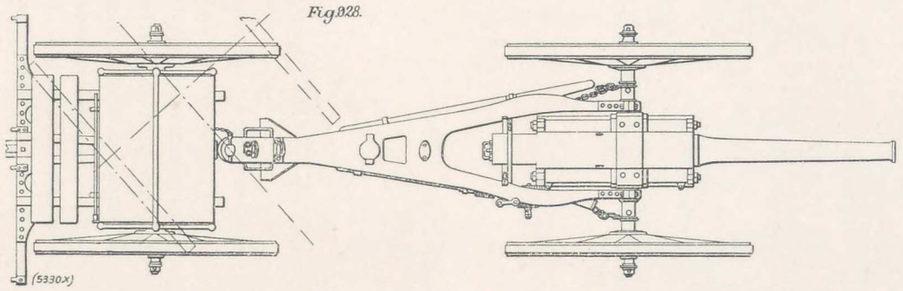


Fig.328.

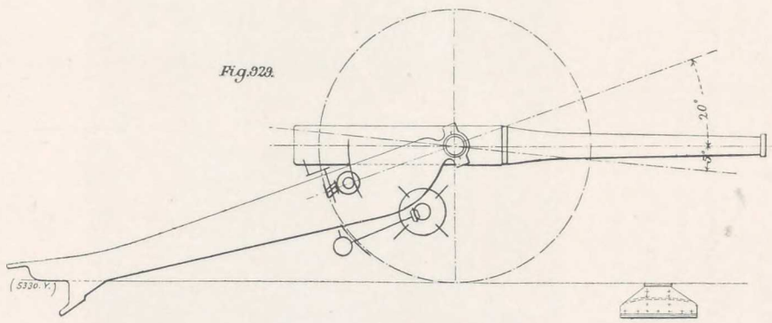


Fig.329.

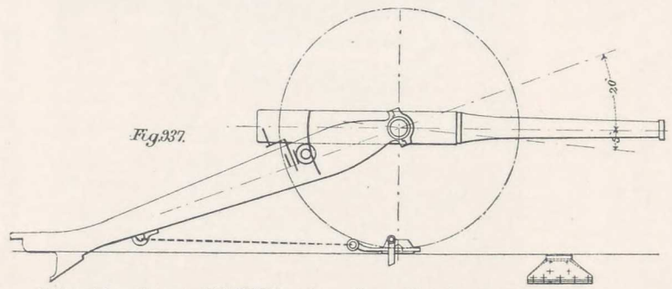


Fig.337.

Schneider-Canet 75-Millimetre Gun Carriage and Limber.

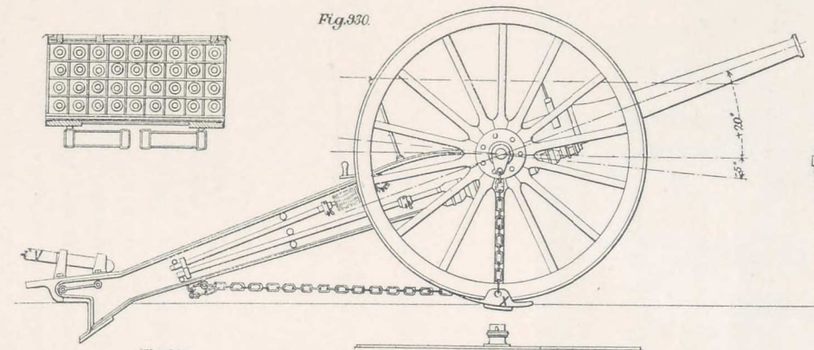


Fig.330.

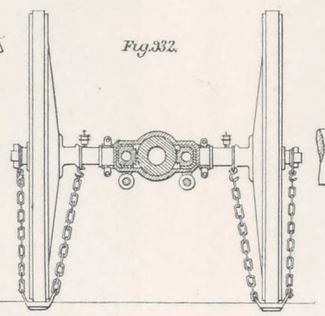


Fig.332.

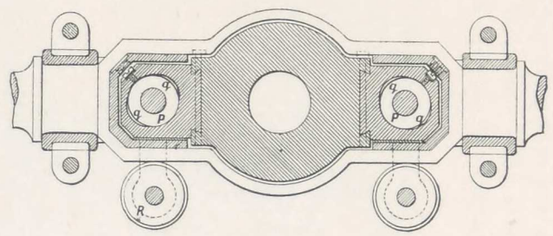


Fig.333.

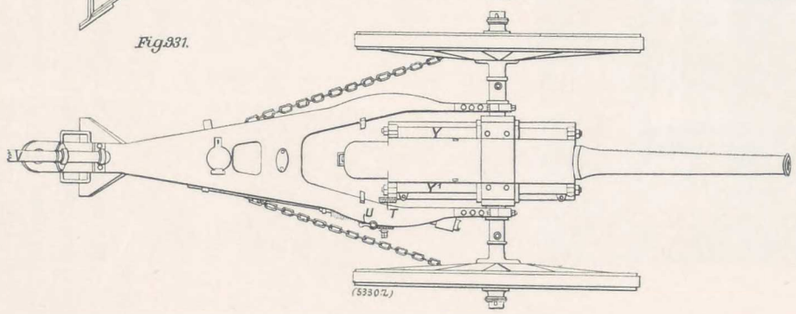


Fig.331.

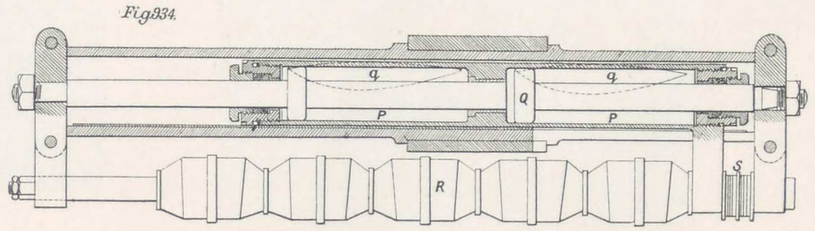


Fig.334.

PLATE CLVI.

however, easily be replaced at any time by one of ordinary type, with plastic obturator, so as to fire a cheaper kind of ammunition; in this case, however, rapidity of firing would be reduced by one-half.

firing on very soft ground. When the surface is of average hardness, it is not necessary to resort to this device. Percussion being absent owing to the action of the recoil cylinder, the carriage rises only slightly even

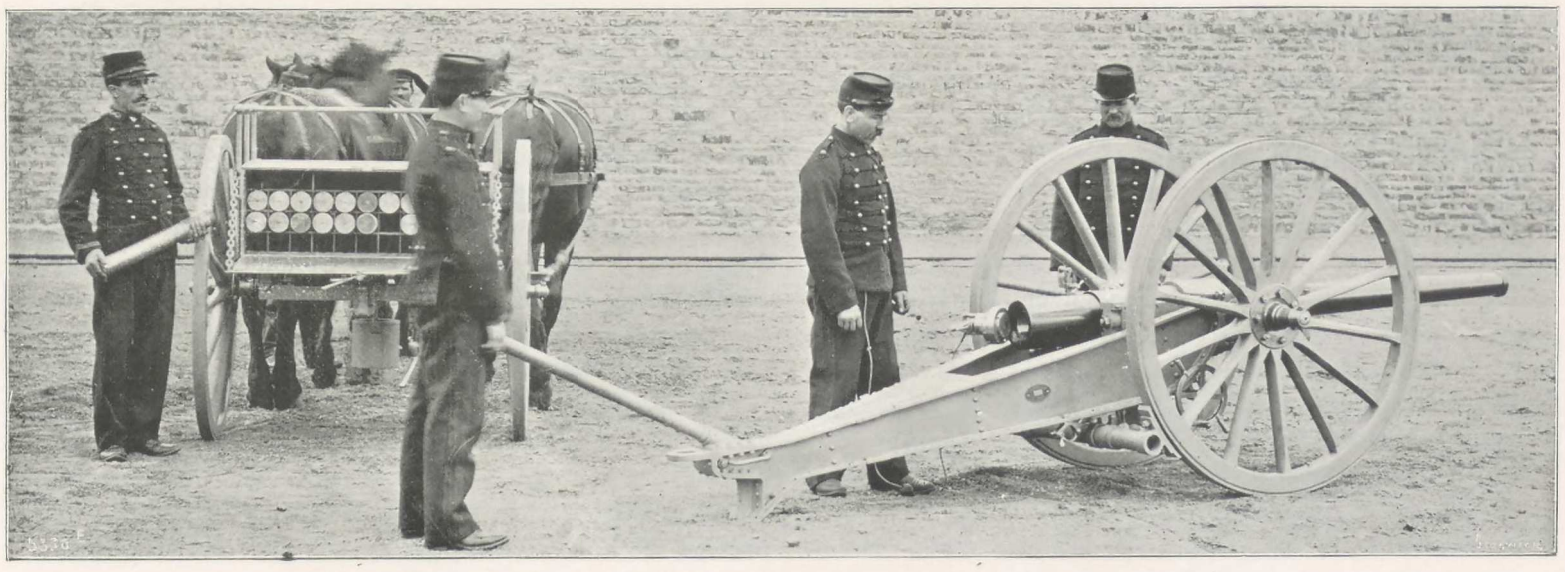
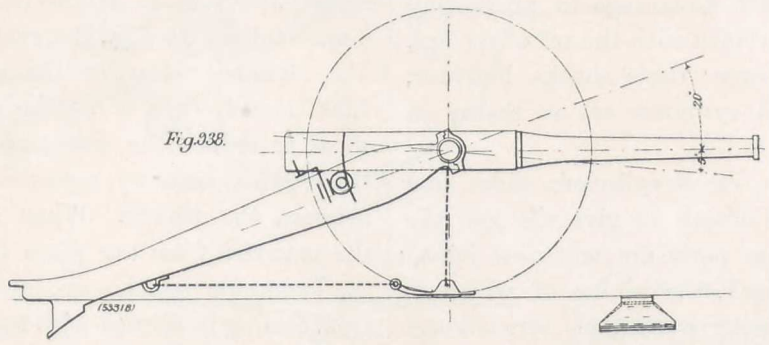


Fig. 935. 75-Millimetre Quick-Firing Gun on Rigid Carriage, with Trail Spade.



Fig. 936.



Figs. 936 and 938. Schneider-Canet 75-Millimetre Gun, Carriage, and Limber.

The carriage is provided with hydraulic recoil cylinders, a trail-spade, and wheel drags. The gun runs out automatically; the trail-spade is shaped so as to automatically penetrate ground of average hardness, and preliminary digging is not necessary. The wheel drags are used when the gun is hauled from one place to another, and also when

when on ploughed ground. In this case, however, correction in training after each round is hardly necessary, unless minute precision is required, as, for instance, when firing against a cavalry charge. The carriage is very simple in construction, and requires no preparation for firing; the recoil cylinders are filled with incongealable

liquid, and as they are permanently tight, it is not necessary to inspect them when the gun is placed in battery. The recoil cylinders and their rods are protected against grape-shot and dust by closed slides, which form a protective armour; the whole of the system occupies but little room, and is easily taken to pieces. Expansion of the gun has no influence on the working of the various parts, for the cylinders can extend freely in the cradle, and the glands round the rods are not liable to become hot. The carriage is built up of steel plates; it consists of two cheeks stayed by hollowed-out plates, which allow free recoil. It is jointed on the axle, the trail end being fitted with the pivot-bolt seat and the spade. The lever for lateral training, and the gun sponge, are hooked on the carriage; the gun sponge is in two parts, to fit more easily against the trail. The gun is placed within the axle, so as to reduce the rising of the system under fire as much as possible. It clasps the recoil cylinders, the latter travelling in slides fitted to the axle, and the whole system oscillates on the wheels to obtain the required elevation. The gun, therefore, recoils along its axis, whatever be its incline. The recoil cylinders being movable, the rods are fixed and are joined to the ends of the slides; each of the cylinders is fitted with an arm that serves to take up the pressure of the running-out springs, the latter bearing on a rod placed in front of the system. The length of the set of springs required for obtaining the recoil travel allows the provision of twin-recoil cylinders, and this is an advantage as regards the division of effort. During recoil, the liquid in each cylinder passes from the front to the rear of the piston, through ports, the opening of which is in relation with the speed at all points of the travel; resistance is, therefore, practically constant. The running-out springs being compressed, their action is added to that of the recoil cylinders to run out the gun when recoil has ceased. These springs are sufficient to run out the gun under the greatest firing angle. The piston-rods, while entering the cylinders on one side, are withdrawn on the other, the volume of liquid, therefore, remains constant, and this is of great advantage in preventing leakage. Leather buffers, combined with the set of springs, deaden all shocks during return; these shocks, however, are very slight, for the recoil cylinders act as brakes in both directions.

As above stated, the gun, recoil cylinders, slides, and axle, oscillate together on the wheels to give the gun the required elevation. All these parts are, moreover, joined to the carriage through a rack, the pinion of which is keyed on the same axle, with a tangent screw-wheel provided with a handcrank. The gunner, placed on the right-hand side, keeps his eye on the sights while he works the crank, this being effected independently of the loading of the gun, which is carried out on the left-hand side. In most cases these two operations are conducted simultaneously, it being only when the gun is fired at ranges higher than 3,000 metres that the breech end is raised for closing the breech-block.

The gun is trained by means of the trail lever. It would be impossible to give to such a powerful gun a lateral action independent of the carriage, owing to the deviation that would arise were the gun to be placed obliquely to the trail. Experience has proved that the gunner at the trail can rectify lateral training while the pointer is occupied in correcting the elevation of the gun. On most ground the spade is displaced laterally by lifting the trail; and this causes no difficulty, the wheels being always moveable even when the wheel-drags are on. The wheel-drags are not of much importance, and are not generally resorted to to check recoil; when the trail is fairly held by the spade in suitable ground, their action is unnecessary. The gun and mounting are easily taken apart, by removing two keys that hold the gun to the slide-shoes and sliding the gun forward.

The fore-limber contains no special arrangement. It carries a chest which contains 36 cartridges, placed horizontally in wooden compartments, and two boxes of tools and spare parts. It is so designed as in turning to form an angle of 60 deg.; the system can therefore turn half round in a width of from 7 to 8 metres.

75-Millimetre (2.952-In.) Gun, Long Type, on Carriage with Trail-Spade and Hydraulic Recoil Cylinders (Figs. 939 to 948, Plate CLVII., and Figs. 949 and 950, Plate CLVIII.).—The following are particulars:

Weight of gun	333 kg.	734 lb.
,, carriage	670 kg.	1476 lb.
,, projectile	6.5 kg.	14½ lb.
Muzzle velocity	560 m.	1862 ft.
Energy of projectile	104 t.-m.	346 foot-tons

This type contains the following chief modifications:

The breech is opened in one action: the carriage embodies a device for lateral training; the trail is fitted with an elastic spade and a trail-shoe; the fitting of the gun in the cradle is not the same as in the preceding model; the recoil cylinders form part of the cradle, instead of recoiling with the gun. Recoil is reduced owing to the combined action of a hydraulic cylinder, a spring recuperator, and an elastic trail-spade. Under the maximum angle of 20 deg., the range is 8 kilometres (5 miles). The distance between the wheels on the ground is 1.200 metres (47¼ in.). The gun goes through the axle, so as to reduce the rising up of the system, and give it the required stability, notwithstanding the slight distance between the wheels. When it is required to transport the material from one place to another, the gun is given the maximum positive angle, so as to prevent the muzzle from coming in contact with the ground on passing through ditches.

The gun is of forged and hardened steel, manufactured to the requirements of the French ordnance regulations. It is 2.470 metres (97.240 in.) in length, and is built up of three parts: the tube in which the breech-block is screwed, a jacket over about half the length of the tube, and a chase coil fitted in with tongue and groove. The force of recoil is transmitted to the recoil cylinders from

SCHNEIDER-CANET 75-MILLIMETRE GUN-CARRIAGE AND LIMBER.

Fig.339.

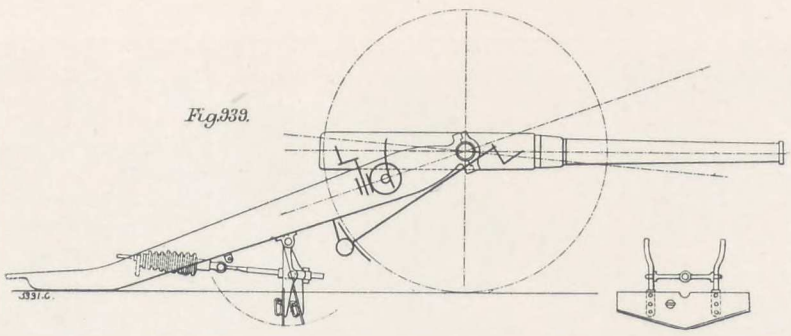


Fig.340.

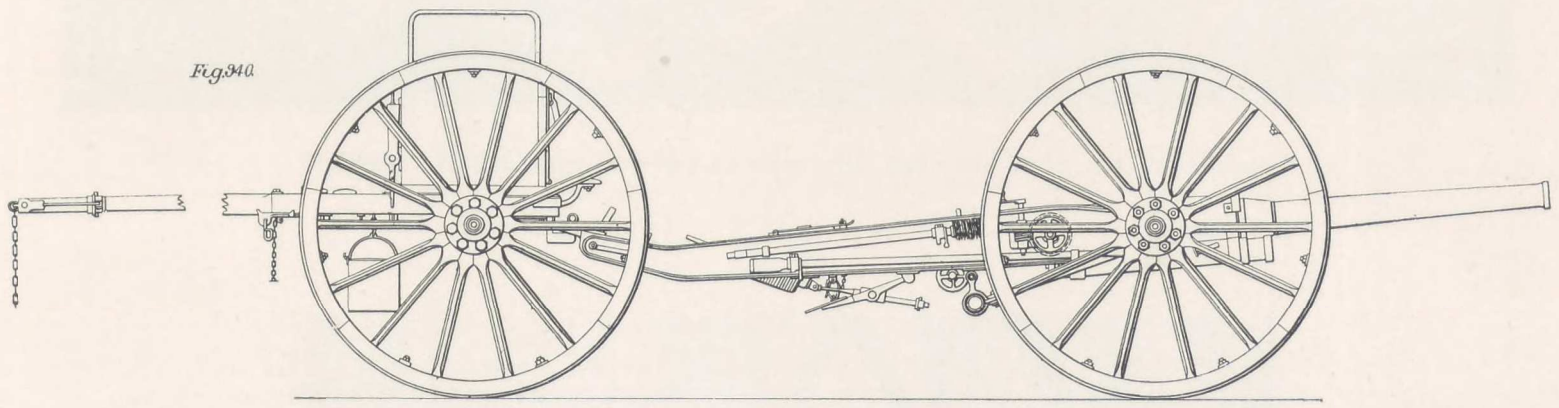


Fig.341.

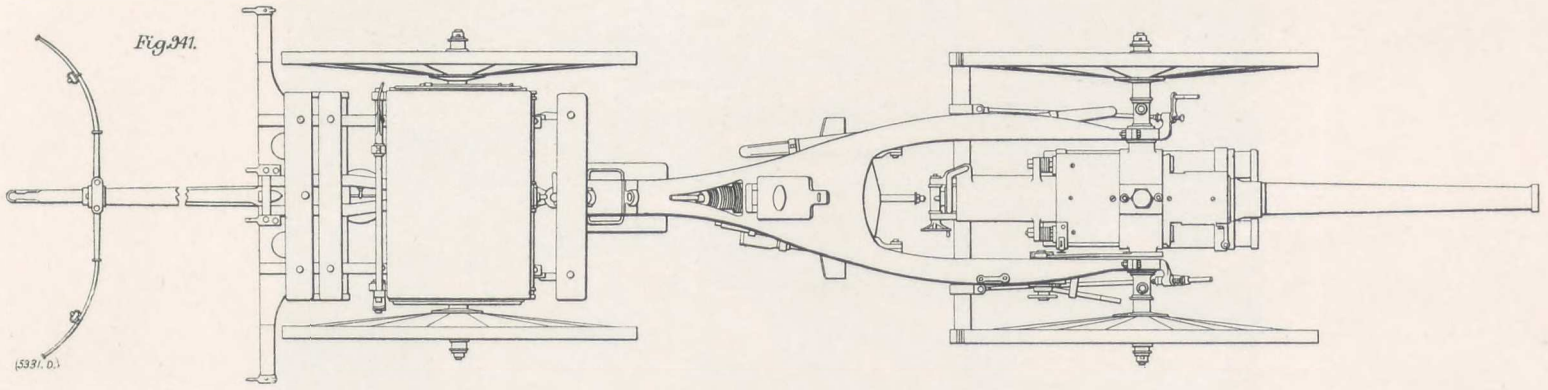


Fig.342.

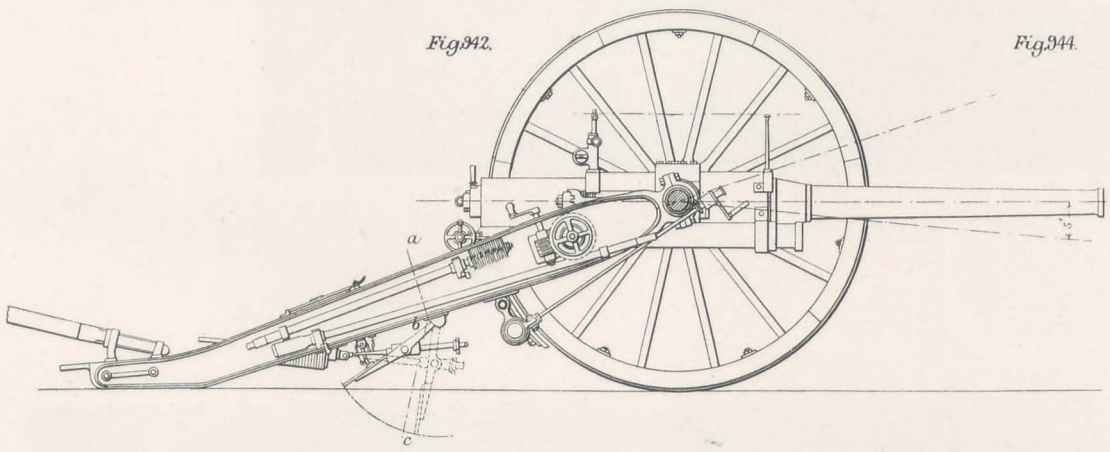


Fig.344.

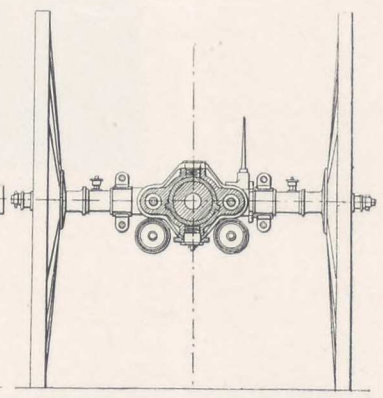


Fig.345. *Brake.*



Fig.346. *Recoil Spring.*

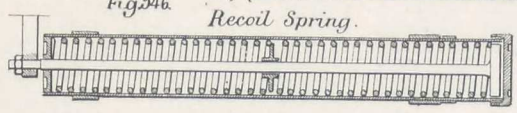


Fig.343.

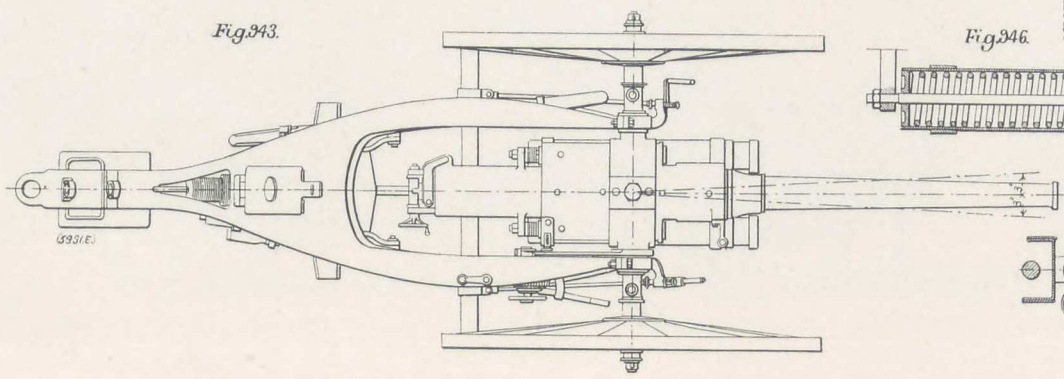


Fig.347. *Back View.*

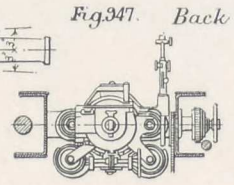
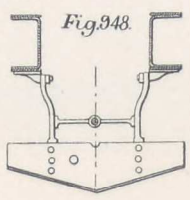


Fig.348.



SCHNEIDER-CANET 75-MILLIMETRE GUN AND CARRIAGE.



Fig. 949. 75-Millimetre Gun and Carriage with Hydraulic Brake and Trail-Spade.

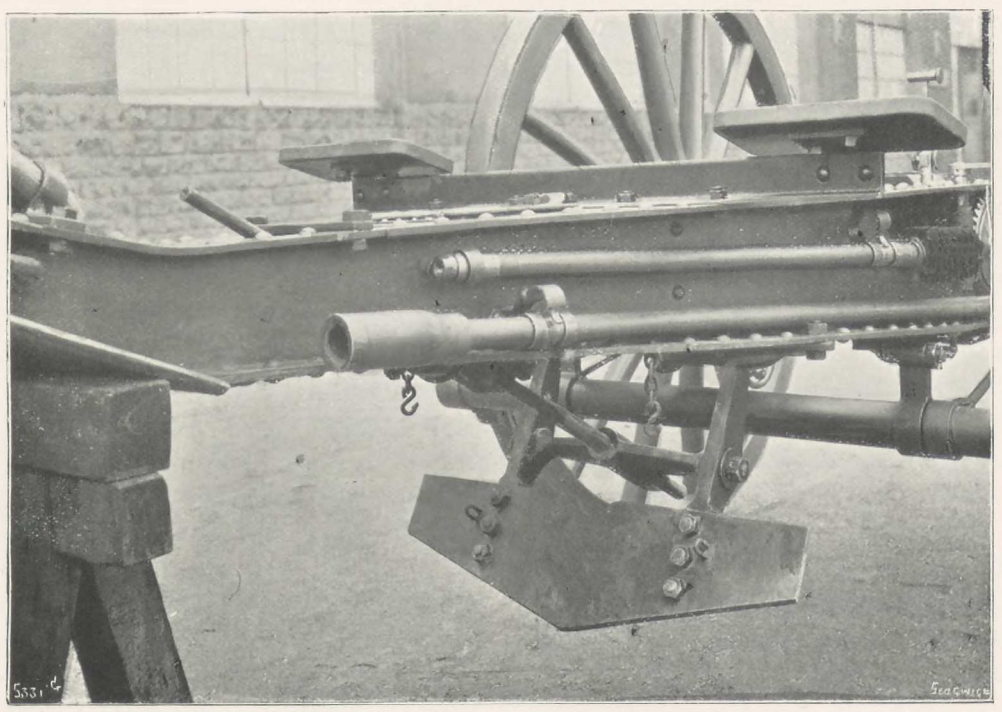


Fig. 950. Detail of Trail-Spade.



Fig. 955. 75-Millimetre Gun with Hydraulic Brake and Trail-Spade.

the jacket, there being, therefore, no unbreeching effort to counteract. The jacket carries a certain number of parts forged in one piece with it, namely, the lugs which hold the recoil piston-rods and the recuperator-rods, the flanges that act as guides in the cradle, the T-shaped guide for lateral training, and the hinge which carries the breech-block. The breech-block seating is made with two threaded parts and two interruptions.

The breech-closing device contains but a limited number of pieces, and these are strong and of simple shape; they are easily put in place and removed by hand, no tool being required. It projects but little over the rear end of the gun. Firing takes place by percussion, the striker being cocked automatically; the gun can also be fired by electricity. The carriage has a hydraulic recoil and independent spring recuperator. It is fitted with a spade placed half-way between the carriage axle and the trail end. The spade is made with an elastic joint. According to the hardness of the ground, it penetrates more or less by varying the length of the traction-rod with a key. During transport, it is raised and hooked on to the trail. The recoil of the gun on the carriage has been limited to .300 metre (11,811 in.); this was the maximum that it seemed possible to obtain with a direct-acting spring recuperator made independent of the recoil cylinders, the liquid in these being under no pressure when the gun is not in action. This length of recoil did not prevent the recoil of the carriage owing to the power of the gun compared to its weight, but this model, as it stands, contains improvements which allow the lateral training to be rapidly rectified, and the firing of eight to ten aimed rounds per minute. The recoil pistons are not made tight; the recuperator springs require no regulating, and the system of connecting the gun to the carriage is very simple.

The axle is made with a wide opening in its centre, in which the cradle is placed (Fig. 944, Plate CLVII.); the latter is made with two trunnions, round which it pivots, carrying the gun with it. The axle journals are conical, and in a straight line; the wheels are lubricated through the centre, so that they need not be removed. The gun-metal cradle is fitted with the recoil cylinders, the seatings for the vertical trunnions and the lugs for fixing the recuperator casings, and the sight and scale. The two recoil cylinders are placed laterally in a line with the centre of the gun, so as not to create diagonal friction of the latter in the cradle. The recuperator springs work in compression; they are contained in steel casings joined to the cradle by collars. The trail is built up of steel plates; it is made with two brackets and two stay-plates, the latter hollowed out to allow a free recoil for the gun. It carries in front the jointed supports on the axle, and in the rear the trail-plate, which rests on the ground; it is, moreover, fitted with all the requisite accessories. When in battery, the gun and cradle are balanced on the axle. To obtain the required elevation, the cradle is made to turn by means of a crank which operates a curved rack fixed to a cradle through an endless screw and a pinion. The crank, endless screw, and pinion are held in a support bolted on the right-hand bracket. A handwheel serves to regulate the pressure on the endless-screw wheel, the latter being driven by friction; thus the junction of the gun with the carriage is not too rigid, yet sufficiently so to prevent any deviation that might be caused by acting on the firing line. For transporting the material from one place to the other, the gun is buckled on the carriage, the breech-end being lowered, and thus the mechanism suffers no shocks.

The gun is trained laterally, as is customary, with the help of the trail lever; in this model, however, two small sights have been added on the axle, which give a central sighting line, and enable the man at the trail to replace the gun in the required direction when a round has been fired. The gunner has then only to give the gun a slight lateral displacement on the carriage, by means of a handwheel and an endless screw, which engages a horizontal sector; with this device the gun can be made to pivot through about 2 deg. on each side. The handwheel is fitted on an arm fixed to the axle, and the sector is made movable over a dovetailed arc. The gun slides, during recoil, in a T-shaped groove, which joins it to the system, while it does not prevent its displacement. The wheel brake consists of a cross-piece fitted with shoes; two suspensions under the trail; two bars and two crank nuts carried in the axle supports. The brake is only used occasionally during firing. The gun is sighted by means of a scale and sight placed on the right side of the cradle, at a sufficient height, so that the gunner has not to stoop when he sights the gun; sighting and loading take place simultaneously. A small oscillating level is provided, to rectify elevation in quick firing.

To maintain the carriage in perfect working order it is only necessary to keep it clean and well lubricated. Leakage of liquid from the recoil cylinders is not to be feared; it could only take place through the glands that surround the rods, and these are easily kept quite tight. The recuperator springs being regulated in advance to run out the gun completely under the greatest firing angle, they are submitted to only moderate action, and require no attention during firing. The surfaces, against which there is a sliding action, remain uncovered only during the time recoil lasts. The limber is practically similar to that of the preceding type.

75-Millimetre (2.952-In.) Gun, Long Type, on Carriage with Hydraulic Recoil, and Spade under Axle or at End of Trail (Figs. 951 and 952):

Weight of gun	330 kg.	727 lb.
,, carriage	686 kg.	1512 lb.
,, projectile	6.5 kg.	$14\frac{1}{3}$ lb.
Muzzle velocity	550 m.	1804 ft.
Energy of projectile	102.5 t.-m.	341 foot-tons

In this specimen the gun is fitted at its lower part with a bearing soleplate, which slides, during recoil, in a gun-metal guide fitted to the carriage. The guide contains

the recoil cylinder and the recuperator; it pivots horizontally on the axle, thus allowing a lateral deviation of 3 deg. on each side. For elevation, the whole system, formed by the gun, the guide, and the axle, pivots to the carriage brackets, with the help of a hand crank, an endless screw, a friction wheel, a square pinion, and a toothed sector. The recoil cylinder allows a longer recoil than in the preceding models, so as to reduce the rising of the carriage when the gun is fired. The recuperator consists of a multiplying piston, loaded with Belleville springs; the opening of the ports in the recoil cylinder is regulated by a central rod with varying section.

At first the carriage was fitted with a wide spade under the axle, but this was, later on, replaced by a wide trail-spade, which worked better. In order to endeavour to still further reduce lateral deviation, this type has been tried with two small plough-shares placed under the axle, and which acted in conjunction with the trail-spade; this gave the carriage three bearing points in the ground, and the arrangement worked well.

Two seats have been added for the gunners, and the experiments demonstrated that the muzzle velocity for this particular type could reach 480 metres (1,575 ft.) without inconvenience to the gunners.

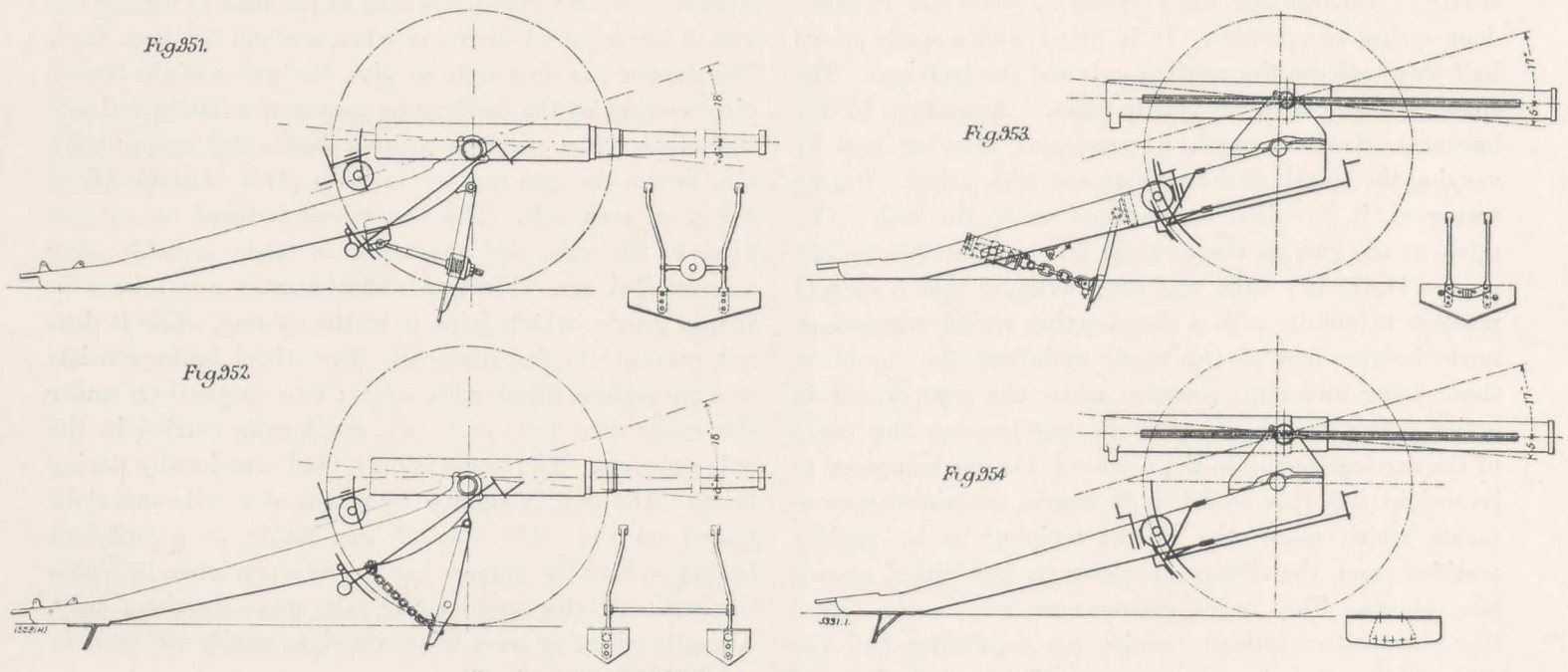
In short, this was the first model which embodied a long recoil for the gun, the carriage being non-recoiling, rising but slightly, and in which seats were provided for two gunners.

75-Millimetre (2.952-In.) Gun, Long Type, on Carriage, with Hydraulic Recoil and Trail-Spade (Figs. 953 and 954, and Fig. 955, Plate CLVIII.):

Weight of gun...	396 kg.	873 lb.
,, carriage	642 kg.	1415 lb.
,, projectile	6.5 kg.	14⅓ lb.
Muzzle velocity	550 m.	1804 ft.
Energy of projectile	100 t.-m.	333 foot-tons

In this type the special objects were to design a carriage adapted for quick and precise firing. In order to prevent rising of the wheels and lateral deviation produced by the percussion when firing, the gun is connected to the carriage by a hydro-pneumatic recoil cylinder. Owing to the length of recoil and to the weight of the gun, the effort on the carriage when the gun is fired is too slight to cause the wheels to rise. Consequently, under the usual conditions of field service and on any nature of ground, each round produces a recoil of only a few centimetres, without increased penetration of the spade or rising of the carriage.

This type contains, besides, all the secondary appliances deemed most advantageous for quick-firing artillery; the cartridge-case is metallic; the breech opens in one action; the empty cartridge-case is withdrawn and the striker is cocked automatically; the gun can be displaced on the carriage for lateral training; the sights are placed laterally on the cradle, which facilitates laying the gun during return and loading; sights enable the gunner at the trail lever to place the gun in position, &c. These advantages, joined to the stability of the carriage, allow the gun to be so quickly served that it can fire 16 aimed rounds per minute.



Carriage for 75-Millimetre Gun with Hydraulic Brake.

The gun is of steel of the standard quality. It consists of a tube, strengthened in the rear by a jacket, and in front, up to the muzzle, by coils. This construction has been chosen in order to strengthen the system followed for guiding the gun, and to render the latter heavier, so as to reduce the effort on the carriage caused by firing; it has, moreover, the advantage of increasing to a marked degree the coefficient of security in case projectiles charged with high explosives should burst in the bore. Besides this, the coiling of the chase reduces the heating of this part of the gun during rapid fire. The tube is made to butt against the rear end of the jacket to which the recoil

piston is jointed. The jacket does not have to withstand any longitudinal effort; both it and the chase coils are made with guiding flanges which project on each side of the gun, and are not liable to sustain any damage. These guides extend over a length of 2 metres (78.74 in.), and during recoil they remain constantly engaged in the cradle; this reduces friction, and insures a regular return of the gun, whatever be the firing angle.

The carriage is in two parts: the larger, which is held on the axle, is fitted at the rear with a rigid trail-spade; the smaller part carries the cradle on horizontal trunnions, and is made to pivot laterally on the larger part of the carriage. The cradle in which the gun slides is in one piece, and is made to contain the liquid and air cylinders of the hydro-pneumatic recoil system. The cradle is of tempered gun-steel; the grooves in which the flanges slide that guide the gun, are lined inside with brass. On the left-hand side of the cradle are placed the scales and sights. The rear end of the guide is connected with the training mechanism. The liquid cylinder is placed near the gun, and immediately below it. The recoil piston is joined to the rear of the gun by an elastic joint, the bushes being made absolutely tight. When the gun recoils, the liquid is forced into the air cylinders at the sides, by raising loaded valves. It compresses the air, and this limits the recoil of the gun. When the recoil is spent, the compressed air exerts a pressure on the liquid and forces it to return through small ports in the liquid cylinder, which causes the return of the gun in two or three seconds, and with equal smoothness, whatever be the firing angle. During the time taken by the gun to return, it is loaded and set, so that no time is lost in serving it. Besides the cylinder covers which limit the air space, diaphragms are provided, which separate the air from the liquid upon which it bears, and which is under an equal pressure. Escape of air cannot, therefore, take place. In exceptional cases, however, if there was such an escape, the joints are easily repaired or replaced, and two men can re-charge the air cylinder in a few minutes, with the help of a small pump, which forms part of the accessories of a battery. The device for checking recoil requires no attention and runs no risk, unless —as would be the case for the gun itself—it happened to be destroyed by the fire from the enemy. Repairing of the joints is quite an exceptional operation, but it is easily carried out from the stores supplied with each gun, and does not require any special skill on the part of gunners.

The smaller part of the carriage is of gun-metal, and it carries the cradle trunnions. It is held on the larger part by circular clamps, and a pivot on which it is movable to correct deviations in training, but which holds it firm during firing; it can easily be taken to pieces. The larger part of the mounting consists of two brackets with the edges brought down, joined together by top and bottom trail-plates and stay-bars; in the rear is fixed a strong spade, the top part of which is bent horizontal, to prevent the trail from ploughing up the ground. Owing to this arrangement, the trail is always displaced easily. This part of the mounting is, moreover, fitted with the setting mechanism, various other devices, and with the wheel drag. The axle is of tempered gun-steel; it is held on top of the brackets, and the journals are lubricated through the centre, this rendering it unnecessary to remove the wheels. It is fitted with two seats suspended on springs. The right-hand seat is provided with a small auxiliary sight, which enables the gunner at the trail to set the carriage in a line with the target.

The gun-training sector is in the plane of the carriage and turns on a pin at the rear of the axle; it is driven by means of a crank, an endless screw, a helicoidal wheel, and a pinion. The endless screw and the helicoidal wheel are placed in a casing which protects them from dust and accidental shocks. The helicoidal wheel is not keyed on the training shaft, but drives it through a spiral spring; this gives a certain elasticity to the system, and protects the mechanism against shocks caused by the firing and the jolting during transport. When it is required to shift the *matériel*, the gun is strapped to the carriage at the breech end, to insure the safety of the training mechanism. The top part of the sector is fitted with a dovetailed slide, made to travel laterally through an endless screw worked by a crank. The slide is joined to the cradle by means of a spherical head that moves in a groove; it causes the lateral displacement of the cradle as well as its elevation. The cradle and gun being balanced when the gun is run out, the training is rapidly and smoothly effected.

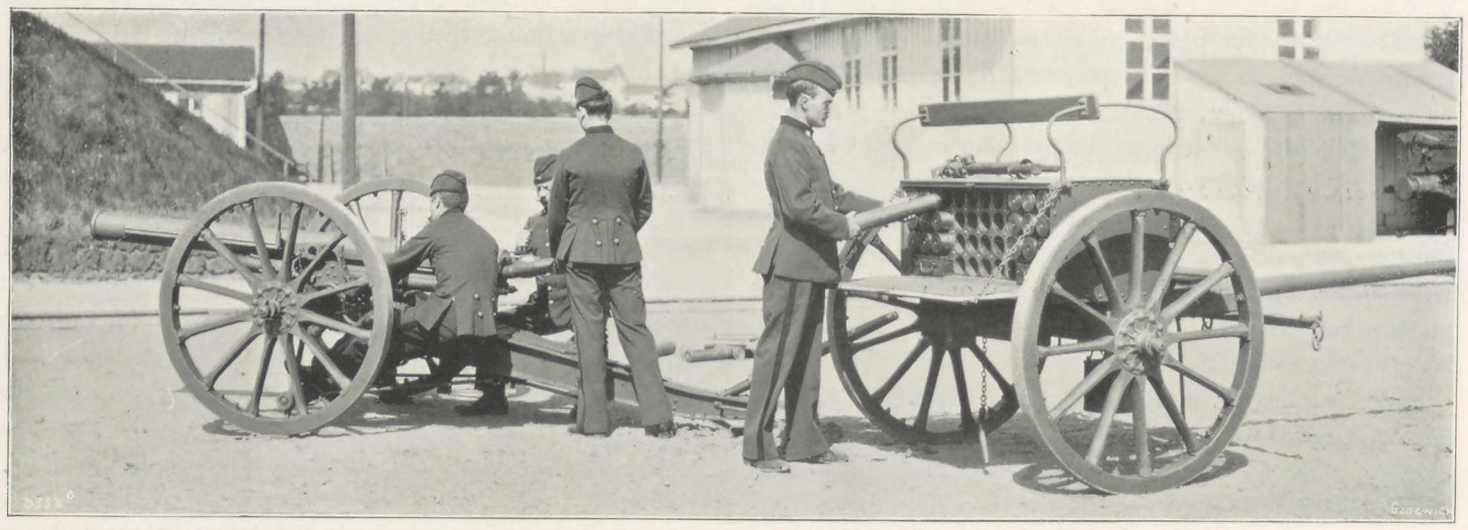
75-Millimetre (2.952-In.) Gun, Long Type, on Carriage with Hydro Pneumatic Recoil and Trail Spade, 1898 Pattern (Figs. 956 to 958).—This type may be taken to embody all the experience obtained by trials of previous models, and to represent the most advanced Schneider-Canet practice. It may be fairly claimed for it that it is the most efficient type of gun-mounting that has yet been produced The following are some particulars:

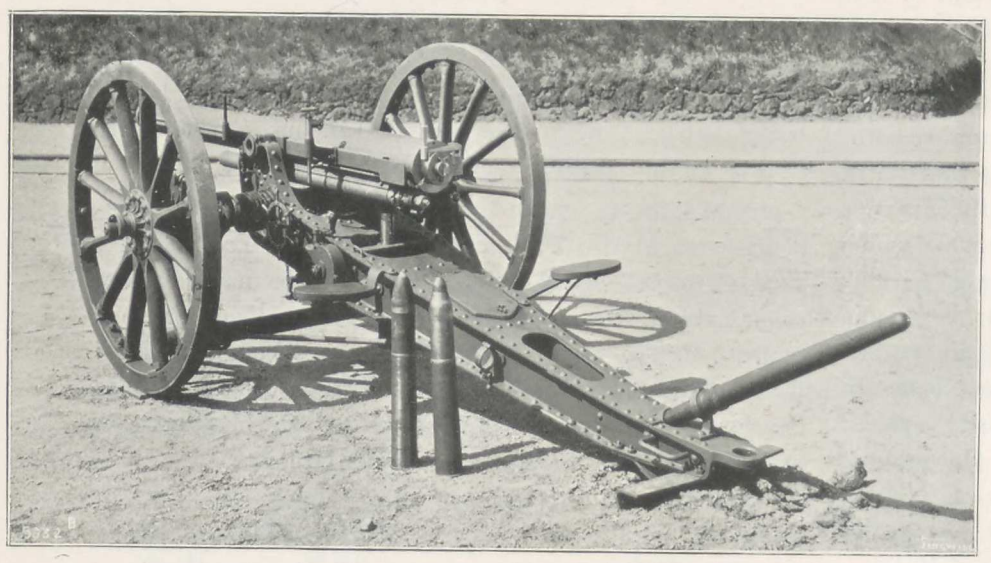
Weight of gun...	365 kg.	804 lb.
,, projectile	6.5 kg.	14⅓ lb.
Muzzle velocity	550 m.	1804 ft.
Height of axis of gun above ground level	.855 m.	33.661 in.
Elevation	from − 5 deg. to + 14 deg.	from − 5 deg. to + 14 deg.
Training	through 4 deg.	through 4 deg.
Diameter of wheels	1220 m.	48.030 in.
Distance between wheels	1400 m.	55.118 in.
Weight in battery	1010 kg.	2226 lb.
Weight of fore-limber with 38 cartridges	772 kg.	1702 lb.

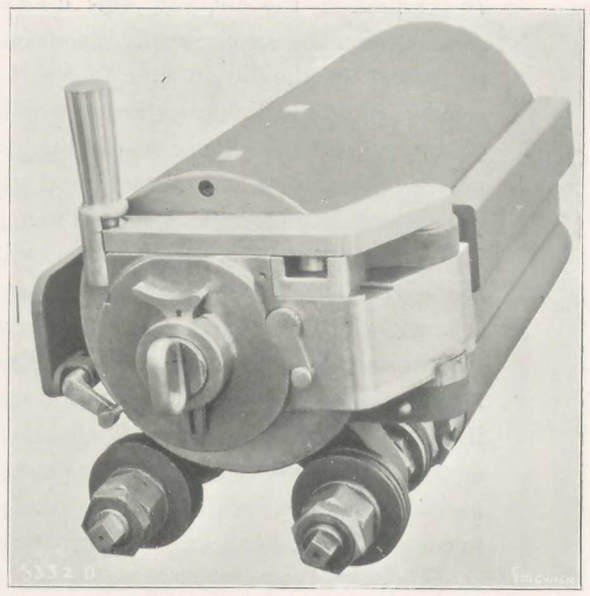
This type is characterised by an almost complete immobility of the carriage under firing, a condition which has been obtained without reducing in any way the power of the gun, the precision with which it is fired, or the ease with which the material can be carried from one place to another. The gun is joined to the carriage by a long-travel recoil mechanism, with constant resistance; the

effort due to recoil has been reduced to a minimum owing to the weight of the recoiling mass—365 kilogrammes (804 lb.). The carriage does not recoil; it is held to the ground at three points, by the trail-spade and by two drag-spades placed under the wheels. Lateral deviation is practically absent; and vertical deviation is very slight, the trail not penetrating the ground; corrections for training, when they are necessary, are therefore very quickly effected. As the carriage scarcely moves under fire, it is possible to seat two gunners on the trail; their weight contributes still more to the stability of the carriage, and they can rapidly train and load. Lateral training is effected by displacing the carriage on the axle, the wheels turning on the drags; this arrangement does away with the strain that would result from the obliquity of the gun on the carriage. Trained gunners can fire with this type 20 to 24 aimed rounds per minute, owing to the simplicity of the manœuvres. The quick and smooth return of the gun is one of the elements necessary for rapid firing. The system followed for fixing the carriage to the ground does not cause trouble and delay in the placing of the gun in battery, nor in removing it to other spots and attaching it to the fore-limber.

The force of recoil is absorbed by the hydraulic recoil cylinder in the simplest manner possible, and return is insured by an independent compressed-air recuperator, which, being quite tight, requires no special attention. As it is independent of the recoil cylinder, in case of an accident firing can still be proceeded with, the gun being run out by hand. A pump forms part of the equipment; and with it one man can charge the recuperator afresh in five minutes.







Figs. 956 to 958. Schneider-Canet Carriage (1898 Pattern) for 75-Millimetre Quick-Firing Gun.

The gun consists of a tube, a jacket, and seven chase coils, of tempered and annealed steel. The same remarks made in the description of the preceding type, regarding the construction of the gun, apply to the present model. The breech opens with one circular action. Firing takes place by pressing on the catch through a spring rod fixed to the cradle, either direct or through a line; the firing device does not, therefore, recoil with the gun; and the gunner has it constantly under his control, but he cannot fire the gun until it has run completely out.

Thousands of rounds have been fired with this device. No tools are required for taking apart the breech-block and firing device, and this can be done in less than one minute.

The carriage is fitted at the rear with a rigid trail-spade; it carries the cradle in front on horizontal trunnions. The axle runs through the carriage. The cradle in which the gun recoils is of forged gun-steel in one piece; it contains the trunnions, slides, recoil cylinder, and the cylinder and reservoir of the air recuperator. The slides are lined with brass, and are so arranged that recoil is always insured, whatever be the state in which the sliding surfaces happen to be, whether damp, or rusty, or covered with sand or mud. On the left-hand side of the cradle are fitted the scales and sight, and to the rear of these is a small guard-plate. The hydraulic recoil cylinder (on the left-hand side) is very simple in design; the piston works in the cylinder. The inside surface of the latter is made in such a way that the liquid, by flowing through ports of varied sections, opposes a constant resistance to the force of recoil. The piston-rod gland is made tight, and a hydraulic buffer counter-rod does away with all shocks on return of the gun. The recuperator cylinder contains compressed air, which acts on a piston, the head and rod of which are fitted with tight linings, to prevent air escape. The middle cylinder acts as an air reservoir, and is in communication, at the rear, with the recuperator cylinder. To the air reservoir are fitted the valve and joint for the charging pump. The recoil and recuperator piston-rods are symmetrical; they are joined together by an elastic joint formed of Belleville springs. They are completely down when the gun is not in action, and run out during one second only, at each round. The recoil cylinder requires no attention, and, like the other parts of the mechanism, it is well protected against hostile fire. The joints and bushes are taken apart only in exceptional cases; this is easily effected with the help of the tools carried with the battery, by gunners under the supervision of a non-commissioned officer.

The body of the carriage is made with two brackets, joined together by top and bottom plates and stay bars. A cast-steel headpiece is fitted with a cylindrical jacket, which slides on the axle for giving lateral training. The carriage trail is fitted in the rear with a strong spade, the top part of which is bent horizontal, and prevents the trail from ploughing up the ground. A trail ring, trail levers, and all the other requisites are provided for the service in the rear. The axle is of tempered gun-steel; it is round, and is fitted at its central part with a rack for lateral training; the journals are lubricated automatically. The wheel rims are in three parts, and are made of bent wood; they are joined to the nave by 12 spokes cut with the grain. The nave is of brass; steel plates are interposed between the spokes and the rim to prevent the yielding of the wood. The naves are fitted with friction brake.

The gun and cradle, which oscillate round trunnions, rest, with a slight preponderance, on the top of the elevating rack. The latter is in the carriage plane, and slides in a brass guide; it is worked by means of a crank keyed on an endless screw, which gears with a helicoidal wheel on the elevation shaft. On this same shaft is a pinion which engages the rack. Each revolution of the crank gives a variation of 26 minutes in the angle, corresponding to a variation in the range of about 175 metres (574 ft.). The endless screw, helicoidal wheel and rack are cased round to protect them from dust. For transport, the gun is elevated to its maximum positive angle, and strapped to the carriage, a slight preponderance of muzzle being allowed. For training the gun, the rack on the axle engages a pinion, the axis of which carries at one end a helicoidal wheel worked by an endless screw driven by a handwheel. The pinion, by turning in the rack, displaces the carriage on the axle over 80 millimetres ($3\frac{1}{8}$ in.) on each side, the wheels turning on the brake; this produces a rotation of the carriage round the trail-space as centre, through 4 deg. When the gun is being transported, the lateral training mechanism is held fast by a small chain. The brake used in firing consists of two arms fitted with shoes, which can turn round the axle or be displaced lengthwise over about 100 millimetres (4 in.); the arms are joined by a cross-piece. The shoes, the top surface of which are flat, are fitted at their lower part with spades made parallel with the carriage axis; the cross-piece is joined to the trail by two tie-rods, at the end of which is a balanced lever and a slide. A key fixes the slide in the firing position. When the material is shifted, the cross-piece is held up under the carriage. The fore-limber and caisson are practically similar to those of the preceding models.

XLV.—SCHNEIDER-CANET SYSTEM OF MOUNTAIN ARTILLERY.

MOUNTAIN artillery, which has a more limited range of usefulness than that for field service, has been designed and experimented upon by Messrs. Schneider and Co., concurrently with the latter class of ordnance. The special conditions to be fulfilled as regards weight and transport have limited the programme of mountain artillery construction. Moreover, the experiments carried out with field artillery have frequently resulted in the setting aside, as unfit for mountain service, certain patterns that had been designed for this special service.

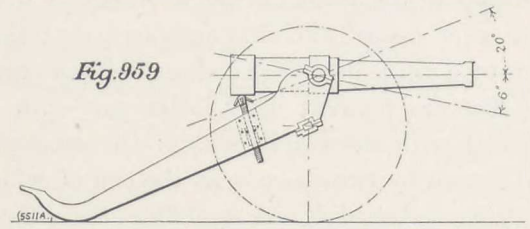
The following descriptions are, therefore, limited to a comparatively small number of types, comprising the ordinary ones, with free recoil, and also quick-firing, in each case, specimens of medium, and of high power, having been chosen, the free recoil being taken first.

Free Recoil Mountain Artillery: 75-Millimetre (2.952-In.) Gun of Medium Power (Fig. 959, and Figs. 960 to 965, Plates CLIX. and CLX.).

Weight of gun...	100 kg.	220 lb.
,, carriage	154 kg.	339 lb.
,, projectile	4.6 kg.	10.14 lb.
Muzzle velocity	260 m.	853 ft.
Vis viva of projectile...	15.7 t.-m.	52.28 foot-tons.

The gun is of steel, and is fitted with a screw breech-block with a plastic obturator; firing is effected by friction,

Fig. 959



a safety device being provided. The gun is 16 calibres in total length. The sight and scale are on the right-hand side.

The carriage consists of two brackets, joined together at the trail and strengthened by stays, the last one forming the head-plate. It is fitted with a lever for training the gun, and with a sponge and rammer shaft. The carriage rests in front on the axle; the wheels are of wood, with metallic nave.

For elevating the gun, a screw is provided, that works in a fixed nut, and on the top end of which the gun rests, on account of the preponderance of the breech. The screw is worked by a handwheel.

The brake for reducing recoil acts on the naves of the wheels, and prevents them from turning freely. The ends of the axle journals are threaded, and are fitted with recessed sockets, which bear direct against the wheel naves. In tightening the sockets, by means of levers which fit in the recesses, an energetic friction is obtained when recoil takes place.

A hook is provided at the end of the trail, for hooking-on the shaft. For transport on mules, the gun is taken off the carriage; the wheels are removed from the axle, and all the various parts of the material are placed on pack-saddles, suitably arranged in the following manner: One mule carries the gun and its fittings; a second one, the carriage; a third one, the wheels and shaft; a fourth, two cases filled with ammunition; a fifth, two cases filled with implements and tools; a sixth, a portable forge.

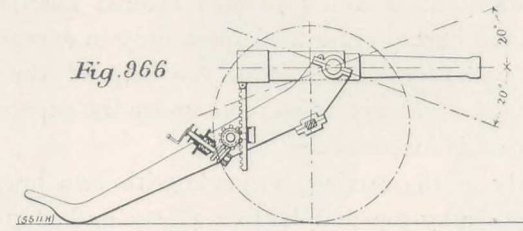
Specimens of this type have been supplied to Morocco; they are of most simple construction.

75-Millimetre (2.952-In.) Gun of High Power (Fig. 966).

Weight of gun...	100 kg.	220 lb.
,, carriage	147 kg.	324 lb.
,, projectile	4.6 kg.	10.14 lb.
Muzzle velocity	315 m.	1033 ft.
Vis viva of projectile	23 t.-m.	76.59 foot-tons.

Besides these types, another is manufactured of higher capacity; the weights are, of course, greater in con-

Fig. 966



sequence. The general construction, however, is the same for both types, except the elevating mechanism, which in the latter consists of a vertical rack, which ends at its top part in a lug, to which is jointed the breech-end of the gun. The rack is made with a scale in front, and is worked by a handwheel held by the gunner. A set of Belleville springs is provided in the gearing to deaden the shocks on the mechanism. The mule saddling is arranged in the same way as for the lighter gun. Both types are designed for firing with black powder and friction fuse, but they can be fired with but slight alterations, with smokeless powder, cartridge cases, and percussion fuse.

Mountain Guns with Checked Recoil: 65-Millimetre (2.559-In.) Gun on Carriage with Spring Brake (Figs. 967 to 969).—The following description is that

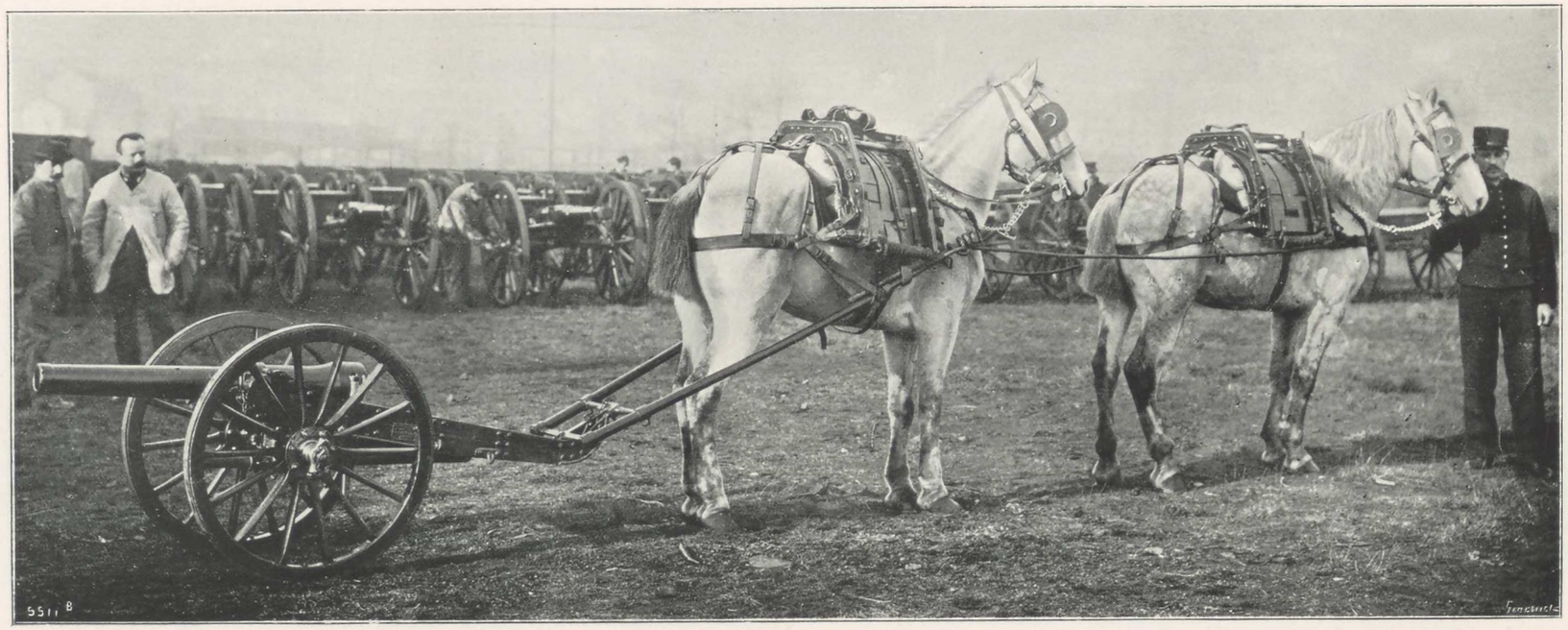


Fig. 960. 75-Millimetre Mountain Gun ready for Service.

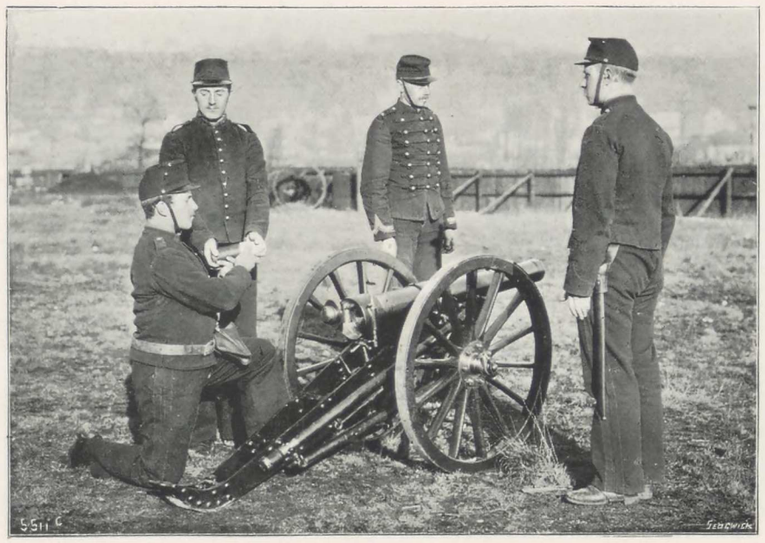


Fig. 961. Working a 75-Millimetre Mountain Gun.

MOUNTAIN GUN, 75-MILLIMETRE CALIBRE, MEDIUM POWER: METHOD OF TRANSPORT.

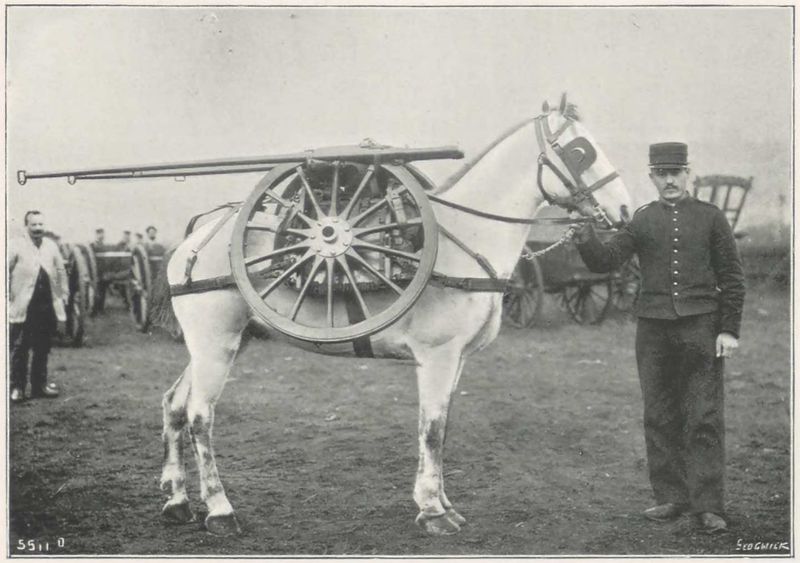


Fig. 962. Transport of Shafts, Wheels, etc.



Fig. 964. Transport of Ammunition.



Fig. 963. Transport of Carriage Body.

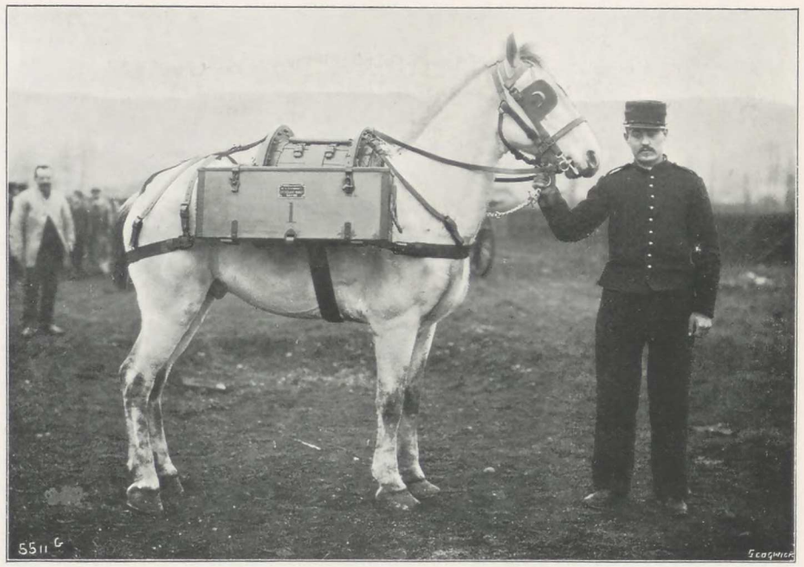


Fig. 965. Transport of Ammunition.

PLATE CLX.

of a mountain gun-carriage with checked recoil, which has been put in service, and has been supplied to the Chinese Government.

Weight of gun	110 kg.	243 lb.
,, carriage	178 kg.	392 lb.
,, projectile	3.6 kg.	7.93 lb.
Muzzle velocity	375 m.	1230 ft.
Vis viva of projectile	25.8 t.m.	86 foot-tons.

This is manufactured in two patterns, which differ from each other only in the arrangement of the brake device. The gun does not embody any special appliance; it is fitted with an ordinary breech-block, with a plastic obturator. The carriage is formed of two cheeks of forged steel, joined together at the trail, and strengthened by stay bars and by the head-plate at the top. An upper trail-plate, hollowed out on part of its surface, is rivetted on the two cheeks. On the top of the trail is fixed a plate, which is provided both with the seating for the horsing hook, and with two lateral lugs, to which are fixed the brake chains. The elevating mechanism consists mainly of a vertical screw, on which bears the breech-end by reason of the preponderance; a lateral handwheel on the left hand cheek serves to turn the elevating screw. In order to work the gun, the gunner sits astride on the trail. Lateral training is obtained by acting on the trail-lever. The wheels are of wood, and the naves of gun-metal. Recoil is checked by creating friction directly under the wheels, either by causing them to hold fast or by interposing a shoe-brake. In the first arrangement, two chains are fixed to the trail-plate, and carry two collars which surround the wheels at their lower part. A spring is placed between every two links to deaden the shocks. During firing, the wheels are held practically fast by lateral chains, though, at first, a slight oscillating motion takes place; this, however, quickly ceases under the action of the springs. In the second device, the ends of the axle-journals are made with two cylindrical bearings, on which are placed the flat links at the end of the outside brake chains; a key prevents their shifting. The inside chains are fitted to two lugs on the axle, and are hooked to lugs on the brake-shoes, the latter surrounding the rim directly beneath the nave. The shoes are, moreover, joined to the trail-plate by two other chains fixed to lateral lugs. This system holds the wheels quite fast during firing, and creates a friction which checks recoil to a certain extent. A third pattern has also been manufactured, in which the handwheel is placed on the right-hand side; the chains are fitted to the lower trail-plate direct, the horsing hook being replaced by a ring.

Fig. 967

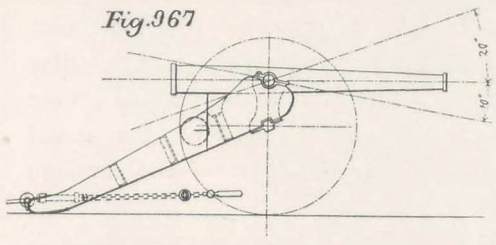
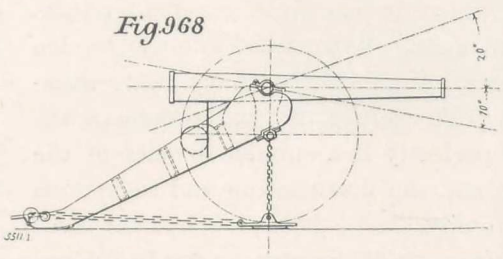


Fig. 968



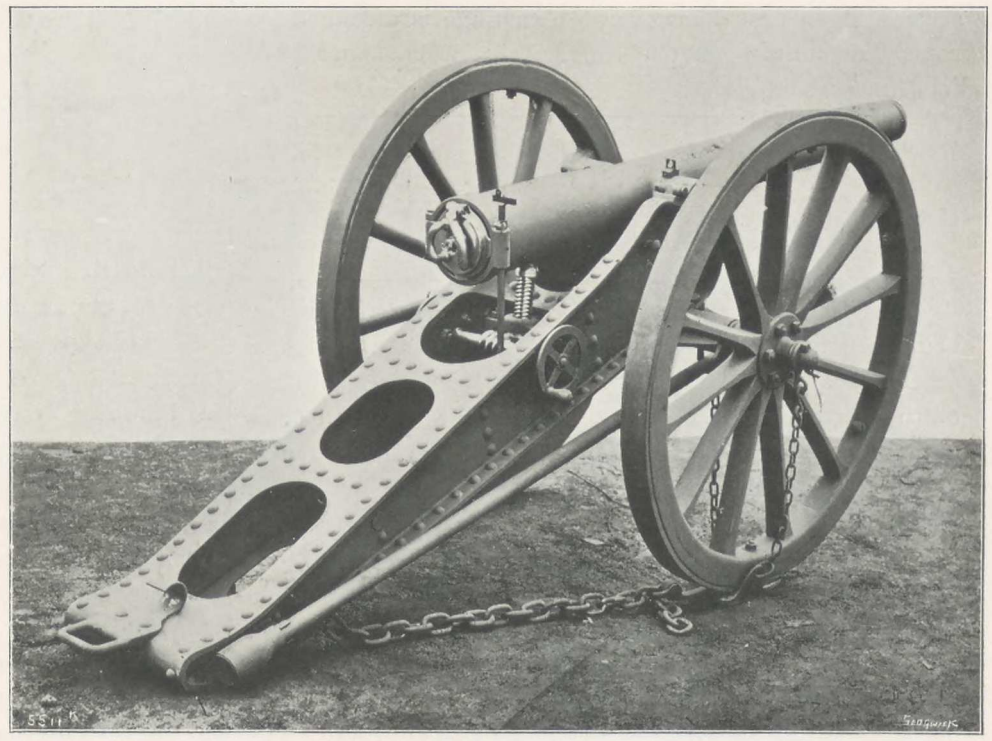


Fig. 969. 65-Millimetre Mountain Gun and Carriage, with Spring Brake.

XLVI.—QUICK-FIRING MOUNTAIN GUNS.

Medium-Power Guns (Figs. 970 to 973, Plate CLXI.).—This first type is placed on a carriage with compressible trail, similar in design to that described in the field-gun series. In this case, however, the carriage is arranged for rapid dismounting, in parts of suitable weight and bulk for transport on mules.

Weight of gun...	100 kg.	220 lb.
,, carriage	253 kg.	557 lb.
,, projectile	5 kg.	11 lb.
Muzzle velocity	250 m.	820 ft.
Vis viva of projectile	16 t.-m.	53.28 foot-tons.

The carriage rests on the axle, a rectangular recess being provided at the lower part of the tube, which is extended laterally; flanges insuring the perfect jointing of the system and its easy dismounting. On both sides are rectangular enlargements, which slide, during recoil, on guides similar in section provided on a gun-metal jacket screwed on the front end of the trail. The tube that forms the carriage support is swelled out at the rear end, for the fixing of a collar made to slide on the trail during recoil, a system of lugs and jointed levers insuring the rapid fastening of the collar. In the front, the tube is closed by a cover, in the centre of which is placed the end of the recoil piston-rod. The collar is fitted with two steel wedges, which, when the gun is in battery, bear on the guides of the gun-metal jacket, thus completing the joining together of the carriage support, the trail-tube, and the trail.

The trail and spade remain fixed when the gun is fired. The trail-tube is closed in front by a bush, through which runs the recoil piston-rod, and in the rear by a screwed cover, in the centre of which is placed the neck for charging the air recuperator. The recoil cylinder and the recuperator, formed by the trail, do not recoil; but the piston, being fitted to the carriage support, is driven together with the movable part. The vent through which the liquid flows is cut in the centre of a diaphragm forged with the trail, and in the front of which is the recoil cylinder; the air recuperator, in the rear, is separated from the liquid by a movable diaphragm.

The required elevation is obtained, as is the case with field guns, by means of a screw, on the head of which a bearing lug, forming part of the breech end, rests permanently, owing to the preponderance of the breech. The lateral training mechanism consists of a screw, the nut of which is jointed on a sole-plate bolted in the body of the carriage, the rear end being jointed on the arm of the smaller carriage.

For transport, the material is taken apart as follows: The gun, the small carriage (with carriage support), the trail, the axle and wheels. To disconnect the carriage support from the trail, the two levers jointed on the collar are raised, the belt which holds them down having been previously unfastened. The recoil piston is then driven to its extreme position, the belt hooks which hold it being previously placed in the rings fixed to the collar levers; the belts carry a rectangular steel-piece, the centre of which is recessed to take the end of the recoil piston-rod. When this is done, this part of the carriage is ready for transport.

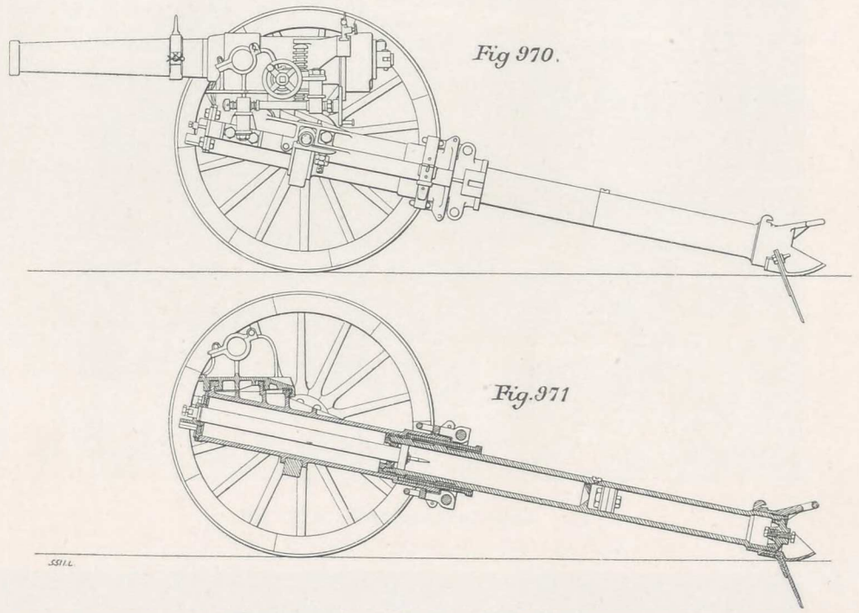
This type has been supplied to the Japanese Government, among others; and it has given excellent results at the firing trials in Japan. With native gunners, twelve rounds were fired per minute, the accuracy being satisfactory. The system followed for the construction of the carriage lends itself perfectly to a suitable division of the weight for transport, and the dismounting and re-erection are carried out very easily.

High-Power Guns. 75-Millimetre (2.952-In.) Gun, on Carriage, with Hydraulic Recoil and Elastic Trail-Spade (Figs. 974 to 977, Plate CLXII., and Figs. 978 to 981).—This has been designed with a view to obtain very quick firing, without complicating the construction; all the various parts can be rapidly put together by hand. With reference to its weight, this pattern is specially characterised by its high power, as will be seen from the following data:

Weight of gun...	105 kg.	231 lb.
,, projectile	6.5 kg.	14.32 lb.
Muzzle velocity	300 m.	984 ft.
Total *vis viva*	29.8 t-m.	99.23 foot tons.
Weight of carriage	240 kg.	529 lb.
,, gun in battery	345 kg.	760 lb.

The gun is of special forged steel, in one piece; the breech-block is with interrupted threads, on the Schneider-Canet system, and opens out in one action. Two lugs, forged in one piece with the gun, guide it in the cradle during recoil and return; to the rear is the shoulder piece to which is fitted the hydraulic recoil rod. The mounting is built of two main pieces easily taken apart, namely: (*a*) the carriage body and (*b*) the trail-piece. The carriage body consists of two brackets, made of wrought steel plates, joined together in front by a gun-metal staypiece; the latter is hollowed out to take the cradle trunnions and the axle. In the rear, the two brackets are stayed together by top and bottom trail-plates, and are provided

QUICK-FIRING MEDIUM POWER MOUNTAIN GUN, 75-MILLIMETRE CALIBRE.



Construction of Compressible Trail.



Fig. 972. Serving a 75-Millimetre Mountain Gun.



Fig. 973. Serving a 75-Millimetre Mountain Gun.



Fig. 974. Transport of Gun.

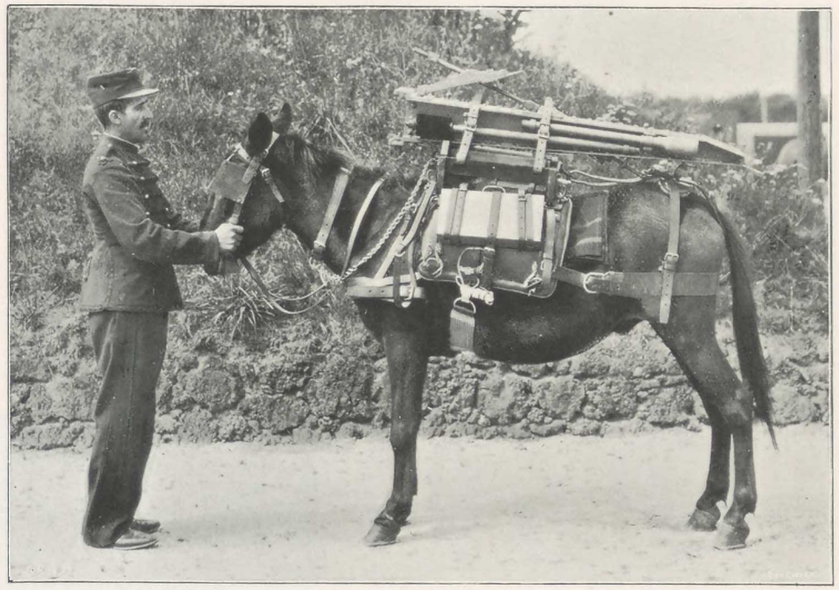


Fig. 976. Transport of Cradle Shaft and Wheels.

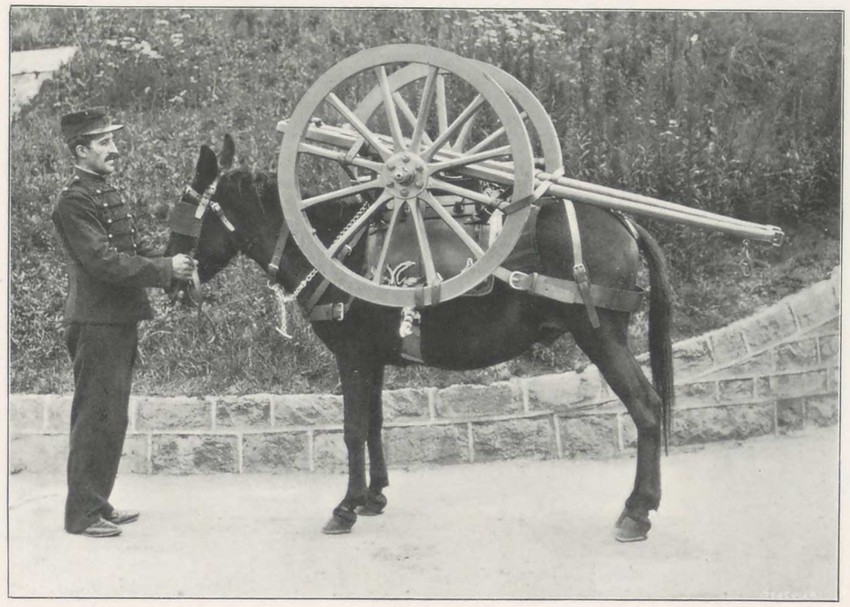


Fig. 975. Transport of Trail and Wheels.

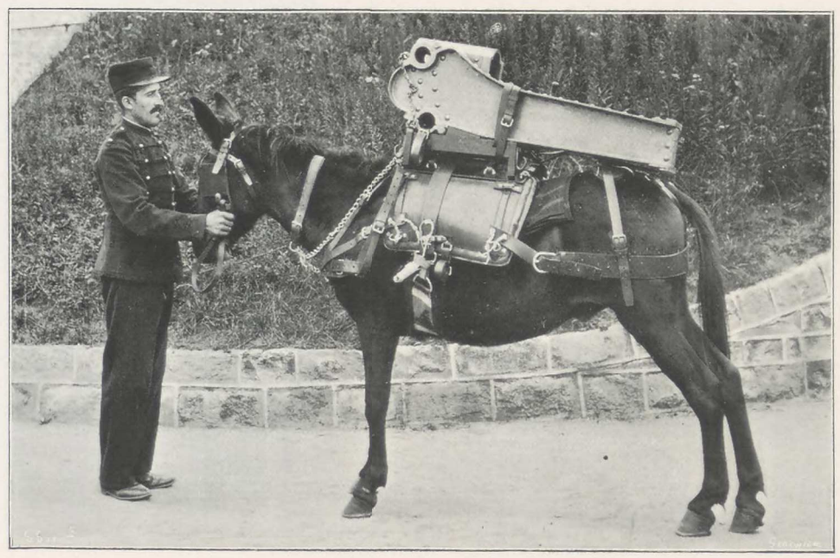


Fig. 977. Transport of Carriage Body.

with clamps for holding the trail-piece. The gun-metal cradle is on trunnions on the front staypiece; it is fitted with a recoil cylinder, and with lugs for the spring recuperator.

Below the gun, and in a vertical plane, is placed the hydraulic recoil cylinder; this is with constant resistance, on the Schneider-Canet system, and is independent of the recuperator. The latter is formed of two sets of spiral springs, placed on each side of the recoil cylinder, joined to the cradle in front, and in the rear to the recoil rod cross-piece.

The initial tension of the springs is sufficient to run the gun out under the greatest angle. When the gun recoils, it draws with it the piston-rod and compresses the recuperator springs under the action of the cross-piece.

The required elevation is obtained by means of a crank which works the sector pinion placed on the cradle through a tangent screw. Lateral training is given by the trail-lever.

This material is in four parts, each forming the load for one mule, namely: the gun; carriage body with cradle; trail-piece; and tools, mounted axle, and shaft. In dismounting, the recoil piston-rod is unkeyed, and the gun drawn back; the trail-piece is separated from the carriage body by a lateral action, after removal of the fixing spindle; the mounted axle is taken from the carriage-body by unkeying the lower trunnion-plates that hold it to the head staypiece. These operations only require a few minutes. The ammunition is contained in series of seven rounds in a wooden chest lined with sheet steel; two similar chests form the charge of one mule. A two-wheel caisson fitted with one traction shaft carries four ammunition chests, easily exchanged. The caisson is not arranged for transport on mules.

Fig. 978.

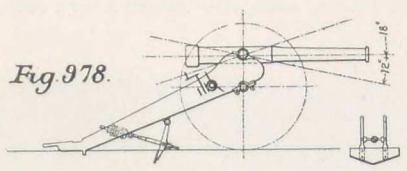


Fig. 979.

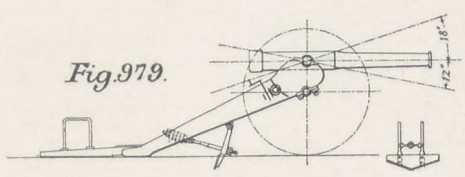
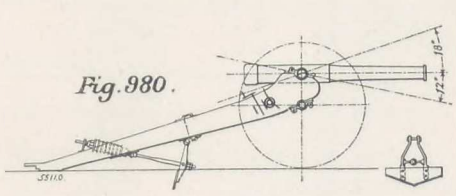


Fig. 980.



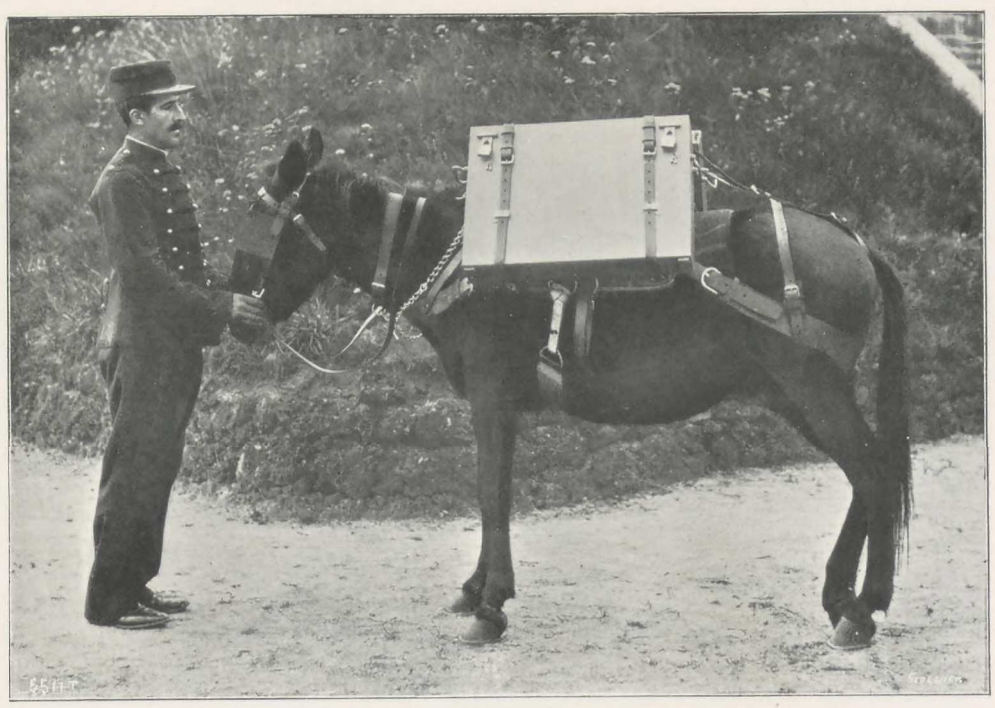


Fig. 981.

Quick-Firing High-Power Mountain Gun, 75-Millimetre Calibre, with Hydraulic Recoil.

When the recoil has ceased, the gun runs out again under the action of the springs, the movement being limited by a leather buffer and brass washers placed between the cross-piece and the recoil cylinder. The trail is formed of two wrought-steel cheeks, two stay-plates, a trail-plate, and the required accessories for wheeling the piece when mounted. An elastic trail-spade is provided, the shape of which is calculated so as to penetrate ground of various degrees of hardness, while enabling the gun to be easily trained laterally. The spade is jointed under the lower traction ring, and is connected to the trail by a rod that bears on a set of india-rubber rings; it slides on the rod so that the trail can rest on the ground when the gun is placed in battery. The carriage is of strong construction, and does not require any special preparation for service. The recoil cylinder is filled with incongealable liquid, and is perfectly tight.

75-Millimetre (2.952-In.) Gun, on Carriage with Rigid Trail, Hydraulic Recoil, and Independent Air Recuperator (Figs. 982 to 990, Plates CLXIII. and CLXIV.).—This gun was designed with a view to fire 8 to 10 aimed rounds per minute. To obtain this, and an increased stability during firing, the length of recoil was carried from 200 millimetres ($7\frac{7}{8}$ in.) to 450 millimetres ($17\frac{3}{4}$ in.). It is so arranged as to be easily mounted for action, and dismounted for transport on mules. It fires with a metallic cartridge in one piece, weighing 5.8 kilogrammes ($12\frac{3}{4}$ lb.).

The gun is not made with trunnions; it fits in a carriage, in which it can recoil for 450 millimetres

(17¾ in.). The cradle is with two trunnions, which fit in trunnion-plates on the head-plate, thus insuring the required mobility for elevating the gun. The trail is in two parts, joined together by hinge clamps, and is provided with a spade, which, when it is down in suitable ground, prevents almost completely all recoil of the carriage. The recoil of the gun in the cradle is absorbed by a hydraulic recoil cylinder, and return is secured by an independent recuperator.

Weight of gun	105 kg.	231 lb.
,, projectile	5 kg.	11 lb.
Muzzle velocity	290 m.	951 ft.
Total *vis viva*	21.5 t.-m.	71.6 foot tons
Weight of carriage	250 kg.	551 lb.
,, material in battery ...	355 kg.	782 lb.
Height of centre of axle above ground level	.670 m.	26⅜ in.
Angles of elevation	+ 18 deg.	− 14 deg.
Diameter of wheels	900 m.	35 7/16 in.
Distance between wheels on tread ...	750 m.	29½ in.
Weight of shaft	22 kg.	48½ lb.

The gun is of forged steel, in one piece; it is fitted in the rear with lugs, which hold the recoil and recuperator rods. It is made with two longitudinal tongues placed laterally, which support and guide it in the cradle. The breech-block works in one action, and is similar to that of quick-firing field guns. The carriage consists of a cradle, which rests through its two trunnions on the head-plate, and contains the hydraulic recoil cylinder and the recuperator. It is made with two guides, in which slide the lateral lugs on the gun. The hydraulic cylinder which absorbs the recoil of the gun contains a piston, the rod of which is jointed on the gun. During recoil, the liquid flows from the rear to the front of the piston, through ports that are regulated in order to maintain a constant pressure. The front of the piston forms a hydraulic buffer to deaden the return in battery. The compressed air recuperator, which causes the gun to run out, is absolutely independent of the recoil cylinder; it consists of two cylinders, in one of which works an air-tight piston, the piston rod being jointed to the gun. When the gun is fired, the compressed air is driven in the other cylinder; this acts as a reservoir; when the recoil is spent, the compressed air causes a reaction, and runs the gun out again. The trail is in two parts, a carriage body, with trail extension. Both are built up of steel plates, and are joined together by clamps and pins. Two supports are provided in the rear for the shaft. A cast-steel staypiece acts as a support for the cradle; the axle runs through it. The trail-end is fitted with a rigid spade and two rings for the lateral training lever.

For elevating the gun, a handwheel is provided on the right-hand side of the carriage; this works through an endless screw and a helicoidal wheel, a pinion that gears in a rack the head of which supports the cradle.

The axle is of steel; it runs through the head-plate to which it is held by screws. The wheel-naves are of brass; the rim is in three parts, and the spokes are held to the rim by steel plates.

A sight and scale are placed on the right-hand side of the cradle; they do not, therefore, recoil with the gun.

For drawing the gun along, the trail is bent down and brought under the carriage body, where it is held in place by a pin; this allows the shaft to be placed in its rings. For transport on mules, the *materiel* is taken to pieces as follows:

Weight of gun	105 kg.	231 lb.
,, carriage body	100 kg.	220 lb.
,, trail and wheels	99 kg.	218 lb.
,, cradle, shaft and tools ...	80 kg.	176 lb.

The cartridges are placed in sets of six in a metallic chest; two such chests form the charge of a mule, and weigh 95 kg. = 209 lb.

The pack-saddles are metallic, and are arranged to suit the various parts to be carried.

QUICK-FIRING MOUNTAIN GUN, 75-MM. CALIBRE, WITH RIGID TRAIL.

Fig.982

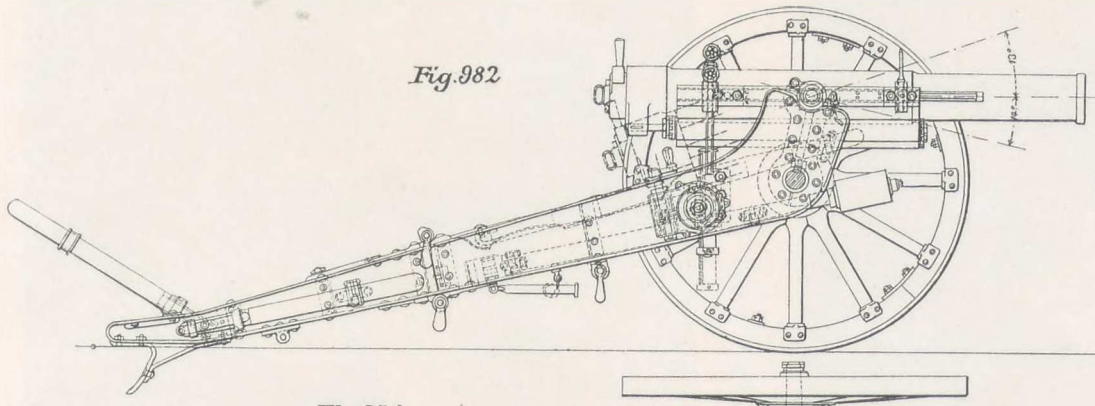


Fig.983

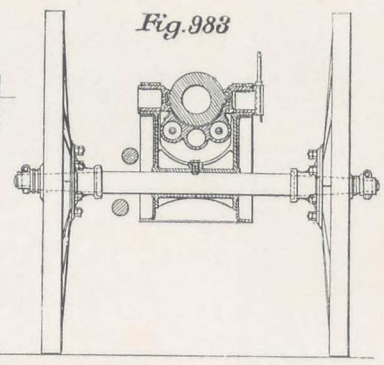
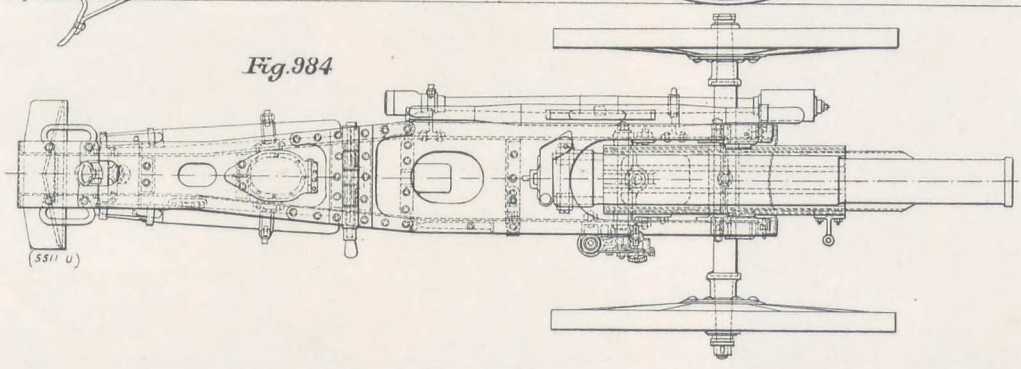


Fig.984



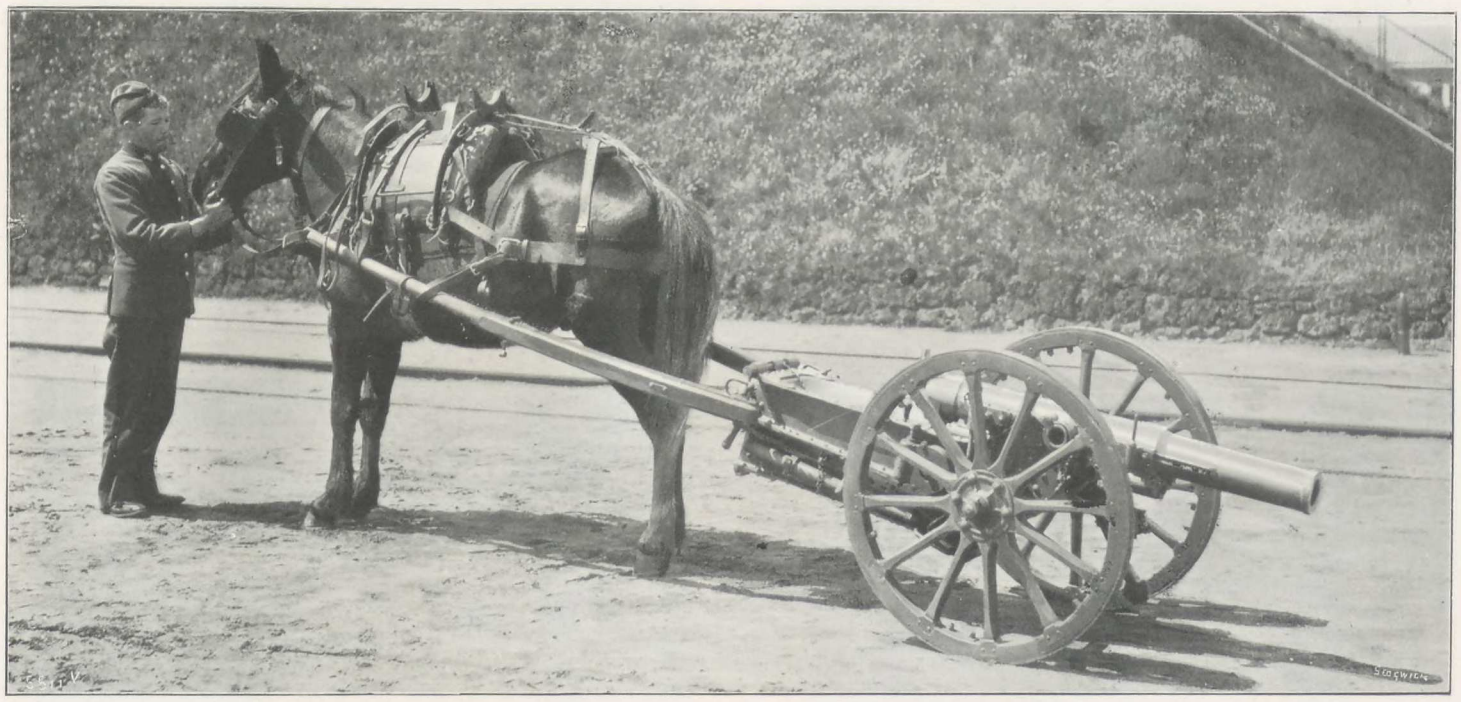


Fig. 985. 75-Millimetre Mountain Gun, with Rigid Trail, Mounted for Service.



Fig. 986. Mule Transport of Ammunition.

QUICK-FIRING HIGH-POWER MOUNTAIN GUN, 75-MILLIMETRE CALIBRE, WITH RIGID TRAIL.

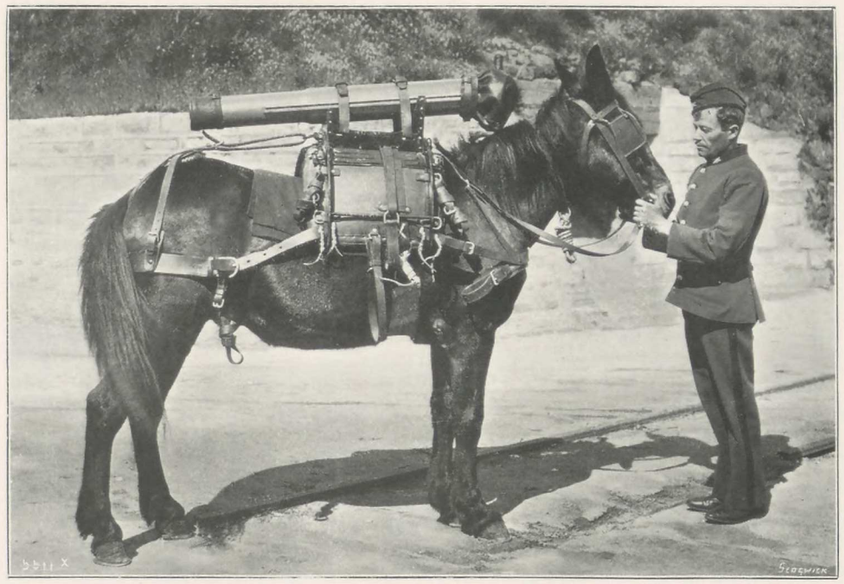


Fig. 987. Transport of Gun.



Fig. 989. Transport of Trail and Wheels.



Fig. 988. Transport of Carriage Body.



Fig. 990. Transport of Cradle Shaft and Tools.

PLATE CLXIV.

XLVII.—LANDING OR BOAT GUNS.

IN the following paragraphs, some particulars are given concerning the Schneider-Canet guns which have been designed and manufactured for landing batteries or boat guns:

75-Millimetre (2.952-In.) Gun, on Rigid Landing-Carriage.

Weight of gun...	100 kg.	220 lb.
,, carriage	141 kg.	310 lb.
,, projectile	4.6 kg.	10 lb.
Muzzle velocity	285 m.	935 ft.

The gun trunnions rest in two trunnion-plates riveted to the carriage; the latter is rigid, and is formed of two steel plate brackets, stayed together, and raised up at the rear to form the block-trail. A wide trail-plate prevents the trail from ploughing up the ground, and contains the hooking ring. The brackets rest direct on the axle; they are strengthened on the outside by means of a riveted plate. The ends of the axle journals are threaded, and are fitted with a nut which serves to tighten the system more or less on the axle, by means of a steel ring, to lessen the extent of recoil. The elevating gear is on a type similar to that described in the preceding chapter on mountain guns. For facilitating the displacement of the gun when it is landed, the block-trail is made to rest on a roller, the support of which ends in a spindle, round which the pivot bolt socket and shaft attachment are made to turn freely. The shaft consists of a steel tube with cross-piece, by which the gun can be drawn along by the men. The carriage wheels are of iron throughout.

65-Millimetre (2.559-In.) Guns.—This specimen differs from the preceding one, only in the details of the recoil device and recuperator.

Weight of gun...	80 kg.	176 lb.
,, carriage	140 kg.	308 lb.
,, projectile	3.5 kg.	7.71 lb.
Muzzle velocity	310 m.	1017 ft.

The wheels are of wood; the nave is of brass, and is made with a drum, round which fits a steel strip brake lined inside with leather. The steel strip is fixed at one end to the axle, and at the other to the brake swing-tree. The latter is fitted with a nut, which moves along a threaded rod worked by a crank. By acting on the crank, the brake is tightened or loosened. The required elevation is given by a screw which turns in a nut fixed to the carriage. The nut is made on the outside with helicoidal teeth, which engage an endless screw on a horizontal shaft, worked by a handwheel. The fore-limber has a watertight caisson, built up of plates and angles, and made to bear direct on the axle; it carries four ammunition chests. The latter are also made watertight, and are provided with handles, so as to be easily carried; they are divided into three compartments, the centre one containing the charges. It is made to be fitted with one or two shafts.

65-Millimetre (2.559-In.) Quick-Firing Gun, on Landing Carriage, with Compressible Trail and Hydro-pneumatic Recoil (Figs. 991 and 992).

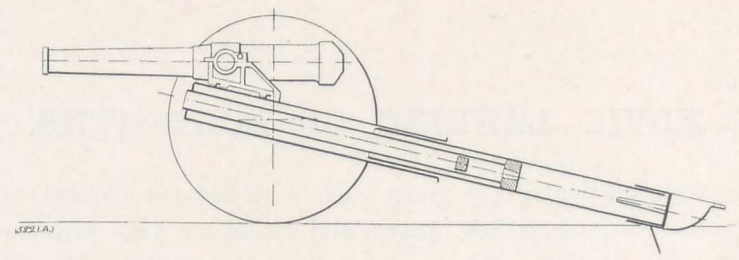
Weight of gun...	80 kg.	176 lb.
,, carriage	250 kg.	551 lb.
,, projectile	4 kg.	8.81 lb.
Muzzle velocity	300 m.	984 ft.

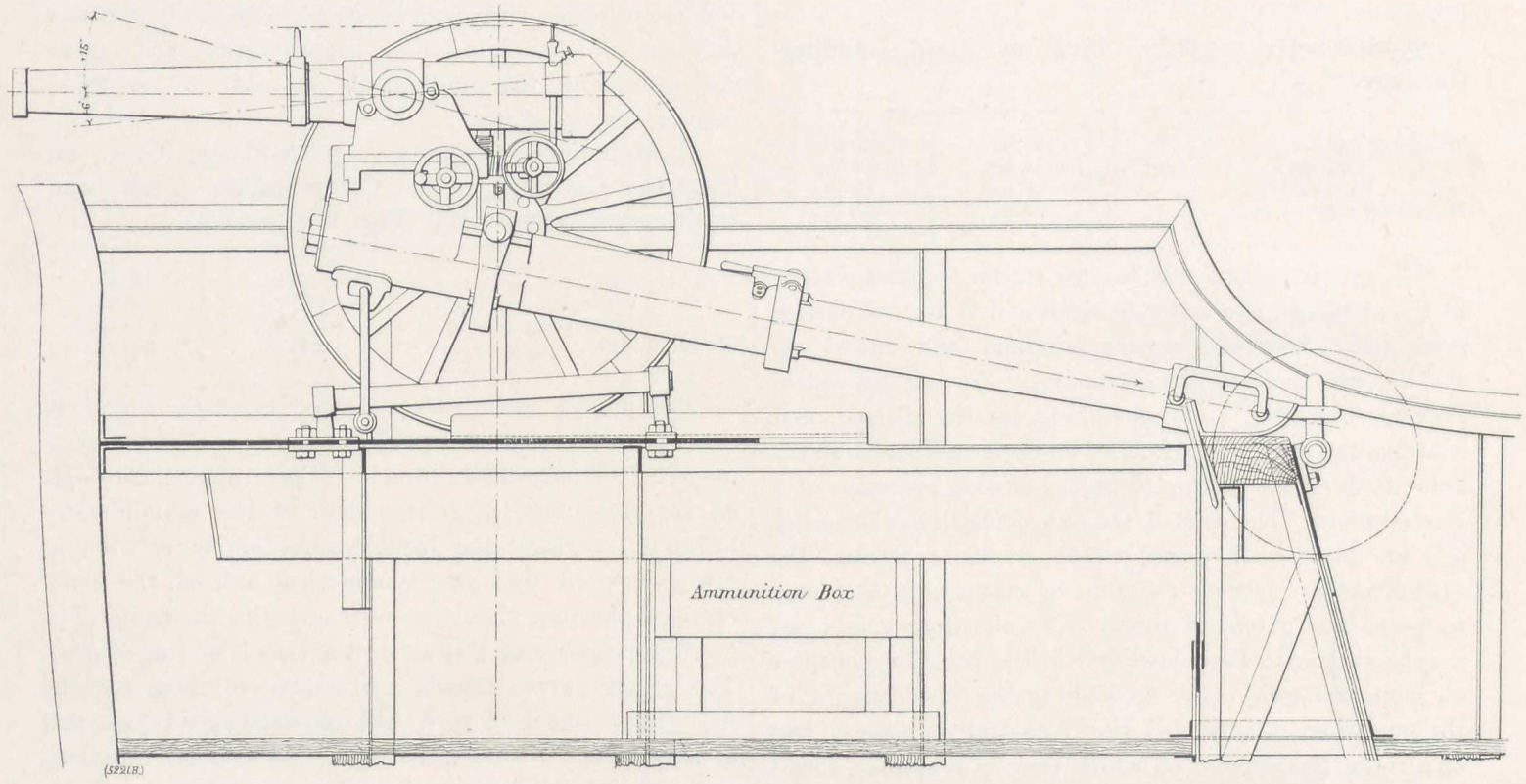
The gun is mounted on a small carriage, similar to that of the 70-millimetre (2.756-in.) mountain gun already described; it only differs from it in the arrangement adopted for the slides, as in the case of the 65-millimetre (2.756 in.) carriage; the displacements for lateral training are so devised that the symmetrical axis of the small carriage platform always corresponds with the trail. The carriage proper is of cast steel; the trail is of forged steel. The general arrangements are similar to those for the field guns of the same type; the cast steel tube is provided at its rear end with a collar made with two solid sections and two interruptions; the collar can be displaced by means of a handle, and made to occupy two positions, one 90 deg. from the other. The collar is held fast by bringing down the handle, and fixing it to a lug on the tube. When it is required to render the trail rigid, either for transport or when the gun is fired with free recoil and without a spade, it is sufficient to raise the handle and to turn round 90 deg., when the solid sections meet corresponding extensions on the trail. The length of the trail can be reduced for transport by bringing back the carriage support, and causing the collar to turn, so that the solid sectors come in the rear of the extensions on the trail.

The recoil cylinder and recuperator are contained inside the trail, the liquid and air being separated by a movable diaphragm. The air contained in the piston-rod is compressed during recoil, its expansion insuring the running out of the gun.

Fig. 992 shows the manner in which the gun can be arranged on board a boat, to cover, for instance, the landing of troops. To this effect, the boat is provided in front with a platform built up of plates, on which is riveted the path for the wheels; a slot is cut in the

platform to take the trail-spade, the rear surface of which bears against a wood beam held on a plate support. The trail-block ring is placed on a hook that forms part of a nut made to travel on a horizontal screw worked by the gunner. To prevent the carriage from rising, when the boat rolls, it is held to the platform by a round stay-rod placed in the centre of the platform. The front of the boat being too narrow to allow an extended lateral training, the steersman, who is placed direct in the rear of the gun, is provided with sights, and by acting on the rudder, he can sight the gun practically in a line with the aim, the gunner making the final adjustment.





Figs. 991 and 992. 65-Millimetre Quick-Firing Boat Gun, on Landing Carriage, with Compressible Trail.

XLVIII.—SIEGE AND GARRISON GUNS.

THE Schneider-Canet guns for the attack and defence of garrisons comprise the whole series of types and calibres in use for this special service. In this class may be numbered also the guns which have been designed during the last few years, to serve for garrison and field duty. The latter are especially of the mortar and howitzer kind, ranging in calibre from 90 millimetres to 15 centimetres (3.543 to 5.905 in.), and their carriages are so arranged that they allow firing on ordinary ground, without preparing a suitable platform beforehand. They answer the programme recently laid down by various governments, the object of which is to constitute (besides the normal armament in field artillery) batteries easily shifted, and formed of large calibre guns, quickly set for firing with high trajectories. This *matériel* embodies all the Schneider-Canet improvements, and a certain number of examples are also provided with the devices that enter into the construction of quick-firing guns.

In this section, the Peigné-Schneider-Canet system of transportable batteries will also be passed in review; these have been designed for all siege operations, whether for attack or for defence, and also for coast service. This *matériel* is of interest, owing to the important services it will be called upon to fulfil; it has been adopted by the French Government, and has also been supplied to the Russian and Danish War Departments.

SIEGE GUNS.

A description of the complete series of guns of this class manufactured by Messrs. Schneider and Co. would be a too lengthy one, and as the general arrangements vary but little from one calibre to another, the types which have been made in the greatest numbers at Messrs. Schneider and Co.'s Creusot Works—those of 12 centimetres and 155 millimetres (4.724 and 6.102-in.) calibre—will only be reviewed.

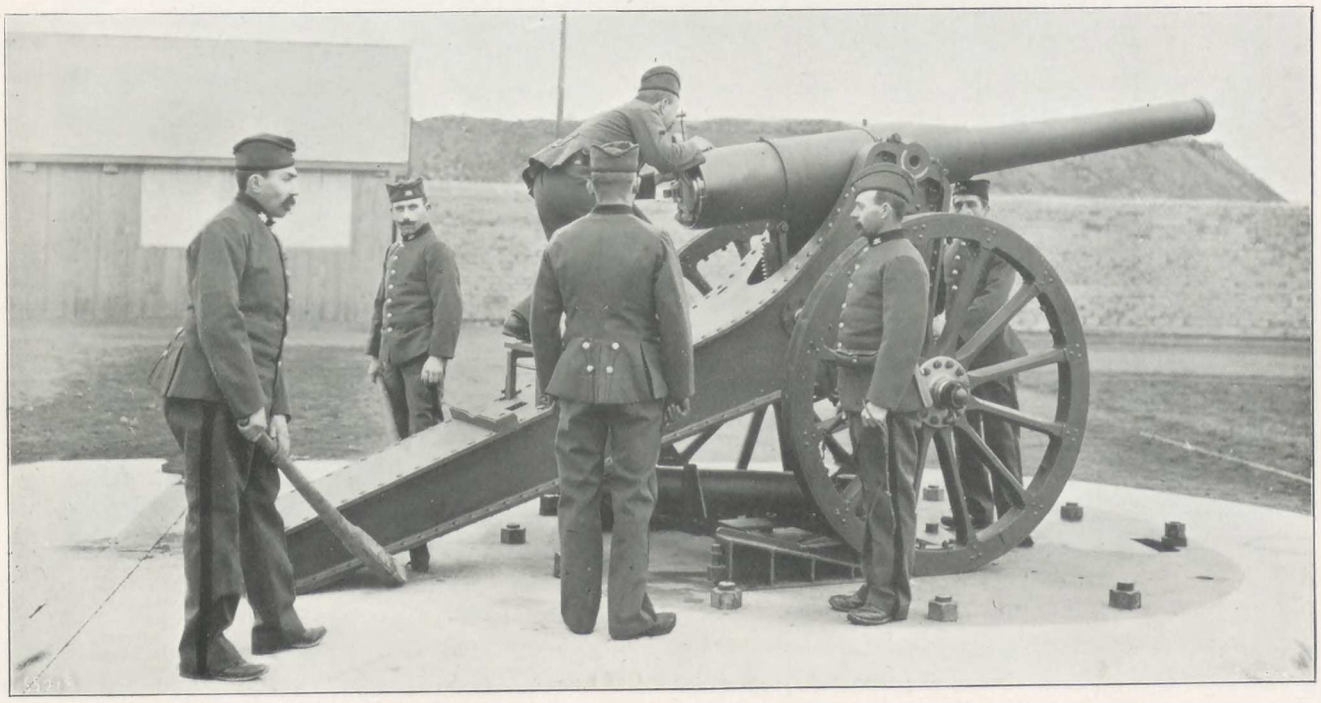


Fig. 993. 12-Centimetre Schneider-Canet Siege Gun.

12-Centimetre (4.724-In.) Schneider-Canet Siege Guns (Figs. 993 and 994).—These have been adopted by the Servian and Bulgarian Governments, to complete their armaments, which hitherto had been formed of German-made guns.

Weight of gun...	1180 kg.	2600 lb.
,, carriage	1400 kg.	3085 lb.
,, projectile	20 kg.	44 lb.
Muzzle velocity	500 m.	1640 ft.
Elevation	+ 30 deg. to − 12 deg.	+ 30 deg. to − 12 deg.

The gun is built throughout of steel, and is formed

of a tube which runs the whole of its length, the breech-block fitting in the rear end of the tube. It is strengthened by a jacket, a trunnion-ring, and a wedge coil. The jacket is fitted with a coil, on which are jointed the elevating bars. The breech-block is of the ordinary threaded type, with a plastic obturator of the Schneider-Canet system; firing is effected with a friction fuse. The breech is opened in three actions of the breech-block.

The carriage consists of two brackets built up of steel plates; they are held apart by top and bottom stay-plates, a stay-bolt, and a head-plate fitted with the angle bar which forms the chase rest. The two brackets are joined together at the trail end by a cast steel piece held by a trail-plate. The brackets carry the gun trunnions, the supports for the elevating mechanism, and the various accessories required for working the gun. The bottom trail-plate carries the socket which holds the recoil piston rod. The hydraulic recoil cylinder is on the Schneider-Canet system, with central counter-rod and constant resistance. The carriage rests on a steel axle, with the interposition of an axle body of hard wood. A shoe-brake acts on the wheels in the ordinary manner when the gun is wheeled about.

The elevating mechanism contains a toothed sector, joined by two bars to the coil on the jacket; it gears with a pinion keyed on a horizontal shaft, worked direct by the elevating handwheel.

The platform on which the carriage rests is formed of oak beams, placed in the ground. A bolster bolted on this platform carries the pivot round which the jointed axle of the recoil cylinder turns. It is also provided with a frame, to which the brake shoes are fitted.

The trail end is fitted with the accessories for hooking it on a fore-limber. When the gun is transported on its carriage, it is placed in special rests on the trail. The recoil cylinder is mounted in two collars on the fore-limber. The gun can also be transported on a special car, the carriage being wheeled together with the fore-limber.

The above description is that of the guns supplied to the Bulgarian Government. Those furnished to Servia differ only in that they are fitted with a threaded breech-block, which works in two actions, firing being effected with a percussion fuse; the road brake has two shoes, held to the trail by chains.

155-Millimetre (6.102-In.) Schneider-Canet Siege Guns.—The gun consists of a steel tube which runs for its whole length; it is strengthened by a wedge coil, a trunnion ring, three lower breech-coils, and three upper breech-coils. The breech-closing device is on the Schneider-Canet system, with plastic obturator; the breech-block works in three actions, firing taking place with friction fuse.

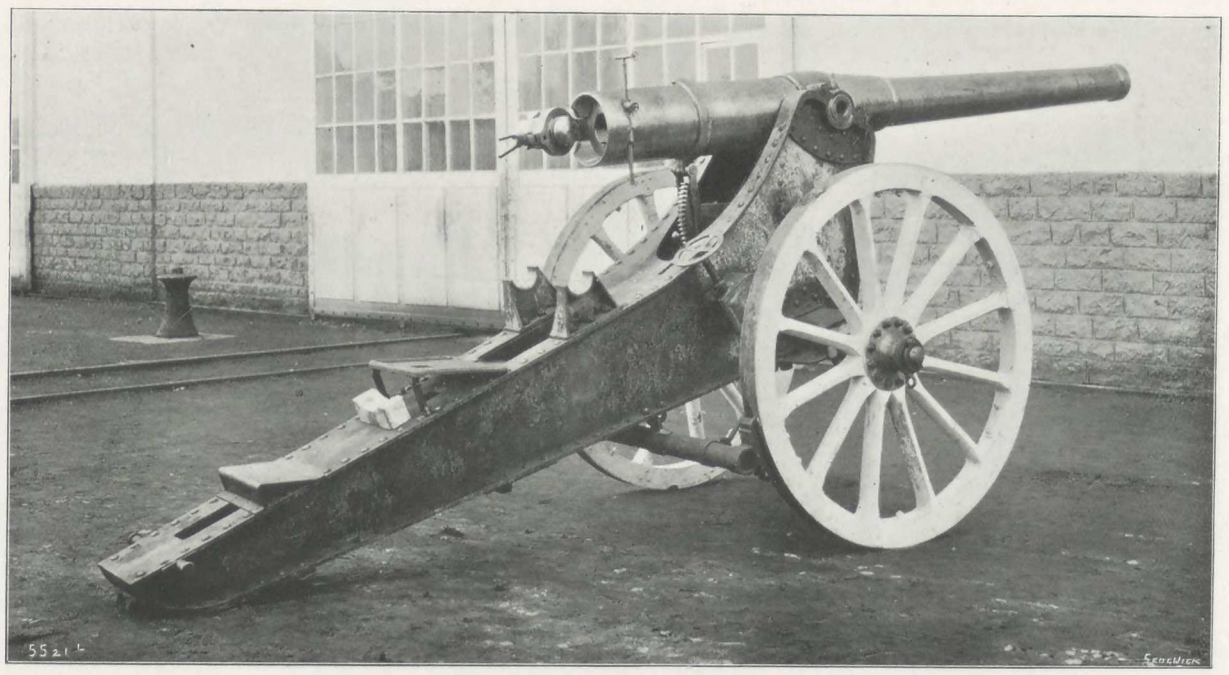


Fig. 994. 12-Centimetre Siege Gun.

The carriage is similar to that of the 12-centimetre gun, and is fitted with brake shoes.

Weight of gun	2500 kg.	5510 lb.
,, carriage	3200 kg.	7053 lb.
,, projectile	40 kg.	88 lb.
Muzzle velocity	480 m.	1575 ft.
Elevation	+ 28 deg. to − 13 deg.	+ 28 deg. to − 13 deg.

Designs and firing-trials have been carried out for a number of years by Messrs. Schneider and Co., with a view to put in service, ordnance of comparatively large calibres, from 90 millimetres to 15 centimetres

(3.543 in. to 5.905 in.), mounted on wheeled carriages, and suitable for immediate service on any kind of ground without it being necessary first to construct firing platforms. This programme has also been considered by several Governments, and followed by them for completing their field armament. Messrs. Schneider and Co. have manufactured and supplied two principal types of ordnance of this class, especially to Brazil, Norway, Servia and Bulgaria.

The first type includes mortars and howitzers. The carriage is of special construction. It contains an elastic device which allows a certain displacement of the brackets on the axle; it is made, besides, with a bearing block, which rests on the ground and absorbs part of the percussion, developed to a high degree when firing takes place under great angles.

the centre of which is on the trunnion axis, so that the line of sight remains constant under all angles of elevation.

The carriage consists of three main parts: namely, the trail, formed of steel plates; the mounted axle; the bearing-stock, formed of two oak blocks strengthened with steel bars. The trail rests on the axle through inclined sole-plates, which enable it to slide when firing takes place, until the bearing-stock comes in contact with the ground. The elastic joining of these parts together is obtained by two sets of springs that weigh on the axle at one end, and at the other on two bars which go through the axle, and are jointed to the trail. The sliding of the brackets causes the pressing down of the springs. Owing to this arrangement, the percussion caused by firing is almost entirely transmitted to the ground, the axle under-

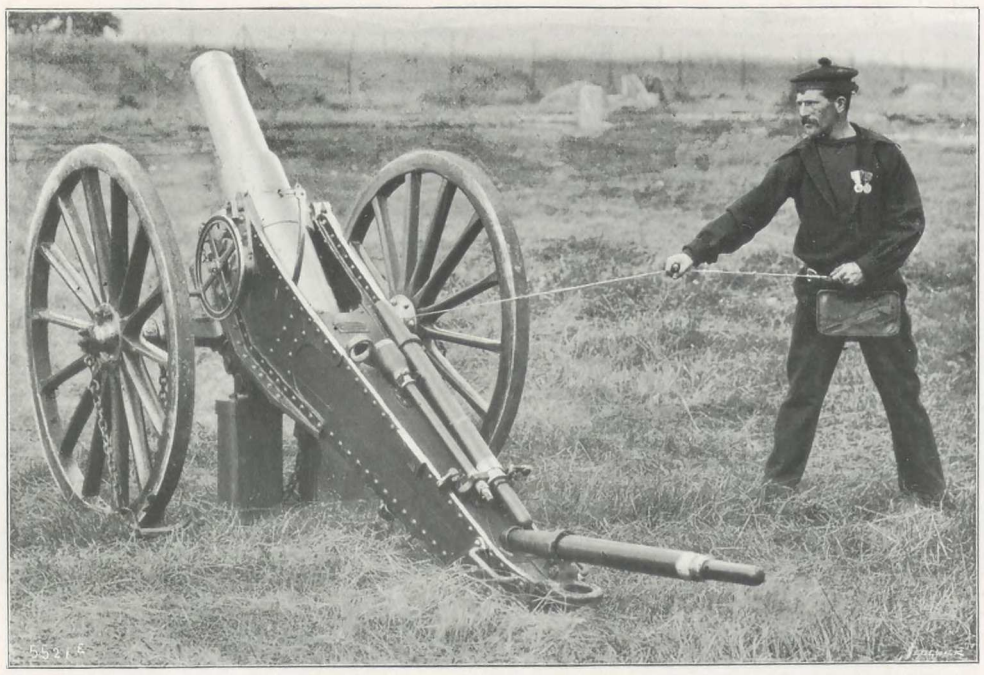


Fig. 995. 10-Centimetre Howitzer.

10-Centimetre (3.937-In.) Howitzer (Fig. 995).—This has been supplied to the Brazilian Government.

Weight of howitzer	290 kg.	639 lb.
,, carriage	595 kg.	1311 lb.
,, projectile	9.5 kg.	21 lb.
Muzzle velocity	300 m.	984 ft.
Elevation	0 deg. to + 50 deg.	0 deg. to + 50 deg.

The howitzer is of steel, and is formed of a tube strengthened by a trunnion jacket with clamp in the rear, and by a truncated conical coil in front. Rifling is made progressive. The breech-closing device is with a plastic obturator; firing takes place by percussion. The breech-block has interrupted threads cut out on two helicoidal segments; the swing piece which carries the breech-block is conical, and fitted with rollers that guide the block in its travel. A special description of the breech-mechanism has been given in the section dealing with breech-pieces. A sight and curved scale are provided, going no strain, apart from that which results from the temporary pressing down of the springs. The height of the stock is such that, before firing, its sole-plate is a few centimetres above ground level. When the reactions due to the firing are completely spent, the springs cause the brackets to resume their former position with regard to the axle. This return action is controlled by the contact of the end of the bars with the axle. Belleville springs are employed to deaden the shock of return. Recoil is limited by a system of drag-shoes, which can be used also as a brake.

The elevating mechanism is placed on the base of the left trunnion, and consists of a curved rack, in which a pinion engages set in motion by differential non-reciprocating gearing, for elevating the gun.

Each howitzer is provided with a fore-limber, made to carry chests containing twenty projectiles, twenty powder charges, and a quantity of fuse, besides accessories and spare parts.

12-Centimetre (4.724-In.) Howitzer (Fig. 996).—This pattern has been adopted by the Servian Government.

The howitzer is in three parts: the tube, in the rear of which is screwed the breech-block; the jacket, made with trunnions, and the wedge coil in front of the jacket. The tube is rifled to the right, with an initial pitch of 3 deg., and a final pitch of 6 deg. The breech-block has interrupted threads, with two threaded parts and two interruptions; obturation is obtained by a plastic disc placed between the breech-screw and the movable head. The firing mechanism is repeating.

Weight of howitzer	493 kg.	1,086 lb.
,, carriage	872 kg.	1,922 lb.
,, projectile	16.4 kg.	36 lb.
Muzzle velocity	300 m.	984 ft.
Elevation	− 5 deg. to + 45 deg.	− 5 deg. to + 45 deg.

The carriage consists of three main parts: the trail, formed of two brackets made of chased-out steel plates, strengthened by an outside plate which extends over the whole part between the axle and the lower trunnion plate; the latter is of cast-steel; the top trunnion plate is of forged steel. The trail is strengthened by top and bottom trail-plates, by a stay-piece placed between the brackets and sufficiently in the rear to enable the breech-end to enter the trail, and by a nose-plate arranged for hooking on to a pivot bolt fitted to the fore-limber, in the same way as with field artillery. The wheels are of wood, with gun-metal naves; the rim is of bent wood, in three pieces. The spokes are joined to the rim by means of iron sockets fixed to the rim, and which hold the end of the spokes; the latter do not penetrate the rim, the whole being held firm together by the shrinking of the iron hoop. The axle is square in section, and is made with two transverse holes through which run spring rods. The bearing stock is provided with a view to remove from the axle and the wheels, the percussion strains produced when firing under positive angles. It consists of two oak blocks jointed under the trail, and joined together at their base by a wide sole-plate, to which is hooked a chain, the other end of the chain being hooked on the trail, with the interposition of india-rubber buffers. The two steel pieces riveted under the trail, and to which are suspended the two blocks, are each joined to an inclined bar which goes through the axle; these bars carry a spiral spring, pressing on the nut at one end of the bar and on the socket placed on the axle. The carriage is therefore not fixed rigidly on the axle; on the contrary, it can be shifted with regard to the axle on a plane parallel with the bottom part of the trail. The axle remains constantly in contact with the under side of the trail, by means of heeled sole-plates riveted under the carriage, in which slide the flanges of the two spring sockets placed on the axle Thus, when the howitzer is fired, the carriage and the two sets of springs slide on the axle until the sole-plate of the blocks bears on the ground; the latter, therefore, take up the whole of the percussion strains, the axle and wheels undergoing no other strain than that due to the pressing down of the springs. The relaxing of the springs causes the trail to resume its former position with regard to the axle.



Fig. 996. 12-Centimetre Howitzer.

The elevating of the gun is obtained by a lateral hand-wheel, which works a pinion that gears in a rack fitted to the left trunnion. A brake on the left top trunnion plate holds the gun fast when it is fired. Two brake shoes with chains are resorted to for the road and for firing. Lateral training is effected by displacing the trail by means of a lever. The fore-limber carries a chest which can take sixteen rounds.

15-Centimetre (5.905-In.) Howitzer (Fig. 997).

Weight of howitzer	815 kg.	1,796 lb.
,, carriage	1,577 kg.	3,476 lb.
,, projectile	40 kg.	88 lb.
Muzzle velocity	260 m.	853 ft.
Angles of elevation	− 5 deg. to + 45 deg.	− 5 deg. to + 45 deg.

This howitzer is similar to that of 12 centimetres calibre, but all parts are of correspondingly larger dimensions. The fore limber is without a chest, and consists of

a frame on which is fitted a pivot-bolt for its junction with the trail. Swing-trees are provided for the rear horses, and a crosspiece with shafts for the front horses.

15-Centimetre (5.905-In.) Mortar (Fig. 998).—These have been built for the Brazilian and the Servian Governments. They are generally similar to the 100-millimetre (3.937-in.) howitzers, except as regards the dimensions of the various parts. They fire also three kinds of projectiles: common shell, with percussion fuse; shrapnel, with double-acting fuse, and high explosive shell, with percussion fuse.

—	Brazilian mortar.	Servian mortar.
Weight of mortar ...	390 kg. = 860 lb.	491 kg. = 1,082 lb.
,, carriage ...	805 kg = 1.907 lb.	981 kg. = 2,162 lb.
Maximum firing angles:		
Positive	50 deg.	50 deg.
Negative	0 deg.	0 deg.
Weight of projectile ...	32 kg. = 71 lb.	32 kg. = 71 lb.
Muzzle velocity ...	200 m. = 656 ft.	200 m. = 656 ft.

The fore-limber is fitted with a chest to carry eight rounds of ammunition. The projectiles are placed two by two on movable wicker baskets; the charges are placed three by three in a movable drawer, another drawer containing the tools, spare parts, fuses and accessories. Part of the spare pieces are placed in a chest carried in the caisson fore-limber. Shafts and swing-trees are provided for the team.

Ordnance on Carriage with Hydro-pneumatic Recoil.—These types contain a rigid trail, with trail spade and hydro-pneumatic recoil cylinder, and they embody all the improvements carried out in the carriages of quick-firing field ordnance. Large orders are on hand for these at Messrs. Schneider and Co.'s works, and, among other Governments, for Norway, Japan, and Bulgaria.

90-Millimetre (3.543-In.) Mountain Howitzer (Fig. 999).

Weight of howitzer	110 kg.	242 lb.
,, carriage	281 kg.	619 lb.
,, projectile	6.5 kg.	14 lb.
Muzzle velocity	300 m.	984 ft.
Angles of elevation	0 deg. to + 60 deg.	0 deg. to + 60 deg.

The howitzer is without trunnions, and is carried in a cradle in which it can recoil over 300 millimetres (11.811 in.). The howitzer and cradle oscillate for elevation round two trunnions, which form part of the cradle, and fit in trunnion-plates on the carriage. The trail is in two parts, and is fitted in the rear with a trail-spade, which prevents recoil almost completely when firing on ordinary ground. The recoil of the gun in the cradle is absorbed by a hydraulic cylinder, the return of the gun in battery being effected by a compressed air recuperator.

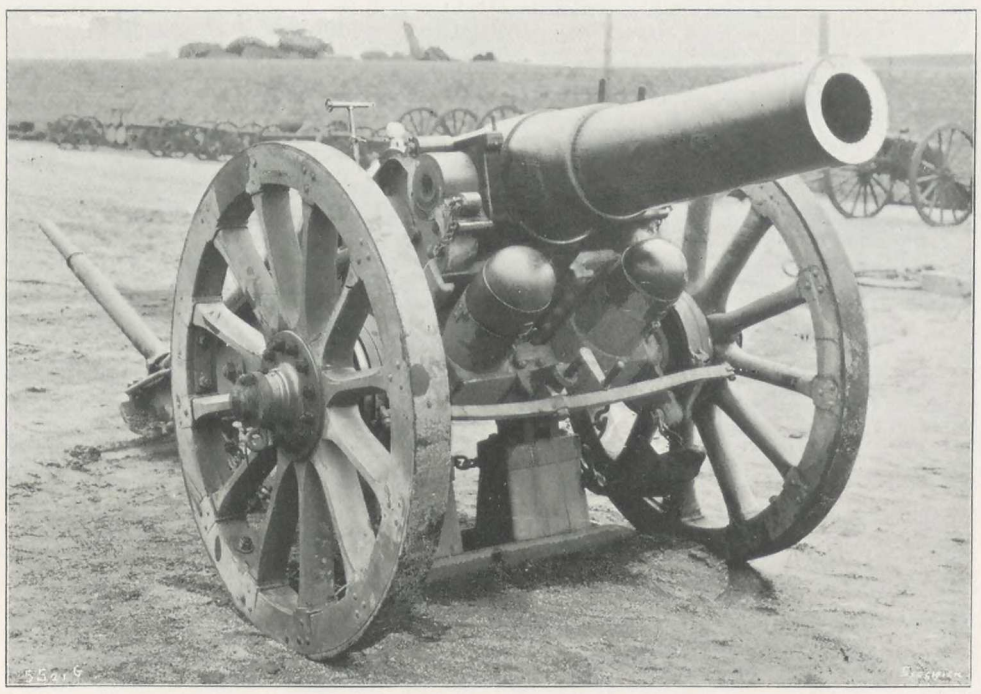


Fig. 997. 15-Centimetre Howitzer.

The howitzer is forged out of a single steel block; it is fitted in the rear with the breech-block and its fittings, and with the shoulder-piece, to which are jointed the recoil piston and recuperator rods. It is made with two lateral longitudinal flanges, which guide it in its travel in the cradle. The breech closes in one action of the breech-block.

The carriage contains the cradle, which rests through its trunnions on the trail and carries the gun. The hydraulic recoil cylinder is in one piece with the cradle, and contains a piston jointed to the shoulder-piece on the breech-end of the howitzer. During recoil, the liquid flows from the rear to the front of the piston, through a vent, the opening of which is regulated by a central counter-rod; the section is regulated so as to obtain a constant resistance. The counter-rod constitutes also a hydraulic buffer,

which deadens the return shock. The air recuperator is independent of the recoil cylinder, and is formed of an outside cylinder in one piece with the cradle, and one containing an inside piston, the rod of which is jointed to the shoulder-piece already referred to. When firing takes place, the compressed air which is in the inside cylinder, and in the space between the two cylinders, is forced into the latter space; as soon as recoil is spent a reaction of the air takes place, and the piston works forward. The carriage is in two parts, the carriage proper which gears in a curved rack fixed under the cradle on the centre line of the carriage.

The wheels and axle are designed for a track of 800 millimetres (31.496 in.) on the tread; the wheels are 700 millimetres (27.559 in.) in diameter, the nave is of brass, and the rim of bent wood, in three pieces. The spokes are joined to the rim by means of steel sockets.

The sighting device contains a scale fitted to the cradle: it does not move, therefore, when the howitzer recoils, and

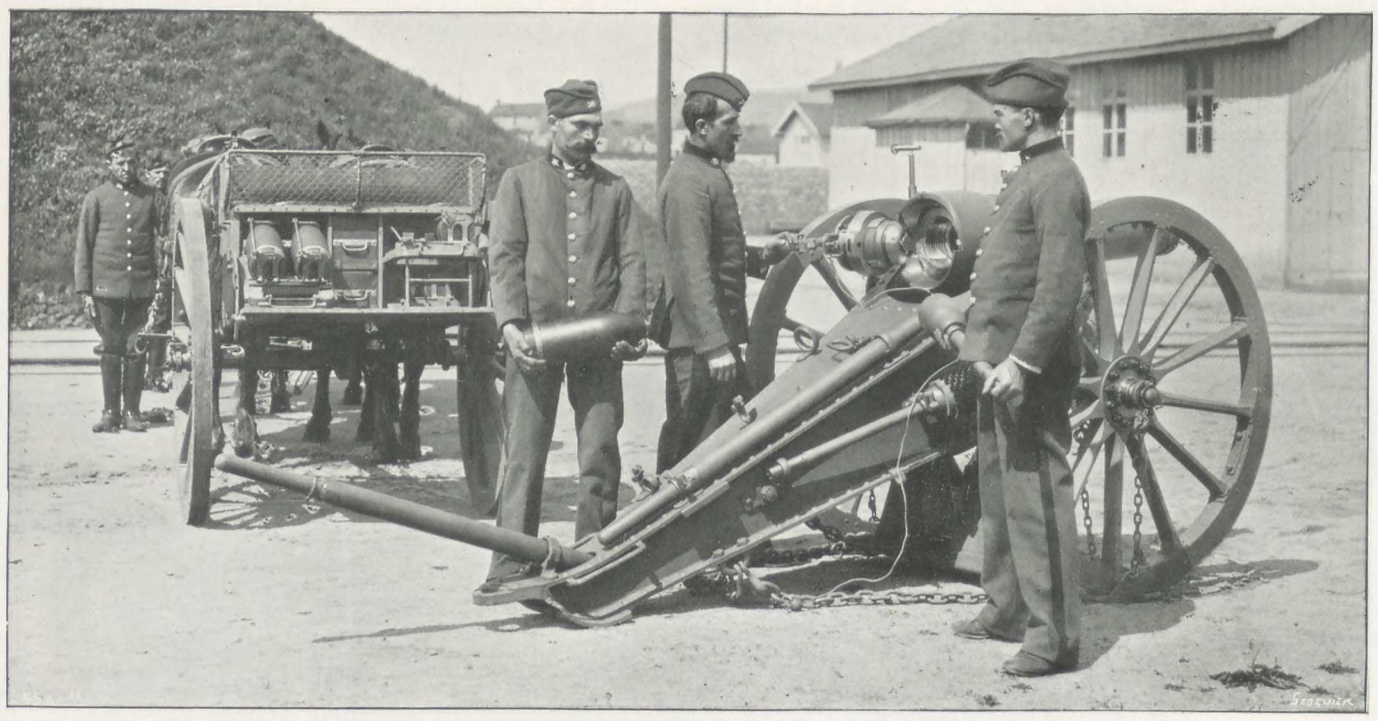


Fig. 998. 15-Centimetre Mortar.

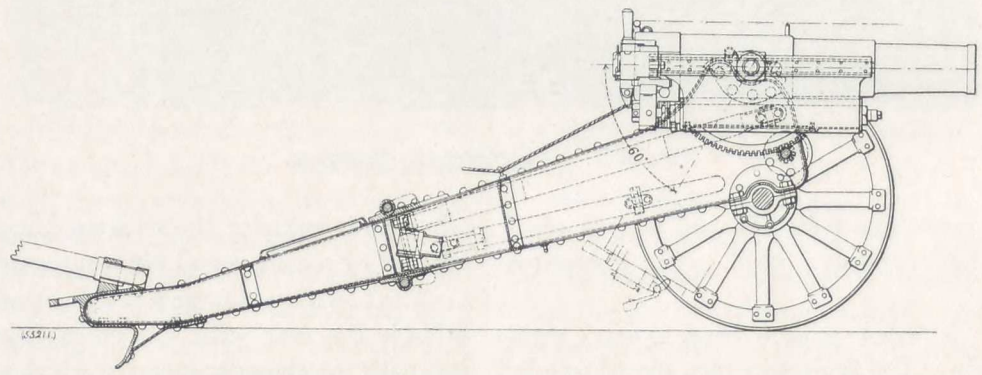


Fig. 999. 90-Millimetre Mountain Howitzer.

and the trail; they consist of two brackets of wrought steel plates, joined together by top and bottom trail-plates and by stay-plates. The two parts are quickly joined together by means of clamps and pins. The end of the trail is fitted with a rigid spade, similar to that of quick-firing field guns. The nose-plate is arranged for hooking on the fore-limber, by means of a pivot-bolt of the usual shape, or for direct hauling, two rings being also provided for holding the shaft.

The elevating mechanism is set in motion by a crank placed on the left side of the carriage; it works a pinion is arranged for laying the gun direct from 0 deg. to 60 deg.

For transport on mules, the piece is divided as follows:

Weight of howitzer	110 kg.	243 lb.
,, carriage body	112 kg.	246 lb.
,, trail wheels	100 kg.	220 lb.
,, cradle, shafts, and tool chests	101 kg.	222 lb.
,, two ammunition chests ...	119 kg.	262 lb.

As above mentioned, it can be also wheeled direct or hooked on a fore-limber. The latter is on two wheels,

and is built for carrying three ammunition chests, which are of two sizes, each made to contain six cartridges, the larger size is made to take cast-iron and high-explosive shells, the smaller ones the shrapnel shell.

105-Millimetre (4.133-In.) Position Guns.—Guns of this class have been supplied to the Norwegian Government, among others.

Weight of gun	1,000 kg.	2,204 lb.
,, projectile	16 kg.	35 lb.
Muzzle velocity	500 m.	1,640 ft.
Weight of mounting	1,400 kg.	3,085 lb.
,, *matériel* ready for hauling	2,735 kg.	6,028 lb.

The gun is 28 calibres in length, and is formed of a tube which runs on its whole length, and in the rear of which is screwed the breech-block. A jacket strengthens the rear part of the tube, and is made with a shoulder-piece, to which are jointed the recoil position-rod and the reglets which slide, during recoil, in grooves made in the cradle. The breech-block is on the Schneider-Canet system for quick-firing guns, and opens out in one action of the lever; it is made with two threaded parts and two interruptions. A loading plate is at the lower part of the breech-block, and it rises automatically when the breech is opened to facilitate the introduction of the cartridge. The percussion mechanism is cocked by manœuvring the breech-block; the mechanism comprises safety devices against hang-fire and premature firing.

The carriage contains two distinct parts: the carriage proper and the carriage support. The carriage proper consists of a movable cradle for elevating the gun; it embodies the recoil cylinder, the recuperator cylinder, and the slides in which travel the lateral flanges of the gun. The trunnions rest in trunnion-plates on the slide. The recoil cylinder is with central counter-rod of the type already described. The compressed air recuperator is designed so as to run out the gun under all firing angles. The carriage support consists of: the trail, formed of two cheeks of wrought steel plates, joined together by top and bottom trail plates and by stays; the axle, made independent of the trail, in view of the lateral training; the wheels; the trail-spade, easily displaced for wheeling the gun; two service platforms, of chequered plates, one to the left of the trail for the gunner who lays the gun, the other to the right, for his assistant in charge of the breech; the brake, which acts direct on the wheels; the lateral training and elevating mechanisms, worked by two hand-wheels within easy reach of the gunner.

The elevating mechanism contains a screw placed under the carriage-body, and which bears on a trunnion support with the interposition of a nut; the latter in turning causes the rising or lowering of the screw, the required action being obtained by gearing worked by the hand-wheel. Lateral training is obtained through a screw joined to the carriage, and which works in a nut fixed to the axle; the screw is worked through gearing, and a shaft set in motion by the hand-wheel.

12-Centimetre (4.724-In.) Howitzer on Quick-firing Field Carriage.

Weight of howitzer	500 kg.	1,102 lb.
,, carriage	635 kg.	1,400 lb.
,, projectile	21 kg.	46 lb.
Muzzle velocity	300 m.	984 ft.
Elevation	+ 45 deg. to − 5 deg.	+ 45 deg. to − 5 deg.

This howitzer can fire six to eight rounds per minute, and is very portable, considering its power; it can be shifted from place to place as easily as the current types of field guns. The powder charge is contained in a metallic cartridge case separate from the projectile, so as to facilitate the using of various charges as may be required. The howitzer is without trunnions; it is carried in a cradle in which it can recoil over 480 millimetres (18.897 in.). For elevation, the cradle oscillates on its two trunnions, placed in the trunnion-plates of the carriage. A trail-spade is provided, and in ordinary ground it almost completely prevents the carriage from recoiling. The recoil of the gun in the cradle is absorbed by a hydraulic recoil cylinder, return being secured by a compressed air recuperator.

The howitzer consists of a tube, in the rear of which is the breech-block seating; a jacket fitted in the rear with the breech-block hinge, and with a shoulder-piece to which are jointed the recoil piston and recuperator rods, the jacket being made with two longitudinal lateral flanges, by which the howitzer is supported and guided in the cradle. In front of the jacket are two coils. The breech opens out in one action of the breech-block; the latter is with repeat-firing action.

The carriage contains the cradle, which rests through its trunnions on the carriage trail; it carries the gun as above mentioned. The hydraulic recoil cylinder, which absorbs the recoil of the howitzer in the cradle, is in one piece with the cradle, and contains a piston jointed to the shoulder-piece of the howitzer. During recoil, the liquid flows from the rear to the front of the piston through a vent, the opening of which is determined by a central counter-rod, the section of the latter being designed to maintain a constant resistance during the whole time recoil lasts. The counter-rod acts also as a buffer to deaden the shock of return. The air recuperator is independent of the recoil cylinder; it consists of an outer cylinder in one piece with the cradle, and an inner one in which is a piston fixed to the shoulder-piece of the howitzer. When the gun is fired, the compressed air contained in the inside cylinder, and in the annular space between the two cylinders, is driven by the piston in the annular space, and when recoil is spent a reaction sets up, and it drives the piston forward. The trail consists of two cheeks of wrought steel plates, joined together by top and bottom trail-plates and by plate stays. It is fitted with a spade, as already mentioned. A nose-plate, with coupling ring, is provided for hooking the carriage on a fore-limber.

The elevating mechanism is worked by a crank placed on the left side of the carriage; it works through a set of

gearing, a pinion which gears in a circular rack on the side of the cradle. Lateral training is given by turning a hand-wheel placed on the left side of the carriage; this works a nut placed on the axle and joined to the trail; the nut by turning causes the displacement of the trail on the axle, the whole system pivoting round the trail-spade. This allows the lateral training to be corrected up to 2 deg. on each side.

The distance between the wheels at the tread is 1,400 millimetres (55 in.). The wheels are 1,220 millimetres (48 in.) in diameter; the boss is of brass and the rim of bent wood, in three parts. The spokes are joined to the rim by means of steel sockets. The axle is fitted with two clasps with treads, on which stand two gunners, who hold lateral training levers placed vertically in sheaths held by the clasps.

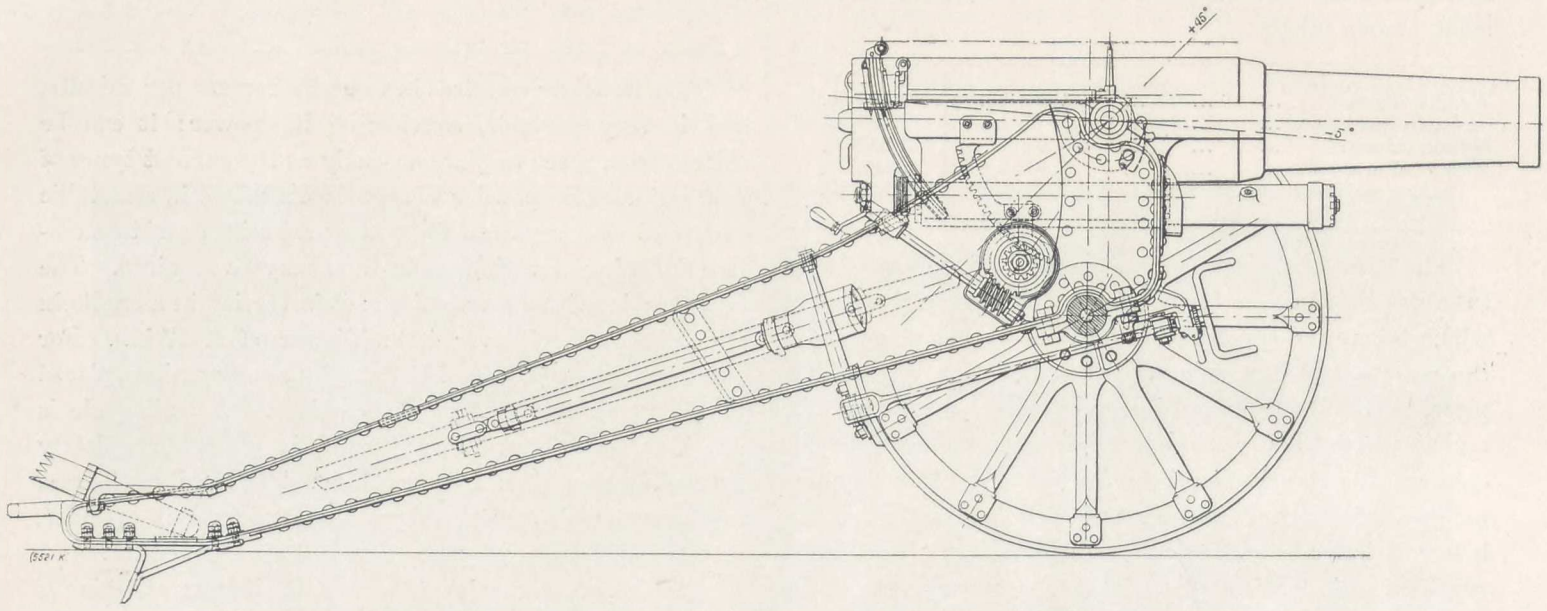


Fig. 1000. 15-Centimetre Howitzer on Hydro-Pneumatic Carriage.

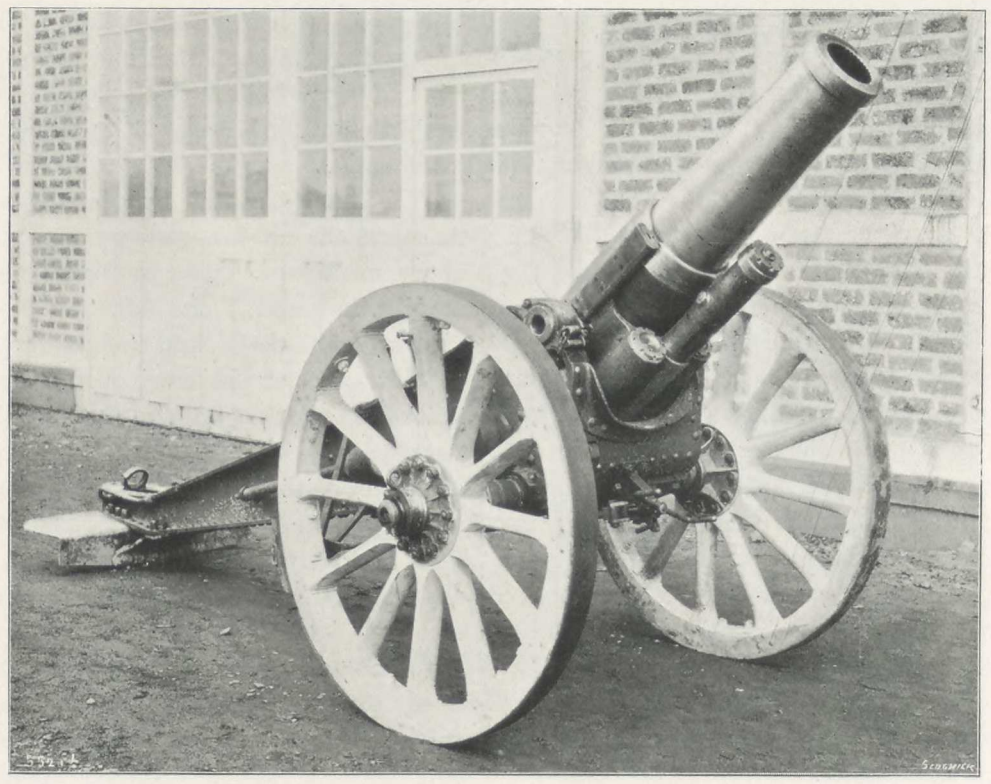


Fig. 1001. 15-Centimetre Howitzer on Hydro-Pneumatic Carriage.

Special shoe-brakes hold the wheels on the ground during firing; when hauling, they act as ordinary brakes. They are joined together by a cross-bar, and to the axle by special forked arms made movable round the axle.

The fore-limber is made to carry fifteen rounds. Each projectile is placed in a separate inclined cell, where it is

maintained by the chest door. The cartridge-cases are placed in boxes, in sets of three. The fore-limber carries also the necessary tools.

15-Centimetre (5.905-In.) Howitzer on Hydro-pneumatic Carriage (Figs. 1000 and 1001).—This type has been adopted in service by the Bulgarian Government.

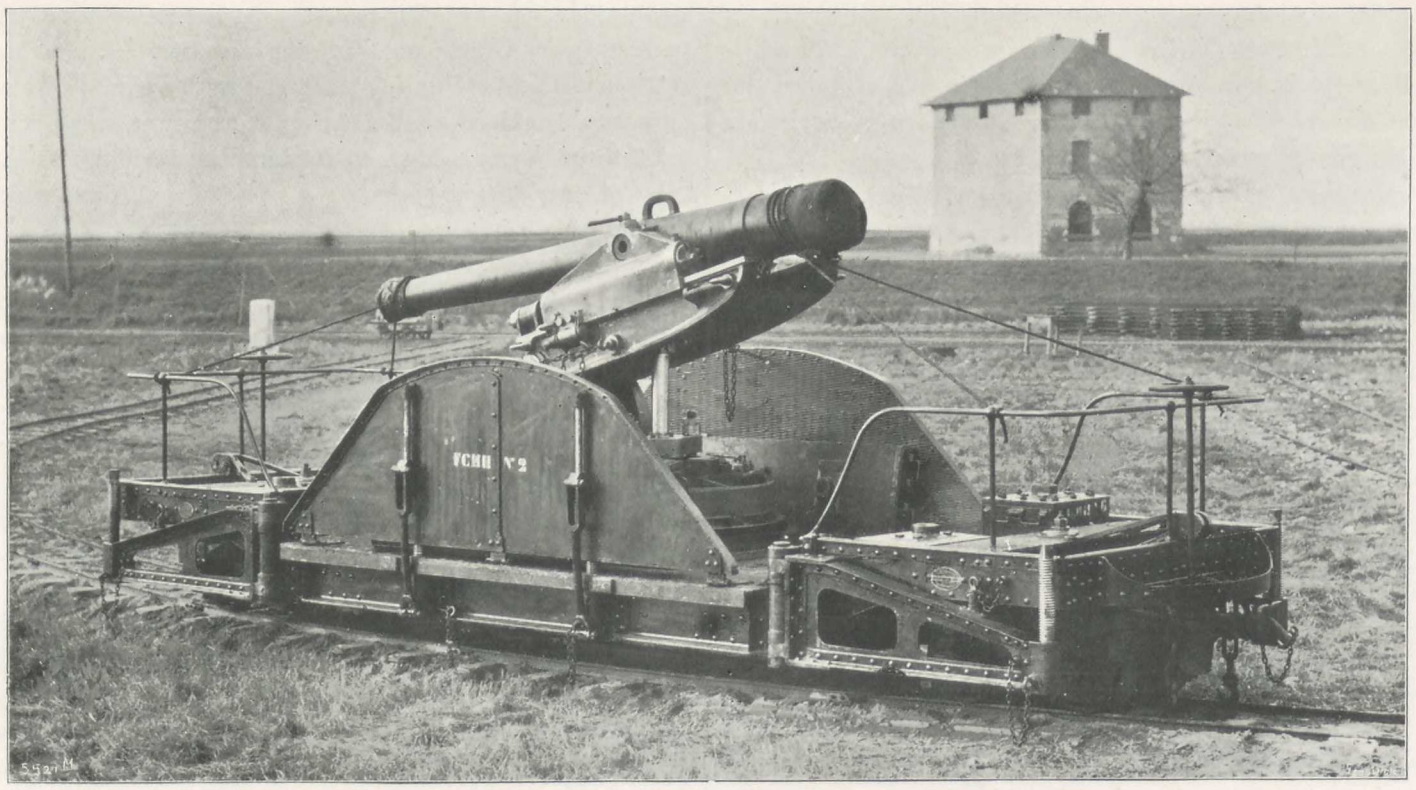
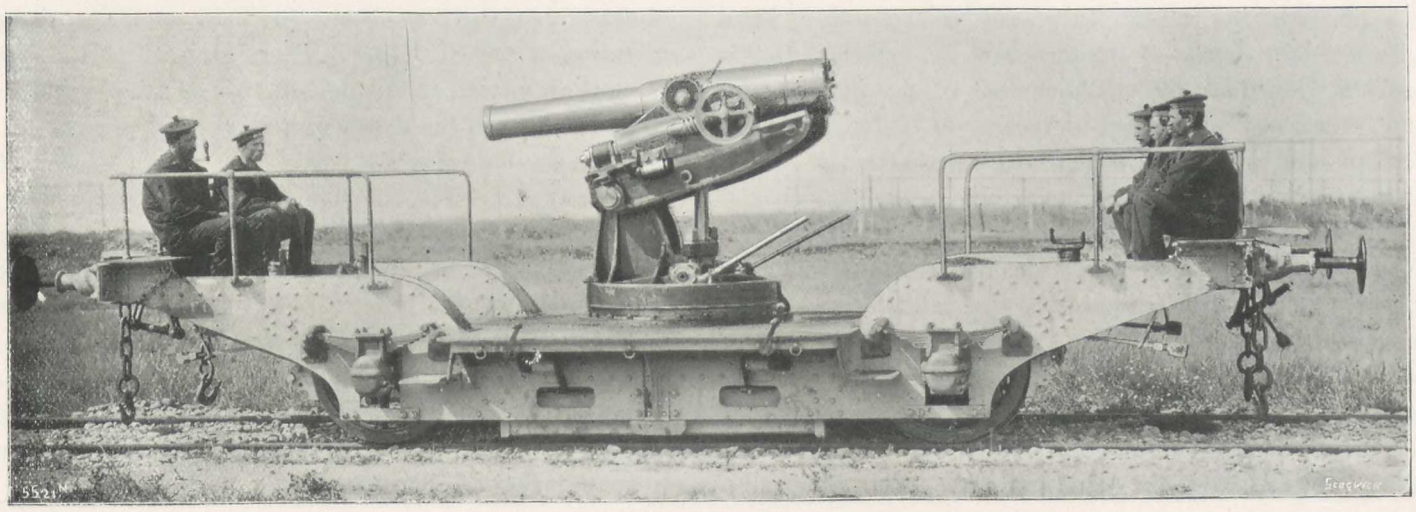


Fig. 1002.



Figs. 1002 and 1003. Railway Batteries.

Weight of howitzer	750 kg.	1,653 lb.
,, carriage	1,050 kg.	2,314 lb.
,, projectile	40 kg.	88 lb.
Muzzle velocity	260 m.	853 ft.
Angles of elevation	− 5 deg. to + 45 deg.	− 5 deg. to + 45 deg.

The howitzer is built up of the following parts: a tube in the rear of which is the breech-block seating, and a jacket similar in shape to that of the howitzers previously described. The breech opens out in three actions of the breech-block; the latter is fitted with a plastic obturator, firing being effected by means of obturating friction fuse. A special vent-cover allows the fuse to be screwed in when the breech-block is opened out and when it is closed, but the firing-line cannot be adjusted until the breech is completely closed.

The carriage contains the cradle, which rests, through its trunnions, on the trail, and carries the gun through two slides, in which fit the lateral flanges of the gun; the latter can recoil in the cradle over 450 millimetres (17.716 in.). The two hydraulic recoil cylinders absorb the recoil of the gun in the cradle; they are in one piece

with the cradle and contain two pistons, the rods of which are jointed to the shoulder-piece of the gun. During recoil, the liquid flows from the rear to the front of each piston through a vent, the opening of which is regulated by a central counter-rod ; the section of this rod is designed so as to obtain a constant resistance during the whole time recoil lasts.

The distance between the wheels, on the tread, is 1,300 millimetres (51.180 in.). The wheels are 1,270 millimetres (50 in.) in diameter; the bosses are of brass, the rims of bent wood in three parts, the spokes being joined to the rim by means of steel sockets.

For sighting the gun, an alhidade scale is provided; it is placed on the cradle, and therefore does not recoil with the gun. It is arranged in such a way as to enable the laying of the gun, with rectification of the firing angle up to an angle of + 35 deg. The scale and sight are mounted on a horizontal spindle, which allows of maintaining the sight-line in a vertical plane, parallel with the axis of the gun, whatever be the incline the carriage may take, owing to the unevenness of the ground or an unequal settling of the wheels. From + 35 to 45 deg., the required elevation is given with the help of an ordinary dial-plate level or of the alhidade scale.

The fore-limber carries a chest to hold five rounds.

TRANSPORTABLE BATTERIES.

The transportable batteries, Peigné-Schneider-Canet system, have been designed and built to meet the special requirement of transporting large calibre guns by rail, in order to concentrate rapidly at a given spot a large number of pieces of ordnance; the guns are fired from the platform on which they are transported. Even with artillery depôts of limited area, the solution of this problem facilitates the establishment of a very powerful and practically invulnerable means of defence for all centres and garrisons which are served by a system of railroads. Another advantage lies in the fact that it renders possible the doing away with a certain number of ramparts and fixed forts, the maintenance of which is costly, as such works require to be modified periodically, in order to keep them always well in advance of the progress made in the means of attack. The transportable batteries meet the case perfectly in every respect; they are armed with 155 and 120 millimetres (6.102 in. and 4.724 in.) guns, and the platforms are adapted both for the usual gauge and for that of 60 centimetres (23.622 in.). They can fire on extempore lines, rapidly laid down in times of emergency; and this, of course, increases to a marked degree the range of their usefulness. Such platforms can be made to suit all classes of guns.

The object followed in the design of the carriage is the reduction to a mimimum of the traction and percussion strains, developed on the platform during the recoil of the powerful guns which constitute the batteries. The carriage is fitted with an oscillating slide and two hydraulic recoil cylinders, combined with a spring recuperator, which runs out the gun again after each round. A description of this type of carriage is given in a preceding section, which deals with disappearing carriages. The system has invariably given satisfaction, even after the batteries had remained for a time in the open, where no means were available to protect them from bad weather; and this constitutes a further great advantage in favour of this class of *matériel.*

For the normal gauge lines, the platform is made as low as possible above the rails, to which the system is clipped, to prevent transverse displacement; the wheels are of normal diameter, and the bufters are placed at the usual height. The distance between the axles is calculated so as not to interfere with any of the manœuvres; the width of the platform is such that the battery can travel on all lines without interfering with, or being in the way of, other rolling-stock which it may cross in transit. On both sides of the platform are two flaps that can be brought down when the gun is placed in battery, to give sufficient area for serving the gun in all positions. Above the wheels are placed seats for the gunners. Long wooden beams are laid on the truck, and are raised when the latter is ready for transport. When the guns are placed in battery, the beams are placed along the line to deaden the effects of firing.

When the batteries are for service on a 60-centimetre (23.622-in.) gauge line, the line itself offers but a limited resistance, and the pressure of the wheels on the rails has to be sufficiently counterbalanced to prevent all lateral displacements of the line. To this effect, the platform, which is carried by the pivot-bolts of two bogies when the *matériel* is in travelling order, rests on the ground through lateral brackets, when the gun is placed in battery.

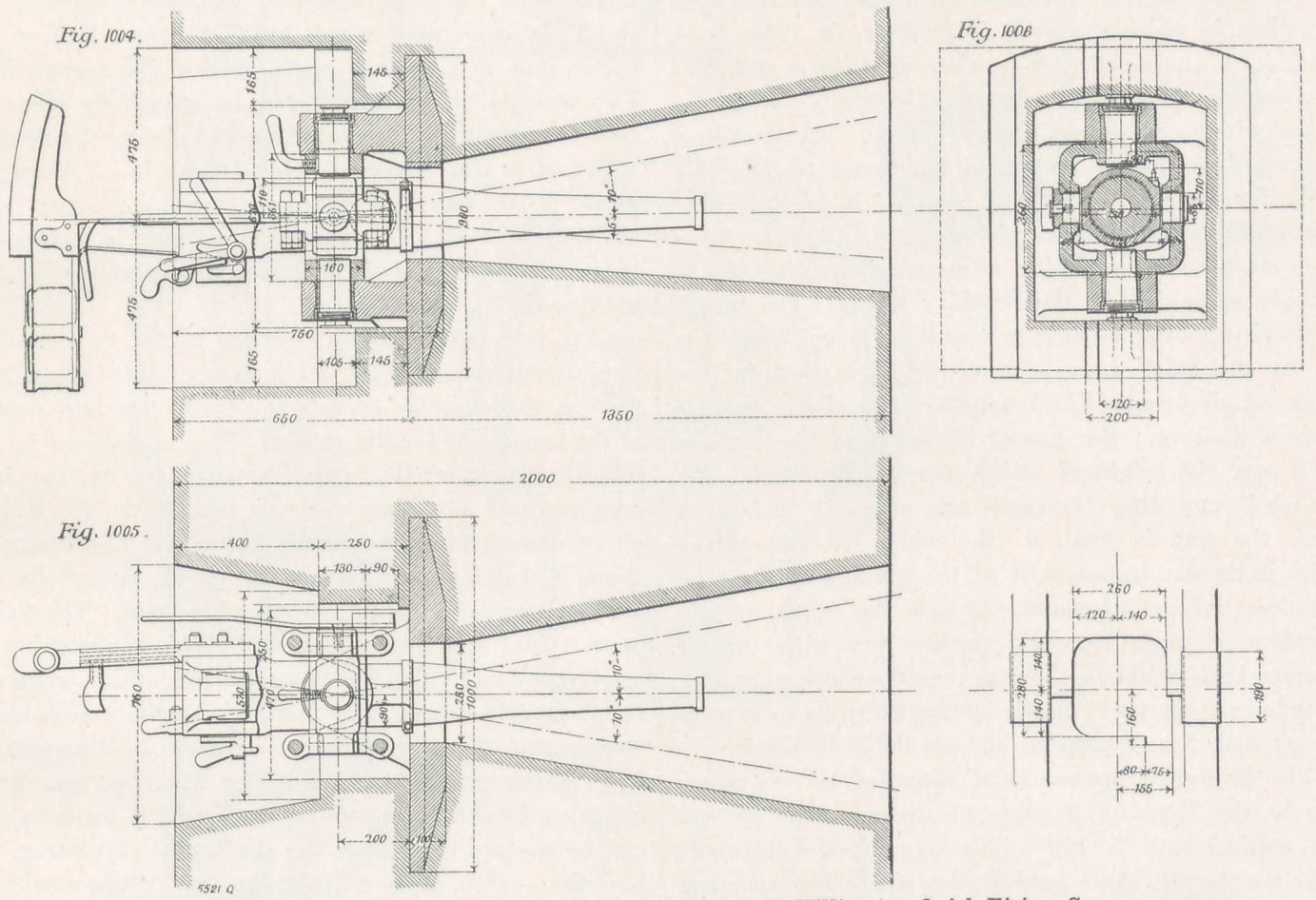
Figs. 1002 and 1003 show such batteries carrying guns on disappearing carriages.

XLIX.—LAND TURRETS.

A LARGE number of chilled cast-iron turrets, armoured caponiers, disappearing armoured turrets, transportable cupolas for machine guns, &c., have been built by Messrs. Schneider and Co. for the French and various other governments. These cannot all be described in detail; the following descriptions of a few examples will, however, give an idea of the activity displayed by the firm in this class of work.

gun is trained laterally by the gunner, who bears against the butt end; he is thus enabled to fire rapidly against troops.

To set the gun in place, the frame is first mounted on the trunnions; the gun and frame are then let into the embrasure and the vertical pivots are placed in their sockets, one above and the other below; the pivots are fitted with a ring that holds them to lugs cast on the cast-



Figs. 1004 to 1006. Mounting in Casemate for 57-Millimetre Quick-Firing Gun.

Mounting in Casemate for 57-Millimetre (2.244-In.) Quick-firing Gun (Figs. 1004 to 1006).—This consists simply of a plate which forms both a shield and a support for the gun, the latter being fixed to the mounting. Elevation ranges from − 5 deg. to + 10 deg., the gun being made to turn on its trunnions in a frame. The gun can be trained laterally over 10 deg. each side, by causing the frame to turn on vertical pivots. The frame is in two parts, bolted together; it is made with two holes in a vertical line with the trunnions; the vertical pivots fit in these holes. The plate that closes the casemate embrasure is strongly fitted in the wall by means of eight armour-plate bolts. This plate is of cast steel. The steel plate. This arrangement adds strength to the system; it resists the shock caused by firing much better than the stay and lower pivot in general use for this kind of fortification work, while it allows of a suitable range to follow the target aimed at without difficulty.

Weight of gun...	210 kg.	463 lb.
,, charge	.680 kg.	1½ lb.
,, projectile	2.720 kg.	6 lb.
Muzzle velocity	425 m	1,394 ft.
Approximate weight of mounting ...	800 kg.	1,763 lb.

Disappearing Turret, Armed with One 57-Millimetre (2.244-In. (Quick-firing Gun (Figs. 1007 to 1012, Plate CLXV.).—This has been designed specially with a view to

resist main force attacks. It remains down during the shelling of the place, and is run up when convenient to fire a volley. It can also be made to disappear and be raised for each round in succession, the manœuvres and the laying of the gun being effected within a very short time. The turret is armed with a 57-millimetre (2.244-in.) quick-firing gun, that fires with a muzzle velocity of 425 metres (1,394 ft.), ordinary shell or grape shot shell weighing 2.720 kilogrammes (6 lb.). The range of elevation is through − 5 deg. to + 10 deg., and the turret can be made to turn through the whole circle.

The body of the turret consists of a cylinder, 1.400 metres (4ft. 7in.) inside diameter, formed of steel plates, covered by a cast-steel spherical head. It is carried on two brackets, built up of plates and angles, the top flange of which serves as a roller-path for the gun-mounting. The brackets are joined at their lower part by a cast-steel stay-piece, in which the pivot is made to fit. The pivot turns in a gun-metal step-bearing fixed in a cast-steel pivot-rest; this rises or descends vertically under the action of the disappearing mechanism. A cast-steel support, placed at the bottom of the turret pit, acts as a guide for the pivot-rest and prevents it from turning round. The cylindrical body is fitted outside with a brass ring, made to slide inside a cast-steel guiding shaft, strongly embedded in the masonry work. The turret, when rising, disappearing, or rotating, is guided at the top by the fixed shaft, and at the lower part by the pivot and pivot-rest. The lower stay-piece of the brackets forms a platform; the gunner in charge of the gun sits on a seat, the height of which can be regulated. The non-recoil mounting transmits the effort it undergoes when the gun is fired, to the whole of the turret, which in its turn transmits it to the guiding shaft. The gun does not get displaced through the firing; it can therefore be made to work quicker and with greater accuracy than would be the case were the shock caused by firing to be taken up by elastic buffers, which do not always resume their former position, and are liable to break.

The protective armour is of cast-steel, in one piece; it is in the shape of a cap made to cover the system. The vertical wall is 100 millimetres (3.937 in.) thick; 1.625 metres (5ft. 4in.) outside diameter. The spherical top is 120 millimetres (4.724 in.) thick, and is made with a slight overhang that fits, when the turret is run down, in a bevel cut in the fore-shield.

In the turret armour are cut the following openings:

(*a*) In front, the gun embrasure, as small as possible, and an opening for sighting the gun.

(*b*) In the centre, at top, an opening of about 80 millimetres (3.149 in.) for taking observations; this is usually closed by a brass screw from the inside.

(*c*) In the rear and in the sides, three small openings 40 millimetres (1.574 in.) in diameter, to survey the ground during firing.

A rod is jointed under the pivot-rest, through which the whole of the movable part bears on a lever, the other end carrying a cast-iron counterweight. The point of suspension of the lever is above the line that joins the centre of the counterweight and the point to which the lever is jointed; the counterweight is so designed that the whole system is balanced when the lever is in a medium position. In this way the turret, when in battery, has a preponderance which tends to cause it to disappear; on the other hand, when the turret is completely down, the counterweight has a preponderance which tends to run it up. A very slight action, therefore, is necessary to start the rising or disappearing of the turret; and in order to cause it to disappear completely, it is only necessary to drive it a little while the power of gravity acts, so that the speed obtained during the first half of travel compensates the preponderance developed during the second half. This is facilitated by a small winch, which transforms the uniform speed of the crank, in accelerated speed during the first half of the travel, and in slackened speed during the second half. Two seconds only are required to completely lower or raise the turret, one man working the crank. The height of travel is over 310 millimetres (12.204 in.). When the turret is run down, it rests on the guiding shaft, with the interposition of wood wedges; a play is maintained between the shoulder of the turret cover and the level of the fore-shield.

The gun takes up two positions in the turret: when the latter is run down, it is completely inside; when it is run up, the chase is outside the turret, leaving a space at the breech-end for the gunner. This is obtained in the following manner: The gun is carried by its trunnions on a movable mounting, made to run on the top flanges of two brackets. Two strong bolts hold the mounting when in battery, and prevent all recoil; these bolts are worked by the gunner, by means of a lever. The fixing of the bolts sets free a latch, and allows the working of the breech-block; the latch resumes its position when the bolts are driven back, thus fixing afresh the breech-block mechanism. The turret cannot be made to disappear so long as the gun is not run in, for when the gun is in battery a latch in the rear of the turret is made to run out on the top of the guiding shaft, thus preventing the lowering. This latch is only run in by the mounting when the latter is brought completely back. The elevating mechanism for the gun is arranged in such a way that the gun takes up automatically a horizontal position in running in, whatever be the range of elevation at which it has been fired.

The required elevation is given by the angular displacement of a movable slide, worked by a hand-wheel which the gunner holds in his left hand; the hand-wheel drives a screw jointed on the end of the movable slide, through two bevel pinions. When the gun is run in the turret, and whatever be the angle of elevation, the screw runs down the movable slide, and causes the gun to resume its horizontal position. A screw fixes the elevating mechanism when firing takes place. The gun is trained

DISAPPEARING TURRET, ARMED WITH ONE 57-MILLIMETRE QUICK-FIRING GUN.

Fig. 1007.

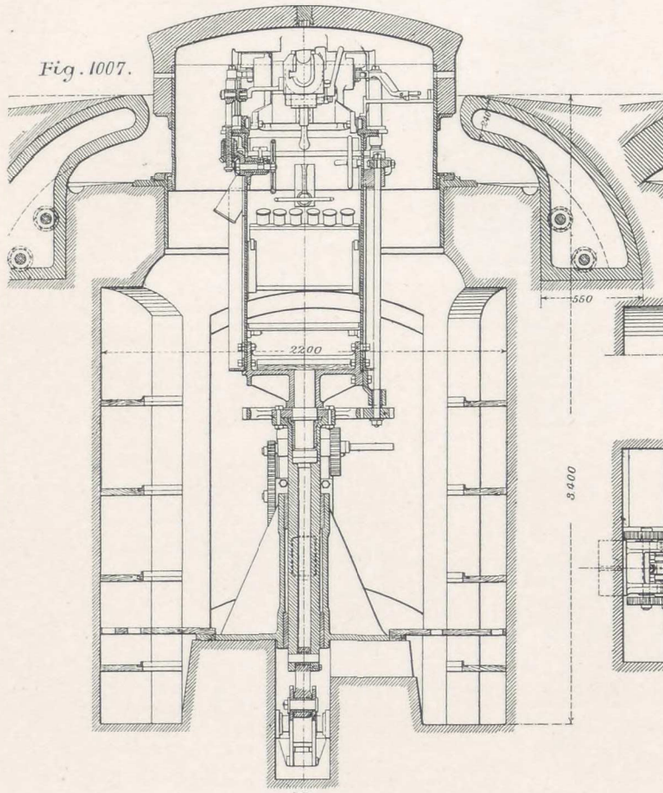


Fig. 1008.

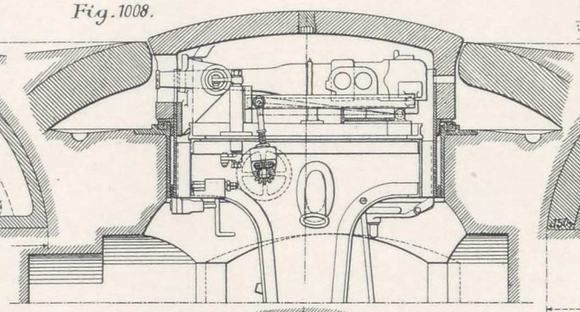


Fig. 1009.

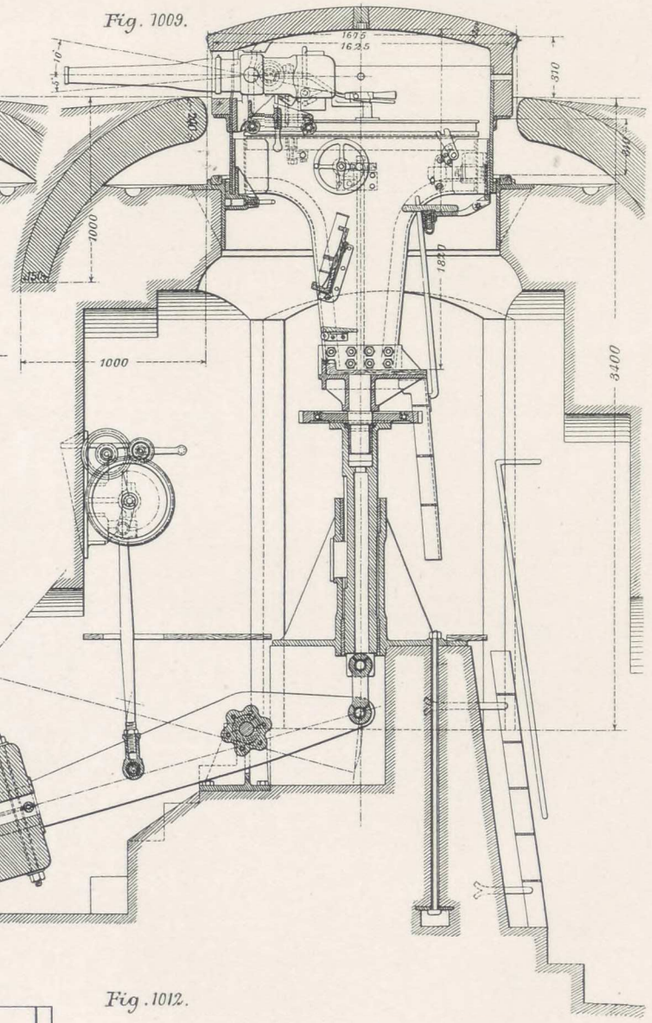


Fig. 1011.

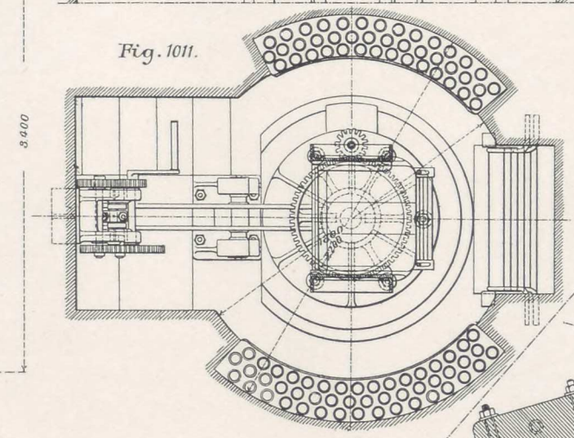


Fig. 1010.

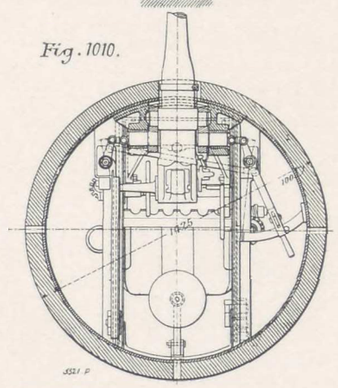


Fig. 1012.

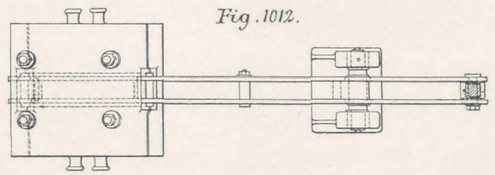
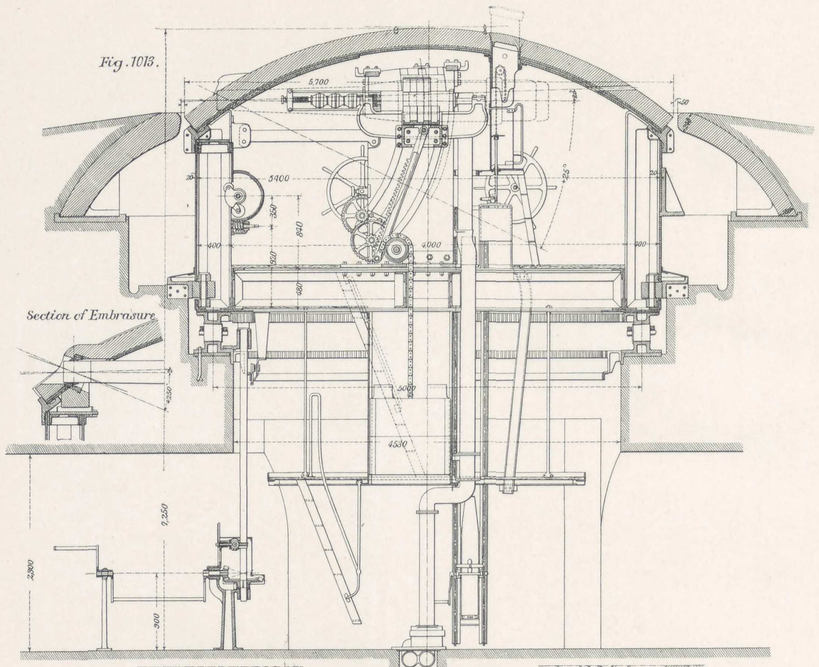
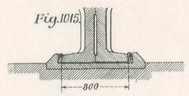
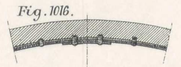


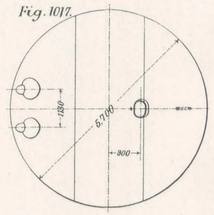
PLATE CLXV.

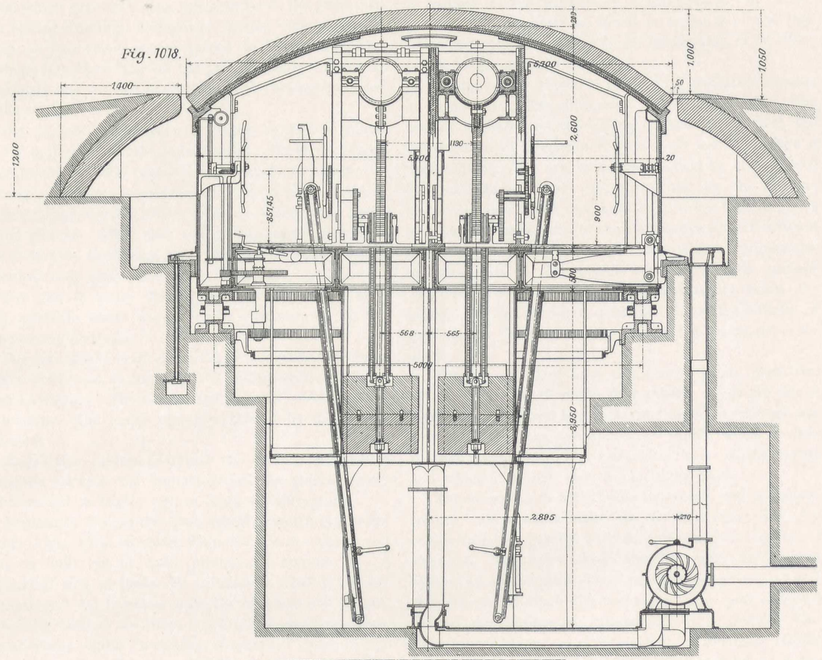
ARMOURED REVOLVING CUPOLA, WITH TWO 150-MILLIMETRE GUNS.

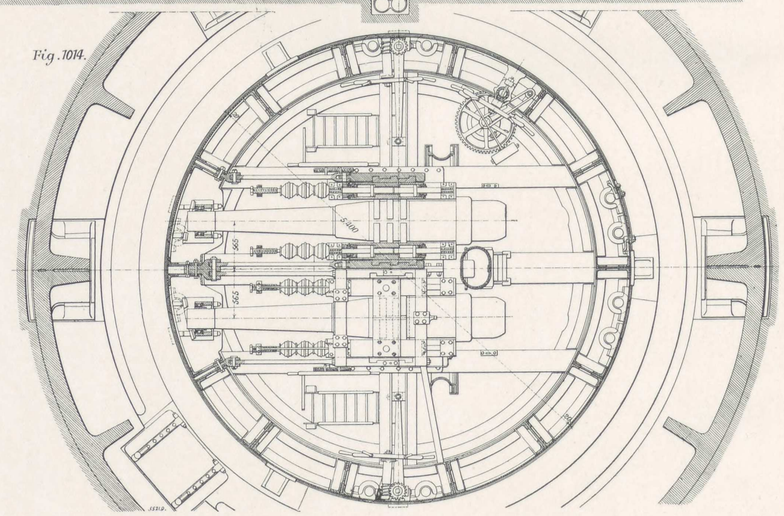


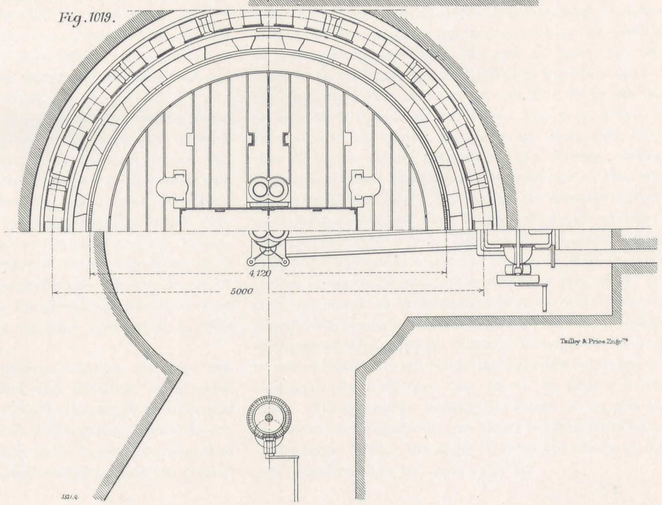












Weight of gun	6743 lb.
Weight of charge of "P.B." powder	22 lb.
Weight of projectile	85.8 lb.
Initial velocity of projectile	1575 ft.
Firing angles	+25 deg. / − 2 deg.
Number of men at turning gear	2
Maximum recoil	5.90 in.
Number of men at aiming gear	6
Capacity of turning gear	360 deg.
Duration of one complete revolution	1 min.
Corresponding speed per second at muzzle of gun ...	10.15 in.

Tailby & Price Engrs

through a hand-wheel held in the right hand of the gunner. This works through a set of screws and pinions, a square pinion which gears in a large wheel fitted to the pivot rest. The lateral training mechanism works very smoothly, owing to two small rollers placed in front, in spring bearings, and which bear on the guiding shaft. A strong brake fixes the turret fast for firing; the brake is worked by the gunner.

The required ammunition is placed on shelves round the circumference of the lower room. These can carry a minimum of 500 rounds. An assistant places the cartridges, as they are needed, on a small plate between the mounting cheeks, where they are within easy reach of the gunner. After each round, the empty cartridge-case is thrown through a brass shoot, whence it falls into a chest or sack easily removed.

The gun is easily dismounted, with the help of a small portable winch fixed for the circumstance on the manœuvring platform.

The fore-shield is of cast iron, in two parts, 240 millimetres (9.449 in.) at top and 150 millimetres (5.905 in.) thick at bottom. The section can be inscribed in a square of 1 metre. The joints are strengthened by inside ribs and bolts.

Rain-water cannot penetrate the turret; it falls in the space between the fore-shield and the guiding shaft, and flows out through a pipe or drain suitably placed.

Armoured Turret for Two 150-Millimetre (5.905-In.) Guns (Figs. 1013 to 1019, Plate CLXVI.).—The turret body is built up of steel plates, and consists of: A cylindrical wall of plates 20 millimetres (.787 in.) thick, strengthened by fourteen uprights of plate and angles; a flooring carried on three longitudinal and two transversal beams, similar in section; a spherical cover, formed of two plates 20 millimetres (.787 in.) thick each.

The cover is joined to the cylindrical wall by means of a strong circular cast-steel piece, the section of which is that of an angle with a heel flange, and which serves as a frame for the protective armour.

The turret turns on a series of forty-two rollers placed between two racers, one bolted to the turret and movable with it, the other being fixed to the masonry work. One of the segments of the latter racer is cut and fitted with a movable wedge, to allow the replacing of the rollers. The turret is centred by vertical rollers, which bear against a ring strongly fixed to the masonry work. Clamps which hook on this ring prevent the raising of the turret when firing takes place; it serves also in fixing the turret, and facilitates obturation for preventing the gases from penetrating. The whole rotating mechanism is thus perfectly protected.

There are two mechanisms for lateral training: one, placed in a recess made level with the lower room, serves to cause the turret to face rapidly the target aimed at, and the other, within easy reach of the gunner, to lay the gun accurately. The mechanism in the lower room consists of a winch which drives, through conical gearing, the vertical shaft of a pinion that gears in the toothed ring fitted to the top racer. That worked by the gunner contains a set of toothed wheels worked by a hand-wheel, and which drive a vertical shaft, on which is keyed a pinion that actions a toothed ring fitted to the lower racer, or, in other words, to the masonry work.

The top of the turret is covered by protective armour in three parts, 200 millimetres (7.874 in.) thick. The armour is placed on the ceiling of the turret, with the interposition of a certain thickness of lead, to insure a close contact. The armour-plates are held by bolts, placed 300 millimetres (11.811 in.) apart, and by the circular cast-steel piece above mentioned. In order that besiegers may not see the position of the embrasures while the turret is manœuvring, the armour is made without projections, and the guns do not project over the outside surface. The outside edge of the armour-plates comes below the glacis, and is, therefore, protected from the effects of grazing fire. The turret only projects one metre above the glacis.

The fore-shield, of hard cast iron, is in six parts, two of which are less than the four others. They are joined together by cast-steel heel plates and keys. A wide passage is made under the fore-shield, to which access is had through a door cut in the cylindrical body of the turret, and which is closed when firing takes place.

The mounting is with hydraulic recoil and automatic return. Its characteristics are the following: The gun recoils in a line parallel with its axis under all angles of elevation. The recoil check and the device for insuring return, act in the plane which passes through the axis of the gun and through the trunnions. The gun oscillates around the embrasure, without any other guiding than that insured by curved guides, cut in the mounting cheeks. The whole of the movable system is balanced by a counter-weight, which transmits its action as near as possible to the centre of gravity. The gun is carried in two slides let in the trunnions, and joined to the lower part of the chase by a ring made in two parts, so as to prevent all oscillation round the trunnions. The slides travel in slide-paths of the cradle; their sides are made with heels that fit in the curved grooves of the carriage cheeks. Return is obtained by means of spiral springs in two sets, in a line with the slides. The springs are mounted on rods, and bear against stays fixed to the cradle; the system is held up in front by a collar fitted to the gun chase. Four cylinders are provided to absorb recoil; the rods that are jointed to the cradle stays are so arranged that when the front one leaves the cylinder, the rear one enters it; and by establishing a communication between the two cylinders on one same side, a constant volume is maintained. Grooves of varied section are cut inside the cylinders, to insure the flowing of the liquid from one side of the pistons to the other. The springs for insuring the return of the gun are capable of running out the gun under the maximum angle of elevation. Under the angle — 2 deg. the return of the gun is moderated by the recoil cylinders.

The required elevation is given and controlled by a system of gearing, with balancing counterweight.

The two mountings are completely independent one of the other.

A powerful brake for fixing the turret is placed in the firing room, in a line with the target aimed at. It consists of clamps which clasp the circular against which travel the vertical centring rollers; the clamps work under the action of an endless screw and a vertical screw driven by a handwheel.

Openings in the flooring, on each side of the mountings, give access by means of ladders to the inside of the turret. A lift is fitted to each ladder for raising the projectiles and charges; a small hand-winch serves for this purpose.

The turret is provided with a look-out, to effect the direct training of the gun.

Inside diameter of firing room ...	5.400 m.	17 ft. 8 in.
Outside diameter of armour ...	5.900 m.	19 ft. 4 in.
Maximum height of firing room under ceiling	2.700 m.	8 ft. 10 in.
Maximum projection of turret above glacis	1.000 m.	3 ft. 3 in.
Thickness of armour...	.200 m.	8 in.
Time required for one complete revolution of the turret	1 min. 30 sec.	1 min. 30 sec.
Weight of each gun	3.065 kg.	6755 lb.
,, armour-piercing projectile	39 kg.	86 lb.
,, charge	9 kg.	20 lb.
Muzzle velocity	470 m.	1542 ft.
Angles of elevation	− 2 to + 25 deg.	− 2 to + 25 deg.
Time taken from one extreme degree of elevation to the other	25 sec.	25 sec.

Messrs. Schneider and Co. have built similar turrets for two 150-millimetre (5.905-in.) guns for Roumania, and other countries.

Disappearing Cupola for One 5.7-Centimetre (2.244-In.) Quick-Firing Gun, 25 Calibres in Length (Figs. 1020 to 1024, Plate CLXVII.).—This consists of the fore-shield, the turret proper, and the disappearing mechanism.

The fore-shield is of hard cast-iron, in three parts, of 28 centimetres (11.023 in.) thickness at the top, and 20 centimetres (7.874 in.) below; these are strengthened at the joint by pillar-shaped ribs, which rest on a cast-steel support. The three parts are joined together by keys, and the joints are filled with molten lead.

The turret armour is of nickel steel, in the shape of a vertical ring 8 centimetres (3.149 in.) thick, which carries a spherical cap or cover 10 centimetres (3.937 in.) thick. The armour is held in place by a plate backing. The following openings are cut in the protective armour:

(*a*) In front, the embrasure for the gun, and a slot for sighting.

(*b*) In the centre, at top, is a hole of 6 to 8 centimetres (2.362 in. to 3.149 in.), usually closed from the inside by a screwed plug; this serves for ventilation, and also as a look-out, with the help of a reflector.

(*c*) In the rear and through the sides, are three small openings 40 millimetres (1.574 in.) in diameter, for surveying the ground during firing. A buckled plate, lined with india-rubber, fitted to the circumference of the armour, prevents rain water from entering the cupola through the joint between the turret armour and the fore-shield.

The turret body consists of a shaft built up of plates, that fits exactly the inside of the armour, and of two cheeks of plates and angles, the top part of which serves as a roller path for the mounting. The lower part ends in a cast-steel base, in which the pivot is fitted; the latter turns in a gun-metal step-bearing. The turret-body is fitted outside with a brass ring, that slides inside a cast-steel centring shaft, strongly embedded in the masonry, the turret thus being guided at the top by the fixed shaft and at the bottom by the pivot. One gunner loads the gun and lays it completely.

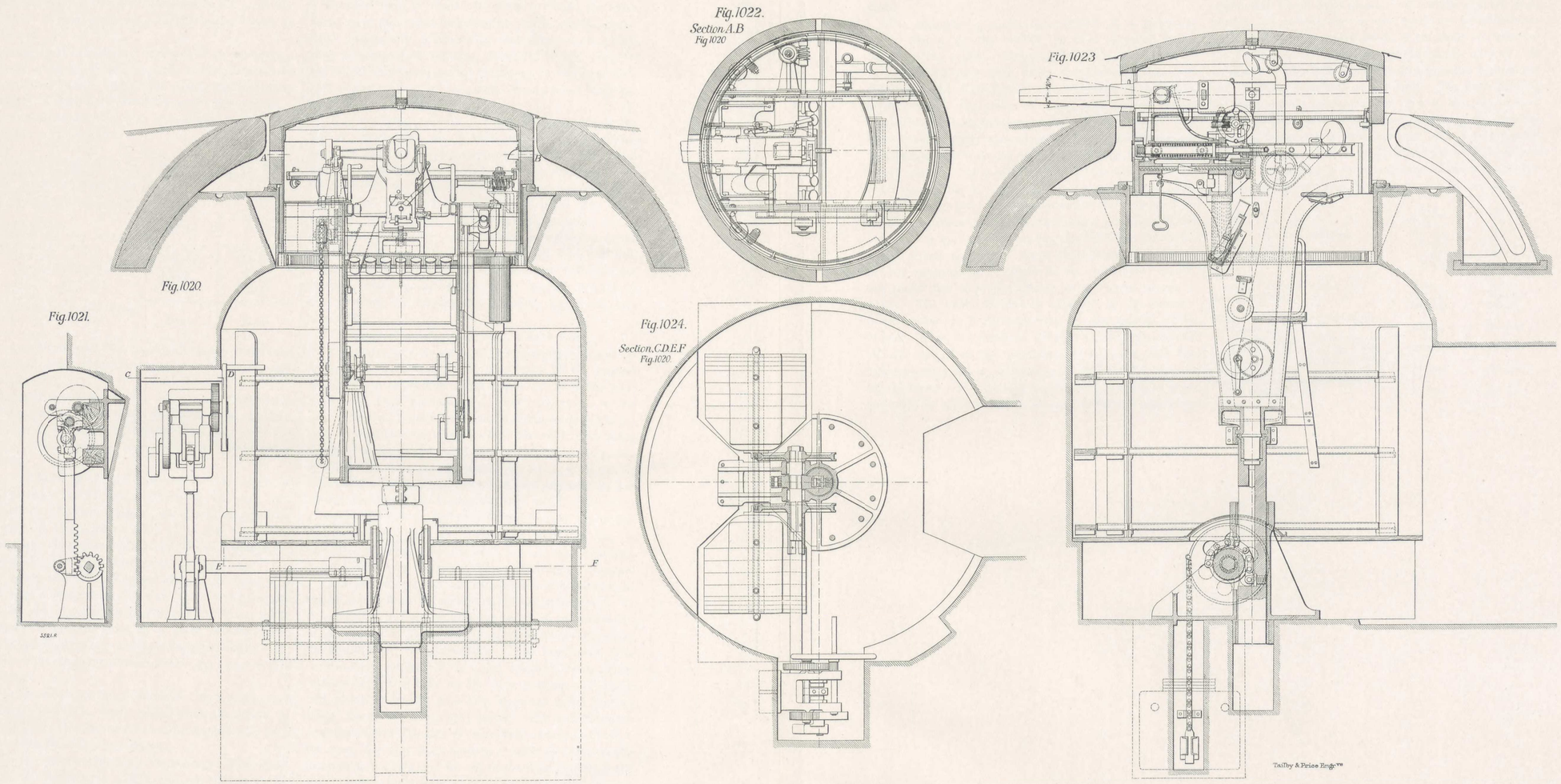
The mounting consists of a cast-steel support, in the top of which rest the gun-trunnions; the lower part is in the shape of a sole-plate, and bears on a gun-metal slide-path; the sides of the sole-plate are so shaped that they prevent the lateral shifting of the mounting. A forged steel hydraulic recoil cylinder limits the recoil to about 10 centimetres (3.937 in.); it contains also a spring to run out the gun. Besides the sole-plate above mentioned, the mounting is fitted on each side with two rollers that travel on paths on beams, and facilitate the complete running in of the gun. Special gearing is also provided for moving the mounting backwards and forwards.

The range of elevation is from − 6 to + 6 deg.

The turret can be made to turn completely round by means of a handwheel in the right hand of the gunner, which drives an endless screw wheel and a pinion that gears in a fixed toothed ring. The mechanism is not reversible, but it contains an elastic disengaging device, so that any unforeseen rotary action can only take place through an accidental effort that would exceed the power at which the elastic disengaging device has been regulated. This ensures the fixity of the turret, and prevents the too violent shocks on the mechanism that would result were a heavy projectile to strike the armour or the gun chase, and cause the turret to revolve. Lateral training is registered by a brass circular scale, in view of the gunner. A hand, driven by the turret, shows the azimuth position.

The turret contains all the necessary apparatus to ensure complete safety and prevent false manœuvres. It is impossible to open or close the breech if the gun is not in battery, and if the brake piston is not completely set in its jointing on the turret body. The mechanism that ensures this consists of a hinge which a bent spring compels always to take up the same position. A strong bolt placed under the mounting stops the latter, during firing, should the piston-rod break. The turret cannot disappear before the gun is completely run in the turret, for when the gun is in battery, a latch in front of the firing-room projects over the top of the fixed guiding shaft, and prevents it from being lowered. The latch is only brought in by the mounting when the latter is brought completely back.

DISAPPEARING CUPOLA FOR ONE 5.7-CENTIMETRE QUICK-FIRING GUN.



The fixed centring ring and the turret support are of cast steel; the former is embedded in the top part of the pit, the latter resting on a central foundation at the bottom of the pit.

All the required accessories for ventilation, for the ammunition service, for removal of the gun, &c., are carefully designed for the work they have respectively to fulfil.

The disappearing mechanism consists of a balancing device and a driving winch, the force of recoil being utilised. The central column on which the turret rests is furnished by a plate-chain, which turns on an eccentric, so that the height of the turret varies according to the radius around which the chain is rolled, the largest radius corresponding to the position of the turret in battery. The counterweight that balances the turret is carried by two platechains that surround eccentrics of same shape as the turret eccentric, but keyed inversely on the same shaft, the maximum radius corresponding to the greatest height of the counterweight. The counterweight is calculated to balance the turret exactly in its medium position. When the turret is up, and the gun run out for firing, the radius round which the turret turns is the maximum; that of the counterweight chains is the minimum radius; the turret has a preponderance which tends to run it down. The turret is exactly balanced by the counterweight when it is approximately in the middle of its travel. When the turret is completely down, the position of the chains on the eccentrics is reversed, and the counterweight has a preponderance which tends to run up the turret. To start each manœuvre, a certain amount of work is required, equal to the resistance caused by friction of the various parts, to bring the turret to its extreme positions. This is given by the driving or starting winch. This consists of a set of gearing working a rack; this acts in conjunction with a pinion keyed on the eccentric shaft. A crank-shaft forms part of the system, and its dimensions are such that for a complete movement of the turret the rack slightly oversteps the upper and lower dead-points, and strikes against wood blocks. As at both ends of the travel, the preponderance tends to cause the rotary action of the shaft to continue, the whole system stops at the right moment, and it is only necessary to act on the winch crank to pass the dead-points, and cause the system to act of itself. The parts forming the disappearing mechanism are few in number, and of strong make; one man can effect the complete running-down of the turret in three seconds. The turret reaches the ends of its travel with slackened speed and without shocks; the action is automatic, and requires no power. It is served by two men, one gunner and one assistant.

Weight of gun	180 kg.	397 lb.
,, projectile	2.720 kg.	6 lb.
,, recoiling mounting ...	210 kg	463 lb.
Maximum recoil	100 mm.	3.937 in.
Range of elevation	– 6 deg. to + 6 deg.	– 6 deg. to + 6 deg.
Time required from one complete range of elevation to the other ...	4 secs.	4 secs.
Lateral training	Through 360 deg.	Through 360 deg.
Time required for one complete revolution of the turret	60 secs.	60 secs.
Time required for withdrawing the gun and running down the turret	12 secs.	12 secs
Time required for resuming the firing position	10 secs.	10 secs.
Time required for dismounting and remounting the gun	25 min.	25 min.

L.—AMMUNITION.

POWDERS AND OTHER EXPLOSIVES.

All the powders supplied by Messrs. Schneider and Co. are manufactured in the French Government Powder Factories, under the direct supervision of the French Government Engineers. This is in accordance with the Law of 1883, which regulates the manufacture and the sale of explosives in France. These powders fulfil all the conditions stipulated by the French Admiralty for the powders used in the French Navy. Their qualities and characteristics are therefore accurately known. As a rule, all the Schneider-Canet guns are now fired with ammunition prepared with smokeless explosives. Several Foreign Governments, however, continue the use of various types of powder, either for the sake of economy or to maintain uniformity in their stocks of ammunition. The manufacturers of war material are consequently obliged still to provide for two distinct kinds of explosives, each including various grades, to suit both the calibre and the class of ordnance.



Fig. 1025.

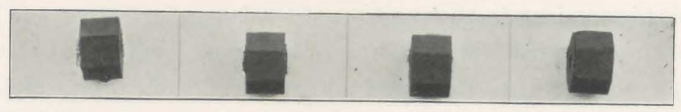


Fig. 1027.

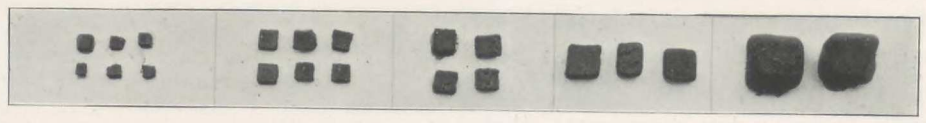


Fig. 1026.

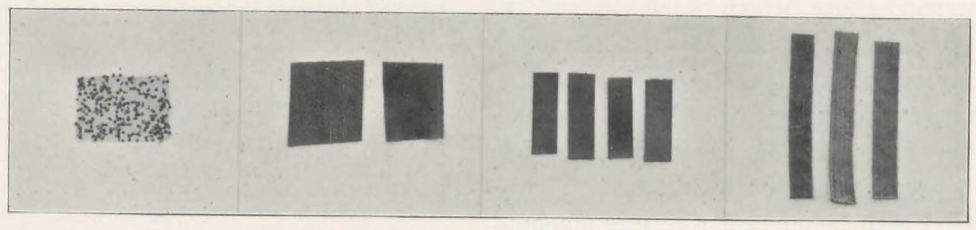


Fig. 1028.

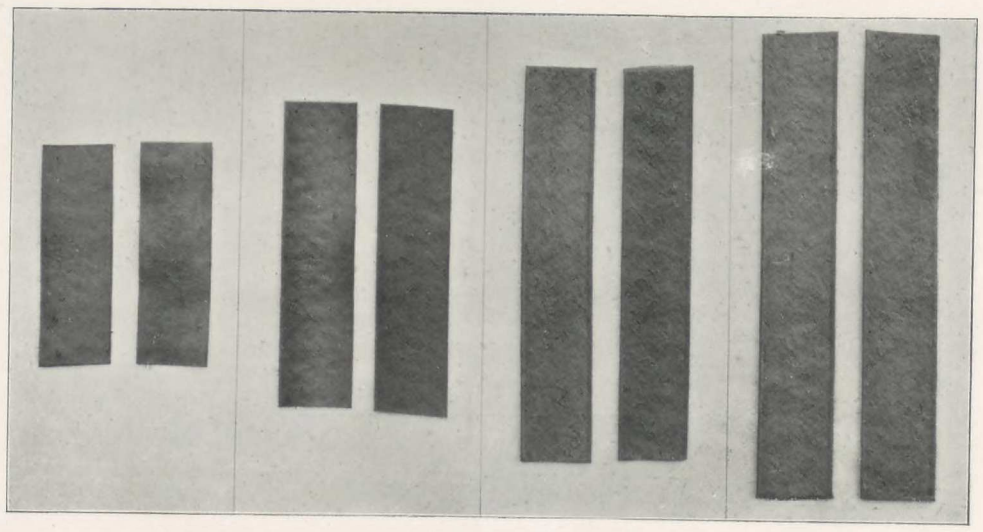


Fig. 1029.
Examples of Powders and Smokeless Explosives.

Black or Brown Powders.—Leaving aside a certain number of qualities of powder, the manufacture of which is gradually ceasing, we may mention that the black and brown powders now used with the Schneider-Canet field, siege, and naval guns, are divided into three classes, to

facilitate their general identification, as follows (Figs. 1025 to 1027):

C 1, C 2	For field and mountain guns, and, as a rule, for all small calibre guns.
S P 1, S P 2, S P 3	For siege and garrison guns,
P B 1, P B 2, P B 3	For coast defence and naval guns.

This is not, however, an absolute classification, and in service the uses to which the various powders are put are not always those stated above. These powders are all of ternary composition; their constituent parts—sulphur, saltpetre, and charcoal—varying in proportion, according to the quality required. The two first types are made in the shape of flat grains, the thickness of which differs according to the calibre of the gun. The third is finished to a hexagonal shape. When these powders are delivered loose, *i.e.* not prepared in charges ready for firing, they are packed in wooden cases lined with zinc, or in metallic chests with air-tight covers.

Smokeless Powders.—These form the usual ammunition for the Schneider-Canet guns; they are of the quality known as "French smokeless powders" and contain the whole series of varieties for guns of all calibres, for naval and land service. They are made in rectangular strips, of a straw-colour, the section and length varying according to the class of gun. These powders are prepared from nitrocellulose; one of their characteristics is that they contain no trace of free nitro-glycerine, or of nitro-glycerine in the state of simple mixture. This distinguishes them from many other smokeless explosives. As a direct consequence, the use of these powders does not entail any undue wear in the guns. Nitro-glycerine under high temperatures and pressures has a great erosive effect on metals; and in certain smokeless powders it is contained as a mixture and not in combination, being held mechanically with the help of an absorbing ingredient.

The French smokeless powders are chemical compositions, and therefore their use does not give rise to any of the serious disadvantages among which we may mention: the more or less rapid erosions in the bore, and their consequences as regards the resisting power of the gun, and the precision of firing; exudation of free nitro-glycerine on the surface of the explosive, when the latter has remained for a time in store, and constituting a permanent danger of premature explosion which a simple shock might precipitate. Besides this, these explosives maintain a longer stability as regards quality; this quality has been proved by numerous tests and analyses carried out periodically on quantities in stock. On the other hand, however, it has been remarked that the pressures being equal, they impart to the projectile a lower speed than do the explosives prepared from nitro-glycerine. But this difference in speed is slight, and out of proportion to the advantages

Fig. 1030. Section a.b.c.d.e.f

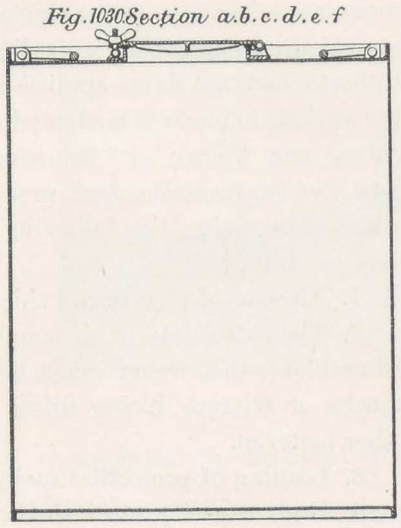


Fig. 1031.

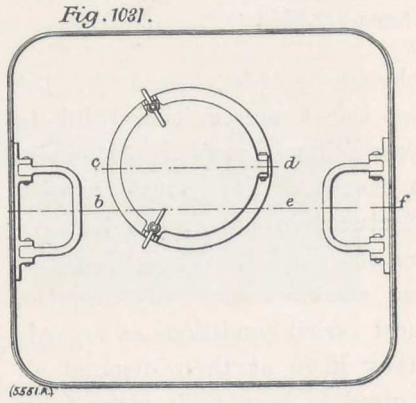


Fig. 1032.

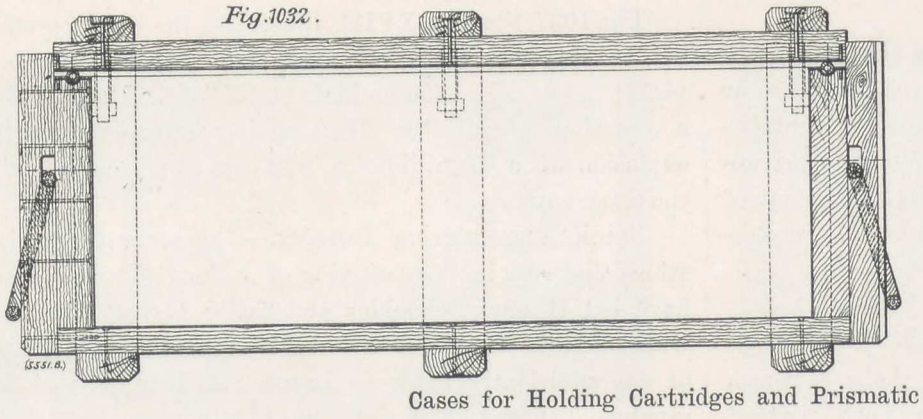
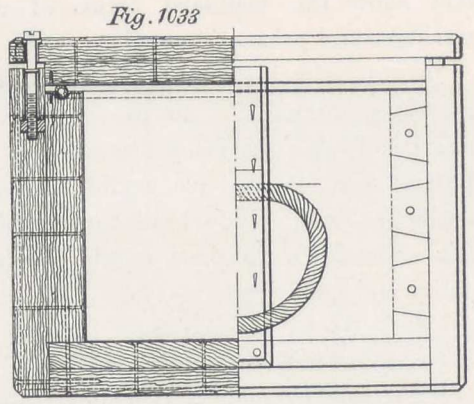


Fig. 1033



Cases for Holding Cartridges and Prismatic Powder.

derived from the use of the French smokeless powders: preservation of the guns, and their consequent longer duration in service. Moreover, the difference in speed can be made good, by lengthening the gun by a few calibres, or by increasing the charge, or better still, by combining both means.

These explosives comprise a whole series of distinct grades, for firing in all guns of all calibres. The following Table gives their classification (Figs. 1028 and 1029):

Machine guns	S	1	grade
47 mm. (1.850 in.) guns	S	4	,,
65 mm. (2.559 in.) ,, ...	S	6	,,
10 cm. (3.937 in.) ,, ...	S	10	,,
138.6 mm. (5.456 in.) and 164.7 mm. (6.486 in.) guns ...	S	14	,,
164.7 mm. (6.486 in.) ,, 194 mm. (7.637 in.) ,, ...	S	16	,,
240 mm. (9.449 in.) ,, 274.4 mm. (10.802 in.) ,, ...	S	24	,,
305 mm. (12 in.) ,, 340 mm. (13.386 in.) ,, ...	S	30	,,

The black and smokeless powders used in the manufacture of Schneider-Canet ammunition fulfil to a high degree all the conditions required of service powders. They have the benefit of the guarantees with which all products manufactured in the French Government powder factories are surrounded. These factories have to keep the land and marine forces fully supplied, taking into account the most varied conditions as regards climate; to obtain this, they have at their disposal all the funds and credits required to keep their plant fully in a thorough condition of advancement. Figs. 1030 to 1033 show the standard forms of cases for holding cartridges and prismatic powder.

Messrs. Schneider and Co. are therefore able to supply first class ammunition to the countries who order war material of all description from them. Such advantages as those mentioned above would not be found in private powder factories, which have to depend on the extent of their orders to maintain a regular output both as regards quality and quantity.

EXPLOSIVE CHARGES.

1.—Black Powder.—Armour-piercing shells, cast-iron Common shells, and the Shrapnel, which form part of the Schneider-Canet ammunition, contain explosive charges of black powder of special manufacture. This is made in fine irregular grains; it is very quick burning, and developes in consequence, and rapidly, a large volume of gas. It is supplied either in the shells, or in air-tight cases, in the shape of charges ready for insertion in projectiles.

2.—High Explosives.—For the destruction of certain classes of field works, and for the attack of weak parts in protected ships, the Schneider-Canet guns are generally provided with shells of large capacity, loaded with more powerful explosives than black powder. Various Governments have adopted explosives of this class, and have given them various names; but all of them owe their main characteristics to the same series of substances, in which combinations of picric acid are largely resorted to. Among these explosives may be mentioned lyddite and roburite. These explosives have, so it would appear, considerable destructive effects, but their manufacture and manipulation require experience. Consequently, though they may be considered, in their present state, as surrounded with all the required conditions of safety when used in countries where special plant and trained men are at hand, they cannot well be used by those countries which, for many reasons, have not cared to go to the considerable expense of putting down plant for their manufacture, manipulation, and storage.

Messrs. Schneider and Co. have endeavoured to produce an explosive which, while it is of the required quality as regards destructive power, does not demand any special measures of safety in manipulation and loading. Their investigations and trials were directed to compounds which hitherto had not been applied in military arts. Among the various explosives made and tested by them, they have chosen one, known as "Schneiderite." Without entering into the enumeration and proportion of the substances which it contains, the following claim for "Schneiderite" may be stated:

1. Absence of picrate and chlorate compounds.
2. Absolute safety in all manipulations; immunity from all accidents that would result with other explosives, from shocks or friction during firing, or through contact with other material.
3. Loading of projectiles easily effected.
4. High capacity steel shells, with thin walls, loaded with "Schneiderite," possess considerable explosive power.

Fig. 1037, Plate CLXVIII., illustrates the bursting effect of a "Schneiderite" free cartridge placed on a lead plate; and Fig. 1038, Plate CLXVIII., the side of a bursting pit at the Hoc testing ground, after the explosion of a 47-millimetre cast-iron shell loaded with the same explosive.

Smoke-engendering Powder.—The several considerations that rule in the designing of modern shrapnel shells, have led Messers. Schneider and Co. to perfect a powder which, though it be low in weight, may develope a cloud of gas sufficiently thick to insure visibility even at the greatest distances. In order to obtain this, they have carried out methodically a whole series of experiments, during which they noted carefully all the phenomena developed. Figs. 1034 to 1036, Plate CLXVIII., are reproductions of the most interesting photographs taken. The smoke-engendering powder was placed in steel shrapnel shells, the explosive charge being fired electrically. After these experiments, which were carried out with various kinds of substances, Messrs. Schneider and Co. adopted one compound they have styled "Creusite," the main characteristics of which are claimed as follows:

1. Simplicity in preparation, the compound remaining uniform in quality.
2. Low density.
3. Ease in loading.
4. Production of dense smoke on explosion of the projectile.

AMMUNITION.

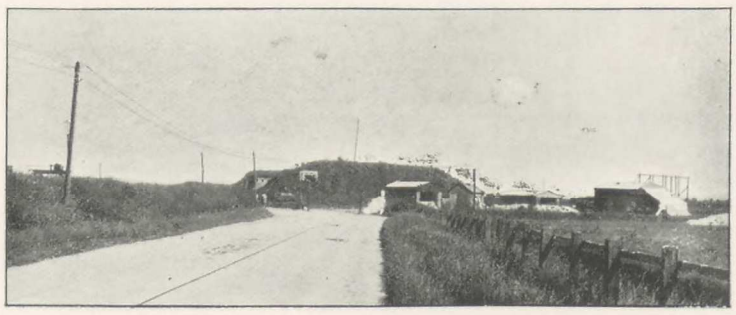


Fig. 1034.

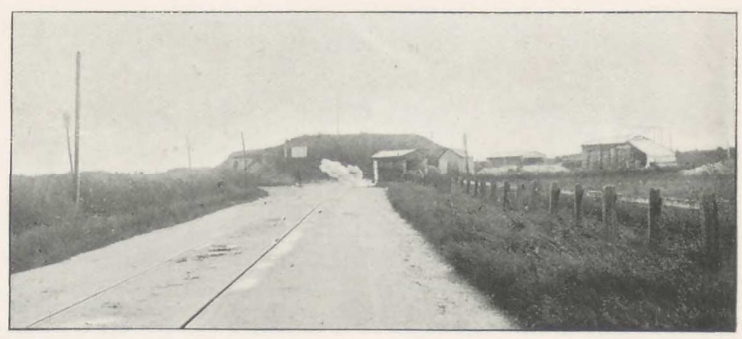


Fig. 1035.

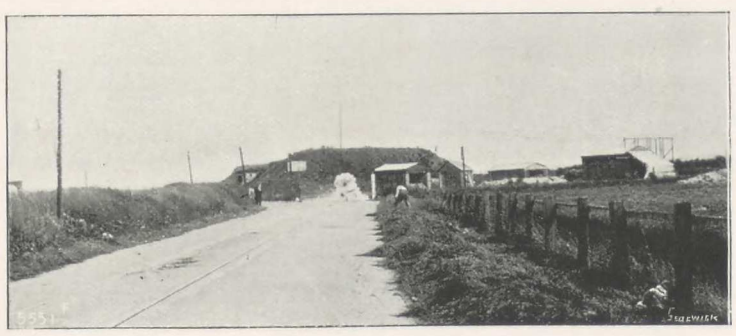


Fig. 1036.

Explosion of "Creusite" Shells at the Hoc Testing Ground.

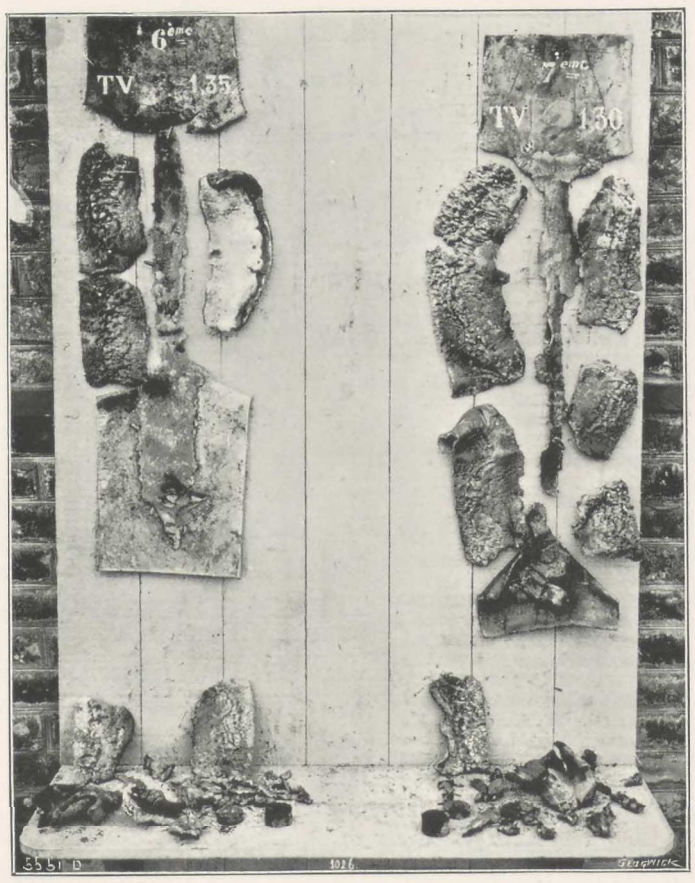


Fig. 1037.



Fig. 1038.

Destructive Effect of "Schneiderite."

These qualities combined make this a very serviceable powder, especially for shrapnel shells in which the space available for the charge is very small.

PRIMERS.

Firing Tubes.—In considering the place allotted to the primers, the guns may be divided into classes and subdivisions, as follows:

Firing-tube in breech-block	Firing by friction	Old type guns.
,, ,,	,, percussion	Non-quick-firing guns.
,, ,,	,, electricity	Accelerated-firing guns, without metallic cartridge cases.
Firing-tube in cartridge case	Percussion firing	Quick-firing guns.
,, ,,	Firing by electricity	,, ,,

Whatever be the method of firing adopted and the calibre of gun, the primer in the Schneider-Canet ordnance can always at any time be replaced by another identical one, or simply by a plug, without it being necessary to modify any of the conditions of the charge. This constitutes an important measure of safety and a great advantage.

Friction Tubes.—These are still used by many Governments; they are supplied with the Schneider-Canet ammunition, only when they are ordered specially. Their mode of acting is so well known that it is not necessary to describe it. They consist of a large tube filled with powder, of a smaller one containing fulminating-powder, and of a friction-bar ending in an eye in which is hooked the firing-line. By drawing the firing-line, the friction-bar explodes the fulminate and this lights the powder charge. Several types of friction-tubes are used. Fig. 1039 shows a smooth-shafted tube 5 millimetre (.196 in.) in diameter and 45 millimetre (1.771 in.) long, with felt ring to keep it in place. This is used with small calibre guns. The second type, Fig. 1040, is made with threads; it is screwed in the breech-block, and is used especially for large calibre guns.

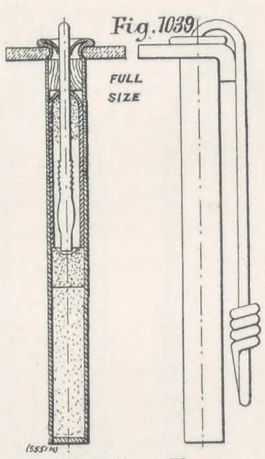
These tubes are generally packed in strong paper, in sets of ten, to make up parcels of a hundred tubes. They are kept in air-tight cases. When the tubes are liable to be kept long in the magazines, the cases are fitted with a moveable cover, for inspection at stated intervals.

Percussion Tubes.—The Schneider-Canet percussion tubes are of one type, manufactured in two sizes, namely:

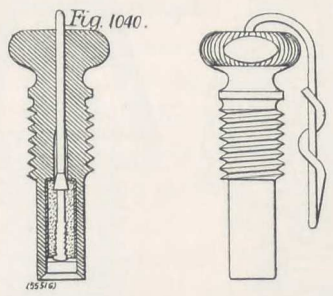
No. 1	9 mm.	.354 in.	Smooth.
No. 2	9 mm.	.354 in.	Threaded.
No. 3	13 mm.	.511 in.	Smooth.
No. 4	13 mm.	.511 in.	Threaded.

They are shown on Fig. 1041, and consist of the tube body, the threaded nipple inside, the percussion cap, and the charge of fine black powder. Varnish and isolating substances are placed between the black powder and the body of the tube, and between the nipple and the fulminating compound. The deflagration of the fulminate causes the powder charge to burn, the fulminate being fired by the shock of the striker against the bottom of the tube. The smooth tube is used with guns that do not take cartridge-cases, also for the discharge of automobile torpedoes. It is placed in a suitable vent cut in the breech-block, in which it is held by a latch fitted with the striker.

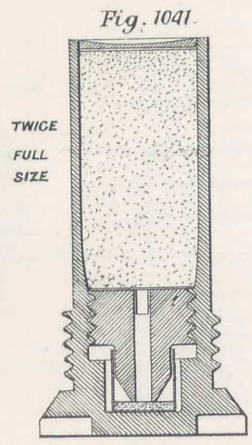
The percussion tubes are greased on the outside, and are tied together in sets of ten; packets of hundred tubes are then formed, and put in small metallic cases, closed and soldered, or in large chests, with moveable cover to allow periodical inspection,



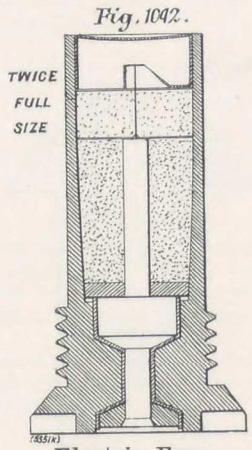
Friction Fuse.



Friction Fuse.



Detonating Fuse.



Electric Fuse.

Electric Tubes.—The recent patterns of Schneider-Canet quick-firing guns are fired with electric tubes, unless otherwise specified in the order. The breech-blocks, however, are always designed with a view to percussion-firing also, either in order to be able to use existing ammunition, or as a measure of safety, shouid the electric connections get out of order.

The electric tube is therefore the normal primer of the Schneider-Canet ammunition; and this does away with fulminating compounds which constitute a permanent danger of premature explosions, that might be caused by shocks during the many manipulations of the cartridge-cases.

The Schneider-Canet electric tubes have exactly the same outside dimensions as the percussion tubes, this facilitating the change in the method of firing. They consist of a brass body, threaded for screwing in the cartridge-case. In the centre, inside, is placed a cylindrical rod, swelled out on part of its length, to prevent the gases

of the charge from returning to the rear, when firing takes place. Varnish and isolating substances are placed between the rod and the tube; the rod is held in the rear by a plug inserted in the bottom of the tube. The platinum wire, the incandescence of which insures firing, goes through a special composition placed in front of the tube, directly above the relay of powder. The wire is fixed in the top end of the rod. The working of these tubes is easily seen by reference to Fig. 1042.

FUSES AND DETONATORS.

The Schneider-Canet fuses may be classified under three headings, namely, percussion fuses, double-acting fuses, and detonators. Each kind contains a whole series of distinct types, which correspond to the calibres of the guns and the class of projectiles fired. A specimen of each will be chosen for description.

Percussion Fuses.—The Schneider-Canet patent percussion fuses are characterised by a double safety device, which renders impossible the working of the interior parts until the projectile has left the gun. The principal parts of this fuse are shown in Fig. 1043. The fuse contains:

a. The body ending in a head, the outside shape of which depends partly upon the shape of the head of the projectile. It is made with two threaded parts, one for fixing the fuse in the projectile; the other, the inside threaded part, for holding the percussion plug:

b. A slot through which the fire of the igniting charge is transmitted to the bursting charge of the projectile.

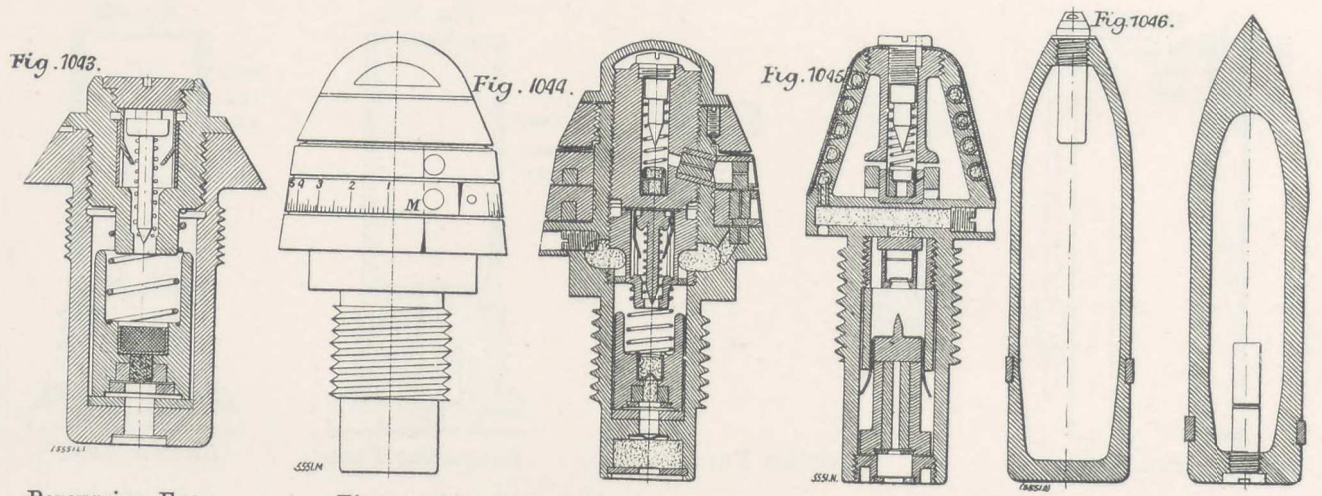
c. The percussion-piece holder, closed by a screwed plug, and comprising a threaded piece which ends in an extension of small diameter; it contains the striker which is constantly maintained at the lower part of its recess by a spiral spring. A catch-spring is placed in the same recess.

d. The cylindrical nipple contained in the fuse is constantly held down by a spring; it carries the fulminate priming and a little quantity of powder.

So long as the projectile has not undergone the shock caused by the firing of the gun, the striker and nipple are held in place by their springs, and remain in the position shown in the illustration. When the projectile is fired, the striker tends, through inertia, to remain back and presses down its spring, while the flange presses out the branches of the catch-spring; these prevent the striker from resuming its former position. The fuse is thus ready for acting. When the projectile strikes, the nipple is driven forward by inertia; it presses down its spring, and the priming by coming in contact with the striker, gets inflamed and fires the powder inside the projectile.

Double-Acting Fuses.—The Schneider-Canet double-acting fuses are of two principal patterns:

a. Ring fuses, containing: the body, the two burning rings, the head and timing ring, the concussion device, and the percussion device. The body of the fuse is of brass, threaded at the lower parts, for screwing in the head of the projectile. The concussion device is contained in a threaded plug, which screws in the eye of the fuse. Each burning ring is made at its lower part with a circular recess, which is filled with a special powder; the top ring is held fast by a rib, the lower ring alone being moveable. The concussion device serves to fire the special powder when the projectile is fired from the gun. It consists of a striker and a primer, which are held apart by a spring. The percussion device consists of a nipple-seat with primer, placed in the lower part of the fuse, and of a nipple screwed above it, and in which is held the percussion striker. Charged vents are cut round the percussion piece, which establish a communication between the fusing device and the interior of the projectile (Fig. 1044).



Percussion Fuse. Time and Percussion Fuses. Spiral Fuse. Detonators for Shells Charged with "Schneiderite."

Two conditions are to be considered in the working of these fuses:

1. *Time Firing.*—When the projectile is fired from the gun, the concussion piece is driven by inertia on its primer; the powder is fired first in the top ring, and follows in the lower ring, the charge in the projectile getting fired through the slots cut in the fuse.

2. *Percussion Firing.*—For percussion firing, the moveable ring is turned so that it masks the vent which

establishes a communication with the lower part of the fuse. When the projectile is fired from the gun, the striker has a tendency to hold back, and its flange presses out the branches of the catch-spring, which prevent the percutor from resuming its former position. The fuse is thus ready to act, and when the projectile strikes, the cup that contains the primer presses down its spring, and arrives in contact with the percutor, and the fulminate fires the explosive charge.

b. Fuses with time spirals are illustrated in Fig. 1045. This consists of the body of the fuse, the barrel, the concussion device, and the time-firing arrangement. The fuse body is of brass; its lower part is threaded for fixing the fuse in the fuse-hole of the shell; it is fitted inside with the percussion device; a screwed plug at top closes the socket, in which acts the concussion piece. The barrel is in the shape of a truncated cone, in which is cut a helicoidal groove that contains the powder for the time acting of the fuse. The whole is protected by a cover of the same shape as the barrel; the cover is marked with a timing scale. The concussion device consists of a striker and a cylinder provided with the priming; a spring keeps both apart. The percussion arrangement contains a primer cup fitted in the top part of the rear of the fuse, and a striker. A safety ring holds the striker back. Vents are provided for establishing communication between the top part of the fuse chamber and the inside of the projectile.

For time firing, the barrel is drilled opposite the division which corresponds with the distance at which the projectile is required to burst. When the projectile is fired from the gun, the striker, owing to its inertia, is driven against the primer; it fires the fulminate, which, in its turn, fires a ring of compressed powder and the powder of the spiral, through the drilled opening above referred to. Combustion continues in the spiral, and reaches the charge inside the projectile.

For percussion firing, no preparation is necessary. When the projectile is fired from the gun, the safety ring presses down, by its inertia, the arms of the cock-spring, covers the nipple, freeing the striker. As soon as the projectile strikes, the nipple is driven forward, the striker strikes the primer, and fires the explosive charge of the projectile.

These three types of fuses undergo modifications as regards the shape of inside arrangements, according to the conditions to be fulfilled. For instance, the percussion device described with the pattern with movable ring, can form part of the serpentine fuse.

DETONATORS.

The Schneider-Canet detonators are used principally with projectiles charged with high explosives, and according to the section of the projectiles, are fired either in the head or in the base. Fig. 1046 shows the general arrangement for shells charged with "Schneiderite."

The manufacture of Schneider-Canet primers is carried out in special shops (Fig. 1047), and the patterns are so designed that they can easily be substituted, one for the other. The various parts of the tubes and fuses are made with precision tools; the tubes and fuses when charged, put together and tested, are stored ready for use, or for the execution of orders.

PROJECTILES.

Projectiles for Field, Mountain, Siege and Garrison Guns. — Messrs. Schneider and Co. have perfected the necessary plant to supply with their field, mountain, siege and garrison guns, projectiles of all calibres used in service. These are delivered by them completely finished and charged. The various types are the following (see Fig. 1048):

Cast-iron, common shell (*a*)	Cast-iron body, central charge, copper band, percussion fuse.
Cast-iron, ball shell (*b*) ...	Cast iron body, cast iron balls imbedded in the walls, central charge, copper band, percussion fuse.
Cast-iron, segment shell (*h*)	Same as above, but with segments instead of balls.
Grape-shot shell (*g*)... ...	Wrought-steel body, cast-iron rings and balls, hardened lead balls, charge in front, copper band, double-acting fuse.
Cast-iron shrapnel (*e*) ...	Cast-iron body and head, charge in the rear, lead balls held by means of sulphur or rosin, copper belt, percussion or double-acting fuse.
Steel shrapnel (*d*)	Same as above, but with steel body, double-acting fuse, and containing a smoke-engendering powder.
Flat-headed grape-shot shell (*f*)	Zinc body, wood base, hardened lead balls, held with sulphur.
High-explosive shell (*c*) ...	Steel body, central charge, copper band, percussion fuse or special detonator.

In the manufacture of these projectiles, cast-iron is being gradually superseded by steel, owing to the higher resisting properties of the latter metal; and to this other great advantage that, for a given total weight, it allows the carrying of a heavier explosive charge. As, however steel projectiles are more expensive, only a comparatively small number of governments put them in their ammunition stores for war purposes, the greater number being satisfied, for the present, with cast-iron.

The Schneider-Canet high-explosive shells are charged with "Schneiderite" and armed with a special detonator. Their inside section varies according to the calibre and the type of gun; one tracing is shown in Fig. 1046.

These various projectiles are sufficiently known, and require no further description.

Projectiles for Naval and Coast-defence Guns.— The above brief description of projectiles applies generally to those in use for naval and coast-defence guns, as regards:

Cast-iron common shells,
Steel shrapnel,
High-explosive shells.

For naval and coast service, may be added:

Steel common shell	Steel body, central charge, copper belt, percussion fuse.
Steel armour-piercing shell ...	Steel body, hard point, solid head, base plug, copper belt, percussion fuses for calibres below 65 mm. (2.559 in.). (Fig. 1049.)

The Schneider-Canet steel common shell will in time completely supersede the cast-iron common shell in war stores. The latter have been found wanting in resistance in many circumstances; their explosive charge is also comparatively a small one. Except for motives of economy, they may be considered obsolete.

Two distinct classes of projectiles are made; those of forged steel, and those of cast steel.

The latter are made according to the Hadfield processes, for the use of which in France Messrs. Schneider and Co. have purchased the exclusive license. Cast-steel has this advantage over forged steel, that it gives, by bursting, fragments of regular size and of sufficient weight to have a great destructive effect. Cast-steel shells are greatly in favour with the British Admiralty, which orders annually large quantities. Besides this, the production of cast-steel shells is slightly cheaper than that of forged steel shells.

Armour-Piercing Shell.—These are projectiles specially used with naval and coast-defence guns. The difficult task they have to accomplish is the attack and destruction of ironclads and the perforation of the belt of protected cruisers. Messrs. Schneider and Co. supply two types:

a. Holtzer chrome-steel shells.

b. Schneider steel armour-shells, forged and hardened.

Fig. 1047. Interior of Fuse Factory.

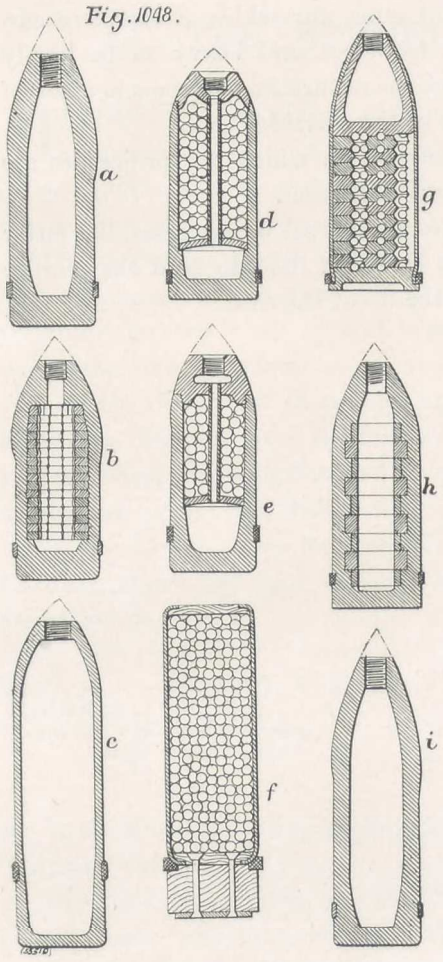
The Company has the monopoly for the supply to foreign governments of Holtzer chrome-steel projectiles, the reputation of which is now universal; they are so well known that it is not necessary to enlarge upon their merits. They are particularly suited for firing against ironclads of modern construction, and more especially against cemented armour-plates, As, however, their manufacture is surrounded with many intricate operations, their price is comparatively high, and several governments store projectiles made of Schneider steel instead.

The armour-piercing shells of more than 65 millimetre (2.559 in.) in calibre are not fitted with a percussion fuse,

the high temperature developed on impact being sufficient to fire the explosive charge. For calibres below 65 millimetre (2.559 in.), the projectiles are fitted with a percussion fuse at the base; these are fired mainly against small craft, carrying but little protective armour, or quite unprotected.

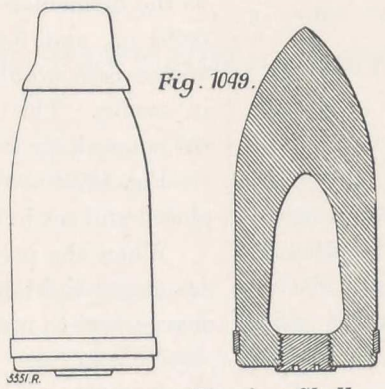
facture, and the surfaces treated chemically. A circular blank is used, the diameter and thickness of which depend upon the dimensions of the finished case. Fig. 1050 shows the process of manufacture followed for a 15-centimetre (5.905 in.) cartridge case.

Fig. 1048.



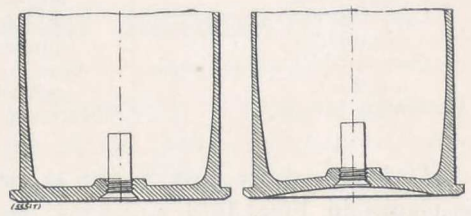
Standard Types of Shell.

Fig. 1049.



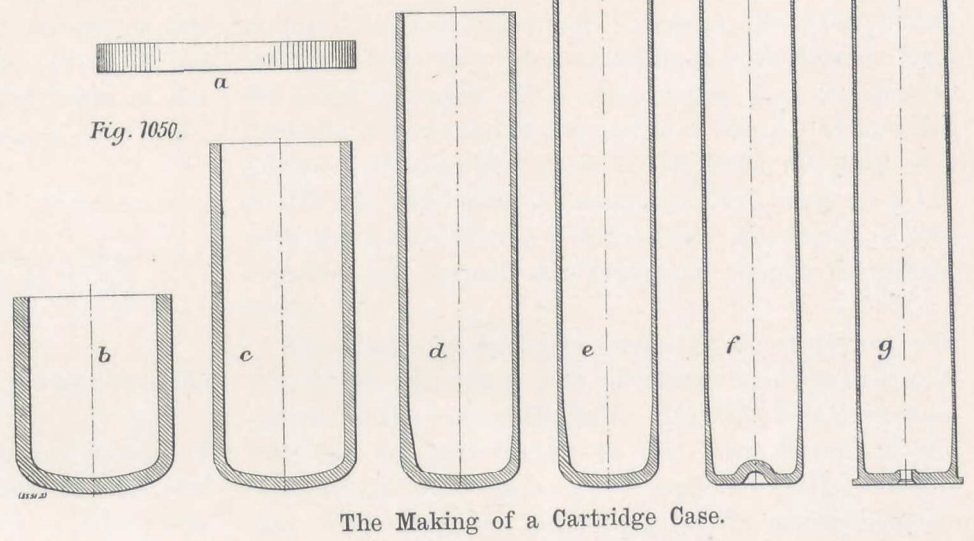
Steel Armour-Piercing Shell.

Fig. 1051 Fig. 1052.



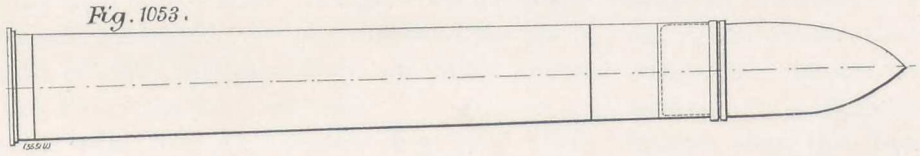
Flat and Concave Base of Cartridge Case.

Fig. 1050.



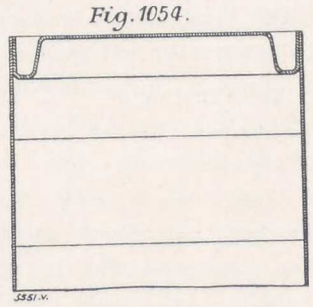
The Making of a Cartridge Case.

Fig. 1053.



Shell and Cartridge.

Fig. 1054.



Cover for Cartridge Case.

They penetrate easily the sides, and their *vis-viva* may not be sufficient to fire the explosive charge; they are therefore provided with a percussion fuse.

CARTRIDGE CASES.

The Schneider-Canet cartridge cases are characterised by the method followed in their manufacture, by the special quality of the metal used, and by their design.

They are obtained by successive chasing and drawing operations, the cases being annealed in course of manu-

The Schneider-Canet cartridge cases are divided, as regards shape and without distinction of calibre, into two main classes:

Flat-bottomed cases, for medium calibre guns.
Concave-bottomed cases, styled safety cases, for small calibre guns.

The first include the cases for guns with screwed breech-blocks; the second, those for guns with concentric threaded breech-blocks. Each class contains complete cases, distinguished from each other according to the way in

which the projectile is set, and contains also obturating bottoms. The following Table gives a general classification of the cartridge cases:

SCHNEIDER-CANET CARTRIDGE CASES.

Flat-bottomed Cases.	Concave-bottomed Cases.
Complete case—	Complete case—
Case for permanent setting of projectile.	Case for permanent setting of projectile.
Case for temporary setting of projectile.	Case for temporary setting of projectile.
Case in which the projectile is not set.	Case in which the projectile is not set.
Obturating bottom.	Obturating bottom.

The cases differ only in the shape given the bottom, as shown in Figs. 1051 and 1052; the concave-bottomed cases are styled safety cases, as the firing tube is within the surface plane formed by the outside edge of the base, and is not liable to be fired by shocks during the charging operations of the gun.

The obturating bottoms are very short cases; they only contain a small part of the charge, the remainder being a combustible cartridge. They are used either for the sake of economy, or for large calibre quick-firing guns, such as the Schneider-Canet 20, 22, and 24-centimetre (7.874 in., 8.661 in., and 9.449 in.) guns, for which a complete cartridge case would be too large and heavy to be handy in service. The base of the obturating bottoms is made of the same shape as that of the cartridge cases.

Fig. 1053 shows the way in which the projectiles are placed and set in the cartridge cases.

When the projectiles are not set in the cases, the latter are closed tight with a disc, Fig. 1054, to hold the powder charge, and to protect the lip of the case.

LI.—THE SCHNEIDER PAVILION AT THE PARIS EXHIBITION.

MESSRS. SCHNEIDER and CO.'S Pavilion is erected on the left bank of the Seine, below the Army and Navy building; it is situated practically in a line with the Avenue de la Bourdonnais.

The shape given to it is that of a huge dome, crowned with a campanile; it is 41 metres (134 ft.) in diameter, and the circumference is cut by a straight line at three places, where the main entrances are located. The portals which give on the Seine, and those opening to the Quay d'Orsay, being on a different level, the floor covered by the Pavilion, and on which the exhibits are placed, is formed of two levels, the upper one being 5.60 metres (18 ft. 4 in.) above the lower. The heights of various parts of the Pavilion, above the floor level on the side of the Seine, are as follow:

Height of the floor level on the Quai d'Orsay	5.60 m.	18 ft. 4 in.
Height of ridge-piece of trusses	32.64 m.	107 ft.
,, ridge of campanile	39.30 m.	129 ft.

the latter dimension being approximately the height of the Vendome Column.

The outside covering of the Pavilion is formed of plaster made perfectly smooth; that part of the roof around the base of the campanile is filled in with plate-glass; the outside covering and the inside lining—the latter made of wood battens—are held by wood rafters in the usual way; the rafters are fixed to iron purlins, carried by the main ogee trusses. Two galleries, one inside the Pavilion and one outside, are placed around the whole circumference of the building; they are 4.50 metres (14 ft. 9 in.) above the top platform.

As will be seen from the section (Fig. 1055, Plate CLXIX), the Moulineaux Railway, in covered way, with brick walls and iron roof plates, passes through the building. The walls forming the cutting existed previous to the designing of the Pavilion; they could not be relied upon as supports for the beams intended to carry the enormous weights of the exhibits, nor of the lower parts of several trusses of the building. It was therefore necessary to build other walls parallel with those of the railway cutting, and this increased the span of the beams to 17.20 metres (56 ft. 6 in.), a comparatively large span. The beams are stayed directly below the foot of the trusses, in order to prevent the thrust causing any flexure of the beams in a horizontal plane; besides this, the flooring has been designed to withstand the shifting which the resulting force of the drift of the trusses it supports, tends to produce. This shows what minute precautions were necessary in the erection of a pavilion which rested both on recently built and comparatively high foundations, and on an iron flooring covering a railway cutting, and liable to be affected by the vibrations caused by the passing of the trains.

As mentioned above, the double covering of the dome is held by wood rafters and iron purlins; the latter are placed about 3 metres (9 ft. 10 in.) apart, and follow the radius of the mean curve of the trusses; their inclination, therefore, becomes greater according as their distance from the ridge increases. This arrangement was necessary to facilitate the erection of the double covering. The purlins consist of ribs, made of plates and angles, in the shape of a double tee with unequal flanges, the web being in a line with the radius of the trusses; they withstand, in consequence, the normal and tangential weight component forces.

The trusses are twelve in number; the twenty-four half ribs divide the dome into as many equal sectors, 5.50 metres (18 ft.) wide at the base. Eighteen half trusses are ribs, the six half curved to the form shown in the illustrations, which serve as a support for the window bays, differ from the others only in the construction of their lower parts, which is made with an abutment.

The system of construction is one with three hinges, and in order to fulfil in practice the theoretical conditions aimed at, *i.e.*, that the trusses should be usefully hinged at top, it was necessary to make them converge over a sphere, instead of making them bear, according to the usual method, on a ridge ring. This is the first time, we believe, that this particular mode of construction has been adopted: for though the ribs, separately, are on the three-joint type, as a whole they meet exactly at top. This arrangement has the advantage that it aids the rapid distribution of the loads; should some trusses become more loaded than others, the result would be a displacement of the ridge joint, but this displacement would be counter-balanced by the action of the less loaded trusses.

The ribs consist of a web 8 millimetres ($\frac{5}{16}$-in.) thick; and of four angles 70 by 70 by 8 millimetres ($2\frac{3}{4}$ in. by $2\frac{3}{4}$ in. by $\frac{5}{16}$ in.), with flanges 270 millimetres ($10\frac{5}{8}$ in.) wide, the thickness of which varies. The web is 750 millimetres ($29\frac{1}{2}$ in.) high for the first sections, 1 metre ($39\frac{3}{8}$ in.) at the spandril, and 600 millimetres ($23\frac{5}{8}$ in.) at the top. In a running truss, consisting of two similar half-ribs,

the centres of the first-course joints are 41.91 metres (137 ft. 6 in.) distant horizontally. The vertical distance between the first-course joint and the top joint is 26.74 metres (87 ft. 9 in.). The calculations for designing these three jointed trusses call for no particular notice; they were based on the following figures:

(*a*) Permanent Loads.

	Kilogrammes.
Trusses, per running metre developed	160
Window purlins, per running metre	30
Running purlins	50

Wall-plate and lower gallery per running metre of circumference:

	Kilogrammes.
Wall-plate	80
Plate glass	50
Gallery joists	350
Total	480
Covering, ceiling, rafters, per metre super ...	140
Glass and window-bar iron at top, near the base of the campanile, per metre super	30
Campanile (frame and covering), total weight on each half truss	2230

(*b*) Extra Loads.

On the covering, from the lower galleries to the top, per metre super	50
On the flooring of the galleries and of the campanile, per metre super	450

(*c*) Force of Wind.

Horizontal strain, per metre super	120

The trusses have been calculated to include:

1. Permanent loads and general extra loads.
2. ,, ,, extra loads on half trusses only.
3. ,, ,, wind pressure on one side only.

The limit of resistance of the steel, without deducting the rivet holes, was taken at 10 kilogrammes per square millimetre (6.35 tons per square inch), under the action of permanent and of extra loads and at 13.5 kilogrammes (8.57 tons per square inch), under the action of permanent load and of wind pressure. When the surfaces struck by the wind are in an oblique plane, the component parallel with the surfaces is not generally taken into account; in the case of the Pavilion, owing to the redans formed by the lower gallery, the line of portholes and the campanile with its projections, the forces of the wind usually ignored had to be reckoned with. Therefore, the wind strains have been calculated at the rate of 120 kilogrammes per square metre (24.5 lb. per square foot) of vertical projection of the surfaces exposed; but, on the other hand, the comparatively high limit of resistance of 13.5 kilogrammes per square millimetre (8.57 tons per square inch) has been allowed for the steel.

The most intricate part of the building is the common joint at the ridge of the trusses. Seen in a horizontal projection (Figs. 1059 and 1060, Plate CLXIX., and Figs. 1061 and 1062), the trusses being twelve in number, the joint shows the intersection of twelve rotules, concentric one with the other and of the same diameter, which gives it the form of a ball.

The bearing of the trusses on the central sphere is given by the web of the trusses and two thicknesses of plate, equal to a total thickness of 1 in. These twenty-four bearings which radiate round the summit almost touch each other, their ends being only 100 millimetres ($3\frac{15}{16}$ in.) distant from the vertical axis of the ball, the diameter of which is 400 millimetres ($15\frac{3}{4}$ in.). The contact of a half truss, supposing the thrust to be horizontal, is over an arc of a circle, the chord of which is 350 millimetres ($13\frac{3}{4}$ in.) in length and the abscissa 100 millimetres ($3\frac{15}{16}$ in.); or, in other words, over an arc of 120 deg.; therefore, a radius drawn from the end of the bearing makes an angle of 60 deg. with the horizontal.

The greatest angle of thrust at the top occurs when the wind blows with the intensity of 120 kilogrammes

Fig 1061

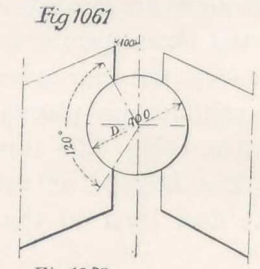


Fig 1062

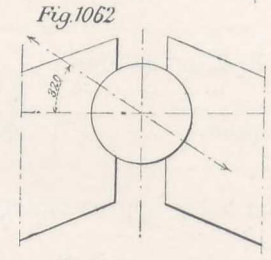
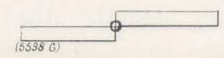


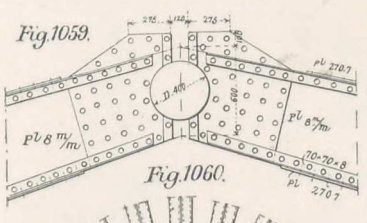
Fig 1063

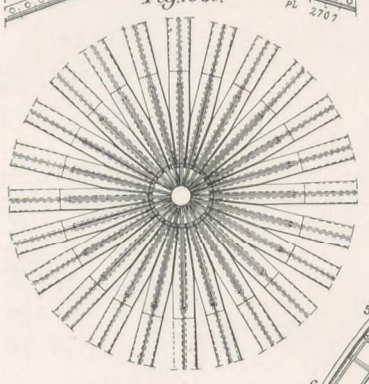


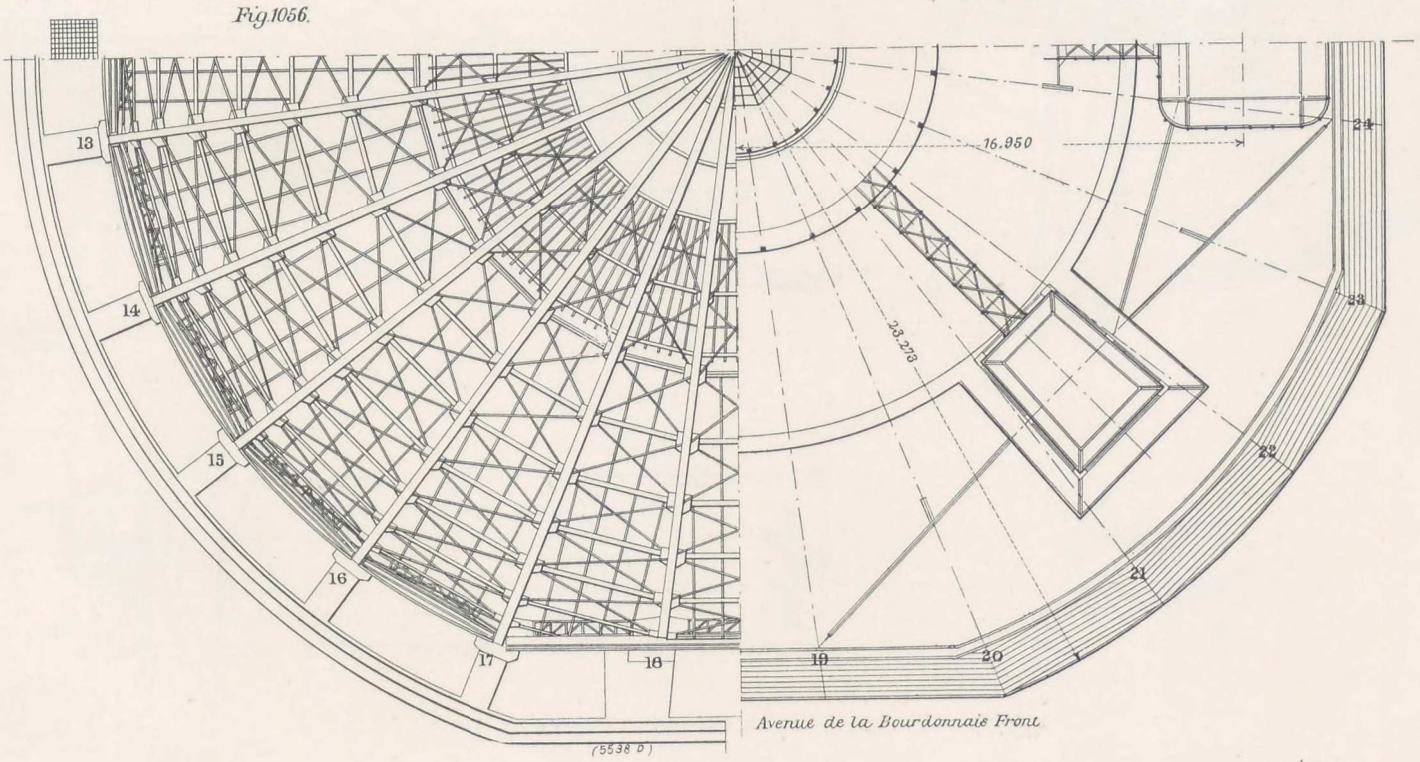
(24.5 lb. per square foot). The greatest angle with the horizontal is then 32 deg. approximately, but the line still passes sufficiently far from the end of the trusses to insure a good bearing; under these conditions the maximum strain on the bearing surface is 3.7 kilogrammes per square millimetre (2.35 tons per square inch). The low strain at the top permitted the sphere bearing to be made of cast iron. When this bearing is equally loaded on all sides by the trusses, uniformly surcharged, the thrust of each half truss being of about 9400 kilogrames (say, 9 tons), it will be seen that the strain per square millimetre of diametral section is very low, being only .57 kilogrammes (.36 tons per square inch).

In ordinary work, when more time can be given to erection, the purlins are fixed only when the trusses are in place, in order to be certain that they fill the conditions for which they have been designed. In this case, however, owing to the rapidity with which the building had to be completed, it was necessary to put in place the last sectors —the closing ones—and to regulate the fixing of the purlins, before building the campanile, and when the placing

THE SCHNEIDER PAVILION AT THE PARIS EXHIBITION.







THE SCHNEIDER PAVILION AT THE PARIS EXHIBITION.

Fig.1067

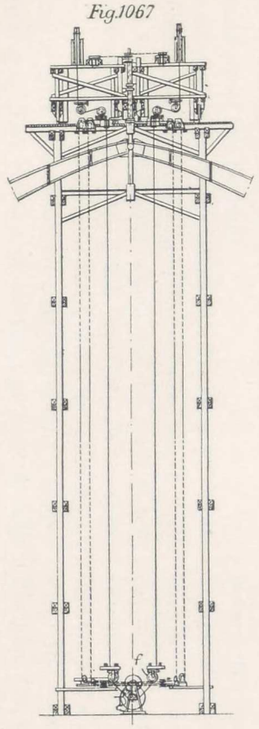


Fig.1064.

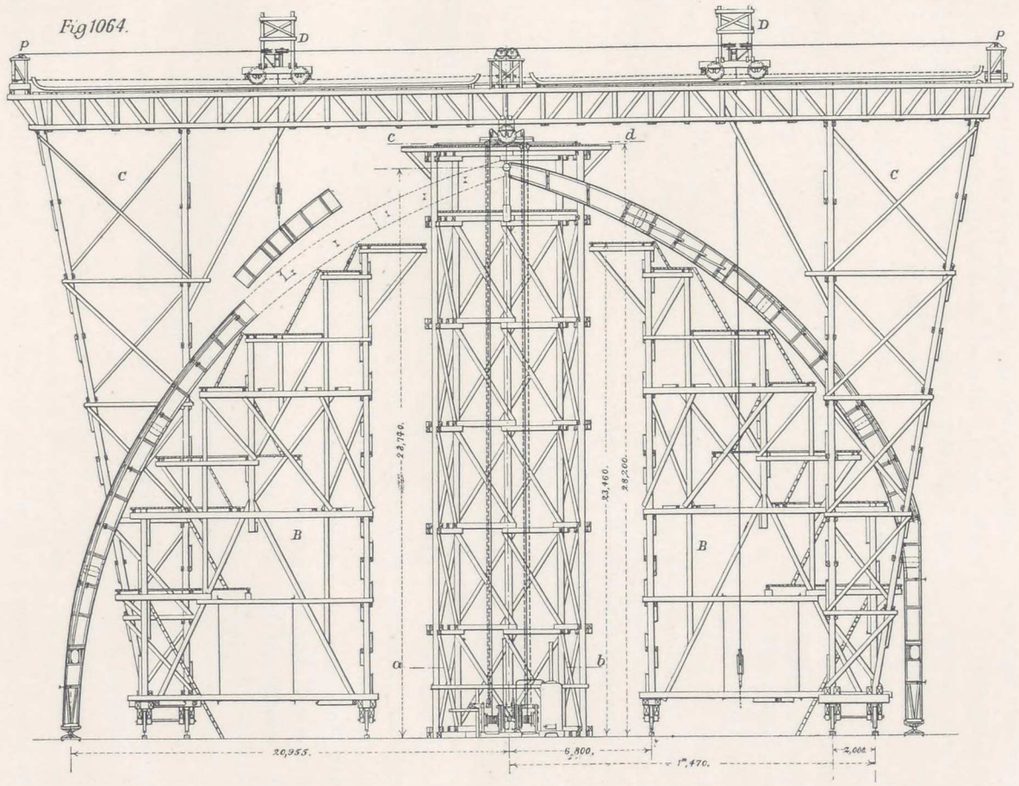


Fig.1065.

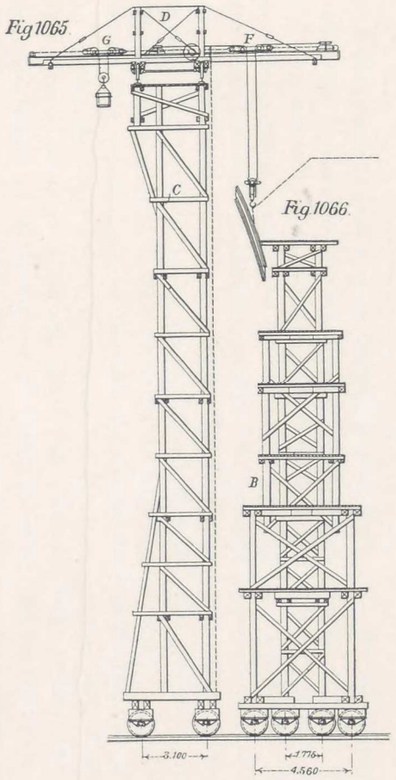


Fig.1066.

Fig.1070 Section a.b.

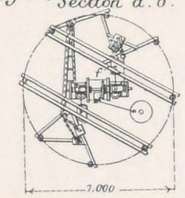


Fig.1068.

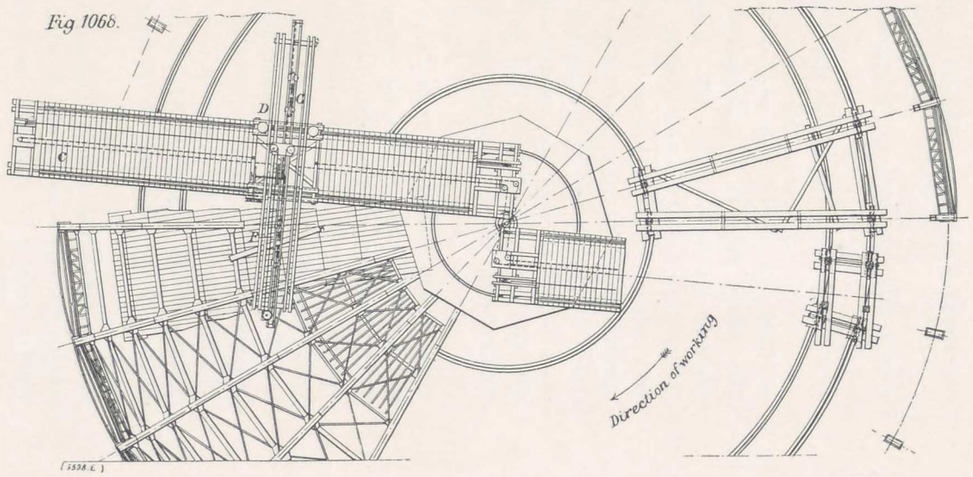


Fig.1069. Section c.d.

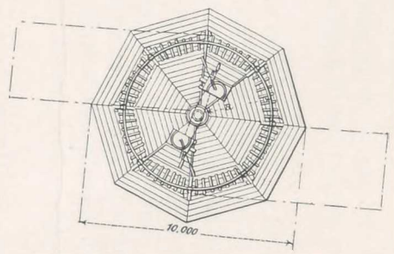


PLATE CLXX.

of the double covering had already begun. It was, therefore, important to ascertain, in view of the measures to be taken during erection, what was the set produced in the trusses under various loads. The set due to the bending moments was rigorously calculated, taking into account the various sections of the trusses, from the first courses to to the top. The fixed position of the top joint had to be insured until the placing of the last truss, for the following reasons: (*a*) The trusses built on the same pattern at the Chalon Works had to be found, on erection on the spot, with the same dimensions as regards chord and abscissa; (*b*) under the weight of metal, the top of a truss subsides when left free; the trusses last erected would not, in this respect, have undergone the strain which the first underwent, and they would not all have been in the same state as regards wear and working. It has been calculated that the top of the truss subsides 5 millimetres ($\frac{3}{16}$ in.) under the weight of metal. That part of the double covering from the wallplate to purlin No. 4 raises the top by 12 millimetres ($\frac{7}{16}$ in.), and that part which is on the purlins Nos. 3 to 1 causes it to subside 2 millimetres ($\frac{1}{16}$ in.); an increase of 10 deg. Cent. in temperature causes the top to rise by 5 millimetres ($\frac{3}{16}$ in.). This involved a double wedging of the ridge ball to prevent it from rising or subsiding. It has been found, besides, that for preventing a truss from subsiding by 5 millimetres ($\frac{3}{16}$ in.) it was necessary to create a reaction on the top, with a lifting force of about 650 kilogrammes, equal, for the twelve trusses, to a load of 7800 kilogrammes (7 tons 15 cwt.) on the axis of the central column.

When the trusses had been put in place and had to be released, it was necessary to know, in order to regulate the fixing of the purlins, what were the variations in the abscissæ of the half trusses variations which were the more important at the spandril near the purlins Nos. 7 and 8, the double covering flattening the trusses, while the campanile produces a bulge greater in extent than the flattening. The resultant is an increase is the abscissæ up to 11 millimetres ($\frac{7}{16}$ in.).

When the closing sectors were put in place, the bolts holding the purlins near the spandril had to be eased to let the trusses set freely, so that the theoretical conditions could be maintained.

The horizontal displacement of the top was ascertained in a truss, half of which was in the sun, and the other half in the shade; this would be of 2.7 millimetres (.105 in.), for a difference of 10 deg. Cent. in the temperature of the two half trusses, and is of no great importance, considering the dimensions of the Pavilion.

The circumstances under which the Pavilion had to be erected led Messrs. Schneider and Co. to make use of very powerful tools and appliances, which enabled them to put the building together with great rapidity. With these appliances, of great power compared with the tonnage of the metallic parts to be dealt with, the object aimed at was fully attained. The erection of all the heavy work only lasted thirty-five days, from February 15 to March 20; at the latter date the dismantling of the scaffolding was begun, and the Pavilion was completed and painted with the help of lighter apparatus.

The trusses were erected in succession, by putting in place at the same time the two half trusses, which balanced each other; when one truss was put in place and joined to the preceeding ones, it was left and the next one was erected. A platform for working and shifting the scaffolding was put down level with the base of the trusses; it consisted of an iron flooring above the Moulineaux Railway cutting, and of a provisional flooring with scaffolding on the river side.

The lifting apparatus consisted of the following parts (see Figs. 1064 to 1070, Plate CLXX.):

1. A central fixed column.
2. Two inside rolling scaffolds, acting as supports for the trusses in course of erection.
3. Two travellers, carrying the large movable trucks for raising the pieces.
4. A double steam winch, with the necessary mechanism for lifting and shifting the pieces.

The central wood column was fixed; it served to regulate the whole construction. The top joint was wedged in this column. The latter consisted of eight round wood uprights, 25 centimetres ($9\frac{7}{8}$ in.) in diameter, placed on a circumference 7 metres (23 ft.) in diameter. It was tied and stayed in the usual way. The top flooring, above the top of the trusses, was 28.20 metres (92 ft. 6 in.) above the base of the trusses; it had the shape of an octagon, 10 metres (32 ft. 10 in.) in diagonal. In the centre of the flooring was placed the pivot round which the two travellers turned.

The two movable scaffoldings were placed diametrically opposite each other, under the sectors formed by the two half trusses already erected, and under the two half trusses in course of erection. They contained several platforms placed in redan, the ends of which followed the curvature of the trusses. The top platform was 23.46 metres (77 ft.) above the base of the trusses. These scaffoldings travelled on two concentric lines 6.80 and 17.47 metres (22 ft. 4 in. and 57 ft. 4 in.) in radius. Each one was carried on four rollers, the two rollers on the outside rail being 4.56 metres (15 ft.) apart.

Each traveller contained a top horizontal flooring rectangular in plan; the flooring was supported by two parallel beams on which was the track for a truck. These beams, placed over the central column, rested on the column at one end, and at the other on a vertical wood tower; the latter travelled on two concentric rails 2 metres (6 ft. 6 in.) apart (see Figs. 1064 and 1068, Plate CLXX.). The outside rail was the same as that of the movable scaffolding. In plan the top flooring of the two travellers were almost diagonally opposite each other; the vertical shaft round which they pivoted was in a line with the central column. The space allotted for the Pavilion did not allow surrounding the trusses by the travellers; it was not possible, therefore, to place the

top floorings direct above the sectors in course of erection, which would have much simplified the work. Consequently, it was necessary to have recourse to the large trucks that travelled on the top floorings and raised all the pieces required for the framing with the help of smaller trucks, the track of which was perpendicular to that of the large ones. These trucks worked in conjunction with other small movable trucks, to which were suspended the counterweight boxes. Three motions could, therefore, be given to the pieces, namely, a vertical or rising action; a motion of translation in the direction of the radius of the building, produced by the displacement of the large truck on the traveller; and a motion of translation perpendicular to the preceding one, given by the displacement of the small truck with regard to the large one.

For insuring safety, all the manœuvres were executed from the floor level, with the help of a steam winch; with this arrangement the foreman had all his men well in hand, and all dangers that usually surround work done at great heights were done away with. The only men who were compelled to work on the top parts of the scaffoldings were those entrusted with the putting together of the various parts of the building. The winch consisted of two drums, round which passed the lifting cables, and of two chain wheels on which turned the translation chains; with the help of disengaging levers the two drums and two wheels could be made to turn together or separately. Each half of the winch, containing one drum and one chain wheel, served one side of the building, namely, one of the travellers and its mechanisms. Lifting was effected by a steel cable which rolled round the winch drum, and ended at a fixed point on the end of the top flooring of the traveller. The return pulleys, which led the cable from the drum to the fixed point, were so arranged as not to interfere with the displacement of the traveller; moreover, during the translation of the trucks, the cable did not vary in length, so that the hook from which the charge was suspended remained at the same height. This result was obtained in the following manner:

The lifting cable on leaving the drum of the winch passed on a pivoting pulley *f* (Fig. 1070, Plate CLXX.), the groove of which always followed the varying direction of the cable during its rolling up on the whole length of the drum; the cable then rose vertically, and passed on a pivoting pulley placed on the top flooring of the central column, from there on another pivoting pulley placed under the traveller C, then on a fixed pulley, from which it took up a horizontal position; it then engaged a series of other pulleys up to *p*, where it was fixed.

The motion of translation of the truck D was given by an endless chain that turned on the chain wheel of the winch: it was also guided by a series of pulleys. The smaller trucks F and G were worked by hand.

The scaffoldings B and travellers C were shifted by hand, by acting with crowbars under the carrying roller; the extreme positions taken up by each of the travellers formed an angle of 150 deg.; or, in other words, each one turned through half the circumference, less the arcs of two sectors of 15 deg. each.

The brief description, with the illustrations, will give an idea of the numerous conditions that had to be fulfilled, and of the way in which Messrs. Schneider and Co. carried out the work with safety, rapidity, and economy. A brief notice of the principal exhibits in this remarkable building will find a fitting place here.

ORDNANCE.

Naval artillery is represented by a practically complete series of quick-firing guns 37 millimetres (1.456 in.), 47 millimetres (1.850 in.), 10 centimetres (3.937 in.), 12 centimetres (4.724 in.), 15 centimetres (5.905 in.), 20 centimetres (7.874 in.), and 24 centimetres (9.449 in.) in calibre. All these guns are of recent patterns, and are remarkable by their power and the ease with which they are worked. With the exception of those of 20 and 24 centimetres, they have all been described in this volume, and the only feature to be noted in passing is that these large-calibre guns are fitted with devices that insure rapid firing by one gunner, who can easily follow an aim moving at a 35-knot speed at a distance of 500 metres. These guns are shown fitted with three types of breech-blocks, namely: those of 37 and 47-millimetre calibre have an extra rapid-working, concentric-threaded block; those from 10 centimetres to 20 centimetres in calibre are fitted with a cylindrical breech-block, which is opened by one action of the lever; for the larger calibre guns, a type of which would be the 24-centimetre quick-firing gun, the breech-block is cylindrical also, but it is worked by means of a crank placed on the side. Three turns of the crank are sufficient to open or to close the breech. All the breech-blocks are fitted with safety devices against premature and hanging fire; and they are held fast when open by a special device.

The Pavilion contains also a naval turret complete for a 24-centimetre gun, with the necessary mechanism for working it by hand or by electricity; also two quick-firing naval howitzers, 15 and 24 centimetres in calibre, firing shells charged with high explosives, for the attack of armoured decks. These two howitzers are of a quite new type; they contain very interesting devices—amongst others, an independent sight-line on the Schneider-Canet system.

These various guns, the howitzers included, would be equally well suited for coast defence.

Field Artillery is represented by a whole series of guns, one group of which illustrates the various transformations of the quick-firing Schneider-Canet guns, dealt with at great length already in these columns. Among these are the following:

A quick-firing gun, 1893 pattern, on carriage with hydraulic recoil cylinder and spring recuperator, elastic trail-spade, with india-rubber washers.

A quick-firing gun, 1895 pattern, on compressible trail, with hydro-pneumatic recoil cylinder and fixed trail-spade.

A quick-firing gun, 1895 pattern, with hydraulic recoil cylinder, spring recuperator, and elastic spade, with set of springs. This is of great interest, as it is this type of gun that has proved its qualities in such a remarkable way in the South African war.

A quick-firing gun, 1896 pattern, with hydro-pneumatic recoil cylinder and fixed trail-spade.

A second group of guns is formed of guns of quite recent types, which can fire in service as many as twenty-four rounds per minute, the laying of the gun being rectified after each round. It contains:

A quick-firing gun, 1898 pattern, powerful type, with hydro-pneumatic recoil cylinder and fixed trail-spade.

A quick-firing gun, 1898 pattern, light type, which differs from the preceding one only in the conditions of firing (weight of projectile and muzzle velocity).

A quick-firing mountain gun, 1898 pattern, with hydro-pneumatic recoil cylinder and fixed trail-spade.

These various guns have been described in the articles above referred to.

In this group may be placed a special weapon: the Schneider-Canet quick-firing 15-centimetre howitzer, on field carriage, with hydro-pneumatic recoil cylinder, which meets the programme of artillery commissions who were desirous of counting in their armament a powerful and light gun suitable to act in conjunction with field guns proper, and firing heavy projectiles under a great angle. The howitzer has a two-motion breech-block and plastic obturator. The carriage resembles that of the 1898 field gun, and, like it, is fitted with a fixed trail-spade.

Siege Guns are represented by a powerful 12-centimetre gun on platform mounting, with hydraulic recoil cylinder. This gun, though of a smaller calibre than the "Long Tom" guns of South African fame, reproduces all their general arrangements.

In this class may be placed also:

A 15-cm. howitzer on truck mounting, "Schneider-Canet-Peigné" system, used alike for the defence of garrisons, entrenchments, and for coast defence.

A disappearing turret for a 57-millimetre gun, specially designed for the armament of advanced positions surrounding a fortified town.

Besides the above material, of which a certain number of types are described further on, the Pavilion contains a complete series of full-sized or reduced models of breech-blocks, coast-defence guns, disappearing gun-carriages, disappearing cupolas, &c.

The following data refer to guns which we have not yet described:

37-Millimetre (1.456 In.), 60 Calibre Schneider-Canet Quick-Firing Gun.—This is designed for the armament of maintops and decks of cruisers, torpedo-boats, gun-boats, &c.; it can fire as many as 50 rounds per minute when served by experienced gunners:

Weight of gun	155 kg.	341 lb.
Length in calibres	60	60
,, metres	2.230 m.	7 ft. 4 in.
Weight of projectile	.800 kg.	$1\frac{3}{4}$ lb.
,, smokeless powder charge	.225 kg.	$\frac{1}{2}$ lb.
Muzzle velocity	800 m.	2624 ft.
Vis viva at muzzle	26.2 t.-m.	87 foot-tons
Thickness of wrought-iron plate perforated	.128 m.	5 in.
Weight of mounting	285 kg.	628 lb.

The gun is fitted with a breech-block, which opens out in one action of the lever; firing is effected by percussion, the striker being cocked automatically when the gun runs out. The breech-block is fitted with safety devices against premature and hanging fire. The gun is carried in a jacket mounting, on which are fitted the hydraulic recoil cylinder, the resistance of which is constant, and the spring recuperator, which insures running out under all angles. The jacket is carried on a frame supported by a baseplate, bolted on deck.

Lateral training and elevation are given by the gunner by bearing with his shoulder against a butt-rest, the height of which can be regulated at will. A bolt serves to fix the movable part in any lateral direction. A shield is generally provided, to suit the place in which the gun is mounted.

15-Centimetre (5.905-In.), 42 Calibre, Schneider-Canet Quick-Firing Guns, on Double, Central-Pivoting Mounting:—This is a completely new type (see Fig. 1071):—

Weight of each gun	4700 kg.	10,358 lb.
Length in calibres	42	42
,, metres	6.300 m.	20 ft. 8 in.
Weight of projectile	40 kg.	88 lb.
,, smokeless powder charge	11 kg.	24 lb.
Muzzle velocity	740 m.	2427 ft.
Vis viva at muzzle	1120 t.-m.	3730 foot-tons
Thickness of wrought-iron plate perforated	.510 m.	20.079 in.
Weight of mounting	7500 kg.	16,530 lb.

In both guns the breech opens in one action of the breech-block, the latter containing safety devices against premature or hanging fire, and accidental opening of the breech-block. An extractor withdraws the empty cartridge-case automatically, when the breech-block is completely opened out.

The two guns are placed in one single jacket, fitted with the four hydraulic recoil cylinders and the two independent air recuperators, which insure running out again under all angles. The two guns can be fired simultaneously or successively; in either case one gunner suffices for the service.

Sets of cylindrical rollers are placed between the trunnions of the jacket-mounting and the trunnion-plates of the slide, in order to reduce the efforts required for elevating the gun. The elevating mechanism consists of an endless screw with helicoidal wheel, which insures the absolute irreversibility of the system; the action is

transmitted to the mechanism by a handwheel held by the gunner.

The movable system for lateral training is guided at top by a series of cylindrical rollers and rests on a ring of balls, the lower racer being fixed in the bedplate. With this arrangement, one man, by acting on the crank, can follow a target moving at a 35-knot speed, at a distance of 500 metres. When the handwheel is released, after having been turned rapidly, the movable system tends to continue its motion, but is quickly held fast by a special friction-device. A small hydraulic brake and a spring buffer allow the firing of one gun only, the mounting deviating but little.

The gun and men are protected by a shield fixed to the slide by elastic couplings, the shape of the shield varying at will. The principal advantages of this *materiel* are the following:—

The placing of two guns in one jacket-mounting, which reduces to a minimum the distance between the axes of the guns, and reduces also, to a large degree (compared with the guns joined together in the usual way), the couple of forces which act on the lateral training mechanism, when only one gun is fired. The mountings and shield are, besides, lighter in weight also.

Complete solidarity of the two guns, as regards training, which can be effected by one man, who has within easy reach all the mechanism enabling him to follow with both guns the displacements of a movable target. Firing is rapidly regulated, and all manœuvres are most easily carried out, owing to the special measures taken to reduce all resistances. A lesser number of attendants is required for serving the two guns. Concentrated firing is easy, resulting in double the effects, at least, to be obtained with a single gun, owing to the greater concussion due to the simultaneous delivery of two shots on the target.

20-Centimetres (7.874-In.) 45-Calibre, Schneider-Canet Quick-Firing Gun, on Central-Pivoting Mounting with Closed Shield:—

Weight of gun	14,000 kg.	30,856 lb.
Length in calibres	45	45
,, metres	9 m.	29 ft. 6 in.
Weight of projectile	90 kg.	198 lb.
,, smokeless powder charge	35 kg.	77 lb.
Muzzle velocity	840 m.	2756 ft.
Vis viva at muzzle	3240 t.-m.	10,789 foot-tons
Thickness of wrought-iron plate perforated at muzzle	.750 m.	29½ in.
Weight of mounting complete without shield	10.500 kg.	23,142 lb.

The breech is opened in one action of the breech-block; the gun is fired by electricity or percussion; the breech-block is provided with all the safety devices already mentioned; obturation is insured by a plastic ring, or by movable brass discs.

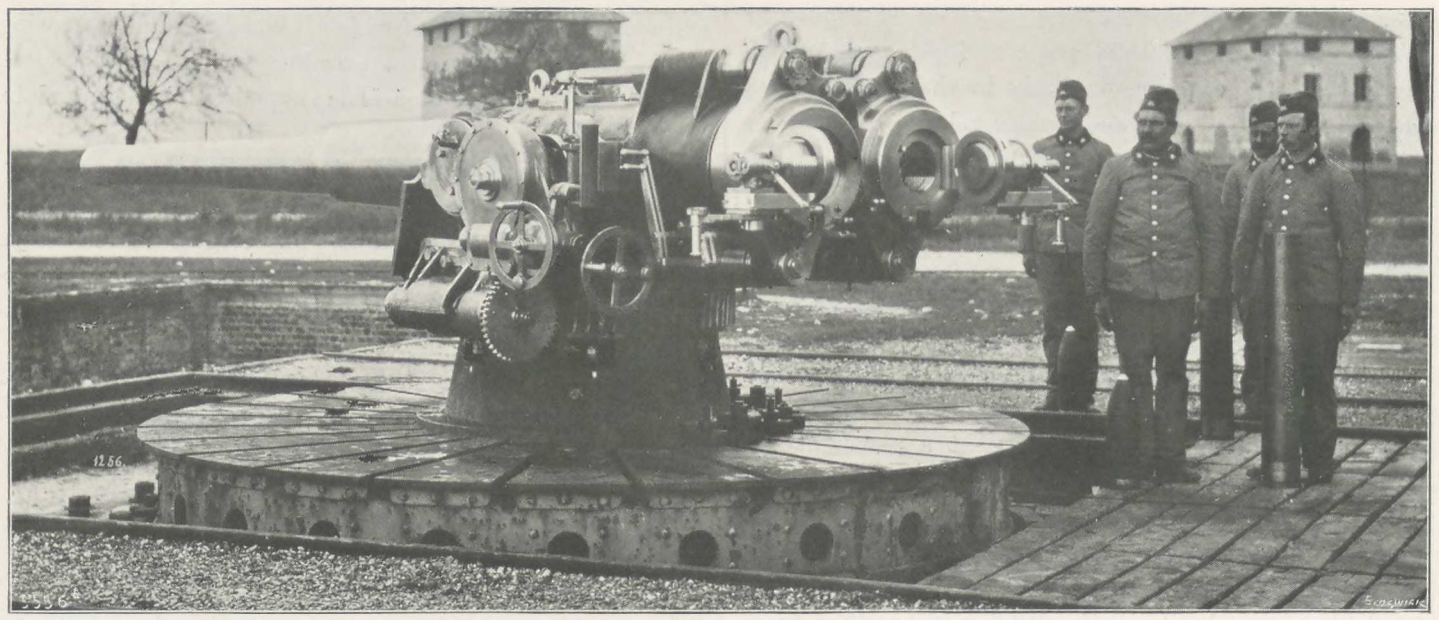


Fig. 1071. 15-Centimetre Schneider-Canet Guns on Double Mounting.

The mounting contains two hydraulic recoil cylinders, diametrically opposite each other, and an independent compressed air recuperator underneath. The hydraulic recoil cylinders are arranged in such a way that the gun can be run out and in, with the help of a pump; this enables the continuation of firing under all angles, should the recuperator accidentally get out of order.

Elevation is facilitated by placing a ring of cylindrical rollers between the carriage trunnions and the trunnion-plates of the slide. The handwheel which drives the elevating mechanism is held by the gunner; it works a curved rack fitted to the mounting through an irreversible device of special design, and which allows one single man to cause the gun to pass through 1 deg. 32 minutes per second.

The gun and mounting rest, for lateral training, on a set of balls carried on the bedplate. The mechanism for this training is driven by a handwheel held by the gunner; it works a pinion which gears in a fixed curved

rack through an irreversible device similar to that for elevating the gun. It allows one man to follow a target moving at a speed of 35 knots, at a distance of 600 metres. An electric sector is also provided, for increasing the speed of rotation in case of need.

Ammunition is raised to the breech of the gun by a lift, which follows the mounting in its motions. It is worked by hand or by electricity, and delivers on the right-hand side of the slide, the projectiles and the cartridges. The latter are taken up by hand, while the projectiles are slid on a jointed elevator which delivers them at the breech of the gun by a counterbalanced device. The elevator is fitted with a charging plate, to facilitate placing the projectile in the chamber. It is introduced by a telescopic apparatus worked by hand, jointed round a vertical pivot, and which is shifted to one side when not needed.

The gunners and the gun are protected by a closed-in shield, carried on a plate flooring fitted to the brackets of the slide; the shield is in the shape of an ordinary turret. An opening is cut in the rear part; it can be closed by a door. This mode of protection unites all the advantages of a closed-in turret, besides being lighter and less bulky.

24-Centimetre (9.449 In.) 45-Calibre, Schneider-Canet Quick-Firing Gun, on Central-Pivoting Mounting (Fig. 1072):

Weight of gun	23,100 kg.	50,912 lb.
Length in calibres	45	45
,, metres	10,800 m.	35 ft. 5 in.
Weight of projectile	150 kg.	330 lb.
,, smokeless powder charge	60 ,,	132 ,,
Muzzle velocity	850 m.	2789 ft.
Vis viva at muzzle	5530 t.-m.	18,415 foot-tons
Thickness of wrought-iron plate perforated at muzzle	.920 m.	36 in.
Weight of complete mounting without shield	11,860 kg.	26,140 lb.

The gun is fitted with a cylindrical threaded, quick-action breech-block, worked by a lateral crank, and fitted with a plastic obturator; $3\frac{1}{2}$ turns of the crank suffice to open or close the breech completely. The plastic obturator can be removed when metallic bottoms are used. Electric or percussion firing can be resorted to, worked by the same device placed on the left side of the mounting, within easy reach of the gunner. The breech-block is fitted with the safety arrangements mentioned for preceding patterns of guns.

The carriage proper, like the one for the 20-centimetre gun, is provided with two hydraulic recoil cylinders, opposite each other, and with a compressed-air recuperator, independent of the cylinders placed underneath. The cylinders are so arranged that the gun can be run out again with the help of a pump; this, as in the previous case, allows the continuation of firing under all angles, should the recuperator get accidentally damaged.

The elevating and lateral training mechanism and arrangements are the same as those for the 20-centimetre gun. For the latter, one man alone can cause the 37 tons to revolve with sufficient rapidity to follow a target travelling at a 34-knot speed, at a distance of 500 metres.

A suitable shield protects the gun and the men.

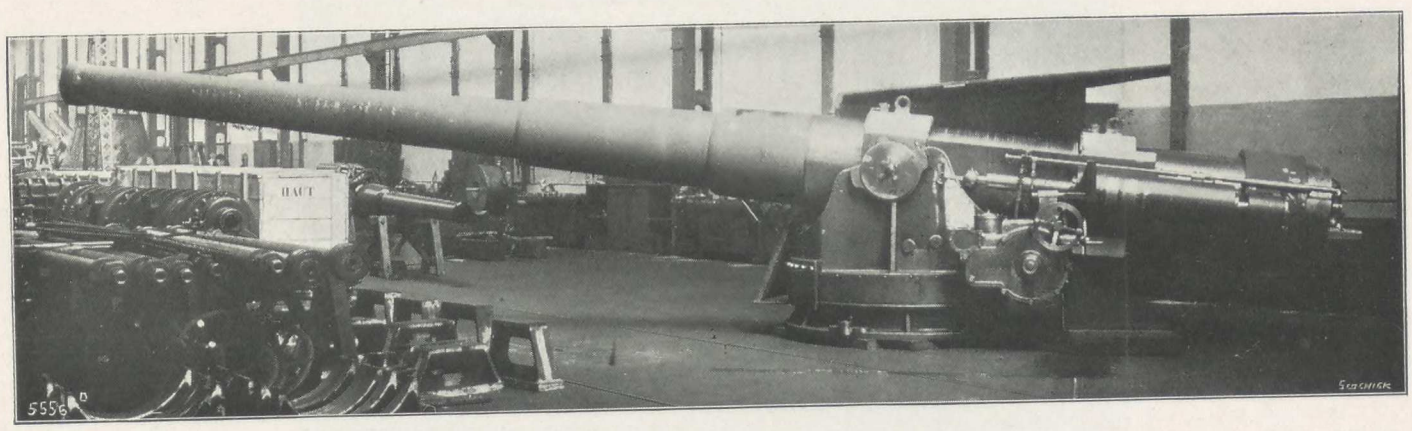


Fig. 1072. 24-Centimetre Quick-Firing Schneider-Canet Gun.

This gun is worked as easily as those of medium calibre.

15-Centimetre (5.905-In.), 10-Calibre, Schneider-Canet Quick-Firing Howitzer, on Central-Pivoting Mounting (Fig. 1073, Plate CLXXI). — This is used indifferently as a naval howitzer and for coast defence.

The breech-block is of simple pattern, and works very easily; it is fitted with a plastic obturator, and is provided with safety devices against premature and hanging fire.

Weight of howitzer	920 kg.	2028 lb.
Length in calibres	10	10
,, metres	1.500 m.	4 ft. 11 in.
Weight of projectile	40 kg.	88 lb.
,, smokeless powder charge	1.400 kg.	3 lb.
Muzzle velocity	260 m.	853 ft.
Vis viva at muzzle	138 t.-m.	460 foot-tons
Weight of mounting	3600 kg.	7934 lb.
Elevation	− 5 deg. to + 60 deg.	− 5 deg. to + 60 deg.

The recoil is checked by two hydraulic recoil cylinders with constant resistance, placed symmetrically with regard to the axis of the howitzer, one above and one below the jacket mounting. Return is effected under all angles by a compressed air recuperator, independent of the recoil cylinders. The jacket in which the howitzer slides is carried in a frame which rests on the bedplate, with the

interposition of balls. Lateral training is given by hand, by means of non-reversing mechanism. The elevating device contains an endless screw and a helicoidal wheel, which insure its irreversibility.

By a special arrangement the line of fire can be adjusted, whatever be its incline, the loading operations not delaying the service in any way. When the breech is closed, it is only necessary to bring the howitzer rapidly in the firing position given by the independent sighting.

The jacket mounting is fitted with an inside shield, which oscillates with the howitzer and closes the port for the chase, cut in the outside fixed shield.

24-Centimetre (9.449-In.) 10-Calibre, Schneider-Canet Quick-Firing Howitzer, on Central Pivoting Mounting (Fig. 1074, Plate CLXXI.).—This is suitable both for naval service and for coast defence.

The breech-block is used with a plastic obturator, the opening mechanism acting direct on the block; it contains a double disengaging device. The electric firing mechanism is worked by the gunner, an attendant operating the percussion device. Safety arrangements are provided against premature firing.

Weight of howitzer	4400 kg.	9698 lb.
Length in calibres	10	10
,, metres	2.400 m.	7 ft. 10½ in.
Weight of projectile	150 kg.	330 lb.
,, smokeless powder charge	5 kg.	11 lb.
Muzzle velocity	690 m.	2263 ft.
Elevation	− 7 deg. + 60 deg.	− 7 deg. + 60 deg.
Weight of mounting	10,700 kg.	23,583 lb.

The howitzer slides in a jacket-mounting during recoil and in running out. Two constant-resistance hydraulic recoil cylinders and a compressed-air recuperator, similar to those above described, are fitted. The gun and mounting rest on the bedplate, with the interposition of a ring of balls. In order to accelerate firing, all the manœuvres for elevation, lateral training, sighting and loading, are carried out with special quickworking arrangements.

The required elevation is given by a handwheel held by the gunner; it acts on a curved rack fitted on the mounting, through irreversible gearing. The howitzer is brought very rapidly from the loading to the firing position, and *vice versâ*. Manœuvring is facilitated by sets of rollers placed between the mounting trunnions and the trunnion-plates of the slide.

Lateral training is effected by the action of a handwheel held also by the gunner; it drives a pinion which gears in a circular rack, and the mass is rotated very rapidly. The projectile is placed in the chamber with the help of a jointed rest, at the rear of the platform, and which raises the projectile from the platform level and guides it to the chamber. A safety device prevents the complete operation of the charging rest until the breech is open. The sighting line is independent of the elevating motion, the howitzer can therefore be sighted while it is being loaded. The howitzer is protected by two shields.

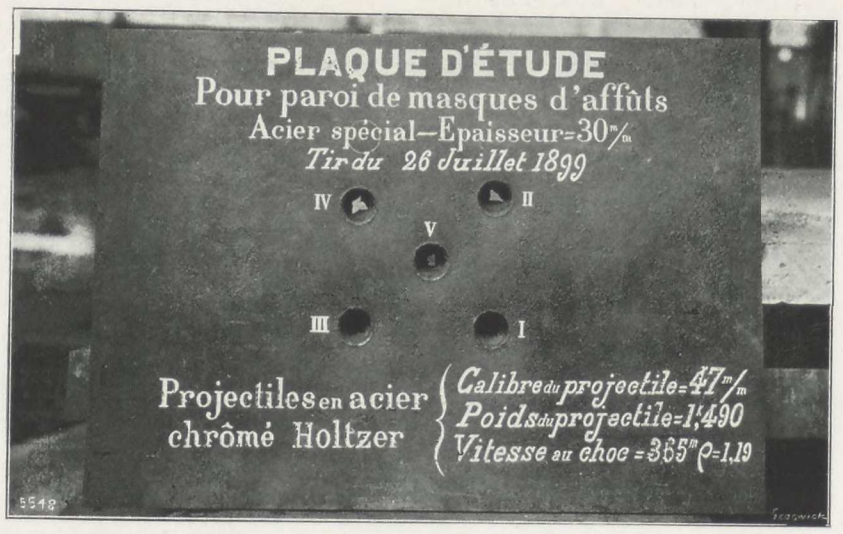


Fig. 1075. Armour Plates.

ARMOUR PLATES.

A large number of armour plates, tested and untested, were exhibited; of these several are selected for illustration (see Fig. 1075, and Figs. 1076 to 1080, Plate CLXXII.); no comment, however, is needed, for the appearance of the plates speak for their quality, and the legend is written legibly on each. The collection was a very remarkable one, and included types of iron plates of 1855, down to the special cemented steel plates of to-day.

HIGH-SPEED LOCOMOTIVE (Thuile System).

The locomotive illustrated in Figs. 1081 to 1094, Plates CLXXIII., CLXXIV., CLXV., and CLXXVI., forms a conspicuous feature in the pavilion of Messrs. Schneider and Co., of Creusot, at the Paris Exhibition; it was designed to haul trains weighing 180 to 200 tons, at a speed of 120 kilometres (75 miles) per hour on a level gradient. The energy developed in the cylinders amounts to 1800 to 2000 indicated horse-power.

The locomotive has two coupled wheels in the middle, a four-wheeled bogie in front, and a six-wheeled truck in the rear; the steam distribution is on the Walschaert principle. The boiler is fitted with a Belpaire furnace with

ORDNANCE AT THE PARIS EXHIBITION.

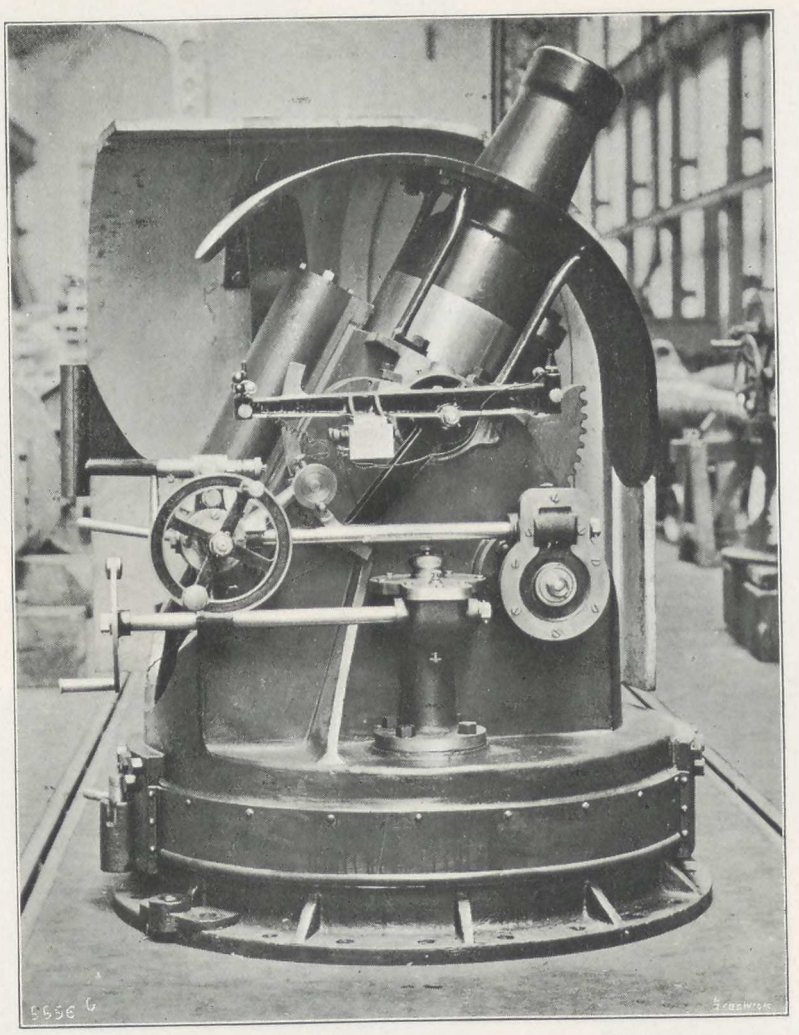


Fig. 1073. 15-Centimetre Schneider-Canet Howitzer.

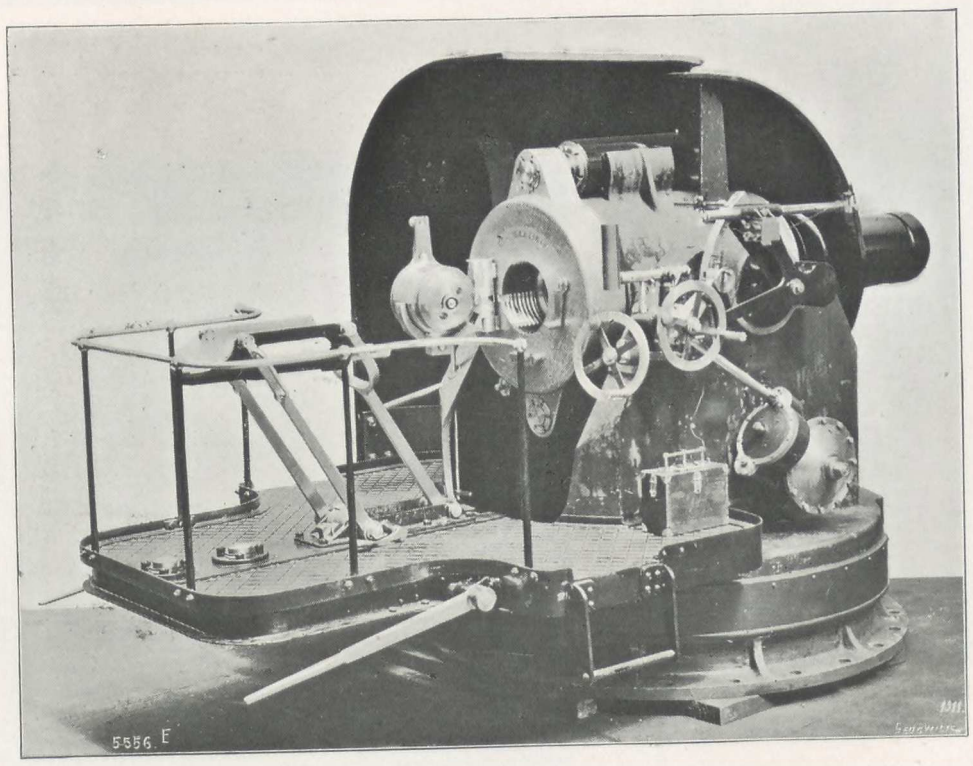


Fig. 1074. 24-Centimetre Schneider-Canet Howitzer.

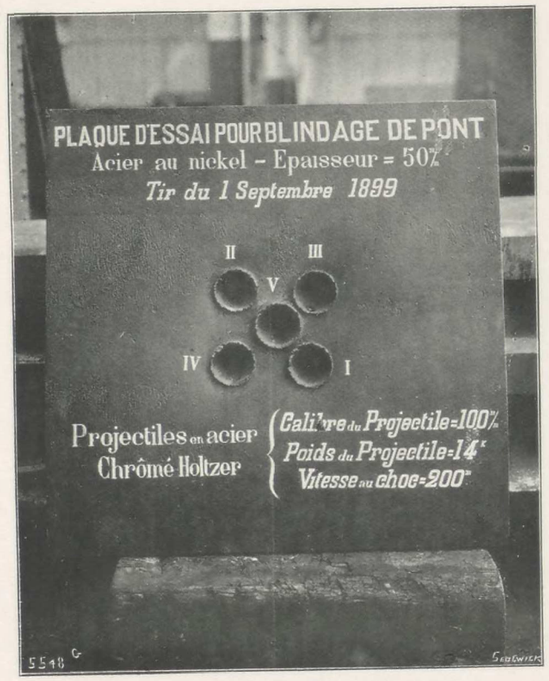


Fig. 1076.

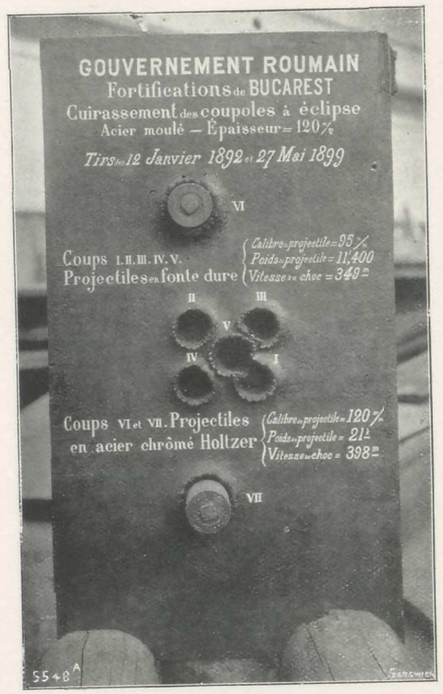


Fig. 1077.



Fig. 1078.

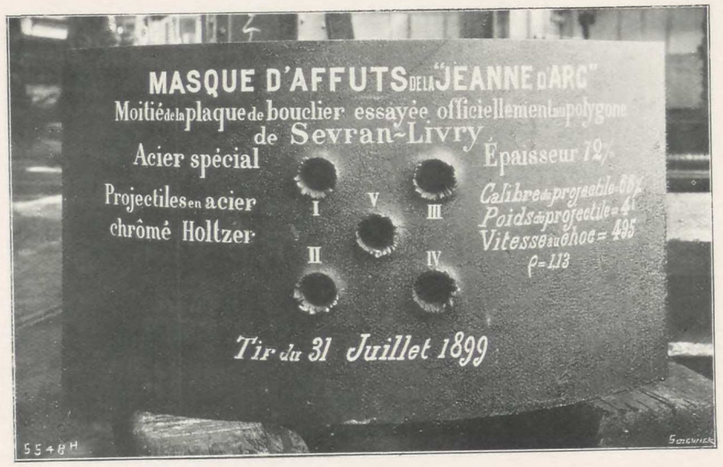


Fig. 1079.

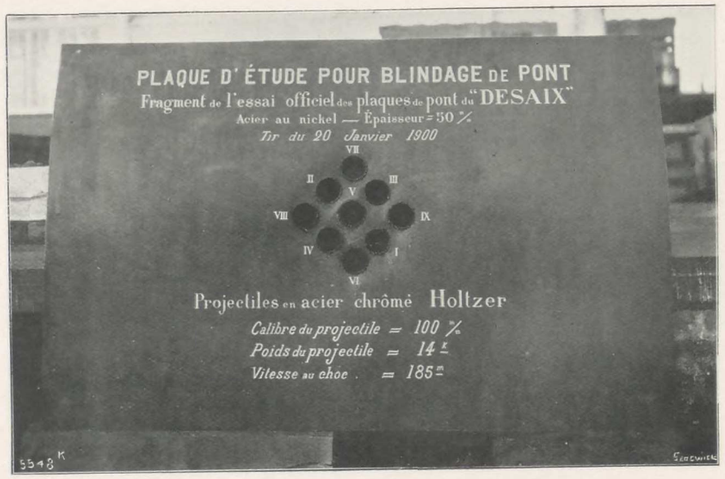
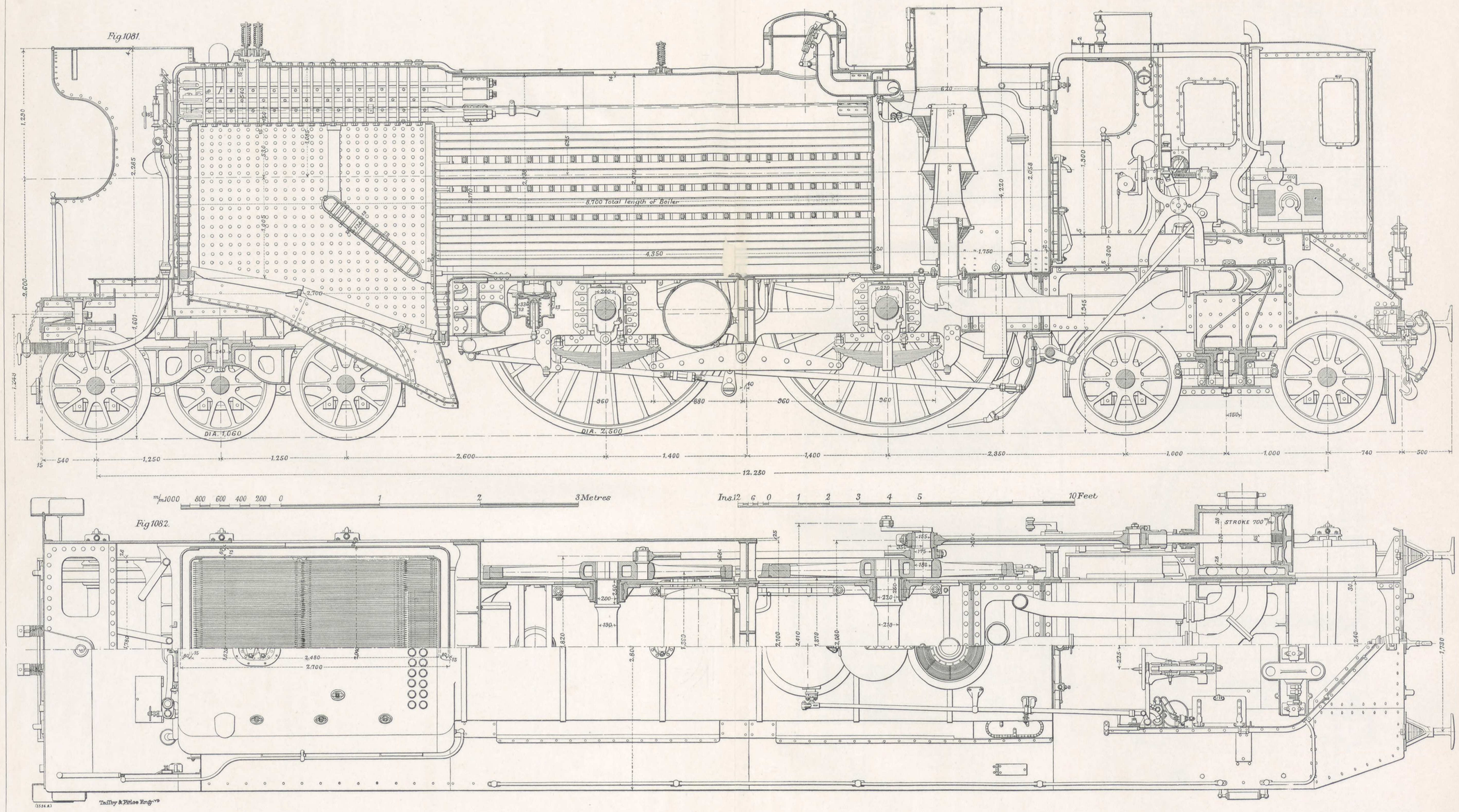


Fig. 1080.

HIGH-SPEED LOCOMOTIVE (THUILE SYSTEM).



HIGH-SPEED LOCOMOTIVE (THUILE SYSTEM.)

Fig. 1083.

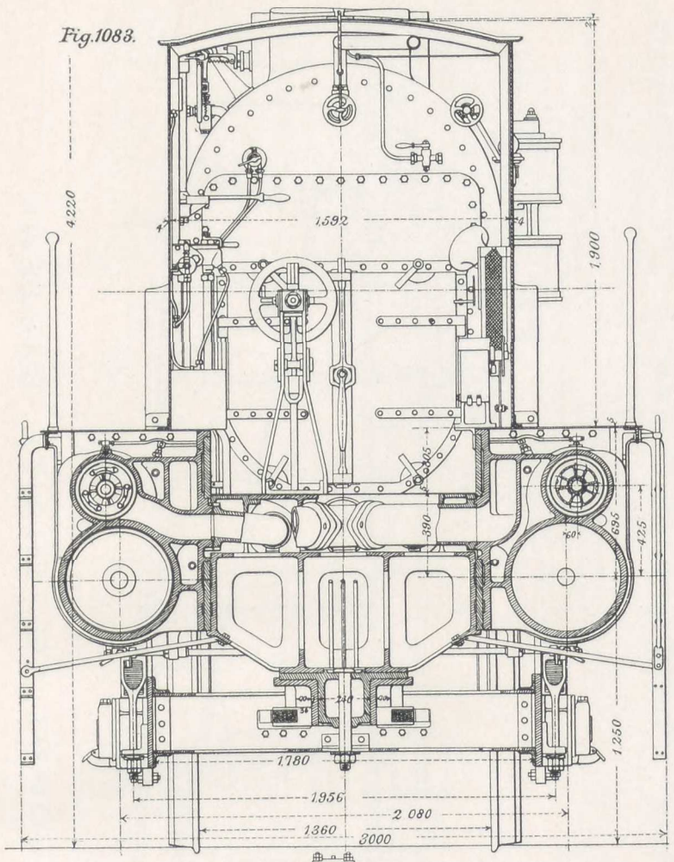


Fig 1084.

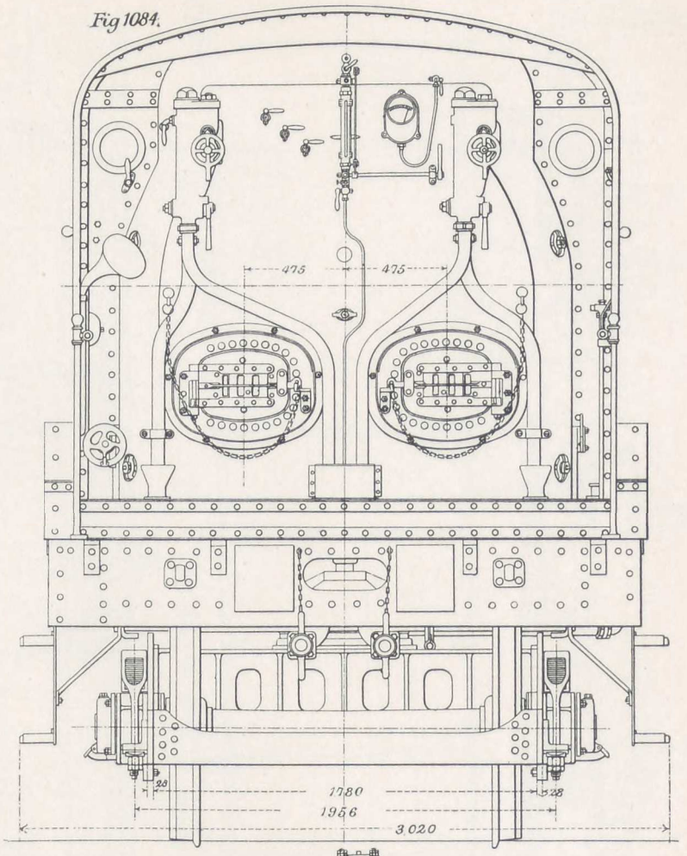


Fig 1085.

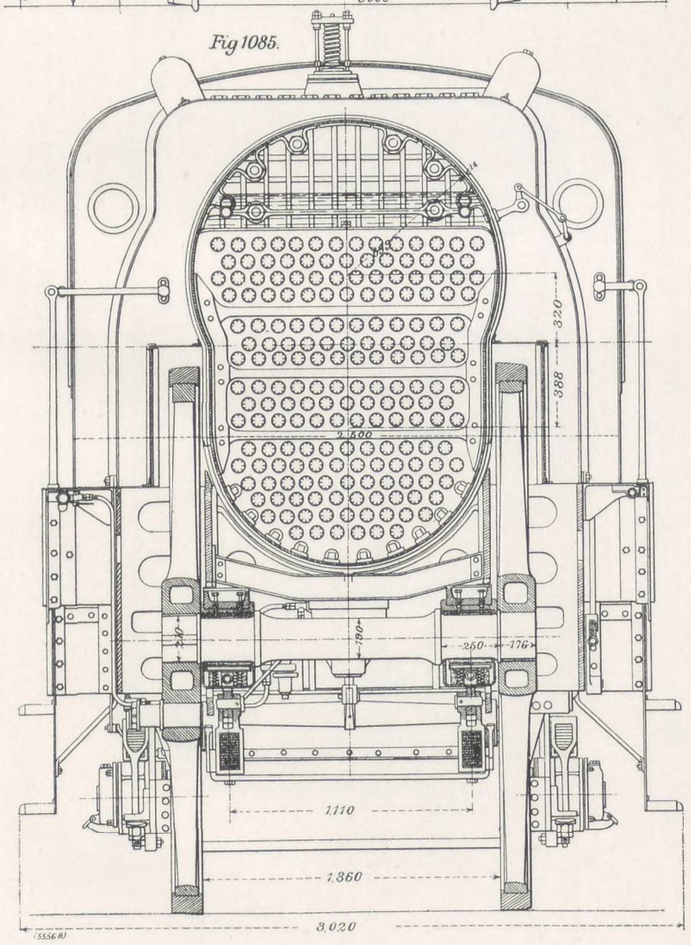
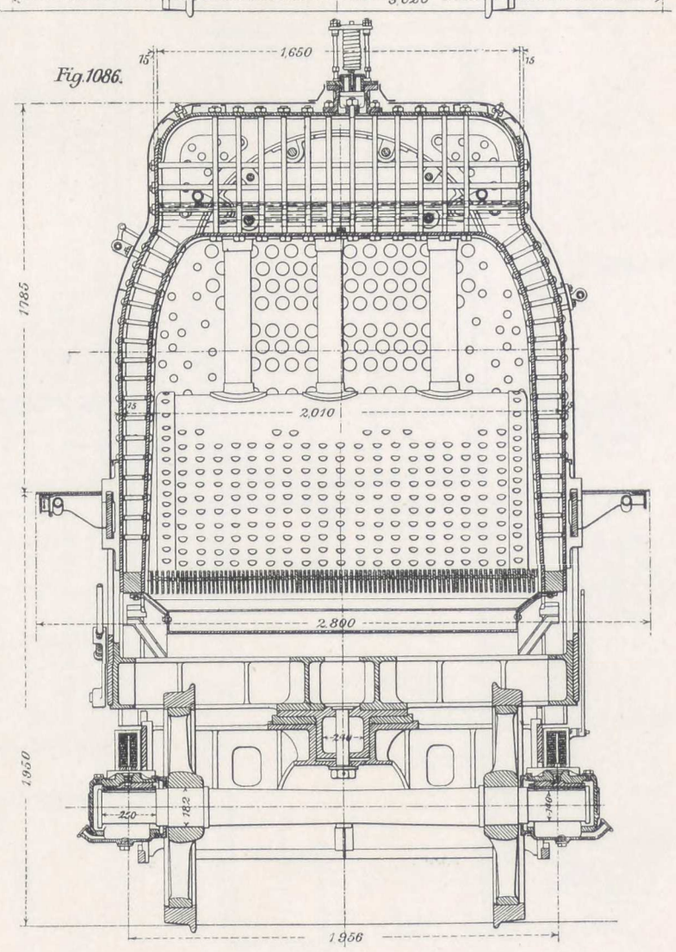


Fig. 1086.



TENDER FOR HIGH-SPEED LOCOMOTIVE (THUILE SYSTEM).

Fig.1087

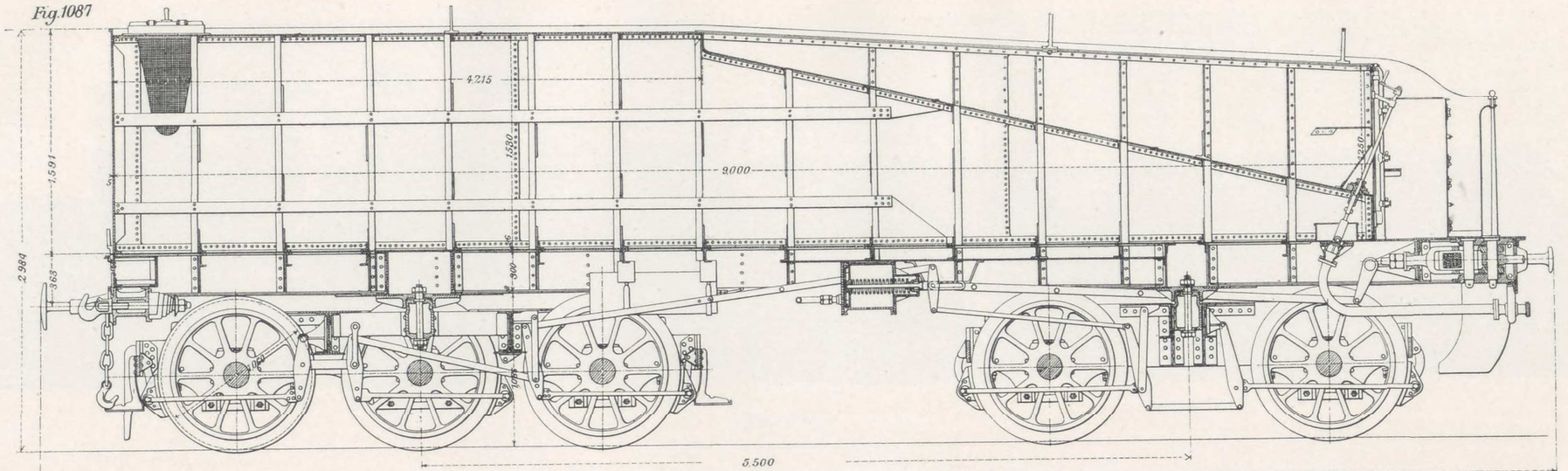


Fig.1088.

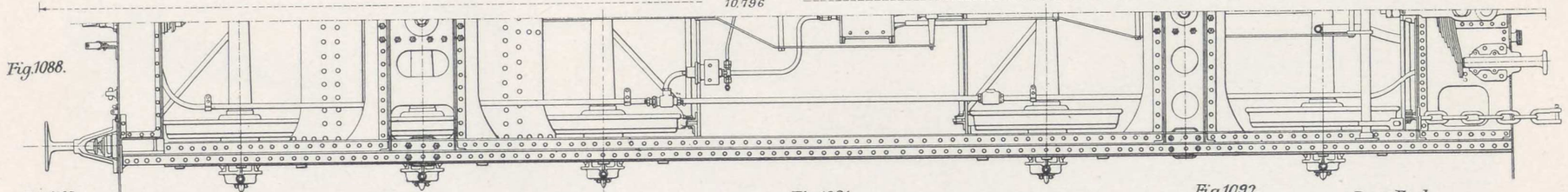


Fig.1089.

Front End.

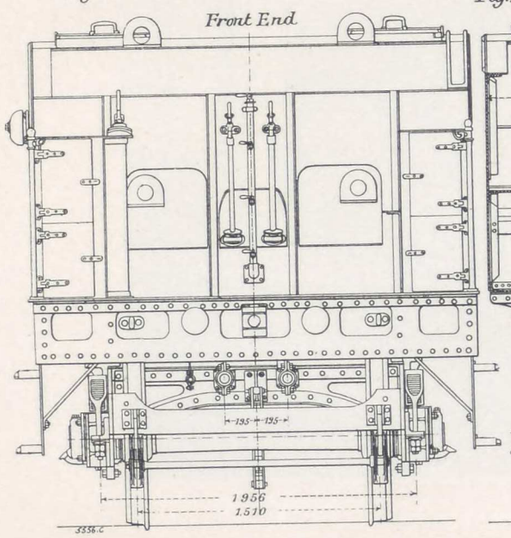


Fig.1090.

Section thro' Front Bogie

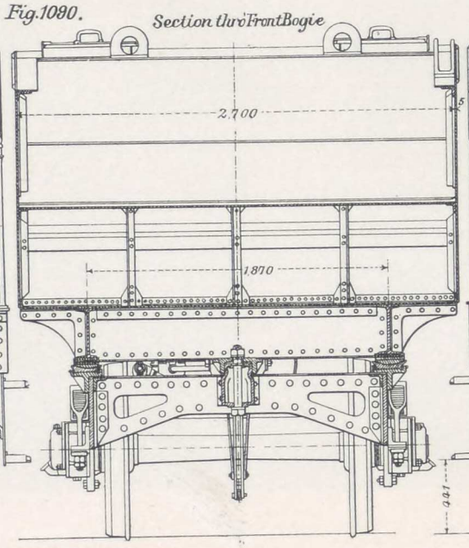


Fig.1091

Section thro' Rear Bogie

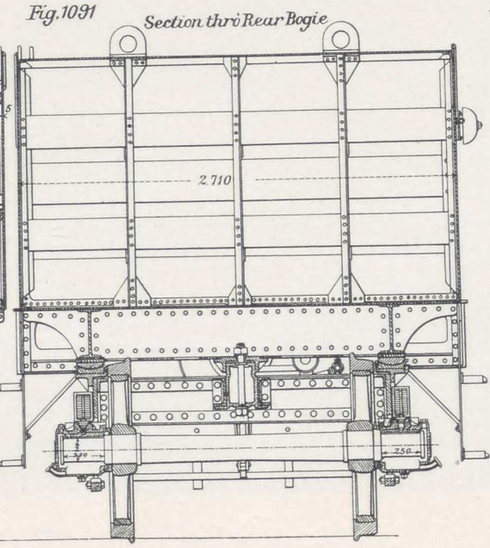
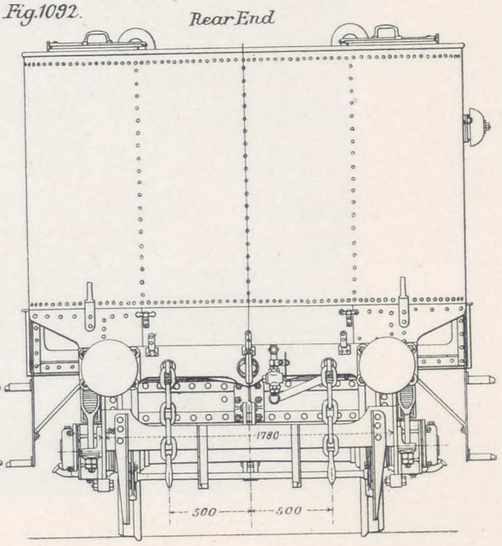


Fig.1092.

Rear End.



HIGH-SPEED LOCOMOTIVE (THUILE SYSTEM).

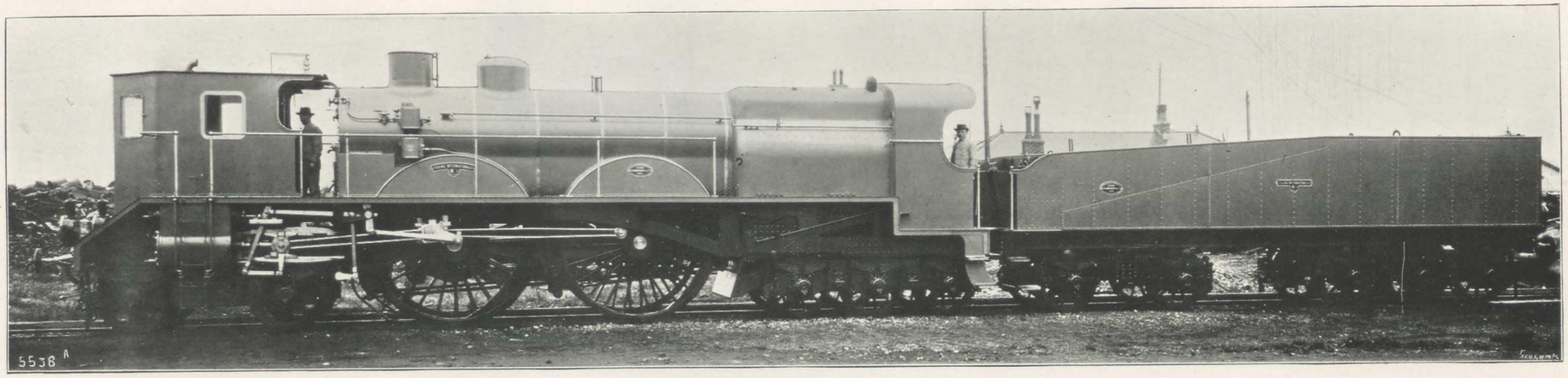


Fig. 1093.

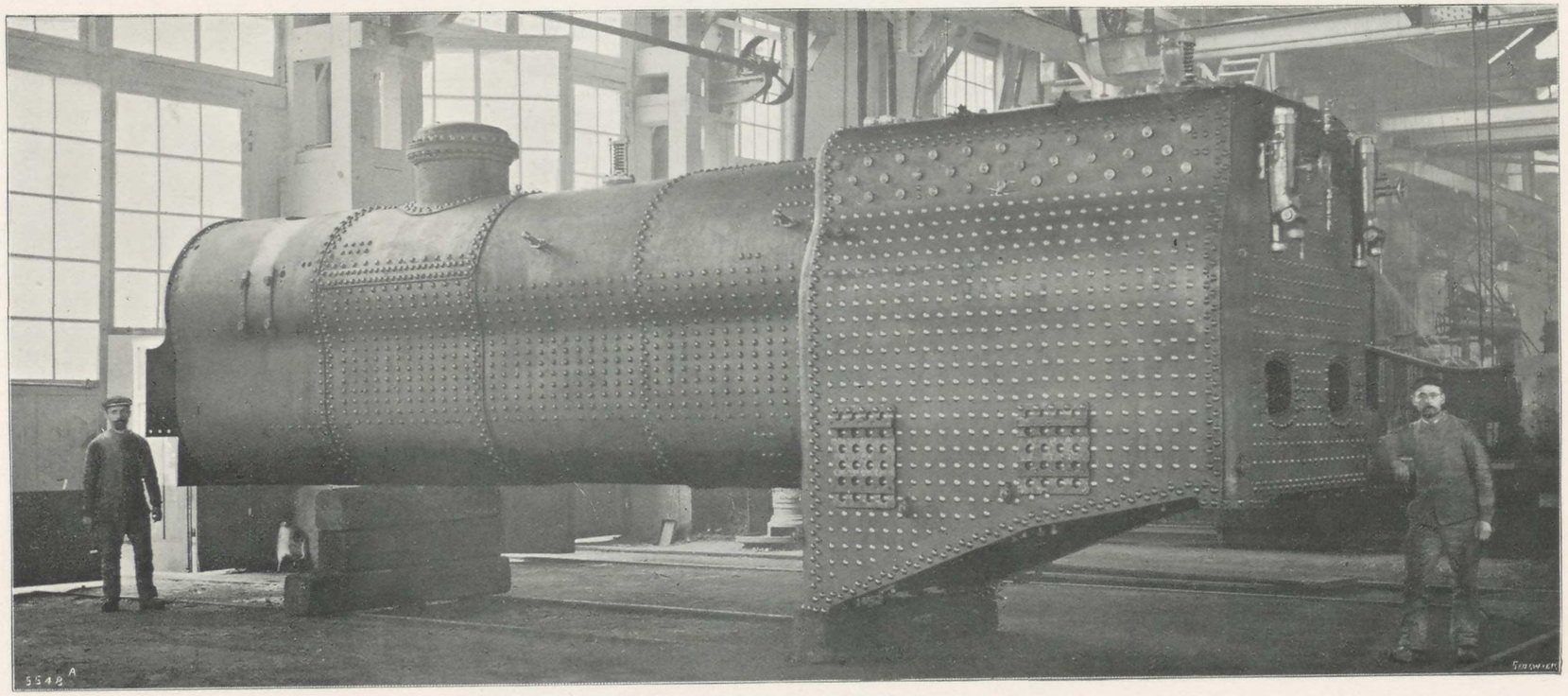


Fig. 1094.

PRINCIPAL DIMENSIONS OF THE THUILE LOCOMOTIVE.

Grate area	4.68 sq. m.	50.37 sq. ft.
Outside length of firebox	2.700 m.	8 ft. 10.2 in.
,, width ,, ...	2.040 m.	6 ft. 8.3 in.
Mean diameter of upper part of boiler	1.370 m.	53.87 in.
Mean diameter of lower part of boiler	1.234 m.	48.58 in.
Height of boiler	2.010 m.	6 ft. 7 in.
Total length of boiler	8.700 m.	28 ft. 6.5 in.
Number of tubes (ribbed)	183	183
Outside diameter of tube	70 mm.	2.76 in.
Length between tube plates	4.350 m.	14 ft. 3.2 in.
Heating surface, firebox	24.50 sq. m.	263.72 sq. ft.
,, tubes	273.20 sq. m.	2940.80 sq ft.
Total heating surface	297.70 sq. m.	3204.52 sq. ft.
Capacity of boiler water	7.350 c.m.	259.5 cub. ft.
,, steam	2.700 c.m.	95.35 cub. ft.
,, total	10.050 c.m.	354.85 cub. ft.
Working pressure in boiler	15 kilos.	213 lb. per sq. in.
Diameter of cylinders	.510 m.	20.08 in.
Length of stroke	.700 m.	27.56 in.
Length of connecting-rod	2.100 m.	6 ft. 10.7 in.
Distance between centres of cylinder	2.080 m.	6 ft. 9.8 in.
Diameter of coupled wheels	2.500 m.	8 ft. 2.4 in.
,, truck ,, ...	1.060 m.	41.73 in.
Distance from centre to centre of trucks	10.00 m.	32 ft. 9.7 in.
Total wheel base	12.250 m.	40 ft. 2 in.
Lateral displacement of front truck on each side	70 mm.	2.76 in.
Lateral displacement of rear truck on each side	0	0
Distance between inside frames ...	1.240 m.	48.82 in.
,, outside frames ...	2.100 m.	6 ft. 10.68 in.
,, truck frames ...	1.710 m.	70.18 in.
Distance from rail to centre of buffers	1.060 m.	42.73 in.
Outside length of engine	14.005 m.	45 ft. 11.3 in.
Height from rail to top of chimney	4.220 m.	13 ft. 10 in.
Tractive energy	7100 kilos.	15,652 lb.
Weight of engine, empty	75.000 kilos.	75 tons
,, in running order	83.000 kilos.	83 tons
Distribution of load, driving axle ...	16.000 kilos.	16 tons
,, ,, coupled axle ...	16.000 kilos.	16 tons
,, ,, forward truck...	19.800 kilos.	19.8 tons
,, ,, rear truck ...	28.800 kilos.	28.8 tons

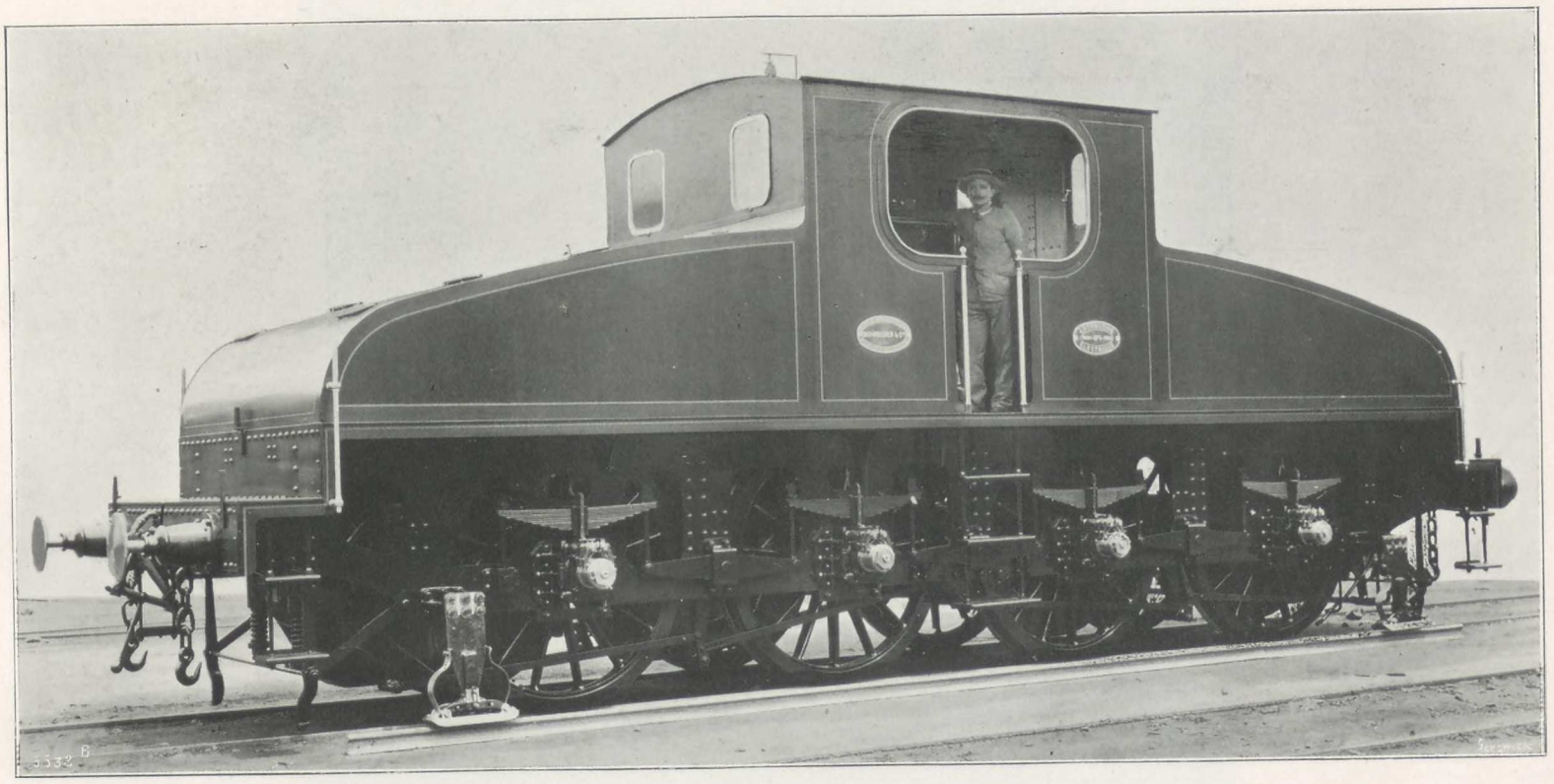


Fig. 1095. Electric Locomotive built by Messrs. Schneider and Co.

Tenbrink heating tube. The cylindrical body of the boiler is of the oval section shown on the cross section and on Plate CLXXV. Provision is made for the admission of steam to the cylinders, when working with closed regulator valve. A cab is fitted in the rear for the firemen, and a second in front for the driver. The engine carries a Laval dynamo turbine for lighting the train.

The boiler-plates, rivets, tie-bars, angle bars, connecting-rods and cranks, are of nickel steel. The large wheels are of cast steel.

The tender illustrated on Plate CLXXIV., is carried on two trucks; the following are some particulars:

Diameter of wheels	1.060 m.	3 ft. 5¾ in.
Total wheelbase	7.800 m.	25 ft. 7 in.
Weight empty...	24,000 kg.	24 tons
,, in working order	59,000 kg.	59 tons

The tender contains 28 cubic metres (989 cubic feet) of water and 7 tons of coal. The breaking strain of the nickel steel for boiler-plates, rivets, &c., averages 50 to 55 kilogrammes (31.75 to 34.92 tons per square inch); that of the connecting-rods and cranks 60 to 65 kilogrammes (38.00 to 41.27 tons per square in.).

The driver communicates with the firemen through a speaking-tube and by ringing signals.

ELECTRIC LOCOMOTIVE.

The electric locomotive (Fig. 1095) built by Messrs. Schneider and Co., and exhibited in their pavilion, was designed with a view to carry out complete traction tests with heavy trains at a high speed, on the works track from Creusot to Montchanin, with a third rail for taking the current and return to ground. It consists of a frame, with

platform which rests, with the interposition of springs, on four driving axles each worked by a 200 horse-power dynamo. It contains all the apparatus necessary to the good working of the motors; and to insure the safety of the electrical devices, it is fitted with a Wenger brake and with a screw brake.

The eight wheels of the locomotive are 1.60 metres (5 ft. 3 in.) in diameter; each axle is worked through toothed-wheel gearing, by a separate motor. The four motors are of the ironclad type, with 6 poles, of 550 volts, 423 revolutions. They are so fitted that all shocks are completely deadened; they are joined to their respective axles, around which they can turn. The starting mechanism placed in the cab is provided with double levers, so that the driver can always place himself in the direction in which the locomotive travels.

Tonnage hauled on a gradient of 11 per 1000	300 tons	300 tons
Speed, per hour	45 kilom.	28 miles
Traction strain on starting	7 tons	7 tons
Weight of locomotive, approximate ...	50 tons	50 tons
Length, between buffers	10.70 m.	35 ft. 2 in.
Maximum height	3.88 m.	12 ft. 9 in.
Total power of the four motors ...	800 h.p.	800 h.p.
Weight of each motor	4 tons	4 tons

All arrangements have been provided in order to obtain an easy and progressive starting, and to prevent sparking, or to cut the sparks should they be produced at the breaking of the current. The apparatus for reversing the current and coupling the motors is fitted with double couplers, to secure efficiency.

1500 HORSE-POWER ALTERNATOR, TYPE O, CLASS 23.

This three-phase alternator produces part of the electromotive force required for the Exhibition. At 70 revolutions per minute it has a frequency of fifty periods, and a tension of 3000 volts per phase.



Fig. 1096. 1500 Horse-power Alternator.

It consists of a fixed, laminated armature, 6.400 m. (21 ft.) bore, held in a cast-iron shell, in two halves, which rests on two frames. (Fig. 1096 shows one of these halves.) The armature coils are in recesses, cut along the inside circumference.

The magnet acts as a flywheel; it contains 84 poles of solid wrought iron, recessed in a cast-iron ring, weighing 50 tons, keyed on the engine shaft. The magnet coils take up the exciting current at 140 volts through two rings driven by the shaft, and fitted with brushes (rubbers).

Tension is regulated by a field rheostat placed on the excitation.

The putting together of the three circuits, at 120 deg., is done in triangle, and each one is formed of 82 coils, connected in series.

The efficiency in full charge reaches 94 per cent. The alternator is characterised by the regularity in electro-motive force at the terminals; the fall in tension between full load and no load does not exceed 4 per cent. for $\cos \phi = 1$.

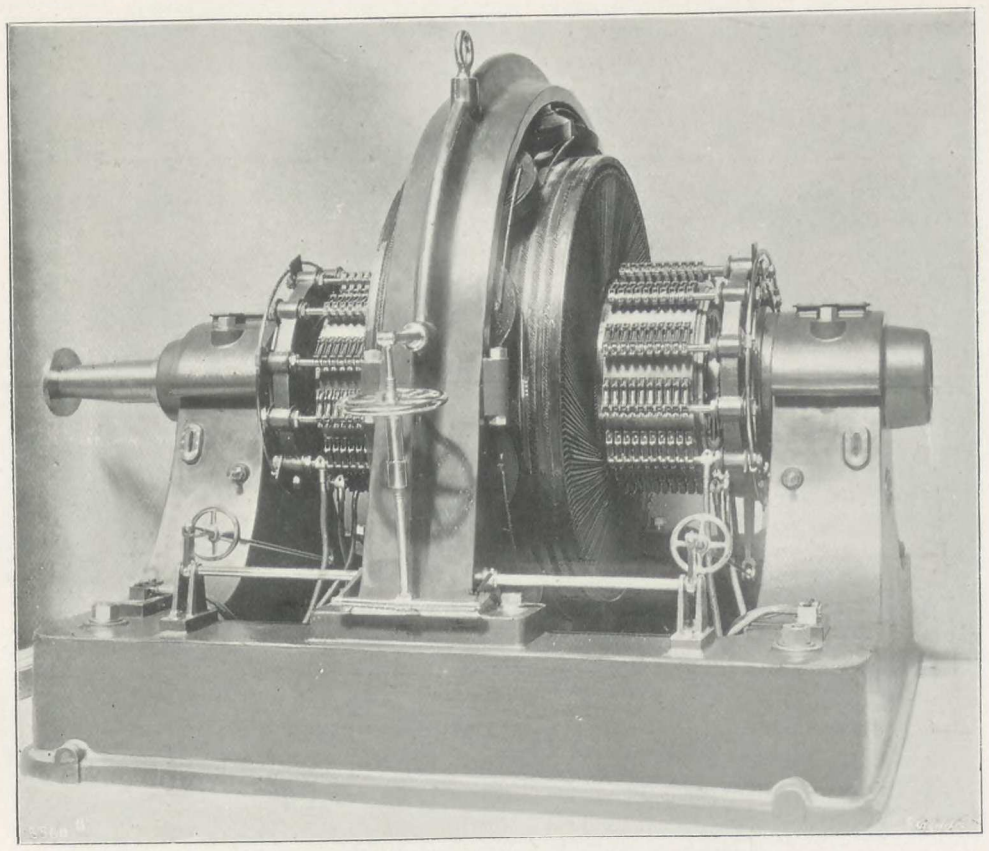


Fig. 1097. Continuous-Current Dynamo, 500 Horse-power.

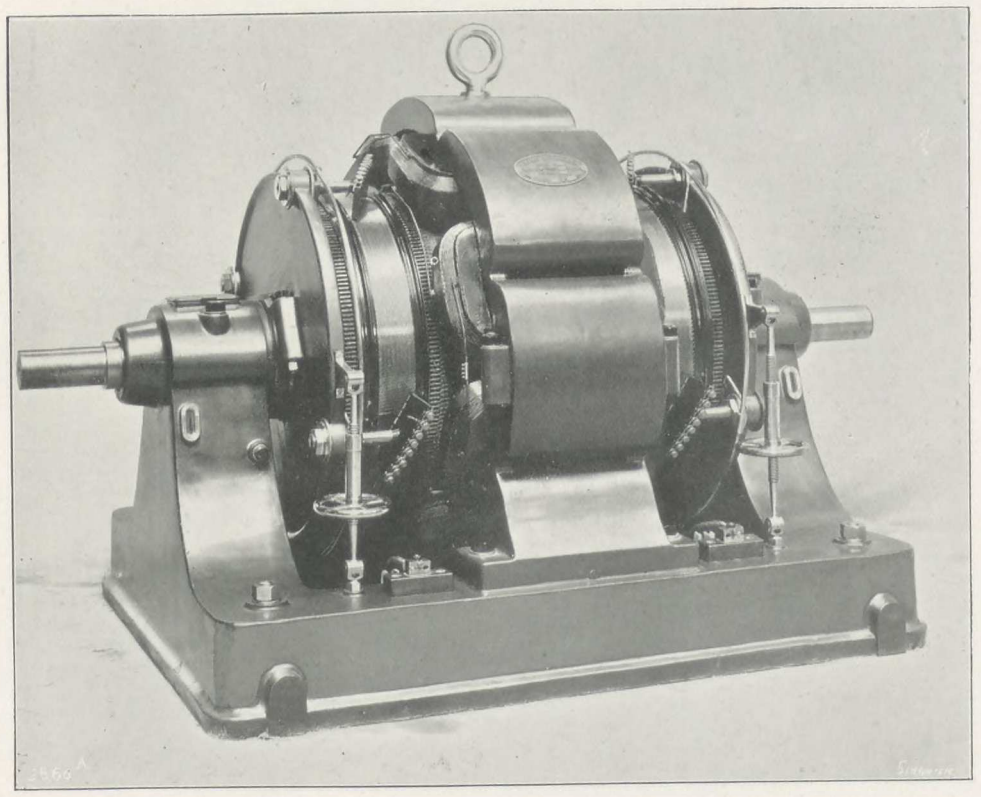


Fig. 1098. Continuous-Current Dynamo, Type S.

500 HORSE-POWER DYNAMOS.

A continuous-current dynamo intended for electrolytic work is illustrated in Fig. 1097. At a speed of 250 revolutions, it will furnish current of 3000 amperes at 110

volts. The armature is serrated and doubled, each being independent of the other, and connected to a commutator on each side of the armature. The current is collected by carbon brushes, which can be regulated simultaneously, or independently. As the armature windings can be placed in parallel or in tension, a current of 3000 amperes at 110 volts, or 1500 amperes and 220 volts, can be delivered at pleasure. The inductor, which has twelve poles, is of cast steel; it will be noticed that much care has been taken with the design to ensure rigidity.

There are four generators, of the type shown in Fig. 1098. This is the Schneider Company's S pattern. The principle features of this type are the very large commutators; the design is well considered throughout.

Steam is provided from 20 Niclausse boilers distributed in four groups, two forward of the engine and two aft.

Working pressure	18 kg.	256 lb. per sq. in.
Total grate area	102.1219 m.	110 sq. ft.
Total heating surface	3310.84 m.	33,519 sq. ft.

The total weight of machinery and boilers for the "Kléber," is 1275 tons, of which the engines account for 663 tons, and the boilers (filled with water) the remainder.

STEEL INGOTS.

A number of steel ingots were shown in the Pavilion, and a wooden model of the largest yet cast at Creusot, and which is reproduced in Fig. 1100. Particulars of the series are as follows:



Fig. 1100. 150-Ton Steel Ingot.

1. An ingot of Martin steel that had been compressed in the Creusot 10,000 ton press. The weight of this ingot is 29 tons; it is about 40 in. in diameter at the base, 36 in. in diameter at the top, and 16 ft. 4 in. long. The ingot is intended for gun manufacture; the pressure to which it was subjected during 2 hours 30 minutes was about 4500 lb per square inch; under this pressure the length was reduced by 20 in.

2. Facsimile of an ingot in wood, copper coated, so as to reproduce the exact surface of the original casting; the ingot is square at base and summit, the measurements being respectively, 7 ft. 2.61 in. and 6 ft. 6.74 in; the height of the lower part is 13 ft. 1.50, and of the upper

ENGINES OF THE FRENCH WARSHIP "KLÉBER."

One of the three sets of the engines for the French warship "Kléber" was shown in the Pavilion; each set of engines drives an independent screw. As will be seen from Fig. 1099, Plate CLXXVII., the engines have three vertical cylinders, and are triple-expansion. The valves of the cylinders are cylindrical; the high-pressure cylinder has one valve; the intermediate, two; and the low-pressure, four valves. The principal dimensions are as follows:

Diameter of high-pressure cylinder...	.860 m.	33.86 in.
,, intermediate ,, ...	1.255 m.	49.41 in.
,, low-pressure ,, ...	1.950 m.	77.77 in.
Length of stroke	.800 m.	31.50 in.
Number of revolutions	150	150

TRIPLE-EXPANSION ENGINES OF THE FRENCH WARSHIP, "KLEBER."

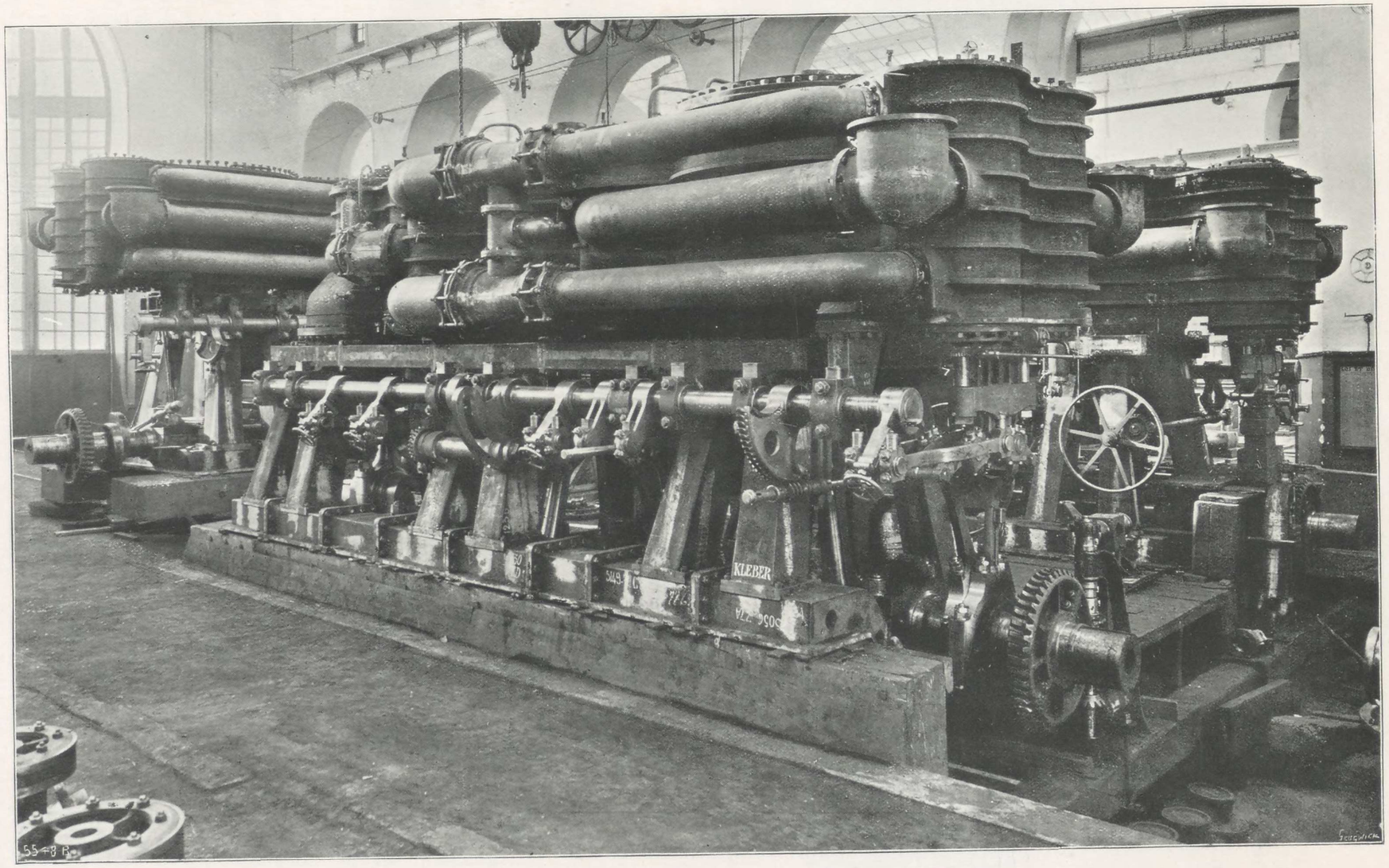


Fig. 1099.

part, 5 ft. 8.9 in. To cast this ingot five Siemens-Martin furnaces of 16, 30, 35, 40, tons were employed.

Fig. 1101 shows another example of cast and forged steel; the pieces shown form parts of a press used in Messrs. Schneider and Co.'s Works, to compress liquid steel. They were formed out of ingots having about 50 in. diameter, and weighing, one 55 and the other 36.5 tons. They were finished by forging on a mandril.

charts, equal to (17+7.85)=24.85 metres (81 ft 6 in.) below the average high-water spring tides.

Principal dimensions of caisson :

No. 1.—63×35.50 (206 ft. 6 in.×117 ft. 6 in.); weight, 730 tons.

No. 2.—10.50 × 24.30, average (34 ft. 6 in × 80 ft. average); weight, 90 tons.

No. 3.—10.50×11.80 (34 ft. 6 in.×38 ft. 6 in.); weight, 50 tons.

(*b*) The other set of caissons will be sunk to a depth

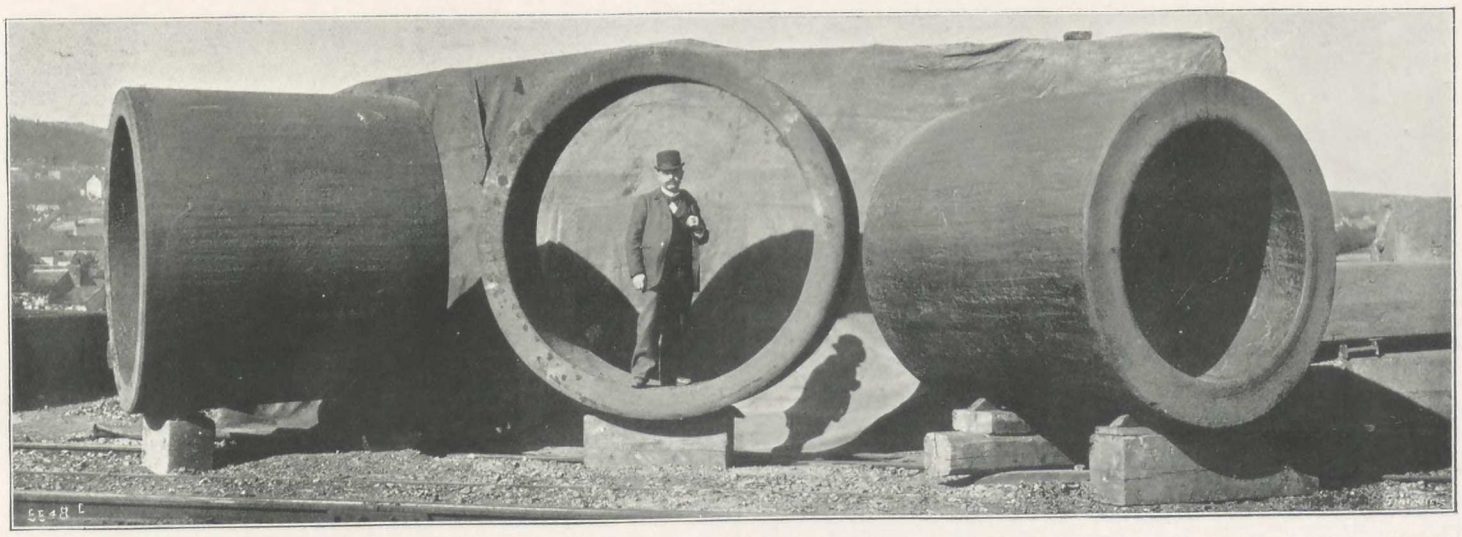
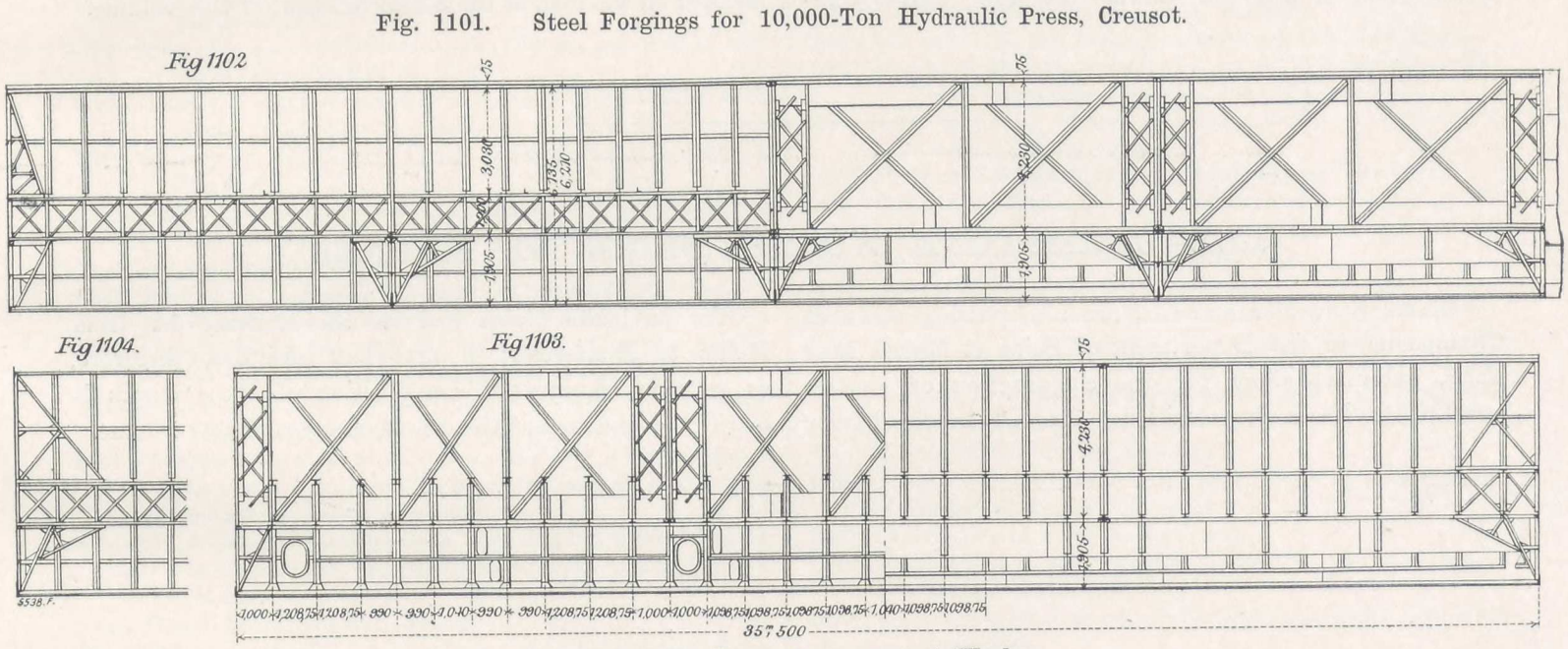


Fig. 1101. Steel Forgings for 10,000-Ton Hydraulic Press, Creusot.



Caisson for the Havre Improvement Works.

IMPROVEMENT OF HAVRE HARBOUR WORKS.

Head Works of the Wet-Dock Sluices.—This sluice forms part of a general programme for improving the conditions of Havre Harbour; it will transform the Eure and Bellot basins into full-tide wet docks; they can now only act as half-tide docks. The construction was given in 1899 to Messrs. Vigner and Schneider and Co., who tendered for it jointly.

The two head works will rest on iron caissons sunk by compressed air; each contains a main caisson, to which are fitted two other caissons of less importance, for establishing a junction with the adjoining quay walls.

(*a*) The caissons of the one head will be sunk to a depth of −17 metres (55 ft. 9 in.) below 0 of Havre naval of −9.50 metres (31 ft.), the No. 1 caisson, and of −7 metres (23 ft.) those of Nos. 2 and 3.

Principal dimensions of caisson :

No. 1.—65.10×32 (213 ft. 6 in.×105 ft.); weight, 700 tons.

No. 2.—17.50×23 (57 ft. 6 in.×75 ft. 6 in.); weight, 135 tons.

No. 3.—1.70×38, average (5 ft. 6 in.×124 ft. 6 in., average); weight, 210 tons.

The total measurement of the masonry is 85,000 cubic metres (3,000,000 cubic ft.). The work is now in progress.

The designs, processes to be followed in sinking the caissons, calculations of stability of resistance of the various parts under various conditions to be encountered, &c., were carried out jointly by Messrs. Vigner and Schneider and Co. The working designs of the construction of the caissons were completed by Messrs. Schneider and Co. at their Chalon yard.

LII.—CETTE WORKS (HÉRAULT).

Messrs. Schneider and Co. are putting down at Cette, on the Mediterranean coast, a very large plant for the manufacture of pig-iron, steel, and rolled bars and plates. These Works will be served by the Paris-Lyons-Mediterranean, and by the South of France Railways; by the Cette-Rhône and the South France Canals, and by the Cette Harbour. The position of these works is marked on the map at the commencement of this volume.

LIII.—CHAMPAGNE WORKS (SEINE ET MARNE).

Messrs Schneider and Co., are also putting down at Champagne, in the Department of Seine et Marne, near Paris, extensive shops for the construction of electric machines. These shops will be situated on the border of the navigable Seine and on the Railway line from Melun to Montereau; in first-class positions, therefore, as regards transport. The position of these works is marked on the map at the commencement of this volume.

LIV.—CHRONOLOGICAL TABLE.

A.D.	
1253	Henri de Monestoy sells to Hugues IV., Duke of Burgundy, the "Villa de Crosot."
1502	The existence of coal beds discovered in Creusot.
1769	Concession granted to Mr. de la Chaise, of the Creusot and Blanzy coal mines.
1781	Mr. Wilkinson, English engineer, and Mr. Toufaire, French architect, conclude in Creusot their designs concerning the construction of the Royal Foundry.
1782	Formation, under the patronage of Louis XVI., of a Company, for working the Royal Foundries of Indret and Montcenis (Le Creusot). (The King, Louis XVI., owned large interests in this Company.)
1785	Foundation, under the patronage of the Queen, Marie-Antoinette, of a Company for working the "Manufacture des Cristaux de la Reine."
1787	This Company is combined with the Royal Foundries of Indret and Montcenis.
1788	Trial of a gun manufactured with French cast-iron in substitution for English cast-iron.
1793	Creusot is made a separate "commune," independent of its ancient chief place, Le Breuil.
1793	Opening of the Central Canal, which unites the Saône to the Loire.
1793 to 1814	Creusot Works are appointed for the Manufacture of War Material, and are worked, from 1794 to 1797, for account of the Nation.
1805	Birth of Mr. J. Eugène Schneider, at Bidestroff (Meurthe).
1818	Mr. Chagot, Senior, purchases Creusot Works,
1826	Creusot Works are sold to the English Company Manby-Wilson. Formation of the Manby-Wilson Company.
1828	Formation of the Company for the working of the Mines, Forges and Foundries of Creusot and Charenton.
1835	The first Blast Furnace is in blast. The date of lighting cannot be traced; it appears to go as far back as 1830. Same remark as regards coke-ovens.
1836	Mr. J. Eugène Schneider, owner of mills at Bazeilles (Ardennes), and his brother, Mr. Adolphe Schneider, purchase Creusot Works.
1838	First Locomotive built in France.
1839	The Chalon Works are put down, for the construction of iron bridges and buildings, iron boats and craft.
1839	Building of the first Iron River Boat for service in France.
1840	Birth of Mr. Henri Schneider.
1840	Delivery to the Milan Railway of the first Locomotive built in France for a foreign country.
1840	Building of the first engines for a marine steamer for France.
1840	Invention and construction of the Steam Hammer.
1842	Purchase of the Perreuil Forges (Saône and Loire), transformed into fire-brick works.
1843	Building of first River Steamship for a foreign country.
1845	Death of Mr Adolphe Schneider.
1845	Mr J. Eugène Schneider is elected Member of Parliament for Saône and Loire (5th district), on the 13th September, 1847, and is re-elected on the 1st of August, 1846.
1851	Mr. J. Eugène Schneider is appointed Secretary of State for Agriculture and Commerce.
1852	Mr. J. Eugène Schneider is elected Député of the Corps Législatif, who appoint him one of their Vice Presidents.
A.D.	
1853	First Lighters built for navigation on the Rhône.
1853	The concession of the Mazenay Iron Mines is granted Messrs. Schneider and Co.
1855	Purchase of the Change Iron Mine, granted to Mr. Monnet, 19th June, 1852.
1855	First Iron Bridges built by Messrs. Schneider and Co., at their Chalon Works, for the Paris-Lyons Railway.
1855	Manufacture of armour plates for floating batteries.
1858	Swing-bridge for Cherbourg Harbour.
1861	Floating dock-gate for Brest.
1861	Commencement of works for the new Rolling Mills.
1863	Puddling is started at the new Rolling Mills, also the working of Mills numbers 8, 9, 10 and 11.
1865	Mr. J. Eugène Schneider is elected President of the Corps Législatif: office he holds up to 1870.
1865	Starting of Mill number 4, thick sheets and plates; of Mills 7, 8, 9 and 10, for thin sheets and slabs.
1866	Delivery of the first locomotives built in France for England.
1866	Starting of Mills numbers 1, 2, 5, and 6; of Sheet-mill number 3, and consequent stoppage of the Old Forge mills.
1866	Construction by Messrs. Schneider and Co. of their St. Laurent draining-pump.
1867	Mr Henri Schneider is appointed partner with his father.
1867	The Siemens-Martin steel process is started in the Rolling Mill department.
1867	Fourteen Blast Furnaces are in blast.
1868	Birth of Mr. C. P. Eugène Schneider.
1868	Manufacture of Siemens-Martin steel rails.
1869	Purchase of the Montchanin and Longpendu coal mines. The Montchanin coal mine formed part of the Creusot concession, from which it was separated in 1838. The Longpendu coal mine had been granted on the 6th October, 1832, to the Marchioness de Montaigu.
1869	Purchase of the Decize coal mines, which had been leased in 1836 to Mr. de Mallevault.
1869	Construction of Tug-boats for Russia.
1869	Construction of the first chimney built up of iron plates by Messrs. Schneider and Co.
1870	Construction of a group of Bessemer converters (two 6-ton converters).
1870	Stoppage of the manufacture of puddled iron at the Old Forge.
1870	Manufacture of Field-guns for France.
1872	Putting down of a second group of Bessemer converters (two 8-ton converters).
1873	Laying down of the Siemens-Martin steel plant (six 8-ton furnaces).
1873	Opening of the railway, to join the Decize coal mines with the Nivernais canal and the Paris-Lyons-Mediterranean Railway.
1874	Stoppage of the Siemens-Martin steel plant at the Rolling Mill department.
1874	Putting down of a third group of Bessemer converters (two 8-ton converters).
1874	Purchase of the Allevard Iron Mines.
1875	Erection of a 27-ton hammer for forging 95-millimetre guns.
1875	Construction of Siege and Garrison guns for France.
1875	Death of Mr. J. Eugène Schneider.
1875	Starting the manufacture of tyres for locomotives and wagons.

A.D.

1875, 1876 The workmen inhabitants of Creusot raise a private subscription for erecting a statue to Mr. J. Eugène Schneider. The statue was inaugurated in 1879.

1876 Putting down of mechanical puddling plant, containing two rotary puddling furnaces, Schneider patent system, for the production of superior quality iron, for the manufacture of gun and armour-plate steel.

1876 First competitive Firing Trials at Spezia. Substitution of mild steel for iron in the manufacture of armour plates.

1876 The patent Schneider Bolt is used for the fixing of armour plates.

1877 First transformation of No. 3 Plate-mill; use of Siemens gas-furnaces.

1877 Putting down of zincing plant at the Chalon Works.

1877 Building of iron work for the 1878 Exhibition hall.

1877 Taking out of a 76 years' lease for the St. Georges (Savoie) iron mines, seven concessions.

1877 Laying down of special plant for the manufacture of armour-plates and forgings for large-calibre guns, including:
One 100-ton Steam Hammer, with four furnaces and four cranes (three of 100 tons and one of 150 tons).
Casting pit for gun and armour-plate ingots.
Pit for hardening armour plates, served by a 100-ton traveller.
Machine shops for armour-plates.

1877 Supply to the Italian Navy of the armour for the "Duilio" and the "Dandolo."

1878 Construction of Field Bridges for the French Corps of Engineers.

1878 Construction of a 20-ton hammer.

1878 Putting down of a seventh Siemens-Martin furnace (20 tons).

1878, 1879 Construction of railway and inclines for working the Allevard iron mines.

1878, 1879 Construction of Armoured Turrets for France.

1878 Mr. F. de Lesseps sets fire to the blast-furnace which has been the longest in blast (seventeen years and seven months).

1879 Inauguration of Statue to Mr. J. Eugène Schneider.

1879 The manufacture of basic Bessemer steel is started.

1880 Putting down the plant for tempering gun forgings vertically.

1880 Building of furnaces for roasting the Allevard iron ore.

1881 Supply to the French Admiralty of the first Schneider metal armour-plates (for the "Terrible"), Messrs. Schneider and Co. thus overcoming all the difficulties they had met with up to that date.

1882 Second competitive trials at Spezia. The Schneider metal plate is the only one that withstands the firing of the 100 ton gun. The English plates are destroyed at the second round.

1884 Putting down of a 40-ton Steam Hammer.

1884 Building of Steam Launches for France.

1884 Transformation of No. 4 Plate Mill. Putting down of rolls three-high for plate rolling.

1885 Erection of 6000-ton hydraulic shaping-press for armour plates.

1885 Starting the manufacture of steel castings.

1886 Building of 35-metre Torpedo Boats for France.

1886 Messrs. Schneider and Co. cease rolling iron rails and heavy steel rails.

1887 First Torpedo-Boats built in Chalon yard for Foreign Governments.

A.D.

1887 Construction of bridges for Chili; the Malleco Viaduct and others.

1887 Starting of No. 2 Plate Mill. Special piling plant near puddling furnaces (Group No. 1).

1887 Provisional steel foundry plant near the Bessemer converters.

1888 Building of artillery shops.

1888 Nickel steel first used in the manufacture of armour plates.

1888 Starting the manufacture of Rolled Armour Plates. Transformation of thin sheet mills. Messrs. Schneider and Co. cease manufacturing thin iron sheets.

1889 Mr. Henri Schneider is elected Député for the second division of Autun.

1889 First delivery of nickel steel armour plates to the French Navy (for the "Dupuy-de-Lôme").

1889 Starting the Corliss Blowing Engines at Creusot blast furnaces.

1890 Firing trial at Annapolis (United States) of a Schneider nickel steel plate.

1890 Putting down the 2000-ton hydraulic forging press.

1890 The Blooming Mill starts working.

1891 Building the bridge over the Borcea (Roumania).

1892 Putting down of the Steel Foundry.

1892 Increase of the armour-plate finishing shop.

1893 Mr. Henri Schneider is re-elected Député for the second division of Autun.

1893 Putting down of an eighth Siemens-Martin furnace (25 tons).

1893 Enlarging the casting pit for heavy ingots; building of 150 ton electric traveller.

1893 Manufacture of Cemented Armour Plate.

1894 Construction of tunnel under the town, for transit between the Steel Works and the Rolling Mills.

1895 Application of electricity, as motive force at Rolling Mill department.

1895 Construction at Chalon yard of the first high-power tugs for service on the Rhône.

1895 Construction of new Tyre Shops.

1895 Construction of new shops for cementing and tempering armour plates.

1895 Construction of 30-ton Siemens-Martin steel furnaces to replace the older furnaces.

1895 Putting down of a 1200-ton hydraulic press for shaping armour-plates.

1895 Installation of electric motive-power at the Decize coal mines.

1896 Putting down of a 10,000-ton hydraulic press, for fluid compression sf steel.

1896 3000 ton hydraulic press, for forging on mandrils, of hollow cylindrical pieces (shafts, gun-parts, &c.).

1896 Mr. C. P. Eugène Schneider is appointed partner with his father.

1897 From 1836 to 1897, seventy-seven blast-furnaces have been put in blast.

1897 Building of special shops for electric construction.

1897 Construction of iron work for the Santiago (Chili) Railway Station.

1897 Purchase by Messrs. Schneider and Co. of the Havre Artillery Works, which belonged to the Société Anonyme des Forges et Chantiers de la Mediterranée.

1898 Commencing the sinking of the St. Antoine Pit, Creusot.

1898 Construction of new Artillery Shops, Creusot.

1898 Death of Mr. H. Schneider.

1899 The heavy Forging Shops are enlarged.

1900 Laying out of long-range Proving Ground at Harfleur.

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