(Paper No. 3241.)

“The Bursting of a 48-Ton Krupp Gun, and the Method of Repairing it.”

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IN the early part of the year 1897 the Author was called upon by the Chinese Government to investigate officially, and to report upon, the cause of the explosion of one of the large Krupp guns mounted at the mouth of the River Min, near Foochow, in China; also to devise, if possible, a means of rendering the gun again fit for service.

The gun was purchased, with several others, from Messrs. Krupp in the year 1891, and was, according to the official description, of the design known as “Construction 1886.” The following are the principal dimensions and weights:—

Diameter of bore	11·02 inches
Weight of gun	48 tons
Weight of projectile	759 lbs. (345 kilograms)
Weight of powder charge	352 lbs. (160 kilograms)
Length of gun	36 feet 9 inches (40 calibres)

An outline elevation of the gun is shown in *Fig. 1*.

Fig. 1.

Scale, 1 inch = 10 feet.

THE ORIGINAL GUN. ELEVATION.

The gun burst on 17 October, 1896, during a trial at which no Europeans were present; the circumstances which led to the accident could therefore only be gathered from Chinese sources. It appeared, however, that, from some notions of economy on the part of the officer in charge, and possibly also to demonstrate

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that native gunpowder is quite as strong and therefore as good as the imported European powder, a charge of Chinese black "cracker powder," moulded in prisms to imitate foreign prismatic powder, was fired from the gun. Two guns of the same pattern were mounted close together in one fort, the gun which burst being known as Gun No. 2. Orders were issued for a round to be fired from Gun No. 1, with a full charge of 160 kilograms of the Chinese powder and a projectile weighing 345 kilograms. It was found, however, that the chamber could only contain about 150 kilograms of this powder; the gun was therefore fired with a charge of 150 kilograms of the Chinese powder, without apparent accident, except that the breech could not be opened. This warning was, however, disregarded, and orders were given for a similar charge to be fired from Gun No. 2, with the result that the breech portion of the gun, together with the breech-block, weighing over 4 tons, was blown about 200 feet to the rear, carrying away in its flight part of the loading-platform, de-

Fig. 2.

Scale, 1 inch = 10 feet.

THE BURST GUN. ELEVATION.

molishing several buildings, and killing outright nearly the whole of the gun's crew and several onlookers. It was stated that twenty persons were killed and about the same number were wounded. The fracture occurred just in front of the breech-block, *Fig. 2*.

The Chinese endeavoured to hold Messrs. Krupp responsible for the accident, asserting that as the gun was fired with 150 kilograms of powder, instead of 160 kilograms, it followed that the gun must have been defective. On examination of the gun the fracture was found to possess a fine granular structure, without the slightest trace of a flaw. A permanent enlargement had taken place in the rear portion of the bore, the maximum increase in diameter being 0·039 inch at a distance of 2 feet from the front of the chamber. All sign of permanent enlargement of the bore terminated at a distance of 10 feet from the chamber, the remaining 17 feet of the bore being unaltered. Gun No. 1 had also undergone permanent enlargement of the bore in almost exactly the same position and to the same extent. All efforts to

move the wedge breech-block proved unavailing, although powerful hydraulic jacks were used, so that for all practical purposes both guns were equally useless.

Test-pieces were cut from the breech portion of the gun as near to the fracture as possible. Three of these were cut parallel to the axis of the gun, and three at right angles to the axis; those cut parallel to the axis showed, on an average, a breaking strength of 40·5 tons per square inch, with an elongation of 24·47 per cent. on a length of 2 inches; the breaking strength of the pieces cut at right angles to the axis of the gun was, on an average, 37·89 tons per square inch, the elongation being 20·83 per cent. on a length of 2 inches. These tests were made with a Wicksteed testing-machine, made by Messrs. Buckton & Co., of Leeds; the greatest care was exercised in preparing and making the tests, so that the foregoing figures may be taken as being correct. As the original forging must have measured about 3 feet 4 inches in diameter and 15 feet in length, and must have weighed about 29 tons, the Author considered the quality of the steel to compare favourably with the best qualities of English gun-steel; certainly the Chinese officials had no ground for their contention that the gun was made of inferior material.

It was further contended that the sectional area of the gun at the point of fracture was insufficient; measurements were very carefully made, and the area of the fracture was found to be 482 square inches, the area of the obturator exposed to pressure being 184·4 square inches. Taking the ultimate strength of the steel to be 40·5 tons per square inch, as shown by tests, it would require a pressure of over 130 tons per square inch to cause rupture, provided, of course, that the pressure was uniformly distributed and slowly applied. Messrs. Krupp held that the gun was constructed to withstand a working pressure not exceeding 23 tons per square inch, and naturally disclaimed responsibility, expressing the opinion that the pressure must have been at least 46 tons per square inch. That the Chinese gunpowder did develop an enormous pressure seems to be beyond doubt, for not only was it a black powder of uncertain chemical nature, but it was found that the density was only 1·51 to 1·52 instead of 1·77 to 1·80, the density of brown prismatic powder. The low density accounts for the fact that the chamber of the gun would only contain 150 kilograms of this powder. Gunpowder of such very low density would certainly burn with great rapidity and would consequently develop violent pressures; but, according to experiments made by Sir A. Noble and Sir F. Abel, the maximum

pressures recorded with "brisante" powders did not exceed 43 tons per square inch.

It seems probable that the fracture may have been caused by waves of pressure being set up in the gun; Sir A. Noble, speaking on the subject of waves of pressure at the Oxford Meeting of the British Association in 1894, said:—

"I have heard it urged that these waves of pressure are, after all, not of high importance, because their maxima act at the same time only upon a very small section of the bore, and the continuity of the metal is amply sufficient to resist the stress. This is no doubt true, but it is not true of the base of the bore, which in modern guns is almost invariably a movable piece, and which under certain circumstances might have to sustain the full force of the violent pressures."

The rapidity with which these waves of pressure are applied must be an important factor in influencing the resistance of the steel. With ordinary pressures of 15 tons to 20 tons per square inch, the rapidity of the combustion of gunpowder has been found to be less than $\frac{1}{200}$ second; and as the rapidity of combustion rapidly increases with increase of pressure, it is suggested that the rapidity may have been so great as to upset the molecular arrangement of the metal, and to rupture the parts first receiving the shock before they had time to transmit the stress throughout the whole section. Another circumstance which may have had some influence on, at least, the position of the rupture, was the non-uniform distribution of stress, due to the abrupt change of form and cross-sectional area of the gun, *Fig. 3*. It will be seen that the gun possessed these abrupt changes in a marked degree; the cross-sectional area at A (*Fig. 3*), just behind the fracture, was 482 square inches; at B, close in front of the fracture, it was 749 square inches, and at C, still within a few inches of the fracture, the cross-sectional area was 586 square inches.

Method of Repairing the Guns.—The guns were dismantled and sent by sea to the Kiangnan Arsenal, near Shanghai, where the repairs were carried out in accordance with the design of the Author, *Fig. 4*. A length of about 16 inches of the breech end of the A tube was cut away, the end of the fractured breech-jacket was squared, and the interior of this jacket was screwed to receive a breech-screw of the ordinary "interrupted" pattern, fitted with a De Bange obturator. It will be observed that the breech-screw is unusually heavy, owing to the large diameter of the A tube, but by the use of a running-in-and-out screw and ball-bearings in the

hinge, no difficulty has been experienced in opening or closing the breech after firing. The powder-chamber was carried 16 inches further forward, in order that the gun might be able to fire the full charge; this had the effect of shortening the effective length of the gun by $1\frac{1}{2}$ calibre only, although the part blown away

Fig. 3.

Scale, $\frac{1}{2}$ inch = 1 foot.

VERTICAL SECTION AT BREECH, SHOWING POSITION OF FRACTURE.

was 3 calibres in length and weighed over 4 tons. The alteration to the powder-chamber may be seen by comparing *Figs. 2 and 3*. The breech end of the "mushroom" stem of the De Bange obturator was screwed to take the ordinary pattern Krupp axial friction primer, which has the merit of being extremely

Fig. 4.

Scale, 1 inch = 10 feet.

THE REPAIRED GUN. LONGITUDINAL SECTION.

simple and effective. The breech tangent-sights were originally attached to that part of the gun which was blown off; the new sights are placed in the bronze breech-ring, the right side passing through the centre of the hinge of the "carrier," *Fig. 4*. The balance of the gun is maintained by means of a heavy steel hoop and a cast-iron weight attached to the breech end of the gun.

This does not at all detract from the appearance of the gun when mounted.

Both guns were repaired in the same manner; they were ultimately remounted, and in the year 1899 they were each fired with full charges of 160 kilograms of brown prismatic powder and projectiles weighing 345 kilograms. For sighting, the old range-table was used, the range being 5,000 yards; very good practice was the result, incidentally showing that little, if any, loss of energy had resulted from the shortening of the rifling by $1\frac{1}{2}$ calibre. The registered gas-pressure in the powder-chamber for these four rounds averaged 2,399 atmospheres, or 15.73 tons per square inch.

The Paper is accompanied by nine photographs, and by two tracings from which the Figures in the text have been prepared.