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LIFE.

Lloyd, E., Lieut. 108th Regt., 9*l*.

ANNUAL.

Symes, W. A., Capt. 94th Regt.	1 <i>l</i> .	Eaton, H. F., Lieut. Gren. Gds.	1 <i>l</i> .
McCragh, M., Major, late 4th Dragoon		Sprot, J., Lieut. Col., 91st Highlrs.	1 <i>l</i> .
Gds., 1 <i>l</i> .			

THE PROGRESS OF OUR HEAVY ORDNANCE AND THE PRINCIPLES AND PROCESSES OF ITS CONSTRUCTION.*

By Captain F. S. STONEY, R.A., Assistant-Superintendent Royal Gun Factories, Woolwich.

WHEN the Council of the Royal United Service Institution did me the honour of inviting me to read a paper on the construction of heavy ordnance, my first impulse was to refuse, because I knew well the magnitude of the subject, and my own inability to deal with it properly; but on second thoughts, I considered that such conduct would be moral cowardice on my part, as well as ungrateful towards this Institution, the benefits of which I have been silently enjoying for several years back. I consequently consented to read a paper, resolving, however, to confine my observations to our own guns—the Government guns which are actually in our land and sea services—and to avoid as much as possible any invidious mention of foreign ordnance, or of the merits of the various experimental systems, the inventors of which are for the most part both able and willing to advocate their own cause.

Hence it is that I appear before you to read a paper on “The Pro-

* Portions of this paper have appeared in the Royal Artillery Institution Proceedings,—F. S. S.

gress of our Heavy Ordnance, and the Principles and Processes of its Construction." The subject is one of immense Military moment, for of all weapons of war, the big gun is of paramount importance to Great Britain. Continental nations may rely on their infantry breech-loaders, or on their numerous field artillery; but to England,

Whose march is o'er the mountain wares,
Whose home is on the deep,

heavy artillery is an absolute necessity of imperial existence; for no one whose mind is not narrowed by regimental prejudices will attempt to deny that our insular country, with its wide spread colonies and extensive commerce would cease to rule the seas if the Union Jack, afloat and ashore, waved over less powerful guns than those of our neighbours. But this point is so obvious to the professional audience which I am addressing that I will not dwell any longer upon it, but pass on at once to my subject, which is really so extensive that the utmost I can hope to do within the prescribed time is to bring the leading features of it to your notice.

What, then, do I mean by the progress of our heavy ordnance? Simply this. The battles of the Nile, Trafalgar, and all the other naval actions about the beginning of this century, were fought and won with no heavier pieces than 68-pounder carronades of 36 cwt., for short ranges, and 32-pounder guns of 56 cwt.; and that if we went to war to-morrow, some of our ships—the "Captain" and "Monarch" to wit—might go into action with 12-inch guns of 25 tons, capable of penetrating any hostile ironclad afloat at short ranges; or, if distant firing were required, capable of throwing their 600 lb. projectile into a moderately sized magazine two miles away.

I will now very rapidly trace this progress of our heavy ordnance. The first marked improvement, after Lord Nelson's time, was made about 1830 by General Millar, R.A., the head of the Gun Factories at Woolwich, who introduced the 8-inch and 10-inch shell guns, for horizontal firing. Ten years afterwards, *i.e.*, in 1840, Mr. Monk, Chief Clerk in the Department, proposed the 42-pounders and 56-pounders; and subsequently to this, Colonel Dundas, R.A., who succeeded General Miller, introduced 68-pounders—a great stride, as it was then thought, in the progress of heavy ordnance, and so indeed it was; but the supremacy of the 68-pounder was not of long duration. It is no longer a heavy or a powerful gun, according to modern artillery ideas. It has been dwarfed by its big rifled brothers of recent date; but the origin and growth of rifled ordnance constitute such an important and novel era in the history of artillery, that I must henceforward proceed with greater deliberation and detail, premising that my facts and figures are principally taken from published official documents.

When the Crimean war was impending, the general adoption of rifled small arms necessitated the introduction of rifled ordnance, in order that artillery might still retain its superiority over infantry, and remain, as before, the principal arm in the field, which certainly would not be the case if an enemy's skirmishers had the power of

placing a battery *hors de combat* before its too-short ranged guns could be brought into action on the advancing columns.

To supply this great want in warfare involved a complete reformation in the architecture of artillery, which had been almost at a standstill since the time of the Tudors; for although modifications had been occasionally made in the manufacture of ordnance, any one who examines the old guns in the Tower of London, or in the Museum of Artillery at Woolwich, may see that they are of the same genus as modern smooth-bores, and even notice some specimens quite as soundly and as artistically cast as any of those of the present century, nay more, he may infer that our modern cast guns can scarcely be superior to their prototypes in range-power, or susceptibility to rifling.

It is, however, worthy of note, that this stagnation in the construction of ordnance was not to be attributed to ignorance of the theories of gunnery, but to the backward state of metallurgy and mechanism, for professional as well as amateur artillerists have, even at remote periods, understood the value of rifled guns, but their endeavours to obtain them were rendered abortive by the want of suitable materials and proper machinery.

Such being the state of the case, it was indeed fortunate for the ascendancy of artillery that, owing doubtless to the spread of railways, suspension bridges, &c., &c., the requisite improvement in metallurgy and in mechanical appliances should have opportunely taken place in recent years. It is only of late that the manufacture of cast-steel as a material for rifled ordnance has made rapid progress, whilst the difficulties which used to attend the forging of wrought-iron in large masses were so great that a heavy anchor was one of the greatest achievements of the forge-master until the comparatively recent introduction of steam-hammers enabled him to forge our modern monster guns. But, thanks to the able mechanics of the day, we have now rifling machines so perfect and so easily manipulated that the operator could, if he pleased, engrave his name in the bore of a gun, and withal so accurately is their action, that they work "true" to less than $\frac{1}{1000}$ th of an inch, a dimension which can now be very easily measured by means of a Whitworth's micrometer, but which is fifty times too minute to be ascertained by the primitive measuring instruments of the last generation of mechanics.

In the lull which succeeded the Crimean campaign, the continental nations turned their attention to the rifled artillery problem. The Emperor Napoleon III was particularly energetic in the matter, and the French rifled field gun contributed nearly as much to the defeat of the Austrians at Solferino, in 1859, as the Prussian needle-gun did to their defeat at Sadowa seven years afterwards.

Meantime, the Indian mutiny did not prevent our own authorities from carrying on careful and comprehensive experiments with breach-loader rifled guns, on Mr. (now Sir William) Armstrong's system, which he brought first to official notice in December, 1854.

At the same time, extensive experiments were carried on to test whether any safe method of strengthening cast-iron guns could be found, or whether any better, speedier, or cheaper system of construct-

ing rifled ordnance existed than that proposed by Sir William Armstrong. None such having been found within the period for inquiry, the Armstrong system was completely adopted;* and in order to obtain a supply of the guns and projectiles as soon as possible, so that we might not be behind other nations, Government not only entered into a contract in January, 1859, with the newly-established Elswick Ordnance Company, but commenced their manufacture in the Royal Arsenal, Woolwich.

Our field artillery was soon furnished with the new field guns, and a goodly number, especially of the larger natures, were, at the urgent request of the Admiralty, supplied to the fleet, and subsequently the whole series of Armstrong guns, from the 6-pounder of 3 cwt. to the 7-inch of 82 cwt., was added to our armaments.

These breech-loaders were used on active service in China, New Zealand, Japan, and Cape Haytien (1866); and although they did not play their part so perfectly well in the heat of action as at their quiet rehearsals at Shoeburyness, their performance, on the whole, was excellent, and fully justified their adoption by the Government. But it is the heavier natures—7-inch and 40-pounders—which most concern now; they were used both at Japan and Cape Haytien, and especially at the latter place, with great success.

Notwithstanding the progressive excellence of his breech-screw guns, Sir William Armstrong introduced not only two natures of wedge-guns (40-pounders and 64-pounders) as an improvement on the breech-screw arrangement, in points of safety and simplicity, but also 64-pounder muzzle-loading guns with shunt rifling, and proposed other shunt guns of larger calibre.

As was natural, however, in this mechanical age and country, Sir William Armstrong was not permitted to bear away the palm without a contest.

Various propositions for rifled guns were submitted to the Ordnance Select Committee, and in 1858 General Peel, the then Secretary of State for War, "called upon Colonel Lefroy, his scientific adviser, for a report on all the experiments that had been tried on rifled ordnance," and in accordance with the recommendation of that report, appointed a Special Committee to examine as to what was the best rifled gun for field service. This Committee came to the conclusion that it was not expedient to incur the expense of trying further experiments with any except those of Messrs. Whitworth and Armstrong.

The trial accordingly took place; but as at that time Mr. (now Sir J.) Whitworth did not propose any gun of his own construction, and had only rifled Government blocks of brass and cast-iron, the Armstrong breech-loading gun, which was complete in every respect, was, as we have seen, adopted. Nothing daunted, however, Mr. Whitworth carried on a series of private experiments, and having perfected his plans, he obtained such good results with his guns that he again challenged the rival system which the Government had adopted.

A Special Committee was then appointed, 1st June, 1863, to examine

* Report of the Select Committee on Ordnance, 1863.

and report upon the different descriptions of guns and ammunition proposed by Sir W. Armstrong and Mr. Whitworth.

The inquiry was to embrace the comparative qualities of the several systems with respect to range, accuracy, endurance, ease of working, cost, &c., the fitness, in short, of the guns and ammunition for the various purposes to which ordnance may be applied either on land or sea service.

The Committee accordingly made patient and extensive competitive experiments with Whitworth 12-pounders and 70-pounders, Armstrong 12-pounder and 70-pounder breech-loaders, and Armstrong 12-pounder and 70-pounder muzzle-loaders; the 12-pounders having been chosen to decide the question for field artillery, whilst the 70-pounders were the best available representatives of heavy artillery, comprising siege, garrison, and broadside guns.

The Whitworth guns were muzzle-loaders, and had his well-known hexagonal rifling, and mechanically fitting projectiles.

The 12-pounders were of solid mild steel (having trunnion rings screwed on to them) with a hoop of the same material over the powder chamber.

The 70-pounders were of the same material, but consisted of an inner tube closed by a breech-screw and strengthened by hoops pressed on cold by hydraulic pressure.

Sir William Armstrong, who declared that his system was not limited to breech-loaders, put forward both breech-loaders and muzzle-loaders for competition; both were constructed with steel barrels, and with wrought-iron coils superimposed as usual.

After a searching examination of important witnesses, and complete and comprehensive trials, which cost over £30,000 for stores &c., and which lasted two years and a half, the Committee concluded their labours.

The results of these experiments were very creditable to both inventors, especially as regarded the construction of their respective guns, each of which, after firing about 3,000 rounds, was only burst at last by abnormal means; but the report was, on the whole, most in favour of the Armstrong muzzle-loaders, and among the points of the utmost importance to gunnery, which the Committee established in the course of their experiments, are the following:—

“That muzzle-loading guns can be loaded and worked with perfect ease and abundant rapidity.

“That guns fully satisfying all conditions of safety can be made with steel barrels, strengthened by superimposed hoops of coiled wrought-iron, and that such guns give premonitory signs of approaching rupture; whereas guns composed entirely of steel are liable to burst explosively, without giving the slightest warning to the gun detachment.”

The expensive and extensive experiments of the Armstrong and Whitworth Committee and the conclusions they arrived at in favour of the former system, which has since been brought to such simplicity and perfection in our present service guns, are very interesting and suggestive at the present moment, when a further trial of Sir Joseph

Whitworth's guns is said to be smiled upon by the powers that be. But I have referred to the facts of the case because they bear directly on the construction of our heavy guns; and save me the trouble of discussing the merits of the various materials for ordnance, except to say that all our experience up to the present corroborates the opinion of the Committee that steel from its hard and elastic nature is the best material for the inner barrel, and that coiled wrought iron is the most suitable for the exterior parts, as its pliant and fibrous character checks and counteracts the explosive tendency of the steel.

Necessity for heavy M.L. Rifled Guns.

It is remarkable the effect which rifled guns had on the science of artillery. Although rifled guns were made more powerful than the smooth-bore 68-pounders, they soon became insufficient for the modern requirements of naval warfare, for the power and precision of rifled guns and the growing use of concussion shells which would burst on striking on a ship's side and make a hole beyond repair, or having penetrated, would burst between decks, dealing death and destruction around, and probably setting fire to the vessel, necessitated the use of ironclads. To penetrate these necessitated in turn still more powerful guns, and then commenced the Shoeburyness campaign of guns *versus* armour plates, which is not yet decided.

The judgment which the Armstrong and Whitworth Committee pronounced in favour of muzzle-loading guns was only in accordance—so far at least as heavy guns were concerned—with the preconceived opinion of our leading artillerists, for any breech-loading arrangement with guns using the enormous charges required would not only be too cumbersome but actually unsafe.

As the striking effect of a projectile depends more on its velocity than on its weight, and as a round shot fired from a smooth-bore gun has considerably greater initial velocity than an elongated shot fired from a rifled gun, owing to the friction in the bore of the latter, as well as to its smaller proportionate charge, the Admiralty at first proposed wrought-iron smooth-bore guns of large calibre to penetrate armour-plated vessels at close quarters. Accordingly in 1864, after mature experiments, two natures of wrought-iron smooth-bore guns were adopted; these were the 100-pounder of 9" calibre, and 150-pounder of 10·5" calibre. They were built up on the Armstrong coil principle, but only about fifty of the former, and a dozen of the latter were made, as it soon became evident that still more potent guns were necessary; and that we could make them too in the shape of wrought-iron M.L. rifled guns. In fact, such good results were obtained from the 64-pounder M.L. shunt gun (which was approved as a sea service gun March 10, 1865), as well as from larger experimental guns on the same system of rifling and construction, that the O.S. Committee suggested (Report No. 3553, 25/11/64), that the above two natures of smooth-bore guns should be also rifled on the shunt system.

But the shunt-rifling itself was eclipsed in 1865 by the "Woolwich" system, and as the steps which led to this result throw con-

siderable light on the whole system of rifling, they will be briefly referred to.

By instructions first received from Lord Herbert in 1859, the O.S. Committee carried on an extensive trial of cast-iron 32-pounder guns rifled for different gentlemen in accordance with their respective views as to the best way of rifling the existing store of smooth-bore cast-iron guns.

The result of this competition simply proved that cast-iron was altogether too weak and precarious a material for rifled guns.

The trial was then extended to wrought-iron guns rifled on the respective systems of Commander R.A.E. Scott, R.N., Mr. Lancaster, Mr. Jeffery, and Mr. Britten, who with Messrs. Lynam Thomas, Hadden, Nasmyth and Whitworth, were rivals in the cast-iron competition.

A gun rifled with French grooves and another gun with shunt grooves were also tried.

All the guns selected for competition were 7-inch muzzle-loading guns of 7 tons, built on the Armstrong coil principle, and having inner barrels of steel.

Experiments were carried on which tested these competitive guns in all the cardinal virtues of ordnance, and though the shooting qualities were alike, the O.S. Committee in their final report, No. 3730, dated 1st May, 1865, recorded their unanimous opinion in favour of the so-called French system:—

1. "Because of the simplicity of its studding on the projectiles.
2. "The simplicity of the grooving of the gun, and
3. "From a disposition to admit the advantages of an increasing "over a uniform spiral."

And further, the Committee recommended "that the heavy 7-inch guns then in course of manufacture should be rifled in the same manner as the competitive so-called French gun, except that the width and depth of the grooves should be slightly decreased, and that 8-inch and 9-inch guns also should be completed with similar rifling." Fig. 1, plate XVIII, shows a section of the modified groove.

The Woolwich Guns.

This was the origin of those powerful pieces of ordnance known by the comprehensive term of "Woolwich guns," a binomial which may be expanded into "wrought-iron muzzle-loading guns built on Sir William Armstrong's principles improved by Mr. Anderson's method of 'hooking' the coils, and with solid-ended steel tubes toughened in oil and rifled on the French system, modified as recommended by the O.S. Committee for projectiles studded according to Major Palliser's plan."

It is now time to consider the principles of this construction.

To Sir William Armstrong is undoubtedly due the merit of employing wrought-iron coils shrunk together. His main principles of gun architecture consist essentially—

Firstly, in arranging the fibre of the iron in the several parts of

Fig. 1.



Fig. 2.

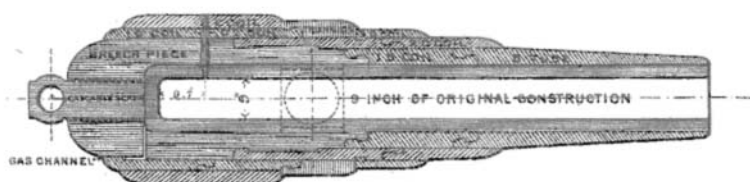


Fig. 3.

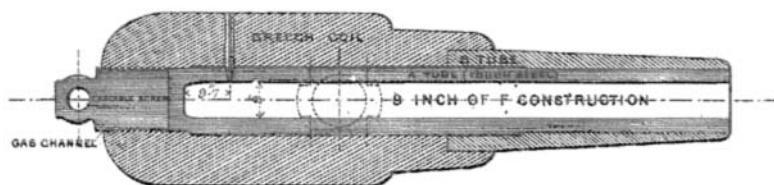
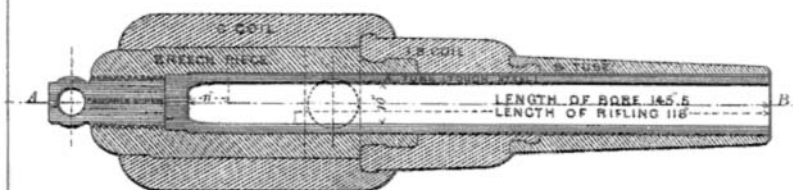


Fig. 4.

WROUGHT IRON MUZZLE-LOADING GUN 10 INCH 18 TONS.



the gun, so as best to resist the strain to which they are respectively exposed; thus the walls or sides of a gun are composed of coils with the fibre running *round* the gun, so as to enable the gun to bear the transverse strain of the discharge without bursting; whilst the breech end is fortified against the longitudinal strain, or tendency to blow the breech off, by a solid forged breech-piece with the fibre running *along* the gun. Secondly. In shrinking the successive parts together, so that not only is cohesion throughout the mass ensured, but the tension may be so regulated that the outer coils shall contribute a fair share to the strength of the gun.

With regard to the first principle, a gun may be destroyed either by the bursting of the barrel, or by the breech being blown off. Now wrought-iron in the direction of its fibre is about twice as strong as it is in the cross direction; hence the best way to employ it to resist the transverse strain is to wrap it round and round the piece like a rope. This is the foundation of the Armstrong coil system. For a similar reason the best way to resist the longitudinal strain is to place the fibre lengthways or end on; so a breech-piece was made from a solid forging with the fibre in the required direction.

With regard to the second principle, the strength of a gun is not proportional to its thickness. The interior of a homogeneous gun bears the brunt of the discharge, while the exterior parts are scarcely affected. The exact law which regulates the amount of resistance offered to the discharge, by each lamina of the gun is not precisely known, but it is admitted that *a gun should, if possible, be so constructed that each part of its mass would do its due proportion of work at the instant of firing.*

Sir Wm. Armstrong endeavours to carry out this theory by giving, through means of shrinking, greater tension to the outer coils than to the inner ones, so that the former do a certain amount of work in compressing and energetically supporting the latter, which are thus strengthened at the expense of their exterior neighbour, and the theory is further carried out by the employment, in addition, of a stronger material (steel) for the inner barrel.

You will observe that although our breech-loaders are commonly called "Armstrong guns," the muzzle-loaders built on the same principles have an equal right to that honourable title; but seeing that there were many modifications made by various people with regard to the rifling, &c., they have been, as already stated, styled "Woolwich guns." And this name should still, I think, be applied to the present guns, for they are a modification of the original ones, and that modification is the fruit of the Royal Gun Factories at Woolwich.

"Woolwich guns" of 7-inch, 8-inch, 9-inch, 12-inch, and 13-inch calibre—very few, however, of the higher natures—were made up to the close of 1866 on the "Armstrong" or "original" single coil system. As a type of the rest, I will briefly describe the construction of the 12-inch gun of 23½ tons.

This gun consists of a solid-ended steel barrel, a forged breech-piece, a trunnion-ring, a cascable, and nine coils—thirteen separate parts.

The steel cylinder having been bored for a barrel and toughened in oil, is turned on the exterior to suit the interior of the breech-piece, which has been built by a series of wrought-iron slabs successively welded together and then drawn out, bored, and turned. The breech-piece will not fit on the steel tube, both being cold, the difference in size being the designed shrinkage. The breech-piece must, therefore, be expanded by heat until it is sufficiently large enough to go over the end of the steel barrel, where it is allowed to cool and contract or shrink.

The screw is then cut for the cascade, and the mass taken to the turnery and turned down for the 1·B coil,* which is shrunk on. The mass is then turned down in succession for the 2·B tube, which is composed of two coils united together. This is shrunk on, and so on coil by coil, until the whole gun is built or shrunk up. The gun must still be turned on the exterior to its proper shape, rifled, proved, sighted, &c., &c., before fit for issue.

So far as strength and efficiency were concerned, these guns were nearly all that could be desired, but their expense, £100 a ton in round numbers was a serious point, and to diminish it Colonel F. A. Campbell, who succeeded Sir W. Armstrong as superintendent of the Royal Gun Factories in 1863, set practically and patiently to work. Two questions presented themselves for solution.

(1.) Could not a coarser and cheaper iron be obtained which would be sufficiently strong for the exterior of the gun?

(2.) Could not the guns be constructed in a simpler and cheaper form?

By personal visits to most of the leading ironmasters, and by a series of experiments, Colonel Campbell had already found a very superior and satisfactory iron for the inner barrels of B.L. guns, and by following up his success, he now obtained a very cheap iron sufficiently strong for the exterior of our heavy guns, whilst in the plan of construction proposed by Mr. R. S. Fraser, C.E., Royal Gun Factories, he discerned a still more gratifying solution to the second question.

Mr. Fraser's plan is an important modification of the original method, from which it differs principally in building up a gun of a few long double or triple coils instead of several short single ones and a forged breech-piece.

For example, in addition to the steel barrel and cascade, a "Fraser" gun of the pattern most generally followed has only two separate parts, viz., the breech coil and B tube (or as they are sometimes familiarly called "the jacket and trowsers") whereas the 9-inch gun of original construction has a forged breech-piece, a B tube, a trunnion ring and seven coils—ten distinct parts—which are shrunk on separately. (See Figs. 2 and 3, plate XVIII.)

The formation of a double or triple coil is a simple forge operation, but great expense is saved by its means, as there is so much less surface to be bored and turned, for each coil having to be made as smooth as glass and at the same time true to gauge (to a thousandth of an

* The various coils are lettered as a ready mode of description.

inch) it follows that it must be cheaper to have a few thick ones in lieu of many thin ones. For the same reason there is also less waste of material, for although the turnings are afterwards worked up into bars, iron in its scrap state is only worth one-third of its forged value.

Moreover, time and labour are also saved in having fewer pieces to move from workshop to workshop; for instance, in the case of a gun of original construction, when a coil was shrunk on, the mass had to be moved from the shrinking pit to the turning lathe, and turned down for the next coil, and so on, coil by coil, until the gun was built; but in the new construction, only two or three separate shrinkings are required; and it is computed that where 50 tons were moved in the former case, only seven are moved in the latter.

From these circumstances, combined with the employment of cheaper iron, a "Fraser" gun can be made at two-thirds of the cost of a gun of the same nature as originally manufactured.

But it will be naturally asked, is this cheap construction as strong as the old one?

With respect to theory it may be urged in its favour, in the first place, that a forged breech-piece (which is a comparatively expensive article, and liable moreover to fly into fragments should the gun burst) is not required with a solid-ended steel barrel and long thick coils, although it is absolutely necessary with several short coils to compensate for the longitudinal weakness of their several joints. The whole of the wrought iron therefore can be *coiled* round the barrel and thus give extra transverse strength. Again, the trunnion ring, which was merely shrunk on in the original construction, is *welded* on to the breech-coil in the Fraser construction, so there is no fear of the slipping which sometimes took place in the early Armstrong guns.

With regard to the second Armstrong principle already stated, although a series of thin coils help us to distribute the induced strain on a gun by shrinking on each coil separately, the method is open to the serious objection that it is practically difficult to calculate the respective proportionate amount of tension, and consequently the greater the number of pieces in a gun, the more likely some weakness will exist in the mass owing to the undue strain on some of the parts; for instance, a 13-inch gun of original construction (Experimental No. 300) split some of its outer coils while the interior ones remained uninjured, thus clearly proving that there was too great strain on the former. Shrinking on the coils successively was adopted by Sir William Armstrong as a convenient mode of adhesion and not on the distribution theory, which was subsequently enunciated. In the formation of a triple coil it is generally a manufacturing necessity to have the first coil cold before the second bar is wound on, but the third bar is wound on while the second coil is hot; the second and third layers therefore cool and contract simultaneously, and are kept in a state of tension by the first, which they compress to a certain degree. So here also the theory may be carried out, for assuming that iron expands irrespective of its density, the three layers could not recover their natural condition on subsequent heatings.

But "one fact is worth a cart-load of argument;" and one grand

decisive fact bearing on this question was the favourable result of the trials for comparative endurance which 64-pounder and 9-inch specimen guns on the cheap construction underwent, and in virtue of which it superseded the original single coil system of Sir William Armstrong at the close of 1866.

Again, when two years afterwards a "Fraser" 9-inch gun burst at proof, although hundreds of the same sort had stood the proof without wincing, and although it was evident that the gun which failed had a defective steel barrel, nevertheless, to make assurance doubly sure, as well as to ascertain which of the two constructions proposed by Mr. Fraser was the stronger, two 9-inch guns were subjected to a very severe test with most satisfactory results, as I will now explain. I must tell you, however beforehand, that as a measure of precaution, the authorities in 1866 had limited the service of a 9-inch gun to 400 rounds, of which not more than 150 should be with battering charges.

9-inch gun No. 1 consisted of five parts, viz., a thin steel barrel, a *B* tube, two breech coils, and a cascable. It had previously fired 500 rounds with full charges (30 lbs.) and 214 with battering charges (43 lbs.), the vent being at the rear—a fact which causes less strain on the gun than when the vent is further forward. The old vent having been plugged, and the gun vented on the underside in the service position, *i.e.*, about $9\frac{1}{2}$ inches forward, it was subjected to a crucial test of 500 rounds with battering charges at the rate of 50 rounds a day—an ordeal which it accomplished most triumphantly 11th March, 1869. So that this gun fired altogether 1,114 rounds, of which 714 were with battering charges—a great increase on the number of rounds laid down for the service of a 9-inch gun.

No. 2, a new 9-inch gun, of the service pattern, that is, re-inforced with a triple coil, like the gun that burst, was then subjected to the same test as No. 1 had undergone, in order to ascertain which of the two modifications of the new construction was the stronger. It fired 400 rounds with full, and 207 with battering charges, with the vent in rear; it was then turned over, vented in the service position, and the second part of the programme, namely, 500 rounds with battering charges, was commenced. At the 100th round, the impressions showed a faint crack in the steel tube at the crown of the bore. This increased regularly to the 401st round—that is, the 1008th round of all—when the gas escape indicated that the breech end of the tube was split right through. After this the gun fired 41 rounds, and then at length, at the 1049th round, the *A* and *B* tubes were bodily forced about an inch forward. This closed the vent, and consequently put an end to the trial.

The result was deemed most satisfactory, not only because the steel tube failed so gradually, but because the great strength of the outer fabric—the point at issue—was proved beyond all doubt by the gun actually firing 41 rounds after the tube was split through, and yet remaining sound exteriorly.

Both guns behaved so exceedingly well under trial, that the authorities were left in the pleasant dilemma of not knowing which pattern to choose, No. 1, with a steel tube 2 inches thick, and re-inforced with

two double coils, surviving the trying ordeal. No. 2, with a steel tube 3 inches thick, and re-inforced with one massive triple coil, did not, it is true, complete the test, but it refused to yield, although its tube was split.

With respect to the precise pattern for future construction, it would, perhaps, have been the safest course to have continued firing No. 1 gun, and then, if it did not blow its breech off (its tube being so thin), or burst explosively without giving ample warning, to have adopted it as the pattern of all the heavier natures. The authorities, however, have decided on constructing 7-inch and 8-inch guns as before, on the No. 2 type, but to make 9-inch guns and upwards, on the No. 1 type.

You will now observe that the adoption of the present construction is not due to the caprice of an individual authority, or to the Parliamentary influence of an inventor, but that it is the ripe fruit of ten years of the most scientific and exhaustive experiments which the artillery world has ever seen.

Present state of the Question.

The question then stands thus:—Up to April, 1867, all our heavy guns were made on the original construction, like the 9-inch gun, Fig. 2, and from that date up to the present nearly all have been made like the 9-inch gun No. 1, or Fig. 3,—i.e., consisting only of four parts, viz., steel tube, cascable, *B* tube, and breech coil, and 7-inch and 8-inch guns will still be made in the same way. Of all these the 9-inch gun is the most important; it is very powerful for its weight, and has been made in considerable numbers; it is therefore taken as a type of the most common form of the present construction, and its manufacture will now be described in detail.

The alteration in future manufacture for 9-inch guns simply consists in having a thinner steel tube and two coils on the breech, instead of one triple one; or perhaps the difference in construction will be more readily remembered by using the familiar illustration, and saying that in the former instance the steel tube is enveloped in “jacket and trousers,” whilst in the latter it is thinner, and has “jacket, waistcoat, and trousers.” The higher natures are made in the same way, but have a “belt” in addition.

Details of the Manufacture of a 9-inch Gun, Fig. 3.

The gun consists of—

- An inner barrel or tube of steel.
- A *B* tube.
- A breech coil.
- A cascable.

The Inner Barrel.

The inner barrel, which when in the gun weighs only 36 cwt., is made from a solid forged cylinder of cast-steel, weighing 67 cwt., which is supplied to the Royal Gun Factories by the contractors,

Messrs. Firth, of Sheffield. Casting is necessary, not only for the purpose of obtaining a sufficiently large block of steel, but also for making the block homogeneous and uniform in density. Forging, or drawing out the cast block imparts to it the desirable properties of great solidity and density.

The block is sent to the Royal Gun Factories, where it is subjected to the following tests and treatment.

A slice is cut off from the breech end and divided in pieces for testing. Some of these are flat bars, 4 inches long and $\frac{3}{4}$ by $\frac{3}{8}$ in section, and others are of the shape usually tested in the machine for tensile strength and elasticity. Three of the former are marked respectively *S*, *L*, and *H*. One end of the *S* or soft (*i.e.*, untempered) piece is gripped in a vice, whilst the other end is hammered down towards it, to ascertain that the steel, by bearing this bending without cracking, is naturally of the mild quality required. The *L* and *H* pieces are raised to a low red, and high heat respectively, immersed in oil, and, when cold, treated in a similar manner.

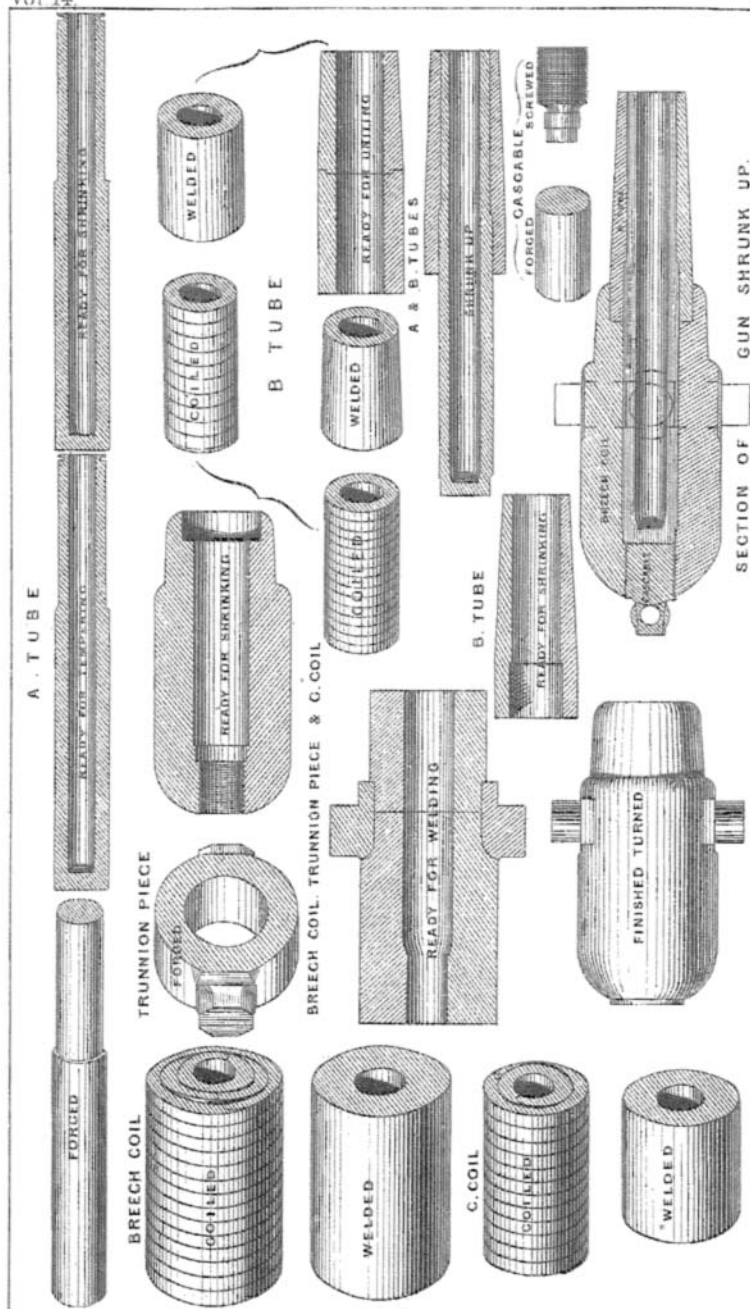
Whichever of these pieces bears the hammering best, determines the heat at which the whole tube is to be toughened. Should neither piece answer, others at intermediate temperatures are tried, and if all fail, the block is returned to the contractors; but some specimen having succeeded, as is generally the case, two of the remaining pieces—one in its soft state, and the other toughened at the ascertained temperature—are tested for tensile strength and elasticity.

A steel ingot or block which stands all the foregoing tests is "rough turned." In this operation a lip or collar is formed at the muzzle, to facilitate the lifting of the tube in and out of the furnace and oil bath. The fine turning is not done until the *B* tube and breech coil are gauged and ready to be shrunk on.

The block is next bored roughly from the solid, $8\frac{1}{4}$ inches of diameter being taken out by one cut in segmental chips $\frac{1}{8}$ th of an inch thick.

The tube thus formed is now ready for toughening in oil. This consists in heating the roughly bored tube (from 4 to 5 hours) to the approved temperature in a vertical furnace, and then plunging it bodily into an adjacent bath of rape oil, in which it is allowed to cool and soak till next day, generally 12 hours or more.

The effect of toughening steel in oil is to increase the elasticity and tensile strength; the process, however, is not without some slight disadvantages, it not only warps the steel a little, but frequently causes the surface to crack. The barrel must therefore be slightly turned and bored, to make it straight inside and outside, as well as to remove any flaws that may have been generated. By these means the cracks are generally removed, but several tubes have been rejected in consequence of flaws still appearing to penetrate to a dangerous depth, and lest there should be any not visible to the eye, the steel barrel is subjected to the water test of 8,000 lbs. per square inch, and if no flaw is detected by the formation of moisture on the exterior, the tube is considered safe and sound. The barrel is left in this state until the *B* tube is ready to be shrunk over it.



to illustrate the most common construction of Woolwich Guns as modified by M^r. Fraser.

The B Tube.

The *B* tube is composed of two single and slightly taper coils united together. The first coil is formed of two bars joined together—one 16 feet long and $5\frac{1}{2}'' \times 4\frac{3}{4}'' \times 4\frac{3}{8}''$ in section, the other 33 feet by $5'' \times 4\frac{1}{2}'' \times 4''$. The second coil is also composed of two bars—one 18 feet by $4\frac{1}{2}'' \times 4\frac{1}{2}'' \times 4''$, and the other 31 feet by $4'' \times 4'' \times 3\frac{1}{2}''$.

The two coils, being made and welded in the usual way, are faced and reciprocally recessed to the depth of about one inch, and then united together endways by expanding the faucet of one coil by heat, and allowing it to shrink round the spigot of the other. This sticks the two coils sufficiently tight together to admit of the tube thus formed being placed upright in a furnace, whence, when it arrives at a white or welding heat, it is removed to a steam hammer, and receives on its end six or seven pressing blows which weld the joint completely. The weight of the tube in this rough state is about $55\frac{1}{2}$ cwt., but when finished, as it is on the gun, it only weighs 31 cwt.

The *B* tube is next "rough turned," in which process a rim is formed near the muzzle for the convenience of lifting the tube in "shrinking." After this, the tube is "rough" and "fine bored" in the same horizontal machine.

The interior of the *B* tube having thus been brought to the degree of smoothness requisite for close contact with the steel barrel, is gauged every twelve inches down the bore, and also at the shoulder. To the measurements thus obtained, the calculated amount of shrinkage is added; a plan is made out according to which the exterior of the *A* tube (or rather that portion of it on which the *B* tube is to go) must be turned down, in order that it shall be exactly larger than the bore of the tube by the required amount of shrinkage at the respective parts.

The plan is made on a slip of paper, and together with a corresponding series of accurately measured horseshoe gauges, is furnished to the turner, who turns down the muzzle end of the *A* tube accordingly.

The reason an *inner* tube is turned to suit an exterior one, instead of the latter being bored to suit the former is, that it is much easier to turn than to bore to very exact dimensions, on account of the great command which the operator has over the turning lathe, and the facility he has of testing his work by gauges, and correcting it by emery powder and oil.

The Breech Coil or Jacket.

The breech coil or jacket is composed of a triple coil, a *C* double coil, and a trunnion ring, made and welded together as follows:—

The *triple coil* is made of three bars all of the same section, viz.— $4\frac{1}{2}'' \times 4\frac{1}{2}'' \times 4''$, but differing of course in length, the first or innermost one being 78 feet, the second 118 feet, and the third 158 feet in length, the middle one being coiled in the reverse direction, so as to break joints. In order to weld its folds, it is placed in a furnace for about ten hours, at the end of which time it is at a welding heat, whereupon it is rapidly transferred to a powerful hammer, and receives

a few smart blows on its upper end, which close the folds longitudinally. A mandril somewhat larger in diameter being then forced down it, it is turned on its side, and well hammered all round to make it dense. It is replaced in the furnace for about six hours, and the same process repeated at the breech end, but with a smaller mandril.

When cold, the ends are faced and the outer coil is turned down at the muzzle end to form a shoulder 14" long for the reception of the trunnion ring.

The *C* coil is made of bars of the same section as those used for the triple coil. The inner bar is 46 feet in length, and the outer one 69 feet. This double coil being welded, has a shoulder formed on the lower end about 9 inches long and $\frac{3}{4}$ inch deep, so that it may overlap the trunnion in the welding.

The trunnion ring is made like all wrought-iron trunnion rings—namely, of slabs of iron consecutively welded together on the flattened end of a porter bar, and gradually formed into a ring by means of, first, a small iron wedge, which is driven through the centre and punches an oval hole, and then by a series of taper mandrils increasing in size, which make the hole sufficiently large and round. The trunnion ring has to be heated for each punching, and the occasion is used to hammer the trunnions roughly into shape, one of which is in continuation of the porter bar. Eventually the ring is cut off from the bar by means of strong blunt hatchets of steel hammered through it. The trunnion ring is next roughly bored out.

All three parts (breech coil, *C* coil, and trunnion ring) being thus prepared, the trunnion ring is heated to redness, lifted by a crane, and dropped on to the shoulder of the triple coil, which is placed upright on its breech end for the purpose.

While the trunnion ring is still hot, the *C* coil is dropped down upon the front of the triple coil, through the upper portion of the trunnion ring which was left projecting. The trunnion ring thus forms a band over the joint, and in cooling contracts round the two coils, and grips them sufficiently tight to allow of the whole mass being placed bodily in a furnace, where it is raised to a welding heat in about thirteen hours (see diagram, breech coil, trunnion ring, and *C* coil ready for welding, Plate XIX).

The glowing mass is then quickly placed on its breech end under the most powerful hammer in the department. Six or seven blows on the top suffice to amalgamate the three parts together; but to make the welding more perfect on the interior, as well as to obviate any bulging inside, a cast-iron mandril somewhat larger than the bore is forced down to within 20 inches of the breech end, a series of short iron plugs being used to drive it down. The mass is then reversed, and the mandril is driven out with the same plugs, which have fallen out in the tilting over.

The rough jacket thus made weighs over 16 tons, but this weight is reduced to 9 tons by the turning, rough and fine boring, &c., which are necessary to bring it to the proper size and shape.

The body is turned in a very powerful lathe, weighing, with its

foundation, 100 tons, to the required shape. The operation takes sixty hours; consequently all the four big lathes, which are in a row, may be often seen at work together, and a fine mechanical spectacle it is.

It being impracticable to turn down the trunnion belt in a lathe, it is slotted smoothly down by a self-acting vertical machine with a double motion, one of which moves the jacket round for a fresh cut at every stroke of the tool which the other works up and down accordingly.

The trunnions themselves have yet to be turned down to shape; so the jacket has to be moved for the purpose to another machine—a break lathe—in which it is made to revolve on the axis of the trunnions, while the sliding cutters act on their surface.

The jacket is next rough and fine bored in a machine like that used for the *B* tube, but stronger, and the front of the *C* coil is recessed on the inside to a depth of 9 inches, and broad enough to overlap the *B* tube.

Finally, the female thread for the cascade is cut by a machine in which the jacket revolves horizontally, while the cutter is fed forward by a copying screw—one pitch for every revolution of the jacket.

Building up the Gun, or shrinking the parts together.

The steel barrel and *B* tube being prepared for one another as described, are shrunk together in this manner:—The *B* tube is placed on a grating, and heated for about two hours by a wood fire, for which the tube itself forms a flue, until it is sufficiently expanded to drop easily over the muzzle end of the steel barrel, which is placed upright in a pit ready to receive it. The *B* tube is then raised, and the ashes, &c., being brushed from the interior, is dropped over the steel barrel by means of a travelling crane overhead. During the process of shrinking, a stream of cold water is poured into the steel barrel, to keep it as cool as possible, the water being supplied and withdrawn by a pipe and syphon at the muzzle. A ring of gas is placed at the muzzle or thin end of the *B* tube, to prevent its cooling prematurely, whilst jets of cold water play on the other end, and are gradually raised to the muzzle, for the purpose of cooling the whole tube consecutively from the breech end, which it is desirable should grip first, to ensure a tight fit at the shoulder. Moreover, were both ends allowed to contract simultaneously, the intermediate part of the tube would be drawn out to a state of longitudinal tension, and weakened accordingly.

The *A* and *B* tubes shrunk up (see diagram), are placed in a lathe, and while one cutter fine-turns the *B* tube to its proper shape and dimension, another cutter fine-turns the breech end of the *A* tube according to the plan of the breech coil, which has been made out on a principle already explained.

The half-formed gun, composed of *A* and *B* tubes shrunk up, being next placed standing on its muzzle in the shrinking pit, the jacket is heated for about ten hours, and shrunk on in the same manner as the *B* tube; it is however (being nearly of the same thickness throughout),

allowed to cool naturally, and the cold water has to be forced up, fountain fashion, into the bore of the gun by a jet round which the muzzle rests.

The process of building up a 9-inch gun is very similar. There are, however, three shrinkings instead of only two—viz., the coiled breech-piece on the breech-end, the *B* tube on the muzzle end of the barrel, and then the outer breech coil over the inner one.

Processes after the Gun is built up and before proof.

These are :—

1. Screwing in the cascable.
2. Engraving the Royal cypher.
3. Fine-boring.
4. Second rough-cutting of chamber.
5. Finished boring.
6. Broaching of bore, and finishing of chamber.
7. Lapping.
8. Rifling.
9. Temporary venting.

(1.) *The cascable* is made of the best scrap iron. It is first forged into a simple cylinder; it is then turned, and a bevel thread cut on it. The button is turned on it, and a hole (which is afterwards enlarged into the loop), is drilled through one end, for the purpose of screwing it into the gun. The operation of screwing in the cascable requires great care, for the front of it must bear evenly against the end of the steel barrel, and in order that this may be the case, the end of the tube is smeared with red lead and the cascable screwed in tentatively, then unscrewed again, and filed down on the prominent parts, which are indicated by the absence of the red lead. This is repeated several times, until the equal distribution of the lead on the front shows that it bears evenly against the steel barrel.

At this stage, one round of thread is turned off the end of the cascable, so that there may be an annular space there, which in connection with a channel now cut along the cascable and across the thread, will form a gas escape, or tell-tale hole, in case the steel barrel should split at the end. The channel is about $\frac{3}{8}$ th inch broad, and extends $\frac{1}{10}$ th inch below the thread. In all guns made before the 1st September, 1869, the channel comes out directly under the loop; but in guns made since that date, it will be found at the right side of the loop, where it may be more easily noticed. The channel ought to be kept clear, and should the barrel be split at the end, some gas may be seen issuing from the hole; it is therefore advisable to keep an eye on this hole, and to cease firing, should it give warning.

When at length the cascable fits properly, it is screwed in, and to prevent its moving, a hole $2\frac{1}{2}$ inches long and $\frac{3}{4}$ inch in diameter is drilled and tapped through the male and female threads in a slanting direction on the left side, and a plug is screwed in.

(2.) While the cascable is being prepared, Her Majesty's mono-

gram is engraved in front of the vent, the outline being marked on the gun by means of a perforated brass plate, rubbed over with charcoal.

(3.) The gun is next removed to the boring mill, where it is fine-bored to 8".9.

(4.) The chamber is next roughly bored out with the same boring head as before.

(5.) The finished-boring to 8".997 is then performed.

The fine-boring and the finished-boring are effected with the boring-head used in the second rough boring, and together occupy twenty-six hours.

(6.) In each boring the cutters wear a little during the operation, so that the bore becomes slightly taper towards the breech. This is of no consequence in an outer tube, as the exterior of the inner one can be turned accordingly, but the bore of the gun must be cylindrical, so broaching is employed—that is, boring the barrel by means of a cylindro-conoidal head, fitted with four long cutters at right angles to one another, and slightly tapering. The cutters are edged on the front as well as on the side, as the chamber is also finished off at this time, and for this latter purpose there is also a peculiar centre cutter for the very end of the bore.

(7.) Still, however, the bore is not yet truly cylindrical, and "LAP-PING" is resorted to. In this no cutter is used, but a wooden head, covered with lead and smeared over with emery powder and oil, is worked up and down at those portions of the bore which are indicated by the gauges as imperfect.

(8.) The 7-inch M.L. guns are RIFLED with a uniform spiral—i.e. with grooves having the same amount of twist at every point of the bore; and all the higher natures with a uniformly increasing spiral—i.e. uniformly increasing from the breech to the muzzle. The advantage of an increasing spiral is, that the inclination of the grooves, being little or nothing at the breech, the projectile's initial motion is not checked by any resistance offered to the studs. The projectile therefore moves quickly from its seat, and relieves the breech a good deal from the strain of the discharge.

The groove is of the "Woolwich" shape, 1".5 wide and 0".18 deep, with concave edges. It is the same width for all natures, but it is a little deeper for the 10-inch and 12-inch guns. The number of course varies with the calibre, 7-inch guns having three, 8-inch four, 9-inch six, 10-inch seven, and 12-inch nine.

As a rule, about two calibres in length is left plain or unrifled for a powder chamber. The exact proportion is not fixed. The unrifled part, however, should be no shorter than actually necessary to prevent a detrimental air space between the smallest charge used and the base of the projectile, as the grooving tends to weaken the barrel very much, and the seat of the charge should be the strongest part of the gun.

(9.) Previous to the 23rd January, 1868, rifled M.L. guns were left altogether unvented until after proof, at which they were fired by means of electric wires passed in at the muzzle. Since that date, all

guns are drilled and tapped before proof, and fired through a removable steel vent, which is unscrewed after proof and replaced by the permanent vent; the object of this is to prevent the proper vent being strained by the large proof charge.

Proof.

Before a gun is proved, gutta-percha impressions are taken of the whole-length of the bore in the four quarters. The gun is then proved with two rounds—the projectile being equal in weight to the service one, but flat-headed, for 7-inch guns and upwards, in order that it may penetrate as little as possible into the butt, and the charge being $1\frac{1}{4}$ th the weight of the battering or highest charge used in service. The gun is fired in the open by means of an Abel's electric tube, connected with a magneto-electric battery in a bomb-proof shed.

With the early rifled guns much larger charges were used at proof, and then service charges and a double-weighted shot were used for some time; but this was found to strain the gun too much, and the Ordnance Select Committee having thoroughly investigated the matter, and having obtained the particulars of proof of guns in France, Belgium, Holland, Austria, Spain, Saxony, Denmark, America, Wurtemberg, Bavaria, and Sweden, came to the conclusion that the proof should be based on the highest charge which the gun will have to bear on service, and recommended the present proportionate charge for rifled M.L. guns, which was approved 13th July, 1864.

After proof, water is force-pumped into the bore, with the pressure of 120 lbs. to the square inch. This was instituted for guns with wrought-iron barrels to ascertain that the breech was perfectly closed, and is still continued in the case of solid-ended steel barrels, to make sure that the end has not been split in proof. After this the gun is cleaned, and gutta-percha impressions of the bore being taken as before, the two sets of impressions are compared, to ascertain that no flaw of a serious character has been developed by proof. If any defect appears of which there is even the slightest doubt, the gun is subjected to five more rounds with service charges, and if after that the flaw does not appear to have increased, the gun is passed.

Processes after Proof and before Issue.

- (1.) Lapping.
- (2.) Obtaining preponderance and weight.
- (3.) Lining.
- (4.) Sighting.
- (5.) Venting.
- (6.) Marking, and the "marks" denoting pattern.
- (7.) Fixing on elevating plates and small fittings, sloping sides of cascable, and scoring breech.
- (8.) Painting and lacquering, and final inspection.

All the above processes, except the last, are performed in the one

workshop (the sighting room), and generally, but not necessarily, in the exact order given.

(1.) Every gun is LAPPED after proof, for the purpose of removing any little burs which may be thrown up on the edges of the grooves by the impetuous proof rounds.

(2.) The meaning of the term "preponderance" as applied to modern guns, is the pressure which the breech portion of the gun, when horizontal, exerts on the elevating arrangement.

The preponderance of heavy guns should be as small as possible, so as not to interfere with the easy action of the elevating arrangement. 5 cwt. was assigned for 9-inch guns, and between 5 and 6 cwt. for the heavier guns; but by a recent order, 13th April, 1869, all sea-service guns of 18 tons and upwards are to have no preponderance, and as this is practically impossible, it is further stated that anything under 3 cwt. will be considered as none.

The actual *weight* of each gun is taken by means of a strong steel-yard, to the short arm of which the gun is slung by the trunnions.

(4.) M.L. guns are *sighted* like B.L. guns on both sides, and with the same kind of tangent sights; but M.L. guns have in addition short centre, hind, and fore-sights. They have therefore three pairs of sights attached to the gun, and besides these there is a wood scale for use on board ship.

(5.) The *vent* in rifled M.L. guns does not enter near the end of the bore as in S.B. guns, but at a point two-fifths the length of the service cartridge from the end, for it has been proved by experiment that by igniting the cartridge at this point, the maximum initial velocity is obtained.

Up to 1st November, 1868, the vent bushes were the ordinary copper cone vents, let in perpendicularly, but at that date a new kind of vent (proposed by Major Palliser) was inserted in the 10-inch guns. This vent consisted of a steel bush, lined with copper, screwed in from the exterior, against a platinum tip screwed up from the interior, the tip having a flange or button-shaped head projecting into the bore to close the joint; and instead of entering the bore vertically, it was fixed upon the side* of the gun at an angle of 45° to the vertical axis, in order that it might be more easily served (see List of Changes, 1st December, 1868). It was subsequently decided (25th November, 1868), that all wrought-iron guns of 7-inch calibre and upwards should have similar vents, but let in vertically as before, except in the case of guns of 10-inch calibre and upwards, whose size would render the vertical position awkward.

This was acted on for a short time, but the vents not proving satisfactory, the employment of the platinum tip was suspended, and steel vents lined with copper were used; but as these too did not answer expectations, all the big guns are now vented with copper specially hardened, the letter *H* being stamped on the top to indicate the fact.

* The vent is on the right side of the gun if intended for broadside purposes, but if for a turret gun, the vent is placed on the right or left hand side as convenience demands.

The matter, however, is not yet settled; platinum-tipped vents, without the flange, are under trial. The more powerful the gun, the greater is the wear and tear on the vent. Simple copper vents are most satisfactory for guns up to a certain size, and in spite of the softness of this metal, many think it will answer for very large guns quite as well as a more costly material.

This difficulty about vents is only one of the many which have to be overcome before we can obtain heavy guns perfect in every respect.

(6.) In addition to the *marks* made in lining, and the Royal cypher before mentioned, the broad arrow and actual weight are stamped behind the vent, and two parallel lines are cut across the vent field to indicate the unrifled space. The material of the inner barrel (for example *Firth's steel*) is stamped on the face of the muzzle, as is also the number of the steel barrel as entered in the registry of manufacture.

On the left trunnion are the initials R.G.F., the register number of the gun, the numeral signifying its pattern, and the year of proof. The register number is that by which the gun is registered in the Department records; it indicates also the number of that nature manufactured. With respect to the numeral, the word "pattern" was superseded by "mark," and the construction of guns has been designated accordingly since 20th April, 1868.

(7.) *The extra fittings* or appurtenances of M.L. guns are very few and simple when compared with those for B.L. ordnance. They are limited to gun-metal elevating plates for guns for both services, guide-plates, and friction tube pins for sea service, and muzzle studs and shot bearers for land service.

(8.) The exterior of the gun being well cleaned, receives one coat of "Pulford's magnetic paint," which is now used for all iron guns instead of anti-corrosion, to which it is superior in point of cheapness and durability. The bore receives one coat of the usual lacquer.

Finally. The gun and all its fittings having been inspected, and found in exact accordance with the sealed pattern, is issued for service.

I have done little more than enumerate the processes of construction, as I have not time to describe them, but I may state generally that the manufacture of one of our big guns is a triumph of forge craft, involving a combination of strength and science in the mechanics; power and accuracy in the machines.

England has always excelled in smith work, but we can imagine the admiration and surprise which a cunning worker of old—nay, even which a scientific engineer of the last generation would express—could he but visit the Royal Gun Factories, and follow through acres of furnaces and machinery, the various processes in the manufacture of our ordnance. Here, amid the glow of a dozen fires, he would see certain quantities of scrap iron taken from an incongruous pile of old articles—such as horseshoes, linchpins, bolts, nuts, screws, locks, keys, musket barrels, door knockers, hooks, crooks, &c., &c., which a thousand different smiths must have forged—and put into furnaces to replace others just brought out at a white heat, and which he would see pressed as if they were made of cheese into "blooms" or oblong

blocks, and then, while still hot, passed through rolls (the fly-wheel of which weighs 50 tons), and formed into flat bars; other similar bars he would see made from puddled cast-iron in a like manner, but with more trouble and with a more sparkling effect, and then several of these flat bars sandwiched together, raised to a white heat, and passed through the narrow portion of the rolling mill to form one long, thick bar—the unit of the gun.

The process of welding several of these unit bars together one by one would appear familiar work; but the length of the bar thus obtained, 270 feet perhaps, would amaze him, especially when he saw it afterwards drawn at a bright heat out of a long furnace, and by means of machinery wrapped spirally round an iron mandril as easily as a cable is wound round a windlass, and then a similar bar wound round over the first, and then a third one over both.

He would see the immense coil thus created, hoisted from the furnace as white as snow and welded longitudinally so as to close its folds, and he would no doubt feel jealous of the ease and power with which the ponderous steam hammer performed a task which could not be accomplished by any number of sledges wielded by human arms. Nor would his surprise be less on seeing 7 inches in diameter of these massive forgings peeled off in a lathe weighing, with its foundation, 100 tons; nor on seeing 11 inches in diameter bored out of a solid block of steel: nor the subsequent processes by which the bore becomes as smooth as glass, and so exact in dimensions that, when tested by micrometers showing a thousandth of an inch, no error would be perceptible.

Finally, he would see the wrought-iron casings expanded by heat and shrunk over the steel barrel—thus making a gun capable, he would be told, of sending a projectile weighing over a quarter of a ton through an iron plate a foot in thickness and half a mile away, and moreover that six thousand tons weight of guns of various calibres could in one year be produced in the Royal Gun Factories!

It is thus our beautiful guns are made—beautiful not in the sense of exterior ornamentation like the Oriental guns, which are adorned with quaint figures and hieroglyphics, nor yet like our cast guns of the last century, which are ornamented with astragals, fillets, and ogees, but beautiful in their strength compared with their weight, beautiful in the simplicity and durability of their construction, beautiful in their excellence of range, accuracy, and penetration. I do not mean to say that we have reached the *ne plus ultra* in ordnance—I hope we shall still continue marching on, until artillery takes the foremost place amongst the sciences—but I mean to say that we have the best and cheapest system of heavy ordnance.

Marked progress in Heavy Artillery during the last five years.

In conclusion, I would remark that the tests and trials bearing on this question, while exemplifying the pains taken to obtain the best war *matériel*, cannot fail to satisfy the most sceptical that the present construction of our heavy guns is sound and durable, and the general

result must be gratifying to the authorities who approved of the system five years ago.

Indeed the past lustrum must always be a marked epoch in the history of our heavy artillery; for 7-inch, 8-inch, 9-inch, 10-inch and 12-inch guns have been made in numbers, and the system is applicable to still larger guns—nay, tracings have been actually furnished of 700-pounders of 35 tons, 800-pounders of 40 tons, and 1000-pounders of 50 tons, and the guns can be put in hand with every prospect of success whenever the Secretary of State for War thinks fit to order them.

But this progress in the production of heavy ordnance cannot be fully appreciated, unless the difficulty of perfecting a more powerful gun than previously existed, is properly considered and understood. In the first place, the practicability of manufacture and the durability of structure must be ascertained. The weight, calibre, length, system of rifling, weight and shape of projectile, &c., &c., must be all scientifically calculated so as to ensure excellence in range, accuracy, and penetration: and then each and all of these constructional details are liable to alteration should the thorough trial of a specimen gun at Shoeburyness render any amendment advisable. The sights too must be made, graduated, and adjusted, and finally the gun has to be vented—no easy task in the higher natures, as already observed.

Mr. Reed, Chief Constructor of the Navy, maintains that corresponding progress has been made in our ship building:—

“It is but five years ago that Parliament was discussing the practicability of carrying 6½ ton guns at sea, especially in broadside ships; we have now 12 ton guns fought at sea with perfect ease, in many of the broadside ships of the Mediterranean and Channel squadrons, and the ‘Hercules’ has long been cruising about, both at home and abroad, with 18 ton guns worked most satisfactorily at the broadside in ports 11 feet above the sea, and with a horizontal range of fire which no unarmoured ship’s broadside guns possess. The ‘Monarch’ has cruised successfully in heavy weather with 25-ton guns mounted in turrets. None but those who are hopelessly prejudiced can now doubt that, whether they be placed in turrets or out of turrets, the largest guns can be worked successfully with terrible effect at sea, and in heavier weather than the small guns of old could be fought.”*

Surveying the whole question, therefore, by the calm light of facts and figures, I think it may fairly be asserted that, up to the present time at least, England has not lost her naval supremacy.

Captain WHEATLY, R.N.: I only wish to remark, after this very interesting account of ten years’ skill and science applied to heavy guns, that it is no exaggeration to say that, as compared with torpedoes, your heaviest guns bear about the same proportion as the old bow and arrow do to the modern rifle. I do not know whether you remarked the experiment that was made between the “Camel” and the “Royal Sovereign” about a month ago. The “Royal Sovereign” in smooth water was struck eleven times by the torpedo, and could only bring her guns to bear twice on the “Camel.” The chief requisite for a torpedo vessel is speed. Let but a torpedo vessel come near the iron-clad, however large, woe betide her; her fate is just what that of the hare

* “Our Iron-clad Ships.”—1860.

would be when within spring of the hound. As an example of the great destruction that might be caused by one of these vessels, you have only to imagine a torpedo vessel armed with 200 torpedoes among the Anglo-French fleet crossing from Varna to the Crimea, or among the Federal fleet at the attack on Fort Fisher; the general state of affairs would have been very much changed.

Captain WILLIAM ARTHUR, R.N.: You referred to the decreased initial velocity of rifled in comparison with smooth-bore shot, and you attributed it to the rifling of the gun. Do you not think it might be equally attributed to the decreased proportion of the powder used, to the weight of the projectile?

Captain STONEY: I believe I said so.

Captain ARTHUR: In regard to altering the nature of the iron which was formerly used in the construction of the gun, if there was any superfluous strength in the gun which might be dispensed with, do you not think it might have been employed in using a larger powder charge and getting an increase of initial velocity. My question is rather, whether inferior quality of iron was substituted because you had too much strength in the gun?

Captain STONEY: It was uselessly expensive outside; the exterior portion of the gun was uselessly strong.

Captain ARTHUR: But the same quality of iron is retained in the A tube?

Captain STONEY: Yes; but now only a few heavy rifled guns have wrought-iron barrels.

General BOILEAU, F.R.S.: With regard to the construction of the gun I wish to ask a question. The lecturer has described most satisfactorily the way in which the butt-joint forming the two parts of what he calls the jacket are brought together into perfect union by being welded at a white heat. I beg to ask whether the pieces, which the lecturer has called the jacket, but which, as it contains the breech end of the gun, perhaps I may be permitted to call the breeches, whether the breeches brought into contact with the trowsers which form the butt-joint are left merely as a butt-joint, or whether the breeches and trowsers are welded together as in the two parts of the jacket? In regard to what the lecturer has said about the increased size of guns and weight of projectiles, I think we have heard a similar intimation on the part of Mr. Reed at a neighbouring Institution, when describing the thickness of armour-plating upon vessels constructed to meet these projectiles. He told us at the Royal Institution that he had an undivulged plan for an armour-plated vessel to carry iron plates, 24 inches in thickness. Now, I think the race will be hard between guns and armour-plates if vessels of this kind should ever be built and sent afloat. But it will be for experiment, as Captain Stoney has told us, at Shoeburyness to decide whether a thousand-pound projectile will be able to pierce a 24-inch armour plate. I have been extremely interested in the description of the manufacture of these guns, and can quite appreciate what the lecturer has said, that we stand far beyond all nations both in the power, in the endurance, in the range, in the accuracy, and in the projectiles of our guns; and, as in the past, so I have no doubt in the future, as long as ships are afloat, we shall continue to maintain our supremacy on the ocean.

Captain WHEATLY: I beg to say, with regard to the size of ships and the weights of ships, that as it is much easier with a pistol or rifle to hit a barn door than to hit a waistcoat button, so the size of a ship will only make her a better mark for a torpedo; and the weight will only carry her more quickly to the bottom. Both the Russians and the Americans have torpedoes.

Captain ARTHUR: One other point I should like to refer to. It is with respect to the venting of the gun. You mentioned that you thought hardened copper might be used for venting. I have tried hardened copper, and have a clock which was constructed for some magnetic experiments, the works of which even to the main spring, are of that metal. It has been going for some time, and works in a very satisfactory manner. I have no doubt that copper could be hardened to any extent. I see in the drawings the vent does not appear to be screwed into the gun. Is the omission of the thread intentional?

The CHAIRMAN: If no other gentleman has a question to ask, I will now call upon Captain Stoney to reply.

Captain STONEY: I am scarcely in a position to go into the torpedo question. I

do not know what progress has been made in that direction, but I hope we shall have as good torpedoes as other nations. I am sorry to say that I am confused with General Boileau's breeches and trousers.

General BOILEAU: Call it jacket if you please. My question is, the two joints that butt, are they butted or are they welded together?

Captain STONEY: The trousers are put on quite separately: there is no welding.

General BOILEAU: You described the parts of the jacket as welded; then the jacket is put on to the barrel at the breech end, and the trousers are put on in front. Are the two ends merely left butting against each other, or are they welded together?

Captain STONEY: They butt together, a portion of the jacket overlapping the trousers; there is no welding between them.

General BOILEAU: They are held on by shrinkage?

Captain STONEY: They are held on by shrinkage. Nor is there any great strain on the joint, the steel barrel prevents any action between the two. The hardened copper vent is screwed into the gun, but in some of our guns it is only screwed partially. The hardened copper is found to withstand best the chemical and mechanical action of the powder gas.

Colonel JERVOIS, R.E.: I wish to make one observation with reference to the remark of the gentleman who spoke about torpedoes. I merely rise to say that, whilst I have a strong appreciation of the great value of torpedoes, the question of their application should be considered distinctly from that of the construction or application of heavy artillery. The ship must come to the torpedo if the submarine mine is to take effect, whilst the shot from the gun can be sent to the ship, and will take effect at even two or three miles distance. The torpedo must be admitted by all, to be a most valuable and important accessory in the defence of harbours, but the big mine under water cannot supply the place of the big gun above water.

The CHAIRMAN: I will now ask the meeting to return thanks to Captain Stoney for his very interesting lecture. He has gone elaborately into the construction of artillery. I think he has said something about his first appearance. Many people who make their first appearance in a lecture theatre would be very happy if they could make as good an appearance as Captain Stoney has done.

Lieutenant BROOK, 45th Regiment, exhibited a revolver which he had procured in the United States, and which he said was about to be introduced into the Service there, the distinctive feature of which arm is, that the surface of the metal is coated with nickel by electro process, which protects the arm from rust.