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Present Position of the Armour Question

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Friday, February 8, 1884.

VICE-ADMIRAL H. BOYS, Member of Council, in the C

PRESENT POSITION OF THE ARMOUR QUES'

By Captain C. ORDE BROWNE, late Royal Artillery, Lec
Armour Plates, Department of Artillery Studies, Woolv

THE chief object of this paper is to call attention to featur
present position of the armour question that appear to be pec
of great importance. In support of the data on which such
sions are based, I propose to give, as briefly as possible, the
certain experiments conducted during 1882 and 1883, distin
as in previous papers between the effects produced on soft and
armour. By *soft* armour I mean armour which yields by per
By *hard* armour such as cannot be perforated and is dest
breaking up.

The experiments I propose to notice are: (1) Krupp's
trials; (2) the Italian Spezia plate experiments with the 100-
at the end of 1882; (3) the trial of compound and steel
St. Petersburg, at the end of 1882 and the commencement
and (4) the engineer plate experiments at Shoeburyness in
and September, 1883.

Krupp's Meppen plate trials took place in March, 1882. T
sisted wholly in trials as to the perforation of soft armor
directly or obliquely. A 5.9-inch gun was fired twice at tw
plates of wrought iron with 10 inches of wood in between. The
represented on the diagram¹ (Pl. I, Fig. 2, "horizontal section,
"front view,"). The shot weighed 109.6 lbs. (49.7 kg.).
was fired with a charge of 39.68 lbs. (18 kg.), and the second
(17 kg.). The second one had a velocity of 1,750 feet, its
energy was 2,328 foot-tons, and it had sufficient work to hav
trated 11.65 inches of iron in one thickness, or I suppose
12 inches of iron in two thicknesses. It went through th
target and passed on up the range 328 yards uninjured. Th
be accounted for by the circumstance that the wood betw
plates was much too thick. The plates were good, but if th
is sufficiently thick to allow the point of the projectile to get

¹ The figures have been photographed from blocks kindly lent by the
the "Engineer," in which paper reports of the trials appeared.

the bent and broken edges of the front plate before it meets the hinder one, then the maximum resistance is not offered by the plates. Experiments at Shoeburyness established the fact that the best thickness was somewhere about 5 inches, which prevents one plate jarring on the other, and yet does not allow the projectile to get clear of the broken pieces of one plate before it comes to the second one. In that way I understand Colonel Inglis to expect that this shot thus fired might get fairly through these plates. That Krupp's projectiles did more than this may be perhaps owing to their excellence.

The second experiment was one of oblique fire (*vide* Pl. I, Fig. 6). The same gun was fired at an angle of 35° on the normal, or 55° with the plate, against a plate 7.9 inches (20 cm.) thick, with a backing of 9.84 inches of wood, and 0.98 inch of skin. Two rounds were fired with charges of 39.68 lbs. and 37.5 lbs. The latter gave to its projectile a striking velocity of 1,750 feet. It had sufficient work to have penetrated $9\frac{1}{2}$ inches at the striking angle, supposing the projectile to "bite" properly; but at so oblique an angle it has been found that the projectile has to be more than a match for the plate, generally speaking, to bite, and therefore the penetration was unusually good.

There were other incidental features in Krupp's trials worthy of notice. For example, he tried common shells made of steel, the object being to get a thinner shell with a larger bursting-charge, or, on the other hand, to make a shell with a much stronger envelope, so that there should be greater resistance when the shells burst. In some experiments—the "Shannon" trial for one—shells have *broken up* instead of bursting inside the plates at which they were fired, and the result has been but small. Thus there is an advantage in having a strong envelope: or, of course, the advantage may be taken another way, by having a very much larger charge—how very much larger you may see from the fact of a long 8.27-inch "torpedo" shell containing 106 lbs. of powder. You can hardly conceive of a shell $8\frac{1}{4}$ inches in diameter containing 106 lbs. bursting-charge. This, no doubt, is a feature which must receive great attention at some time in this country.

The Spezia trials of last November were made as to hard armour, and consisted in trials of compound plates that were ordered for the "Italia" from Messrs. Cammell, in competition with other compound plates from Sir John Brown and Co., and steel plates from M. Schneider. The dimensions of all were the same—18.9 inches thick, 10 feet 10 inches long, and 8 feet 7 inches wide (*vide* Pl. II, Figs. 1 and 2, for section). Cammell's plates had steel faces made on Wilson's patent, and Brown's plates on Ellis's patent, the back of each being wrought iron, and the front, for about one-third the thickness, steel. The compound plates had somewhat harder steel faces, having rather more carbon in the steel than in Schneider's steel plate, which was entirely of steel containing about 0.45 per cent. of carbon. It was not rolled. It was made from a very large pile 7 feet thick, hammered down to 19 inches thickness under a

important then to note that that was the way in which the were made. Schneider's target was held up with twenty the others with six bolts each only. They fired, as they always, precisely similar rounds at each target one after using the 100-ton muzzle-loader. The first round was fired with of 328.5 lbs. and a 2,000-lb. shot at a low velocity of about thus reduced so as to be something under a match (on the tion base of calculation) for the target. Its stored-up work was 20,710 foot-tons. It was capable of penetrating about 19 of iron, that is to say, it was a match for the thickness of the target had the target been iron. Of course, each target being of pound metal, it ought to have been equal to about 5 inches of iron, to about 24½ inches of iron, and the shot was therefore not for it in penetration. The first shot being fired at Cammell (*vide* Pl. II, Fig. 4), the head was buried in it, and the which you see upon the diagram were made, the corner detached. A similar round was fired at Brown's, only that was a great deal less (*vide* Pl. II, Fig. 6); and at Schneider's shot lodged apparently without the slightest crack anywhere (Pl. II, Fig. 5).

The next round was fired at each with a charge of 478.3 lbs. sufficient work to perforate the targets; that is to say, the enough work in it to penetrate 24.7 inches of iron. The first so fired had 1,545 feet striking velocity, intended to be equivalent, to the perforation of 19 inches of compound armour. Its up work was 33,100 foot-tons. The effects produced are shown in the diagram. Cammell's plate was broken up into four or five pieces (Pl. I, Fig. 14). The whole plate was brought down, the bottom way. If you assembled the pieces, they would have the form shown in that diagram (Pl. II, Fig. 15). In the same way a shot at Brown's plate and brought down part of the target: remained, hanging by a bolt (*vide* Pl. I, Fig. 12). The pieces are shown assembled in Pl. II, Fig. 13. The second round at Schneider's produced the effect shown in Pl. II, Fig. 7. Of course, the difference between those results is very great, and is mainly the fact that Schneider's target is held up by bolts, whereas the targets not being sufficiently bolted fell on the ground, but less, Schneider's plate held better. The cracks are peculiar, not think they show the same complete fractures as the others. If you had looked at the section of the iron you would have seen the steel had a fibrous tough look about it. They then fired a projectile, thought to be a Whitworth. It had a striking velocity of 1,538 feet and about the same stored-up work as the first, 34,080 foot-tons—about a match in penetration for the first. A great piece of steel was brought down, the projectile was flattened bounded back, the top frame round the target was thrown forward so as to overhang the face (*vide* Figs. 19, Pl. II, and 20). Part of the plate was driven into the back and part broken

with the shot, which rebounded and lay in front (Pl. II, Figs. 20 and 23). An inspection of those pieces of plate would give you the idea of its being remarkably good metal (*vide* Pl. II, Figs. 21 and 22). It was afterwards stated that the projectile was not a Whitworth's shot, but one of Terre-Noire manufacture, and sent in mistake for a Whitworth.

One more round was fired. Of course the plate was getting demoralized, and it is hardly worth looking at the result in Pl. I, Figs. 25 and 26. The projectile was a San Vito cast steel shot, and that projectile broke up in a very different way to the last mentioned. The head appeared good, but the body bad: the difference being accounted for by the head having been tempered in oil.

The St. Petersburg experiments began almost on the same day, and were carried on as a competitive trial between Cammell's steel-faced and Schneider's steel plates. In each case, the first shot fired was the heaviest. An 11-inch breech-loading gun was fired at 12-inch plates, 8 feet by 7 feet, and the striking velocity of the first round was 1,506 feet, the charge being 132 lbs. English: the weight of the shot was 553½ lbs., the work in the shot was 8,704 foot-tons, and the power of perforation equal to about 16·3 inches of iron—just about a match for the target. The first round fired at the Schneider plate cracked and broke it, as shown in Pl. I, Fig. 1. The next was fired with 81 lbs. of powder, a striking velocity of 1,167 feet and 5,228 foot-tons work (Pl. I, Fig. 2); it struck it with a power of perforation of 12·21 inches of iron; and the third, with the same, broke a quarter of it away (Fig. 3, Pl. I). The Schneider plate again was bolted up with a great many bolts, whereas the Cammell had only four bolts. The first round being fired at the Cammell plate with a charge, &c., corresponding to the first round at the Schneider, the projectile of course broke up, as in the previous rounds. The head remained embedded in the plate, and very slight cracks were made (Pl. I, Fig. 4). The next round, fired with a charge, &c., as in the second round at the Schneider plate, detached the plate, which fell on its face. When it was picked up surface injuries were found to have been produced. The steel-faced plates are apt to have more or less concentric cracks; while, as far as my experience goes, concentric cracks are not produced on a steel plate, but, on the contrary, all the cracks are radial. Then they mounted the Cammell again and fired at it, with the same reduced charge, with the same sort of effect, until they eventually got four shot planted on it, and obtained the result shown in Pl. I, Fig. 3A, parts of the face being scaled off; but the plate holding together and having a good deal of work left in it.

In this case there is no doubt the Cammell compound plate has beaten the steel plate; but in the case of Spezia the steel was the better of the two. There is little doubt that at Spezia Schneider's plate was specially made for the programme of experiments. The Cammell plate was supposed to be a sample plate, exactly corresponding to those that would go on the "Italia."

On Tuesday, August 22, 1883, an experiment of great interest, especially to England, took place at Shoeburyness. It was carried

nature of the work tested is shown in the accompanying (Pl. III, Fig. 1).

The shields fixed on the face of Portions II and III are such that on No. III, against which the first shot was to be fired, of two plates of 8 inches thickness each, of wrought iron, sandwiched with 5 inches of wood behind each, made up of thicknesses, that is, $2\frac{1}{2}$ -inch planks laid horizontally, next to the plate, and $2\frac{1}{2}$ -inch planks behind them placed vertically (Fig. 9). The dimensions of each plate were as follows: length 12 feet, height 7 feet, and thickness 8 inches. They were made by Messrs. Cammell. They were held in their place by six bolts, in the Palliser English system.

The shield on Portion II consists of 12 inches of Wilson's chilled iron, in a plate 7 feet by 7 feet held up by four bolts inside an iron frame, as shown in Figs. 1 and 2. On the top of the work was laid a quantity of old broken plating, to keep the iron and concrete from rising under the force of the blow—(vide Fig. 9) at Portions II and III. Structures of concrete would have lost their full strength for many months, perhaps years to come, must allow for this in this trial, which it will be seen was a very close one.

The gun employed was the 80-ton gun, M.L., which was fired at 200 yards distance. One round was fired from it at Portion II, an iron sandwich on granite. A projectile weighing 1,700 lbs. with a charge of 450 lbs. of pebble powder, with a velocity of 1,588 feet. This implies a total amount of stored-up work of 29,730 foot-tons, or 594.4 foot-tons per inch circumference, representing a power of perforating about 25 inches of iron. It was a service Palliser chilled iron projectile, about 3 feet 6 inches long, fired without bursting charge, the radius of the hole about $1\frac{1}{2}$ inches diameter. The shot struck a point 3 feet 6 inches from the bottom of the plate, and 3 feet 8 inches from the left end of it. The effects were as follows:—The shot cut a clean hole through both plates, and breaking up during penetration rather to the left, the point reaching a depth of nearly 12 inches, measuring from the front face of the iron. The plates were cut admirably, the hole being cut almost without any apparent damage to the surrounding portion of the plate. The wood was driven out of the plate at the left end, and 3 inches on the right. The granite was pulverized all round the projectile for some distance. Cracks were visible in the granite in front, as shown in Fig. 8. They were observed to radiate from the point of impact, speaking generally of the stones of the course through which the shot passed and layers of wood, forced longitudinally, left and right, projecting beyond the other at each end of the squares of masonry. One or two cracks also were visible in the brickwork lining the small cross passage behind the part struck. The bolts do not

A velocity of 1,100 feet ought to be sufficient to enable a projectile to perforate 16 inches of iron alone.

England is the only Power that has employed wrought iron to a considerable extent in coast forts, chilled cast iron having been used generally abroad. An experiment, therefore, that shows that wrought iron behaves well is specially satisfactory to us as a nation; surely this is the case here. The iron has offered a graceful resistance, and it has suffered only locally. The latter is, however, important as affecting the further powers of resistance of the shield to resist repeated blows of the 80-ton gunshot must be exceptionally strong. When it yields it yields locally, and still a good front protection.

The second round was fired on September 11th at Port Arthur, steel-faced plate, &c. The projectile was in this, and in the case, a Palliser shot, weighing over 1,700 lbs., the striking velocity being something under 1,600 feet. The effect is seen in Figs. 1 and 5, which show the plate, and in Fig. 2, which shows the back of it. It will be seen that the plate stood wonderfully well; the shot broke up, its head being fixed in the plate. (See Figs. 5.) The plate was bent and bulged, the bulge and shot being unusually flat against the masonry supporting the plate. The great annular rents immediately round the shot, where more work must have been done, the radial cracks were nearly a quarter of an inch deep—the depth of the most important may be seen in Fig. 3. The bolts stood well, holding the plate up. They were subsequently examined to enable the back of the plate and masonry to be examined. Fig. 4 shows the granite with the indentation and cracking made by the blow. This, it may be seen, is very slight, the deepest indentation made by the shot point at A. The spring of the masonry opened the joints at the upper bolts B B, and if the side view be examined, it will be seen that a tremendous strain had fallen on these bolts. Crack C was produced by the first shot at Portion III. Hence the cracks in the masonry, as before, all radiate from the point of impact.

Taking this round as nearly the same as No. 1, we may say that about 30,000 foot-tons of work have been delivered on this plate, that a compound 12-inch plate has, under the conditions, borne the blow of a shot capable of perforating about 2 inches of iron.

How is this to be accounted for? The natural suggestion is inferiority in shot, special excellence in plate, or special superiority to this nature of plate by hard backing. There does not seem any reason to call the shot bad. The plate is certainly probably the last-named cause told most—that is to say, hard backing specially brings out the powers of steel-faced plate. This supports the opinion of the Italian Committee, who held that the yielding backing at Spezia told much more for a compound plate than the steel. Anyone who looks at the

judge what would have been the effect on this plate if it had allowed it to bend much more. Would not the line from the point of the shot to the cracks about A have been curved? The bulged back of the plate and the shot have received enormous pressure against the backing. Can we doubt that if it had not been an extraordinary one the plate must have cracked across? I am in no way detracting from the qualities of which is apparently beautiful. It would, however, surely be impossible for any 12-inch plate to stand the blow we have to stand under any ordinary conditions. Giving it all credit for its strength then, we have to explain why it bore much more than twice what would generally smash such a plate up. I suggest the reason. The plate with its hard surface and hard backing resisted very sharply and rigidly; this, being a chilled shot, broke under a shock much more easily than a good steel shot would do. Under these particular conditions, a softer shot with more elasticity might have done better. Still, an enormous force was breaking and tearing out rings of metal close round the shot, actually crushing in the face of the granite behind it, and I noticed that there are no detached bruises on the plate face where the work was delivered well at the point of impact. The plate has been cracked from the front to a depth of $9\frac{1}{2}$ inches as shown in Fig. 3, but the shot was unable to bend it back open the remaining thickness from the opposite side, and so was borne.

To come now to the features in the question that may appeal for special attention. *First our system of calculating effects.*

I think the table herewith will show that in England, in Russia, in Italy the blow is estimated on the basis of the power of the shot to perforate. In the case of wrought-iron armour this is undoubtedly correct, but this table shows cases of steel-faced plates where perforation was not effected, but where the action was more nearly that of fracture by an ogival-pointed wedge striking the plate and splitting it before many inches of the wedge had entered it. The effect is probably be proportional to the total energy of blow delivered by the wedge, that is the shot, but without reference to the full distance the shot, for that never comes into the question.

Perforation is calculated by dividing the stored-up work of the shot either by the area of the cross section or else by the diameter of the shot. Either plan in a modified form is correct where the shot makes a hole whose size depends on its diameter. A shot of small diameter requires less energy to make its hole than a larger one, and proportionately; but in hard armour, when both of them strike their points into the plate before fracture occurs, it is difficult to see how the small diameter gives any sensible advantage to a projectile. This objection is pressed, it is often admitted to be correct, yet it remains that the system of calculation just condemned is the

power to perforate wrought iron of the *same* thickness pound plate attacked (*vide* table, at Shoeburyness, St. Petersburg.) On the higher standard the shot has sufficient power to perforate a wrought-iron plate of per cent. more thickness than the compound plate attacked (Shoeburyness, Spezia, and St. Petersburg). In many cases lead to passable conclusions, but it depends on certain relations and plate being maintained. Cases may arise when it would be wrong. For example, at Copenhagen, a 9-inch Woolwich 5 $\frac{3}{4}$ -inch Krupp were fired in comparison; the former had 1 energy per inch circumference, the latter 123. Their weights would therefore be nearly the same, but their respective energies are 16,403 and 5,760 foot-tons. It would be unreasonable to expect the latter, with little more than one-third the energy of the former, would smash up hard armour to the same extent simply on that, if holes were made by each shot, this would only need one hole, when as a matter of fact no holes could be made.

I have here a simple kind of drop to illustrate this point. At my request in the Royal Laboratory, Woolwich. I have the Director of Artillery for having decided that it should not be a Government expense. It would be very dangerous to attend to questions of impact by a toy like this, where the velocities are so small, only those of a small fall and the substances are so very fragile. We may, however, get illustrations which are very clear and impress facts on our mind, and there is a small probability that the laws governing impact at high velocities apply to these low ones; nay, the machine could only be made on the assumption, and any correct results must be due to this assumption which bear out the assumption. You will observe that the advantage of great simplicity. Having the stored-up work in the form of WH (weight with height), instead of $\frac{Wv^2}{2g}$, we get

square in the formula, and the calculation of effect is independent of the height. On the perforation system the diameter varies with the height, the weight being kept constant, the $\frac{1}{4}$ -inch bullet-punch, of 1 foot, ought to have the same punching power as the 1-inch with about 2 feet, and the 1-inch with about 4 feet drop. Thus a board can be perforated by the 1-inch bullet-punch with a fall of 60 inches, while the $\frac{1}{4}$ -inch bullet perforates it with a fall of 15 inches, but about 17 inches, this small drop giving the same effect of perforation to the small bullet as the higher one does to the larger bullet. As regards *perforation*, then, through soft material, the results are equal under these conditions. But now let me substitute a hard material that yields by fracture rather than perforation. The small bullet breaks it at 9 inches fall; the 1-inch bullet has the same effect at 60 inches fall, but surely I need not say that it will make a much greater *smashing blow*. Yet our *perforating formula*

This is a gross case. I take it, to illustrate the error in the system. Probably in no case has the system been applied when a very small error has been caused, but the system is wrong for hard and fast, in a greater or less degree, must give wrong results.

It is easier to say this, however, than to suggest a rig. The physical conditions are difficult to deal with. How can we calculate the work necessary to make a crack? The commencement of a crack certainly represents more work than the completion. As we arrive at the number to be made? Then while length makes it harder to crack it longitudinally, it is thought that leverage for cracking it across, just as a long stick is not broken so easily as a very short one. Altogether a number of elements exist, which make the question a very difficult one. On one given plate it may be that the total stored-up work in a fair measure of the injury done, but how are we to compare plates of different dimensions?

I have suggested as a check on the perforation standard dividing the stored-up work in the blow by the number of plates struck, we have the shock per ton of plate. This shown in particular cases to be as grossly wrong as the present standard, but, depending on rather opposite conditions, it may be a check on it.²

To apply it to the examples given on the table. The 3 at Shoeburyness was fired on July 21st, 1880, at a steel-plate 18 inches thick. The shot had a calculated penetration of 1 and 12,980 foot-tons energy. The plate weighed about 24 tons, the blow was 541 foot-tons per ton of metal. The effect was slight, the shot breaking up badly. At Spezia, in November 1880, compound plates weighed about 31·5 tons, and the heavies

¹ The perforating equation of the drop is then $WH = \pi D \times t \times K$, weight, H height of fall, D diameter of bullet punch, t the thickness of shell and K some constant. We have just used it with H and D varying, but D with any pair of terms variable according to what may be required. It is out very fairly correctly if we vary H and t , and keep the other terms constant, if we try what thickness the same bullet perforates at different heights, or if we vary t and H and keep D constant. The thickness of the shell may be altered, and I have tried the effect of loose weight on it with Captain Palliser's jacket moving forward on his shot on impact. This glass balls in a groove, illustrates curiously the different effects of the resting loosely on each other, or, on the other hand, riveted together.

possibly the action might be investigated on a small scale by firing steel discs of steel and chilled iron, arranged in series, one series of discs of varying thickness, and so on.

Since writing this paper and getting the proofs in type I have received the kindness of the German Attaché, a report of the Magdeburg explosion which I had referred, by which it appears that the striking energy per ton is used as a measure of the shock on chilled iron. On this occasion the chilled shield was broken, but the pieces still held together after three 12-inch steel projectiles weighing 931 lbs., with a velocity of about 1,400 ft. per second, had borne a total shock of 43,495 foot-tons, or 914.8 foot-tons per ton of shield.

the second blow, the previous one having been 654 foot-ton of metal. The two together then make 1,700 foot-tons metal. At Ochta the steel plate was broken with a blow of tons per ton of metal. The plate tried by the Royal En August last at Shoeburyness probably weighed about 10·5 a blow of 30,000 foot-tons then implies a shock of 2,857 foot-ton of metal, that is, four times as heavy a shock as any s at Ochta on a plate of the same thickness. This was born breaking the plate asunder or penetrating it. Unquestion the Engineers' Shoeburyness shield is a wonderfully good co by whatever standard it may be judged.

Following on from this, we come to the question of *With hard armour they break up, unless of very excellence. Their effect must therefore greatly depend on their power together.* Steel, therefore, ought in the long run to beat cl I would point out that, in this country, our experiments made on softer armour than we may expect to meet for t Even our compound plates are softer than the steel armour Schneider, and much softer than Gruson's chilled iron. mean that the steel face is softer than that of Schneider the other hand, the surface is harder, but the plate itself i the sense in which I have used the word, that is, it is more punch a hole in it. At Shoeburyness, discs have occasio torn out of compound plates, and chilled shot have got t completely through them. I am very much mistaken if th done with Schneider's or Gruson's armour. Hence it fol the comparative softness of our hard armour, that in this c see efforts made to punch hard armour, which I venture to have no future, and we have clung longer to chilled shot t advisable. Sir William Palliser, in his improved shot, so element of reduced diameter is concerned, contemplated hole, and actually did so, in a compound plate. Sir F. Ab carrying fire in a steel shell through armour is only applic armour, and it has, I think, no future on that account.] in this form, or indeed in any form, is so harmful tha recognize the fact that armour will be made hard enough it; and it may be questioned whether the successful results ing achieved by Krupp and ourselves are not rather cal mislead us if we are not on our guard.

I would suggest, then, *that the development of steel shot ing need in this country.* A Commission was sent recen American Government to inquire into the manufacture of jectiles in Europe, and they concluded that England was Continent in this matter. The excellence of the Terre jectile fired at Spezia argues that a very high standard attained in France, even on the gigantic scale of a shot of calibre, weighing 2,000 lbs. In this country it is comp makers shrink from submitting steel projectiles much over

...
 turers naturally shrink from being judged on the merit of unproved quality, and they could hardly be expected to un-
 enormous outlay for plates necessary to investigate thoroughly. It seems most desirable, then, that any available left from experiments should be devoted to the proof of projectiles by manufacturers, not as "champion" shot on which stake their reputation, but as "pioneer" shot whose indifference is not the question, but rather the lesson they teach effect of certain manufacturing processes. Again, one may grudge the loss of the experience that might be obtained if were substituted for the chilled iron ones at present employed Admiralty proof of plates. No doubt, such a substitution is matter. Until first sufficiently tested to insure against its use, a plate could hardly be attacked by shot of an experimental kind. With this reserve, however, steel shot might, perhaps, be introduced, and as their quality becomes known they might be chilled projectiles.

Finally, experiments against really hard armour appear to be needed in this country. Neither Schneider's steel nor Gruson iron have ever been tried by us. It may be perhaps considered that foreign experiments have settled the question in a measure for we are satisfied with the comparison of our steel-faced armour with that of Schneider at Spezia and at Ochta, and that we have as to its employment for our own ships. This, however, is the other side of the question. We need knowledge as to the behaviour of projectiles in war against the armour employed by foreign powers. France has the most formidable Navy, and France largely employs Schneider's steel, against which our Service projectiles have been tried at home or abroad. As to forts, the existence of which depends on the possibility of vessels attacking them, and without exception Gruson's chilled armour is employed abroad. We have never fired at it. Probably not six Officers in this country have ever seen chilled iron fired at. There is some reason to think that our chilled projectiles are unsuitable ones to attack it. Krupp attacked a chilled shield made to represent Gruson's chilled shot. He wished it to be beaten by a wrought-iron shot of his own. In a few rounds he was disappointed at the effect of his shot and replaced them by steel ones, which, in a measure, did the work of the chilled iron.

In 1882 I believe the French made some experiments with chilled iron shields for inland fortifications. They had adopted steel shot, but they found the effect of steel shot so much greater than that of chilled shot against chilled iron that they rejected this material for inland works. At Magdeburg the chilled iron shield was destroyed by the blows of steel shot. The behaviour of the chilled shot at Spezia argues more tenacity though greater than ours. It may be questioned whether our chilled

these very projectiles against these very shields. Is it able to urge the necessity of making experiments against chilled iron shield in this country? This would exhaust the value of our Service shot against really as a general question. Besides which the actual structures are formidable enough to make it desirable to know how with them in particular. They are not costly, and have suffered fundamental fracture they would be available powers of our shot to hold together on impact against ha-

The three features, then, on which I wish to lay stress the need of a better system of estimating effects of anti-armour; 2nd, the need for developing the manufacture of tiles in this country; and 3rd, the necessity of making Gruson's or other very hard armour in this country.

I hope it will not be understood that I am urging this by any means generally behind other nations in the matter of armour. We alone have made 100-ton guns, and our armour is unrivalled. In the most important experiments Powers English *matériel* takes a prominent place. Nevertheless by no means afford to shut our eyes to the elements may be weak, and in which foreign Powers may be at advantage over us.

TABLE showing that in recent experiments shot have been made compound plates according to their calculated powers of (vide Columns 5 and 6), not according to their smashing which 9 is suggested as a measure.

1	2	3	4	5	6	7	8	9
Date and place of trial.	Gan.	Weight of shot.	Striking velocity.	Thickness of compound plate.	Calculated perforation of shot. Inches of iron.	Total energy.	Weight of plate.	Energy per ton of plate.
		lbs.	feet.	ins.		ft. tons	tons.	
July 1, 1880, Shoeburyness.	38-ton ...	829	1,504	18	19.6	12,980	24	541
1882, Shoeburyness.	43-ton ...	703.5	1,870	18	22.3	17,160	...	...
November, 1882, Spezia	100-ton ...	2,000	1,219	18.9	19.3	20,600	31.5	654
			1,563	18.9	25.2	33,960	31.5	1,016
November, 1882, and March, 1883, Ochra, St. Petersburg....	11-in. B.L.	553.5	1,167	12	12.2	5,228	12.25	427
			1,506	12	16.3	8,704	12.25	711
September 10, 1883, Shoeburyness.	80-ton ..	1,700	1,599	12	23.3	30,140	10.5	2,870

burg the compound targets had only a few, and they came to pieces; whereas in other experiment at Shoeburyness a few bolts were quite sufficient to hold them up. In Italy and Russia it was remarked that though the compound targets to pieces, they fell in large fragments. I would suggest that if the English had been supplied with a sufficient number of bolts to keep them up at Spangereid at St. Petersburg they would probably have been initially weakened, because the increased number of bolt-holes takes away considerably from the strength of steel or steel-faced target. It would appear that sometimes a large number of bolts is required, but not always; the large number apparently being necessary where the backing is not hard, but comparatively soft and yielding. So far as the evidence before us, compound armour seems best suited for use with hard backing such as granite, which can be used in the construction of forts, and it is hardly applicable to ships. With regard to the size of steel or compound targets, it appears that there is a great advantage in having the individual plates of small dimensions, on account of what Captain Browne has urged that the amount of "work" in foot-tons in the projectile on striking, per ton weight of target, is a way to be taken into account in considering the resistance which can be obtained with wrought-iron plates this consideration is of very small importance. It appears that modern targets are very thick, the joints consequently get through, or very nearly so; whereas in the plate-upon-plate wrought-iron targets there are overlaps like courses of bricks in a wall. It would therefore seem that steel or compound plates should be heavier than the older ones; this would increase the total weight for a given area protected, but the armour would be made up of fewer parts. I believe the present armour-plates are not much more than 30 tons in weight; if this could be increased by adding to the superficial area not to the thickness, a greater resisting power would probably be obtained without involve extra expense and labour in manufacture, but it may be a desirable feature to consider for naval armour, where the chief object is to obtain the greatest resisting power without increase of total weight. No doubt manufacturers object that their present plant is not sufficient, but they might be urged to increase it and to produce plates of larger dimensions. Captain Browne has pointed out a great difference caused by hard and soft backing; it will probably be very difficult to arrive at any formula or calculation of the effects of fire without taking this into account carefully. The complicated composition of the modern plates will tend to cause difficulties in making estimations of resisting power. The lecturer has suggested that experiments on a small scale might be useful, as they would tend to indicate the direction in which to proceed in making more reliable and accurate ones, and this seems a sound method.

Admiral VESEY HAMILTON: I should like to say a few words, not with regard to the main point of the lecture, but to the conclusion which Captain Browne has drawn. Every naval Officer will perfectly agree that if what he says is correct, we shall go into action with untried weapons, that is to say, with guns and armour which we do not know the effects. Now, I think it is an important point that we go into action we should know what the effect of our shot will be upon the armour.

Admiral SELWYN: When, in 1870, at the Naval Architects, I drew attention to the subject of compound armour by asking them to consider the analogy of anvil, I also proposed to use a pile-driving machine for experiments, and I am glad to see that Captain Orde Browne has carried that out so well. It is subject to certain variations which have to be considered, but they are easily eliminated by the results. For instance, the unsatisfactory results given by the short duration of time will find are complicated by the element of time. Mr. Oliver Browne pointed out in 1870 that when the element of time is ignored a great many new things come out—new effects which you could not previously have predicted. Well now we regard to the compound armour, for that is unmistakably the armour of the future, unless any other method can give less weight, for armoured ships; I do not know what will be done with regard to land batteries, that is a question for engineers.

comparison drawn between the perforation or non-perforation, or on the plate short of knocking the plates to pieces in three rounds: Captain Browne. Now, I should like to know whether the conditions have ever been closely observed in compound armour. I say distinct good effects have been produced in spite of the bad principle on which they have been generally done. I see in late reports of the proceedings of the Committee that Sir John Brown now approaches something more in analogy of the anvil; that is to say, he proposes to reduce the thickness of the plate in front, to fill the wrought-iron armour-plate with molten steel in a crystallized state, and thus to approach to the condition of the anvil, made up of a wrought-iron body, a cast-iron inside, and a steel plate between the crystalline particles of the cast iron. In this way, and in this way, we can be obtained that cone of dispersion which is the only means of escape of a shot if you do not get complete perforation. You must do one of two things: either remove the mass of metal sideways or endways before perforation, or set up an action of the particles of the soft metal which extinguishes, in not very great length the whole force of impact. In the anvil, done by a long and careful experience leading forward to a perfect anvil, will go at once to the condition of the anvil as our starting point. In armour-plates we shall go ahead much more rapidly and with much more success to back us than if we began by putting on a thick piece of steel which no anvil-maker would ever resort to at all. He would expect to put a soft iron plate behind a thick steel plate it would be of no use, neither would the steel plate if it were not accurately tempered on the surface. So as to be that even tempering an anvil the slightest degree out of the horizontal it is spoiled; and this bears upon what was said by Captain Brown about curved plates. If you try to harden the face of a curved plate by the methods it is almost impossible to harden all the surface at the same time; consequently there is a wrong disposition of material. But there is a way in which we can get this hardening without the use of any water at all, and not very occult means; they have been used for many centuries, and can be used again without much difficulty. The condition is this: a steel surface, as hard as it can conveniently be made, for a very short distance, below that the less-hardened part. Then the blow must be delivered through a comparatively softer material than the steel; that is found in the form of particles, by means of which you must distribute the blow. In wrought iron which keeps such particles from lateral expansion. Behind that is an elastic backing, which will take up whatever blow is delivered through the crystalline particles, and which is used generally by blacksmiths in the form of a wooden block. We have that big wooden block in the form of a ship, and as the ship is hollow it has a certain degree of elasticity, which, by the efforts to the whole structure, this disperses the entire work done in a harmless way throughout the ship. You cannot, of course, do this with granite backing, but, however, we have little or nothing to do with granite, which batteries are built unless we are attacking them. In order to put the question, it is absolutely necessary that experiments should be made on Gruson's shield of chilled cast-iron or on steel armour, that material should be neglected, that experiments should be carried out and consistently, on a scale calculated to bring out steady results, but and impulses, for experiments carried out in that way never produce a result. We ought to begin at the beginning, and then to go forward to every result proposed. That can only be done by a continuous government, you get a lot of different people coming in one after another you have such experiments as Beaufoy's and others have transmitted to posterity devoted half a lifetime to it. All men gain by experience, and if a new man is in, unless he is willing to learn from the experience of the others

association with such subjects, and they ought to be associated with the military Service to carry out such experiments. It should not be out of the question to associate all talent, no matter where it comes from what may we expect if the analogy of the anvil is carried out in its shape of a compound plate? We may expect that instead of breaking up of plates there will be obtained a complete resistance to the very heaviest shot, and that by a comparatively light plate. And then as to I am sure this is to be done by the method which I have pointed out. I think I am on a good path. You have abandoned the idea of perforation in iron and you are beginning to see that by proper adaptation of material you can obtain complete resistance. Now we have to go forward, and I think that the machine is a splendid cabinet illustration. I should like to see that carried into a large machine, such as a pair of sheer legs, and then we might get from each of these experiments to the result that they point to with shot and armour-plate. But the expensive form of beginning with a machine and ending with pile-driving machines is one which I do not think will encourage. Captain Browne has contributed most excellent knowledge of this subject. I only trust that as the thing is carried out it will be kept informed, because, unless we know more about it than we do now we are certainly going with our hands tied and our eyes blinded into the future. That should be avoided by every possible means, and I am sure this must give through its lectures more interesting and useful information than could be obtained in any other way on such technical subjects as are necessary to stand in order to the lessening the cost of efficiency during war, and increasing the duration of peace.

Colonel Sir CHARLES NUGENT, R.E.: I did not intend to offer any remarks at the meeting, but I should like to say a few words in reply to what Admiral Selwyn has just said. I do not think the inference he has drawn as to our coming to the plate and ending with the anvil is quite correct. It appears to me that the matter of wrought-iron armour-plates at least we have advanced very far in fact, looking at the experiments that have been made I do not think having begun from the egg, have got up to the full-grown bird, which I have said is the state as regards armour-plates, unless we had done more mention also with respect to the action of the Government in this matter. A happy condition of things that Admiral Selwyn alluded to—the Utopia of the future—is to a certain extent gained, inasmuch as the present Ordnance Commission is upon it a number of scientific naval Officers, and is associated with one of our eminent civil engineers, to whom Admiral Selwyn alluded, Mr. B. another civil engineer of equal repute, and they for the last three years have had the opportunities of being concerned with or cognizant of such experiments as have been made on armour-plates, both wrought-iron and compound, and also experiments as have been made with projectiles and with the design of projectiles, and the materials of which they should be made. Perhaps the time at our disposal it is not worth going much into detail, with the single point of the anvil, to which Admiral Selwyn has attached so much weight. He followed out the analogy of the anvil, or went on that principle, what would happen if we had an unmanageable thickness and weight, because experience has shown that in a compound armour-plate you cannot secure a good result without a certain amount of hard resisting surface. Experience has shown that from one-third to one-half is the best condition of manufacture, that is to say, rather one-third of hard steel face, perhaps rather more than one-third of wrought-iron back, and then the intermediate steel between the two. With regard to questions which the lecturer put, I have one or two words to offer. I think the three features on which he wishes to lay stress are, "first, the need of a system of estimating effects of artillery on hard armour." As he said the most difficult question, but it has not altogether escaped the attention of

of. In the absence of such formula we know the effect of certain wrought iron, and we also know to a certain extent their effect on cor and we are able to say within certain limits that so much compound iron so much wrought iron. Then, with regard to the second point—"developing the manufacture of steel projectiles in this country"—we find that generally the principle of attacking steel-faced armour is to make projectiles. Although steel projectiles for the medium calibre of heavy produced in this country (I may remark that the manufacture of steel purposes in very large quantities is confined to perhaps three or four names—the Cammell Company, Sir Joseph Whitworth, and one or two others—who have recently come into the market to compete). The manufacture of the largest steel projectiles has been thoroughly unsatisfactory up to now because of the difficulties of tempering the large masses of suitable material great that they, the manufacturers, have not succeeded in devising an overcoming them. For myself I think there is a method by which this may be met; however, it is not in being yet. Then, with regard to "the making trial of Gruson's or other very hard armour in this country, I doubt but that a trial is very desirable, but the fault does not altogether lie with this country. I recollect not many years ago, when I was connected with the armour of the country, having many interviews with Gruson and in the end offering to him to produce a section of armour for the competing with what we considered an equivalent of our own armour, was never accepted. With regard to Schneider plates, we have no information in my recollection."

MR. WALTER BROWNE, M.I.C.E.: Being an engineer, and not a military man, I should not have ventured to intrude upon the meeting if the discussion had taken the military side of the question; but as Admiral Selwyn has put forward the illustration of the anvil, which is an engineer's implement, perhaps he has allowed to say a word. It appears to me, in the illustration given, he has forgotten this point—that you never attempt to pierce an anvil with a hammer, and the only danger is that you may be hurt across by the mere force of the blow. That is not the sort of danger to guard against in an armour-plate. Looking at the way in which the plates are shown in the diagrams to have been fractured, I believe the question as to the mode in which it has been brought about. The head has been wedged into the face of the plate, and that has produced a fracture radially outwards round the head, thereby producing a zone of highly compressed metal round the shot. The squeezing outwards of this compressed metal cracked the plate, either in radial or circular lines round it, as the case may be. Look upon the ring crack, seen round the shot in Fig. 3, as representing the outer circumference of that ring of hard metal. Exactly the same has been proved experimentally to take place in the ordinary punching of a well-known series of experiments by M. Barba at Toulon. He found an advantage arose by drilling out a thin ring of metal round an ordinary hole before the rivet was put in, and thus getting rid of the ring of hard metal.¹ Looked at, then, from the point of view of the attacking party, we find that our object should be to produce a shot which shall be sufficient to get into the plate and stop there, and at the same time shall have the power of squeezing the metal outwards in all directions. In fact, the plate is broken up by a wedging action, and the object should be to find the form of wedge. Of course, the more taper a wedge is the more effective

¹ It is well known that riveted plates, especially of hard iron, have a tendency to crack along the line of rivet-holes, and from them to the edge, which seems strictly conformable to that of the steel plates here considered to be due to the same cause, namely, compression and flow of metal round

removed for a given depth of penetration, and the less the amount of round the shot. From that point of view you want to have your as possible: and I would suggest that the object of any experiment or should be to find out a shot which combines in the highest degree the liabilities—that is to say, which has a point sharp enough to wedge itself into the metal, and then is large enough in diameter to produce amount of compression outwards in all directions.

The CHAIRMAN: I would like to ask Captain Browne one or two questions regard to his paper; and I may premise by saying, as Captain Ma Admiral Selwyn have pointed out, that this question is far more important to the Navy than it is for the land service. The Admiralty, when they decide of ship required, give certain conditions to the constructors; they say to be of such and such a size. The constructor has to divide his weights partly in armour, partly in guns, partly in machinery, in coal storage and whatever is taken off the one can be put on to the other; the consequence we can reduce our protecting armour in weight we can put that into guns, and thereby increase the efficiency of the ship. The weight of it is really the first consideration, or the main question in man-of-war. With regard to the diagram relating to the Shocburyncess trials, Captain it is established that the best thickness for the wood between the two plates is somewhere about 5 inches. I would ask whether that is really an estimate and if that answers in all cases? For instance, supposing we have 14 inches in the two plates, one 6 inches and the other 8 inches, does that last good? Say, with different thickness of plates, different distribution of plates, and different sizes of projectiles fired. Captain Browne also in "Shannon" trial, where he says, "Shells have broken up instead of bursting the plates at which they were fired, and the result has been but small that is rather a mistake; because, if I recollect right, the report was, that which broke up were "very effective." What you want is to get done inside the ship. In the cases referred to, the shell broke up on plating, and the powder was ignited inside when unconfined by the act and probably incendiary power was more developed in that way than had actually burst. I do not think, therefore, he is quite right in his there. With regard to the method of bolting the plates on, he gave us of bolts, but he did not give us how the different plates were secured to. My impression is that compound plates are bolted on by screws from the way into the metal, whereas steel plates are fastened by the old system of plates completely through, and nuts. Captain Browne has given us these conclusions special attention: he has put the formula for calculating effects first, a description of the projectile after it. In my view of the case, the principle the first importance, because what is it that we really want to obtain? want merely to punch a hole through a ship's side, and then for a solid go through to the other side. What we want to get at is something through the first side, then burst or break up into numerous pieces, the greatest possible amount of damage to guns and men inside. He says with to Professor Abel's view that we propose to get a shell that will go through and burst inside, "Sir Frederick Abel's idea of carrying fire in a steel shell armour is only applicable to soft armour, and it has, I think, no future account." I must say it not only has no future, but it has never had; I think there are but few cases on record in which shell have really passed through armour-plates, and then burst inside; when they have burst or broken always been in the ship's side or armour itself, and the burst has not been in the ship. No doubt, that would be a great object to attain, but I very much think it is not in the future. As to the method employed by the Admiralty of trials of plates, the Admiralty proof of plates is not made to discover the perfect the armour, but it is a standard trial of the value of the plates for actual use. These plates are by experiment required to offer a certain amount of resistance

ago, when I was first connected with the trials of armour-plates and gun to try our armour-plates with cast-iron round shot. We moored a gun yards from the ship's side on which the plates were bolted, fired from the plate, and frequently obtained very different results from the same plate. This was bewildering, and it dawned upon Captain H. Captain of the "Excellent," that it must be something in the shot, with different degrees of hardness, and I believe he proposed the first steel sh ever made, and it was very remarkable to see the difference between of round steel shot and the old cast-iron shot. That brings us to the sideration, which is, that it is our duty to work out the question of pro, whether they shall be chilled iron or steel; and, whatever they may be institute a series of experiments to test what is really not only the bes but the best form for the head of the shot for penetration. There is ar which we must not lose sight of in armour-plates and projectiles: perh Brown can give us some idea of the difference in cost between a compo steel plate, and a soft iron plate. With regard to the land service, if one enough another can be added; but with regard to a ship it is a ve thing. We must have the best, and as we shall require them in c numbers, expense must to some extent be taken into consideration, but detriment of efficiency.

Captain ORDE BROWNE, in reply: With regard to what Captain observes, I suppose it came to this, that the plates, while they fell to piec their not having sufficient bolts, had a certain advantage in the fact th have at all events split into fewer pieces. In taking into account the disa their not holding up against the backing, you should reckon that ther gain in having fewer bolts as regards the actual cracking. Captain Ma previously suggested this to me, and I remember I took up the two cracks and of bolts and held them against the window to see whether tl which ran through this plate agreed at all with the bolt-holes, and y that they do appear to do so; therefore, I think there is no doubt th able not to have more bolts than is necessary absolutely to hold a plate regard to the ships, I did not quite understand what Captain Mackinlay larger plates for ships or fewer bolts.

Captain MACKINLAY: Simply that if the plate is very large the amo per ton of plate would be rather less.

Captain ORDE BROWNE: Of course the question of area has to be and in any investigation made it would be very necessary to try that from the question of depth or thickness of plate. The great point is to one variable at a time, and keep all the other conditions fixed. I shou series discs of steel or chilled iron on a small scale were fired at you wo it worked. There must be some limit as to the way in which the area cracking by the shot. Admiral Selwyn evidently has had more experi matter of drop than most people, and I am very much obliged for wh It is just the small heights where you have the difficulty. I believe if l of the $\frac{1}{2}$ -inch and inch bullets taken the $\frac{1}{2}$ -inch and the inch, and so d $\frac{1}{2}$ -inch from a greater height than belonged to the $\frac{1}{2}$ -inch, you would hav law come out more accurately. I did not know that Admiral Selwyn had l of dropping weights to illustrate punching before; if I had I should tioned it. It is, however, really an obvious thing to do. With reg question of the anvil, it is not quite the same thing to take the blow of t and to fire at it. If an anvil is to be considered a satisfactory achievement we want, is not there any way in which you could test it? Does Admi think that we could fire a steel bullet at an anvil with good results?

Admiral SELWYN: I made use of the last record of the Ordnance Co show that Sir Thomas Brown is making a precisely similar arrangement.

Captain ORDE BROWNE: Sir John Brown makes armour with a rolled plate on the outside. He is then perfectly certain of his co

being a successful pattern of plate there ought to be some means of anvil in the same way as the plate.

Admiral SELWYN: The impact is the same, whether produced by gun or other force.

Captain ORDE BROWNE: There ought to be some relation of weight, of course, the anvil mass is enormous as compared with any blow.

Admiral SELWYN: The mass is as regards the whole ship.

Captain ORDE BROWNE: If you take the question of the hollownness is not the blow almost too local? An anvil cannot possibly yield locally.

Admiral SELWYN: Oh, yes, it does.

Captain ORDE BROWNE: I think practically it amounts to this, that there is some way of putting the anvil on fair terms of comparison before one admits the application.

Admiral SELWYN: The latest and most successful experiments have been on those lines, and the more nearly those conditions are approached the better the steel plate acts.

Captain ORDE BROWNE: With regard to what Sir Charles Nugent said, like it to be understood at once that my object is not in any way to point the authorities have gone awkwardly to work. I am only trying to point exactly where we stand at this minute. Take, for example, the punching. I think one may consider that the calculations for punching, considering the circumstances under which they are made, are as accurate as you can expect the calculations to be. But the same thing is wanted to a certain extent in armour, and I think it requires to be recognized. You remember in speaking of the unreasonableness of applying calculations to hard armour that I took a case of two shots stand at a level as regards punching, and yet one had three times as much stored-up work of the other. It is monstrous to suppose where no hole is made all that these two stand on a level. I was on one occasion before a court taking a case of that sort, and I was told that no one who had any knowledge could apply that sort of thing to hard armour, but looking at that table before the recent experiments, while the circumstances are such that they do not show any gross mistake, yet the inaccuracy appears in degree. For example, people are under the impression that the Ochterloot trial was at least as severe as Spezia, yet there is grave reason to doubt it.

Sir CHARLES NUGENT: I had no intention of being the champion of the authorities at all; but I thought perhaps an inference might have been drawn from what Captain Browne had said that nothing was being done.

Captain ORDE BROWNE: I do not think Sir Charles Nugent mentioned Hadfield among the names of the makers.

Sir CHARLES NUGENT: I did not, but I was acquainted with Hadfield's experiments.

Captain ORDE BROWNE: With regard to those makers, Sir Charles Nugent said that they want to make small shot, that they feel the difficulty of making shot of 17 inches diameter and 2,000 lbs. weight. Sir Joseph Whitworth has done it successfully, and if that is the case, is not it a very serious thing to the Terre Noire Company have done so, and that Krupp can produce 17 inch projectiles of a great deal better quality than we can in this country? In the case, considering the expense there is in developing the manufacture of steel projectiles on account of the plates required to fire them at, might it not be wished that they could find their way into the proof plates at the Admiralty? I am aware that the primary object of proving plates is to get a point of rejection. When that is the case I wish that steel projectiles could be used, because if you could develop them without expense to the country it is a great matter. I suggested that once, and I was told that makers were very loath to make these shots, and I tried to point out that they were very shy of making them on which their reputation was to depend, but that they would be ready to

plates to try them at. With regard to the 5 inches of wood, I be considered an absolute fixed quantity, no matter on what scale you are of this reason that it wants a certain amount of padding to prevent one fracturing the other, and 5 inches apparently has been found practicable to do that. I think you will find that two layers of 2½-inch plan vertically and the other horizontally, are now generally used, and are prevent the two pieces of metal from coming together, while at the same do not give room for the point of the shot to clear itself of the front coming to the second plate. With regard to the "Shannon" experiment most destructive results for men may be caused by certain shell breaking "Shannon" experiment was an extraordinary one. The effects inside shocking. Happily they were only on dummies. Shrapnel shell will a very great number of pieces from mere impact, but I am afraid that a shell merely breaks from impact it is apt to break in very few pieces, and is the reason why it is desirable that the charge of powder should burst.

Sir CHARLES NUGENT: When you resort to steel you do so with obtaining a thinner envelope of metal and a larger powder charge, and the impression that the tendency of the steel envelope may be to open to burst into pieces.

Captain ORDE BROWNE: That brings me to another point with Krupp's experiments. Sir Charles Nugent's statement would show that make these steel shells rather with a view to incendiary effect than effect. With regard to Sir Frederick Abel's steel shell, there are steel have been through a considerable thickness of metal and have not burst. And in the experiments made at Shoeburyness now and then there promise of the possibility of such a thing, but nothing that could be upon. I think they hoped that that possibility might ripen into a case you could depend upon. I think, however, that there is no chance account of the soft armour giving place to hard. The bolting of the plate, both compound and steel, was so nearly the same that there was no call attention to. With wrought-iron plates the bolts go through the steel and steel-faced that is not the case; in both of these the bolt is the back, entering only to a certain depth, for the reason that you must the continuity of the surface of the steel if you could possibly help brought these questions up in hope of calling attention to them. If an could be said here would end, for example, in Gruson's plates being tried be very glad. I am very glad to hear from Sir Charles Nugent that the offer to try them in England. It is important to know that he has and did not accept it. If that is so, of course we are not entirely to blame.

The CHAIRMAN: It only remains now for me to return thanks to Captain Browne for his very instructive lecture.