ARMOUR-PLATES AT THE PARIS EXHIBITION.

By M. Baclé, Paris.

Armour-plates were shown at the Paris Exhibition by all of the French steel works at which they are manufactured, and by four foreign exhibitors. The list is as follows:

French.

1. MM. Schneider et Cie., Creusot.
2. The Compagnie des Forges et Acieries de la Marine et des Chemins de Fer, St. Chamond.
3. MM. Marels Frères, Rive de Gier.
4. Compagnie des Forges de Chatillon Commentry et Neuves Maisons, Montluçon.
5. Compagnie des Acieries de St. Etienne, Le Marais.

Foreign.

6. The Don Steel Works (Messrs. Vickers, Sons, and Maxim), Sheffield.
7. The Houkoff Works, Russia.
8. The Kolpino Works, Russia.
9. The Italian Works of Terni.

The absence of a number of very important makers was to be regretted, such as Messrs. Cammell and Messrs. Sir John Brown and Co.; the Bethlehem Steel Works, and the Carnegie Works; and before all, perhaps, Fried. Krupp, of Essen. In spite of these abstentions, the exhibits of armour-plates was of extreme interest, for it included types of all the material used, from the old puddled iron slabs to the latest Harvey and Krupp processes of cemented steel. So that, although there were many regrettable absences, the history of the progress of making armour-plates could be traced back to its origin about forty years ago, and not the history of the plates alone, but that of projectiles and explosives also, the means of attack which have ever kept a little ahead of those of defence. There was, it is true, one serious gap in the large series represented at the Exhibition: the compound plate, to which our Admiralty clung so tenaciously for a number of years, was absent; it has practically passed into the region of history, and has been entirely replaced by cemented steel, which offers resistance to penetration and hardness of surface greater than was possible with the best compound armour. It was, indeed, impossible to harden the steel face of compound armour sufficiently to resist the attack of the chrome steel projectiles of the present day, although it offered considerable powers of resistance to the chilled iron, and cast-steel shell used by the Navies of a dozen years ago. It is interesting to recall the fact that compound armour occupied a very important place in the Paris Exhibition of 1889, and that at the recent Exhibition, the smaller thickness of the plates shown, compared strikingly with the far more massive plates of eleven years ago, illustrating the higher resistance of the improved material, against the improved projectiles of to-day.

At the recent Exhibition none of the enormous masses of the earlier time, were met with; in fact, thicknesses of from 25 to 30 centimetres (9.84 in. to 11.81 in.) were rarely exceeded in the plates exhibited. The special characteristic, indeed, was the great number of relatively thin plates made with metal of varying properties, and specially adapted to the numerous requirements of present naval practice, for the protection of the upper works of ships, independently of the main side armour and turrets. Such are the plates of 3 centimetres (1.18 in.) for deck protection or for gun shields, up to those of the greater thicknesses named for the main belts. To reduce weight and increase the power of resistance, are the two great aims of the modern makers of armour-plates. The examples shown at the Exhibition were the latest results of incessant investigations and experiments carried on at all armour-plate works, and if the dimensions were such as failed to appeal to the general visitor, the characteristics possessed a special interest to the technical and scientific student. All the progress that has been realised in this branch of metallurgy during the last 20 years is based on the physical character of the steel, and the power of resistance increased by various alloys and methods of production. It should not be forgotten that the unceasing attention and steady advance in this industry, which is solely for purposes of war, and for the benefit of governments, has reacted also on the commercial side of the steel industry, and has secured to industry higher qualities, and on the whole cheaper production. For this reason the manufacture of armour-plates possesses an interest far wider than its immediate and restricted field, and exercises an important influence on the whole range of the metallurgy of steel, inasmuch as its object is to produce a higher quality of metal qualified to resist severe physical and chemical tests.

As already said, the collection at the Exhibition included examples of all the types of plates made for armouring ships or fortresses, with the exception of the compound plate. Thus, for example, there was shown the old puddled iron plate, long since abandoned in the Navy, but still used for coast defence. Chilled cast iron and cast steel have never found any practical application in the Marine, but, on the other hand, they have been largely used for the fixed armour of land forts; in the forms of cupolas and land turret plates, they were represented at the Exhibition. They possessed, perhaps, rather a retrospective than an actual interest. On the other hand, all examples of the metal employed in the manufacture of armour-plates and the plates themselves—the demand for which seems always to be greater than the supply with all nations possessing a navy—were of the highest interest. It would be too long a task to describe all of the exhibits, but a general review may be undertaken, and with this object it will be convenient to divide the examples into the four following types:

1. Extra soft metal characterised by perfect homogeneity and a higher grade of ductility than that of puddled iron, possessing at the same time a greater power of resistance to perforation, exceeding that of iron by about 15 per cent. Such metal, on account of its high malleability is to-day exclusively adopted in the French Marine in the construction of armoured decks.

2. Special steel containing a small proportion of chrome and nickel, possesses a power of resisting penetration higher than that of ordinary steel, amounting, if referred to the velocity of the projectiles or "speed of perforation," to from 12 to 15 per cent. This metal possesses remarkable tenacity, and can resist a very heavy attack without fracture. It is used by the French Marine in the preparation of plates which cannot be made of cemented steel; the process of tempering cemented steel plates produces deformations, which in some cases cannot be corrected. Such cases are found in thick and considerably bent plates, such as those for the extreme forward part of an armour belt; or in relatively thin plates, 10 centimetres (3.94 in.) or less, and which are peculiarly liable to deformation.

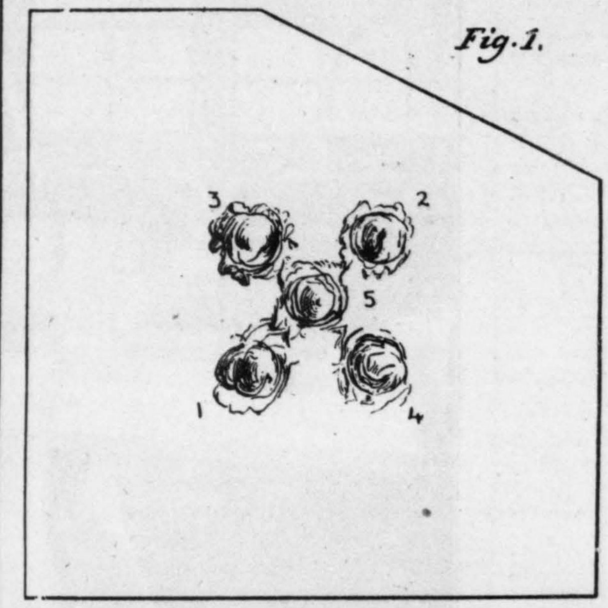
3. Hard steel, in which the proportion of chrome has been increased to produce additional hardness, and at the same time greater resistance. The effect of the nickel is to increase tenacity without adding to the resistance properly so-called; and it is the action of the chrome alone which adds to the resistance. In any case, the metal so prepared is extremely hard, rendering its fashioning very difficult, so that it can be used only for plates having a thickness of 7 centimetres (2.76 in.) or thereabouts. With this steel plates are produced having a resistance to velocity of perforation from 20 to 25 per cent. greater than that of ordinary steel rolled to the same thickness. In the French Marine such plates are chiefly used as shields to protect artillery and men as well as for the roofs of turrets.

4. Cemented steel is a special metal, the surface of which is hardened by a cementing process at a high temperature, and continued long enough to penetrate to a depth of about 2 centimetres (.79 in.). The cementation process is followed by tempering with jets of cold water striking on the prepared surface. This imparts great hardness to the cemented surface, so that it cannot be touched by a cutting tool. A plate so prepared may break up a hard chrome steel shell. As the plate, apart from its cemented surface, is of relatively soft steel with a slight dosage of chrome, it can be worked almost as easily as the special steel as long as it is not tempered, so that plates of maximum thickness can be made by this process, while the thin plates are made exclusively from hard steel with a larger proportion of chrome. Such cemented plates can generally be depended on to break up chrome steel projectiles when these latter are not fired with a velocity sufficient to traverse the cemented surface without themselves breaking up, and it may be estimated that this metal possesses a velocity of perforation more than 50 per cent. greater than that of ordinary steel. This high power of resistance, however, is considerably reduced when the attacking projectile is "capped," which often enables it to penetrate the cemented surface without breaking, and in such a case the velocity of perforation must be taken at from 35 to 40 per cent., instead of 50 per cent., when compared with ordinary steel. Wherever possible cemented steel is used for the thickest armour-plates, and the examples sent to the Exhibition were of the highest interest and importance.

The original cementation process applied to armour-plates is due to Harvey, and his process is for the most part followed by manufacturers, as was evidenced by the specimens exhibited. At some works, however, modifications have been introduced, with a view to increasing the resisting power of the plates. Thus, Creusot has adopted a gas process, and Krupp has made important changes that have largely increased the tenacity of the plates. The Italian works of Terni have adapted a process securing similar advantages; these works showed some particularly interesting specimens at the Exhibition, the more interesting since there were but very few examples of the Krupp process.

We may now proceed to examine in detail the more important of the exhibits, especially with regard to their power of resisting attack, as measured by the "speed of perforation" of a puddled iron, or ordinary steel plate, determined by the formulæ of Colonel Jacob Marre. The impact of the projectile is thus given immediately by the ratio of the effective velocity to this velocity of perforation. This mode of comparison was adopted by the writer twelve years ago in various investigations published by him, and especially in his recent work on *Plaques de Blindage*. The method has the advantage of furnishing very simple and very significant coefficients, and it has been somewhat widely adopted.

Iron Plates.—The use of puddled iron for protective plates has, as we have already said, entirely disappeared in naval construction, and is only used to a limited extent in land fortresses; on this account only two examples of iron plates were to be seen at last year's Exhibition; in that of 1889 such plates were numerous. The first was exhibited by Messrs. Schneider and Co., of Creusot, and was one of a lot of rolled plates, delivered to the Belgian Government for forts at Namur and Liège; it possessed rather retrospective than actual importance. The diagram (Fig. 1) refers to this plate, which was tested



Wrought-iron plate, 7.87 in. thick. Tests made for the Belgian Government, April 9, 1890. Chilled cast-iron projectile, 86 lb.; velocity, 1090 ft.; gun, 15 cent. (5.90 in.).

on April 9, 1890; it is 1.270 metres long, 1.320 metres wide, and 200 millimètres thick (50 in. by 51.97 in. by 7.87 in.). The plate had been subjected to the Belgian Government firing tests, which were similar to those imposed by the French Ministry of Marine for corresponding plates. The projectiles used were chilled cast iron weighing 39 kilogrammes (86 lb.), with a velocity of 332 metres (1090 ft.); five rounds were fired, one at each corner, and one in the centre, of a square measuring 250 millimetres (9.84 in.) on a side. The chief object in view was to test the malleability and toughness of the metal, and the results were certainly satisfactory, only slight cracks appearing on both faces: the tears surrounding the impact marks will also be noted; these do not appear on the extra soft steel plates when similarly tested, as will be seen later on. Such plates, when fired at, show very regular impact marks, an entire absence of cracks, and a homogeneity that is always absent in the iron plates, the contrast being greater on thin plates, those of 2 in. or $2\frac{1}{2}$ in. and less, always failing in a manner never seen in the soft steel plates similarly tested.

The second example of an iron plate was sent by the works of St. Chamond; it was 220 millimetres thick (8.66 in.), and had been tested by eight 6.10 in. projectiles at ordinary velocities, and had stopped them without showing any cracks. This plate furnished a very interesting example of the effect of oblique fire, as two deep furrows had been ploughed in it by two other projectiles fired at a very slight angle to the surface. The plate was bulged at the back, but, as already said, no cracks appeared, a striking evidence of the excellence of the metal. Besides these two plates, there was at the Exhibition one other example of the application of wrought iron to armour protection. This was furnished by the roofs of two cupolas, sent by the Compagnies des Forges de Chatillon Commentry et Neuves Maisons. The one was a disappearing cupola, with two 2.56-in. quick-firing guns, and the other a turret armed with one 8.26-in. howitzer. Both these are for land defence, showing that the use of wrought iron for this purpose has survived until the present. Indeed many such cupolas made in France during the past ten years for foreign Governments—especially in Belgium at the entrenched camps of Namur and Liège; in Roumania, for those of Bucharest; in Switzerland, Denmark, and elsewhere—are fitted with wrought-iron roofs, in spite of the fact that soft steel had given far better results than the iron. There is, however, a reason for this adhesion to apparently inferior material. In the course of comparative experiments in France to determine the relative values of iron and soft steel to resist the effects of high explosives, it was found with the detonation of a charge of mélinite in contact with soft steel and iron plates, that the damage sustained was much greater with the former than the latter, and it was the result of such experience that decided the continued use of the iron for the purposes named. This somewhat contradictory result is due to the fibrous character of the iron which enables it to resist the effect of sudden shocks by distributing the strain over a larger area than is possible for a crystalline structure. With cast metal having a homogenity and local strength much greater than that of the iron, the physical structure is not able to distribute the effect of the sudden explosion, and this being concentrated in its intensity, the resulting damage is much greater. Probably the same differences would not exist in steel plates containing a relatively high proportion of nickel, and which appears to give a fibrous texture, and thus endows the plate with the advantage of greater tenacity, besides the perfect homogeneity characteristic of the steel. It would be interesting if a new series of experiments bearing on this question were carried out, such as would be necessary if any country undertook the establishment or reconstruction of armoured land forts.

(*To be continued.*)

ARMOUR-PLATES AT THE PARIS EXHIBITION.

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(*Continued from page 68.*)

Chilled Cast Iron.—This material has never found any application in the armour-plating of ships; on the other hand, it has been, and is, very extensively used in the construction of land defences. Reduction of weight being of no importance for such work, it can be employed of any thickness that may be found desirable, while complicated forms can be obtained, and a power of resistance to attack that is quite remarkable; on account of these characteristics it is specially suitable for casemates, the fixed walls of revolving turrets, &c. The chilled surface obtained by the process of manufacture was sufficiently hard to insure the breaking up of cast-iron projectiles and even of chilled-iron shells; crucible chrome steel shells, however, are able to break up the hardened surface, and with the introduction of this means of attack, the chilled-iron plate has lost much of its value as a method of defence. In the circular form of the land fort an additional safety was obtained, from the fact that it was almost impossible for a shot to strike normally to the plate, and the ogival head of the projectile glanced off after ploughing a furrow on the hardened surface. This advantage, however, is now lost by making the chrome-steel projectile cylindrical and flat-headed, instead of pointed; with such an attack the hardest plate can very speedily be shattered. For this reason it appears evident that the chilled cast-iron plate must be abandoned as a means of land defence, and give place to cast steel possessing higher tenacity. At the Exhibition there were only two specimens of chilled cast-iron plates; they formed parts of cupolas made by the firm of Chatillon-Commentry, and have been already referred to.

Cast Steel.—This material, which is now finding an increased application for the outer works of armour-clad land forts, is also employed for the roofs of cupolas in comparatively thin plates. The Exhibition contained one example of such a roof for a disappearing turret, in which were mounted two 57-millimetre guns. It formed one of the Schneider exhibits, and had been built by that company for the Roumanian Government. This plate is illustrated by the diagram Fig. 2; it is

Fig. 2.

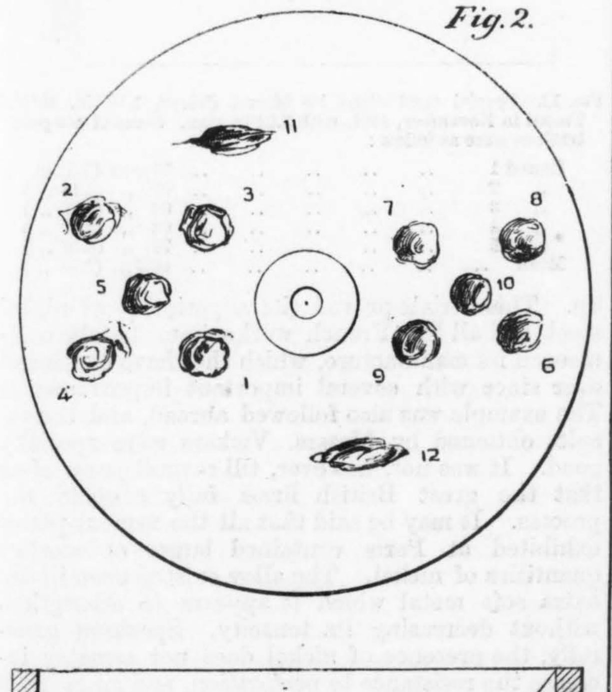

FIG. 2. 4.72-in. cast-steel Schneider roof of land turret for the Roumanian Government; for disappearing 57-millimetre gun. Particulars of test.

Number of Rounds.	Projectile.	Gun.	Weight of Projectile.	Velocity.
1, 2, 3, 4, 5	Chilled cast iron	95 mill. (3.74 in.)	11.4 kilos. (25 lb.)	349 m. (1145 ft.)
6, 7, 8, 9, 10	Holtzer steel	95 mill. (3.74 in.)	14.0 kilos. (30.8 lb.)	360 m. (1181 ft.)
11, 12	Angle of incidence. 30 deg.		14.0 kilos. (30.8 lb.)	400 m. (1312 lb.

1.750 metres in diameter and .120 metre thick (69.9 in. by 4.72 in.). As shown on the diagram, it had been tested by ten rounds from a 95-millimetre gun at short range. The shots were planted very close together, and the entire absence of cracks after this severe test is ample proof of the tenacity of the metal. The ten rounds were divided in two series of five, and were delivered at each corner, and in the centre, of a square of 30 centimetres (11.81 in.) a side. The system of test was that of the French Marine already referred to and illustrated in Fig. 1. The first five rounds fired were chilled iron projectiles weighing 11.4 kilogrammes and having a velocity of 349 metres (25 lb.). The second series were Holtzer steel projectiles weighing 14 kilogrammes (30.8 lb.) and having 360 metres velocity (1181 ft.). Even under this severe test the plate showed no cracks. Two other rounds were then fired obliquely at the plate; these ploughed grooves in the surface without doing any other damage. MM. Schneider and Co. also exhibited a flat plate of cast steel; this was 1.500 metres long and .800 metre wide (59 in. by 31.50 in), the thickness being 120 millimetres (4.72 in.); this was a test-plate made at the same time as a large batch for the fortifications of Bucharest; it is illustrated by Fig. 3. It will be

Fig. 3.

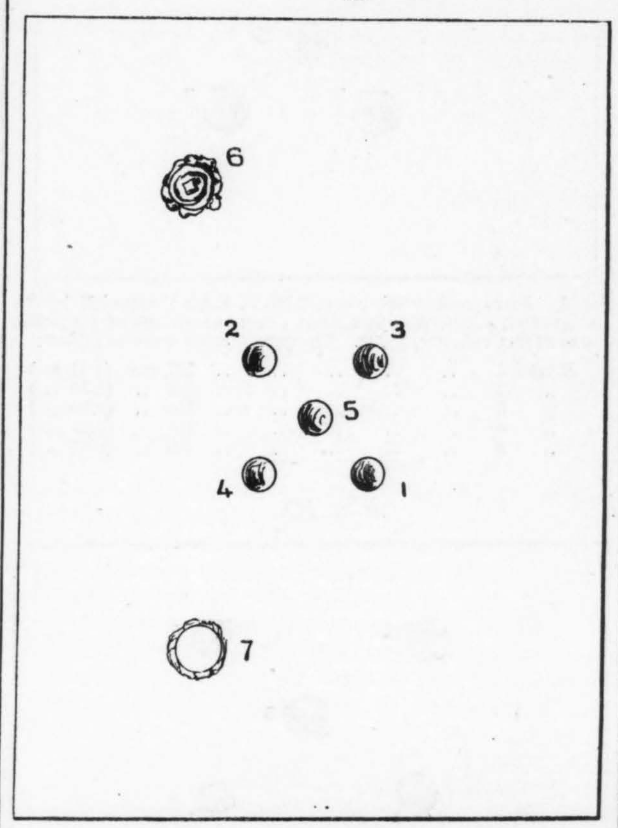

FIG. 3. Armour-plates for cupolas; Bucharest fortifications. Cast-steel plate 4.72 in. thick. Tested January 12, 1892, and May 27, 1899.

Number of Rounds.	Projectile.	Gun.	Weight of Projectile.	Velocity.
1, 2, 3, 4, 5	Chilled cast iron	95 mill. (3.74 in.)	11.4 kilos. (25 lb.)	349 m. (1145 ft.)
6, 7	Holtzer steel	120 mill. (4.72 in.)	21 kilos. (46.2 lb.)	398 m. (1305 ft.)

seen that this plate was fired at five times in the same way as the one last referred to; the projectiles were chilled cast iron weighing 11.40 kilogrammes (25 lb.), the velocity was 349 metres (1145 ft.); the gun was 90 millimetres bore; afterwards, further tests were made by firing two rounds of steel 120-millimetre (4.72 in.) shells weighing 21 kilogrammes (46.2 lb.), the velocity being 398 metres (1305 ft.). These, like the preceding, were resisted by the plate, that showed no signs of cracking.

The Montluçon Works also exhibited a cast-steel test-plate that was of special interest. It was exhibited with its casting head, and had been subjected to the standard trials of the French Marine prescribed for deck armour-plates. As will be seen from the diagram. Fig. 4, it passed through these tests without showing any cracks or tears. These exhibits demonstrated in a remarkable way the improvements that have been made in the manufacture of cast steel of that special quality required to resist such tests as those imposed, and which prove that the metal possesses a degree of tenacity that, a short time ago, it would have been supposed impossible to obtain by the process of manufacture.

Ship Armour: Extra Soft Plates.—This quality of steel was exhibited for the first time at the Paris Exhibition of 1889 by the Montluçon Works, which, after a long and costly series of trials, had succeeded in producing a metal possessing a malleability that had seemed to be the exclusive characteristic of puddled iron. The results obtained at Montluçon led the French Marine to adopt cast metal for armoured deck-plates; and all the armour-plate manufacturers in France soon arrived at the satisfactory production of such plates. At the recent Exhibition there were numerous examples—about 15 in all—of this extra soft metal, that had, in the form of plates, been subjected to proof. In fact all, or nearly all, of the French armour-plate makers were contributors: Creusot, Saint Chamond, Rive

Fig. 4.

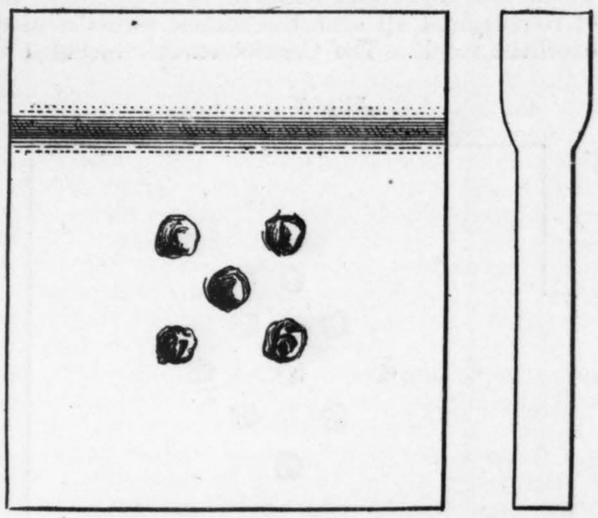

FIG. 4. Cast-steel Montluçon plate; 200 millimetres (7.87 in. gun, 165 (6.49 in.); velocity, 3.55 metres (1164 ft).

de Gier, Montluçon, Saint Etienne, &c., and even others such as Commentry-Fourchambalt, who do not make a speciality of this class of work. Want of space will prevent us from referring to each of these exhibits, but we will select five for description and illustration as typical of the whole, and of a branch of manufacture which has been brought to a high pitch of perfection in France.

The first is a plate that was sent by MM. Marrel Frères; it was 30 millimetres thick (1.18 in.), and was a test-plate from the lot that will form the deck of the Gueydon (see Fig. 5). The rounds fired

Fig. 5.

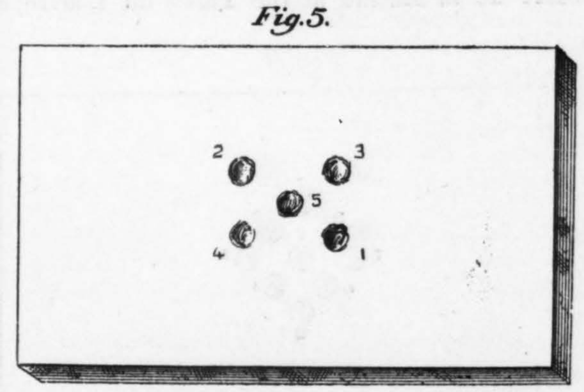

FIG. 5. Extra soft steel plate 30 millimetres (1.18 in.) Marre Frères; deck plates of the Gueydon, tested January 6, 1899 gun, 100 millimetres (3.94 in.); velocity, 132 metres (433 ft.). The penetration was as follows:

Round 1	44 mm. (1.73 in.)
" 2	44 " (1.73 ")
" 3	45 " (1.77 ")
" 4	45 " (1.77 ")
" 5	50 " (1.97 ")
Mean ..	45.5 " (1.79 ")

Fig. 6.

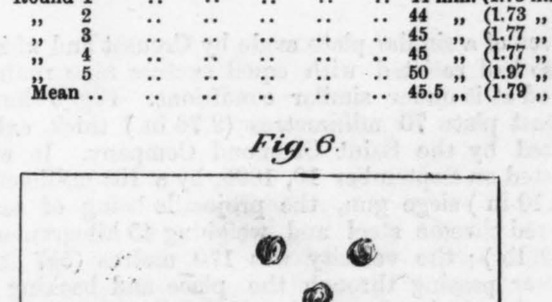

FIG. 6. Deck plate 2.44 in. for the Russian cruiser Aurora by Chatillon-Commentry; extra soft steel. Test, February 17, 1899. Gun, 6.45 in.; velocity, 502 ft. The penetration was as follows:

Round 1	72 mm. (2.83 in.
" 2	60 " (2.36 ")
" 3	71 " (2.80 ")
" 4	71 " (2.80 ")
" 5	74 " (2.91 ")

from a 100-millimetre gun (3.94 in.) at the plate, had a velocity of 132 metres (433 ft.). The projectiles, of course, passed through, punching the plate, but in no way tearing it or producing cracks which are so frequently the result of firing at thin plates. Next followed two other examples of extra soft metal from the Montluçon Works; one of these was a plate 62 millimetres (2.44 in.) thick; it represented the deck plating for the Russian cruiser Aurora, and was tested to the requirements of the French Marine. Five rounds were fired at it from a 164-millimetre (6.45-in.) gun. Only some of these passed through the plate. The other specimen was a test plate 65 millimetres (2.56 in.) thick; nine rounds (see Fig. 7) were fired at this plate at close range from a 160-millimetre (6.29-in.) gun; no cracks resulted from this severe test, which was afterwards followed by a large number of rounds fired all over the surface with a similar excellent result. The Creusot exhibit included a

Fig. 7.

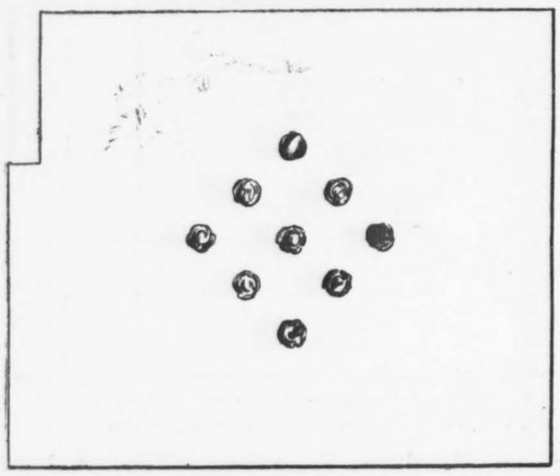

FIG. 7. Deck plate, 2.56 in.; gun, 6.29 in.; velocity, 534 ft.

similar plate which had also received nine rounds without showing any cracks. This was the test plate selected from those made for the deck of the Desaix; it is of nickel steel 50 millimetres (1.97 in.) thick, and was fired at by a 100-millimetre gun with nine Holtzer projectiles weighing 14 kilogrammes (30.8 lb.), and having a velocity of 185 metres (607 ft.). It is shown in the diagram, Fig. 8. It may be mentioned that there is in the Musée de la Marine at the Palais du Louvre, a

Fig. 8.

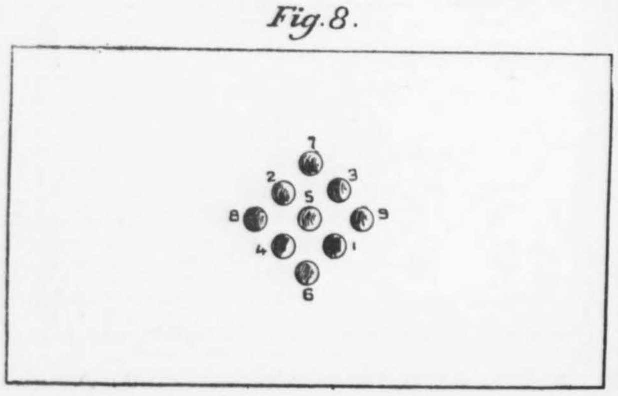

FIG. 8. Test plate, for deck of Desaix; nickel steel, 1.97 in. thick, supplied by Schneider. Tested January 20, 1900. Gun, 3.97 in.; projectile, Holtzer steel, 30.8 lb.; velocity, 607 ft.

piece of a similar plate made by Creusot and which also had resisted with equal success nine rounds fired at it under similar conditions. Fig. 9 shows a test plate 70 millimetres (2.76 in.) thick, exhibited by the Saint Chamond Company. It was tested on September 19, 1895, by a 155-millimetre (6.10-in.) siege gun, the projectile being of tempered chrome steel and weighing 45 kilogrammes (99 lb.); the velocity was 170 metres (557 ft.). After passing through the place and backing to depths varying from 104 to 112 millimetres (4.09 in. to 4.40 in.), the projectiles rebounded entire and the plate showed no cracks.

Steel Plates.—To complete its history of the manufacture of armour plates, MM. Schneider and Co. showed a specimen of ordinary steel plate of which this firm were the sole makers during the ten years from 1880 to 1890. It will be remembered that the Creusot firm was the first to manufacture the all-steel plates, and that the earliest public trials were those carried out by the Italian Government in concurrence with the compound plates. It was the result of these trials that left no doubt as to the superiority of the former. The steel plate that was shown by MM. Schneider at Paris was 9.84 in. thick. It was tested on June 14, 1897, and is represented in Fig. 10. Five rounds were fired from a 15-millimetre gun (5.90 in.). The projectiles weighed 45 kilogrammes (99 lb.), and the velocity was from 580 to 585 metres (1900 ft. to 1918 ft.). Three of the shells were of Holtzer make, and were thrown back from the plate without penetrating. The other two were of chilled cast iron, and were shattered by the impact leaving the pointed heads in the plate which showed no signs of cracks.

Nickel Steel.—The firing tests against plates that were conducted at Annapolis in 1890 were interesting as marking a new departure—the use of nickel steel in lieu of the ordinary steel that had been used prior to that date; and further, the abandonment of the compound types. In the Exhibition

Fig. 9.

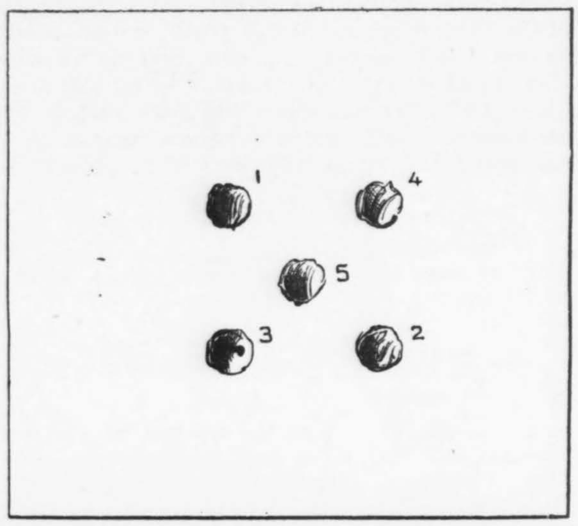

FIG. 9. Extra soft steel plate, 2.76 in. thick; supplied by St. Chamond, and fired at by 6.10-in. gun; the weight of projectile was 99 lb.; velocity, 557 ft. The perforations were as follow:

Round 1	107 mm.	(4.21 in.)
„ 2	112 „	(4.40 „)
„ 3	104 „	(4.09 „)
„ 4	107 „	(4.21 „)
„ 5	109 „	(4.28 „)

Fig. 10.

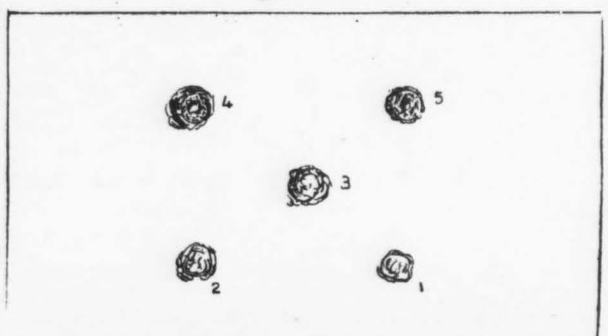

FIG. 10. Schneider steel armour-plate for the Spanish cruiser Cataluna, 250 millimetres (9.84 in.) thick. Tested June 14, 1897. Rounds 1, 2, 3; Holtzer projectile, 5.90 in. in diameter, weight 99 lb.; velocity, 1900 ft. to 1918 ft.

there was only one example of the former, and none at all of the compound plate. The Creusot pavilion contained a sister plate to that historical one of nickel steel that figured at Annapolis; it had been subjected to almost the same test as the American plate, and presented practically the same appearance after the trials. Fig. 11 is a diagram.

Fig 11.

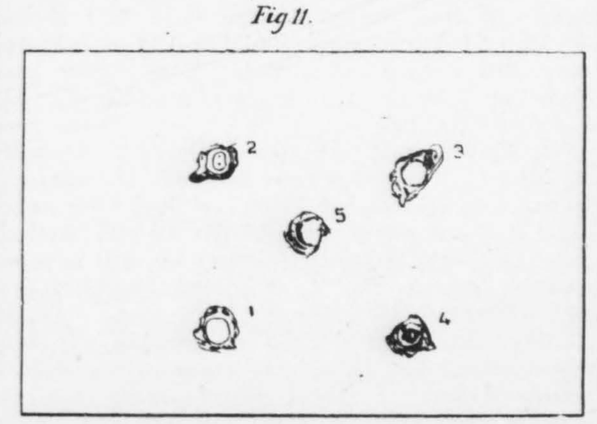

FIG. 11. Nickel steel plate 9.92 in. thick; tested June 11 and 14, 1890. Projectiles, Holtzer steel 5.90 in. in diameter, weight 99 lb; velocity, 1951 ft. to 1974 ft.

The plate, which is 252 millimetres (9.92 in.) thick, is 2.450 metres long and 1.850 metres wide (8 ft. 0.5 in. by 72.84 in.). Five Holtzer steel projectiles were fired at it from a 150-millimetre gun. The weight of the shell was 45 kilogrammes (99 lb.), and the velocities varied from 595 to 605 metres (1951 ft. to 1974 ft.), thus exceeding from 5 to 25 metres the speed of perforation of ordinary steel, which attains 590 metres. The plate thus tested stopped two of the projectiles with a velocity of 595 metres, and was traversed by the other three, so that its speed of perforation is in the vicinity of 600 metres, and corresponding to a coefficient of 1.02 compared with ordinary steel. It will be remembered that the Annapolis plate was first attacked by four projectiles fired from a 152-millimetre (5.98 in.) gun at a velocity of 632 metres (2075 ft.), corresponding to a coefficient of 1.01; then with a fifth 203 millimetres (round from a gun 7.99 in.) calibre and 564 metres (1850 ft.) velocity; this corresponded to a coefficient of 1.07; all these shots were stopped without the plate showing any cracks. The ordinary steel plate, on the other hand, tested at the same time and under the same conditions, was broken at the fifth round into four pieces by two diagonal cracks, and the compound plate was also broken

Fig 12.

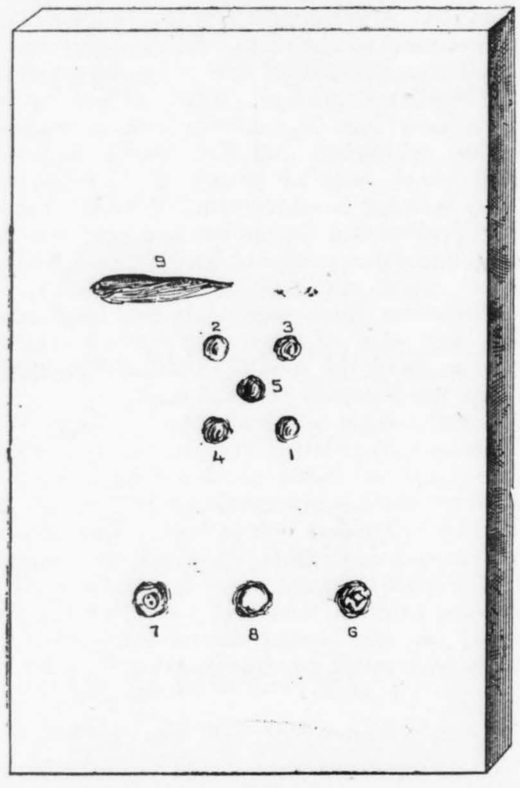

FIG. 12. Special steel plate by Marrel Frères, 1.58 in. thick. Tested in November, 1891, with 3.94 in. gun. Some of the penetrations were as follow:

Round 1	59 mm.	(2.32 in.
„ 2	63 „	(2.48 „)
„ 3	66 „	(2.60 „)
„ 4	66 „	(2.60 „)
„ 5	78 „	(3.07 „)
Mean	66.4 „	(2.61 „)

up. These trials proved the superiority of nickel steel, and all the French works immediately commenced its manufacture, which they have continued ever since with several important improvements. The example was also followed abroad, and the results obtained by Messrs. Vickers were specially good. It was not, however, till several years after that the great British firms fully adopted the process. It may be said that all the armour-plates exhibited at Paris contained larger or smaller quantities of nickel. The alloy existed even in the extra soft metal which it appears to strengthen without decreasing its tenacity. Speaking generally, the presence of nickel does not sensibly increase the resistance to perforation, and since 1889 the investigations have been constant to discover new alloys to produce this result. Of this order is the chrome plate sent by the Montluçon Company, and referred to above; this plate was made in 1889.

The diagram Fig. 12 is the sketch of a plate exhibited by MM. Marrel Frères; it is 140 millimetres (1.58 in.) thick, and was tested in November, 1891, under the usual conditions of French deck-plates; it showed no cracks and a remarkable power of resistance. After the official trials it was fired at a number of times with increasing velocities to determine the speed of perforation, which was found to be about 5 per cent. above that of ordinary steel; oblique fire only ploughed this plate without cracking it. Several other works obtained similar results with chrome steel, as was evidenced by the samples exhibited at Paris.

(*To be continued.*)