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The Heavy Guns of 1884

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Friday, June 20, 1884.

THE RIGHT HON. THE MARQUIS OF HARTINGTON, M.P.,
Secretary of State for War, in the Chair.

THE HEAVY GUNS OF 1884.

By Colonel E. MAITLAND, R.A., Superintendent Royal Gun Factory,
Woolwich.

IN the spring of this year the Council of the Royal United Service Institution did me the great honour of asking for a lecture on the subject with which my work is chiefly connected, viz., "ordnance." The Secretary of State for War cordially granted permission, and moreover most kindly consented to take the chair on the occasion. I felt, therefore, that the time had now arrived for as clear an exposition as I could lay before you—and through you before the public—of the present state of this subject, which is of national importance, setting forth the causes which had led to the necessity for the re-armament of our naval and military forces, the progress now made in that re-armament, and the comparative efficiency of the heavy guns of 1884 in England and in the other chief countries of the world.

As time is short, you will pardon me for being exceedingly brief in summarizing the chief causes which have led to our re-armament.

Putting aside all minor considerations, many of which have frequently formed fertile matters of controversy, I state at once that the chief causes are three:—

1. Improvement in powder.
2. Improvement in mechanical appliances.
3. Improvement in production of large masses of steel.

It will perhaps be said that if this be true, these considerations should affect other nations besides our own, and that the great Continental Powers should be re-arming extensively also.

To this I reply that this is exactly what they are doing, and have been doing for some time past. Their re-armament is being carried out rather more gradually than ours, and the changes they are making are less radical, but none the less are they thoroughly re-arming. It may be admitted that during the latter part of the seventies England fell behind in the artillery race, but not to the extent that is supposed by many who have not thoroughly studied the subject. As a matter of fact, the old short breech-loaders of the Continent are just as obsolete now as the old short muzzle-loaders of England, and up to about 1875 or 1876 the British artillery was as good as anybody else's. Then came

I. COMPARATIVE POWDER PRESSURES.

III. BREECH ACTION.
FRENCH MARINE SERVICE. II. BREECH ACTION.
KRUPP. IV. BREECH ACTION.
FRENCH LAND SERVICE.

V. 6 INCH B.L. GUN. 80 CWT.
BREECH ACTION.
E.O.C.

BREECH SCREW LOCKED READY FOR FIRING.

BREECH SCREW UNLOCKED READY FOR WITHDRAWAL.

VII. 6 INCH B.L. GUN. 89 CWT.
BREECH ACTION.
R.G.F.

VI. 6 INCH B.L. GUN. 81 CWT.
BREECH ACTION.
R.G.F.

VIII A. 7 INCH B.L. GUNS. 10 TONS.
BREECH ACTION.
R.G.F.

a period of comparative stagnation, and we fell to leeward. During the last three years we have been endeavouring to make up our leeway.

One point we have in our favour. In a science which advances as fast as artillery has been doing of late years, the Power which waits longest before committing itself to a new manufacture has the best of it, always supposing that it is not caught napping by an important war.

It is not necessary to explore the debateable land of the Might-have-been; it is sufficient for our purpose to know that we have *not* been caught napping by an important war, and I hope to show you to-day that the result is that having waited the longest, we have got the best of it.

I come now to the improvement which has taken place in powder. It must be remembered that the weight of the gun is the limiting element of power in nearly all cases. It is easy to carry about powder and shot, but the gun is one and indivisible, and taxes the appliances of transport to the utmost. Hence as long as guns have no special counter-balancing points of advantage or disadvantage, the proportion between the energy attained by the projectile and the weight of the gun forms a convenient way of comparing the excellence of various designs. It is briefly called "energy per ton." Conversely, the description of powder which enables a gun to realize the greatest energy per ton without exceeding the pressures which it is constructed to bear, will be the best for that gun, irrespective of the quantity of powder expended in producing that result. There are cases no doubt where the size or weight of the cartridge becomes a serious consideration, but as a rule it is of little importance when compared with the advantage of increased power.

With breech-loaders that powder is found to be the best which satisfies the following conditions. It should fill the chamber of the gun as completely as is consistent with facility of loading. It should burn slowly at first, till the projectile begins to move, gradually setting up just the maximum pressure suitable to the gun; it should then burn faster and faster as the projectile travels onward through the bore, so as to keep up the pressure as long as possible, and give the greatest amount of energy. A low maximum pressure long sustained is the great desideratum of the artillerist, and no one will attain any measure of ballistic success who fails to recognize this fundamental maxim.

Diagram No. 1 (Plate XXIII) shows clearly the amount of progress which has been attained in slowing the powder and producing energy per ton of gun.

The ordinates represent the pressure of the gas measured in tons per square inch; the abscissæ show the length of travel of the projectile along the bore measured in calibres.

The fine curve indicates the pressures with quick burning powder, the medium curve with medium powder, and the thick curve with slow powder. The quick and medium powders were used in short guns, and the dotted portion of their curves is merely added to show

how little gain would have resulted from increase of length. The slow powder is used in long guns, and the amount of pressure kept up to the muzzle indicates that we can go still further in the direction of length with advantage. The area included by these curves of course represents the work done by the powder, nearly all of which goes to produce energy in the projectile.

It at once becomes evident that to get an increased ratio of power to weight, we had to turn thickness of metal at the breech into length at the muzzle: that is, to lower the pressure in the chamber and keep it up longer in the bore.

We sometimes hear statements to the effect that the road to improvement lies in the direction of using very quick powders, and making enormously strong guns to withstand the highest pressures powder can give in a closed vessel, viz., about 42 tons per square inch. This system, from an engineering point of view, is no doubt right as causing the least consumption of fuel; but it is utterly and entirely wrong when seen from the artillerist's standpoint. The artillerist cares little for the amount of fuel consumed, but a great deal for the weight of the machine consuming it. Now, when guns are fired with powders giving different pressures, it is found that the rise in energy of projectile at the muzzle is not nearly in proportion to the rise in pressure in the powder chamber. High pressures are extremely capricious and uncertain in their effects, and no precise rule can be laid down, but taking our usual service maximum pressure with slow powder at $17\frac{1}{2}$ tons per square inch, and substituting an equal quantity of a powder violent enough to give 35 tons per square inch, I should not expect to realize an increase of energy of more than about 20 per cent., though the pressure has been doubled.

But doubling the pressure necessitates doubling the strength of the breech, and hence of adding about 80 per cent. to the weight of the gun. Besides this, high pressures give rise to many inconveniences, the breech fittings and the firing arrangements are apt to be burred, set up, and jammed; the shell and shrapnel are liable to be broken up in the bore unless made so strong as to reduce seriously their capacity for holding bullets or powder.

Hence I think it is clear that slowing the powder is a most important improvement.

There are two reasons why this improvement in the powder renders breech-loading an absolute necessity. First, the guns have to be made so long that loading from the muzzle becomes practically impossible on service. Second, the slow powder cannot be made to burn in the most effective manner unless the projectile be held fast by a strong band which prevents it from moving till a pressure of from 1 to 2 tons per square inch is set up in the chamber. This can only be done in breech-loading guns, and hence they are capable of developing greater power than can be obtained from muzzle-loaders of equal weight.

I am aware that two or three years ago, when breech-loading was young in England, this view was strongly combated by some of our most able artillerists, who held that muzzle- or breech-loading *per se*

made no difference in the power of a gun; but now I think its correctness has been established by frequent experiment, and will hardly be questioned.

Here it may be seen how, by coming last to breech-loading, England was able to build on Continental experience and improve upon it. In 1880 we were using for our heavy muzzle-loaders either Waltham P² or German prismatic powder, which gave, when proved in the 38-ton M.L. guns, pressures of about 19 tons, and velocities of 1,560 f.s. Directly the Royal Gun Factory came to breech-loading, the unsuitability of these powders became apparent to us, though the German prismatic powder was specially manufactured for Krupp breech-loaders. The Superintendent of the Royal Gunpowder Factory at Waltham was promptly asked to make a powder which should give about 800 f.s. velocity in the 38-ton gun with a pressure of not more than 5 tons, using the same charges as with the German prismatic. This modest request would probably have met with derision if regarded simply from an engineering point of view, as involving an absurd waste of fuel, but Colonel Brackenbury tackled the matter very successfully, and, after some preliminary trials, produced an admirable powder, which attained celebrity under the name of H₃. This powder was nearly useless for muzzle-loaders, but when fired in heavy breech-loaders gave by far the best results then known. A modification of it has now been introduced and issued for service as C₂. Since the production of H₃ the Germans have taken a fresh departure, and have quite lately produced a powder which seems to be a little better than C₂. It is known as cocoa powder, and its composition is a secret.

The speciality of this cocoa powder is that although it lights with great regularity and burns very slowly at first, yet when the projectile has got fairly under way it burns with tremendous rapidity. In the 19-ton 9·2-inch guns it has about the same ballistic excellence as the best lots of C₂; that is, it gives about the same pressures and velocities all the way up the bore, but it takes only 170 lbs. of the cocoa to produce the results attained by 200 lbs. C₂. These charges give about 2,050 f.s. velocity to a projectile weighing 380 lbs., the pressure being about 17 tons in the chamber. Thus the extra 30 lbs. of C₂ are required to give off gas as the projectile travels through the bore, to balance the quicker final burning of the cocoa powder.

Darwin tells us, in one of his charming books, how the probosces of the Madagascar moths tend to lengthen in successive generations so as to reach the honey-dew of the orchids, while the nectaries of the flowers tend to deepen continually to force the moths to push their heads in and exchange the fertilizing pollen. So we find, in the struggle for existence, the guns growing longer and longer to get the best effects from the slow powder, while the powder tends to grow slower and slower to meet the wants of the guns, in accordance with the eternal principles of evolution.

The next point is the improvement made in the mechanical appliances of guns.

With a breech-loader the first necessity is a thoroughly satisfactory system of closing the breech. This was certainly not accomplished

by any nation till after the Franco-German war of 1870. Krupp then entirely remodelled his breech fittings, and introduced the form now universal in his modern guns. The French Marine improved the details of their existing system in like manner, and the French land service, after a long series of experiments, retained their system of closing the breech, but adopted an entirely new method of obturation invented by De Bange of the French Artillery, to whom I am very pleased to have this opportunity of expressing my gratitude.

The great Elswick firm also adopted the French system of closing the breech, but applied a method of obturation of their own.

Thus during the seventies, four really serviceable methods of working the breech and sealing the escape of gas became available, and one of the great objections to breech-loading disappeared.

The two first causes named, *i.e.*, the improvements in powder and breech actions, settled the question of breech-loading *versus* muzzle-loading; the third cause of re-armament, *viz.*, the production of steel in large masses, affects construction only.

Were large masses of steel not available, we should still have to re-arm with breech-loaders; but the old system of construction would no doubt be retained, and the change we have made would not be of so radical and complete a character.

In bringing forward the Army Estimates in March, Lord Hartington stated to the House of Commons that, "With regard to the supply of heavy guns for the Navy, fair progress has been made in the present year. During the present and the past two years we have been undergoing a double transition; first, from the muzzle-loader to the breech-loader; and, in the next place, in the material, from wrought iron to steel. Twenty years ago another transition took place, which was of an exactly opposite character. Twenty years ago we reverted from the breech-loader, the more complicated gun, to the muzzle-loader, or more simple gun, retaining the same material of manufacture. At that time the largest guns in the Service were of 7 tons weight, firing 30 lbs. of powder. In the change from the muzzle-loader to the breech-loader the guns are of 40 tons weight, firing 400 lbs. of powder. The Committee may, therefore, imagine what has been the difficulty, and the necessity there has been for hesitation and caution in undergoing such a transition under such circumstances. The main difficulty has been to obtain sufficiently large steel forgings for these immense weapons. There are in France and Germany several firms which have been able to supply steel forgings of the size, and also of the quality, required for these guns; but up to the present time the demand has been a new one to the English trade, and there has been great difficulty in obtaining from the English trade steel forgings of the size and quality required."

This precisely sums up the case, and shows how the improvements introduced into the manufacture of large masses of steel have affected our re-armament.

I speak in general terms of the material of which our new guns are made simply as steel, because I wish to avoid entering at all upon

the vast question of the innumerable qualities and attributes of this wonderful substance.

Although its manufacture is still far from perfect, and will probably not be reduced to anything like an exact science for many years, yet sufficient is known about it to afford matter for many lectures, and I cannot venture in the short time now at our disposal to touch the subject at all. For the purposes of the present lecture I must ask you to take steel as steel.

On the occasion just referred to, speaking of the progress made in our re-armament, Lord Hartington went on to say, "We have supplied, or in a few days shall have supplied, to the Navy 10 guns of 43 tons and 12-inch bore, 18 of 18 tons and 9.2-inch bore, 8 of 12 tons and 8-inch bore, 171 of 4 tons and 6-inch bore; besides 190 smaller guns of 2 tons and under, making a total of nearly 400 new breech-loading guns. Those first in hand were of mixed steel and wrought iron, while the later guns are entirely of steel. There has been some advantage in the delay in the adoption of the new pattern of breech-loading ordnance. We have had the advantage of the experience gained by France and other Powers, and it is believed that we have now obtained a system of breech-loading of a simple and efficient character. In addition to the guns I have enumerated, there are in hand, under construction for the Navy, 3 guns of 110 tons, 4 of 63 tons, and 3 of 43 tons, besides a very large number of smaller guns in various stages of progress. At the same time, there are under construction for the land service 10 guns of 43 tons, 4 of 26 tons, and other guns of smaller size."

This brings the state of affairs down to about three months ago, since which time the manufacture has been steadily proceeding, but of course no important change has been made.

I will now endeavour to give you some idea of the relative excellence of the latest types of heavy guns at home and abroad, selecting three separate features for comparison as being of a crucial character.

These features are—

1. The system of breech-loading and obturation.
2. The construction.
3. The power.

Diagram 2 shows the Krupp system of breech-loading. It consists of a round-backed wedge, which is pushed in from the side of the breech and forced firmly home by a screw provided with handles; the face of the wedge is fitted with an easily removable flat plate, which abuts against a Broadwell ring let into a recess in the end of the bore. On firing, the gas presses the ring firmly against the flat plate, and renders escape impossible as long as the surfaces remain uninjured. When they become worn, the ring and plate can be exchanged in a few minutes. The vent passes through the facing plate to the rear of the wedge. The gun is fired by a frictional vent-sealing tube, which is screwed by the fingers into the vent, and unscrewed after firing.

This form of breech-loading has a decided advantage in loading by hand at elevation, which may sometimes be required, as the weight of the wedge is not working against closing the breech, as in the case with interrupted screw systems. It has, however, several counterbalancing disadvantages; the handles at the side are very liable to be damaged by the enemy's fire or otherwise (in the heavy guns they are unshipped for firing); the length of the gun is necessarily greater in proportion to the length of bore; the recess for the Broadwell ring somewhat weakens the wall of the chamber; the gun can be fired even though the wedge is not pushed properly home, and the breech has to be opened after a missfire, or if the tube is exchanged without opening the breech, it may be unsafely replaced; moreover, the longitudinal strength depends on the soundness of the single piece of steel through which the wedge passes. Still it must be admitted by all unprejudiced persons that the Krupp ordnance, taking system, construction, and material altogether, are not easily to be beaten.

Diagram 3 shows the French marine system. Here the bore is continued to the rear extremity of the piece, the breech-end forming an intermittent screw—that is, a screw having the threads intermittently left and slotted away. The breech-block has a similarly cut screw on it, so that when the slots on the block correspond with the untouched threads in the gun, the block can be pushed straight in, and the threads made to engage by part of a revolution. In the French marine the escape of gas is stopped very much as in Krupp's system; a Broadwell ring is let into a recess in the end of the bore, and a plate on the face of the breech-block abuts against it. The vent bush passes through the screw, and is fitted with a lock at the rear for firing percussion tubes. It is so arranged that the gun cannot be fired unless the breech-block is screwed properly home. The parts are all protected behind the gun, and the only disadvantage seems to be the recess required for the Broadwell ring, which weakens the wall of the chamber and necessitates a corresponding increase in the area of the face of the breech-screw upon which the gas acts, thus increasing the longitudinal strain beyond that unavoidably due to the size of the powder-chamber.

As in Krupp's guns the parts liable to wear are very dependent for their duration on cleanliness and freedom from dust and grit, but when worn they are quickly and easily replaced.

Diagram 4 shows the French land service system. Here we have the interrupted screw as in the marine, but the escape is sealed in quite a different manner. A stalk passes through the breech-block, its foot being secured on the exterior. The stalk has a mushroom-shaped head projecting into the bore. Round the neck of the stalk, just under the mushroom, is a collar or pad of asbestos secured in a canvas cover. When the gun is fired, the gas presses the mushroom against the asbestos collar, and squeezes it against the walls of the bore. It is found that this cuts off all escape.

In this obturation we have no weakening of the walls of the gun, and no increase of longitudinal strain, but the bore is slightly shortened by the protrusion of the mushroom head into the chamber.

Its great advantages are that the soft pad adapts itself to the gun surface, against which it presses, regardless of dust, grit, bruises, or other imperfections. The parts can be replaced easily and quickly; they are also light and inexpensive.

The vent passes through the mushroom head and stalk to the rear, and the gun is fired by a simple friction tube, pulled from the side. This arrangement is defective, as the gas soon wears out the vent, necessitating a new mushroom; while the frame of the firing tube is blown forcibly out, clinging to the hook of the lanyard, and proving a source of inconvenience to the firer.

Diagram 5 shows the Elswick system, which consists of a flat-backed cup abutting against the slightly rounded face of the breech block. The lips of the cup rest against a copper ring let in the walls of the bore. On firing, the gas presses back the cup against the rounded end of the breech-block, and thus forces the lips hard against the copper ring.

The cup takes up very little room in the chamber, but is very sensitive to grit and dirt, so that, as well as the copper ring, it requires renewal at uncertain and often frequent intervals. The cup itself can be replaced in a few minutes, but the copper ring takes several hours to extract and renew; the instructions given lay down that a special cup is to be inserted, and two rounds fired with it so as to fully expand the ring, which is then to be trimmed to fit the reserve cups.

The firing arrangement consists of a removable needle-holder, which carries a percussion tube nearly to the end of the bore; the needle passes from the tube to the rear of the breech-block, and is there struck by a hammer actuated by a lanyard. There is a safety arrangement which prevents the hammer from striking the needle till the breech is properly closed. The chief objection to this plan of firing lies in the difficulty of training men to pull the lanyard in such a way as to give sufficient force to ignite the detonator.

Diagram 6 shows the breech action we began with, viz., the French interrupted screw. The Elswick obturation was selected. I do not know exactly why, but I believe under the idea that the gas would not be able to eat its way between the cup and the copper ring, which therefore would never require to be taken out and renewed. We changed the firing arrangement to one having a removable vent head carrying a friction tube: it was provided with a safety arrangement which prevented the lanyard from being hooked to the tube till the breech was properly home. As experience showed that the copper ring did require to be renewed from time to time at very uncertain intervals, and as this was a serious operation, experiments were forthwith instituted with the De Bange obturation, and with such success that it speedily established itself, and was adopted for all the new guns.

Diagrams 7 and 7A show our present breech-closing arrangement as applied to the steel 6- and 7-inch guns.

It has one great theoretical defect, it appears extremely complicated. This, however, is not quite so serious as it seems at first sight, for not only is it difficult for the parts to get out of order,

but any or all of them can be exchanged in two or three minutes as the fittings are all held together without any screws. The vent passes through the mushroom and stalk as in the French land service guns; a clutch box on the rear end of the stalk carries a percussion lock similar to that of the French marine. The safeguards which cause the apparent complication of the action are numerous. The tube cannot be struck by the hammer, even though the lanyard be pulled, till the breech is screwed home. Should there be a missfire, the slide is drawn back to permit the exchange of the tube, and the new tube cannot be fired till the slide is pushed properly over the tube again. Should the slide not be properly pushed over the tube before loading, the action of closing the breech forces it home; but should the tube be sticking so far out of the vent that forcing the slide home would break it and perhaps explode the detonator, the slide yields, and the attempt to screw the breech-block home reveals the error. Should the thumb slip in cocking, the hammer will not fall on the striker so as to explode the tube, but on a projection which is removed when the lanyard is pulled.

Thus, by coming last, we have been able to select and combine the best features of the French systems, land service and marine, making perhaps a few trifling improvements of our own.

The next point is construction.

The experimental breech-loading guns first designed followed implicitly the system of construction which owed its origin to Sir W. G. Armstrong, and which, though subsequently modified in several ways in the Royal Gun Factory, will ever be associated with his name. This was the system of wrought-iron coils shrunk over each other and lined with a steel tube, which had been adopted for the long discarded vent-piece breech-loaders, and afterwards for the muzzle-loaders up to and including the 80-ton and 100-ton guns. This construction had a long day of success, and its cult was not rudely disturbed till the close of the seventies. Early in the eighties—the revolutionary eighties—however, it was found impossible to vie any longer with the stronger material which was in general use in Germany and France. Guns of wrought iron could not be made to possess the same power as guns of steel without an important excess of weight.

Efforts were made to preserve the advantages of the coil construction by employing a mild steel largely alloyed with manganese, which could be made to weld satisfactorily, and experiments were carried out in the Royal Gun Factory with wrought-iron coils, steel coils, and forged steel hoops. These resulted in the complete victory of the forged steel hoops, and in April, 1882, the first English heavy breech-loader, entirely of forged steel, a 12-inch of 43 tons, was proposed by the Royal Gun Factory.

The matter was so important that it formed the subject of an elaborate inquiry by the Ordnance Committee, who took evidence from the principal experts of the country, and whose recommendations have proved of great value to the Service. They decided upon a general type of gun, which was based upon a design submitted by the

Royal Gun Factory on the 21st July, 1882, and all the guns since made for the British Government have conformed substantially to this type. But before describing it, I will take some of the Continental guns, the constructions of which are earlier in date.

Diagram 8 (Plate XXV) shows the outline of the 71-ton Krupp gun of 1881. The great German manufacturer keeps the sections of his guns a profound secret, and hence the drawing I am going to point to next, Diagram 9, must not be taken as authentic. During a visit to Essen in 1881 I saw the parts of his guns in the machines, and lying about, and I hope he will forgive me for having taken furtive measurements with an umbrella and by the eye, sufficient to enable me to make a tolerably close guess at the construction.

It should be said here that the Russian heavy guns are either made by Krupp on designs of similar character to this, or copied by the Russians in their own steel.

Krupp's latest design is for a heavy gun weighing 119 tons, and 35 cals. long, *vide* Diagram 10, which shows the authentic outline of this grand weapon. I venture to fill in the construction in Diagram 11, on the assumption that no radical change has taken place in the Essen principles since 1881, but again this must be taken as guess-work as regards the actual dimensions of the parts.

This is the heaviest gun in the world, and four are being made for the Italian land service.

It will be observed that the tube forms a lining extending from the muzzle to the face of the wedge, and that it is recessed at the end of the bore to receive the Broadwell ring. Over the tube is shrunk the breech-piece in which the wedge plays. Over the breech-piece are shrunk several hoops. Every portion is made of the finest gun steel.

In this construction the whole of the metal over the powder-chamber comes into play to sustain the transverse strain, which is transmitted from the tube to the breech-piece, and from the breech-piece to the superimposed hoops. Neither hoops nor tube, however, assist in bearing the longitudinal strain, which is entirely taken by the breech-piece. I suppose Krupp has satisfied himself that this gives plenty of strength, and that there is no chance of a dangerous defect, but I confess I should prefer to have a second string with guns of such great size in case anything went wrong with the breech-piece.

Diagrams 12 and 13 show the construction of the latest heavy French naval guns, the 34-cm. and 37-cm. of 52 and 71 tons respectively, proposed by General Dard, the great French artilleryist.

The 34-cm. gun consists of a very thick tube or body strengthened with layers of hoops. As in Krupp's guns, the whole of the metal comes into play transversely, but the longitudinal strain is taken by the tube alone. Personally I do not like this construction. I think too much depends on the tube, and any failure of this part, which is moreover specially subject to the erosive action of the gas, would be disastrous in the extreme. Whether General Dard found it difficult to obtain satisfactory forgings big enough to make the 37-cm.

guns on the same construction I do not know, but Le Crenset and St. Chamond can turn out forgings of 70 or 80 tons weight, and therefore I am inclined to suspect that General Dard preferred to trust less implicitly to the tube in these larger guns, and therefore thinned down the central forging and introduced a breech-piece between it and the hoops, which to my mind is a very decided improvement, as being put on with shrinkage it places the metal in a better position for resisting the transverse strain, and affords far greater security against longitudinal rupture. Every part is of steel.

Diagram 14 shows the Italian naval 100-ton breech-loader of 1882, manufactured by Sir W. G. Armstrong, Mitchell, and Co., of Elswick.

In this construction the tube is in two parts, held together longitudinally by a key-ring in halves. The breech-screw plays in the tube, over which is shrunk a steel breech-piece supported by two layers of thin hoops, and a thick outer wrought-iron coil. The middle and forward parts of the tube are supported partly by steel hoops and partly by wrought-iron coils. This construction was never repeated, though the experiments with it at Spezia were very successful. It is introduced here as showing with remarkable clearness the nature of the transition which has been taking place in construction.

I now give you, in Diagram 15, the typical design submitted to the Ordnance Committee by the Royal Gun Factory on 21st July, 1882, and recommended by them to guide future manufacture. This particular gun weighs 12 tons, and is 8 inches in calibre. Here the tube is thin and extends to the rear only sufficiently far to receive the obturator. Over the tube is shrunk a breech-piece, which is supported by exterior hoops. In this construction the whole of the metal assists in bearing the transverse strain, but the breech-piece does all the longitudinal work. This is not particularly objectionable in a medium sized gun of 12 tons, but would, I think, be so in very large ordnance; as you will presently see, with our heavy guns further provision is made for taking the longitudinal strain. The tube which is subject to erosion by gas is relieved from longitudinal strain, and is moreover so thin that a crack in it would not imperil the safety of the gun; while the form given to the breech opening renders it easy to bore out the eroded surface after long continued firing, and to insert a thin lining into the tube itself, as shown by the dotted lines, thus giving the gun a fresh life. With breech-loaders on the interrupted screw system, the longitudinal strain is found to act most dangerously about the position of the front threads, and it will be seen that at this point the metal of the breech-piece becomes thicker and stronger than in the more forward part over the chamber, while a strong hoop extending to the extreme rear of the gun clasps the breech-piece tightly over the screw, and prevents any tendency to open.

Diagram 16 shows the Armstrong 102-ton guns now being made for the "Lepanto," the great Italian war vessel. This design has

superseded that given on Diagram 14, and has been kindly sent to me by Captain A. Noble.

In Diagram 17 we have the section of the Elswick gun of 110 tons. This magnificent piece of ordnance is being manufactured for the British Government at the works of Sir W. G. Armstrong, Mitchell, and Co., Newcastle-upon-Tyne. It is entirely of steel. The tube is thin, and extends only to the obturator, and the breech-screw works in the breech-piece, which is shrunk over the tube as in the typical design on Diagram 15. Three layers of hoops reinforce the breech-piece. Here also every part of the metal over the chamber assists in supporting the transverse strain. The breech-piece is assisted in supporting the longitudinal strain by the peculiar distribution of the hoops. A long hoop provided with stout shoulders forms the rear part of the first layer. Its front shoulder engages the rear shoulder of a long hoop, which forms the front part of the second layer and carries a front exterior shoulder against which the trunnion hoop, forming the middle part of the third layer, abuts. Hence we have a direct pull from the trunnion hoop to the shoulder on the breech-piece. For the sake of clearness I speak of the trunnion hoop, but in reality there are no trunnions, the exterior of the hoop forms two rings which are held in a strong band attached to the slide.

To prevent the inner tube from moving forward in case the friction between it and the breech-piece should become relaxed on firing, a metal of the character of phosphor-bronze is run into a serrated recess at the front of the breech-piece.

In building up this gun the trunnion hoop forms a kind of watershed, so to speak, that is, all the hoops behind it are put on from the breech, and all in front of it are put on from the muzzle. To assist friction in keeping them in place, phosphor-bronze is run into a serrated recess under the trunnion hoop. It will be observed that in this design several important improvements have been made in the 100-ton gun manufactured for the Italians in 1882, and shown on Diagram 14. Diagram 16 shows an intermediate step in the transition. The tube is thinned down and fitted into the breech-piece which receives the breech-screw. The joint in the front part of the tube is got rid of. The material of the gun is entirely of steel, cast and forged. The system of obturation is changed from the cup to the pad, and the powder-chamber is made shorter and thicker.

Diagram 18 represents the section of the 63-ton guns now being made in the Royal Gun Factory. They are entirely of forged steel, which, with the exception of some of the smaller parts, comes in the rough state from Sir J. Whitworth and Company, who have, so far, met our requirements better than any other maker. In this design the tube is thinned down at the breech, and the breech-piece, which is shrunk over it, receives the breech-screw, as in the typical gun of Diagram 15. The metal is disposed in fair conformity with the transverse strain expected, and considerable weight is saved in front of the trunnion ring. All the metal assists in taking the transverse strain, except a very small layer of which only half assists, as will be seen presently. Over the breech-piece a hoop extending the full length of the

chamber is shrunk on, and the weakness of a joint at this important part is avoided. An exterior hoop of fair length reinforces the breech still further. You will observe a novel feature in the disposal of the hoops, so as to secure the greatest amount of longitudinal strength.

Diagram 19 represents on a larger scale the manner in which hoops which abut against one another endways are linked together by outer hoops. The exterior of the inner hoop carries a ring which is slotted away so as to leave alternate projections and intervals. The interior of the outer hoop carries a corresponding ring, which is also slotted away so as to leave alternate projections and intervals. The outer hoop, expanded by heat, is passed over the inner hoop, so that the projections pass through the intervals; it is then turned so as to bring the projections of one hoop exactly in line with the projections of the other, thus preventing any longitudinal movement. The intervals are then filled up with long steel wedges, which are forcibly driven in. One wedge would be sufficient to prevent any circumferential shift, but all the intervals are filled up so that the strain from the interior on firing is directly transmitted to the whole of the outer hoop. You now see that half the metal of the layer represented by the thickness of the wedges is not available for resisting the transverse strain. This is made up by slightly increasing the thickness of the outer hoop. By this device the gun is stiffened at the joints, and held together longitudinally from the extreme breech end to a point far up the chase—an advantage in point of strength and safety possessed by no other design with which I am acquainted.

Coming last to steel breech-loaders, England has been justified in fearlessly adopting the metal which has been thoroughly tested by German experience. She has also adopted a construction which bears a certain similarity to the French, but is modified somewhat as in Krupp's guns.

Having thus taken what seemed to be best of other people's, we have added a little of our own in the matter of locking all the parts of the gun together. It would be unpardonable in a manufacturer not to adopt what he thought the best, and if I saw anything which satisfied me better than this 63-ton design I should certainly try to get it; hence you will, I am sure, pardon me for saying that I think that coming last we really have got the best forged steel construction known.

I use this expression to avoid including constructions which involve the employment of wire, which may perhaps supersede those consisting entirely of forged steel. It is perhaps hardly correct to include them among the guns of 1884, as they are chiefly experimental, but I believe some have been made and actually issued for service to Chili by the firm of Sir W. G. Armstrong, Mitchell, and Company.

Competitive designs have been prepared for the War Office by the same great firm and by the Royal Gun Factory for guns of this kind, and I have received Captain A. Noble's kind permission to show you on Diagram No. 20 a section of the 18-ton wire-gun proposed by

Elswick. The tube is thinned down inside the breech-piece, which is shrunk over it, and receives the breech-screw, as in Diagram 15. Instead of being reinforced with steel hoops the breech-piece receives great transverse support from a steel flat wire or ribbon which is wound round it like thread on a reel, but at considerable tension. This wire breaks at 60 tons per square inch. Thin protecting hoops of steel cover the wire and form the exterior of the gun. Here all the metal over the breech assists in supporting the transverse strain, but the longitudinal strain falls entirely on the breech-piece. The great obstacle to the employment of wire in a gun has always been the difficulty of getting sufficient longitudinal strength; no means have yet been devised of putting on high class wire to give both longitudinal and transverse strength. A portion of the wire may be put on, as was done in one construction most ingeniously by Sir W. G. Armstrong, so as to give longitudinal strength, but then it becomes useless transversely. That device has been abandoned in this design, and hence the longitudinal strength is rather low.

The Royal Gun Factory design submitted at the same time is shown on Diagram No. 21. In this construction the tube extends the whole length of the gun, and receives the breech-screw. It is protected from the erosive action of the gas by a thin lining, which extends from the obturator as far as necessary up the bore. The breech end of the tube is much thickened over the breech-screw, so that this is the strongest part longitudinally. Over the chamber is wound a high class flat wire, which confers immense transverse strength, but does nothing longitudinally. This wire breaks at 100 tons per square inch. Over the wire are shrunk two long hoops of forged steel, which transmit the longitudinal strain from the rear end of the tube to the trunnions, by means of two systems of locked projections.

In this construction the whole of the metal over the chamber assists in supporting the transverse strain. The longitudinal strength is divided about equally between the tube and the outer hoops, and is ample.

In considering the probability of forged steel constructions being supplanted by those containing wire, it must be borne in mind that the lighter the gun in proportion to its power, the more work is thrown on the carriage in checking and absorbing the recoil.

There is some doubt whether a practical limit has not already been reached in this respect with the latest patterns of forged steel guns; that is to say, any further reduction of weight in proportion to power may be found to necessitate more than a corresponding increase of weight to the carriage. Should experience prove this to be the case, there will be little advantage in the introduction of wire except in certain special cases, such as siege howitzers, &c.

Our third and last point of comparison is the power developed by the various types of ordnance which have been brought before you. In this respect we have had nothing to learn from abroad. We owe much to the labours of the Explosives Committee, and much to the admirable experiments with fired gunpowder in closed vessels which were carried out in 1874 by Captain A. Noble of Elswick and Sir

Frederick Abel, but our chief superiority is due to the practical results obtained with enlarged powder chambers and lengthened bores during a searching trial at the Royal Gun Factory in 1873; from these causes our ballistic knowledge has long been fuller and more complete than that of any of the Continental authorities; and it was really owing to this circumstance that England's guns held their ground as long as they did under the double disadvantage of being wrought-iron muzzle-loaders instead of steel breech-loaders.

The principle of chambering, that is of enlarging that part of the bore which contains the explosive, depends upon a peculiarity in the action of powder charges which is not very generally known or understood. I will endeavour to make the facts clear to you. Let us now turn to Diagram 22. Supposing I fill a chamber which measures 3.15 inches in diameter and 18.7 inches in length with R.L.G.² powder, at a density of 35.6 cubic inches per lb., as in the proof charge of the 13-pr. M.L. field gun, the pressure will be extremely capricious, varying from about 26 tons to 40 tons per square inch; the velocities will vary also, but to nothing like the same extent.

Next, supposing I fill a chamber which measures 7 inches in diameter and 18.7 inches in length with 20 lbs. 3 ozs. of R.L.G.², at the same density as before, as in the 7-inch M.L. gun, I shall get fairly regular pressures and velocities; the pressures will be about 22 tons only, varying about a ton above and below, although the densities of the charges are equal, and there is more than five times as much powder in the charge which gives the lower pressure.

This anomalous result arise from the shape of the chamber. It is found that long narrow chambers favour the development of "wave pressures," as they are called, in a surprising degree, and experience has clearly shown that to get the best effect out of the charge, the chamber should not be longer than from three to four times its diameter; with a powder which is slow in proportion to the size of the gun, it is generally safe to approach or possibly exceed four diameters in length; but with a powder quick in proportion to the size of the gun, it is often dangerous to exceed three diameters in length.

The cause appears to be that as soon as the charge is lighted, the gas first evolved travels through the chamber from end to end with great rapidity, and sets up a dynamic action of a vibratory or wave character. But if it is asked why increasing the diameter of the chamber should mitigate and indeed remove this action, I have to confess frankly that I do not know. In the cases given in Diagram 22, the gas has just as far to travel, and to acquire momentum in, but it seems to lose the intensity of its rush from end to end when afforded increased space laterally.

Many efforts have been made to overcome this difficulty and to obtain satisfactory combustion in long narrow chambers by means of extensive air spacing, or by introducing central tubes of zinc and other substances, but the results have not been very promising, and in the Royal Gun Factory we have kept all our chambers short and thick, so as to consume the charges under the most favourable conditions.

There are also certain incidental advantages in shortening the cartridge by chambering; the length of travel of the projectile and consequently its velocity at the muzzle are increased. The shell has not to be rammed so far in, and the cartridge is more compact and serviceable. The disadvantage lies in the necessity for making the gun stronger and therefore heavier over the powder charge; in fact the breech must be that due to the size of the chamber and not of the bore. Still the ballistic advantages outweigh this, and as you see by the following table (p. 709), the chambered guns beat all others in energy per ton.

There is one more point where chambering will probably prove of great service. The special duty of all very heavy guns, either for land or sea service, is to get their projectiles through armour. Of late years the armour question has undergone very great change. The guns easily mastered the wrought-iron plate armour of the seventies, whether solid or in layers, but the use of steel which has become general in the eighties, has checked the artillerist's victorious career. Plates made either entirely of steel or of wrought iron faced with steel—the plates known as "Compound"—are very difficult to get through or to smash, if thoroughly well supported by firm backing. They break up the chilled iron shot, which splash harmlessly on the surface, while the steel shot fired at them usually break if too hard, or flatten out if too soft. We are trying to find the shot material which will prove most effective against this improved armour, and till this is accomplished we shall be unable to say with certainty what proportions should be given to the projectiles. The smashing or racking effect of a very heavy projectile of large diameter, striking with moderate velocity, may prove more effective than a lighter shot of smaller diameter and high velocity, or the reverse result may take place.

We can adapt our chambered guns to suit either scheme. Since the calibre does not bear any fixed relation to the diameter of chamber, we can either enlarge the bore, or reduce it by a thin lining, at pleasure, without interfering with the powder charge or its stronghold.

To recapitulate the principal points alluded to in this lecture, having come last among the Great Powers to steel breech-loaders, we have been able to select the best points from the various systems worked out by others. The material is that proved admirable chiefly by German experience; the system of breech-loading is that of the French land service; some parts of our present construction have been tested in Germany and some in France, while we have been able to improve on both, and solidify the whole structure in a marked degree. Not being hampered by the necessity for utilizing old material, we have been able to devote all our energies to new guns of the best quality, instead of repairing and altering old guns of inferior type, as is being largely done all over the Continent. We have, moreover, greatly extended the ballistics of our guns, and have conferred on them unsurpassed power in proportion to their weight.

It is true that in numbers we are behind, but having the best

THE HEAVY GUNS OF 1884.

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Comparative Table of Powers of B.L. Guns, 1881-1884.

Nature of gun.	Date.	Weight of gun.	Weight of charge.	Weight of projectile.	$\frac{aC}{aB}$	$\frac{W}{D^3}$	Muzzle velocity.	Muzzle energy.	Perforation of iron at 1,000 yds.	Energy per ton of gun.
		Tons.	Lbs.	Lbs.	Ratio.		Ft.-secs.	Ft.-tons.	Inches.	Ft.-tons.
French, 34-cm. (13"38).....	1881	52	362	926	1·07	·39	1,908	24,803	22·9	478
French, 37-cm. (14"56).....	1884	71	546	1,180	1·02	·38	1,955	31,272	24·5	440
Krupp, 40-cm. (15"75).....	1881	71	485	1,715	1·21	·44	1,703	34,502	23·8	486
Krupp, 40-cm. (15"75).....	1884	119	615	1,632	1·31	·42	2,017	46,001	29·2	387
Elswick, 17".....	1882	100	772	2,005	1·34	·41	1,832	46,600	28·5	460
Elswick, 16"25.....	1884	110	900	1,800	1·69	·42	2,020	50,924	30·5	513
R.G.F., 13"5.....	1884	63	625	1,250	1·78	·51	2,050	36,415	28·6	569
R.G.F., 9"2 wire.....	1881	19	330	380	2·32	·50	2,520	16,730	23·2	880
Elswick, 9"2 wire.....	1884	18	200	380	1·85	·50	2,200	12,759	20·0	709

types, all that is required is money and a little more time. The money will no doubt be forthcoming at the good pleasure of the country, which must not hesitate to pay its war insurance. But time is more serious; a heavy gun cannot be made under about fifteen months, and the only way to economize in this respect is to put up sufficient plant to permit of a considerable number of heavy guns being under manufacture at the same time. This has been done to some extent, and the next two or three years will see us in a very different position as regards numbers. Still there is much more to be done, and I will conclude by earnestly representing that though sufficient confidence may not have been felt two or three years ago to justify the heavy outlay which was seen to be necessary to rapid rearmament, yet that now the time has arrived for the country to face the question seriously, to grant the money, and to push the manufacture.

The CHAIRMAN: My lords, ladies, and gentlemen, I must apologize for having kept you waiting for a few moments, but I was detained longer than I expected by having to answer some questions in the House of Commons. I had great pleasure in giving the permission which Colonel Maitland asked for, as the head of the War Department, to deliver his lecture upon a most important subject on which he was so well qualified to give the latest and fullest information. We have had a most interesting and instructive lecture from him, and it now, I think, only devolves upon me to invite—as I believe is the custom on these occasions—any gentlemen to discuss the subject under the usual rules of discussion which take place in this Institution. I would only add that I have had great pleasure in taking the chair on this occasion, as showing the interest which I feel in this most important question. I understood it would not be necessary, if other business should prevent my doing so, that I should remain until the close of the discussion—and I fear that there is official business which will make it necessary, both for Lord Northbrook and myself, and I am afraid also for Mr. Brand, the Surveyor-General of the Ordnance, to leave, if not at once, at any rate very shortly. I will therefore ask Mr. W. H. Smith to take our place.

Admiral VESEY HAMILTON, C.B.: There is always a difficulty in this Institution in getting some one to make the first move; I do so now, and I have nothing controversial to say, the subject, in the four years I have been away from it, having got beyond me—I may say as a naval Officer, however, it is a source of great gratification to me to know that we have a near prospect of our Navy being eventually armed in a manner equal to, if not superior to, that of any navy we are likely to encounter. Speaking as a naval Officer also—I do not think I am saying too much when I speak for others also—I think we have every reason to be thankful to Colonel Maitland and the department over which he presides, for the way in which during the last few years they have made up for the leeway we had undoubtedly made, and I hope every other department under the Surveyor-General will treat us equally well.

Admiral BORS: I do not find myself capable of criticizing this lecture, but I am sure the interesting matter which it contains, and the care with which it has been brought before us, deserve our best thanks. With regard to the "leeway" mentioned in the lecture, and which Admiral Hamilton has referred to, I must make a remark, and to some extent perhaps make some little excuses. We all know in our system of Government there can only be a certain amount of money devoted to certain Departments, and therefore each Head of a Department must make the most of the money he has to deal with. Well now, those who have been in office know that the slightest alteration in any one item of manufacture connected with guns particularly, involves very heavy expenses indeed. I know that such a thing as an alteration in a projectile which, generally speaking, may be looked upon as a trifle only—just a change in this stud or that gas-check, when it is done throughout the

Service, involves an expenditure of thousands of pounds for the purpose. Therefore I think we are to be excused for objecting to the very material change which has now been found necessary in altering all our old muzzle-loading guns, which in their time were as good as any other nation possessed, to the present system of breech-loading without positive proof of the advantage to be gained. We may be excused for the delay that has occurred, and in consequence of that delay now I think we must probably have got a better weapon than we should have had without it. In proof of what the old muzzle-loader could do, I will only bring forward the case of the action at Alexandria. In that action there was not a single gun that was disabled from its own fire; that is, although some were afterwards condemned they could have continued the engagement if it had been required. This from our present experience is not to be expected from breech-loading guns. This may be called simply an excuse, but it is an extremely good reason for not launching into a new system without great consideration and experiment. With regard to the "energy per ton"—that is a most important point for the naval service. "Energy per ton" simply means the power of a gun in comparison to its weight; and in arming a ship the object is to get the greatest amount of work out of the guns she is to carry. On board ship every ton weight saved in guns can be added to armour or in some other way will tend to increase the efficiency of the ship. Perhaps Colonel Maitland will tell us what is generally considered to be the life of our breech-loading guns—I mean from the effect of erosion in the bore from firing large charges. He has told us—and I am very glad to hear it—that we can now repair our guns very easily by lining them and obviating the effect of erosion. With regard to the heavy nature of the new guns, what experiments have been made to show their power of endurance with heavy charges and the effect of continuous rapid firing? A few years ago we had an experiment with a 38-ton muzzle-loading gun at Shoeburyness, partly at my instigation, to try continuous rapid firing up to 200 rounds, as nearly as possible assimilating the conditions to those of an action at sea, firing as rapidly as possible for a quarter of an hour, then ceasing for a quarter of an hour, and so on alternately until 100 rounds were fired in one day; during the night re-venting the gun, and repeating the operation the next day. The gun stood the test satisfactorily. I would like to ask what experiments have been made in that direction with our new heavier guns so as to test endurance.

Mr. G. W. RENDEL (Admiralty): The large and distinguished company assembled here to-day testifies to the interest felt in our artillery, and the importance attached to everything that may fall from the lecturer on this subject. I fully share that interest, and I trust that if I criticize anything advanced by Colonel Maitland, it will be understood that I do so in no controversial spirit, but to assist—as all who have studied the subject are bound to do—in forming correct conclusions on a matter of such high importance to the country as its artillery. On one statement made by the lecturer I for my part should like to have heard more detailed and exact explanations. I refer to the proportions which he laid down for the powder-chamber of our heavy guns. Colonel Maitland gives a rule for the proportion of the powder-chamber which in effect limits its length to $3\frac{1}{2}$ diameters; and I understand that he does so on the ground that if the length be made greater in proportion to diameter, there is a liability to dangerous wave-pressures in the gun. At the same time he states very fairly that an obvious result of this mode of proceeding is to oblige us to construct our guns over the powder-chamber with reference to the diameter of the powder-chamber and not to the calibre of the gun. He has carried the theory into practice in recent guns, and I may take as an example the new 43-ton gun.¹ In that gun the chamber has 16 inches diameter, the bore being 12 inches; consequently the strength of the gun over the breech has to be that adapted for a 16-inch calibre instead of only a 12-inch calibre. Now it may be said that although this is so, yet the gun is shorter and lighter on that account. But I should like to have seen Colonel Maitland's own estimate of the actual increase of weight involved by this rule. I myself have made a rough calculation, and I find that if the gun were made without an enlarged powder-chamber, leaving it identically the same from the base of the projectile forward and lengthening the rear to give the same volume of

¹ See Sketch annexed.

Diagram to illustrate Mr. Rendel's remarks on Colonel Maitland's Paper.

Approved 12" Gun { Weight of Gun with Breech-screw and Obturator..... 43 tons.
 " Breech-screw and Obturator 1,400 lbs.

Modified 12" Gun { Weight of Gun with Breech-screw and Obturator..... 36 tons.
 " Breech-screw and Obturator 710 lbs.

powder-chamber, you would have a diminution of weight from 43 tons to, I think, a little over 36. That is a very large reduction of weight of very great importance—at any rate to the Navy, where, as Admiral Boys has said, every ton we have to carry is of moment. If we save it in the gun we can put it into armour, speed, or some other form of efficiency. But Colonel Maitland says that if he diminishes the weight of the gun he thereby so increases the energy of its recoil that he would have to put into the mounting that which he saves on the gun. I think that statement requires to be confirmed by more exact investigation. The energies of recoil in the case I have assumed would be approximately in the heavier gun 275 foot-tons, and in the lighter gun, I think, something like 315. The increase no doubt involves some increase in the size of the hydraulic buffer in particular, but the change is accompanied with a diminution of the dimensions of the gun, because it is obvious that a gun of 16-inch calibre will have a larger outside diameter than one of 12 inches, and in point of fact the reduction of the outside of the gun is very considerable, viz., from 54½ inches to 43½ inches. To the Navy such a reduction of outside dimensions has special value, because we mount our turret and barbette guns generally in pairs. One of our reasons for doing away with trunnions was to enable us to place two guns as close as possible side by side. They now stand so close that they more resemble a double-barrelled gun than two independent cannon. This has two advantages: it diminishes greatly the couple tending to rotate the turret, a difficulty which abroad has led to the abandoning of double guns on revolving platforms; it also reduces the diameter of the circumscribing circle, and consequently has a tendency to reduce the size of the turntable and of the armour required to protect it. Therefore I think it may be found that instead of the diminution of the powder-chamber leading to an increase in weight of the whole system of mounting, it may do the reverse. Of course the argument on which the very large powder-chambers were adopted is correct as far as it goes. There is no doubt that wave-pressures have been found of a very violent character with quick-burning powder fired in chambers long relatively to their diameter, but I think there are plenty of experiments with slow-burning powder in which the proportions laid down by Colonel Maitland have been greatly exceeded without wave-pressure. In the 100-ton breech-loading gun made at Elswick and fired at Spezia in 1882, the powder-chamber is over five diameters in length, and the powder was fired from the end. Notwithstanding this there was no trace of wave-pressure at any time. That would tend to show that at any rate we need not fix a limit at 3½ calibres. Then again we have not seriously studied all the means by which we may hope to reduce those wave-pressures. I am not by any means satisfied that we have exhausted the subject of mode of ignition of the charge. The advantage to be gained by the diminution of

the chamber once admitted and appreciated we should be more likely to expend our ingenuity in getting rid of the difficulties of attaining that end, and therefore I think it unwise to lay down a rule on the subject with the authority which belongs to the position and ability of the lecturer. I may point out one more objection to the very large powder-chamber, namely, the large size and weight of the breech-screw which it involves, and which is of course particularly difficult to handle on a moving platform like that of a ship. In the comparison I have cited the weight of the breech-screw would be reduced one-half by the reduction of the powder-chamber, although of course that would be accompanied with the disadvantage that you could not put in a lining from the breech which Colonel Maitland mentioned as a possible means of repair.

Lieutenant-Colonel W. HOPE, *U.C.*: I brought with me the official text-book on the construction of ordnance, and I came here prepared to demolish a good deal that I expected Colonel Maitland to say, but I am very glad to be relieved from the necessity of doing that owing to the very frank manner in which he has thrown the text-book overboard. There is scarcely a word in the text-book which he appears to agree with, although it is only dated 1879. He invited any one to explain, if they could, what produced the waves of pressure in long narrow powder-chambers, and I am very happy to be able to do that, and to tell him that I have successfully fired a cartridge of over 15 calibres in length in a powder-chamber 20 per cent. larger than the bore of the gun without bursting the gun and without setting up any wave-pressure; and I may say I accomplished that by lighting the powder not in two or three places, but in 140 places all at once. And alluding to what Colonel Maitland said as to the action of the powder after the shot began to move, I may say I first of all begin by moving the shot before I light the powder. Sir William Armstrong, some twenty-two or twenty-three years ago, tried to accomplish the same result of relieving the gun by moving the shot prior to the ignition of the powder, because no gun bursts except owing to some accidental flaw or some other such circumstances after the shot has once moved. It is in the short space of time that elapses before the shot moves that the gun bursts, and Sir William Armstrong tried drilling a vent immediately in the rear of the shot, but although he probably accomplished moving the shot first, he also accomplished an unexpected result, for he blew out his breech. And for this reason:—although we know now that gunpowder is not an explosive and does not explode, we still go on setting fire to it in the powder-chamber of the gun as if we still believed it was an explosive and did explode; in short, in the method of igniting the powder we have absolutely made no advance whatever since the battle of Crecy in 1346. That is a hard fact. Well, what happens when the Officer gives the word "fire" and the man pulls the lanyard is this: the friction-tube sets fire to the small portion of the powder immediately in front of the vent or underneath it, as the case may be, and that small portion of the charge is instantaneously converted into gas. The pressure due to that conversion depends upon the form and size of the grains of powder, but in the case of small-grained violent powder it would be in the neighbourhood of 42 tons to the inch. A differential action is at once set up in the powder-chamber; the front of the charge remains unignited while the rear is converted into gas. That gas is confined by the rigid incompressible walls of the gun, and unless it succeeds in blowing out the breech, the only escape for it is by driving out the projectile with which it is not in contact, and as the powder in front of it is compressible, it naturally succeeds in compressing, and very violently compressing, the unignited powder against the base of the shot. Now, if you compress a cubic inch of powder into half a cubic inch of space before you set fire to it in an enclosed chamber it will give exactly double the pressure that it would have given if it had not been compressed, and therefore in proportion as the charge of powder is long, and the powder-chamber long and narrow, if the powder is ignited in the usual way, the front of the charge is violently compressed against the base of the shot before the shot moves, and you set up a circumferential wave of pressure that nothing will stand.¹

¹ The reader is referred for further explanations to Colonel Hope's paper on "A Revolution in the Science of Gunnery," read on the 23rd July, and which will be published in due course.—Ed.

Sir FREDERICK BRAMWELL, M. Inst. C.E.: I was very glad indeed to hear from Colonel Hope that he was about to solve the problem Colonel Maitland put to us, but I trust he will pardon me if I say I do not think he has done so. Colonel Maitland has put before us this problem, which seems to me, at all events up to the present, to be insoluble. There is Diagram 22 upon the wall. He says, "I put a cartridge of a certain length into a gun 3.15 inches bore, and having in front a projectile, also 3.15 inches diameter and of a certain length. Below this figure is that of the other cartridge, 7 inches in diameter, having a 7-inch projectile in front of it considerably longer than the projectile of the 3.15 bore. Each inch area therefore of the larger gun and the cartridge in that gun has got a greater resistance upon it than each inch area of the smaller cartridge, because the projectile is a longer one, and if it is solid the resistance will be in proportion to the length. Under these circumstances the small cartridge when fired gives pressures which vary from 26.3 up to 40 tons from the first to the fourth round, whilst the large cartridge gives 22, 23, 20. I think Colonel Hope's explanation would have been satisfactory if both these cartridges had behaved in the same way, that is, if it had appeared that a cartridge of a certain length always gave the same wave-pressure; but Colonel Maitland points out to us that it does not depend upon length, but upon length considered in its ratio to diameter; and I have failed to appreciate how that which Colonel Hope put forward as an explanation does explain that most curious fact. Colonel Maitland did not call attention to the fact in his paper to-day (but he was good enough to speak to me about it some time ago), that in the large guns there is a greater resistance per unit of surface on the powder; but I mentioned it as I think it should be kept in view as adding to the difficulty of the explanation. I must for one say I do not feel any shame in confessing—especially after Colonel Maitland's most frank and honest admission of his inability to solve the problem—that I have not the most remote conception as to why the length of the chamber relative to the bore should have anything to do with a variation in pressure. I can quite see why the actual length should, but why the relative length should is to me a mystery.

Mr. KRAFTMEIR: I should like to mention one point. Colonel Maitland referred to the improvement made at Waltham Abbey by the present superintendent of the manufacture of C_2 powder. In connection with this I may say that there has certainly been most astonishing progress made in the manufacture of powder. As Colonel Maitland said, "for certain guns a charge of 200 lbs. of C_2 powder would be required to give the same result as a charge of 170 lbs. of cocoa powder." I think that, taking into consideration the increased cost of the extra 30 lbs. of powder, the further weight of carriage, the considerably heavier cartridge, and the more difficult way of handling the same, it is of very great importance to adopt, if possible, charges which are lighter and yet give the same result. I believe that several English Officers are very much in favour of further experiments being made with brown prismatic powder, of which very large quantities have lately been ordered by most of the European Governments, and further believe that even the Superintendent of Waltham Abbey is in favour of this powder, and, as Colonel Maitland says, he hopes the Government will grant the necessary funds for the construction of guns, so I express also the hope that some further steps will shortly be taken with regard to the brown prismatic powder. Colonel Maitland mentioned that R.L.G.² powder had given very irregular results in different powder-chambers. I believe that it is a powder which can certainly not be trusted to any great extent. I have been told that in some cases this powder has given up to 30 and more tons' pressure. There is a desire that a new powder should be made in place of the R.L.G.², and I should like to mention that the United Rhenish Westphalian Company is at the present moment engaged in adapting the brown prismatic powder for field artillery purposes. They have constructed small prisms of about half an inch in diameter and three-quarters of an inch in height. The experiments have so far been satisfactory, but they are not yet sufficiently advanced in order to bring the matter before the English Government.

Captain PALLISER: Colonel Maitland is to be congratulated on the success of his guns. I have long watched his exertions and progress with the greatest interest. It happens that the subject under discussion is of special interest elsewhere, for I

may mention a fact which, though of great importance, is probably new to many here: it is that the Canadian Government has suggested the erection of a gun factory at Quebec. I need hardly say this would be the first step towards establishing an arsenal in that fortress. Quebec will before long be connected by railway with Vancouver's Island, on the Pacific Coast, where our naval station is established, and where the great coal mines for our fleet are being worked. The suggestion, therefore, of the Minister of Defence is not premature. No Colony can be said to be out of leading strings until it has established an arsenal with the machinery necessary for the manufacture and repair of its weapons of defence. I have therefore received a request to furnish an estimate for a gun factory at Quebec in connection with the cartridge factory already established by the Government of the Dominion. My report will embrace the amount of subsidy required, the expenses of the establishment, and the amount of work it might be expected to turn out annually. It would be an exceedingly difficult operation for the Canadians to make guns if any great forgings were required to be made in their country, but the steel manufacturers of England turn out all portions of the guns rough bored and tempered, so that the defences of the Empire are now greatly facilitated by the mode of construction due to the great efforts of our friend Colonel Maitland. I have no doubt we shall soon find the Government of Canada with machinery sufficient to turn out a moderate supply of the new steel breech-loading guns, the same machinery being available for keeping their present armament in repair. Whether the other Colonies will follow this example, and thus greatly contribute to the defence of the Empire, remains to be seen.

Thursday, June 26, 1884.

The RIGHT HON. W. H. SMITH, M.P., in the Chair.

(Adjourned Discussion on Col. Maitland's Paper.)

Mr. LONGRIDGE, C.E.: In the first place, Sir, I cannot but feel considerable disappointment and a good deal of alarm at the general features of Colonel Maitland's paper. We have been accustomed to hear for many years that we had the very best artillery in the world. I remember that many times, when the Army and Navy Estimates were brought forward in the House of Commons, we were assured over and over again that our artillery was the very best in existence. I find in Colonel Maitland's paper an admission that since 1876 we have been lagging behind the rest of the world. That is not new to me; I was perfectly aware of that fact. But there is another thing which alarms me, perhaps, more than that, and that is, that our future progress in artillery appears to be dependent on watching the experience of other nations. Credit has been taken by Colonel Maitland for our having kept back, seeing what other people have done, and then adopting their improvements. Well, Sir, I think myself that it is very fortunate for the nation that we have not been "caught napping," and I should like to know what would be the consequence if within the next eight or ten years we should be "caught napping." We have heard from Colonel Maitland that to make one big gun is a matter of fifteen months. No doubt he coupled that with the assertion that, if the nation would find plenty of money and plenty of plant, we could make more great guns in the same time. I confess I look forward with very great dismay to the fact that in making these great guns we are to follow upon the lines of what other nations have done. I think myself that a country like this ought to lead the van. I think an establishment like Woolwich should not follow Krupp or Elswick, or the French; and I look upon the prospect with more dismay still, because I know that there is another system of artillery which is now at least coming to the front, and which, two years ago, Colonel Maitland himself said appeared to be a very dangerous rival to these steel forgings which he now praises so much. I know that the system of wire, which I have now advocated for pretty nearly thirty years, is being studied carefully by other nations. And I should be greatly dismayed, and I shall

not be much surprised, if we find that by the time we have got this new armament, on which we are asked to spend so much, we are told that it again is obsolete, and shall have to follow the other nations in the reconstruction of a wire gun armament. I know quite well it will be said that these are matters which cannot be done in a day, but it is two years since Colonel Maitland told us the subject was one which was attracting attention. What has been done since? What experiments have been made with the wire gun system since then? I happen to know pretty nearly what has been doing at Elswick; I know something of what has been done at Woolwich. I know the Ordnance Committee were instructed to investigate this subject, and I know the nature of the investigation they have made, and this knowledge does not lead me to look forward very hopefully towards our immediate future in wire gun construction. Having made these few general remarks, there are just one or two observations I should like to make with reference to some of Colonel Maitland's statements. I entirely disagree with Colonel Maitland in considering that we have made improvements in the powder. I am not alone in that. I am perfectly satisfied myself that slow-burning powder is not an improvement: it is a modification of the powder to suit the inherent weakness of our guns. I say it is just as much going back from what we ought to do, as it would be now if our great steam-ship companies were to go back to the low-pressure engine, where we were confined to 4 lbs. per square inch of the boiler. The results we have arrived at in steam navigation have been from the development of high pressure, and, weight for weight, a high-pressure gun will give a far higher result than a low-pressure gun. I point to that table with the utmost confidence. You have an energy of 880 foot-tons per ton of gun. I may say that that method of estimating energy is utterly fallacious, because I can make wire guns equally strong and very much lighter than these present guns, and I can develop 1,000 tons energy per ton of weight, but I know that to do so would be perfectly useless, you must have the weight to meet the recoil; therefore, although there are all sorts of appliances for meeting the recoil, yet, unless you take the questions of weight of gun-carriage and appliances altogether, a statement like that is perfectly fallacious. But I would take the gun by itself, and I am prepared to show that, instead of those guns with large chambers and large charges being lighter than others, they are a very great deal heavier than the high-pressure gun. Colonel Maitland states that doubling the pressure would increase the weight of the gun 80 per cent. I beg to say it would do nothing of the sort. I have shown in my "Treatise on the Application of Wire to Construction of Ordnance" that, weight for weight, I can make a 40-ton gun which I compare with a 40-ton gun of Sir William Armstrong, and the result is this, that if I am allowed to use powder giving 33 tons pressure instead of 21, I can get with 413 lbs. of powder an energy of 33,000 foot-tons; whereas the chambered gun, with 500 lbs. of powder, will not exceed 24,000 foot-tons, the guns being the same weight. There is no doubt, therefore, that weight for weight, if you have high pressure, you can get a very much more powerful machine. It is precisely the same in a steam-engine as in a gun; and I must take exception to one expression of Colonel Maitland's, in which he spoke of a thing being right in an engineer's point of view and utterly and entirely wrong in an artillery's point of view. I cannot understand the difference. If he tells me the navigation of a ship is very different from making the engines, I agree with him, but he will scarcely expect the Captain of a ship to go and tell the engine-builder how thick his piston-rod is to be. It is exactly the same thing in a gun. A gun is exactly as much a machine as a steam-engine. The same mathematical rules of strain and proportion must be applied, and these are precisely those matters which are within the scope of an engineer; and therefore, if an artillery is different from an engineer, let him tell us what sort of gun he wants, and then we will make one for him; but do not let him come to us and say it is not our business to make guns because we are not artillerymen. There is another point connected with chambering which seems to be rather puzzling to Colonel Maitland, but I confess I can see no difficulty about it at all. The fact is simply this: that the pressure in a space like this (referring to Diagram 22), with a loaded valve upon it, which a projectile is, when the inertia of the valve is very great the pressure depends directly as the rate of generation of the gas, and inversely as the space it has to occupy. The ratio of generation depends

simply as the surface of combustion, that is, it increases directly as the radius; the space varies merely as the square of the radius. Consequently the pressure must be a function of the radius divided by the square of the radius, and therefore it follows necessarily that in the large gun you should have a lower pressure than in the smaller one. There are two fundamental differences betwixt myself and Woolwich and Elswick. The one is this question of longitudinal strain. I maintain, and have for years, that the materials to resist the longitudinal strain should be entirely independent of the material to resist the bursting strain. When you have that, you know the amount of each strain, and you can calculate accordingly. When you do not know it, when you divide the two by a haphazard system, it is impossible to tell how the strain will be apportioned between the two, and therefore I differ altogether from Colonel Maitland in thinking it is an advantage to divide the strain between the tube and the outer casing. He talks of having two strings to his bow: just as well might an engineer have two piston-rods to the cylinder of a steam-engine. You know the strain in both cases, and if you apportion the material to the strain you have no danger of failure; but if you divide it between two or more you introduce an element of very serious difficulty indeed. There has been no allusion in Colonel Maitland's paper to the very important question of the mode and pitch of rifling. We have heard a good deal about these, and I do believe myself they are of the very highest importance. I am sure the amount of rotation is a most important thing. My own opinion is, that Sir Joseph Whitworth, with his rapid rotation, is on the right track. But rapid rotation is required by a long shot, and requires a high velocity. High velocity cannot be obtained without high pressure except by these enormous charges, fully one-half the weight of the shot, involving an enormously long, cumbersome, expensive, and dangerous gun. I have no hesitation in stating that as my deliberate opinion, and that a lighter, stronger, and equally safe gun can be made in which no portion shall be strained more than in the heavy and low-pressure gun as now proposed if you take the pressures 30 and 35 tons per square inch, instead of 15 and 17, and with no more strain upon the gun; but, in order to do that, you must not go on making experiments haphazard, and without proper calculation as to how those strains will be distributed.

Captain R. EDMONDS: I am one of the representatives of Woolwich, and therefore you will expect that I shall defend to a certain extent what we do at Woolwich. Mr. Longridge has just said that we have not the best artillery, that we are lagging behind other people, that we are following other nations. Now it appears to me we shall have some time to wait before we follow other nations with regard to wire as a material for guns. They have not gone into that subject any more than we have, although it has been before the public for nearly thirty years. Mr. Longridge does not give us the credit that he ought, with reference to our guns as far as strength is concerned. It is all very well to have a formula, and I admire formulæ as much as anyone, but it is expected that you will use those formulæ in the manner in which the authors have intended them. The formulæ of Hart, Lamé, Rankine, and Mr. Longridge himself all have reference to a cylinder filled entirely from end to end with an uniform pressure, and in which the ends are not supported in any way by any extraneous parts. I should like to know whether a gun is in such a condition when it is fired. A gun is a cylinder filled partially with a certain amount of pressure, and the two ends of the cylinder beyond the chamber, both front and rear, are adding very materially to the strength of the chamber itself. A gun in this condition resolves itself into a cylindrical beam from front to rear, in which the ends from the longitudinal tension may be considered to be firmly fixed; and for the purposes of calculation you may consider the beam to be divided into a number of longitudinal staves. Now those staves are giving a large amount of resistance to deflection, which is inversely as the cube of the length and directly as the cube of the height of the material brought into play. In our old guns the powder was strong; the charges were short; the guns were thick; consequently, you will find when you calculate these resistances that you get a large acquisition of strength from the resistance to deflection which the gun itself possesses. I think it is from this cause that when we had an experiment called the "crucial test" of the 9-inch muzzle-loading guns, in which the outside portion of one gun was in one thickness,

and the outside of the other in two thicknesses, the two guns went through the same test and were as nearly alike as possible. Each gun fired over 1,100 rounds. The one in one thickness, by theory, ought to have burst, but it did not, and I fancy that strength was in consequence of the increase of strength from its resistance to deflection. Again, recently a cast-iron gun all in one thickness, with the exception of the wrought-iron tube, was fired, and in the gun there were developed pressures of over 34 tons per inch. That gun, taking the ordinary theory with reference to cylinders, ought to have burst with a pressure of 30 tons. It did not. Why? I think because you had a short, thick, cylindrical beam, whose resistance to deflection was assisting the transverse strength of the chamber; you had this longitudinal deflectional strength added to the ordinary calculated strength. In a wire gun you get nothing of the sort. In a wire gun each little piece of the chamber stands upon its own merits; it gets no assistance from the wires at its sides, or anywhere else, and if it cannot do the work put upon it, it must give way. There may be differences in the pressures at different parts of the chambers from one cause or another. If the wire gun is not strong enough in that particular part where the maximum pressure is exerted, it has to yield, whereas in the case of a gun made in the ordinary manner, if a variation of pressure in one part of the chamber occurs, you will find that the material at both sides and top are all adding their assistance; they are doing their work unitedly, and they stand firm together. I think if you were to take a wire gun, and if you have the wire simply of the same strength as the ordinary steel of which we make guns, you would find that the wire gun would be a much weaker gun (although you might have it all strained to its elastic limit throughout the whole of the substance) than a gun made in two or three pieces, provided you put on the proper amount of shrinkage. Now a word or two about shrinkage. Mr. Longridge thinks that we people at Woolwich are benighted beings, and are perfectly ignorant of this question of shrinkage. These assertions are based on one or two quotations from the "Text Book on Ordnance." That book is not written for the purpose of teaching all the minutia with reference to the manufacture of guns; it is written as a general description of the process, and, moreover, I may say also that that book was not written by the people who made the gun, and that it is giving us very scant credit for taking any interest in our work to suppose that we have neglected the literature on the subject of the pressure of cylinders for the last thirty years. Surely if we are engaged all our lives in making guns we should take the trouble to look into these things. The first that I learned about this question of building up cylinders was from "Mallet on the Construction of Artillery," which came out in 1856, and which I had in 1860. Then in 1864 there was published a translation of a most elaborate German treatise. Then Lamé gives one article on the subject in his "Leçons." Rankine, in his "Applied Mechanics," gave a few formulæ, and also a diagram which shows how to get all the pressures and tensions in every part of a cylinder, and I may say from his formulæ and from that diagram I deduce everything that is necessary in the construction of guns, and to show in what condition every part of a cylinder is before and after shrinkage. I am now speaking with reference as to how one cylinder acts upon another. I say that from Rankine I deduce everything, even to shrinkage, which we are said to know nothing about. After that came Virgile, whose book was published in 1874. Mr. Longridge and others should give us credit for being able to look at these things for ourselves, and should consider that if we do not do exactly what he thinks is right, there may be some reason for our not doing so, and that if we be mad there is some method in our madness. Mr. Longridge says he thinks there ought to be one set of materials for the longitudinal strain, and another set to take the transverse strain. Supposing you have a piece of metal strained in one direction to its elastic limit, and that you gave it a strain at right angles to the former, I am not quite sure how far it is weakened, but I think I may say this: if you have an inch of metal which is to withstand a strain of 10 tons in a longitudinal direction, and you have another inch of metal which is to stand a strain of 10 tons in a transverse direction, that if you put those two pieces of metal together and then make the combined pieces take the same strain of 10 tons in one direction and 10 tons in the other, you will find that your resulting strain is something like 15 tons each way; but as the result you have 2 inches to stand the strain of 15 tons, instead of 1 inch to stand the

strain of 10 tons; therefore instead of your metal being strained to 10 tons, it is only strained $7\frac{1}{2}$ tons. I mean to say that the metal of a gun should be arranged if possible in such a manner as to offer its quota of strength and resistance in every direction. Now look at this French gun—what you might term almost of a Mosaic pattern. Does not it stand to reason that if all these pieces were connected with each other they would be adding very much to the strength of the gun? A few weeks ago a French gun went. How? It broke through the middle and left the hoops standing. Had these exterior hoops been in one, I venture to say that gun would have remained intact. With reference to our guns of a long time ago, when we had such supposed bad guns—14 or 16 years ago—I think from the manner in which those guns were made that we had guns that were better than those of any other nation in the world. Our guns were standing while other guns were breaking; our guns had to stand the “brutale” powder, while Continental nations were going all round to get a milder explosive. We wanted to get more power, and when the powder was altered we made our guns longer. That leads me to another point. I have said several things against wire; now I may say one or two things in its favour. If wire is to be used in our guns—and I think it most likely will be—it will be in consequence of going in a direction quite opposite to that which Mr. Longridge advocates. He says, “Why not make a very strong gun, use very little powder, and have very little weight?” If you have very strong powder, the probability is the amount will be very small, and therefore the charge will be short, and in that case you get more resistance from a gun which is made in a very solid manner, rather than with wire; but if you have low pressures and long charges, I think the case is altered altogether. If you have a chamber double the length, and the walls are only half the thickness of another chamber, then the resistance to deflection of the first is only about one-sixty-fourth of what it is in the second, and therefore you can dispose of the material in a better manner, and you can use wire with advantage. I think if we make guns in this way most probably the wire will come into use. We can now get wire of which the limit of elasticity is something like 80 tons; that is to say, it does not receive a permanent set until you put a strain on it of 80 tons per square inch. The *modulus* of elasticity of the wire is very little more than that of the tempered steel that we use, which may be taken as 12,500 tons. The *modulus* of elasticity of this enormously strong wire is only 13,000 tons; but you have the elastic limit of 80 tons, and I think that with wire of that character it is probable that we shall be able to use it in the guns of the future. I have taken this opportunity of saying one or two things with reference to Woolwich, because the observations against us have been made so broadcast that I think we ought to be defended. We are not in the habit of defending ourselves at Woolwich, but I could not let this opportunity pass without saying a few words.

Captain NOBLE (Elswick): I agree with so much that Colonel Maitland has said in his lecture, that it may seem somewhat ungracious if the points that I select for remark are those upon which I have the misfortune to differ somewhat from him, or at least if I do not altogether differ—points upon which there is something to be said upon the other side. But before passing to those points let me say first, that I think that Colonel Maitland has very correctly formulated the properties that ought to be sought for in gunpowder to be used with the first-class guns in Her Majesty's Service. I think we may say, however, the properties to be sought for were as well understood fifteen years ago as at this moment, but that when the Committee of Explosives commenced their labours on this subject, they were utterly unable to obtain powder conforming to those conditions. Agreeing as I do with Colonel Maitland as to the share that this country has taken in developing the great strides which the science of ballistics has made during the last fifteen years, it is yet, I think, somewhat a subject for humiliation that the powder makers of this country have not been equally successful with those abroad. If we except a few experimental lots made by the Royal Establishment, the powders made by the makers of this country cannot, I think, compare either in quality or uniformity with the powders that have been in use in Italy, France, or Germany. I think also that Colonel Maitland, speaking with the high authority of his position and with his own personal experience, has done right to point out, as strongly as he has done,

the fallacy of the view urged by some, viz., that in order to obtain increased power from guns we ought to look to an increased maximum pressure in the bore. Colonel Maitland's comments are, I think, unanswerable, and if they were answered, I think others as cogent might be adduced. But I do not quite concur with the views Colonel Maitland has expressed with regard to the relative energies which are obtainable from muzzle- and breech-loading guns. If he means to say that with a given brand of powder higher energies are obtainable with a breech-loader in the case where a shot is held back until a certain initial tension is produced, I agree with him. Or again, if he says that a certain brand of powder which gives good results in a breech-loader, or with a projectile held back, does not give equally good results in a muzzle-loader, there again I agree with him. But if he means to say that results which are obtainable with a breech-loader taken with reference to a given pressure in the gun, or taken with reference to a given weight of the gun, are unattainable in a muzzle-loader, there I think I must venture to differ. I do not know that any experiments which have since been made would cause me to take different views from those which I expressed after making some experiments on this subject seven or eight years ago. In those experiments I allowed shot to start in their passage up the bore without being held back. I had others in which a driving ring of larger diameter held back the projectiles; in the latter case I obtained energies some 15 per cent. higher than in the former; but these energies were—as I think might be expected—obtained at the expense of a higher pressure in the powder-chamber. Sir Frederick Abel and myself commented on these experiments in a paper presented to the Royal Society in 1879, and as I have said, I have very little to add to what we there stated. If I refer to the pressure-curve which Colonel Maitland showed you the other day, it is obvious that if, taking the point in the bore where we may consider the charges practically completely burned in both guns, the portion of the curve from that point forward must in both breech- and muzzle-loader be considered identical. The higher energy obtainable with the breech-loader is therefore due to the higher pressure obtained in the anterior portion of the curve, and I cannot myself see that there is any difficulty in making the areas of the two curves equal, either by lengthening the muzzle-loader or by using a powder slightly more explosive (if I may use the word), and thus giving the same pressure in the muzzle- as in the breech-loader, or by adding to the charge, or by a combination of these methods, or in various other ways. That is the way in which the theoretical view strikes me, and I would only add that several years ago I fired charges of 100 lbs. from a muzzle-loader and a breech-loader, both 8-inch guns and with identical pressures in their chambers. These charges gave to 8-inch projectiles weighing 180 lbs. velocities which were respectively 2,092 and 2,096 feet per second; and these practical experiments seem to me to confirm the theoretical view which I, with all respect to the opinions of others, should almost hold to be unanswerable. I now come to the question of obturation. Colonel Maitland has chiefly dwelt upon two systems—the De Bange system and the Elswick system. Now I do not for a moment mean to say that either of these systems is a bad one,—on the contrary, I think that with both systems you can obtain a very good obturation. I venture to say, however, that with large guns at all events there has been more experience with the Elswick arrangement than with the De Bange arrangement. I have ascertained that in France there is little experience in the De Bange system of obturation with guns above 15 centimetres calibre. There is also another advantage in the Elswick system; it does not add to the weight of the gun, and it also does not take nearly so much power to open and close the gun as does the De Bange system. We have had occasion recently to work out the power necessary to open and close (I mean by hydraulic power) the breech of a 43-ton gun furnished with a De Bange obturator. We found about five times the power is necessary to open the 43-ton gun furnished with a De Bange obturator that has been found necessary with ease to open the 100-ton gun furnished with a Krupp obturator. But having said this, I wish it to be distinctly understood that I am stating the point simply as it occurs to me. Both systems I believe are capable of being made most efficient systems of obturation. I cannot say quite as much with regard to the firing arrangement in use in the Government guns. I think it is both more complicated and not quite

so safe as our system. In our system it is, I think, almost impossible that the men serving the gun can be injured by means of his primer. I should say, with regard to the violent effects that occasionally result from the rush of the gas up a long tube, that sooner or later an accident may occur with the primer placed at the exterior of the gun. But I am perhaps hypercritical, and I think I have omitted to mention a point of some importance as regards our Elswick obturator, and that is that I do not look upon the fact of having occasionally to re-copper the gun as quite so serious as Colonel Maitland seems to do. In all my experience I have only known re-coppering necessary four times—twice for the purpose of instruction simply, and twice because it was necessary. The operation also is not serious, not so serious as re-venting a gun in the old days, or at all events it does not take more time. The next point is as to the history of the construction, and I confess that if I had to write the story of the guns I should have used very different language from that which is used by Colonel Maitland, but points of this nature are interesting perhaps only to ourselves, and I merely mention this particular one in passing, because if I did not mention it, it might be thought that I concurred exactly with what is said. Such is not the case, but it is a much more pleasing task to me to say that if I take the broad principles of construction, leaving out minor matters of detail, that I, and speaking for Elswick I might say we, approve generally most highly of the system of construction now followed in the Royal Establishments. With regard to ribbon or wire construction, I must say that I think that when we have gained more experience this system of construction will be a very valuable one, or I ought perhaps to say “partial wire construction,” because I fancy that it is always easier to obtain the longitudinal strength of the gun in other ways—in the way, for instance, in which we now construct a gun; and when we have so obtained the longitudinal strength we have gone a very considerable way to have the necessary strength in a radial direction as well. At Elswick we have now made and issued somewhere over forty guns upon this construction, with some of which we have obtained very remarkable results. These guns vary in size from 10-inch down to 6-inch, with a few smaller guns for field or howitzer purposes. I agree with Colonel Maitland’s remarks about the weight of guns, but there are some purposes, as indeed he has indicated, where a light gun is exceedingly desirable. I may particularize, in addition to these he has cited, the case of its being desired to mount a gun upon a disappearing carriage, or any arrangement in which you wished to store up the energy of the recoil. The ribbon or wire used at Elswick is not of so high a tensional strength as that required at the Royal Gun Factory. Our reason for that is because we consider it necessary that the wire or ribbon we use should be capable of permanent extension. We have not in our experiments found that we are certain of obtaining this with ribbon of so high a tensile strength as 100 tons per square inch. Time will not permit me to dwell upon the interesting experiments to which Colonel Maitland alluded as to the pressures obtained with similar lengths of cartridges fired in chambers of small and large calibre. I think I should say, with equal frankness to Colonel Maitland, that had I been asked, before any experiments had been made, to predict the pressures that would result from such experiments, I should not have predicted these results. I need not say I have been for many years acquainted with the fact to which Colonel Maitland drew attention, but I have not found the explanation, at all events to my mind, as insoluble as Colonel Maitland, backed by my friend Sir Frederick Bramwell, has seemed to think. I cannot admit that the two experiments can be treated as being under the same conditions, but as the explanation would be a long one I will pass it over. I agree with Colonel Maitland in the remarks as to the lead which this country has taken in ballistics during the last fifteen years, but not entirely as regards the history of that lead. I could wish, however, that Colonel Maitland had not left it for me to claim for this country the great step that was made in the year 1877, one of the years which I think he has somewhat unjustly criticized as being a year of great slumber in this country. It was in that year that we at Elswick designed, following out the principles which had been to experienced eyes pretty firmly established by the experiments of the Explosives Committee and other researches, and early in 1878 we tried a 78-cwt.

70-pr. 6-in. gun, and an 8-in. 11-ton 180-pr., which gave respectively, with very moderate pressures in the chamber, velocities in the former case of 2,066 feet per second, and in the latter of 2,182 feet per second. I think, and in some cases it has been frankly acknowledged abroad, that when Continental nations generally were talking of something like 1,500 feet as the highest velocities, that enormous stride in advance was a step of very great importance, and that that advance is, with every improvement since made in powder and other respects, a precursor of the re-armament which, with Colonel Maitland, I think is absolutely essential. Those guns were both lent to the English Government, and were the subject of a good deal of correspondence and discussion, and I think the facts about them ought to be pretty well known. Before passing to the question of chambering, I should like to say one word about our modes of estimating the length of guns. Following the old establishment routine, we are accustomed to call guns of so many calibres long, but according to the view I take of the length of a gun, I think the term is a misleading one, and I would prefer to see the length of guns given in numbers of lengths of the cartridge, or in numbers of expansions of the powder burned in the bore. The absolute length of the gun, as Colonel Maitland correctly pointed out, is very much greater than the old gun; but their real length, taken with reference to the point which I contend is the important length, is very much shorter than with the old guns, the expansions varying from one-half to one-third of the number of expansions that were allowed in the old pattern guns. Coming again to chambers, I may say that the necessity for chambering was first felt when we had to deal with existing muzzle-loading guns, in which, owing to the shortness of the guns, it was not possible to have length of cartridge, and in which it was therefore absolutely necessary to provide space for the large charges we then wanted to use. The proportions of the chambers which Colonel Maitland has given were those which we followed in the 6-inch and 8-inch guns to which I have just referred; but as in these guns we used the barrel as part of the structure contributing a good deal of strength in the longitudinal direction, we afterwards thought it wise, seeing the great structural weakness that the large diameter of chamber involved, to lengthen very considerably the powder-chamber and to reduce its diameter. I have very little to add upon this point to what Mr. Rendel said when he spoke the other day upon the subject, but I may sum up by saying that if the powder we have permits us to employ a long chamber, we have with that long chamber a lighter and a stronger gun. But to be able to use that lighter and stronger gun it is an absolute necessity that our powder should be free from any of that wave-action which is so disastrous when you have it established to a considerable extent. Now I may state two cases. We made a 12-inch gun in which we had a long chamber. That gun may be called a comparative failure in this way, that we were never able to fire it with the charges of English powder for which it was intended, on account of the high wave-pressures set up. But chambers of similar proportions have been used with the most perfect success, and with perfect freedom from wave-action abroad. In the 100-ton gun the chamber is a little over five diameters long, and there never has been a shadow of wave-pressure either with the Fossano powder or with the cocoa powder which has been used so successfully with it. I may also add, as somewhat strengthening the view I take of it, that in France their chambers are, I should think, rather over five calibres long, and in Germany they are approximately the same. In the Krupp gun—the 40-cm. gun you have there—the chamber is practically the same as in our 100-ton gun. There is one point I should like to correct in the table Colonel Maitland has given there. He gives as the result obtained from the 17-inch gun in Italy an energy of 46,660 foot-tons, but the real energy obtained in that gun with a pressure of 15 tons in the powder-chamber is 51,900 foot-tons. In the same way I calculate, supposing the same powder to be used, the energy to be obtained from the 16½-inch gun at 61,200 foot-tons, that is, using exactly the same data obtained with the shorter guns, instead of 50,920 foot-tons.

The CHAIRMAN: I greatly regret that I am obliged by other engagements to withdraw from the chair on this occasion. I have to thank the Members of the Institution for having permitted me to take part in a discussion the importance of which probably cannot be exceeded, both to the Service and to the country at large.

If I refrain from expressing any opinion upon the questions which have been raised, I may at least be permitted to say this, that it is the duty of all the Members of the Institution, and of all of us who have any interest in the security and prosperity of the country, to obtain for the two great Services the most efficient and most complete weapons which can be placed in their hands. I say so I believe in the interests of economy as well as in the interests of efficiency, and I trust one of the results of the exceedingly interesting and important paper which has been read, and of the discussion which has followed, will be to give more energy and more rapidity to the preparation of those weapons which, as I have said before, are essential to the security and the safety of the country.

Mr. W. H. Smith then left the Meeting, and the chair was taken by Admiral Boys.

Lieutenant-Colonel MAURICE, R.A.: I should like to ask Colonel Maitland a question with regard to what fell from Sir Frederick Bramwell. With the greatest diffidence I venture to say that I was unable to see the force of what Sir Frederick Bramwell said, and I should have felt much more diffidence about it two or three minutes ago. I sent up my card at the very commencement of Captain Noble's remarks, and it was a great relief to me to find that he too did not entirely concur with Sir Frederick Bramwell. Therefore, perhaps I may venture to say what puzzled me with regard to it. I think it would be advantageous if Colonel Maitland would clear up the matter for us. Everyone will remember the very striking part of Colonel Maitland's lecture in which, with reference to that Diagram (No. 22), he told us that a limit had practically been arrived at beyond which it was impossible usefully to employ powder in the gun. He frankly added that there was some puzzle connected with it and asked for an explanation. Colonel Hope offered an explanation which may have been right or wrong—I cannot say. But I must say when Sir Frederick Bramwell came to answer that explanation it did seem to me that the answer was entirely unsatisfactory. As I understand it, what Colonel Hope says in effect is this: that when you light the powder in the cartridge at a certain point in the rear, you immediately convert into gas at a high pressure a certain portion of the powder which immediately begins to act upon the remainder of the powder that has not been up to that time inflamed. So far he agrees both with our text-books and with everything that we have been taught about it. But here the difference begins. We have always been accustomed to hear that when there was a surplus of powder beyond what was immediately inflamed, what happened was that that surplus powder was liable to be blown out at the bore. "No," says Colonel Hope, "that is pure theory. If you want to know what happens to powder exploded under these conditions, you can only arrive at it by experiments with powder exposed to extreme pressure in a closed vessel, for that, no matter whether a projectile be large or small, will be the actual condition of the powder ignited in the second instance up to the time the projectile is moved." "Now," he says, "you will find that the powder so inflamed under intense pressure develops a sudden energy out of all proportion to the energy developed by powder not exposed to such pressure, and as a necessary consequence you will have gas at two or more different states of expansive energy acting and reacting within the chamber, and tending to produce not a steady force of direct propulsion, but a violent disruptive energy at a particular point, and to counter-act against one another." Now that may be true or may not; but Sir Frederick Bramwell did not say that that statement had been proved by any series of experiments to be mistaken, but he did say that it did not explain the action of those two cartridges as shown on the board. I cannot see that. It seems to me, supposing it to be true that you are dealing in the first place with a practically closed chamber, until the shot is moved, the difference in the size of the projectile becomes a very insignificant affair; and so far as the question of the increase of calibre is concerned, if it be true that in the case of a too long cartridge, the powder close up to the projectile itself is exposed to extreme pressure and then ignited, and therefore develops the violent disruptive energy which tends in the first place to burst the gun at that point, and in the second place to produce powders of different pressures, causing that very difficulty which Colonel Maitland has told us is most serious. Then the same thing, *mutatis mutandis*, will certainly happen to a cartridge of too large

calibre. The difference would simply be that the surplus powder round the cartridge would be driven up against the sides of the chamber, instead of against the base of the projectile. It would be equally exposed to extreme pressure, and inflamed under extreme pressure; and therefore you will get these varying pressures within the chamber which prevent you from getting the long-sustained regular pressure, and will give you varying pressures in the bore. Moreover, as I understand him, Colonel Hope, having so far explained the cause of your gaining no advantage either from the too thick cartridge or from the too long cartridge as being due to irregularity and uncertainty of ignition in different parts of the cartridge, goes on to say that he has actually experimentally shown that it is possible to get over that difficulty by lighting your long cartridge simultaneously at a great many points throughout its length, so as to obtain precisely a "low maximum pressure long sustained," and yet also getting a pressure proportionate to the greater length of the cartridge. Again I say that may be a mistake, but I do not think it will be satisfactory unless it can be proved to be a mistake by experiment. I think that after the way in which Colonel Maitland has shown us that the whole point of the possible development of future energy in the gun is stopped at that point of $3\frac{1}{2}$ calibres, it will be a most unsatisfactory thing if, without specific experiment, it should be asserted that we can go no further. Therefore I should like to ask Colonel Maitland if he will tell us—1st. What experiments have been made upon powder exposed to high pressures within a closed vessel, and what have been the results. 2nd. Whether any experiments have been made in inflaming a cartridge much longer than 4 calibres, say up to 15, simultaneously at a great many different points throughout its length. It would be an unfortunate thing that Sir Frederick Bramwell's answer as it stands should go forth as the answer of the Ordnance Select Committee to what Colonel Hope said. The number of people who nowadays are able to follow every stage in the progress of guns, and every incident of those experiments, is exceedingly small; but the number of people who are convinced that there is no such thing as a Pope in matters of scientific investigation, and that where you refuse to accept results obtained by experiment, you can only meet them by producing results obtained by yet more exhaustive and conclusive experiments, is very large indeed. And, moreover, where there has been, as I cannot help thinking there has been in this instance, a distinct flaw in the answer given, the number of people who upon any authority whatever are ready to accept an answer made to an argument founded on experiment, where that answer contains a flaw, is nowadays very small. If I may be allowed to say so, every gunner is disposed very heartily to thank Colonel Maitland for the admirable account he has given us of the work done by his Department of late years. But when you are asking for money to be spent very largely upon the re-armament of the whole of our forces with a gun, the efficiency of which is expressly limited by the fact that it cannot usefully consume more powder than is represented by a cartridge of $3\frac{1}{2}$ calibres in length, and when it is alleged that it is possible to obtain a development of powder which is to that as 15 to $3\frac{1}{2}$, it seems to me it will add enormously to the effect of the appeal if it can be shown by direct experiment that Colonel Hope's results are not those which he alleges that by direct experiment he has found them to be.¹

¹ In order to bring out more clearly the point of the second question, which I put to Colonel Maitland, and the deduction to be drawn from the answers made to me by Captain Noble, after Colonel Maitland had referred me to him, it must of course be understood that the question turns upon the results of experiments in which the cartridge has been *successfully* inflamed simultaneously at a very large number of points. Colonel Maitland has told us in his lecture of *attempts* to inflame a cartridge at four or five different points; and I suppose therefore that it may be understood that the "irregular and uncertain results" which, in his final answer, he said had been obtained in this matter, apply to these attempts. They do not evidently touch Colonel Hope's assertion that he has by his method successfully lighted a long cartridge at 140 different points simultaneously. Captain Noble's answer to my second question shows clearly how very important this result is, nor am I able to see that it is affected by Colonel Maitland's citation of a series

Mr. W. H. BARLOW (Past President of the Institution of Civil Engineers): My only object in rising was to state what I understood Sir Frederick Bramwell to say. He spoke in reply to a remark of Colonel Hope's—Colonel Hope had been giving what he termed an explanation of wave-pressure. The only thing Sir Frederick Bramwell said was that his explanation was not sufficient—it was not an explanation of the fact that wave-pressure was dependent not upon length alone, but upon the ratio of the diameter to the length, and I cannot help thinking Sir Frederick Bramwell was right. I think also that that table of Colonel Maitland's, assuming the figures to be right, exemplifies more correctly than anything else can do the relative merits of guns. It gives the number of foot-tons of energy which can be produced by a ton of gun, and looking at that table one cannot but see the improvement in construction creeping up from the old French system through Krupp's and Elswick's until it terminates in the wire system, which gives a better result than any other. I think that points to the conclusion already expressed by Captain Noble, that the wire system is one which ought to receive attentive study. It seems to me obvious that the gun which gives the greatest energy and power of penetration, with the least weight of gun, is the best gun.

Admiral SELWYN: I wish to draw attention to what I think is a piece of injustice. In this United Service Institution we believe that all foreign naval Officers, and all foreign military Officers, are equally brethren in arms so long as we have not to fight against them, and I do say it is a shame that Captain Engström, of the Swedish Navy, has been left out of mention altogether ever since the Exhibition of 1861, in which he showed his system of breech-closure by a slotted screw, which was perfect for its time, and that it should not only not be called a Swedish system but be considered to be a French system. It is a most ingenious form of breech-loader, and that that should have been exhibited in 1861 is, I think, rather a reproach to the mechanics who did not know, or did not appreciate, how a sailor in the Swedish Navy could devise a better system of breech-loading than all that had gone before. I hope his name may be mentioned in connection with it, as it ought to be. Next I confess I sympathize entirely with Mr. Longridge in deprecating any statement by anyone that engineers and artillerymen, or engineers and any other profession, treating mechanical questions, can possibly be at odds. An engineer is either a man who professes, with the least material, at the least expense, to produce the greatest effect, or else he is not an engineer at all, and to the extent that any man calling himself a mechanic or an artilleryman, a soldier, or a sailor, departs from those sound principles on which engineering has based itself, he must go wrong. If we take it as an incident particularly attaching itself to guns, I mean to say the conclusion we must necessarily draw from Colonel Maitland's theory of natural selection is, that the longer and more clumsy the gun, the weaker and the less efficient the powder, the better ought to be the results. But that is not the conclusion anyone, least of all Colonel Maitland, can wish to come to, although it is a legitimate corollary of the proposition that he brings before us. I say, on the contrary, the whole question lies in the strength of the gun. If you can give us a strong gun, you can give us a strong powder, and we shall not be necessitated, in order to have good guns, to employ weak powder or guns so long, as in some cases to become highly objectionable. Take, for instance, the case of a Moncrieff pit; a very serious question would arise if you have the gun of excessive length. In ships, if you give us guns on the broadside, as will undoubtedly be the case by-and-bye, you completely bar us from having those guns projecting out of the ports for fear our enemies should make use of them in a close attempt at ramming, in order to lever out the ship's side. In short, in every way, the clumsiness and unhandiness of the gun is increased on the plea that without it you cannot burn bad powder. Now, if this wire-construction gun has

of figures which, however they were obtained, are declared by Colonel Hope not to represent in any respect whatever the actual results of his experiments. The matter is so important and so easily determined by public and open experiment that there can surely be no satisfactory reason for attempting to settle it by figures obtained in some secret manner and declared to be absolutely fictitious by the one person who is able to say that he saw the experiments.—M.

not come forward in the past, it has been for the same reason that steel did not in the past come forward at once. People would stick to something that they were doing, and would not believe that anything else could be done, and when at last they were forced by the action of foreign nations into the construction of guns of the better material—steel—they found that they had been waiting until some other nation, not the Anglo-Saxon race, had adopted that which was due to the inventive brain of one of England's eminent sons, Sir Henry Bessemer, and had got ahead of us because our officials would not listen to the native inventor. I maintain that you are repeating the error at the present day. You are going in for wire construction and ignoring the inventor. You say, "We prefer to feel our way towards that which we could be informed of fully if we only condescended to try the thing on the lines laid down by the inventor." Is that a mode of action that can possibly be wisely used? You listen to all that the inventor has done during thirty years, you consistently and persistently decline his offers, and repudiate all his efforts, and then when at last you find you can no longer resist his invention, you turn round and do the thing behind his back. Colonel Maitland says "Greater weight must be given, if we desire to use stronger powder." In another part of the paper he says, "In consequence of the great strength of the wire gun the weight would be too little." Is there any difficulty in proportioning the weight to the requirements? If you have an excess of strength, is there any reason to suppose that you could not have a wise disposition of weight which would enable you at once to go into experiments of what strong powder will do? Is there any reason why we should burn 500 lbs. of weak powder when 250 lbs. of strong powder would do the same work; or burn powder, considered as fuel, to make carbonic oxide and heavy smoke, when we could burn it to carbonic acid and make light smoke? There is a certain amount of common sense in the whole transaction which seems to me to be violated, and a great deal could be done if, besides a little more common sense, there was only just the ordinary courtesy to an inventor who has spent half a lifetime on this subject. If the War Office would only say, "Very well, Mr. Longridge, we have obtained very good results from the trials we have made with your gun so far, though we have not followed you. Now we will take your advice, and construct a gun on your theory, and if that beats ours, we shall be willing to accept it." The expense is not great, the time needed is remarkably less than that required for any other gun construction. Indeed the expense seems likely to be very much less, so that there are really an enormous number of reasons for going forward rapidly and consistently with the examination of wire construction, and declining to admire the beautiful system of construction which promises to put together in a highly ingenious manner—in order to resist the weakest possible powder—the longest and the most unhandy gun that can possibly be used.

Colonel A. MONCRIEFF, C.B.: Colonel Maitland states in his paper that the limit of reduction in the weight of the new guns has been reached, because if they are made any lighter, the gun-carriages would not be heavy and strong enough. This establishes the fact that the manner in which the new guns are to be mounted to some extent influences the decisions of those who have to decide upon the type of our guns of the future, at any rate as far as their weight is concerned. That being so, perhaps my remarks on that part of the subject, to which Captain Noble has already referred, may not be out of place. The method of mounting guns with which my name is associated was commenced with counterweight disappearing carriages. Those counterweight carriages were contrived for the old and less powerful kind of gun, and they are better suited for that class of artillery, and not so well suited for the modern and more powerful guns which we have before us here. But, on the other hand, it is well to note that the hydropneumatic disappearing carriages, which I so strongly advocate, are much better suited for the new and more powerful guns, and not so well suited for the old ones. The reason that Moncrieff hydropneumatic carriages are better suited for guns more powerful in proportion to their weight is this: such carriages are able to absorb any amount of energy from the recoil, and also to utilize it by bringing the gun down into cover, to the loading position. The increase of energy of recoil on the lightness of the gun in proportion to its power is, therefore, instead of a difficulty, a positive

advantage in that new method of mounting. This being the case, I should like to ask Colonel Maitland whether he has considered, or whether it has been considered in connection with this most important and serious decision, viz., fixing the type—more especially in regard to its weight—of the gun of the future, that for various reasons it is highly probable that many of the new guns will eventually be mounted on hydropneumatic carriages, and if not, whether he would be so good as to make the suggestion to those who have to decide this important point. I might also further remark, while on this subject, that for sea service, and indeed for other purposes, the recoil of violent guns might be better controlled by resorting to hydropneumatic compressors, instead of using *hydraulic* compressors, because an elastic fluid is better suited than a non-elastic one for meeting violent strains, and moreover my hydropneumatic compressor saves the labour of running out the gun, whether on a level or inclined platform. This condition might be valuable and convenient in boat service.

Captain NOBLE: I may say that I do not entirely concur with the view that Sir Frederick Bramwell expressed. Of course, I speak with very great deference to his opinions; but I do think that Colonel Hope did make a point in referring to his cartridge, and that was, that he conceived the high pressure might occasionally be developed by the fluid products of the explosion surrounding powder still unexploded, which thus becomes burned in a greatly reduced space, or may be considered as powder of greatly increased density; that is to say, that having the interstices between the grains filled up by fluid will conduce to the attainment of very high pressures. The highest pressure which I have actually measured resulting from fired gunpowder in a closed vessel is somewhere about 78 tons to the square inch, and that was the result of a charge of about 28 lbs. of powder at a density of 1.2. It was fired in a cylinder strengthened by ribbon or wire. As to the second point, I may say that the mode of ignition at different points simultaneously has been tried frequently, and with different results. Sometimes it has been perfectly successful in avoiding those violent impulses of wave-actions and sometimes it has failed; and I fancy it was a knowledge of these failures which led Colonel Maitland to make the remark he did. There is no doubt, if you could be perfectly certain of igniting your cartridge simultaneously at a number of points, you would avoid these wave-pressures, and you would have practically the pressure due to the density of the charge, and to the time necessary for complete combustion.

Colonel MAITLAND: I am afraid I cannot reply at much length to the number of valuable speeches that have been made, but I will endeavour to run over the various questions as rapidly as possible. Admiral Boys asked what was the usual life of our present guns, and what has been done in the way of rapid firing. The term "life" is hardly applicable to our present guns, because I do not think that they die. We can put a lining inside, which will give them a new career, and I hope we shall make them as good as ever by putting in that lining. How long a lining will last, is at present rather a difficult question to answer. It is not a question of danger, it is one of accuracy; for if you fire a gun too long the rifling is injured, and the shot will not rotate so as to have the same accuracy as when the gun was new. It is not a question of danger of the gun bursting, but merely a question of hitting the enemy; and, no doubt, when the guns come home and the ship is paid off, they will have to be lined afresh so as to be issued in a shape of comparatively new birth to a ship going abroad. It will be desirable to send out every gun in as perfect a shape as possible by relining. A 6-inch gun has fired on the "Bulldog" some 800 rounds, and is perfectly good still. As regards "rapid firing," we have had no very extended trial yet of a large gun; the biggest is an 8-inch gun of 12 tons; that, when being tried at Shoeburyness, fired 160 or 170 rounds in two days, with 100 lbs. of powder and 210-lb. shell, the velocity being 2,030 foot-seconds. Sixty-seven rounds were fired in one morning between breakfast and lunch, the last five rounds being fired for rapidity in 4½ minutes. The gun was as good, except for the usual amount of wear and tear, at the end as at the beginning. I have listened with much interest to Mr. Rendel's thoughtful criticism about the chambering. I need hardly say I agree entirely with Mr. Rendel as to the principle. There is no doubt that chambering should be carried no further than is absolutely necessitated by the powder. I have been very keenly alive to that all along, and all our guns

designed within the past two or three years have been so designed that the chambers can be lengthened to take longer cartridges, and thereby still further increase their powers, should it be found that the powder will stand this. You will observe in the diagram showing the 63-ton gun, that the breech-piece is carried well forward, so as to permit of the enlargement of the bore to form a longer chamber. At present, our experience has not been quite as favourable as described by Captain Noble to-day. It is not very long ago that we were firing cocoa powder—that is the very latest development—in a 10·4 breech-loader, which is an experimental gun. In that gun the chamber is 4·46 times as long as its diameter. It was fired with 260, 240, and 220 lbs. of powder. Two independent gauges were placed in the base of each cartridge. The 260 lb. charge gave pressures of 22·5 tons and 22·2 tons, with a velocity of 2,213—an extremely good result. The charge was then reduced to 240 lbs., and the gauges gave 24 tons and 24 tons, the velocity being 2,149. The charge was further reduced to 220 lbs., the pressures then were 15·2 and 15·3, and the velocity 1,923, a 462-lb. shot being used in each case. Thus you have a higher pressure with a lower charge. You have a tremendous jump from 15·2 to 24, and you have a slight drop again with 260 lbs. to 22½. You see there you have a case where the velocity is tolerably regular, and the pressures jump about in a most capricious manner: that to my mind is a clear indication of wave-action. It is impossible to use 240 lbs. without risking a wave-action; and yet 260 lbs., in this particular case, only gave 22½ tons. There is every reason to suppose that, if we had fired another round or two with 260 lbs., we should have got a very high pressure. The moment we get powder that does not give wave-action, I shall be the first to make experiments with it and to lengthen the chambers. The subject has been very carefully watched. Colonel Hope tells us that he has a means of lighting his powder in 140 places, and getting the pressure perfectly uniform all over the chamber. It is a great thing to know that. May I ask Colonel Hope whether he did this in the trials in France, when the gun made for him by the Terre Noire Company was tried? Whether he used that expedient?

Colonel HOPE: Yes.

Colonel MAITLAND: I find that on that occasion, when firing 47½ lb. shot, the gun weighing 7½ tons, and with a charge of 37½ lbs. of powder, Colonel Hope got 32·6 and 33·4 tons of pressure, the velocity being 2,306; with 37 lbs. of powder of the same kind, he got 2,310,¹ 34 feet more, and the pressure dropped from 33 to 23½. With 31 lbs. only of another powder he got pressures of 46·1 and 49·2 tons to the square inch, the velocity being 2,300 f.s. I do not think that is evidence of avoiding wave-action altogether. It seems to me he has a most tremendous wave-action in this cartridge, which he says is lighted in 140 places at once, and that is not, I think, an unmixed success.

Colonel HOPE: Those figures are not supplied by me, and they are not accurate.

Colonel MAITLAND: I got them from France, and have every reason to suppose them accurate. Mr. Longridge says he can make a gun which will have an energy of 1,000 tons per ton of gun. I wish he would do it. Even in a small gun I think I am right in saying he has not done it yet, and when he says that the engineering points are just the same in a steam-engine as they are in a gun, I think I answered that in my lecture, and I do not think you will find a single real gunmaker who looks upon it in the same way. As to rotation, I have not dealt with that subject at all. It is a very large one, and as long as you have given a certain spin to the shot, it does not matter how you give it. The only thing is to secure a method of giving rotation which wears as long as possible under the eroding action of the gas. I have very little to say in reply to Captain Noble. I should be very sorry to have to answer any of his criticisms. It would not be an easy thing to do. I should, however, like to say one word about the power required to close the breech with the two systems of obturation—the Elswick system and the De Bange system.

¹ This, the highest result obtained, developed 231 tons energy per ton of gun. The Royal Gun Factory 6-inch gun of 4½ tons realizes 59½ tons energy per ton of gun with Service pressure.—E. M.

With the 6-inch gun it is a little easier with the De Bange. Referring to the 43-ton gun, I do not quite know what pressure is put on in the hydraulic system of loading, and the pressure might have been very high, but there is no gauge to show it; at the same time, when a man works it with an iron lever, he manages to close the breech, even though the hydraulic cylinder does not do it. I am now speaking of the trials which took place on board the "Handy." Captain Noble remarked that he only knew about four guns that had required re-coppering. Well, we have had several; we began, as I told you, with the Elswick obturation, and there were a great many that required new coppering. There would have been an escape of gas which would very quickly have worn out the caps and rings when once it began to do so. We found that coppering was a troublesome operation; I do not say that it is worse than re-venting; the re-venting was a very troublesome thing in the old days, though now it is not so, because we have movable vents in all the guns. Then as to the advance of artillery science due to Elswick in 1878, with reference to the 6-inch and the 8-inch guns; no doubt these guns were considerable successes, but they were not in the Service in those times. I was of course speaking of the Service artillery of that time, and not of one or two experimental guns. With regard to the increase of power lately gained by the 100-ton Elswick gun above that shown on the table, I accept Captain Noble's statement at once, and I am sorry I did not know it before. I think Colonel Maurice has been answered by Captain Noble, and therefore I need not say much on that point. With regard to lighting the cartridge at different points, we have tried that very often. It has been tried with tubes pierced with holes, but the results, as Captain Noble says, have been extremely capricious; sometimes satisfactory, and sometimes giving dangerous pressures, such as are liable to burst a gun, and hence the method could not be adopted into the Service, because of course a burst gun is a very serious matter. Admiral Selwyn says that I ought to have mentioned Mr. Engström's name. Now the fact is that the system which we call the French, the interrupted screw, is adopted in some old American guns that are now lying in the Arsenal, which were supplied shortly after the Crimean war. It is just the same principle, so that I do not think that anyone in 1861 could lay claim to it at all. Colonel Monerieff mentioned his carriages, and asked me to instigate the authorities to try them with the new guns. I am afraid I should have enough to do if I were to enter into matters of that kind, which are not in my own Department. I should be very glad to be enabled to make the guns lighter. Colonel Monerieff, I know, is a very good hand at instigating the authorities himself, and he shall certainly have my good word, if it is worth anything. The most important criticism, of course, on the lecture is that of Mr. Rendel, about the chambers. It is purely a question of wave-action. If we can get powder which will not set up wave-action, all the chambers can be lengthened at once. It is a great matter to have our attention called to all these points, and wherever a suggestion seems practicable. I am sure we shall very gladly adopt it. I have to thank you very much for your kind attention.

The CHAIRMAN (Admiral Boys): It is now my pleasing duty to return your thanks to Colonel Maitland for his extremely interesting lecture, and also for the very interesting discussion which it has provoked. Very frequently in this theatre discussions are all on one side, but in this case we have certainly had a variety of views, and I hope that the information which has been given will turn out to be very useful in inducing the authorities to press forward in the right direction.