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Monday, February 17th, 1862.

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THE PRINCIPLES OF RIFLED CANNON AND PROJECTILES.

BY JAMES LAWRENCE, ESQ.

It is the object of this paper to endeavour to define those peculiarities in the construction of rifled cannon and projectiles which have a claim to be considered as the principles on which they are constructed, and to show in what respects they differ from an ordinary gun and round shot.

In order to do this, I think it will be convenient, not, indeed, for the sake of information, but for the purpose of starting on firm ground, where the foothold is safe, to shortly advert to those principles which are common to both descriptions of ordnance.

An ordinary gun, equally with a rifled gun, depends for its power of propelling its projectile on the complete ignition of the charge, and its consequent conversion into a highly elastic gas.

It is not disputed that in an ordinary gun the shot should be well rammed home; and the object of this ramming is, that the powder should

be compressed into the smallest space, and the shot brought as closely as possible into contact with it, so that on the explosion taking place the violence of the expansion shall be at its minimum when first brought to bear on the shot. It is obvious that, if this is the case, the instant the shot begins to move, the explosive gas becomes increased in bulk, and, as the first impulse has to overcome the inertia of the shot, it is then that the greatest strain is thrown upon the gun. Now this is one of the principles which is common to both rifled and ordinary guns, and the initial velocities of their projectiles depends upon the proportionate ratio of the volumes of the elastic fluid to the weight of the shot. The next point in which these two kinds of projectiles agree, is their action on the air in passing through it from the mouth of the gun till they arrive at a state of rest. Without entering into any discussion as to the amount of resistance offered to different forms of projectiles propelled at the same or different rates of speed, it is enough for the purpose to say that the air always offers the same amount of resistance to a round shot propelled at a given rate, and always brings it to a state of rest in equal times.

The air acts on an elongated rifle projectile in a precisely similar manner, for it is clear that, supposing the elongated projectile is from its form better adapted for cleaving the air than a round shot, this advantage applies to the whole of the range.

It is, therefore, impossible that a rifled shot can begin slower, and then go on faster, as some ignorantly suppose, or even much further than a round shot. It has no reserve of power; cannot obtain what may be called second wind—in fact it must, and does, follow the ordinary laws of nature, and move slower and more slow every instant after leaving the mouth of the cannon. This principle, however, it has been attempted to deny in the case of rifle projectiles, and it was boldly asserted, at the Institution of Civil Engineers, that different laws regulated the flight of round shot and rifle projectiles. I venture to advocate the simplicity of Nature's laws, and to assert that they are fixed, immutable, and not under the control of man. We now come to the points of divergence, the most important of which is, that the shot being elongated, and not spherical, is made to revolve round its major axis.

The object of this rotation, as is well known, is to correct the irregularity of the density of bodies of metal.

Some one part of every shot is denser than other portions, and this heavy part always exhibits a disposition to get to the front, dragging the rest of the shot after it in the direction of its own position. A rapid revolution of the projectile, of course, corrects this by constantly changing the position of its heaviest part, and thereby counteracting its tendency to act on the other portions of the same body. This revolution of projectile which we desire to produce in rifling a gun, may be fitly termed a fundamental principle of rifled cannon projectiles.

By its means we get accuracy, or rather the power of obtaining accuracy; for accuracy really depends on the skill of the artillerist as much as, or perhaps more than, ever. We have not yet, at least, got—and, probably, never shall get—an automatic gun that will load and point itself.

There are many ways of producing this revolution; such as the numerous small grooves of the Armstrong gun, the ovals of the Lancaster

and Whitworth, and lastly, but by no means the least effective mode, wide and shallow grooves. (See Plate A, figs. 4 and 5, opposite page 109.)

The last I believe to be the best—most certainly the best if cast iron is used; but, whether small or large, oval or hexagonal, none of them contain any principle; they are simply matters of convenience, and are only worthy of consideration as to their relative advantage in giving rotation to the shot with the least reduction in the strength of the gun. The revolution of the shot is attained by making an elongated projectile revolve on its greater axis, and is effected by friction against grooves formed in the bore of the gun; and this is another point in which it differs from a round shot fired from a smooth-bored gun.

A perfect rifled projectile is, for a reason which I will presently advert to, also necessarily expansive—that is to say, when it is fired it fills up the groove of the gun, and completely annihilates the windage.

The windage in a smooth-bored gun not only detracts from the accuracy of the shot, but subtracts from the strength of the powder, by allowing an escape of gas, and even of un-ignited powder, which an expansive, and, as I contend, perfect, projectile prevents. I repeat perfect, because such a projectile absorbs every portion of the force which is used to put it in motion. This friction against the sides of the gun is, therefore, an entirely new element in artillery practice; it is also an element of danger, tending to strain the gun; but, as it is also a necessary evil, the greatest care and intelligence should be brought to bear on the means of reducing this dangerous element to its lowest point. In every machine used for commercial purposes this is a primary object, and the whole art of a mechanical engineer may be said to consist in combating friction; for, after the principle of a machine is once settled, the reduction of friction by accuracy of workmanship, and the simplification of the parts, is the sole aim of an intelligent mechanic. In a rifled gun this object is effected, I believe in the best manner, by reducing the twist of the rifling; but, as this is a moot point, I will pass to one on which there is now no difference of opinion, although I at one time stood alone in advocating it,—I mean the necessity of greasing rifle projectiles for artillery. I saw the necessity of this at the first experiment I made in 1852, and in a letter to the late Lord Hardinge, which I apprehend is still to be found at the War Office, I pointed it out. This idea was totally opposed to all antecedent practice, and I had to bear the whole weight of the obloquy that is sure to attach to any putter-forth of strange doctrines. "Grease a cannon shot!" said the late Lord Raglan, "who ever heard of such a thing?"

Even so late as December, 1859, the same prejudice existed, and I had the mortification to witness the bursting of a 68-pounder gun of 95 cwt.—the only accident that ever occurred in my presence—because the artillery officer chose to consider that soft soap was a fair equivalent for Russian tallow, and would not believe that the lubrication of the projectile could have any effect on the life of the gun.

The principles just stated, although few and simple, will, if established, form a sound basis for the proper construction of cannon, and enable us to criticize, with assurance of accuracy, the pretensions of any novelty in the make of guns.

They define the relative position of the artillery officer and the mechanical engineer, and show that, so far from accurately-made guns supplementing the skill of the soldier, they task his abilities in a greater degree than ever, for a good rifled gun improperly directed or elevated is perfectly certain to miss the mark aimed at, and is not subject to the chances of a smooth-bored gun.

The ranges form an admirable test for the relative efficiency of rifled cannon, for it will require but this knowledge to decide the point with unerring certainty. Again, the motive power of projectiles being reduced to the simple element of the explosive power of gunpowder, no expectation of wonderful or extraordinary effects can be rationally entertained until some agent stronger than gunpowder is produced.

A larger gun may produce greater effect than a small one, but it will bear a strict relation to the weight of the powder and shot used. As well might we hope to get wonderful and hitherto unheard-of results from the power of steam, as from that of gunpowder. We have, in the one case as in the other, got perhaps near the end of our tether; and there ought to be no reason why a particle of doubt should hang over the results of rifled artillery practice, any more than on the duty to be obtained from steam. If it is otherwise, it is because every means has been taken to mystify and confuse the one subject, while in the other every vestige of quackery has been carefully expelled, and the facts have been rigorously sifted and investigated by men combining intelligence with honesty, and having no motive to deceive.

A few words, perhaps, may be allowed on the supposed advantages of very large guns, and to judge of this it should always be borne in mind, that, although we can make guns of any size we like, the men that are to use them can neither be made taller nor stronger, and that therefore machinery for loading any guns much over the size of those in present use must be employed, and this ought to be conclusive against their uses, as far as siege artillery and broadside guns are concerned.

The principles on which rifled projectiles are constructed may be reduced to two. The first, which must be considered rather rudimentary than perfect, is the projectile which is formed entirely of iron, and which is made to rotate either by projections on its sides, fitting into grooves in the gun, or by giving to flat surfaces a twist or pitch, answering to the internal arrangement of the gun.

This form is in great favour with many persons who imagine that the liabilities of a gun to burst are greatly lessened by the shot being expansive and that the shot itself is more efficient from its being homogeneous, and not a compound projectile. There are, however, disadvantages: for unless the shot is made very carefully, and consequently very expensively, so as to reduce the windage to the lowest point consistent with its passage through the gun, the efficiency of the shot is reduced to that of the round shot it is intended to supersede. The result of making it fit tight is, that you have a shot much more liable to burst the gun it is fired from than a compound shot, because, if by any chance it sticks, the rigid character of the shot renders compromise impossible, and something must go. Even on the most favourable supposition that the shots always

fit as tight as possible, and never stick fast under any circumstances, the effects and ranges of such shots must always be variable, and in actual warfare exceedingly so, on account of the expansion of the gun by frequent firing, which, with a rigid inexpandible shot, must increase with every round.

The second principle is that of coating iron, more or less, with lead or zinc, forming a compound projectile. The objections just adverted to, are here evidently obviated, because the zinc or lead, being soft and expansive metals, have the necessary capabilities not only for filling the grooves of a gun at the commencement of firing, but also of allowing a margin for the expansion occasioned by rapid discharges during action.

They have a further advantage. The powder is more perfectly ignited when the shot is expansive, and it is found in practice, that, even with increased range and efficiency, a reduction of the charge, as compared with the charge for iron shot, can be made, amounting to between one-fourth and one-eighth.

These are the two principles which regulate the construction of rifled projectiles for artillery, but there is a modification of the last to which I must invite attention. It is the using two soft metals, as compounds instead of iron and lead. (Plate A, fig. 6.)

The effect of this is, that while with iron alone, or in combination with lead, you have a winged projectile, with the compound of soft metals you possess a missile which has properties not fully developed until the shot strikes.

This peculiarity is so entirely opposed to the prejudices of nearly every person, whether military or civil, that it is not wonderful it should have been so long overlooked. A shot compounded of zinc and lead strikes a harder blow than iron, and, curiously enough, it is against iron that this superiority is most remarkably manifested.

The reasons for this are twofold—the first arising from the fact that the harder of the two metals can be placed in front of the softer, so that at the moment of impact the softer metal behind yields, and the somewhat harder metal in front strikes against the far harder iron plate, and has little tendency to crush up; and the second, because, these metals being inelastic, they do not rebound like iron against iron. Iron against iron will make a hole, but the soft metal projectiles alluded to, not only make a hole, but effect an entrance; and the stoutest iron yet placed as a protection on vessels of war will not resist a shot of 60lbs. to 80lbs. weight, made on this principle, and fired from a 68-pounder.

These shots have been sent in very large quantities to America, and I believe elsewhere; but, although the inventor of them, I have never yet been able to get them fairly tried in my presence at home; notwithstanding, from circumstances with which I have been made acquainted, I have reason to believe that they have been made at Woolwich, and have still better reason to know that whole shiploads have been sent to America.

For myself, personally, I have had nothing to do with the manufacture of more than one shipment of some 1,500 9-pounder projectiles.

I will now conclude these observations by describing the trial of a new kind of shell—one of which is on the table—which is intended to penetrate iron, and was tried in October last at Shoeburyness.

Although the trial was so recent, the idea was hatched in 1856, when, after completing some experiments with solid shot, which to this day have not been surpassed, I made an unsuccessful application to the War Department to have a few shells tried.

Having, however, had the pleasure of hearing the papers on Iron-cased Ships read by Capt. Halsted in this Institution, in which he stated that $\frac{3}{4}$ -in. iron would keep out any shell in the service, I resolved to try again. In this resolve I was not solely actuated by self-conceit, but from memory of an experiment which I witnessed some years previously at Woolwich, when my soft shots were pitted against granite, and, as they made a great impression— $1\frac{1}{2}$ in. deep—in the stone, I argued that they would be equally effective against iron.

I was likewise aware that there was a general impression in the Navy that shells were more dangerous than solid shot, and on one occasion a gallant officer expressed this opinion by saying, "For God's sake, keep out the shells."

I accordingly wrote to the present Secretary of the Admiralty, who was acquainted with the commencement of my experiments in 1852, as well as personally acquainted with my late friend and patron Mr. Muntz, the Member for Birmingham, offering to make an 8-inch shell that should perforate 3-inch iron plates. Lord Clarence Paget referred me to the Secretary of State for War, who, acquiescing, referred me to the Select Committee at Woolwich. The Committee were willing to try the shells, but I wanted to test the matter on a small scale first, and I had some small shells made three inches in diameter. Unfortunately the Committee had no gun that would fire 3-inch shells, but stated that if I made some 4-inch they would not object to try them. This I did at some trouble and expense, but with a clear written understanding that the trial was to be a preliminary one, and that the shells should penetrate 1-inch iron.

When the shells were made and sent to Woolwich, the Select Committee handed me over to the Special Committee on Iron Plates. This body, however, reported to the Admiralty, they having no control over guns, being in this respect like the Admiralty; and they had no money to make experiments, the 15,000*l.* voted for that purpose having been taken from them when they were transferred to the Admiralty.

The gun at length furnished to me was an old iron one, cast some time in the reign of George III., and rifled on a principle which no person has ever since then advocated.

It was considered unsafe by the officers, and was fired with a long lanyard, and every one present was obliged to get under cover at each discharge, an arrangement that precluded careful observation. Bad as the gun was, however, it did not burst, and the shells went through the 1-inch plates with the greatest facility.

It appeared, however, that these soft-metal concussion-shells were expected to go through iron plates whole.

What they really did, however, was not very much short of this: that they went up to the iron *whole* was admitted, and as the time occupied in passing through the iron was but the 24,000th part of a second, and they carried their fire and fragments in with them, the difference was not much: but it was determined that the experiments should not be renewed.

The following week witnessed those experiments with the 100-pounder Armstrong guns, which proved that, in penetrating effect, they were inferior to the service smooth-bore artillery.

I suppose this abstinence from penetrating was ascribed to the good taste of the guns; it certainly has resulted in giving them a higher reputation, and in bringing them more extensively into use.

Asto myself, I have spent nine years on these experiments—endured much labour—and spent some money. I had borne disappointment, and the sickness of hope deferred, with fortitude, though it at last has brought on a nervous affection of the heart, from which I have recovered so slightly that my appearance here this evening is not without risk, and nothing but a sense of the duty of fulfilling a voluntary engagement has induced me to be here.*

Extract from Official Reports of Experiments, showing Times of Flight of Rifled Projectiles, Form and Hoist of Grooves, as well as Depth, suggested by Mr. Lawrence.

Weight of shot, 80lbs.; charge, 12lbs.; weight of gun, 95 cwt.; length, 10 feet; twist, 1 in 30; grooves, 3; depth of grooves, $\frac{1}{16}$ th of an inch; equal lands and spaces.

5" elevation	2,595 yards	7" =	1,112 feet per second.
10" "	4,100 "	13" =	946 "
27" "	7,300 "	30" =	730 "

Mr. LAWRENCE is desirous of adding to his remarks that he has actually witnessed a direct trial of the relative time occupied by the travelling of round shot and rifled projectiles of the same weight and propelled by the same charge. In that experiment the rifled shot went from 30 to 50 per cent. further than the round shot in equal times.

Commander ROBERT A. E. SCOTT, R.N.: I may be permitted to say, with respect to the velocity and range of projectiles, that if an elongated shot be fired at 10 degrees of elevation, with an initial velocity of 1,300 feet a second, and a round shot of similar diameter be fired at the same elevation, with an initial velocity of 1,600 feet, the range of the elongated shot will be considerably above 3,000 yards, and the range of the round ball will be under 3,000. This, I think, shows that Mr. Lawrence has made a mistake in saying that the velocity with which a shot leaves the gun determines the range. Also if a heavy elongated shot leaves the gun with a low velocity it will very possibly have a longer extreme range—that is, when you give the highest elevation, it will range further than a lighter elongated shot of similar diameter, which may leave the gun at a much higher velocity. With respect to what Mr. Lawrence says as to the expansion of shot, it must be remembered, that, in expanding out projectiles to take the rifle grooves, you very suddenly throw a great strain upon the gun, and call into play a very large amount of friction during the shot's passage through the bore, and in thus stopping the windage you really close the safety-valve of the gun. The next point which Mr. Lawrence has noticed is, the expansion of the gun from getting warm. The gun certainly does expand, but it is only in a trifling degree. But, granting that it did expand to a greater degree, what would be the effect? That, when your gun got hot, and the combustion of the powder became more perfect, the lead would be driven out more violently against the bore, which would

* The author has since died.—Ed.

more suddenly cut off the windage and throw a far greater strain on the gun. An iron shot, on the contrary, does not expand by the explosion, and hence gets more windage as the bore warms, so that its safety-valve gets larger as the gun expands and becomes weaker. With regard to simple cast-iron projectiles, there is a specimen placed on the table which can be cast at the same rate per ton as the round iron shell, and the subsequent planing of its bearings and zincing cost about three-halfpence per shot. But rifling is principally valuable on account of its giving the means of throwing a shell of large capacity. It has now been tolerably well ascertained that the simplest and best way to break iron plates, without straining the gun, is to fire round shot. All foreign nations are now striving to combine with the advantage of rifling—so as to use the elongated shell—that of still firing the round ball. Elongated shell are however only valuable if they have a great powder capacity; but if you took two metals—zinc and lead—and joined them in the way proposed, you would really have little or no powder capacity. Besides this, such a shell would be enormously heavy if made of the same diameter and of equal strength with this cast-iron shell for a rifled 32-pounder, which contains 5lbs of powder and weighs only 33lbs., or 6lbs. more than the round ball for the same gun. It is a common error to suppose, that, because a projectile is lead-coated, the strain upon the gun must be less, on account of the softness of the metal, than if the projectile were of iron only. Take the Armstrong shot: this, before the lead (hardened by tin) mixture is put on, is nearly the size that an iron rifle shot would be for a similar bore; and, when the lead is run on, it is larger than the bore. Hence, when the charge is ignited, an immense force is expended in compressing the lead, and squeezing it almost instantly into so many grooves; and consequently the strain upon the gun is enormous. Windage, on the other hand, if only a moderate amount be given, is an advantage, not only as a safety valve, but as a means of cleaning the bore of the gun; it also further reduces the strain by driving out the column of air which would otherwise impede the motion of the shot. When Mr. Whitworth fired a tight-fitting projectile, he did not get so great a range as that which he obtained afterwards on sloping away the bearings, and giving the projectile more windage; but what would be the effect of closing the windage by an expanding shot, if you placed a wad in front, in case of being at sea? The want of a small jet of gas to blow out this wad would very dangerously raise the pressure upon the gun; but with an iron projectile, where the windage is not closed, no such danger could occur from the placing of any wad to keep the charge "home." A wad would always be necessary if the vessel were rolling, and a vessel nearly always rolls if her engines be stopped.

MR. LAWRENCE: Does Captain Scott mean to say that, with a difference of range so great between the elongated shot and the round shot, the diameter of the two shots is precisely similar, or that merely the weight is the same?

COMMANDER SCOTT: The diameter of the elongated shot was rather greater, so that it was really at disadvantage in this respect.

CAPTAIN BLAKELY: It has been pretty well proved by numerous experiments that a 68-pounder, a 56-pounder, a 32-pounder, or any of the round shot, will leave the gun at a velocity of 1,600 or 1,700 feet per second; and at five degrees of elevation, if they range 2,000 yards it is considered very good. Whereas the long shot, whose velocity has also been measured, and supposed to have been correctly measured, and does not move more than 1,100 or 1,200 feet per second, really ranges more. Those actual measurements, I think, must have great weight in coming to any conclusion. I should much like to know, if Mr. Lawrence would be kind enough to inform the Meeting, what was the exact nature of the shell?—how the soft metal was made into the shell? Did it hold powder, or was it intended to burst into fragments?

MR. LAWRENCE: As I said before, the shell which I supplied was intended for a preliminary experiment, and therefore the capacity of the shell was by no means tested. I designedly did not make the shell so capacious as I believe it could be made. The only difference I make in the shell and the solid shot is that I have necessarily put cast-iron in the centre of the shell, for the purpose of preventing the charge blowing up the shell in the gun. That is the only difference. There is nothing but a mechanical junction between the iron and the lead or soft metal.

THE CHAIRMAN: It is a cast-iron chamber?

MR. LAWRENCE: Merely a cast-iron chamber. There is no galvanising or tinning.

THE CHAIRMAN: And what sized chamber? What quantity of powder do you propose to put into the 68-pounder?

MR. LAWRENCE: That is a matter of experiment. The contents of this shell on the

table is, I am told, about five ounces. But that is by no means fixed. I should make the shells as big as I possibly could, to hold as much powder as they possibly could; but, unless I have the means of making the experiment, I could not ascertain this point. As to Captain Blakely's other observation about the range, I can only say that I have seen an 80-pounder shot go 7,300 yards in twenty seconds. Now, I think the initial velocity of that shot must be more than 1,100 feet per second.

Captain BLAKELY: I am afraid a soft metal shell would only break into three or four large fragments.

Mr. LAWRENCE: It broke into hundreds of pieces.

Captain BLAKELY: Has it been tried?

Mr. LAWRENCE: It has. It went through an iron plating of an inch, and it broke into hundreds of pieces. There was a wooden screen at the back, and that was completely covered with fragments, and the piece of iron which was driven out was also driven into the screen at the back, and was quite warm. This shell was not more than four inches at the base, and at the top it is not more than two inches, but yet it took out a piece of iron from six to eight inches in diameter.

The CHAIRMAN: What is the relative expense of the description of shell which you advocate?

Mr. LAWRENCE: That cannot be decided unless made in great quantities.

The CHAIRMAN: What is the expense of the solid shot as compared with the rifled shot?

Mr. LAWRENCE: They cost something under 3*s.* a piece.

Captain BLAKELY: I think I can answer the question of expense. I have bought a great number, and lead-covered shot will cost about double what an iron shot would.

The CHAIRMAN: This shell would be dearer than the lead-covered shell.

Mr. LAWRENCE: I think not. I think from the report of the Armstrong shell that the cost is about the same as these could be made for. These are cast together, and therefore can be easily manufactured. They require no turning, or planing, or anything of that kind. They can be cast in the chill.

The CHAIRMAN: How do you effect the rifling of that shot?

Mr. LAWRENCE: The base of this shot is lead—the one half of it; the other half is zinc.

The CHAIRMAN: The gun is rifled, and it expands into the groove.

Mr. LAWRENCE: It expands into the groove.

Commander SCOTT: Captain Blakely has fired both iron and lead-coated shot; he knows their relative value, and can give you an account of their difference.

Captain BLAKELY: My own experience would lead me to prefer for small guns a shell very similar to what Mr. Lawrence advocates—that is to say, a shell which will enter the gun easily and expand on the same principle as his; its rear may be either lead, or paper, or wrought iron—it is all the same so long as it expands. But for anything like a large size, or for even anything like a medium size, I think such a shell is totally inapplicable. For this reason, if you let a 12-pounder shell fall on the deck of a ship, it would not be so misshapen but that it would go into the gun. But if you let a 40-pounder shell fall, and it gets a dent in the lead, you may get it partly down into the gun; there it sticks, and you cannot get it back again. The expense also is in favour of plain iron shot. The great advantage which lead-based shot have in mere experimental firing, where you do not let it fall, is that you close up the windage; but in a large-sized eight-inch gun the windage need not be so very much greater than it is in a two-inch gun; it is very much less in proportion, and really but a mere film of gas in comparison with the mass of gas which will be acting upon the shell. My own experience leads me to think that for small guns something like Mr. Lawrence's shell would be extremely good; but for large guns I confess I have recently adopted the shell which Captain Scott has so ably produced.

Sir GEORGE SARTORIUS: I do not completely understand what are the great advantages which Mr. Lawrence assumes for his shot over the common shot. Is it penetration?

Mr. LAWRENCE: It is penetration. I contend that this description of shot are very superior to iron shot, for they will penetrate plates much better; that where iron rebound, this will go through. I contend that against an iron-plated vessel an iron shot is perfectly useless, while shot made on this principle will penetrate. It could be very readily proved at a small expense; it could be tried for 10*l.*

Sir GEORGE SARTORIUS: If the experiment can be made so cheaply, and with such results, I am rather surprised that it has not been tried. So far as my judgment goes, from hearing very practical reasonings, I certainly cannot come to the conclusion you have

arrived at; viz., that a combination of soft metals, such as you propose to make, will go through iron where iron shot will rebound. Supposing the two kinds of projectiles fired with the same charge of powder, if the iron shot rebounds, I must confess that I am rather incredulous that yours will go through.

Mr. LAWRENCE: The thing has been actually tried at Shoeburyness; and, if you refer to the Iron Plate Committee, they will acknowledge, I have not the least doubt, that it did actually penetrate a piece of iron.

Sir GEORGE SARTORIUS: You mean through an inch plate?

Mr. LAWRENCE: Yes, through an inch plate; and it was stated here, and acknowledged by Captain Halsted and by Colonel Lefroy, that, up to the time of my making the experiment, no shell in the service would penetrate an inch of iron.

Commander SCOTT: I am sorry to rise again, but I think that is a great mistake. Captain Halsted, if he made such a statement, was certainly mistaken, because a 68-pounder shell will go through an inch plate very easily, and also through a two-inch plate; but it would be picked up broken on the inside, just as your shell was. I may further be permitted to give my opinion as to why the two metals you use are totally inapplicable for shells for guns of large calibres; and, after all, nearly anything will answer for small guns. It has been found in practice by Sir William Armstrong—although he has the lead so closely confined, as already mentioned, that it cannot well escape—that, if he uses a larger charge than about one-eighth the weight of the shot, he loses accuracy; and that, if a stronger powder be used, the shot cuts its way out across the grooves. Expanding projectiles also, which answer well with a small charge from a weak gun, if put into a strong gun and fired with a greater charge, are expanded irregularly. With a soft metal in front and a softer metal in the rear, the powder capacity in the centre must be extremely small to prevent crushing up. In fact, you would blow the iron chamber right through the shell if the centre cavity containing it were large, and this would be more likely to occur as the size increased; so that, with a large shot, you could not get a proportionately large powder capacity. Again, Mr. Lawrence says that, because his shots are soft, therefore they will do more harm to an iron plate than if they were hard. Now, such a thing cannot be correct; for shot of the hardest iron or steel are always found to do more damage than shot of a softer metal. He has also pointed out that the yielding properties of the soft metal shot when in the gun give it great advantage.

Mr. LAWRENCE: No; out of the gun.

Commander SCOTT: I think you said in the gun, and I wish to take it in the gun first. The soft metal, if it meets with any obstruction in the gun, will, I believe you said, easily change its shape. Granting this, it is clear that the ball, on impinging on a plate, will with readiness change its shape and become flattened down, and then a great portion of the force of the blow would be absorbed in effecting this change, and the edges which ought to cut their way into the iron would be gone. The iron shot, on the contrary, will not yield, and, from not yielding, will go through the plate. The fact being that, if the shot of a 68-pounder does not break up, it generally goes through the plate at short distances; whereas, if the shot does break up, it does not go through the plate. If you were to fire a 68-pounder wrought-iron shot, reducing the present excessive windage, I believe it would go through the plate without any difficulty whatever.

Sir GEORGE SARTORIUS: What sized plate?

Commander SCOTT: Four-and-a-half inch plate.

Sir GEORGE SARTORIUS: What range?

Commander SCOTT: At 50 yards; you can only penetrate them at all up to the distance of 200 yards. It has been found in the firing that, when the 68-pounder shot have not broken up, they have generally gone through; and, of course, if they do break up, they do not; but, if you want to cut through a plate with certainty, you must have a cutting edge. Here [pointing to a flat-headed shot] you have a sharp circular edge that will certainly cut the plate if a high velocity be given to the projectile; and you may have a powder chamber in its rear. This is, I believe, the sort of combination of shot and shell that is likely to be used in future warfare against iron ships, because you could first cut through the ship's iron sides, and then there would be the shell in the rear to explode afterward.

The CHAIRMAN: I think that is the form of the Russian shell.

Commander SCOTT: I was not aware of it. I gave a sketch of it, as proposed by me in 1859, in my last lecture, but did not dwell upon the matter.

The CHAIRMAN: I may be mistaken.

Commander SCOTT: The advantage of the combination is so self-evident that when people

come to study the question and to understand the principles of warfare they can scarcely help arriving at similar conclusions. I may repeat one thing that I have said on a previous occasion, that I believe the value of lead coating in making the shot cut its way through numerous grooves, was a proper matter for consideration in the infancy of rifling; but now that we have so much more knowledge, and possess such mechanical facilities, we ought to have no difficulty in rifling the guns and fitting the shot without making it rifle itself by cutting its way through the grooves. This is what is really so detrimental to the breech of the Armstrong guns, as it increases the time the chamber remains under the action of the powder before the shot starts, whereas the great point is to get your shot to start as easily as possible. I do not, however, quite agree with Mr. Lawrence in the nice distinction between soft soap and grease as a means for effecting this, nor do I think that the use of either has much to do with the bursting of any gun, though perhaps the shot might be made to slip out a trifle easier.

Sir GEORGE SARTORIUS: But does not that form of shot, the flat-headed, impede its flight?

Commander SCOTT: The flat front does impede its flight to a small extent; but in no case can the present gun penetrate an armoured ship's side as far as 600 yards. I believe we shall get much more powerful guns, but at present we have nothing that will punch through a ship's armour unless close to it. There is one point which seems to me worthy of attention by every one interested in rifling, which is, that the air in front of the shot is exceedingly compressed. It is not compressed into a solid, but it is very highly compressed, and your shot is really screwing its way through this compressed air, just as a gimlet is screwed into a board, and it meets with a similar kind of resistance. I leave you to investigate this, but I believe such is the case, and Mr. Whitworth has proved that shot fired from a bore rifled with a sharp twist have a longer range than others fired from a less spiral. There is, however, a curious fact, which is, that flat-headed shot will go through water, while round-headed shot will not, as Mr. Whitworth proved. We do not yet fully understand this matter, for we have made so few practical experiments that our knowledge is very confined, and our data on most gunnery questions consist of loose generalities.

Mr. LAWRENCE: I have only one more observation to make. I think theoretical observations ought not to go against proof. I can only say that one of these soft shots has been fired and taken up again, put to rights, and fired a second time—an 80-pounder fired at a long range. Therefore, it can be readily rifled to fire in the way Captain Blakely alludes to. Now that we are getting iron-plated ships, it is of most vital consequence to us to know whether it is true or not that shots of this kind will or will not do more than iron. Other nations will not be bound by our judgment, and, if by an unfortunate fatality it should happen that this shot is more effective than an iron one, we shall be under the disadvantage of having to contend with superior projectiles, because we do not choose to go to the trouble of making them better ourselves.

The CHAIRMAN: I am sure we are much obliged to Mr. Lawrence for coming forward and giving us his views on this subject. These are new matters, and just in proportion as they are new they are liable to meet with objection. The differences that have arisen, generally speaking, arise from the difficulty of getting at facts. Nothing is more difficult in all these experiments than to get at facts. Persons jump to conclusions without having sufficient data. That, I apprehend, is the great cause of the difference. Captain Halsted says that certain shot broke up on a $\frac{3}{4}$ -inch plate. It was a fact, but it was not a relevant fact, and he immediately jumped to the conclusion that all shots would break up on $\frac{3}{4}$ -inch plates. It was only true that the shot would, under that particular condition, break up. It would be the same with any shot; it would break up under a certain condition. This gentleman has made experiments with a soft shot, which under particular conditions went through. But to condemn iron shot on that account would be, on the same principle, as bad as Captain Halsted's theory—that no shot would penetrate a $\frac{3}{4}$ -inch of an inch plate. Hence the necessity of experiments being of the minutest kind, because it is so very important that we should arrive at true results. Of course, the theory of this gentleman should have a certain measure of influence; but, really, where it helps us little in questions of this kind, it ought to be put aside altogether, until we get more facts upon which to base a true theory. It does seem, *a priori*, that he has a claim to have these experiments made; and, notwithstanding our learned friends upon such subjects pronounce *ex cathedra* against it, I think we ought to have the experiment made. There are conditions on which these metals do unite, and have an extraordinary character; in fact, their character alters altogether. There is no question that the character of soft

metals when combined is very materially altered. Look, for instance, at iron in the condition of smelting. If there is a quantity of sulphur present, its whole character is changed. Take a red-hot iron and put a stick of sulphur against it, and the former will drop to pieces. Such is its strange alteration of character, that when there is much sulphur present a condition is produced that will occasion the rapid breaking-up on $\frac{1}{4}$ -inch plates of shot so cast. But that is not to be taken as conclusive against iron shot. Without saying more, allow me to thank Mr. Lawrence for his paper.
