CINEMATOGRAPH LECTURE ON "THE MAKING OF A BIG GUN."

Dr. W. Rosenhain, F.R.S., of the National Physical Laboratory, delivered a Lecture, illustrated by cinematograph pictures, under the auspices of the Faraday Society, on Thursday, April 6, 1916, on "**The Making of a Big Gun.**" The Lecture was held in the rooms of the Royal Society of Arts and was presided over by **Sir Robert Hadfield, F.R.S., President**, who introduced the lecturer with the following remarks :—

The Faraday Society is indeed fortunate in having such an able lecturer as Dr. Rosenhain to give us this Lecture on "The Making of a Big Gun." Dr. Rosenhain is specially qualified to do this, not only by his scientific attainments but also from his wide metallurgical knowledge.

In view of my connection with the firm of Hadfields, Ltd., Sheffield, who for a generation have made a special study of the manufacture of projectiles, it will be understood that I am more than usually interested in the subject of the lecture this evening. Moreover, after all a gun is not of much use without its projectile.

I have seen guns up to 16-in. calibre fired at various proving grounds, both private and Government, including Shoeburyness, Portsmouth, Gâvres, Le Creusôt, Sandy Hook, Indian Head, Ochta, Meppen, Magdeburg, and elsewhere, also results of tests at foreign proving grounds at Spezia (Italy) and Kure (Japan). The largest gun I have seen fired is the 16 in., weighing about 120 tons and being 35 calibres in length. There was at the time only one gun in existence of this calibre, namely, at Sandy Hook. The shot fired from this gun weighed 2,400 lb.

The gun in question was once fired and gave a range of 21 miles. The round I saw was fired at a velocity equivalent to a range of about 10,000 yards, that is a comparatively low velocity, about 1,400 f.s. The 12-in. hard-faced armour plate which it attacked obliquely was inclined about 45°, that is very extreme. The plate was slightly cracked, but not perforated; in other words, the blow was more of a glancing than an impact one. I witnessed the round about a quarter of a mile from the gun, and was able to observe the fragments as they ricocheted out to sea over a distance of about 1½ miles. This gun is not suitable for putting on board ship, that is, it is used for coast defence purposes. I believe a number of these guns have been made for the Panama Defence Scheme.

As the subject of "Large Calibres" is of considerable interest, I may say that 17-in. guns were believed to have been made in Italy, but we have not heard much about them of late. Probably they are somewhat out of date. Gun manufacture, like other branches, has progressed so rapidly that what was made a few years ago is of no service to-day.

It must be borne in mind that usually when big calibre guns are referred to in the daily press, such as the 42 cm., they have been what is usually known as "howitzers." In artillery parlance a howitzer is not con-

sidered to be exactly a "gun." Its internal pressure very seldom exceeds 14 or 15 tons per square inch, and often not so much as that; whereas a real gun, as is used in the Navy or for coast batteries, has to stand a pressure of 20 tons per square inch.

Mr. J. A. Longridge, in his excellent series of Papers given before the Institution of Civil Engineers, namely, from 1879 to 1884, on "Wire Gun Construction" and "The Construction of Heavy Ordnance," also his book "The Artillery of the Future and the New Powders," published in 1891, said that it would some day be possible—in fact, at the time of making the statement, he said that he was prepared to do this—to make guns to stand up to 30 tons' pressure. I have often wondered why this subject has not been further followed up. Mr. Longridge gave a number of excellent papers to the Institution of Civil Engineers, and in view of their acceptance by that body they must have been of more than ordinary merit, that is, the views put forward were of special nature and worthy of consideration.

As regards our own Service, naturally in time of war one's mouth is sealed. It is, however, well known that we have 13·5-in. and 15-in. guns of the highest possible quality. The results obtained reflect great credit upon the British artillery engineer and the metallurgist, who by their combined efforts have produced guns giving, as they have done, splendid results, in fact no fault has been found with them in service. Long may they continue in their duty of protecting our Empire. Our guns, unlike those of the enemy, were made for defence and not for attacking harmless seaside resorts.

It may be of interest to state—and this is an open secret—that a certain foreign nation about two years before the war broke out were wanting to order big naval guns, a commission was appointed to visit the various big gun-making centres of the world, and this commission unanimously reported that the British wire-wound gun was the best which could be procured.

With regard to the construction of the gun, Dr. Rosenhain will put before us some of the mysteries which attend the construction of the wire-wound and the ring or jacket construction gun.

Whatever the future has in store in the way of developments of the power of such guns, whether by means of increased calibre or by constructing calibres such as now made to stand higher pressure, we are quite sure that the British artillery engineer and the metallurgist will continue to hold the proud position they at present occupy of building the most powerful guns the world has yet produced; that is to say, the muzzle energy of British guns has outranked those of any other nation, for the 16-in. American gun to which I have previously made reference, whilst not of the howitzer type, had nothing like so great a muzzle energy as, for example, our 15-in. naval gun. In this respect the so-called big German guns, about which there has been so much talk in the papers, are, as regards their muzzle energy, very small and inferior weapons in comparison with ours. With some of these guns it would be quite possible to send a shell over Mont Blanc.

It may interest those present to know that the life of a gun is really very short, in fact there was an interesting article in the *Engineer* not long ago, in which it was proved that the life of a modern high-velocity gun was not much more than three seconds. By this is meant that before erosion set up and interfered with the accurate aim and direction of the gun it became eroded and lost its value; that is to say, if one adds up, say, the length of time during which the projectile remains in the gun, it will be found that under full service velocities the total time, and consequently the life of the inner gun tube, does not amount to much more than three seconds.

The modern gun is really a heat engine, and it may interest you to

know a few of the feats which I myself personally have been in touch with ; that is, the results obtained from what may be termed the modern high speed and great power heat engine known as the gun. For example, I well remember many years ago at Shoeburyness a 9·2-in. armour-piercing shell being fired through a 9-in. armour plate, known as "compound," that is of combined iron and steel. The shot perforated the plate and backing, got out of the sand butt, and was recovered whole, and alongside it, to the general surprise, was found a small rabbit. In other words, a big gun for little game !

Another instance I well remember which may be of interest, was that a 9-in. wrought-iron plate was being attacked by a 9·2-in. Whitworth shot. This plate was swung upon trunnions projecting from either side, and before firing it would have been possible, with comparatively little energy, to make the plate swing backwards and forwards. To show how quickly the shot acts, when the Whitworth shot was fired against this plate and perforated it, the plate was lifted from its trunnion seating and thrown away some ten or twelve feet, yet the hole was properly punched in the plate. In fact, before the plate had time to swing the shot passed through it. This brings home a fact which is perhaps not sometimes realized, namely, the enormously rapid action of the shot in perforating. For example, a 15-in. shot going through a 15-in. plate would perforate at any rate in about one-thousandth part of a second, probably in even less time than this. It will be understood what tremendous stresses are suddenly brought to bear upon the shot and how the slightest flaw or imperfection of any kind will wreck it. In fact, a 15-in. armour-piercing shell properly hardened and tempered is a very fine metallurgical performance. I have one or two photographs here this evening which show what this type of shot can accomplish, not as in the old days against wrought-iron plates, combined iron and steel, all steel, nor hard-face Harvey plate, but the latest and best type of carburized, quenched, and almost diamond hard-faced. In this respect I do not think British projectiles have been found wanting, and this country has no need to fear for its equipment.

Another instance may be mentioned. This refers to old experiments, but nevertheless is interesting. One of our 6-in. shot was fired against a 9-in. compound plate and recovered unbroken. It was so little injured that it was put in the gun and fired again. A second 9-in. plate was also perforated, the shot being recovered unbroken but slightly ground. It was fired a third time against a hard-faced plate, and being uncapped the shot of course broke. This illustrates how well a shot properly hardened and tempered can resist the enormous complex stresses suddenly brought to bear. That is to say, the shot, by means of its quality and when possessing enough energy, is thoroughly master of its work against any type of plate without a hard face. To overcome the hard face the modern cap has been introduced. This enables even the hardest face to be perforated. I am showing a few caps recovered after firing. It is curious to find these have to swell to the full diameter—in other words, the shot has to pass through the cap ; the cap is not merely dispersed, as might have been thought to be the case. The action is, however, so sudden, and the soft metal of the cap expands, that it is really punched ; the expansion or elongation of mild steel taking place so quickly that it does not break until practically the full diameter of the shot has been reached. It is no doubt owing to this fact, and the radial inertia of the cap itself, that a modern cap is enabled to so completely protect the shot that the latter then passes unbroken through the armour plate attacked ; that is, before the face of the plate is reached, certain support is afforded sufficiently

long enough to the point of the shot that it can transfer some of its energy to the plate attacked.

The following is an abstract of Dr. Rosenhain's Lecture :—

The lecturer began by contrasting the "big guns" of olden times with the gigantic weapons of to-day. The older guns were made of cast iron, and guns of that material reached their highest development in the American Civil War. The conditions existing in modern guns were illustrated by sectional diagrams relating to guns of fairly recent date, in which pressures of 18 tons per square inch and muzzle velocities of 2,500 feet per second occurred. To resist these conditions, the best possible steel was required, and even that only served for a comparatively short time. The work of modern guns was illustrated by some photographs of gigantic projectiles which had been recovered intact after penetrating great thicknesses of modern armour. The effect of use on the inside of a gun was illustrated by photographs showing the "erosion" and the cracking which occur as the result of the high temperature of the explosion gases.

The lecturer then proceeded to describe the modern process of gun-making by the aid of a series of cinematograph pictures of the most interesting and striking stages of the process. These films had been prepared and lent to him by the courtesy of Messrs. Vickers, Ltd., at whose Sheffield works they had been taken. The series began with the blast-furnaces in which the iron ore is reduced by the aid of coke and limestone; next came the open-hearth steel furnace and the processes of filling were shown, and particular attention was drawn to a picture which clearly showed the "boiling" of the molten steel within the furnace. Throughout the various stages of the process, including the refining of the iron to transform it into steel, its various stages of forging, hardening, and tempering, the lecturer gave in popular terms the scientific reason for each step, illustrating his remarks by a series of photomicrographs showing the minute structure of the steel at each stage, and showing how each step served to bring the steel nearer to the ideal condition of perfect homogeneity. The lecturer naturally avoided reference to those confidential matters which relate to the most recent products of the steel-maker's art as directed to the production of guns, but as an indication of the direction in which modern practice tended, he showed the extremely minute micro-structure which can be produced by proper treatment in modern special or "alloy steels." The extreme importance of accurate scientific control, both of compositions, temperatures, and rates of cooling, throughout the process, was strongly emphasized and illustrated.

By means of the series of cinematograph films the gun was followed through its various stages, from the freshly cast ingot weighing 80 tons, through the processes of "cropping" and "trepanning," as the first piercing of the ingot to form a rough tube is called, on through the forging press until it attains its requisite length—in some cases over 70 feet. Then follow the machining operations, and then what is, perhaps, the most delicate part of the process—hardening and tempering, in which the roughly machined tube is heated to a uniform and carefully regulated temperature in a tall chimney-like vertical furnace, from which it is lifted at the proper moment to be plunged into an oil-bath contained in a deep cylindrical well. The process of rifling and the finishing of the outside, after the application of the wire-winding, were also shown. Finally, as a relief to the more severely technical portions of the lecture, some films were shown illustrating the testing and firing of big guns.