On Projectiles

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otherwise burst in the hand and destroy the person. My percussion grenade has no fuze to be lighted, and can be thrown at any time. A daring assailant could pick up the fuze grenade and throw it back; my grenade could not be thrown back with effect. The grenade can be made to fire with a percussion cap if so required. In using revolvers for house defence, the person is necessarily exposed to the fire of the assailants, but in using percussion grenades, the person need not be exposed, as the grenade may be allowed to slide through a temporary spout downwards and outwards.

1. Leaden bolt for pulverizing glass tube.
2. Hole for inserting glass tube holder.

of falling on the ground explodes the grenade.

Annexed is a drawing of the winged tube containing the glass tube igniter, and which is screwed into the iron grenade.*

Directions for Use.

When the grenade is about to be used, the winged tube is held slanting downwards so that the leaden bolt within it slides back and leaves the touch-hole open for the insertion of the glass tube igniter; then holding the winged tube perpendicular, the leaden bolt rests upon the glass tube igniter, and on the grenade being thrown out of a window, the shock pulverizes the glass tube and fires and

ON PROJECTILES.

By MICHAEL SCOTT, Esq., C.E.

With the permission of the meeting the author proposes on the present occasion to confine his observations mainly to a class of projectiles which may be said to occupy an intermediate place between spherical shot and elongated rifle bolts.

In the year 1862 the writer published a pamphlet† in which he explained a principle whereby the want of homogeneity in elongated projectiles might be obviated, and in which he stated that the centre of gravity being corrected, and the projectile made symmetrical, it would not deviate from the true line of flight, even although not rotating upon its axis.

* They can be obtained at Mr. Calderwood's, Gunmaker, Sackville Street, Dublin.

† On Projectiles and Guns. By Michael Scott, C.E. Clowes and Son, Charing Cross.

Nº 1. Elevation.

Nº 3.

Nº 4. Elevation.

Nº 1. Section.

Nº 4. Section.

Nº 2.

Nº 5.

PROJECTILES

Referred to in the Paper by

Michael Scott Esq^r C.E.

Scale One Inch to the Foot.

The experiment had never been tried, and, considering that it would be very interesting to know the result, the writer applied to the Secretary of State for War, and after an extended correspondence with the department, permission was obtained to have a few projectiles tried.

The projectiles referred to, represented by the drawings (see Plate xv), were designed by the author in that year, and the trials took place at Shoeburyness in 1863. The projectiles were found to be defective in certain particulars, the most important being the want of strength in the hollow part of the shot and in the arrangement for correcting the centre of gravity. The author having had no experience of the explosive force of gunpowder naturally underrated it, and the result was, that when fired with high charges, the metal of several of the projectiles broke, and in the whole of them, the arrangement for correcting the centre of gravity gave way.

Moreover, as will hereafter appear, from theoretical considerations, the complete bearing of which were not perceived until after these projectiles were designed, they were imperfect in form—the forward end being either flat or hemispherical, and the backward end having a swell. The gun from which these projectiles were fired was a smooth-bore, $6\frac{1}{2}$ inches in diameter, but unfortunately the bore was not true, being wider at the muzzle than it was further down about the trunnions, so that a projectile which passed easily into the muzzle jammed hard near the trunnions, and it required the united efforts of a number of men to send the shot home. Unfortunately, also, the first projectile which was fired broke in the gun and scored the chase. Under these conditions it was not to be expected that perfect results would be obtained; nevertheless the experiments did establish points of some importance. Disregarding the projectiles which broke in pieces, the first shot (see Plate, Fig. 1) that was fired weighed 104 lbs., the charge was 16 lbs., elevation 5° , the range 1,346 yards, the atmosphere was still, the lateral deviation was unfortunately not measured, but was supposed to be about 4 yards from the line of aim. This shot did not turn over during flight, and ricocheted in a straight line for a great distance.

In loading with the next projectile, it jammed in the gun near the trunnions so hard as to become immovable, and the experiments had to be discontinued, and the gun was sent to Woolwich to have the shot withdrawn. Some months later the experiments were resumed. It was a stormy day, with a high wind blowing across the range so strongly that the author suggested that the experiments should be postponed; but the Assistant Secretary of the Ordnance Select Committee stated that, in estimating the accuracy, allowance would be made for the force of the wind, and the experiments proceeded.

The second shot (Fig. 2) weighed 81·3 lbs., the charge was 12 lbs., the elevation 5° , the range 1,449 yards, the deflection to the left 40 yards, the initial velocity 1,333 feet. As the metal of this shot broke, little information can be obtained from the experiment.

The third shot (Fig. 3) weighed 83·7 lbs., the charge was 14 lbs., the elevation 5° ; range 1,391 yards, initial velocity 1,345 feet, the

lateral deviation 27 yards left. This shot did not turn over during flight, but it oscillated, and the range was deficient.

The fourth shot (Fig. 4) weighed 94 lbs.; it was flat headed; the charge was 14 lbs.; the elevation 5° ; range 1,512 yards; deflection 29 yards to the left; initial velocity 1,280 feet. This shot did not turn over in flight, and went with comparative steadiness, but chiefly owing to the great resistance of the flat end; and the fact that the initial velocity was not so high as it should have been, the range was limited.

The fifth shot (Fig. 5) weighed 107.7 lbs., charge was 14 lbs., elevation 5° , range 1,433 yards, lateral deviation 24 to the left, initial velocity 1,230 feet. A piece broke off this shot, which, of course, affected the flight.

From these experiments, imperfect as they are, results of some importance have been obtained; for example, it was held to be impossible to fire from a smooth-bore gun an elongated projectile, which would not turn over during flight; this has been accomplished, and, if in the case of one projectile, the principle may be considered as established; secondly, it will be observed that, allowance being made for the wind and the imperfections previously referred to, greater inaccuracy might have been anticipated, for, with a range of 1,391 yards, the shot grazed 27 yards to the left—the direction in which the wind was blowing; and with a range of 1,512 yards, 29 yards to the left; the deviation being what would be due to the difference of range.

Again, having regard to the small diameter of the gun in proportion to the quantity of powder, the initial velocities are satisfactory, for it has been said that a charge of 14 lbs. is more than can be beneficially burnt in a 6.5 inch gun. This quantity has been stated to be a full charge for a 7-inch gun, and to be in the same proportion the charge should be only 12 lbs. for a 6.5-inch gun. As compared with results obtained with larger guns, something would also be due to the inferior area of surface acted upon by the propelling force; for example, this surface, which in the 6.5 gun is only 33.18 square inches, is in a 7-inch gun 38.48.

The principal deficiency in the projectiles was want of range, accounted for in the case of the flat-ended shot chiefly by the great resistance, and in the case of the others by the oscillation; and the author, therefore, proceeded to investigate the effect of different forms of ends, and to inquire into the nature and causes of the oscillatory motion observed.

It has been stated that in order that an elongated non-rotating shot, moving in a resisting atmosphere, should not deviate from the true line of flight, amongst other elements, it ought to be perfectly symmetrical. This is true, so far as relates to the surface on which the air impinges; for should the forward end of the shot be not symmetrical, then it is evident that the pressure upon the surface would not be equally diffused. It would be greater on one side than on the other, which would cause the shot to deviate from the true line of flight.

But it appeared that the effect would be modified by variations in the form of the surface on which the air impinges. Take, for example,

a hemispherical and a flat end. In the case of the first, every part of the surface will have its influence, whereas in the case of the flat end it will be different, for it seems to the author that practically it is the edge of the cylinder which is important.

The diagrams represent the supposed action of the air upon the two forms. With respect to the first, the influence of a projection on one side, in increasing the resistance, will be obvious. With regard to the second, it is believed that there would be a cone of air comparatively stagnant, and little motion across the face; but it will be seen that there is a very great motion across the edge of the end, and, therefore, any irregularity of form here would produce important results, which would be modified by another cause to be subsequently referred to.

At high velocities the air outside the supposed cone is driven off laterally from the projectile, and may be assumed to flow into the space behind the projectile somewhat as shown in the diagram (Fig. 3), and as the after part of the shot is thus moving in a partial vacuum, it is obvious that perfect symmetry of that part is not of the importance it has been by some assumed to be.

The effects of the wind of a passing ball shows the lateral dispersion of the air, and as a familiar illustration of the vacuous space left, may be mentioned, the case of a stick passed rapidly through water, when it is seen that an empty space is left. The fact stated by Colonel Thiroux that the velocity of revolution of rifled shot is not diminished to the extent which might be anticipated, seems to confirm the view that the shot moves in a very attenuated atmosphere. A practical conclusion might be arrived at from this, namely, that continuous ribs in rifled shot would not meet with greater resistance than studs; and as the bearing surface in the former case would be greater, the continuous ribs might have an advantage.

An important source of error in considering the flight of projectiles

has arisen from assuming that the conditions are the same in the cases of large and small shot. This appears to the author to be a great mistake, for before similar conditions can exist, and similar effects be produced, it would be necessary that the elements of length, diameter, area, and the velocity with which the projectiles are moving, should each vary in some simple ratio, which is impossible.

For example, take two projectiles—one for a musket, one for a large gun.

Suppose each moves through 100 feet in a given period of time. Each projectile has, therefore, displaced a column of air 100 feet long and of its own diameter, and this space has to be re-occupied and filled with air again.

Supposing that the projectile had been moving inside a tube, the opening for the admission of air to fill up this space would be directly as the area of the projectile, but in moving through the atmosphere the condition is different, because the air flows in from the sides as well.

Hence it follows that the opening for the air to flow in, varies as the sum of the area of the end and the circumference of the sides; but this opening does not vary as the quantity of air required to flow in behind projectiles of different sizes. It does not increase so rapidly as the quantity of air to be supplied, and hence, with a given velocity of flight, the back part of a large projectile is moving in a much more attenuated atmosphere than a small projectile. All this shows the incorrectness of arguing absolutely from musket balls up to large projectiles.

The part of the projectile which specially requires to be symmetrical is that part of the forward end upon which the air impinges, and over which it moves. This in a hemispherical end is a large portion of the whole surface, whereas in a flat end the intense action is confined to the extreme edge. In the case of the flat end, the air appears to be dispersed to the greatest extent, and, therefore, not only will this form meet with the greatest resistance from the air, but it will tend to produce a more perfect vacuum behind it.

The next point proposed for consideration was the nature and causes of the oscillation observed in the projectiles designed by the author.

The oscillation is supposed to be produced as follows: assume an elongated shot with a spherical end—when fired, if from any cause (gravity) the back end of the shot tends to droop, there is nothing to check it until it comes in contact with the air, by which time it will have acquired a certain velocity, and it will, therefore, pass through some space beyond the position in which it might have rested before the downward motion is checked. Consequently, having passed the line of quiescence, it is exposed to an upward pressure sufficient to produce upward motion, and thus it continues to oscillate in the vertical plane.

Another motion which the oscillation of the tail tends to produce may be called the plunging of the shot bodily. The cause of this appears to the author to be as follows: when the tail of the shot passes out of the true line of flight, the pressure of the air on the head

of the shot is greater on one side than the other. If at the lower side, the shot tends to rise bodily; if at the upper side, to fall; and if the shot does not turn over, a plunging motion is produced.

Turning to the forward end of the shot, it will be obvious that the form of end least likely to check the oscillation would be the hemispherical, and the form most likely to check it would be the flat.

It follows, therefore, that were regard to be had solely to the steadiness of the projectile, the best form would be the flat end; but this form we know offers greater resistance than any other. The object, therefore, is to combine the steadiness produced by the flat end with the diminished resistance arising from a modified form.

In dealing with the question of symmetry it was assumed that in the case of a projectile moving with high velocity there was a space of a conoidal form filled with comparatively stagnant air.

It is assumed that the pressure will be greatest in the centre, diminishing gradually towards the sides.

It might, therefore, be possible to add to a flat-ended shot a bow of a conoidal form, as shown in the sketch, without materially increasing or diminishing the resistance. In the same way the body of the shot might be enlarged as shown in the sketch.

Further, the conoidal form of bow in advance of the line A B would be attended with disadvantages; for, first, it removes the centre of gravity in the direction of the length, further back in proportion to the length, thereby increasing the tendency in an uncorrected shot to turn over.

Secondly. The steadying influence of the flat end is lost, and the part of the shot where greatest strength is required is made weak.

The part, therefore, in front of the line A B may be removed.

It has been shown that the additions C A—D B may be made to the projectile without a proportionate increase in the resistance, and as this would give a larger capacity of shell and a heavier shot, this lateral addition may be made with advantage, and the form of the shot becomes that shown in the figures 5 and 6.

Elongated shot for smooth-bore gun.

Elongated shot and shell for 9-inch smooth-bore gun.

It has been stated that the form of end least likely to check oscillation in the shot would be the hemispherical, and the form most likely to check it would be the flat end. This depends upon a principle of resistance discovered by Mr. Froude.

Without entering upon the subject more fully, it will be sufficient to state that Mr. Froude has found, first, that in the case of a plane moving through a fluid in the direction at right angles to its surface, the pressure is symmetrically distributed.

Second, that in the case of a plane moving through a fluid obliquely, the pressure is greater against the leading side of the plane at A than it is against the following side at B.

Now the first is the case of a flat-ended shot following the line of the trajectory, and the second is the case of the same shot moving at an angle to that line; and hence, if a flat-ended shot moves out of the true line, an increased pressure would be brought to bear upon the advancing side, which would tend to force back that side, and tend to bring the shot into the true line. Any deviation from the true line would therefore immediately be met, by an altered resistance tending to prevent such aberrations, and consequently the flat-ended shot tends to remain in the line of the trajectory, and not parallel with the axis of the gun; but this effect would not take place with the spherical end.

From what has been stated, it would appear to follow that it is questionable if some forms which have been adopted are the best for projectiles.

Moreover, in the case of shot intended to be fired against iron plates, the pointed form appears to be objectionable for another reason, that the point would be smashed and the debris of broken metal interposed between the body of the shot and the plate, thereby reducing the influence of the blow; whereas in the form proposed by the author the point is removed, and the shot will combine the punching effect of the flat end with the bulging effect of the spherical.

It will be obvious that, before one could estimate the practicability of employing elongated projectiles fired from smooth-bore guns, several other points would have to be carefully considered, and it is proposed now to advert briefly to these.

In the case of spherical shot fired from a smooth-bore gun, with the ordinary windage, the effect is supposed to be as follows:—The powder being first ignited at the upper side, a pressure is produced forcing the shot down upon the chase of the gun. Subsequently, when the powder is ignited at the lower side and the shot resting on the bottom of the chase, the gas escaping more freely through the windage

at the upper side of the shot, the pressure is greater at the lower side, and the shot is forced against the upper side of the chase.

In addition, the motion of the shot will be affected by the centre of gravity not being in the centre of the shot, and by friction. In the case of elongated projectiles fired from smooth-bore guns it is different; for, as the whole of the powder is ignited before the shot leaves the gun, and as it is guided in its passage by the chase, it does not appear that the irregularity in the ignition of the powder would affect the accuracy.

The conditions in the case of an elongated projectile are quite different from those of a spherical shot. In order to see this, let us trace the action throughout. Suppose the powder ignited as before at the upper side, the gas would rush out along the upper side of the shot, tending to press it down against the bottom of the chase; but the surface to resist this pressure, which in the sphere was only a point, is in the elongated shot a line of considerable length. Therefore, although guns are damaged by this action in the case of spherical shot, it does not follow that they would be affected in the case of the elongated shot. Then, suppose the whole of the powder is ignited throughout the whole depth of the charge, the tendency would be for the gas on the lower side to raise the shot; but if the shot were raised, the pressure would immediately be increased at the upper side; and as this inequality of pressure can exist for only a very short distance from the tail of the shot, the head would hardly be affected; not so in the case of the sphere, where the whole semi-diameter is exposed to the lifting action of the gas, with nothing to resist it, because what in the elongated shot is a long line, in the sphere is a point.

What has been stated would be applicable to a shot which was not moving forwards; but when the tremendous velocity of projection is taken into account, the resistance of the air in front would combine with the pressure of the gas behind to make the shot move parallel with the chase.

We have now to consider how the shot will be affected at the moment that it issues from the muzzle of the gun. Take the case as

shown in the sketch (Fig. 9). The forward end of the projectile is deflected downwards by the pressure of the escaping gas on the upper side, but to counteract this there would be the superior pressure against the lower part of the back end, in addition to the pressure on the forward end, which tends to keep the projectile from deviation.

As it may be said that the pressure of the expanding gas on the upper side of the shot would act behind the centre of gravity, and thus tend to depress the back end of the shot, it should be remembered that to counteract this there would be the upward pressure against the lower edge of the plug.

Further, it is well known that gas of high tension expanding into the atmosphere can exercise but very little pressure, because the great bulk of the power is absorbed in producing its own expansion.

Again, the tremendous momentum of the shot at the moment of its leaving the gun (being then at its maximum velocity) operating to keep it in a true direction, and the extreme minuteness of the period of time to which the shot could be exposed to the action of the escaping gas, should be considered.*

In the case of the projectiles which were fired and which did not break, as the difference in range can be accounted for by other causes, it does not seem that the escape of the gas affected the accuracy, and this with a gun which was bored wider at the muzzle than it was further down the chase; but even supposing a bad effect were produced by the escape of the gas at the moment the shot left the gun, a simple remedy would be to place a ring of soft metal at the after end of the projectile, which would be expanded by the force of the discharge to fit the chase. This was in fact the arrangement adopted in one of the early forms of the author's proposed projectiles.

It seemed to the author reasonable to infer that if the resistance were diminished by a modification of the forms, such as is represented in the drawings, and if the hollow part of the projectile and the arrangements for correcting the centre of gravity were made sufficiently strong to resist the force of the explosion, very superior results would be obtained; and with this view, and considering that this system might be specially applicable to naval broadside guns, the author offered his plans to the Admiralty, stating that he was willing to carry on the experiments at his own expense. The authorities, however, did not think it advisable that any experiments should be made, and as it is impossible for a private individual to carry out experiments with large ordnance, the author regrets that he is unable to place before the Institution more perfect results, nor can he of course hope to prove the truth of a system by the firing of half a dozen shots.

Assuming that a range equal to the rifled projectile is not obtained with the smooth-bore projectile, the advantages over spherical pro-

* Suppose the velocity at the muzzle of the gun to be 1,600 feet per second, and suppose the action of the expanding gas to be limited to the time the shot would pass over 3 inches—that is $\frac{1}{1600}$ th of a second; further, suppose that the pressure of the expanding gas was equal to $\frac{1}{100}$ th of the pressure before issuing from the gun, and that it acted on the whole length and breadth of the projectile, the result would be a deflection of the shot of $\frac{1}{200}$ th of an inch.—M.S.

jectiles would be greater accuracy, increased capacity of shell, and superior strength.

As compared with the rifled elongated projectiles in the experiments, there was a deficiency of range, but with slightly increased initial velocity, which would make the penetrating power as great at close quarters.

As the projectiles do not rotate, there would be no lateral deviation from that cause, and straight ricochet would be obtained.

There being only one trajectory* as against two in the case of the rifle, with an unstable platform and the object aimed at in motion, it is believed that as great accuracy would be obtained from the smooth-bore.

The smooth-bore would have the advantage of simplicity in the gun, and it is believed it could be more readily and more quickly loaded; the gun would be durable, and neither gun nor projectiles liable to derangement or injury. Spherical shot, as well as grape and case, could also be fired from the smooth-bore, which, if fired from a rifled gun, would speedily damage the rifling.

The figures (5 and 6) represent smooth-bore shot and shell constructed on the principles which have been enunciated. They may be constructed of cast-iron or of steel.

The drawings represent those of cast-iron.

For naval purposes it would probably be desirable to have projectiles of both metals, the one to be used against armoured ships, the other against ordinary vessels. The conoidal part of the head of the projectiles would be turned in the lathe; the centre of gravity be corrected by the two pieces of metal shown at A and B. In the projectiles first made, this was effected by wooden discs having pieces of lead let in at one side, the shot being suspended, these were turned until it hung true between two points, which were previously known to be in the same vertical line, they were then secured by a bolt as shown.

As has been stated, this arrangement was far too weak, and gave way when the shot was fired.

It is proposed, therefore, to substitute pieces of metal secured in the manner shown, and which it is believed will stand the force of explosion of any charge without disturbance. From the experience gained, it appears that the cost of correcting the centre of gravity of the largest shot would be very little; not above a few shillings.

It has been objected to the system proposed, that it can pretend to no advantage, not obtainable with shot of simpler construction fired from rifled guns.

In reply to this, the author submits that the proposed shot and shell are simple, there is neither lead-coating nor studs; as to cost, they might be made as cheaply as rifled projectiles, for the expense

* In the case of the smooth-bore, the shot moves in a curve in the vertical plane, whereas in the case of the rifle, the shot has also to move in a lateral curve, making the actual path of flight the resultant of the two, a curve of double curvature, which appears to be not calculable.—M.S.

of correcting the centre of gravity is little, and there is saving in other directions—this point deserves notice. Until a recent date the cost of the heaviest shot employed, such as that for a 68-pounder, was only a few shillings, and the addition to that price of two or three shillings more would be a large percentage; but when we take rifled shot weighing 300 pounds, even of cast-iron, the cost is considerable, and in this case the addition of a few shillings is a small percentage. Further, in the case of steel shot, the cost is enormously enhanced, and the proportion of the few shillings for correcting the centre of gravity, is correspondingly diminished. But more, the cost of the shot is the cost when it is fired, and the large charges of powder now employed involve a corresponding increase in expense, and in the case of shell, the bursting charge would have to be added. Putting these items together, it will be found that the cost of correcting the centre of gravity is a trifle compared with the cost of modern projectiles fired, and if the slightest addition to accuracy could thereby be obtained, it appears to the author that it would be well worth the money.

In conclusion, the author would add that, of course, there is no intention, on his part, to speak dogmatically upon a subject so full of difficulty; his desire is to submit these ideas to the Institution, in the hope that they may lead to discussion on the part of those who are more competent to deal with such questions.

Commander COLOMB, R.N.: I should like to ask two questions which have suggested themselves to me. Firstly, I did not quite understand whether the mere correction of the centre of gravity was sufficient to prevent the shot turning over. Secondly, I do not think it was quite clearly made out how the altered shape of the shot would be sufficient to correct the oscillation which the lecturer stated occurred with the hemispherical-headed shot.

Mr. M. SCOTT: In answer to the first question I think I stated that there was more than the correction of the centre of gravity required. I have taken up the subject at the point where it was left in a pamphlet which I published. I did not desire to go over the same ground, for I dare say many gentlemen present are acquainted with it; and it would have been tedious to discuss the same question again. But it was stated that the correction of the centre of gravity and the perfection of the symmetry were both required. I am unfortunately unable to state what effect this modification of the form would have had. I wish to have it tried. The original forms were only two, the hemispherical and the flat. We found that neither of them was satisfactory. I then proposed to modify these forms for the reason given in the paper, and to make them like Figs. 5 and 6. I applied to the Government for an opportunity to try a shot of that form, but that offer was unfortunately refused. Therefore it remains a question whether it would have the desired effect or not. I have stated my reason for thinking that it would be an improvement upon previous forms; but as to whether it would remove the oscillation altogether is quite another question.

Captain TYLER, R.E.: I have always understood from Mr. Whitworth's experiments,—in fact from all experiments that have been made,—that one of the first principles of projectiles was that when you departed from the spherical form and began to elongate the shot, unless you began at the same time to rattle your gun in order to make your shot rotate, the projectile at once began to show symptoms of turning over; and further, that the more elongated the shot was, the more that tendency exhibited itself. I had the pleasure of being in Mr. Whitworth's gallery, and seeing some of his earlier experiments; and I remember at that time that the pieces of paper which he placed at intervals across the gallery showed the points at which the projectiles turned on their sides; and showed very

distinctly that when, as Mr. Whitworth originally proposed, he elongated his shot to an unusual extent, he was at the same time obliged to increase the number of turns in the gun in order to overcome the tendency of the shot to fall on its side instead of going straight forward. Now, if what Mr. Michael Scott has stated is correct, it would appear that he has the idea that he can, by merely balancing his shot, overcome that tendency.

MR. M. SCOTT: The cases are hardly parallel. Mr. Whitworth's shot were solid; consequently the centre of gravity would be far back. My shot are hollow behind; and these two shot on the table were actually fired and did not turn over. They have a considerable length in proportion to the diameter. But it is not a parallel case quite with shot that are solid throughout.

A MEMBER: Were any practicable means taken to verify that the shot did not turn over?

MR. M. SCOTT: In this way: First we saw them throughout the flight. But there was a better proof than that: The range sergeant who had the noting of the grazes stated that in this case the graze was a long shallow scoop in the sand; so that even when the shot touched the sand, it did not turn over.

Captain TYLER: I dare say Mr. Whitworth, who has had great experience in these matters, will kindly tell us whether he has observed that anything of this sort can be produced: that it is possible to fire an elongated shot that shall not turn over without at the same time giving it rotation.

MR. WHITWORTH: I will state that I never fired an elongated shot without giving it rotary motion. I have never tried the experiment; but I know this very well, that if you give a small rotary motion to elongated shot it will turn over, and that the longer the shot is, the more rotation you must give it.

Captain TYLER: That is what I understood from your earlier experiments.

Captain BURGESS: Provided it is solid.

MR. WHITWORTH: No matter whether it is solid or hollow.

Captain COLOMB: One would suppose that if the rear-end of the shot were much lighter than the fore-part, the tendency to turn over must be proportionately reduced.

MR. M. SCOTT: That may be true in its degree; but if the centre of gravity is not in the centre of the figure, the condition you suppose would not be sufficient.

THE CHAIRMAN: You will doubtless allow me to give your thanks to Mr. Scott for his contribution to the science of projectiles. After what Mr. Whitworth has said, that he has never tried the experiment mentioned, his statement can be no negative to what has been tried. The experiment has been made, and it really appears to me to answer satisfactorily. It is unsatisfactory that such a gun as the one described, which was imperfect, should have been supplied for such a purpose; but it is only what we have had to say before with respect to the guns that were employed for the spherical shot. They were the most rough, we might even say, disgraceful guns. There was no real comparison, no scientific comparison, no skill, no care there. We have pretty much the same thing here. The gun which Mr. Scott has described in the paper was so unequal in the bore that the shot jammed near the trunnions, and it took considerable force to get it home. Apart from any defect in the gun, we must have expected oscillation in the projectile. Therefore it was an experiment all against the projectile. If the gun had been better suited to the purpose, the projectile, as we might reasonably have expected, would have given better results than it did. However, this paper is a contribution to the science of projectiles. It is interesting to know, that that which had been conceived to be impossible, is not, so far as we can rely upon Mr. Scott's information, impossible; that an elongated shot can be projected, and that it will not turn over, if the adjustments are had respect to. It is interesting in this respect too, that with his *balanced* shot a much higher initial velocity is obtained than from the elongated *rifled* shot. Although there was a deficiency in the range, that deficiency seems to have arisen from the greater oscillation. But if you had a perfect gun you might reasonably expect that that oscillation would be materially reduced, and that the range would be materially increased. We have heard admissions lately made at the Institution of Naval Architects with respect to initial velocity; and, by the way,

we should have heard nothing at all about that, if it had not been necessary to support a particular form of construction of vessel. Those who were behind the scenes were let into the secret, and they were told, with regard to a certain experiment, that there was a different description of powder used, and a different initial velocity obtained to that which was reported. But, surely, this is very unsatisfactory. It casts a doubt upon all these experiments. The initial velocity given here, not obtained by Mr. Scott himself, may be incorrect, but it is comparatively correct, and is greater than the initial velocity obtained from the elongated shot; and as it was stated at the Institution of Naval Architects that the difference of initial velocity, though not great, made a difference of an inch of iron in plating, it becomes a very serious and a very important question. It is desirable to get higher initial velocities with safety, particularly when we see the number of guns that give way with large charges. The *Times* to-day mentions Major Palliser's gun. I do not know what initial velocity it gives; but it is quite clear that initial velocity is one of the prime elements for an effective gun. Therefore, anything that will help us to get that without bursting the gun is a *desideratum*. It cannot be but that in rifling the gun, and especially in using studs on the shot, the gun must be materially weakened; therefore, in that proportion with guns so scored, it is impossible to fire large charges. The gun for these shot has no score, therefore it is proportionably stronger. Considering the measure of success Mr. Scott has obtained, it is a waste of money to make experiments in this way. It is very strange, when a man undertakes to pay the expense of these experiments himself, in order to solve problems in science which involve such results as these, that he should not be supplied with a proper gun. However, be that as it may, we have to thank Mr. Scott for his interesting paper.