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The Attack of Armour-Clad Vessels by Artillery

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ADMIRAL SIR FREDERICK W. E. NICOLSON, BART., C.B., Vice-President, in the Chair.

THE ATTACK OF ARMOUR-CLAD VESSELS BY ARTILLERY.

(The original Lecture was delivered at the Royal Artillery Institution on October 19th, 1881.¹)

By Captain C. ORDE BROWNE, late Royal Artillery, Lecturer on Armour to Department of Artillery Studies, Woolwich.

PROBABLY most Officers will agree to the statement that it is very desirable in the case of a deliberate engagement to know the nature of armour carried by an enemy, and also its thickness, within reasonable limits. It may be well to observe that it ought, in most cases, to be possible to obtain this information, for the number of armour-clad vessels possessed by any Power is limited, and such vessels are built sufficiently slowly for their most important features to become widely known before they are afloat, both with regard to outward appearance and construction. It is necessary to state this fact, for on it depends substantially any value that this paper may possess.

When possible, it seems important that a decision should be made as to whether the armoured portion of the ship, containing what may be termed the vital parts, should be attacked, or whether it would be better to bring the battery to bear on to the less protected or unprotected parts. For the sake of distinction, I term the former the "*primary*," and the latter the "*secondary*" attack. Besides, there is also the attack of the horizontal armour on the deck, which is almost a separate question of its own, which, for the sake of convenience, is here put between the primary and the secondary attack. The primary and secondary attacks are best carried out with entirely different kinds of ammunition. It is for this reason that it appears important

¹ The Institution is indebted to the Committee of the Royal Artillery Institution for the use of the blocks which illustrate the lecture.

to adopt and follow one or the other plan of attack thoroughly, instead of firing armour-piercing shells indiscriminately at every armour-clad ship.

Primary Attack.

Whether a ship's armoured portion can be attacked by any given gun with advantage or not, depends on the *nature* and *thickness* of her armour. *Steel* distributes the shock of impact through its mass, and hence it has great power in resisting a single blow, but it is liable to succumb to the continued fire even of inferior guns. No better illustration of this could be given than the comparative behaviour of the 22-inch steel and iron plates at Spezia in 1876. The steel crumbled away gradually, even under the fire of 10-inch guns, a fire which proved almost harmless to the 22-inch wrought-iron plates. On the other hand, the steel completely stopped the projectile of the 100-ton gun, which enormously outmatched it. This it did at the expense of the plate, itself shivering into fragments, while the iron allowed this projectile to pass completely through it; both experiments were repeated with the same results. It may be seen, then, that *penetration* through steel is hardly to be looked for, but rather the *shattering* of it.

A steel-clad ship, from its power to resist a single blow, is admirably suited for running past a small number of guns, however heavy they may be; but, on the other hand, it suffers from the continued fire even of light guns: hence it might depend on the probable duration of an attack whether it was wise to fire at a ship's side armour or only at her unarmoured places. The effect of a shot against steel plates is probably proportional, not to the shot's power of penetration, but to the stored-up work contained in the shot at the moment of impact, which is expressed by $\frac{Wv^2}{2g}$, where W is the shot's weight, v the

striking velocity, and g the force of gravity. To take an example:—The 9·45-inch Krupp B.L. gun, firing a shot weighing 348·3 lbs., with a velocity of 1,890 feet a second, can, according to Colonel Inglis, penetrate a plate 18·1 inches thick. The 38-ton gun, 12·5 inches calibre, firing a shot weighing 812 lbs., can penetrate a plate 17·9 inches thick only. That is to say, of the two, the Krupp gun has rather the advantage in penetrating wrought-iron. On the other hand, it may be seen that the 38-ton gun shot has about 12,260 foot-tons stored-up work, whereas the Krupp gun has only 8,630 foot-tons work. Consequently, while the latter gun would be equal, or slightly superior to the former if fired against iron, two rounds of the former would probably produce nearly the same effect as three rounds of the latter against steel plates. It appears reasonable to suppose that the cracking of the steel represents the stored-up work in the shot as fully as the shearing effected in the wrought-iron; although, in so curious a mechanical problem as the cracking and breaking up of steel which goes on for some minutes after the moment of impact, it is unsafe to dogmatize. One conclusion arrived at by the Sub-Committee on Plates and Projectiles is, that it is necessary to attack steel-faced

armour with steel projectiles; the fact, I believe, being that chilled iron under the sudden resistance experienced breaks up before the conditions favourable to its success are established.

Steel-faced armour, that is, armour composed of a wrought-iron foundation plate and steel-face plate, comes under the heading of steel in a modified form: not that a plate composed of a compromise between steel and wrought-iron would answer, for the object is to have a hard surface and tough back. Compound armour, however, so far behaves like steel, that it is seldom fairly penetrated, but generally destroyed by fracture. It has recently exhibited great powers of resistance. The diagram on page 3 shows the condition of a compound 11-inch plate of Brown's after being struck by the following projectiles:—Three 9-inch chilled shot from a 12-ton gun, one 9-inch steel with chilled point, and one 12·5-inch steel shot from a 38-ton gun. The latter projectile has only penetrated to a depth of from two to three inches in the steel, flattening out and breaking up, but still making a hole through the plate at the point of impact. The metal in the shot may be rather soft, but the shield has borne its blow of 11,820 foot-tons admirably. Three of the 9-inch shot contain about the same total quantity of work. I fear, however, that it would be difficult to make a diagram such as would enable you to compare the effect of the one heavy and three light projectiles.

Wrought-Iron.

Wrought-iron yields locally at the point of impact only. It is universally admitted that for direct fire a sharp-pointed projectile is best. This forces in its sharp point, which experiences comparatively slight resistance at first, and soon gets deep enough to cause the plate to begin to yield at the back, just opposite to the shot's point, in a star or cross-shaped tear, which is opened, the corners bending back as the shot gets deeper, until at length the projectile forces its way through, mainly by tearing the iron in lines, whose lengths are directly proportional to the calibre of the gun. It is this action that appears to support the use of the first power of *D*, rather than the square in the formula used for so many years in the Department of the Director of Artillery. However, what is mainly to the point here is the fact that the shot shears or punches a comparatively clean hole, leaving the surrounding portions of the armour and fastenings almost uninjured. I have here two photographs, taken almost at hap-hazard, being duplicates from the R.M. Academy which were not required for cadets. These sufficiently exhibit the well-known behaviour of wrought-iron under continued fire—one in the case of direct and the other oblique fire. In the latter the effect of the blow is more distributed than in the former. For all practical purposes, however, it may be considered that unless a projectile passes through *wrought-iron* sufficiently far to cause injury by lamage, it effects nothing. Even a projectile passing bodily through, in the form of dead metal, may produce but a very limited amount of damage; the armour of the ship being left in good condition, except that it has a clean hole through it, and even that may be plugged up by the base of the projectile. In the case of

Palliser or steel shells, fired under ordinary conditions, a certain thickness of iron will probably cause the charge of the projectile of almost any gun, even the heaviest, to explode at an early stage of penetration, so that the flash does not get through the armour. So long as armour-clad ships were able to keep all fire out, they enjoyed a measure of security altogether beyond that belonging to wooden ships, even supposing them to be penetrated through and through.

The possible introduction of steel projectiles, which stand up to their work and retain their shape sufficiently well to allow them to carry a bursting charge entirely through the armour, seriously threatens this advantage. You see before you a 9-inch Whitworth steel shell which was fired by the Sub-Committee on Plates and Projectiles. This shell has, as far as I can ascertain, passed twice through a solid iron plate 12 inches thick. It is not of the best proportion of calibre to weight, nor has it the best shaped head, yet it is capable of carrying a gun-cotton charge unexploded through 12 inches of iron, for this was actually effected by one supplied with it. It will be seen that this danger can hardly be said to threaten steel armour seriously, for a shot must enormously overmatch a steel plate to get through it, as we have seen in the case of the Spezia trials.

The *increased power* that has been obtained in *new type guns* still further favours the attack of iron by penetration. Let us take an actual experiment showing what might be effected by *new type guns* firing *steel shell* with *gun-cotton* charges. At Meppen, in August, 1879, a Krupp gun, 9.45-inch calibre, weighing 17.7 tons, was fired at a target consisting of 20 inches of wrought-iron in two thicknesses, namely, 12 inches and 8 inches, sandwiched with about 3 inches of wood between the plates. The projectiles passed through the target and went 3,590 yards up the range before grazing. When recovered, they scarcely showed signs of having been fired. They could undoubtedly have carried gun-cotton charges through the plates. It is a serious reflection that a new type 18-ton gun may be able to drive a projectile carrying fire into the strongest part of any English ship afloat, except the citadel of the "Inflexible."

Where wrought-iron is concerned, then, it is practically a question either of "*perforation*" or else failing to damage at all: consequently, it is specially important to know what is the limit of a gun's power at any range. Very complete diagrams showing this have been drawn up by Colonel Inglis and Colonel Maitland, which will be found in the "Report on Plates and Projectiles." Colonel Maitland has, I believe, recently completed a diagram, from which additional information, such as the diminution of the velocity of any shot on any increase of range, can be taken directly. As Officers are not likely to want to decide these questions with guns in action, which they are handling for the first time, these diagrams might be used to furnish them complete information as to their guns before coming into action. I think, however, it may be well to have also a rough rule for fixing the limit of a gun's power against wrought-iron, which can be carried in the head: I may, therefore, point out a very simple one, namely, *one calibre thickness of armour for every thousand feet velocity*. I believe

this was noticed by different Officers in the case of the Armstrong gun trials. It is no matter of chance, but admits of mathematical proof, if two suppositions are made, neither of which is monstrous. Sometimes both are true, and how far they are wrong may always be known and allowance made. I would point out, however, that the simple application of the rule is never very far from the truth. Herewith is a table showing the thickness of plate penetrated by projectiles of nearly all the best known heavy guns at velocities of 1,000 feet, 1,500 feet, and also at the muzzle velocity of each gun as taken from Colonel Inglis' diagram, and also as obtained by this simple rule. It may be seen that in the maximum penetration column, in two cases the result is absolutely correct, in twelve instances the error of the rule is only the fraction of an inch, and in seven cases it exceeds an inch. In the two other columns the differences are rather larger. I give the mathematical proof of the rule herewith,¹ by which it may be seen that the two assumptions required are (1) that the formula formerly used in the Director of Artillery's Department is correct when the resistance of the plate is supposed to increase with the square of its thickness; (2) that the ratio of the weight to the cube diameter of the projectile is about '4. The first of these is most nearly correct when the plate approaches two calibres in thickness, and the latter in the projectiles of new type guns is close to the truth. Whether these conditions are approximately true or not would probably be known; for an Officer would know generally whether his gun fired light or heavy projectiles in proportion to its calibre, and whether its velocity was high or low: he ought, therefore, without trouble, to get better results than those on the table. To take an example, however—where nothing is known and allowed for—say that an Officer has 9-inch guns, and supposes an enemy to be 1,000 yards off (failing actual knowledge); an old type gun's initial velocity might be guessed at 1,500 feet, and a really new type one at 2,000 feet, the velocity falling about 100 feet for every 500 yards' range. Guessing the 9-inch gun as having 1,500 feet initial velocity, and

¹ The equation formerly employed in the Director of Artillery's Department may be written—

$$t = \sqrt{\frac{Wv^2}{2g \times 2\pi R \times c}}$$

where t = thickness of plate perforated, v = striking velocity, g the force of gravity, $2R$ or D = the diameter of hole or of shot making it, and c = a certain constant. Assuming that the weight of every projectile bears a *constant* relation to the calibre that is ($W=c'D^3$), and collecting all the constants together under the letter K , by which we may express all the constant part of the expression, we have—

$$\begin{aligned} t &= \sqrt{K \frac{D^3 v^2}{D}} \\ &= \sqrt{KD^2 v^2} \\ &= \sqrt{K} DV. \end{aligned}$$

Experience shows that the constant part, $\sqrt{K} = \frac{1}{1000}$; in other words, that the penetration in inches is equal to the calibre $\times$ the number of thousand feet velocity.

consequently 1,300 feet at 1,000 yards, the limit to possible penetration would be 1·3 calibres, or something under 12 inches. This is one of the worst examples; the 9-inch shot being light for its calibre, and the diagram shows well under 11 inches. Even this, however, is a better result than a guess is likely to yield.

Take a new type gun, however—such as the 43-ton gun—say at 1,500 yards, guessing 2,000 feet as initial velocity, and taking 300 off for the three 500 yards in the range, we get a velocity of 1,700 feet, and limit of penetration of 1·7 calibres, or something under 20½ inches. Colonel Inglis gives 20·9 inches; surely for a quick estimate, made without data, this is close. However, this subject may be dismissed by observing that Officers should be provided with diagrams, and from these obtain an accurate estimate of the powers of their guns at any likely range. Failing diagrams, a table of velocities, with the rule of one calibre for each 1,000 feet, gives a fair idea; and even if the velocity has to be guessed, the rule gives a much better estimate than a direct guess at the thickness would be likely to yield.

Supposing that the enemy is known to carry iron armour at all over the limit which is calculated for the most favourable circumstances, it is useless to fire at it, and the secondary attack might then be adopted. Before dealing with that, however, may be noticed the attack of the deck.

Attack of Decks.

This, when practicable, is probably the most formidable of all, but may be attempted with guns incapable of piercing the side armour. Batteries in positions of high command may generally prefer to fire at the deck. This attack is formidable in proportion to the descending angle, both with regard to the possibility of penetration and the mischief that may be done when penetration is achieved.

The four 100-ton guns which are going out to Malta and Gibraltar will be mounted with about 90 feet command above the sea. Unquestionably these guns would terribly injure any ship they struck on the deck. Probably they would employ common shells. The more common case to consider would be that of much smaller pieces. It was concluded at Shoeburyness, in 1870, that 9-inch guns at 8° would not penetrate single inch decks at 100 yards. At 15° it appears from recent experiments, they would destroy double that thickness of deck plating. The position of the ship affects this question: a broadside view gives but little opportunity. On the other hand, some vessels have special protection when lying head on. The armour bulkhead of the "Shannon" is an instance; she might be much better struck from astern. In some cases, I believe, vessels attack by following each other on an elliptical path, firing in succession from the nearest point to the fort. In such a case some guns might be devoted to fire at the receding vessels. On the occasion of her capture the "Huascar" kept her stern away from the enemy systematically.

The attack of decks by high angle or mortar fire has generally been little considered owing to the inaccuracy of ordinary mortar fire. At Meppen, in August, 1879, Krupp fired an 11-inch howitzer at

28° 36' elevation at a horizontal target meant to represent the deck of the "Inflexible," though rather larger, being 100 metres (328 feet) long, and 25 metres (82 feet) broad. The range was 6,700 metres (7,327 yards) to the bows, which were presented towards the firing point. Out of ten rounds five fell on the deck, the four last all being within about 3 feet of the centre of the deck. The shell weighed 476·3 lbs., and the firing charge was 39·7 lbs.

This firing appears to me to be far too accurate to justify the question of vertical fire being neglected, at all events at an enemy at anchor.

Secondary Attack.

Protected vessels have latterly come in in notable instances where the armour is almost confined to the water-line, as in the "Shannon" class; or to the machinery, &c. (vital parts), as in the "Italia" and "Lepanto." Even citadel ships, like the "Inflexible," "Duilio," "Dandolo," "Ajax," "Agamemnon," "Majestic," and "Colossus," have unarmoured ends, which may be attacked by ordinary projectiles. In fact, armour-piercing projectiles would be likely to do little injury to these parts, for projectiles which depend on violent impact for firing their powder most likely would not explode at all. The Director of Naval Ordnance, in writing on the "Inflexible" about 1877, said:—"The projectiles that would be fired at the 'Inflexible' would certainly be armour-piercing, either chilled iron or steel; and such shell would not burst in passing through the thin iron sides of the ship, as they require the resistance of armour to ignite the bursting charge." The Committee wrote:—"The most effective armament to bring against the 'Inflexible's' ends alone would undoubtedly be one of numerous shell guns." At the present time, perhaps, we should hardly assume that every foreign Naval or other Artillery Officer would prefer an inefficient mode of attack to an efficient one. Possibly, however, few Officers present even to-day would think of attacking an armour-clad in her weak parts with *shrapnel shells* and *sensitive fuzes*. Yet the "Shannon" trials at Shoeburyness, in 1875-76, indicated that this was often the most effectual kind of fire. The profile resembling the "Shannon" at Shoeburyness had 1 inch of iron and steel in different portions. Common shells with Pettmann fuzes sometimes acted well, but more frequently broke into a few fragments, the powder only firing after the fracture, and so burning without much effect. Even with the Laboratory sensitive or direct action fuzes this was liable to happen. The behaviour of shrapnel, which break up into a multitude of fragments and bullets, is much less dependent on the bursting charge than that of common shell. One shrapnel in these trials dismounted a gun and destroyed the entire detachment, and the effect of these shells was generally remarkably good. Probably common shell for incendiary effect, and shrapnel to sweep the batteries, both having sensitive fuzes, would be the proper projectiles to fire. It is important to bear in mind that common shell have been found equal to the penetration

of armour half their calibre thick, that is, 10-inch shells 5 inches, a 16-inch shell 8 inches.

The portions of ships below the water-line may appear to some to present a vulnerable spot to aim at; and doubtless this is a possibility to be kept in view, but it is at present scarcely feasible to strike the sides of English, or most foreign, ships below the water-line. The *conning tower* is another important mark for attack. It may be remembered that Admiral Grau was killed in the conning tower of the "Huascar," which was repeatedly struck and destroyed by the guns of her adversaries. The *funnel* may appear to be a tempting mark for light guns, but little can be done by striking it above deck, as the following consideration may show:—

The boilers are placed low down in the hull, and the funnels must be measured from the fire grates. Suppose the total length of funnel to be 50 feet, and that it is cut down to 30 feet. The diminished power of generating steam will be to the original power in the proportion of $\sqrt{30}$ to $\sqrt{50}$, that is 5.5 to 7.1. The ratio of the speed is, I believe, proportional to the cube root of the generating power, that is, as $\sqrt[3]{5.5}$ to $\sqrt[3]{7.1}$, or about 1.763 to 1.920. In other words, the vessel would only lose 1 knot in 12 by such an injury—though inconvenience might doubtless be felt from the escape of smoke on deck.

Models of Ships of War.

These models of hulls are intended to show the general plan and the disposition of guns and armour of a few typical ships of war, to enable Officers to understand their general construction, and form their own judgment as to how coast batteries should deal with the classes of vessels they represent. The projectiles and fuzes recommended are those indicated by experiments, in some cases not yet introduced into the Service.

The models are all made to the same scale, viz., 16 feet to the inch. They are painted in accordance with the vessels they represent, except that, on one-half, sections of the armour and the face of it also are painted. Wrought-iron is coloured dark blue, and steel plum-coloured, or light bluish colour (*vide* face of "Inflexible" turret). They are weighted with lead to float nearly at the depth of the water-line.

The "Glatton" and "Inflexible" are made from Admiralty drawings, and have been corrected in the Admiralty, and are fairly accurate. The "Admiral Duperré" and "Polyphemus" are made chiefly from drawings in "King's War Ships," and "The Engineer," and do not claim to be accurate in all respects.

"Glatton" (British).

Coast defence; breastwork, single turret type; length between perpendiculars 245 feet, extreme breadth 54 feet, displacement 4,912 tons.

The principal artillery features are:—

All-round fire with two 25-ton guns, combined with *complete protection* by *heavy armour*. She is fitted to engage with an enemy of great

power, because her all-round fire enables her to place herself obliquely to the enemy's guns. When built, it appeared as if she was unlikely to suffer from the effect of the heaviest guns then extant.

At Portland, in 1872, her turret was fired at by the 25-ton gun of the "Hotspur." One round struck the centre of the turret near the ports; the plates were forced back $5\frac{1}{2}$ inches, and some distortion caused (Figs. 2 and 3). The second round struck the junction of the

FIG. 2.

turret with the glaucis-plate of the deck (Fig. 4). The object being to try the effect of wedging the turret and so preventing its working, the shots were directed at the most likely places to cause this, the 14-inch plates being selected rather than the 12-inch plates, which would have

FIG. 3.

allowed the shot to pass through with less shock to the ship. Perforation was not effected, and the turret was in no way prevented from working freely.

The introduction of new type guns, firing projectiles of comparatively small calibres with high velocity, in no way favours the operation of distorting a turret, but rather the reverse, for the power to contort depends on the resistance offered, and this decreases with the calibre of the projectile.

FIG. 4.

The introduction of new type guns, and also of steel shells which remain intact after penetration, will, however, seriously detract from the invulnerability of this vessel to *penetration*. A new type 9-inch gun might undoubtedly perforate her sides and turret at close quarters *striking directly*. Steel shells charged with gun-cotton and delay-action fuzes would be the most formidable projectiles to attack her with. Taking her altogether, with her powers of all-round fire and *complete armour*, she would still probably bear heavy artillery fire very well. Against two antagonists, the fact of her possessing only a *single turret* is a disadvantage. The Captain and staff are very secure in the conning tower immediately aft of the turret. This ship is erroneously described as having no ram in some foreign works on ships of war.

The coast defence vessels of Great Britain are the—

"Glatton."	"Gorgon."	"Wyvern."	"Magdala."
"Hotspur."	"Hecate."	"Scorpion."	"Abyssinia."
"Rupert."	"Cyclops."	"Viper."	"Cerberus."
"Prince Albert."	"Hydra."	"Vixen."	

Our sea-going turret-ships "Dreadnought," "Thunderer," &c., resemble the "Glatton" generally as to armour.

The French first class coast defenders of the "Tonnerre" class closely correspond to these.

The Russian Navy has many vessels of this type, including the "Great Peter."

"Inflexible" (British).

The largest ironclad at present afloat. Length between perpendiculars 320 feet, extreme breadth 75 feet, displacement 11,406 tons. (The Italian ships "Italia" and "Lepanto" will be larger, viz., 13,480 tons.)

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Type, *Citadel*. Diagonal turret type of sea-going ship (*vide* elevation and plans, Fig. 5). The "Agamemnon," "Ajax," "Colossus," and

"Majestic" (English ships) are being built on the same plan. The Italian ships "Duilio" and "Dandolo" are also on the same principle.

The model is made to pull asunder (masts and rigging being left out) so as to enable the vulnerable unarmoured portions to be removed; leaving the armoured citadel, with its turrets and its submerged projecting ends covered with horizontal armour (*vide* Fig. below).

Portion of H.M.S. "Inflexible" protected by vertical or horizontal armour.

Supposing this part of the vessel only to be left sufficiently perfect to keep out water and cause displacement, thus giving floating power, the rest of the ship would be merely dead weight; and Sir E. Reed argued that in such a condition this ship, as well as the "Duilio" and "Dandolo" would be liable to capsize. Practically, considering the construction of the superstructure, with its cork, &c. (*vide* model section), this is out of the question. It could only be effected by many days of continued firing. The citadel is very heavily armoured (*vide* model)—24 inches in thickest parts. Turrets have 16 inches (17 inches at ports), the outer plate of 9 inches being steel-faced (light blue or plum colour on model section).

It would be useless to attack the heavily armoured parts of this ship with anything of much less power of penetration than the 80-ton gun. Practically the 80-ton gun would severely injure her only by repeated blows. She would also be able to resist plunging fire very well. With smaller guns all ships of this class might be attacked in the unarmoured parts by common shells and sensitive fuzes, and shrapnel with special sensitive¹ percussion fuzes. Lighter guns also might disturb the Captain and staff of the vessel posted in the corners of the iron plate cross in the conning tower² near the foremast (on model).

As to her own fire, the diagonal position of turrets is intended to enable the citadel to be shortened, and thus to effect a saving in armour and weight. It is also meant to give fire with four guns (80 tons) fore and aft. This has not yet been actually attempted. The turret guns have fired hitherto only up to about 15° of this line, and thus pointed are only directed on two adversaries 30° asunder.

The "Duilio" which so strongly resembles the "Inflexible," has steel armour, which might gradually be destroyed by comparatively light guns, but would probably stop a single projectile of any gun afloat. She has no deck structure for cabins like the "Inflexible," but her funnels and casings, being outside the citadel, interfere with all-round fire. The vessel is narrower than the "Inflexible," and the turrets are therefore necessarily constructed with their centres in a line making a smaller angle with the keel than is the case with the "Inflexible." Although, as already said, there is no prospect of causing a vessel of this class to capsize by destroying her unarmoured ends, these might be so far injured as to cause serious inconvenience, and they form a natural object of attack for any but the very heaviest guns.

The "Admiral Duperré."

Length on water-line 319 feet 10 inches, extreme breadth 66 feet 11 inches, displacement 10,322 tons (French); building; *special barquette type*, copied more or less in other French ships—the "Duguesclin," "Triomphante," "Victorieuse," "La Gallisonière," &c. (*vide* "King's War Ships"); is armoured only along the water-line and on the towers, being a "protected ship" rather than an

¹ Not the fuze formerly termed "sensitive."

² The cross plate is surrounded by very thin walls and roof in the actual ship.

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"armour-clad." The guns (46-ton) revolve on turntables, one in each barbette tower. There are also fourteen broadside $5\frac{1}{2}$ -inch guns unprotected (*vide* elevation and plans, Fig. 6).

FIG. 6.

The principal artillery features are the great command of her guns ($27\frac{1}{2}$ feet above the water-line), and her power of all-round fire; though, it is to be observed, that is less complete than in turret-ships. She fires two guns directly ahead—probably only one directly astern. She can hardly fire her four heavy guns in any direction. She will have, however, great power of offence if she carries new type broadside guns.

Her defence is very imperfect; she is open to attack from common shells (of all calibres) with sensitive fuzes, and even larger machine-guns, in all unarmoured parts. Shrapnel with special sensitive fuzes might also be used against the broadside guns, and shrapnel with time fuzes or special percussion fuzes, and bullets from machine-guns might be directed on the men in the barbette towers, as well as common shell with percussion fuzes.

The English ship the "Collingwood" is being built on the barbette system, though with much more regard to protection than is exhibited in this ship.

The "Polyphemus."

Length on water-line 240 feet, extreme breadth 40 feet, displacement 2,640 tons. Ram and torpedo ship. She carries no heavy guns, her weapons being the torpedoes, which she discharges from her bow and on each side amidships, machine-guns, and her ram, which simply consists of her steel bow torpedo tube strengthened by ribs (*vide* model), consequently she must not be expected to discharge torpedoes from her bow after once ramming.

She is protected by steel scales and steel plating specially made by Sir J. Whitworth and Co. The sides of the vessel are made of double half-inch ship-building steel of about 26 tons per inch tenacity. The entire "turtle back" to 5 feet below the water-line is covered with a Whitworth steel inch plate (45 tons tenacity). From 2½ feet below the water-line the turtle-back is further protected by Whitworth steel scales, till the tangent to the curved back comes down to 20° with the horizontal. These scales are each about 10 inches square and 1 inch thick, held on by one screw in the centre and one at each corner, holding down the corners of four plates, so that each plate has one screw in the centre and a quarter of a screw at each corner, making two screws for each plate throughout. The steel for the scales has a tenacity of 65 tons. The scales will resist the direct blow of any machine-gun easily, and will perhaps prove suited to resist a very oblique blow, even from heavy projectiles, to which only they are exposed in action.

This vessel has special peculiarities which are not artillery matters, such as the power to drop heavy weights carried along her keel (in all 240 tons) so as to make her float higher, and recover herself if a compartment fills with water, &c.

The best method of attack might be to fire armour-piercing projectiles as directly as possible, common shell, charged with gun-cotton, and percussion fuzes might also be tried. Her top structure might be destroyed by the projectiles of almost any guns. Common shells filled with gun-cotton and with percussion fuzes might probably be the best.

The engagements of the "Huascar"—more particularly that one which ended in her capture—may seem to deserve special notice in this paper. This is, however, a matter on which I should hope to hear something from naval Officers in discussion, and I would only put before you drawings of the "Huascar" (showing the places where

she was struck) (*vide* Plate, Figs. 1, 2, and 3) which has been kindly contributed by Lieutenant Montgomery, R.N., of H.M.S. "Shannon," adding a very few remarks.

Officers unacquainted with the "Huascar," from the general resemblance she bears to our own turret vessels, might take her to be much stronger than she really is. She has only $5\frac{1}{2}$ inches of iron on her turrets, $4\frac{1}{2}$ inches on her sides, and 3 inches on her conning tower; and she carried two 10-inch guns, two 40-pounders, and one field-gun. On the occasion of her capture she maintained a very gallant fight for $1\frac{3}{4}$ hours against two vessels, enormously outmatching her, protected by 10 inches of armour. She endeavoured to keep between them, to keep her weak parts out of fire and to ram, which was defeated by the advantage her adversary (the "Cochrane") possessed in having twin screws. Finally, when her staff and half her crew were disabled, and she had resisted one attempt to board, she surrendered. It seems ungracious to point out any flaw in so noble a defence, but the fact cannot be allowed to pass that her guns failed in their part, for neither in her encounter with the English vessels "Shah" and "Amethyst," nor on the occasion of her capture, can she ever be said to have hit any ship to any purpose, though at times at close quarters.

The two models before us, the "Inflexible" and "Admiral Duperré," may serve to remind us of certain points of contrast between our own ships and those of France. We have, either afloat or well advanced in building, eleven first class turret sea-going ships, and fifteen coast defenders, in which is embodied the principle of carrying a very few very heavy guns behind thick armour—the turret principle enabling the guns to engage on either side. The French ships have generally more pieces, but of lighter weight. The average number of heavy guns in our first class turret-ships is 6.1, and in our first class broadside ships 11.1, while in the French first class ships it is 15.3. The total weight of metal (in ordnance) carried (which may, perhaps, be best shown by the number of tons displacement per ton of gun) is as follows:—English turret, first class, 56.1; broadside, 43.5. French, first class, 39.5; second class, 52.3. The advantage of the all-round fire of the turrets may enable the English ship to bring a great weight of artillery into action perhaps; but the question is, whether the greater number of guns carried by French ships may not be an advantage which must not be overlooked. So long as the medium guns carried in broadsides could not pierce our armour, the question was less serious than it may shortly become if medium new type guns are carried capable of piercing nearly everything we have afloat. No doubt we can hardly for a moment compare the "Admiral Duperré" and the "Inflexible." The 80-ton guns of the latter ought to penetrate the thickest part of the "Admiral Duperré's" armour, striking fairly, up to 2,000 yards' range; while the 46-ton guns of the "Admiral Duperré" could not pierce the citadel of the "Inflexible." On the other hand, the English ship could in many positions only engage with two guns. The "Inflexible" is the bigger vessel by over 1,000 tons. The "Admiral Duperré" could, perhaps, compare better with

INJURIES SUSTAINED BY THE HUASCAR.
8TH OCTOBER, 1879.

the "Dreadnought," 564 tons bigger than herself, whose armour her heavy guns could readily pierce; but much better with the "Colossus" class, because her light guns would find work on the unarmoured parts, while her men would work in the barbettes towers and behind the thin unarmoured iron sides of the ship with comparative impunity, owing to the small number of her adversary's guns. Sir William Armstrong, in his recent presidential address to the Institution of Civil Engineers, discusses the condition of a fight supposed to take place between one armour-clad and three unarmoured vessels costing the same sum of money. Sir William considers that the latter vessels would prove too formidable for their adversary if they were constructed so as to be almost incapable of being sunk, and also if they were armed with torpedoes. He even thinks that the effect of a shell entering the side of a ship is overrated.

I confess that I am unable to follow him in his reasoning, because while the ironclad would probably suffer very little from the *armour-piercing projectiles* of her adversaries, she might fire shrapnel and common shell at them, and I have instanced the sweeping effect of such projectiles on the battery of the "Shannon," to say nothing of the possibility of setting fire to them.

In the attack of harbours unarmoured ships would, I think, be almost useless. Forts are generally armed with numbers of guns which are almost powerless against armour, but it would be almost madness to bring an unarmoured vessel into the zone of their fire.

Sir William, however, reminds us of a type of vessel such as Elswick has supplied to China, which carries powerful ordnance and is so small as to present but a bad mark to an enemy. The spectacle of the "Inflexible," attacked by half a dozen such boats, and defending herself with her two pairs of 80-ton guns, and her necessarily limited supply of ammunition, would afford a painful illustration of power awkwardly employed. I think that she would feel the need of the medium new type guns which I have advocated in such a case.

It is not here denied that heavy guns have a special power of their own, in comparison with the same weight of lighter ordnance. Colonel Inglis has suggested one case, which deserves notice, when a heavy gun might effect more than many light guns, namely, against chilled iron armour. The French, Germans, Russians, Danes, Dutch, Spanish, and Portuguese have forts of chilled iron on their coasts. This material resists a good deal of heavy fire without suffering severely. It is employed on the presumption that at sea it is difficult for ships to plant many shot near the same spot. It appears likely that the blow of a projectile from an 80- or 100-ton gun might wreck a great portion of a chilled iron parapet entirely. However, this is a question of ships and forts, which certainly concerns our naval Officers, but hardly the English artillery, as it is difficult to imagine a case in which they would attack the coast batteries of European Powers, and we have no chilled armour on our own coasts.

With the object of inviting discussion, it may be well to draw one or two conclusions. It is therefore suggested, 1st, that at present we

18 THE ATTACK OF ARMOUR-CLAD VESSELS BY ARTILLERY.

need *medium new type guns* introduced as far as possible into the armaments of our ships and forts. Against *steel*, such guns are, in their measure, available for gradual destruction, and very heavy guns can only deal with steel in the same way, though much more rapidly, that is to say, they crack it to pieces, but do not actually pass on into the ship. Iron must be *punched*, and how well this may be done by a new type gun is seen from the fact that we found an 18-ton new type gun beating an old type one of 38 tons. 2nd, that the secondary attack of weaker parts of armour-clad vessels by common or even shrapnel shells deserves more attention than it has received. 3rd, high-angle fire at decks deserves more attention than it has received, especially as employed in the defence of harbours where, owing to the presence of submarine mines, attacking ships may be compelled to anchor. Lastly, it is suggested that we should guard against the disposition to take advantage of the small number of our guns by exposing detachments and confining armour to the vital parts, which form the natural object of attack of our heavy pieces.

Table showing how far the results obtained by the Rule of Thumb agree with those given on Colonel Inglis's Diagram.

Nature of Gun.	Calibre.	$\frac{W}{D^3}$.	At Maximum or Muzzle Velocity.				Penetration at 1,500 ft. Velocity.			Penetration at 1,000 ft. Velocity.		
			Velocity.	Penetration.		Difference, Rule of Thumb - Diagram.	By Rule of Thumb.	By Diagram.	Difference.	By Rule of Thumb.	By Diagram.	Difference.
				By Rule of Thumb.	By Diagram.							
100-ton Armstrong B.L.	17.72	.40	1500	26.6	25.3	+1.3	26.6	25.3	+1.3	17.7	16.1	+1.6
" " M.L.	17.72	.36	1735	30.7	28.1	+2.6	30.7	28.1	+2.6	17.7	15.3	+2.4
71-ton Krupp B.L.	15.75	.44	1633	26.2	26.5	-0.3	26.6	24.0	+2.6	15.8	15.2	+0.6
80-ton M.L.	16.0	.42	1613	25.8	25.2	+0.6	24.0	23.3	+0.7	16.0	14.6	+1.4
51-ton Krupp B.L.	13.98	.42	1650	23.1	23.0	+0.1	21.0	20.7	+0.3	14.0	13.1	+0.9
46-ton French B.L.	13.38	.39	1640	21.9	20.9	+1.0	20.1	19.0	+1.1	13.4		
38-ton M.L.	12.5	.42	1475	18.4	17.9	+0.5				12.5	11.7	+0.8
38-ton Krupp B.L.	12.01	.43	1650	19.8	19.7	+0.1	18.0	17.8	+0.2	12.0	11.3	+0.7
43-ton B.L.	12.0	.42	2005	24.1	23.9	+0.2	18.0	17.5	+0.5	12.0	11.1	+0.9
25-ton M.L.	11.0	.41	1410	15.5	15.0	+0.5				11.0	10.3	+0.7
26-ton B.L.	10.4	.41	2080	21.6	21.6	0.0	15.6	15.1	+0.5	10.4		
25-ton Armstrong B.L.	10.0	.40	2012	20.1	20.0	+0.1	15.0	14.5	+0.5	10.0		
18-ton M.L.	10.0	.42	1515	15.2	14.7	+0.5	15.0	14.5	+0.5	10.0		
17.7-ton Krupp B.L.	9.45	.42	1890	17.9	18.1	-0.2	14.2	14.0	+0.2	9.5	8.9	+0.6
18-ton B.L.	9.2	.41	2000	18.7	18.7	0.0	13.8	13.4	+0.4	9.2	8.4	+0.8
18-ton Armstrong B.L.	9.0	.34	2250	20.3	19.0	+1.3	13.5	12.1	+1.4	9.0	7.7	+1.3
12-ton M.L.	9.0	.35	1540	13.9	12.4	+1.5	13.5	12.1	+1.4	9.0	6.9	+2.1
11.5-ton B.L.	8.0	.36	2040	16.3	14.9	+1.4	12.0	10.8	+1.2	8.0	6.6	+1.4
33-ton Krupp B.L.	5.86	.55	1664	9.7	11.5	-1.8	8.8	10.2	-1.4	6.9	5.7	+1.2
5-ton French B.L.	6.23	.40	1738	10.9	10.7	+0.2	9.4	9.1	+0.3	6.3	5.7	+0.6
4-ton Armstrong B.L.	6.0	.37	1960	11.8	11.2	+0.6	9.0	8.3	+0.7	6.0	5.3	+0.7

The Rule of Thumb gives the best results when $V=2,000$ feet about, and $\frac{W}{D^3} = .41$ about.

The CHAIRMAN: Captain Browne is very anxious that this paper should be fully discussed. We shall be happy to hear any gentleman who has any observations to make.

Captain CURTIS, R.N.: With reference to unarmoured vessels carrying guns attacking armoured vessels, I believe it was found in the French War that if a vessel of very little power attacked a stronger one, and was taken, he was treated without mercy for incurring a reckless loss of life; and I think inferior vessels attacking a very superior one in all probability would meet with the same fate. Therefore, I do not think that is the correct policy. I have read in the papers lately about the protection of our commerce, and it appears to me that our merchants are led to suppose that in case of war commerce would have to protect itself. I do not wish to speak disrespectfully of the Admiralty, but if they provide them with guns and so forth it is very much like saying to Englishmen. "When you are invaded you 'must protect yourselves,' by putting rides into their hands." I think ironclads will, or should, be engaged against foreign ironclads; and with respect to our merchant ships, they can only protect themselves against similar merchant ships armed by foreign Powers. It may be a satisfaction to know that a friend of mine lately came from Vancouver, where he entertained the Russian Admiral, and the Russian Admiral rather laughed at the vessels which they had bought from America, for, although they were strengthened, they were afraid to fire their guns, and they had small guns for saluting. I do not think it is policy for light armed ships to attack armoured ships. I perfectly agree with the lecturer that light vessels ought to have the heels of the armour-clad, and I think when we meet a superior force "discretion is the better part of valour."

Commander W. DAWSON, R.N.: We never listen to Captain Orde Browne without learning a great deal of the details of our profession, for which we must be very thankful to him. I am sure he will go with me in saying that the experiments put before us are simply valuable for comparative purposes as between one gun and another, or between one kind of armour and another, but that they are not to be relied upon as representing at all what takes place when the gun is brought into action against an actual ironclad ship. In nearly every instance in the experiments before us it is assumed that the armour is penetrated at right angles, and there is also a large assumption that the shot does strike the armour, which is a very large assumption with reference to naval warfare, in which only one shot in fifty is an effective hit. It is a comfort which we may take to ourselves when attacked behind armour, that the guns will not perform in action as they do when attacking a mere shield, because most of the shot will fail to strike, and the few that do so will strike obliquely, and so will not penetrate to anything like the depth which they might be supposed to do according to the rule which Captain Orde Browne has put before us. I think his practical rule ought to be amended, so as to include some allusion to oblique hitting, because the greater part of the shot that hit us would be either vertically or horizontally oblique. We have very little experience of British guns firing against foreign ironclads; the only example, I think, is that of the "Huascar," when the "Amethyst" and "Shah" attacked that vessel. The old rule in firing was that the gun's weight in shot was required to kill one man. There was one man killed on board the "Huascar." The heaviest British gun attacking her was a 12-ton gun, and so it ought to have taken twelve tons of shot to kill that man, but it took sixteen tons. Therefore we must not be discouraged by thinking that the guns are going to do in action all that they are represented as doing at a target. It was my fate some nine or ten years ago to bring before the notice of this Institution the weak penetrating powers of British guns, and also their lack of endurance, as well as their small shell power. The result was a private Departmental Committee to enquire into these allegations against British guns. I did not know of this Committee till some time after it had

¹ We require something besides the guns—men that know how to work them. Surely out of an approximate number of fishermen and boys of 125,641 we could raise a reserve force for any emergency. See "Fishermen's Almanack" for 1882, by O. T. Olsen, F.R.A.S., F.R.G.S., of Great Grimsby.

decided, when I was told the Committee had determined to whitewash the guns. British guns were accordingly whitewashed for a time, but I am glad to see by the table brought before us to-day that the whitewashing has not been very durable, and that at last it has been washed off, and that sailors are promised in the future guns that will give not "*decidedly the lowest velocities*," which was the official report of the then Ordnance Select Committee upon the so-called Woolwich system when it was first introduced in 1865, but will give as high a velocity and as hard a hitting power as any foreign weapons. That will alter the case as to British guns against foreign ironclads. Still, looking at the prevalence of oblique hitting, it strikes me that the primary attack as Captain Orde Browne spoke of it will sink even more into the background than he has put it, and that the secondary attack will be more frequently successful. It is on these grounds that I have always held it very important that ironclads should have, besides their protected armour-piercers, a number of smaller guns in order to destroy the ends and pierce below the water-line. When ships are in vertical motion at sea, piercing the ends may let in the water, and sinking one extremity may so raise the other end out of water as to make it easy to hit below the water-line; so that the partial defence by ironclad patches, or even by submerged decks, may not, perhaps, be so successful as is expected. That point of increasing the offensive powers of ships by increased velocities of shot, and by multiplying guns, is one I have always advocated in this Institution, and I am very happy to see that Captain Orde Browne has taken it up in his present paper.

Captain P. H. COLOMB, R.N. : I have always been accustomed to consider that the target offered by an ironclad is divided into three parts, which I have usually called the vital target, the effective target, and the ineffective. The vital target is some space near the water-line, according to the state of the sea, at which you might suppose if struck by a shot a vital injury might be done to the ship, in point of fact, you might sink her. The vital target is also that part containing the machinery, where a single shot might destroy her propulsion; also that part containing the steering gear, where a single shot might destroy her manœuvring power. Then the effective target I suppose to be that part of the ship where the fighting power is contained, where the men are. You might, of course, destroy the ship by operations on her vital target, but you might capture her by operations on the effective target—by the destruction of her men, and the fear of greater destruction induced thereby. Then, lastly, you have the ineffective target, and, as I understood the lecturer, he did not seem quite to draw a complete distinction between the ineffective target and the effective target. Because, when you concentrate your men in the protected parts of the ship, your enemy can do almost no damage whatever by his light guns on the ineffective part of the target, as it does not hurt the floating power of the ship. There are no men to hurt, and the only damage you can do is in setting fire to the woodwork. Of course, we are gradually decreasing the woodwork, and so that danger of fire passes away. But I very fully agree with the lecturer in the attention he draws to the fact that a ship with very few heavy guns, incompetent to pierce the plating of an adversary, is not in a good condition. She is open to the attack that Sir William Armstrong speaks of, and the more I think of it the more satisfied I am that that attack will be developed by numerous small unarmoured vessels, which can be cheaply built, and whose shot will be effective on the hull of the ship carrying the few heavy guns. I should like to see some method given to us of comparing gun with gun by some still more general and readier rule than that which the lecturer has given us. I should like very much to see an established distance taken—500, 200 yards, whatever it might be—and that we invariably spoke of the power of a gun in inches of iron capable of being penetrated at right angles at that range, so as to have a general standard of comparison. I find it myself exceedingly difficult to compare gun with gun by reason of the various measures of power which are given. The lecturer, in one of his sections, spoke of the "Huascar" as keeping her stern away from the enemy systematically. I can only say I did not gather from such study as I have made of that section that she did that; it seemed to me that she simply made away from her adversaries, who overpowered her six to one. They had twelve guns to her two, and it seemed to me she simply made away from them to the very best of her ability without any tactical views whatever. The lecturer drew attention to what appeared to him to be a.

discrepancy. The Director of Naval Ordnance, in writing on the "Inflexible" in 1877, said: "The projectiles that would be fired at the 'Inflexible' would certainly be armour-piercing, either chilled iron or steel; and such shell would not burst in passing through the thin iron sides of the ship, as they require the resistance of armour to ignite the bursting charge." And then the Committee wrote: "The most effective armament to bring against the 'Inflexible's' ends alone would undoubtedly be one of numerous shell guns." I do not think there is any discrepancy in the two things, the point being that the Director of Naval Ordnance did not think it was any use firing at the ineffective target formed by the "Inflexible's" light ends, and the Committee thought that if you did fire at those light ends, the proper course to pursue was to get light guns to bear upon them. There is a peculiarity about the "Admiral Duperré," and some of the French ships, which I do not think is fully noticed. When I tried my hand at a little ship designing I came to the conclusion that we were omitting in our designs to adopt a principle which had many good points about it; that was, to armour a little above the water-line down to whatever depth might be needful, to join with horizontal armour the upper edges of this vertical armour, to have a clear space over it through which the shot might pass, and then to mount your battery, where you put your men, above this clear space. Then you would have your vital target at the water-line, your ineffective target the whole length of the ship under the battery, and the batteries themselves the effective target. In the "Admiral Duperré" you have very nearly that; and, except where she mounts her light battery, the shot can pass harmlessly through. If the horizontal armour joins on to the top of the vertical armour on the ship's side, and the shot would pass under the barbette battery, doing no harm, she would have a very large structure and a very small effective target. I think the lecturer confirms the view that is beginning to be more and more strongly held, that is, the necessity of a double armament in all ships without exception. This is done in the "Admiral Duperré," and it is still more carried out in the Italian ships "Italia" and "Lepanto." I think that it will go on and develop, that we shall have one or two heavy guns for the purpose of attacking the citadels of ships, and a continually increasing battery under armour, I believe, too, under lighter armour, of lighter guns for the purpose of attacking the effective target.

Colonel INGLIS, R.E.: I did not come here with the intention of saying anything to-day, especially as the subject is mainly that of naval construction, on which, of course, I do not presume to have any opinion; but as I have been quoted in the matter of tables of perforation, and as Captain Orde Browne has mentioned his "rule of thumb," I may just say that I quite agree as to the utility of that rule, and generally with its correctness, but I had previously given a similar rough formula. Captain Orde Browne's rule gives rather too low a velocity for the perforation of plates of thickness about equal to the calibre of the gun. I think he will find that it will not do to take the velocity so low as 1,000 feet for a plate equal in thickness to one calibre of the gun. I find it comes out between 1,050 and 1,150 velocity, and for one and a half calibre thickness of plate to between 1,500 and 1,600, and for the two-inch calibre it would be more correct to put it at 2,000 to 2,500 feet; the discrepancies are no doubt due to the shot of all guns not being of

uniform weight in proportion to the calibre, that is to say, the value of $\frac{W}{d^3}$ varies very much in different shot. If that were uniform in all guns Captain Orde Browne's rule would be nearly true. It is not a very important point, but I should like to mention something with regard to the Meppen experiment referred to by the lecturer. I have been long interested in the matter of what is called the sandwich construction, that is, where, instead of having one solid thickness of plate, we use two thicknesses, and fill up the intervening space with softer material. The target at Meppen was a sort of imitation of our sandwich targets, but it was not a good target, and it has given rather a fallacious idea of the value of that kind of construction. I think you will find that it did not offer anything like the resistance that one of our targets would have given. It consisted of a 12-inch iron plate with an 8-inch plate behind it, and 3 inches of wood between them. That is not a good arrangement to begin with. I think I should put the 8-inch plate in front of the 12-inch, or perhaps not adopt those thicknesses at all. In the next place, the intervening

thickness of wood was by far too little, and, further, the back plate was a bad one. I do not know about the quality of the other, but, judging from the photographs I have seen, the back plate was decidedly a very indifferent one. Also the method of holding the two plates together was altogether wrong; in fact, I do not gather from any account that I have seen that they were held together at all. If we had to make this target, using English armour-plates, it would just let the shot employed at Meppen through and no more; so that here we have the difference between a good and bad target represented by 3,500 yards of flight of shot through the air; so great is the difference between a properly constructed target and one of inferior construction and material. I do not know whether it would interest anyone to hear how I constructed the curves of penetration of shot referred to by Captain Orde Browne. It was, shortly, on this principle: I observed in a great many rounds fired at Shoeburyness that for a given proportion of thickness of plate to diameter of shot, there was a constant amount of energy required to displace a unit mass of plate. I, therefore, took from actual results what was the amount of foot tons of energy necessary to remove, for instance, a cubic inch of plate when the diameter of the shot and thickness of the plate were the same; that gave one constant. Then I took the same for other proportions of diameter of shot to thickness of plate, and found for each the energy necessary to displace a cubic inch of plate. By that means the velocities under various conditions were obtained, and so I was enabled to lay down the curves of penetration of plates of all thicknesses by shot of all guns. I also thought it was desirable to show what perforation of iron cash gun would do at all points of its range; and my tables show this for all ranges up to about 8,000 yards. One thing strikes me that ought to be mentioned in regard to the experiments at Spezia in 1876. These trials were on a very large scale, and in many respects were very important, but the results were much invalidated, I think, by the narrowness of the plates that were used. Thus, although one can derive some information from them, still they would have been much more valuable had plates of better proportions been employed. It should always be remembered that a big shot requires a wide plate; otherwise it will break it asunder without meeting with much resistance.

Vice-Admiral SELWYN: I think I must ask Captain Orde Browne if he does not consider that the great advance made within the past few months, both in armour and in guns—the strength of the guns and the resisting power of the armour—would considerably interfere with any calculation that he could make from the existing state of things; since we learn that by the so-called “compound armour” (a name originally given to a totally different structure), that is to say, armour-plates faced with steel, we have arrived at a resistance which enables us to diminish the weight of the plates by one-third. In the case of the guns, I do not quite understand what he calls the “new type gun,” whether it be a gun as advocated now by Sir William Armstrong, and as originally devised by Captain Blakeley and Mr. Longridge—the steel band gun—of which we have no very correct knowledge, but we know at least that it is so very much stronger that it may be made very much lighter and give the same results. And all this must necessarily go still further if, on the one hand, the guns should turn out to be so much stronger as to permit the employment of a quicker burning powder without any disadvantage, but the contrary; and if, on the other hand, the indications given by steel-faced armour of the present day be followed to their legitimate conclusion. I am disposed to think very strongly on the subject of steel-faced armour, because it is now some ten or twelve years since I first advocated its use at the Institution of Naval Architects on the analogy of the anvil, but I do not think this has been considered completely in the so-called armour-plate of to-day. A plate of two inches of steel does not really represent the physical conditions necessary in an anvil, or in any structure designed to resist severe impact. We must consider that the anvil receives the blow at first on an elastic material. The steel is carefully tempered when put on the anvil, and it distributes the blow to a mass of cast-iron whose molecules will create a cone of dispersion, and spread the force of the impact. Then the tendency to disperse so created is controlled by the exterior wrought-iron casing of the anvil. We have nothing like that in the case of a compound plate, as now made, yet that is undoubtedly what experience.

teaches us as the best way of receiving and distributing a blow without damage to the structure, but it is not yet worked out, and I hope to see some experiments made with a view to doing so much more accurately and largely than has yet been the case; the results hitherto obtained being extremely encouraging. If we could afford to diminish the weight of armour carried on our ships' sides, and the weight of the guns, then it would be perfectly practicable on the one hand to increase the area covered by armour, and the thickness of the armour in what has been called the vital target; and we could on the other hand carry more guns, which seem to be very much required in the present day, without materially increasing the weights, for we must recollect the problem of the naval architect is how to carry an enormous number of weights of very great localization high up in the ship. How is he to provide sufficient buoyant power? The more those weights are distributed the more easy will be his task; in the one case because damage to any portion of the guns does not entirely destroy the offensive power of the ship, and in the other case because great weights if distributed over a large amount of surface are more easily so arranged as not to make the ironclad, what she unfortunately now is, a vessel unable to incline 45 degrees without turning bottom up. We say to the naval architect—"We wish you to do something better for us," but Sir E. J. Reed tells us that in the vessel built for Japan you have the only ironclad that could be inclined to 45 degrees without turning bottom up. We shall, I have no doubt, have to fight an increased power of guns: Captain Orde Browne has shown that. He is one of the gentlemen attacking ironclads, of course we occasionally do so, but an artilleryman looks upon an ironclad as a nice little target which he has to pierce, and he takes the greatest delight in proving that his guns can pierce it. But I must tell him we have a resource which he has not taken into consideration, namely, that we can go so low into the water that he will have no target at all, and that when he has got his gun to its highest perfection, and can hit a fixed target at four miles distance, which I should think a very difficult thing to do with any ship afloat, and under way, then we shall have to go under water, or at least we shall have to go so much below water with our men and crew, and with all of what Captain Colomb so well called our vital target, that he will no longer be able to assault us with any fatal effect at all. Naval Officers look more to the improvement in armour than in guns, since of late years they have had several very efficient weapons given them for attack under water; and as to the artillery fire, they think that however good an artilleryman might be at his work, he is not likely on moving ships to be able to get quite as good a result as he shows on those diagrams. I may mention that Hobart Pasha during the late Russo-Turkish War went to inspect the defences of Sebastopol. He advanced within the zone of fire, and, as it appeared from the flashing signals that the harbour was no doubt plotted out, he put his helm down, and told me that he happened to put his helm down at the moment when they fired all the guns together at him, and the whole of the 35-ton shot fired at that moment plunged into the water in one mass within 100 yards of the stern of his ship. Had he been proceeding in a direct line, instead of putting his helm down, there is very little doubt that every one would have fallen on his deck. This shows the danger we may incur in running into a harbour plotted out in that way; but I hope naval Officers will consider that a fort is a thing to be avoided—that you can do very much more damage by not attacking a fort than by attacking it—and had better keep your offensive powers for some foe more likely to suffer by your action. Probably an undefended commercial port would suffer very considerably from an ironclad, and I am sorry to say in our own country, as well as in others, there are a very large number of practically undefended commercial ports, where any ironclad running in would at the present moment have her own way entirely until an ironclad could be telegraphed for to go to that particular port to meet her. Now I come to the part of the discussion which has touched on the subject of having many small vessels; and I want to point out what an enormous advantage it would be to this country if those large guns could be set afloat on moderate sized and moderate drafted vessels in such numbers that we could have a great many of them in each port. I would not confine myself to one or two, I should say ten, carrying each the heaviest gun that can be put afloat. There is no reason why you should not do this,—it is perfectly possible. If you will consider that we might have

twenty such vessels with twenty 80-ton guns to go to the attack of one ironclad coming in with four 80-ton guns, I think, as she can only fire those four 80-ton guns at four out of the twenty ships, at a time, she will be very thoroughly punished before she gets rid of her mosquito antagonists. Add to that the power of torpedo launches, and I think it will be found that we ought to turn our attention much more persistently to the creation of a mosquito fleet around our own shores: if we are to carry out the policy of "Defence, not defiance," we should pay less attention to the creation of types of vessels which cannot be made to serve their purpose directly there is an improvement made in guns or armour. You cannot profitably pull them to pieces, and the result is you have to say that others must be built as soon as possible. There never will be any finality in the combat between the gun and the armour until both disappear from the field altogether, so that these mosquitoes of which I speak, inexpensive, always on the spot, not to be telegraphed for to go round to find the adversary gone away, but always ready and employing your naval volunteer artillerymen in learning work for which they would be much better fitted if they had a few of these boats in their ports. Thus they would be practised with real guns and vessels such as they would be called upon to use, while at present the practice is very little in accordance with what they would have to do in case of war. I hope to see this lecture followed by others. I must say that it has been of great advantage to this Institution to have this lecture, and I think it will be of greater advantage to this Institution to have it followed up by gentlemen giving each detail; one taking the armour,—I hope, supplemented by experiments which might be made very cheaply and efficiently by the Committee, another taking the progress of the gun, and keeping the Institution thoroughly informed on these subjects. We hear from the papers a great many things which are quite unreliable; we know in the Institution comparatively little of what is going on outside, and it is most desirable that Officers of both Services should be kept posted up to the day, for we do not know how soon our services may be called upon, and if knowledge might have been had previously, the whole nation would have cause to regret that it was not available at the moment it was required, but had then to be sought for, when neither time nor means could be spared to acquire it.

Mr. WHITE, Chief Constructor: I did not intend to say a word, but Admiral Selwyn has made one statement which I cannot allow to pass without contradiction, not wishing, of course, to contradict his accuracy in repeating what he may have heard. I wish to say that it is not right to assert that no ironclad in the Service can be heeled over to 45°, and return again to the upright. There are many ironclads in the Service, most of them now lying in the harbours, which have at sea rolled over to 45°, and yet they did come back to the upright. I think these somewhat sweeping statements about the stability of the ironclads might be at least examined with reference to publications which are available to every one before they are repeated. If this were done it would be seen that the range of stability of the ironclads is not anything so small as 45°, but a great deal beyond in all cases, except those of vessels built especially for smooth water service along the coast. The facts which I speak of will be found in the Report of the Committee on Designs in 1871; that is all I wish to say upon that point; it is rather an important one, as this discussion, I presume, will be printed. I did not have the pleasure of reading the paper or of hearing the earlier part, and therefore I would ask Captain Orde Browne if his remarks as to the slow destruction of steel armour by comparatively light guns are intended to apply to steel-faced armour, such as we are using in the ships of the Navy? I may say, for the information of Officers in the Service, that our test for these steel-faced armour plates is this: we take a plate 8 feet by 6 feet, which is from 9 to 11 inches thick. This plate is placed 10 yards off the muzzle of a 9-inch gun, and three shots are planted upon it in the form of an equilateral triangle, the sides of which measure about 21 or 2½ inches. That is to say, in a plate 48 square feet in area, we deliver three closely placed blows from the 12-ton 9-inch muzzle-loading gun, and we are accustomed—I am speaking now of mere matters of fact—to get steel-faced armour which successfully resists that amount of punishment. When we take a plate down, it commonly has no crack on the iron back and no sign of detachment of the steel face from the iron back. In view of these facts, it is obvious that when we hear of steel armour crumbling away under the fire of com-

paratively light guns, that is not the kind of armour which is being put on English ships-of-war. Another word I may be permitted to say, as the subject is one in which I take very great interest, although only as an outsider, on the artillery side. It seems to me that Captain Orde Browne preserved a singular silence as to the possible effects of artillery fire below the armour belt when ships are rolling at sea. I hold that in comparing the efficiency of war-ships, steadiness in a sea-way is of immense importance, and if you have two types of ships armoured to the same extent below the water, one of which is much steadier than the other, that quality surely must be reckoned as a substantial advantage. It also must be held to be true that since there are very few ships in which the armour goes more than 6 feet below the load-line, there must be a chance of artillery doing damage under water as well as above; in a part of the vessel which I presume Captain Colomb would include in his vital target. The difficult problem we have to face as naval architects was very clearly put by Admiral Selwyn, and I am thankful to him for having put the case. We are continually being called upon for ships of moderate size, with high speed, carrying heavy guns, many light guns and machine-guns, thick armour, torpedo armament, possessing great handiness. Every desirable quality is asked for in a ship of moderate size. That is all we are asked to do; it is a very modest request, but our lives are made a burden by being asked to do so many things—and always in ships of moderate size. If any gentleman can invent armour or guns that will enable us to associate greater power of offence and defence with less weight, we shall be extremely grateful.

ADMIRAL SELWYN: I may explain that I quoted Sir Edward Reed on this subject; I did not give my own figures in speaking of 45°.

Captain BROWNE, in reply, said: The first question I ought to notice is that put by Captain Dawson on the limit of penetration. I did not mean to say that the shot generally would penetrate the amount that I gave by the rule of thumb, but what I was pointing out was that in iron armour you should know the *maximum* your guns can do, and I think that that limit is about the maximum. There are one or two cases of Krupp guns where the weight is very great in proportion to the calibre, and the guns may do a fraction of an inch more; but it is so extremely unlikely that a gun will do even its maximum on conditions of service, that you may take this approximation to the maximum as certainly the *limit*. I was endeavouring to fix a distinct limit with reference to wrought-iron armour, at which you may say "It is no use my endeavouring to penetrate that armour, I may give it up altogether." An Officer would not be justified in giving up the possibility of penetrating a ship unless he had clear ground for believing that it was impossible. Now, if you find you have not got 1,000 feet velocity for every calibre of your guns, you may say that *perforation* is impossible. For example, if a ship has 9 inches of armour, and you have 9-inch guns, a 1,000 feet velocity may possibly do, but if you have not got that you may give the primary attack up with a thoroughly good conscience and take to the secondary. That was the limit I was endeavouring to fix, and I think Captain Dawson would not disagree with that. With regard to the division of the ship into three targets, the only doubt that I should have about such a ship as the "Admiral Duperré" would be whether practically you could have an effective target and a vital target with an entire space in between, which is called the ineffective target. For I question, if that ineffective target were shot away to a great extent, would the effective target, which must be of a considerable weight above, be capable of supporting itself? This is one of the points that I think comes out in the construction of ships, namely, how far it might be possible to capsize armour of a certain weight fixed on comparatively weak supports above the deck. It seems to me that that may happen if you have the effective target above the ineffective target. In firing at the "Inflexible," I admit if the ship engaging her had a single gun heavy enough to be able to pierce her armour, then I can understand the Director of Naval Ordnance saying the most effective attack would be the primary attack, and that would be consistent with what the Committee said as to shell-gun fire at unarmoured parts. But it is so very seldom you would have guns capable of piercing the citadel of the "Inflexible," that I think it remains probable that the most effective attack would be that of the unarmoured part. With regard to the "Huascar," I stated, I believe, that she

kept her stern away from the enemy. The authority I quoted was King's account, page 440, where he states that, seeing escape was impossible, the commander of the "Huascar" ran his vessel as close to the shore as possible, keeping her most vulnerable part, the stern, away from the enemy. I only quoted it from that, and you must take it for what it is worth.

Captain CURTIS: It is stated in the Journal of the Institution that her steering gear was three times disabled.¹

Captain BROWNE: With regard to the double armament, I was glad to hear that noticed by a naval Officer, because it appeared to me to be necessary to have an armament capable of engaging unarmoured antagonists. With reference to the rule Colonel Inglis spoke of as my rule, I do not lay claim to that rule, I noticed it for myself and found that it admitted of mathematical proof, but it had been observed, so I hear, by others. I believe that that rule could never come quite right for thin armour such as one calibre of thickness, no matter how the shells might be proportioned. I noticed that the rule appeared to run right for a great number of experiments, so much so that I tried how it would prove mathematically. That proof depends on two things: one, the proportion the weight bears to the calibre; and also the resistance of the target being as in proportion to the square of its thickness. Now, the resistance of the target becomes most nearly proportional to the square of its thickness when the target is *thick*. You can see mechanically that, as the target increases very much, there is a much greater mechanical resistance to a projectile than when the target is thin in comparison with the shot, and eventually there comes a place about which the proportion runs up and down nearly as the square of its thickness. When the target gets very thin the rule fails. I only mentioned it as a rough rule, happening to be most nearly correct under the circumstances, which are most important when you are firing with the maximum power of your guns at thick armour. Colonel Inglis mentioned his rule. I think it is undesirable here to go into mathematics, you cannot do it satisfactorily in a discussion of this sort, but I may point out that his rule, under the conditions in which it is found to be accurate (the condition in which he does not alter his constants) is precisely the same as the old rule employed in the Department of the Director of Artillery. This is a thing that admits of mathematical proof, and I am prepared to say that Colonel Inglis's rule, under the conditions in which he does not change his constant, is absolutely the same thing as the other rule. Colonel Inglis's formula makes the resistance a sort of resistance due to inertia, and proportional to the volume of the disc of plate removed by the shot in perforation, that is $\pi \frac{d^2}{4} \times t$, where d is the calibre and t the thickness of plate. The old formula treated it as a resistance due to cohesion, proportional to the circumference sheared away and multiplied by the square of the thickness. That is to say, Colonel Inglis's was—

$$\frac{Wv^2}{2g} = c_1 \pi \frac{d^2}{4} \times t \quad \dots \dots \dots (1),$$

and the old formula

$$\frac{Wv^2}{2g} = c_2 \pi d \times t^2 \quad \dots \dots \dots (2),$$

c_1 and c_2 being constants. In point of fact, all constant parts of any expression may be included under one constant, say K , and determined by practice once for all. We need only consider the variables. Hence we may write these two equations (1) and (2)—

$$\frac{Wv^2}{2g} = K d^2 t \quad \dots \dots \dots (1),$$

and

$$\frac{Wv^2}{2g} = K d t^2 \quad \dots \dots \dots (2),$$

in which the only difference consists in (1) containing one power of d instead of the

¹ See "Journal," No. CXII, p. 699.

power of t contained in (2). But Colonel Inglis only applies his rule rigidly to cases when t bears some fixed relation to d . Whenever this relation changes, he changes his constants. So that Colonel Inglis's rule rigidly applies only to cases when it becomes immaterial whether t or d be used, for the constant relation may be disregarded as part of the K , which is to be determined by practice, and the two formulæ becomes thus identical under these conditions. I will not go into the case when Colonel Inglis changes his constants. I think it is satisfactory when you see formulæ arrived at in different ways coming practically to the same thing. I believe what Colonel Inglis says about the rule of thumb; undoubtedly he gave you more accurate rules in his diagram. I did not endeavour to give an exact results; I only endeavoured to give some extremely simple general principles, which was good enough for practical purposes. It is very difficult to remember rules of thumb if not very simple, and I find I can remember the rule "a thousand feet velocity gives the calibre of penetration." With reference to the Meppen target, I think you can see from the drawing that it was an indifferent plate—the front target may have been brittle. I think I was told that it had phosphorus in it, which would have inclined to make it rather brittle. Of course, in accounting for power of penetration, when you have calculated the stored up work in the projectile, and the size of the projectile, you know you have got the whole thing. There can be no magic in the projectile. I suppose then that one cause of the penetration may be that the plates were made of indifferent iron. Another reason may be the fact that the point of the shot was sharper than that on which most of our calculations are based. It was a 2-diameter point, and I think there is something due to that. I believe for direct firing, there is no question the sharper the point the better. The third thing I suppose was that the target may have been badly made. I should not have thought that the plates not being bolted together would have given better penetration, though I should have supposed it would have made them bend more easily. Colonel Inglis, however, I see signs to us that it would actually give more penetration. With regard to what Mr. White said with reference to steel fronts, I did not mean that our steel-faced targets would behave in the way in which the solid steel targets behaved at Spezia. I do not believe they would behave in that way at all. I believe they have mainly the toughness of the back with what hard surface you may put on to break the shot, with the mechanical advantage which is obtained by pressing against a point before it enters the plate, but I believe it does remain true in a very small degree, that the advantage which is possessed by the compound target compared with the iron does not hold good for repeated firing to the same extent that applies to the case of a single blow, judging from the report of the Committee on Plates and Projectiles. They speak of 10 inches of compound armour being as good as 12 inches of wrought-iron for a few blows. I think you sacrifice something of the power to resist an enormous quantity of firing in having a compound front to the armour. With regard to 6 feet below water, I should have thought that a ship with armour extending 6 feet below water could not have been struck by artillery below the belt. If you take the probable angle of descent of the shot, and then take 6 feet under water, and draw a line, you will see it has to go through a tremendous quantity of water.

MR. WHITE: I was speaking of where the armour came out of the water.

Captain BROWNE: If the armour had come entirely out of water, of course you might possibly strike it. I should have thought few vessels could have engaged to much purpose when there was such a roll on, but that is a naval subject. To finish up, with reference to these Chinese boats, I think there is no doubt the question that has been touched on with reference to the mosquito fleet is an extremely serious one. I had a question put to me some time since by Sir Henry Gordon as to what the guns of the Chinese boats would do against such a ship as some of our first-class broadside ships, such as the "Swiftsure." I believe that they carry guns that would pierce the armour of any of our broadside ships. Those vessels would of course be extremely formidable, because they would trust to their small size; they would come in number, and perhaps keep a considerable distance, and we should then need to have an auxiliary armament of light guns to our turret-ships. I think Admiral Selwyn gave the "Inflexible" credit for firing at four adversaries, but it seems to me she could only fire at two, and that was why I

took the case of six vessels engaging her, and being able possibly to hold their own, and annoy her.¹ I do not think there was any other thing that was noticed. I am not particularly defending anything I have said, because the object is to discuss this, and I am not putting forward any very distinct views. I have, however, put two or three questions forward at the end of my paper, and it appears that they are generally agreed to, namely, 1st, that we want a second armament of medium new type guns; 2nd. I also noticed the necessity for mortar fire, and the reason I did so was because Admiral Hornby, in the discussion that followed at Woolwich, spoke of vessels engaging at anchor. I was under the impression that vessels would not have engaged at anchor. I thought they would have followed some sort of elliptical path, and engaged in motion. But I now believe that there were instructions given at times to our ships when war was threatened, to clear a small space of water of submarine mines, and then to engage forts at anchor. It is only the case of a ship engaging at anchor that would make me suppose you could bring any high-angle mortar fire to bear, but if you have a harbour laid down in squares, and ships then clear a certain square of submarine mines, and proceed to engage forts at anchor, it seems to me the most effectual way of attacking them is to have mortars or howitzers that bear on that place, and if they fire with one-tenth part of the accuracy of Krupp's mortars at Meppen, they would be extremely formidable.

The CHAIRMAN: We have had a very interesting paper, and I think I may say a very interesting discussion. It only remains for me in your name to thank Captain Orde Browne for all the facts he has brought before us. He has evidently taken great pains with this lecture, and I trust that on some future occasion he will favour us with some other views.

¹ The "Inflexible's" supply of heavy ammunition is necessarily limited, and much of this would be wasted quickly in such an action.

² As can be done on Captain Watkin's system.