RIFLE

AMMUNITION.

RIFLE AMMUNITION.

BEING

Notes on the Manufactures connected therewith,

AS CONDUCTED IN

THE ROYAL ARSENAL, WOOLWICH.

BY

ARTHUR B. HAWES,

CAPTAIN (r.h.p.), BENGAL ARMY.

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LINCOLN'S-INN FIELDS.

TO

SIR GEORGE RUSSELL CLERK, K.C.B.

Under Secretary of State for India.

AS A SMALL ACKNOWLEDGMENT OF HIS KINDNESS.

INDIA OFFICE,
July, 1859.

INTRODUCTION.

A STEP in the right direction, and one calculated to be a great boon to all branches of the service, was taken, when, by the endeavours of General Hay, Commandant of the School of Musketry at Hythe, permission was obtained for officers on leaving that establishment to extend their knowledge of all things connected with Musketry, by continuing their studies at the Government Establishments of Woolwich Royal Arsenal, Enfield Small-Arms Factory, and Waltham Powder-mills; thereby enabling them to have more than a superficial knowledge of the many points comprehended within that one word, "Musketry;" a subject including a multitude of scientific questions, of many of which we are still quite in ignorance.

Many have an idea, that when the drill has been mastered, correct practice obtained, and a slight knowledge of the laws which govern projectiles during their flight in the air attained, all that Musketry can teach has then been fully accomplished. No error is greater than this. To be able to give a fair opinion upon any one point connected with this subject, it is absolutely essential to be acquainted with the laws (if there are any), or at least with the Phenomena, connected with the ignition of that capricious compound, Gunpowder; and to be so, even slightly, requires weeks of careful experimental study. The same applies to all the other points, such as the projectile, the cartridge, the arm, rifling, &c. &c., all requiring separate close and attentive study. And this is not only requisite as a theoretical study, but essential to any one who wishes to obtain good practical results.

It may be said, and is urged by many, that this is raising the standard far too high for such a subject, and for those who have to acquire it.

My answer is, that the standard can never be too high; and if the British Army continues to be formed of the same stuff as it is at present, it will not be found for either officers or men a bit too high. The profession of the soldier will be raised, by introducing into it fresh objects of study and interest, closely connected with its practical duties; and the country will have the satisfaction of paying for an Army which either in war or peace can be most useful to it.

It may be urged that no military man has the time to really study these points, or the opportunities of practically mastering them. The first objection needs no answer. If one half of the time uselessly spent, and even wasted, were to be applied to the acquisition of knowledge connected with Musketry, the country would, probably, have in the Army the pick of some 40 per cent. of really scientific men; and the practical results in war, and in maintaining peace, would soon be evident.

Opportunities, however, of stretching their intellects, learning to think, or means of study, are as yet officially given but in a limited degree to officers or men. But no one who has seen the difference in men, after the short (far too short) period of training allowed in the School of Musketry, can say that either the officers or men of the Army are, as a body, unwilling to commence schooling again, or that such exercise of mind does not improve the man, and shorten the defaulters' list.

If ten weeks will do this, how much more will be the results of a year's training in the various sciences connected with the military profession, and after that of a continuous study excited by the interest gained? And who more willing to tackle to an interesting course of practical and theoretical study well combined than the English soldier? The effect of thus looking into these matters, and learning to think, and become an intelligent being instead of a mere machine, will improve the *morale* of the whole Army, and will, in its telling effects, soon shut up those who assert that the result of teaching the soldier aught but his drill is spoiling the man and injuring the profession.

A move to obtain more knowledge for the instructors of Musketry has been made, and the fact of permission being obtained for Infantry officers to study, and become acquainted with the manufacturing as carried on in the Government Establishments, will, I feel convinced, have the effect of allaying much prejudice, by sweeping away a great deal of ignorance, as well as calculated to create a better feeling between two arms of the service, and thus, by increasing knowledge, enable the Government to obtain opinions worth recording on the many points of military economy connected both with the manufactures and material employed in Small Arms, as also with the practical results, to give opinions upon which, at the present period, most men are very diffident, feeling that they have not had those opportunities of studying carefully, and in detail, the various requirements sufficiently to enable them to form any decisive opinion.

Being fortunate enough to be among the first for whom, at the instance of General Hay, permission was obtained to proceed to Woolwich, Enfield, and Waltham, after having undergone a course of study I attended at the Royal Arsenal for that purpose, and commenced a study of such materials as were connected with Small-Arms manufactures in the Royal Laboratory.

But in the absence of any system of instruction or arrangement, or *modus operandi*, I experienced some difficulty in knowing how to set about getting more than a superficial knowledge of the various subjects. To remedy this, I commenced noting down, and arranged as I went on, endeavouring to systematize as much as possible, each particular branch.

These notes, intended at first only for myself, were, I am happy to say, useful to others; and from that reason more than any other, I am induced now to offer them, imperfect as they are, for the perusal of all who feel interested in the preparation of ammunition of different descriptions, with the exterior of which all soldiers are so familiar.

I offer them in the sincere hope that they may not only be useful, and serve as a guide-book, but be the means of some more extended work on the subject, and induce others far more qualified than myself to build a perfect work on my foundation. There exists the necessity for such a work; if it only had the effect of preventing so much ignorance and prejudice being disseminated on the subject. For it is really marvellous to see the amount of bad feeling which has arisen, and the bitter asperities which have been exchanged, on such an apparently simple subject as Small-Arms Ammunition. Free trade in knowledge will go some way to prevent this.

Before concluding, I must observe that an impression has been made upon some minds, that there is a great mystery among the officials connected with these subjects; that information will be but meagrely given, and then with a bad grace; and that those connected with such manufactures have interested motives in keeping all snug to themselves.

Now many, perhaps, may not have heard all or any of these remarks, or of the spirit which suggests them; but I have, and can only, therefore, think it my bounden duty to take this opportunity of refuting them.

From the moment I arrived at the Royal Arsenal,—and I am sure all others who have come for the same purpose will join with me in saying the same,—the greatest courtesy was shown, and every facility was given not only for acquiring information on all points, but for doing so with ease, as well as satisfactorily.

I have had all possible assistance and help, more than I could in any way have anticipated or hoped for; and all I had to regret was, the absence of a course or system of instruction, which, I hope, however poorly, I have in some measure sketched out.

For these notes I claim no originality; I assert no opinions: I have merely jotted down the valuable information uniformly accorded to me with the greatest kindness and readiness by all in their several departments.

The sketches, with but few exceptions, are mostly reductions (with slight variations from the machines themselves) of larger drawings; Captain Boxer, R.A., having, as Superintendent of the Royal Laboratory, given me all the assistance he could, and most kindly desiring all under him to render me every help. Captain Orr, R.A., Captain-Instructor Royal Laboratory, personally put me in the way of seeing everything clearly; and Mr. Anderson, Inspector of Machinery, also took the trouble of giving me the greater part of the information respecting the bullet-machine; so that, coming from such a quarter, it will, I think, be found valuable.

I am perfectly aware of the many defects and omissions in this compilation of information. Many more sketches of the different ingenious machines in use might have been added; but I feel convinced it would have been out of place to have added more than were actually wanted to understand the principles of the manufacture; and those who wish to go deeper into each of those must necessarily study the machinery by personal inspection.

It is much to be regretted that there is no detailed work with sketches containing the machinery in use in the Royal Arsenal; but, the necessity of some such work existing, the example having been set by Prussia and America, I shall feel that this manual had done more than its duty if it incited others to the compilation of the complete work.

A. B. HAWES, *Captain Bengal Army.*

Woolwich, January, 1859.

POST SCRIPTA.

It not having been my original intention to publish these notes, it may perhaps be as well to state the reasons that induced me to do so; and I will, therefore, give a few extracts from correspondence on the subject.

The notes, after I had completed them, having met with the approval of Captain Boxer, they were forwarded, in January last, by him to the War Office, with a view to their being printed by H.M.'s India Government. Lord Hardinge forwarded them to Sir G. Clerk; whereupon the following letter, in answer, was written to Lord Rosslyn:—

INDIA OFFICE, 31*st March.*

MY LORD,

I have received, and laid before the Secretary of State for India in Council, Lord Hardinge's letter of the 9th ult., with a copy of a letter from the Superintendent of Royal Laboratories, Woolwich, enclosing a volume of MS. notes on Small-Arms Ammunition, drawn up by Captain Hawes, of H.M.'s Indian Army, and expressing Major-General Peel's sense of the great credit which must attach to Captain Hawes for the compilation of the memoir, and believes that the notes, if printed, could not fail to be of great service both to the officers of the Indian Army, and to those of the army generally. Under this view, Lord Stanley will be prepared, should Captain Hawes see fit to publish his work, and his Lordship approve of the price at which it will be published, to subscribe for such a number, say 200, as can be advantageously distributed among the Departments and corps in India. Captain Hawes' MSS. are herewith returned.

(Signed) JAMES COSMO MELVILL.

Government having thus thrown the whole into my own hands, I immediately took steps to have them printed and published.

On the 22nd of May I received a letter from Lord Rosslyn, informing me that the "work, when published, should be placed on the general catalogue of military libraries, and supplied to those libraries as required, from time to time." Owing to this, the work now makes its appearance. It is of so exclusively a professional and technical character, that I am afraid those it will interest, or to whom it may be useful, are very limited in number.

A. B. H.

India Office, 21*st July*, 1859.

EMENDATIONS AND ERRATA.

At page 9, it is stated that the reels upon which the lead rod is wound, contain about 130 yards, &c. The correct particulars are 140 yards, weighing 4 cwt., making about 5,000 bullets.

At page 10, it should have been mentioned that Weem's lead-squirting machine was patented by him. And at the same page, for "*not* counterbalanced," read "*more than* counterbalanced by its defects."

At page 56, fifth paragraph, for "as increasing the windage *from* ·001 *to* ·018 *of an inch*," read "*from* ·01 *or* ·009 *to* ·018 *of an inch*."

At page 65, the present proportion of Caps to Ball Ammunition is 90 Caps to every 60 rounds, being 50 per cent. in excess.

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SMALL-ARMS AMMUNITION.

WHAT SMALL-ARMS AMMUNITION CONSISTS OF.

THE ammunition, as at present used for Small Arms in the British service, consists, in the first place, of the Bullet, with, in some cases, a plug of wood in its base, and in others an iron cup; the charge of Powder; and the Containing Paper. The greater part of the ammunition used in the British service is made up in the Royal Arsenal at Woolwich, although for Indian service a large proportion has been, and is at present, made up on the spot where required, the necessary appliances for so doing having been despatched to the several presidencies.

Opinions vary on several important points connected with the ammunition for rifled arms; viz., as to the shape of the projectile, proportions of the hollow at its base, its weight, as to whether an advantage is gained by a plug or cup proportionate to the expense of its manufacture, and whether or no cannelures (or grooves round the cylindrical part of the bullet) are the best means of procuring that hold for the bullet in the grooves of the rifle sufficient to impart to it the required amount of rotation.

Some, again, strongly maintain that the bullet should be used naked, *i. e.* without the paper that serves to hold it in the cartridge; and in that case we should in all probability have to revert to the powder-flask for loading.

All seem, however, to agree that pure lead and correct manufacture of the projectile assist greatly in obtaining a good result.

But in studying these results, so many different points have to be considered and eliminated, as to what are really the moving causes, and what are the merits and demerits of any particular component of the ammunition, that unless a series of most careful and elaborate experiments under every different circumstance have been carried out, no decided opinion can be entirely depended upon.

The description of powder and the quantity used in the charge are points that influence in a very large degree the quality of the results obtained; and the mode of making the cartridge up is another important point, on which a diversity of opinions exists.

Lastly, the lubrication, or anti-fouling agent, as it ought to be more correctly named, is a point upon which many different opinions have been freely expressed.

At the time when loading was performed by force, some (then properly called) lubricating agent was required to enable this operation to be performed at all; but on the introduction of the expansive or groove-taking-after-explosion systems, bullets of less diameter than that of the bore of the piece were used; and except where the windage (or difference between these two diameters) was very small, no lubrication was required to assist in the operation of loading, its real duty being to prevent the fouling, or the residue or ash of the powder after ignition from adhering to the sides of the barrel, and so, by combining with this residue, enabling the gases of the powder to expel it on ignition.

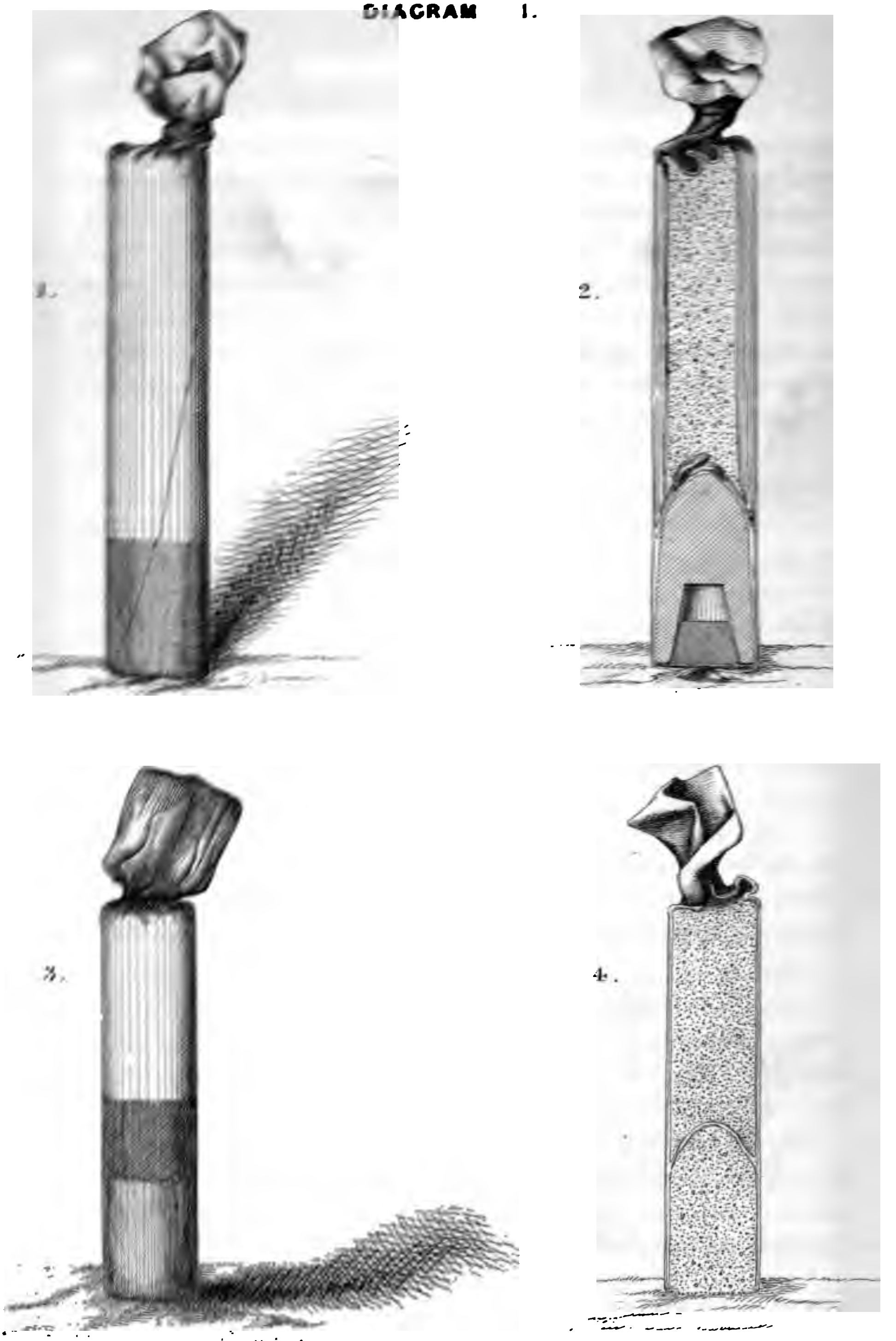
The description and texture of the paper used for the cartridge is another point requiring close attention; and, indeed, so many and various are the questions that have to be considered in the production of a perfect cartridge for a rifled arm, that the greatest care, patience, and no small amount of scientific knowledge are required on the part of those intrusted with this duty.

Some of the main points to be considered in striving to obtain such ammunition are as follows:—

1. The projectile, if elongated, should have its centre of gravity as near its point as possible;* but care must be taken,

* Opinions vary as to the advantage of having the centre of gravity in front. Captain Boxer thinks there is no advantage.

DIAGRAM 1.



Arthur H Hawes, Capt del.

Cox & Wyman, Printers, Great Queen St London.

1. Sketch of the Ball Cartridge for the Enfield Rifle, as issued for Service. The lubrication which is shown extends about 5/8 of an Inch from the base.

2. Section of the same Cartridge, showing the folds of paper round the powder & round the bullet. The bullet & plug are also shown in section.

3. The new pulp-made blank Cartridge, with a purple paper band round it as a distinguishing mark. The lubrication extends up to the bottom of the band.

Section of the same, showing the powder-bag & mock bullet bag or cup. The dotted line at the base is the Muslin. All these real size.

in so doing, by making a hollow in its base, that the bullet is not rendered too weak to withstand, uninjured, the rough treatment it is subject to on service.

2. It should be of such a weight as to secure velocity of flight and good penetration, and, still preserving the minimum of diameter and the maximum of length, to be of such proportions as not to be liable to "topple over" or revolve on its shorter axis during its flight.

3. That the cartridge, when made up, should be strong enough to bear the rough treatment of transport on service.

4. That in making up the cartridge, it should be so constructed as to prevent the possibility of the powder escaping between the bullet and paper, thereby rendering loading difficult and fouling inevitable.

5. That the paper should not be too thick round the bullet, nor uneven in texture.

6. That the paper should be so folded and contrived as to hold the bullet firmly, but still to be easily freed from it on its leaving the muzzle of the rifle.

7. That the lubricating or anti-fouling agent should be free from acids; as a very small proportion of acid will greatly affect the durability of the ammunition when in store, by penetrating the paper and corroding the lead of the projectile. These keeping qualities are very important.

8. And lastly, the whole should be so constructed and arranged as to render the process of loading as easy and simple as possible.

In the accompanying diagrams, some of the different forms of cartridges and projectiles are shown.

Fig. 1, diagram 1, is a sketch of the Enfield Rifle Cartridge. The lubrication is shown by the darkened part at the base, extending upwards about ·8 of an inch.

Fig. 2 is a section of the same, showing the numerous folds of paper (five on one side and seven on the other) to strengthen that part containing the powder, whilst that round the bullet has but two folds. It also shows how completely, in a well-made cartridge, the powder is separated from the bullet. The bullet is also shown in section, exhibiting the hollow and the wooden plug.

Fig. 3 is the new Blank Cartridge,* made from the pulp. A purple paper band is pasted round it, to distinguish it from the ball-ammunition. The lubrication extends up to the band.

Fig. 4 is a section of the same, showing the powder-bag and mock bullet-bag or cup, also filled with powder. The dotted line at the base is the book-muslin pasted over the hole in the base, and through which the powder in the mock bullet is ignited. A more detailed description of this cartridge is given hereafter.

Fig. 5, diagram 2, is the Sea-service Cartridge, made of yellow paper.

Fig. 6.—A section of the same, showing the bullet with its hollow, and the iron cup, the end of the paper being tucked into it.

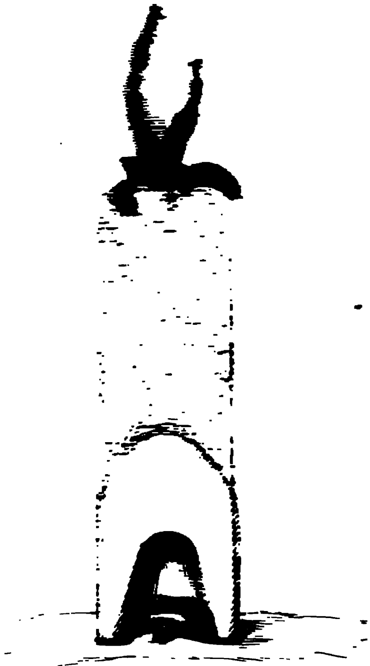
Fig. 7.—Sharp's Breech-loader Cartridge, made from the pulp.

* The following Circular Memorandum was addressed to the army at home and abroad, dated Horse Guards, S.W., 25th February, 1859 :—

"The General Commanding-in-Chief has been pleased to sanction the adoption of a new pattern blank cartridge proposed by the superintendent of the royal laboratories, for the purpose of assimilating the method of loading with blank to that of loading with ball cartridge, and it appears by a communication from the War Office, that cartridges of this description are now ready for delivery. They are composed of the same number of parts as the service ball cartridge; viz., an inner bag containing the powder; a mock bullet, consisting of a paper bag, with a muslin bottom, filled with fine grain powder; and an outside bag to contain both.

"In order to insure the flash of the discharge igniting the powder in the mock bullet, and to prevent its being projected from the musket *entire*, a portion of the bottom of the outside bag is cut away. The operation of loading with the blank cartridge is to be performed in exactly the same manner as with the service ball cartridge. Care must be taken that the cartridge is *reversed* after the powder is poured into the barrel, and that the mock bullet, which occupies the portion covered with bees-wax, is *alone* rammed home upon the powder, the empty powder-bag being detached in the usual way before the ramrod is inserted.—By command, G. A. WETHERALL, *Adjutant-General.*

"N.B.—This Memorandum is to be substituted for the circular of the same date and number issued last week, and which is to be cancelled."



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8.

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Fig. 8.—The old Blank Cartridge, which is simply a purple paper bag, tied at each end when filled with powder.

Without offering any opinion on the merits or demerits of, or entering into discussion on, the numerous points connected with Small-Arms Ammunition, I will at once commence a description of the manufacture of the various parts, as it is at present carried on in the Royal Arsenal, Woolwich; and for this purpose shall take them in the following order:—

The Bullet, the Plug, the Cartridge, and the Cap.

THE BULLET.

The Material used, and the Tests for it.

THE bullets for the rifled arms at present in use are made of lead, which is procured as pure as possible, the alloys and impurities that are often found in large quantities in lead—such as antimony, copper, silver, iron, tin, sulphur, and arsenic—rendering it too hard for the process of manufacture into bullets, as well as destroying that softness which is an essential property for the lead in the expanding bullet; the lead, therefore, which arrives at the Arsenal, although it is procured from and carefully selected by a broker, who is previously informed for what purpose it is required, is subjected on arrival to a test in the Chemical department of that establishment.

The lead usually arrives from the broker in pigs weighing 1 cwt. To ascertain the purity of this lead, the following test or examination is made; one-tenth per cent. of antimony being sufficient to condemn the metal for the purpose required, and so to cause its rejection.

Chemical Test or Examination.

Samples weighing 200 grains are cut from each of the pigs, and after having been scraped bright and clean, are placed in a phial or conical flask, and on each sample is poured 6 drachms of concentrated nitric acid (the greatest care being taken to procure it pure); this is then diluted with 12 drachms of distilled water, and placed in a sand-bath or heated place, to assist dissolution.

If the solution be perfectly clear, it may be presumed that there is no considerable amount of antimony or tin present, and the lead is, comparatively speaking, pure. If, however, the solution has a milky, turgid appearance, and a greyish powder is deposited, or if it has a decided blue colour, antimony, tin, copper, or other impurities may be suspected.

The solution is then evaporated by being placed in a dish or saucer in a heated place. Crystals of nitrate of lead remain in the bottom of the dish after this has been done.

In most cases, in the purest specimens, a slight precipitate of nitrate of copper is left in the form of bluish-green crystals with the nitrate of lead; but as a very minute portion of copper will cause this, no notice need be taken of it, unless very marked or in large quantities. Iron may be easily detected by its imparting a reddish hue to the crystals.

The crystals are then dissolved in about 4 oz. of water, and if the solution has a reddish-brown colour, iron is present; but if clear and bright, the lead may be presumed to be pure. If, however, it is turbid, and there is a considerable amount of deposit, it is passed through a paper filter. The nitrates of lead, copper, and silver, being soluble in water, will pass through the filter, leaving the arsenic, antimony, tin, and sulphur, in the shape of matter upon the paper. In conducting this operation, it is as well to test, from time to time, whether all the lead has passed through the filter, by placing a little of the filtered solution in a test-glass, and pouring a small quantity of sulphuric acid upon it. If lead remains, a white precipitate will be thrown down; in which case the washing through the filter must be continued. When the whole of the lead in solution has been passed or washed through, the paper funnel is placed upon a clean glass, and the impurities on it, either antimony, arsenic, or sulphur, are dissolved by pouring upon them hydro-chloric acid and pure water, equal parts, both boiling, or at least heated. By washing through with this mixture, these impurities will be completely dissolved; but if any portion remains on the paper and is not soluble, it shows that the lead contains tin;—other impurities, such as clay or sand, will remain as matter not being soluble. If there is a considerable amount of tin, it will be necessary to "fuse" it with carbonate of soda or cyanide of potassium. Sulphur is tested for by adding to this solution chloride of barium. If a white precipitate takes place, it is due to sulphuric acid, and shows that there is sulphur in the lead; if, however, it remains bright after this test, there is no sulphur.

Arsenic and antimony are tested for by placing a piece of litmus-paper into the above solutions, and adding ammonia until the paper is permanently changed to a blue colour. A small quantity of sulphide of ammonium is then added as a portable agent. This mixture is then warmed and filtered through paper, and neutralized with hydro-chloric acid, to get rid of the ammonia. It is then boiled, and the antimony and tin will be precipitated in sulphides. If antimony is present in any considerable quantity, the substance which separates has a deep orange tint; if arsenic, a yellow colour: if only of a white or green hue, the absence of arsenic or antimony in the lead is proved.

To test the pureness of the nitric acid to be used in the foregoing examination, evaporate to dryness about half an ounce. If there is any residue, dissolve it in water and add a little chloride of barium. If sulphuric acid is present, a white precipitate will appear, and will prove that the nitric acid is unfit for the purpose of testing lead.

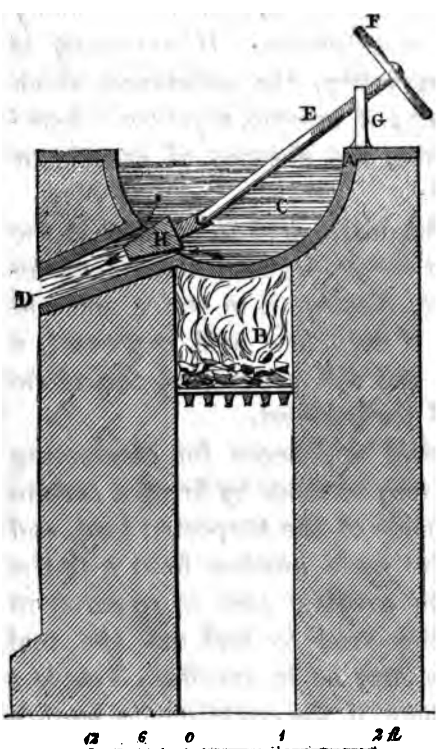
In the absence of chemical appliances for conducting this examination, a rough test may be made by firing a certain number of rounds of bullets made of the suspected lead, and comparing the results with the same number fired with the standard ammunition; but the greatest care is required in conducting experiments of this kind to find out the real causes of any difference there may be in results. This is a very good test as to its efficiency, if the experiments be properly conducted; but not a good test as regards the purchase.

Another rough physical test may be made by pressure or indentation to test its malleability and softness.

The lead, after it has been ascertained that it is pure by the above-mentioned examination, is conveyed in pigs to the melting-pots attached to the "lead-squirting" machine, and in this machine the semi-fluid lead is forced by hydraulic pressure into the form of rods, previous to its being brought to the bullet-machine to be compressed into bullets of the required dimensions. In order that it may be clearly comprehended, I will proceed to describe, in a detailed manner, each process, in the order that they occur, commencing with the "lead-squirting" machine, as it is technically called, and its melting appurtenances.

The "Lead-squirting" Machine.

The pigs are melted down in melting-pots, shown in the accompanying diagram in section.



A A is the melting-pot.

B the furnace.

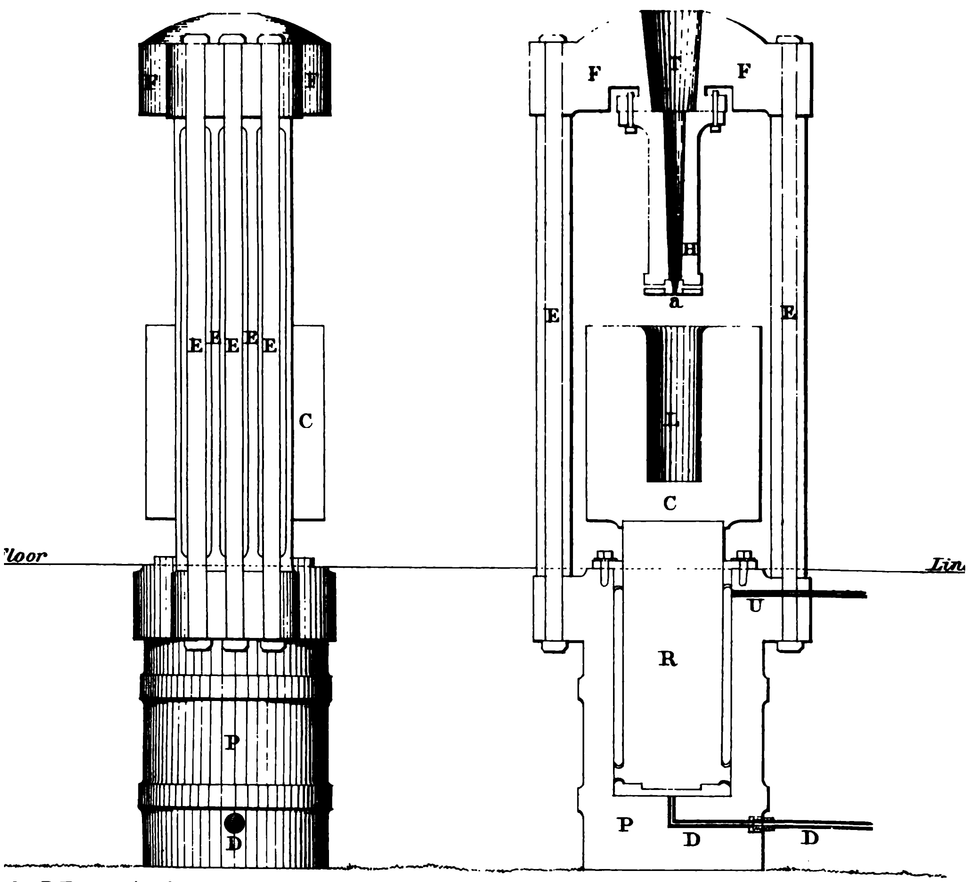
C the melted metal.

D the orifice through which the lead is discharged. This is accomplished by turning the wheel F, which acts upon the rod E, working in a fixed female screw, in the arm G. By this means the plug H, at the end of the rod, is withdrawn from the orifice, which it fits when screwed home, and thus the melted lead escapes through the orifice D, into a trough, by which it is conducted to the squirting machine into a cylinder or reservoir to receive it. I will now refer to the diagram of this machine.

DIAGRAM 3.

Fig. 1. *End Elevation.*

Fig. 2. *Longitudinal Section.*



Thur B. Hawes Capt. delt. *Cox & Wyman, Printers Great Queen St. London.*

WEEMS' LEAD - SQUIRTING MACHINE.

Scale ¼ Inch to a Foot.

0 1 2 3 4 5 Feet.

Diagram 3 shows in section and elevation one of these "lead-squirting" machines, of the same pattern as those in general use in the Royal Arsenal.

Fig. 1.—C is the lead cylinder into which the lead is run from the melting-pots. It is also shown in section in fig. 2. It is made of a massive form, to resist the pressure, and also to retain the heat. This cylinder is placed upon the ram R of the hydraulic press P. The water entering the press at the lower feed-pipe D, forces up the ram, and with it the lead cylinder, against or upon the die-holder H, which is made in the form of a piston, fitting accurately into the lead cylinder. Into this die-holder the die *a*, which is of the exact diameter of the required rod of lead, is bushed; and to cause it to be perfectly concentric with the cylinder and the piston, it is constructed so as to be adjustable by screws.

As the cylinder ascends upon the die-holder, the lead, having no other escape, is forced or squirted up through the die. This is only done when the lead has set, which is usually about eight minutes after it has been poured into the cylinder. It has thus acquired sufficient solidity to maintain its form, and is forced up through the opening T, in the frame FFFF, which is made very strong, and strengthened further by the stays E E.

The rod, after it has been forced up through T, is wound upon a reel fixed close to the machine.

When all the lead in the cylinder has been forced or squirted through, the cylinder descends. This is also performed by hydraulic pressure, the water, in this instance, being forced through the upper feed-pipe U, acting with a downward pressure on the piston, and causing the ram to descend.

The first few yards of lead rod, as well as the last few which are squirted up, are cut off, being, in most cases, unformed; a portion of the former charge of lead always remaining in the cylinder: it is in too solid a state to form a perfect rod.

The reels upon which the lead is wound contain about 130 yards, weighing 4½ cwt., and sufficient to make about 6,804 bullets for the Enfield rifle.

To insure good results with this "lead-squirting" machine, several precautions have to be observed.

The cylinders should be retained at an even temperature during the night, so that they may be ready for work in the morning; and in order to secure this, they are detached from the machine and kept in ovens constructed for this purpose. A small fire is lighted immediately underneath, the heat and flame being allowed to traverse them on their outside. Such a small fire is used for this purpose that ½ cwt. of wood ought to suffice for four or five days. If the lead is not allowed to settle a sufficient time in the cylinders, which, from experience, as mentioned above, has been found to be about eight minutes, it is too liquid for the operation to be performed properly, as it is squirted through in too soft a state to retain its form in the manner required, and thus clogs in the hollow part above the die. When this happens, not only is no proper rod formed, but increased force is required to drive up the ill-shapen mass, and generally more than the machine is calculated to resist, and then something must give way. A pressure of 800 or 900 tons is sometimes required on ordinary occasions. Again, if the lead has been allowed to settle too long, the pressure required to force the solid metal through the die is more than the machine is capable of sustaining; and if this happens, the lead has to be melted out from the cylinder. Another point upon which attention must be paid is the lubrication of the ram of the press; for if that has been done in excess, the lead rod will not be solid. This results from the oil mixing with the lead.

To keep up a constant supply, two of these machines are always at work at the same time in the Royal Arsenal. Six men are an ample allowance to attend to the two machines, melting-pots, and furnaces.

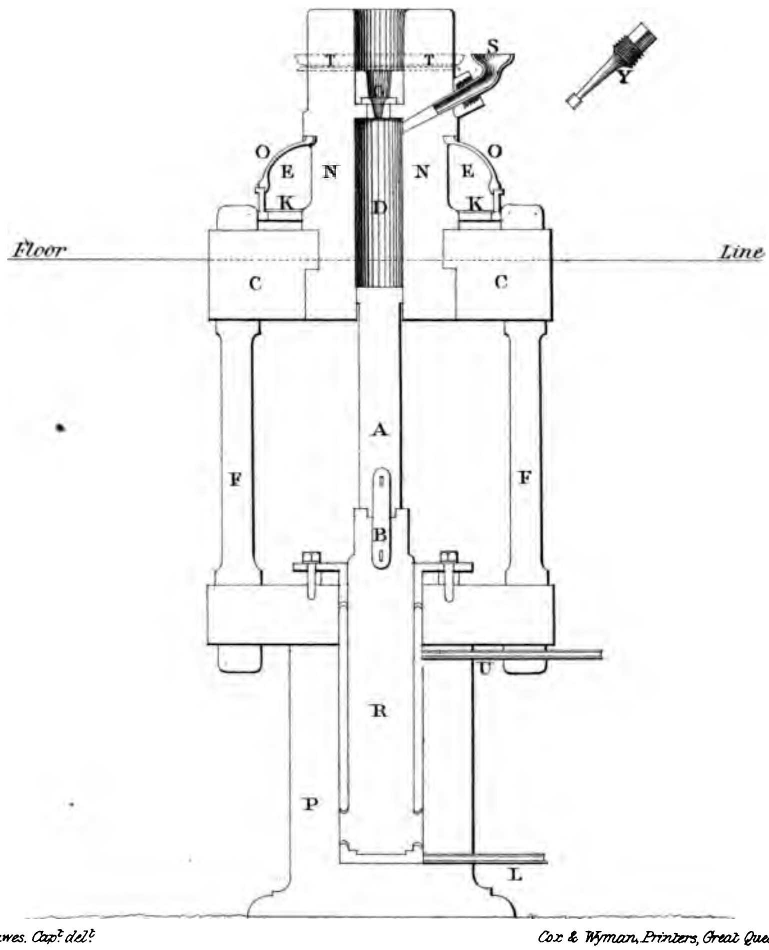
The cost of the two machines as made by Weems was, including the pumps, presses, melting-pots, and lifting-cranes, £2,380.

In diagram 4, another arrangement of a machine for the same purpose is shown in section. It has one advantage,—not counterbalanced, however, by its defects, being

DIAGRAM 4.

Fig. 1.

Transverse Section.



Arthur B. Hawes, Capt. delt.

Cox & Wyman, Printers, Great Queen St. London.

LEAD - ROD - SQUIRTING MACHINE.

Made by Nasmyth & Gaskol, Patricroft, near Manchester.

Scale ¼ of an Inch to a Foot.

0 1 2 3 4 5 Feet

practically a very bad machine,—that the cylinder for the lead has not to be removed at night to be heated, as it is so constructed, that it is kept at the required temperature by small fire-grates, shown at E in the diagram. This machine was constructed and patented by Nasmyth, of Manchester. It will be seen, by referring to the diagram, that the lead reservoir D in the cylinder N is stationary, and the die G is fixed above it; the ram A is bolted at B to the ram R of the press P, and forces the lead upwards through the die.

T T are strong iron bars or keys, to prevent the die-holder being forced up. The lead is poured in at S, which funnel is taken out before the machine is set in motion, and the plug Y inserted and screwed in tightly. F F are the pillars of the frame C C. O O are cast-iron segments, of which there are nine, to cover the fire-grates; K K, the fire-bars; L, the lower feed-pipe of the press; U, the upper feed-pipe. Several difficulties have arisen of a practical nature in working this machine, the ram A becoming frequently clogged. The machine is not, therefore, in such general use as those made by Weems, although machines of this pattern are worked in India.

Having followed thus far the preparation of the lead for the bullet-machine, I will endeavour to show clearly the further process that the lead undergoes, in describing the action and principles of the bullet-machine.

The Bullet-machine.

The reels on to which the lead-rod has been wound, when formed at the lead-rod "squirting machine," are conveyed to the bullet-machine, and one end of the lead being attached to a reel fixed to the upper part of the frame of this machine, which reel has motion imparted to it by being connected at will to the driving-gear, it is put in motion, and the lead-rod is wound upon it, until all has been unwound from the other reel upon that on the bullet-machine. (The former is then taken back to the lead-squirting machine.) One end of this rod is then inserted between two rollers (after having been passed through a guide) with semicircular grooves in them; and, by the motion of these, is drawn forward, first passing through a box (which is loosely clamped upon the lead-rod), containing a flannel rag soaked in some lubrication, for the purpose of giving the rod an easy passage through the machine. It then passes through a small hole in a movable arm or lever (which rises and falls when the machine is in motion). The required length having passed through, which is regulated by a screw in front of the lever, the protruding piece is seized by a pair of grippers or nippers, and held firmly, whilst the lever rising cuts it off; the nippers then opening, the piece falls, and is caught below by the two lower arms of these nippers closing upon it, and held in front of a die of the exact dimensions and shape as the required bullet. A punch of the shape and size of the hollow which is necessary in these elongated projectiles now advances, and forces the lead pellet into the die, stamping it at the same time with the number of the machine, and affixing the Government mark of the broad arrow to the sides at its base. The top part of the die, or that part which forms the apex of the bullet, being movable, is now caused to advance with a smart jerk, and throws the bullet out of the die, passing it at the same time through a hole in a plate, which rises in front of the die at the same moment. This movable top has a small air-hole drilled through it lengthwise. The superfluous film of lead round the base of the bullet, caused by the punch not being permitted to touch the die, is thus cut off, and the bullet at the same time gauged. The bullet now falls into a gutter, by which it is conducted to the box placed underneath the machine to receive it. By a reference to the diagrams of this machine, and the detailed descriptions given, the whole process, and the beautiful arrangements (calculated to meet most difficulties) which have been devised, may be much more readily understood.

The frame of the machine is so arranged that there are four complete bullet-machines on one square frame. These are driven or worked by two sets of driving-gear, and the punches obtain their reciprocating motion from two eccentrics: one of these serves to work two of the punches. One machine is similar in every respect to the others. It is not, therefore, necessary to show the whole frame, but merely one complete machine for making bullets, which forms a corner of the whole frame. The eccentric, which is, however, common to two machines, is shown in section.

The reels on which the lead is wound, for want of space are not shown, but they are fixed to the upper part of the pillar of the frame, which is shown in the diagram as if broken off. The punch, die, and die-holder are shown in a separate diagram further on, half the real size. By referring to diagram No. 5, a general acquaintance of most of the parts can be quickly acquired.

F F F, the main frame. E, the eccentric, which is fixed upon G, the shaft, in such a manner that its centre is an inch and a half from the centre of G; thus giving a throw to the reciprocating spindle of three inches. B B, the box for the eccentric to work in, within which the brass casing of the eccentric slides freely vertically; thus imparting to the box only the horizontal movement, or throw of three inches to each side. S S S, the reciprocating spindles, which are bolted or pinned to the box B. They are shown in section, the whole of one and a part of another: they slide horizontally in chambers, into which they fit accurately. O, section of the punch-holder screwed into the reciprocating spindle. P, the punch, which is shown in section. It is screwed into the punch-holder, and is shown in the diagram pushed into the die to the full extent. It is also shown in diagram half the real size. D, section of the die bushed into the die-holder, shown also half the real size in diagram No. 8. H H, the die-holder, adjustable by screws, so as to make the die concentric with the punch; shown in diagram No. 8 half the real size. I I, section of the die-box. J J J J, screws, by means of which the ejecting spindle is adjusted concentrically. K K, section of the box through which the spindle works, and adjusted by the screws J J J J. L L, the spindle, which has an horizontal movement or throw, and to which is screwed the ejector, which forms the movable bottom of the die. M M, frame for holding the screw m, which regulates the amount of motion or throw of the ejecting spindle. N N, a standard, on which are fixed funnels or tubes, as guides to the lead-rod from the reel to the rollers. The rod is guided by two of these in its progress. R R, the lead-rod, shown in dotted lines.

The working of the machine and process of making the bullet may be divided into several operations, *viz.*—

1st. Unwinding the lead-rod, and passing it up to the cutting-off lever and nippers.

2nd. Cutting off the lead from the rod, and delivering this pellet to the die.

3rd. Compressing the bullet into the die.

4th. Ejecting the bullet from the die.

5th. Cutting off the ring of superfluous lead that remains round the base of the bullet after compression.

I will endeavour to make each operation clearly understood by describing them in the order given above; and whilst doing so, will refer again to the diagrams.

Unwinding the Lead-rod, and passing it up to the Cutting-off Levers and Nippers.

This operation is performed by a pair of rollers, *r r*. They are worked by means of W, a ratchet-wheel. After being worked for a short time, these rollers become leaded; and although the semicircular grooves in them are perfectly smooth, the cohesion of the particles of lead on the part that becomes leaded to the lead-rod enables the rollers to push on and unwind the rod. The ratchet-wheel is worked by means of the ratchet U. There are four of these ratchets, so as to insure a continuous action, and to diminish the chance of a slip stopping the delivery of the lead.

V V is a rocking-lever, to which the ratchets are fixed. Motion is given to it by means of X X, a rod connected to the eccentric box; and thus is imparted to the rocking-lever a reciprocating motion. The amount of this motion is regulated by a screw and stud in the rocking-lever. This is adjustable, and by this means the amount of motion given to the rollers is regulated.

At first several methods were devised for causing the feeding-rollers to pass on the lead-rod, and for this purpose they were roughened in the grooves; but it was found in a short time that the fact of these grooves becoming leaded was sufficient, without any other extraneous aid, to push the lead-rod onwards.

Cutting off the Lead Pellet, and delivering it to the Die.

This is done by means of a lever, shown in section in diagram 5, but better in diagram 6. The lead-rod is pushed through a hole *h*, diagram 6. This hole is bushed with steel. When the proper quantity has been pushed through, the lever rises, and the piece or pellet of lead which has been previously seized by the nippers is cut off. The nippers are shown in section at *n*, diagram 5.

The motion of opening and closing these nippers is gained by a lever being attached to one of the nippers, and which receives motion from a cam on the cam-shaft. At the end of this lever, to which the nipper is attached, is a toothed segment, working into a similar segment connected with the other nipper. Thus, by the rising of the lever, the upper parts of the nippers close and the lower open, and the reverse of this when the lever falls; an alternate opening and shutting being thus obtained.

When the upper part of the nippers which are holding the pellet of lead open, the pellet falls, and is caught by the lower arms, and held immediately in front of the die D.

Compressing the Bullet into the Die.

P, the punch, or movable die, now advances towards the fixed die D, and pushes the pellet in a short distance, the nippers opening at the same time to allow the larger part of the punch to advance, and thus compressing the lead pellet into the die, and forming the hollow in the base of the bullet, leaving a small ring or film of superfluous lead round the base of the bullet. At first the punch was found to stick, at times, in the bullet; therefore, to obviate this difficulty, it was found necessary to lubricate the point of the punch. This is done by means of a spindle worked by a cam on the cam-shaft. At the end of this spindle there is a piece of iron, covered with flannel saturated with oil; this darts out in front of the punch just before it enters the die, and lubricates it at the point. The die is a most important part of the machine, and requires to be turned with care, precision, and accuracy. It is very liable to injury, its duration depending, under ordinary circumstances, upon the quality of the steel. Close attention must be paid during the working of the machine to see that the bullets turned out are of the proper dimensions and generally well made. At times the bullet was found to stick in the die, for two reasons; firstly, the die had become leaded, and, secondly, the resistance of the air in front of the die, from a vacuum being formed at the top, as the ejector advanced to force it out. From these causes at times the bullet adhered so firmly as to admit of the ejector being forced quite through it. To obviate the first of these difficulties, the lead-rod was lubricated previous to its being compressed. This was done by screwing on to the lead-rod, close behind the cutting-off lever, a small box containing flannel saturated with some lubricating agent; but if there be already oil or grease in excess on the lead, turpentine is employed in this box. To obviate the second difficulty, a small air-hole was drilled through the ejector, allowing the air to enter through it.

Ejecting the Bullet from the Die.

The fixed die is made of the same shape and size as the required bullet, but with a large hole at the end, in which the movable bottom or ejector works. The end of this ejector is hollowed out so as to form the apex of the bullet. When the lead has been forced in, the punch retires, and the ejector on the spindle L is smartly pushed forwards, and the bullet is thus ejected from the die.

Cutting off the Film.

On the punch retiring, a plate of steel, *t* (with a hole in it of exactly the same diameter as the bullet), rises. The bullet is ejected through this hole, which has a sharp edge.

The film is thus cut off, and the bullet drops into a gutter, and is thence conducted to a box or receptacle for it, whilst the film falls underneath the machine. The motion necessary for the film-plate is gained in three ways,—the first to raise the plate, the remaining two to lower it. The raising is performed by a lever and cam, shown in the diagram No. 6. The lowering is obtained in two ways, so as to secure the plate from remaining in front of the die; in event of which, it would be forced into the die and broken by the punch, probably breaking and seriously injuring all three; viz., the punch, the fixed die, and film-plate. A strong spring, *f*, hooked on to the arm to which the plate is attached, keeps a constant downward pressure or strain upon the plate; and another cam is so constructed as to work upon a lever attached to the plate, and lower it; so that, in the event of one failing to do its duty, the other arrangement insures the lowering of the plate: *e* is the rod for connecting one end of the lever to the film-plate. By carefully examining the orifice in the film-plate, and keeping it constantly in repair and of the proper size, it acts as a gauge for the bullets, in the event of the die wearing away, and the bullet becoming too large: $\frac{1}{1000}$ of an inch is allowed as a margin to work the dies; *i. e.* the die for the ·568-inch bullet is cut originally ·567 inch, and worked till worn to ·568.

Explanation of Diagram No. 6.

This gives an end-elevation of the same machine shown in diagram No. 5.

F F F F is the main frame. A is that part to which the levers for moving the nippers and cutting off the lead, and the nippers themselves, are fixed; the whole of which being bolted on to the main frame, is technically called the "head." B is the lever for moving the nippers. It is raised by means of the cam No. 6, which acts against the friction-roller *b*, in the arm. The weight at the end serves to bring the lever down again, and keep it in close contact with the cam. C is the lever for cutting off the lead: it is moved by means of cam No. 4. When raised, it closes the upper part of the nippers, the weight at the end of the lever serving to bring it down; and thus closes the lower part of the nippers and opens the upper. O is the arm by means of which the ejecting spindle is forced in and out. It is worked by means of the cam No. 1, which is so constructed as to give to the arm O an horizontal reciprocating movement during each revolution. P P is the arm or lever by which the film-plate is raised and lowered. It is worked by means of the cams Nos. 3 and 2 working against the friction-roller fixed in it. Cam No. 3 lowers one arm of P, and thus raises the film-plate fixed to the other end by the connecting-rod *e*. Cam No. 2 raises one end of the arm, and thus lowers the film-plate, the spring *f* performing the same office. Cam No. 5 is so constructed as to give to a spindle an horizontal reciprocal movement. At one end of this spindle is attached an arm rolled with flannel soaked in some lubricating agent. This passes in front of the punch, and thus lubricates it, previous to its entrance into the die. G G are the upper arms or fingers of the nippers, the lower half being exactly similar, with the exception that to the upper arms are fixed small springs, with pins working into holes in the top of the nippers, and which serve to force the lead pellet out of the nippers, in event of its sticking to them when they open. H is a small frame fastened to the lever C, with an adjusting-screw to regulate the length of the lead-rod forced through. J J J J are the adjusting-screws for the die-holder; N N, the guide for the lead-rod; M M, the frame in which the ejecting-spindle works: *m* is the screw by which the length of its throw is adjusted. V is the rocking-lever; the connecting-rod, or link, X, being connected with it. W is the ratchet-wheel; S, the fly-wheel driven by the spur-gear; T, a spur-wheel, which is driven by the driving-pulleys on the same shaft; Q, the shaft which works the eccentric, and by means of bevel-gear drives the cam-shaft.

The cost of this machine, as it is on one frame, viz., four sets with one die to each, and capable of producing 12,500 bullets in a day of ten hours, was £2,000. With it the following additional apparatus are required:—Two spare head-stocks, costing £170; one lathe for repairing dies, costing £80; and

DIAGRAM 7.

Fig. 1.

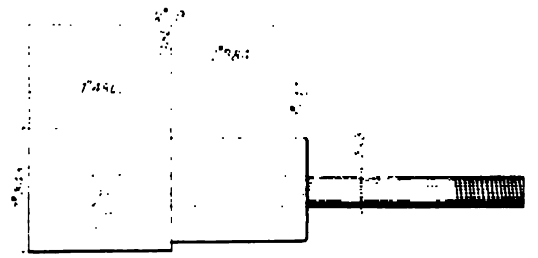


Fig. 2.

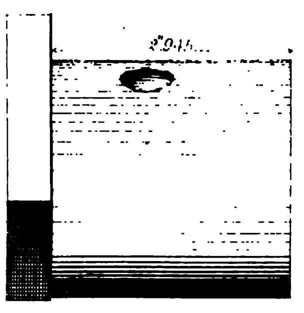


Fig. 3.

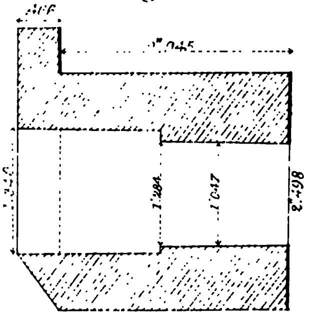


Fig. 4.

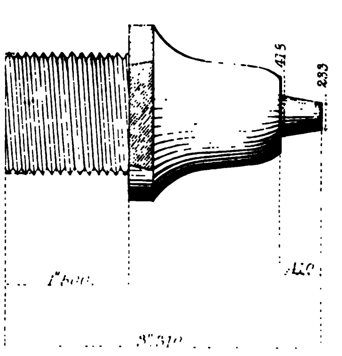


Fig. 1. *The die and the ejecting spindle.*

Figs. 2 & 3. *The die-holder.*

Fig. 4. *The punch.*

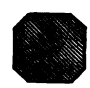
also reels, reel-truck, small crane, boxes, nut-wrenches, &c., costing in all about £140.

Most kinds of elongated projectiles can be made in this machine; but the machine is not calculated, as at present contrived, to turn out these with cannelúres. Mr. Anderson is, however, quite prepared to overcome that difficulty.

In diagram 7, fig. 1, the die is shown half the real size. The spindle which forms the bottom of the die appears as if slightly advanced into the die, as it is when ejecting the bullet. The small air-hole is also shown, which is drilled up the centre. Fig. 2 shows the die-holder into which the die is bushed. There are two small hollows in the top for the adjusting-screws to fit into. Fig. 3 shows the die-holder in section. If the die should not fit well into the die-holder when it is bushed, a small piece of paper is fitted round it to cause it to do so. In fig. 4 we have the punch which compresses the lead pellet into the die, and forms the hollow in the bullet. The shape of the top of course varies with the different hollows required. The die and punch shown here are for the Enfield rifle bullet ·55 inch diameter. A certain per-centage of bullets manufactured in the machine are taken out daily, and carefully examined and gauged, both as regards diameter, length, form, and weight, and also as to the position of the hollow in the base, that its concentricity may be insured.

Forging, Turning, and Finishing of Dies for the Bullet-machine.

For this purpose a bar of the best cast steel is brought to the forge. (These bars are square, and $1\frac{4}{8}$ in. × $1\frac{4}{8}$ in.) It is heated to a red heat, and the angles are flattened either by a steam hammer, or on the anvil, thus—



This is done to facilitate the turning-work. After this, a piece 18 inches long is cut off, and when it has been heated to a red heat, is put into an iron box containing finely-powdered charcoal, where it is left until quite cool, completely covered with the charcoal: it is softened by this process, called annealing. It is then brought to the lathe and turned to the required size, so that it may be nicely bushed into the die-holder, and then driven into the die-holder by force, until it accurately fits; the die-holder being then fitted into the centres of the lathe, the die is turned flush to the top of the die-holder. After this has been done, boring commences. It is first commenced with a drill that bores right through, then with a small half-round bit that makes the hole the size required for the spindle or movable top of the die. After that, with a steel tool called a "rymer," which is angular, and being worked about in the hole corrects the taper, if there be any. It is finally bored out with the boring-tool, which bores it to the size and shape of the bullet required; the spindle being fastened in at the same time, so that they may both be bored out together. The spindle has a hole drilled through it with a very fine tool, to allow the air to escape, as previously mentioned. After this has been done, it is filled with prussiate of potash (ferrocyanate), and heated to a red heat, and then plunged into cold water (end on), and continually worked about until quite cool. This case hardens the outer surface of the steel. If, however, it should contract, it is necessary to grind out the interior to the proper size with emery powder. This completed, the die is fitted to, and adjusted in the machine.

Forging and Finishing the Punches, Film-plates, and Steel Bushes.—Of Cutting off Levers of the Bullet-machine.

The Punch.

This is made from the best cast steel; it is forged as nearly as possible into the required shape, tapering to a point. It is then annealed in the same manner as the die, and after that the piece is fixed and centred in a lathe, and the screw end, which is intended to fit into the reciprocating spindle, turned, great care being taken to turn this concentrically. This finished, it is fitted into a chuck, and the punch is turned to the shape of the hollow required in the bullet. The punch is now finished, and ready for the machine, as it is never hardened, as is the case with the die, &c.; the process being likely to render it brittle, and thus easily liable to be broken off.

The Film-plate.

This is also made from the best cast steel; it is forged by means of a gauge to the exact size. The hole is then bored through, ·002 of an inch smaller than the diameter of the required bullet, allowance being made for grinding out and hardening.

After this, it is carefully ground out and made as hard as possible; the dimensions of the plate being as follows—length, $4\frac{1}{2}$ inches; breadth, $1\frac{1}{4}$ inch; thickness, $\frac{5}{16}$ inch. The diameter of the hole for cutting off the film, and for the bullet to pass through, is, of course, regulated by the diameter of the bullet desired, to which it ought to coincide exactly.

It is fixed to the lever of the machine by means of two screws. The steel bushes, in cutting-off lever, are prepared in a similar manner.

Cost of Enfield Rifle Bullets, and Rate of Production.

From 25 to 35 Enfield rifle bullets can be turned out of the machine in a minute; as, to insure a good action of all the parts of the bullet-machine, it is necessary to work it at a considerable speed. Including steam power, repair of the machines, and, in fact, all contingent expenses, the price of bullets may be taken at 16*s.* per 1,000, or a little more than five for a penny.

Casting Bullets.

The necessary appliances for compressing bullets being of too complex and cumbersome a nature to be always carried about in the field, and an army being often in want of ammunition without the means of procuring it in the regular way, the necessity exists of making it up on the spot. The only means of making the bullets is by the process of casting. And as there is an art in everything, a few words on even such a simple operation as casting bullets will not be out of place.

Much care must be necessarily taken to procure the lead as pure as possible, previous to its being used for this purpose; but of course, as far as speed of production and economy, independently of the impossibility of producing quite as correct a projectile in form and density, this is far inferior to the process of making the bullet by compression; its only advantage being the portability of appliances and facility of manufacture.

The cost of bullets by this process may be estimated at 18*s.* 4*d.* per 1,000, whilst as to rate of manufacture, two men and one boy are occupied ten hours in casting 2,648 bullets; the same number being compressed in the machine in less than two hours!

The appliances required, are the melting-pot, ladles, moulds with plugs for forming the hollow in the bullet, nippers, and the rectifying-machine. This is a small hand-worked machine, worked by means of a lever with a handle at the end. To this lever is attached a spindle, working horizontally in a socket; to the end of this is fixed a punch of the same form as the hollow in the bullet; in front of this is a die, funnel-shaped, the smaller end being of precisely the same diameter as the bullet: it is open at both ends, and the bullet being placed point foremost in the large end, with its base towards the punch, the punch is driven forwards into the hollow by means of the lever handle, and the bullet pushed smartly through the die; the superfluous lead being thus cut off, and the bullet at the same time gauged or pared down to the required size. To preserve this die correct, of course requires constant attention, gauging, and repair.

In casting bullets, the lead should be poured in rather slowly, after having taken it out from the melting-pot carefully with a ladle.

Care must be taken to get a freedom from air-holes, and the moulds should not be closed too tightly, but so that the air may escape easily; for, unless it is allowed to do so, an uneven surface to the bullet will invariably ensue. The moulds also should be of a proper temperature. Practice alone can regulate the requisite speed in pouring the lead in.

When the lead has cooled slightly, the bullet must be taken out with the pliers, holding it by the piece of superfluous lead, and placed point first, as before described, in the die of the rectifying-machine. The punch must then be forced forwards with a smart but firm pressure; thus cutting off the superfluous lead and regulating the size of the bullet.

The plugs of the bullet-moulds require occasional examining and gauging. The following precautions, taken in America for casting bullets, are recommended in the United States Ordnance Manual, and also in the French "Aide-Mémoire d'Officiers d'Artillerie:"—

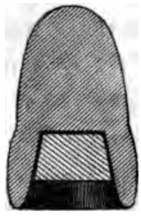
"Weigh the lead, fill the kettle (or melting-pot), and cover it; as the lead melts add more, until within three inches of the edges of the kettle. Cover with a layer of powdered charcoal one inch thick, push the heat until paper in contact with the lead is inflamed by it: this requires from one to two hours.

"Immerse the ladle and fill it about three-quarters full of the lead, covered with the charcoal, which is kept back by a piece of wood. The first castings are thrown back into the kettle, being imperfect, from the moulds being cold.

"The diameter of some of the bullets should be verified from time to time with gauges. The moulds must be carefully cleaned when it is perceived that the lead sticks to them.

"With proper care, 100 lb. of lead will give 96 lb. to 98 lb. of bullets."

THE PLUG.



To insure the expansion of the bullet into the grooves of the rifle, plugs and cups of different forms have been used. General Hay proposed giving the hollow in the bullet and the cup conoidal forms; he also recommended the adoption of a wooden plug in the place of the iron cup. This plug is the one at present used in the Enfield rifle bullet. And that it answers the purpose will be seen by the annexed section of a bullet, taken from amongst many others similarly effected, which had been fired into water.

Description of Wood used.

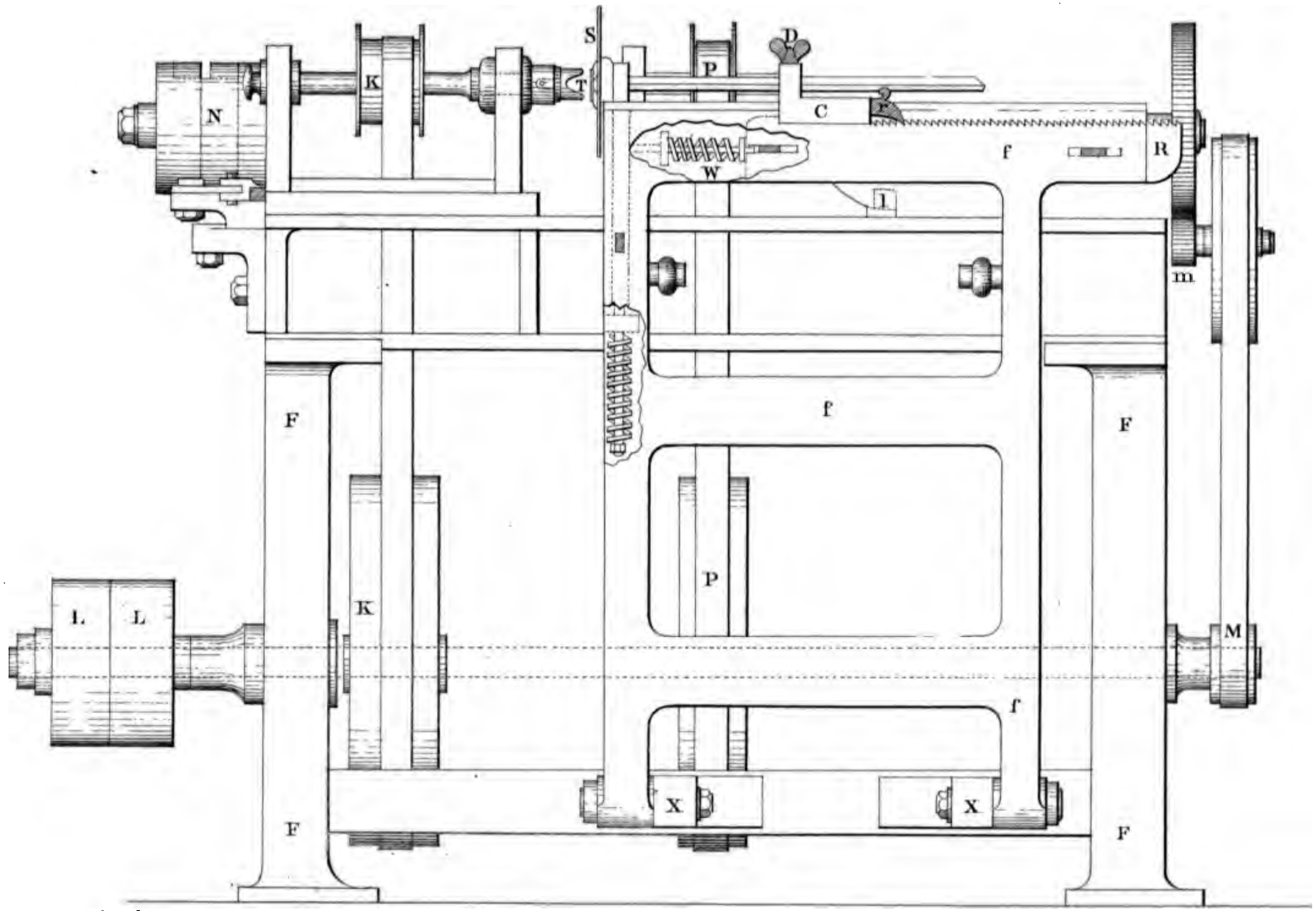
The wood required for the purpose of making these plugs must be hard, close-grained, and well seasoned; and therefore box-wood which has been well seasoned is selected for this purpose. It is mostly procured from Turkey; it is not the best description of box-wood that is required, but that which is technically called "split," *i. e.*, which has cracked open during the process of seasoning.

The wood is prepared for the plug-cutting machine by being cut up into slips or square rods at a circular-saw machine; these rods being about ½ an inch square, and from 1 to 3 feet long. These are brought to the machine, and one is fixed firmly into a bracket on a movable frame in the machine. The slip is caused to advance upon a cutter, which, revolving rapidly, cuts out the plug; the movable frame now advances towards the main frame, bringing the already turned plug in contact with a circular revolving saw, which cuts it off, and the plug falls into a receptacle placed underneath the saw to receive it.

To understand this machine more fully, it will be necessary to refer to the lettered diagrams, in which this machine is shown in elevation as well as in a plan. The same lettering refers to both diagrams. The shape and dimensions of the plug are, as shown in fig. 2, diagram 1, in section.

The Plug-cutting Machine.

Diagram 8 is an elevation of the front of the plug-cutting machine; F F F F is the main frame of the machine; *f f f* is a movable frame upon which a rack R is fixed. This rack has a slight play, which is made reciprocating by a spring W. C is a slide which moves upon the upper part of the frame *f*, and to which the slip of wood is fixed by means of a bracket and thumb-nut B. The slide, and the wood-slip with it, are advanced forwards on the frame by means of



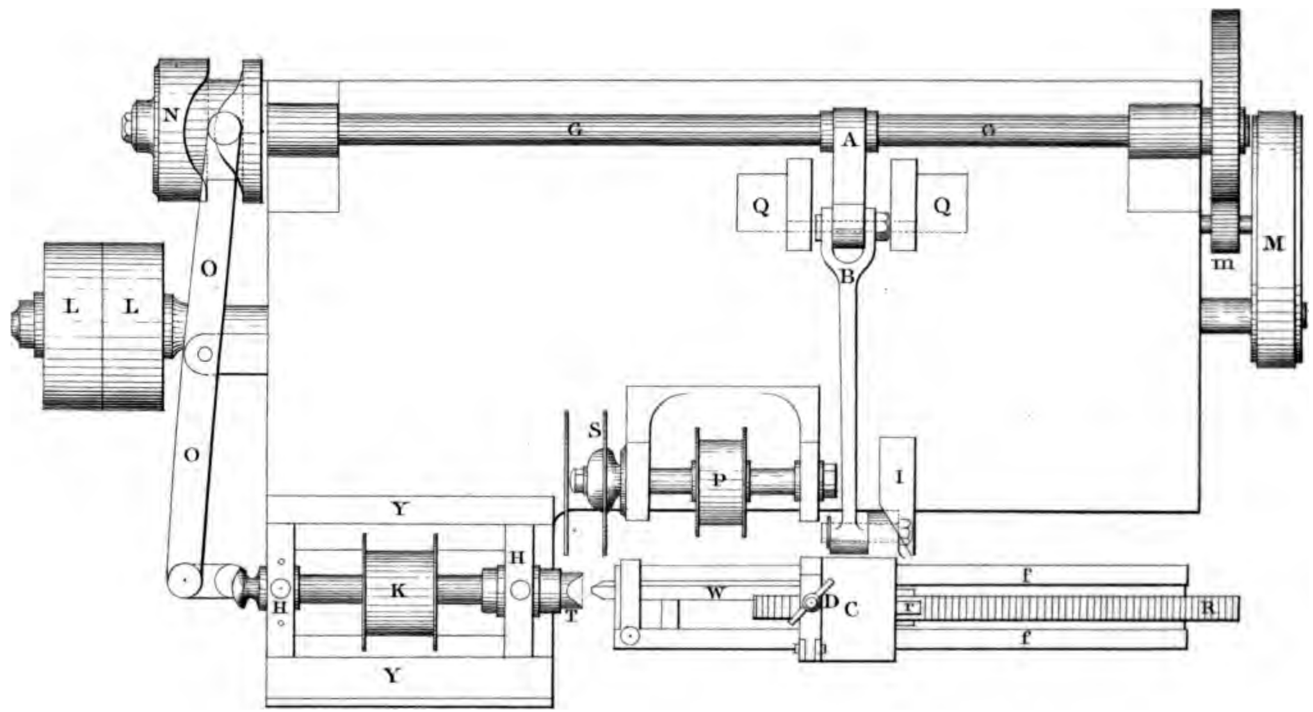
Art̃ur E. Hawes, Capt. delt.

Cox & Wyman, Printers, Great Queen St. Lond.

PLUG – CUTTING MACHINE

Elevation.

DIAGRAM 9.



Arthur B. Hawes, Capt. delt.

Cox & Wyman, Printers, Great Queen St. London

PLUG - CUTTING MACHINE.

Plan.

Scale of Feet.

0 1 2 Feet

the rack R acting against the ratchet *r*, hinged on to the slide. The rack receives its forward motion in the following manner. The frame *ff* is hinged on to the main frame at X X, and receives a reciprocating motion from a cam on the cam-shaft, as seen in the plan. As the frame is brought towards the machine, a piece that projects underneath and is fixed to the rack R, catches in the inclined plane or "fixed am" I, and throws the rack forwards, the spring W serving to bring it back again to its place, after it has moved the slide C, the space between two notches in the rack: the slide thus travels the whole length of the rack. S is the circular saw for cutting off the plug from the wood-slip; it is worked by means of a band on the pulleys P P. T is the cutter for turning the plug; it revolves rapidly in a sliding frame, and is worked by means of a band and the pulleys K K. L L are the pulleys for driving the main shaft, on which are fixed the larger pulleys P and K, and M, a pulley which gives motion to the spur-gear *m*, driving the cam-shaft. N is a cam for giving a reciprocating motion to a lever, by means of which a sliding frame, on to which is fixed the revolving cutter, is caused to advance and recede: by turning to diagram 9, this will be the more easily comprehended. *f f* is the movable frame; R the rack; *r* the ratchet; C the slide holding the wood-slip W; D is the thumb-nut for fixing the wood-slip into the bracket; I is the inclined plane for giving motion to the rack; T the revolving cutter fixed in the frame H H, which slides within the frame YY; K the pulley giving motion to T, also on the frame H; O O the lever which gives to the sliding frame H a reciprocating motion. This lever is worked by means of the cam N. A a cam working against the friction-roller in the arm B, which is fixed to the frame *f*; and thus causing the frame to advance and recede, serving to bring the wood-slip at each stroke up to the circular saw, which cuts off the plug turned at the end. This connecting-rod B slides in slits in the arms or guides Q Q; G G is the cam-shaft; *m* the spur-gear giving motion to it by means of the pulleys M; L L pulleys driving the main shaft; S the circular saw.

This ingeniously-contrived machine is calculated to turn out 10,000 plugs in a working day. The cost may be estimated at somewhat less than 10*d.* per 1,000, if box-wood be used, which includes the repair of the machinery. The cutter, saw, and bands require constant care, as they frequently are in need of repair. If, however, this repair of machinery were excluded, the cost of 1,000 plugs would be reduced to 8½*d.* This also includes the waxing them, and placing or fixing them into the bullets,—a process performed in the following manner.

Plugging, Gauging, and Examining the Bullets.

The plugs, previous to being placed in the bullet, are dipped into a composition of beeswax and a very small quantity of spirits, to prevent alteration in size and shape.

This mixture is kept in a melted state in coppers, and the plugs being placed in a metal sieve, are dipped into it, being stirred about briskly at the same time with a copper shovel. When completely covered and saturated, they are thrown out of the sieve on to a zinc-covered table, and left to cool, being, however, moved about from time to time with the hand to separate them. They are carried thence to be placed into the bullet.

Each bullet is first carefully examined to see if it is perfect. It is then plugged, an operation easily performed by pressing the base of the bullet upon the small end of the plug as it lies on the table, the plug remaining fixed within the hollow, which it fits exactly. Care, however, must be taken in doing this, that the plug is flush with the sides of the bullet, *i. e.*, placed evenly into the cavity. The bullets are then gauged, by being passed through a steel ring gauge fixed to the table, and which is ·001 of an inch larger in diameter than that of the bullet: the bullet ought to pass through freely. The bullets are then placed in trays perforated with holes, and so constructed with covers, that, by turning them, the points of the bullets alone are visible, the bases are then carefully examined, any defect being seen at a glance. The main points viewed are, as to the plugs, whether they are placed in properly, neither sinking in too far nor projecting. If any of these defects exist, the bullet is at once rejected, and the points of the bullets, if found to be defective or broken, necessitate their immediate rejection. This being done, they are taken away to be made up into cartridges.

THE CARTRIDGE.

Having followed the bullet through its various stages until complete, the process of forming or making it up in the cartridge, ready for use in the field, will next come under consideration.

The Paper and the Tests for it.

There are several sorts of paper used in the manufacture of small-arms ammunition; the same qualities are, however, required in all; viz., regularity of texture, evenness of surface, a certain amount of tenacity, and freedom from spots.

The paper of which the greatest quantity is used is that which is called technically White Fine (WF). It is procured in reams weighing 13 lb., the cost being 26*s.*; size of each sheet is 29 inches × $19\frac{5}{8}$ inches.

Each ream is first tested by weight; and if there be a difference of $\frac{1}{2}$lb. over or under the proper weight, it is rejected.

A certain per-centage of sheets from each ream are also examined; and if they have not sufficient toughness, and are not regular in texture,—the former tested by stretching or pulling, and the latter by holding them up to the light, and if not found perfectly free from spots, they are rejected.

The "wrapping," or cartridge paper used in making the cylinder which contains the powder, is a thicker paper than the WF. The same tests are employed to prove its suitability. It weighs 45 lb. per ream, and costs 25*s.* 6*d.* The size of a sheet is 19 × 25 inches.

The "wrapping" paper for the sea-service musket cartridges used at the present time, is a yellow hand-made paper, costing from 24*s.* to 26*s.* per ream, each sheet being 19¾ inches × 23½ inches in size.

For blank ammunition, for all arms, a purple paper is used, weighing 15 lb. per ream, and is procured in sheets 21¾ inches × 17¾ inches; costing about 32*s.* per ream, and is also hand-made.

The new rifle blank cartridge, and Sharp's breech-loader blank cartridge, are not made from this paper, but in a manner which will be described hereafter.

For all paper used in making ball ammunition, care must be taken that such paper is selected as will not increase the diameter of the bullet, when rolled tightly round it, more than ·009 of an inch, and the paper should not be highly sized.

In making up the cartridges for small arms, the following is a list of apparatus required:—

A former, plug, scissors, small piece of catgut, twine, choking-pin fixed to the table, a board fixed on trestles, or in any way so as to form a table, and a box to place the cartridges in when made, and a tray for the ready-plugged bullets; gauges, or cylinders of metal, usually of the same diameter as the bore of the piece for which the cartridge is intended: the gauges for the bullet ·550 inch diameter is ·559. The cartridge should pass freely through the gauge.

Tin patterns are also required, so that the paper may be cut to the required shapes. In the Royal Arsenal this is done by machinery.

The choking-pin is a small brass pin, with a round knob at the top, screwed or fixed to the table by means of a nut underneath. It serves to give a purchase to the catgut, in choking the paper round the base of the bullet to make a "rose."

The string or twine that is used is what is technically called 3-ply. It is tested as to its strength, and costs about 1*s.* 7*d.* per pound.

Cutting the Paper to the Different Shapes required for forming Cartridges.

This is done in cutting-machines of several constructions. The dimensions of the papers, and other points connected with the cartridges used in the service, are given in the tables at the end of this chapter.

The process of cutting is much the same with all; I will only describe, therefore, that for cutting the papers for making the Enfield rifle cartridge.

There are two different kinds of paper used in "rolling" or making this cartridge—white fine, and wrapping, or cartridge paper. The latter is first brought to a machine about two reams at a time, and passed between revolving rollers, on to which are fixed circular cutters. By this means it is cut into strips two inches broad, and of the same length as the sheet. Each half-sheet is thus cut into six strips, and each strip forms four wrappers, cylinders, or "stiffs," as they are often called. These strips, by being folded first into two and then cornerwise, form four trapezoids of the required dimensions. These are shown in the accompanying figure, half the real size; a small piece is cut off the right-angled corner on the shortest side, to facilitate the rolling up. The outside forming-paper is taken to a cutting-machine two reams at a time, and cut into strips $4\frac{1}{2}$ inches broad, and the same length as the sheet. Each sheet is thus cut into four strips, and these strips are again cut into eight trapezoids.

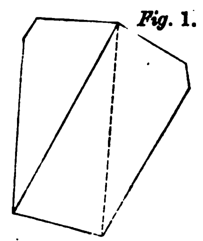


Fig. 1.

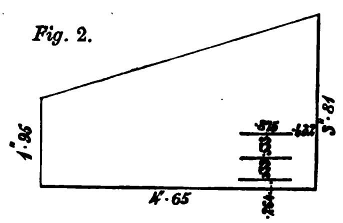
For all conical bullet rifle cartridges, there are two outside forming-papers, and one inside, or "stiff."

The knife of the cutting-machine for these papers cuts into the paper vertically; to save the edge of the knife, a bar of lead is inserted into the frame to receive it; the bar, however, requires renewing from time to time; and for this purpose a mould is supplied with the machine, so that they may be cast when required.

The largest of the two outside papers is brought to a small fly-press, to the end of the spindle of which are fixed three sharp-edged punches. The papers being placed underneath these, receive three cuts at one corner, in the place where the bullet is placed in "rolling;" this enables the bullet to free itself from the paper immediately on being discharged from the muzzle of the rifle; it also facilitates the operation of tearing off. This paper is called the third outside forming-paper. Since the introduction of the three cuts into this paper, a great improvement has been visible in the firing test of these cartridges,—an absence of what was often thought to be a "strip" of the bullet (*i. e.* tearing through the grooves without taking the rotation from them), which produces a peculiar whizzing sound, attributable, however, more frequently to a portion of the paper of the cartridge adhering to the bullet, which of course was calculated to produce great deviation.

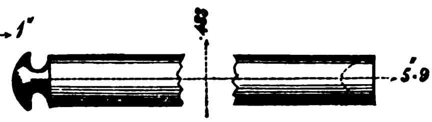
The form of the third outside forming-paper, and the position of the three cuts, are as in the annexed sketch. The papers cut into the above-mentioned shapes are conveyed to the boys who are employed in making up the cartridges, who, being supplied with the bullets ready plugged, and the necessary appliances as before enumerated, commence rolling and making, or forming:—The accompanying diagrams represent two of the tools required in rolling cartridges, and the dimensions of each,—the "former" and the "plug." The "plugs" which have been made for India are of brass, with the exception of the round knob or handle, which is made of box-wood. All others are, however, made entirely of box-wood. The "former," or "mandrel," is a cylindrical piece of wood or metal, upon which to roll the cartridge paper. It has a hollow or cup at one end, into which some of the paper is pressed by means of the "plug," to form the hollow for the point of the bullet. They are all made pierced with an air-hole, shown by dotted lines; this pre-

Fig. 2.



vents the paper from collapsing in withdrawing it after rolling.

Fig. 4.



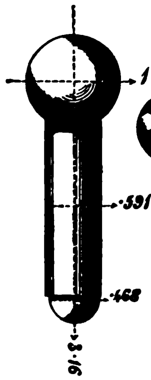
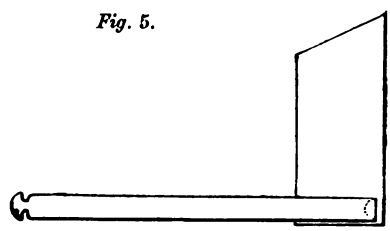


Fig. 3.

Operation of Rolling or Forming Cartridges.

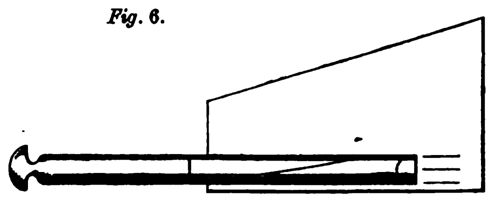
Take the former in the left hand, lay it upon the cylinder paper or stiff, as in fig. 5. The cup being to the right-hand side, roll up tightly until within $\frac{7}{8}$ of an inch of the top on the right-hand side. Take up the second or inside paper (taking care with this, as with all the papers, to keep the side with the acute angle and right angle to the right-hand side), place it on the unrolled part of the cylinder paper, leaving about ·5 of an inch overlapping on the right-hand side; roll up tightly and press this overlapping piece firmly into the cup of the "former" with the "plug." It is important that this should be well done, as, if done carelessly, when the cartridge is made up, the powder may escape between the bullet and paper.

Fig. 5.



Then take the "forming," or outside paper, place the "former," with the rolled-up paper upon it, as represented in fig. 6; place the point of the bullet into the cup of the "former,"

Fig. 6.



the side of the bullet resting on the three cuts in the paper (care being taken that the cuts may extend above the cylindrical part of the bullet, and that a small margin of paper remains to the right-hand side at the base of the bullet, so as to be tied up to secure the cartridge).

Then roll up tightly, choke the paper with a piece of catgut, so as to form a "rose" at the base of the bullet, and tie with string with two half-hitches. The rose should be made in the centre of the base of the bullet, and as small as possible, so that it is secure.

The cartridge has then only to be filled, twisted, and greased, or lubricated.

The cartridges for the navy (that is, those used in the old musket rifled out) are made in the same manner precisely.

Manufacture of Bags for Cartridges from the Pulp.

Besides the method described of making cartridges, they are also made direct from the pulp, by an ingeniously-contrived process, by which every shape and description of paper bag can be made.

As yet, however, no very satisfactory result has been obtained; the cartridges made by this process not fulfilling in every respect the requirements for rifle cartridges.

But as there is little doubt that improvements will suggest themselves in this particular mode of manufacture, there is no necessity however for this ingenious machinery to remain idle, as every description of paper bag for caps, cartridge bundles, cannon cartridges, &c., can be manufactured by means of it, and Sharp's breech-loading cartridge is invariably made in this manner at the present time.

I will now endeavour to make this process, as at present carried on in the Royal Laboratory, clear to the reader.

The pulp is made in the paper-factory, in the following manner:—

The rags, principally linen and canvas, are cut into pieces from 3 inches to 4 inches square, and are brought to a machine called a "rag-winnow" to be dusted of the impurities. This is done by placing them on a broad endless band, which, revolving horizontally, carries them into a cylindrical box, in which they are tossed about by blunt teeth fixed to cylinders revolving in contrary directions: by these means they are thoroughly dusted. A funnel attached to this cylindrical chamber, and having within it fans rapidly revolving, carries off all the light dust to a chamber above, the heavy and gritty substances falling below. This machine has an arrangement by means of a lever and cam, which discharges the rags when dusted, at intervals, through a door in the lower part.

Materials producing a paper of a thin texture are mixed with those producing a thicker or coarser species of paper, so that a pulp of the required consistency may be obtained.

The rags are then boiled in a cylindrical steam-heated boiler, with a solution of lime and soda ash, in the proportion of $3\frac{1}{2}$ lime to $7\frac{1}{2}$ soda ash for 1 cwt. of rags. The proportions, however, are greatly dependent upon the state and quality of the rags. After being boiled for about twelve hours, they are brought to the "breaking-in engine."

This is a large vat or oblong cistern, rounded at the angles and lined with lead; it is divided in the centre longitudinally, the ends of which do not touch the sides of the vat, but leave a channel of about the same breadth all round; in the centre, on one side of this partition, is a revolving wood cylinder, which is furnished with a number of cutters fastened parallel to the axis, so as to project about an inch from the circumference. This cylinder is driven by means of a pinion fixed to one end of its shaft, the shaft extending across the vat. Underneath the cylinder is a block of wood furnished with cutters, similar to those on the cylinder, to which they are parallel, and are very close when it revolves, but do not touch.

The cistern is supplied with water and rags at one end, great care being taken that the water is free from iron; vegetable size is introduced, as also alum and resin, the proportions being about $10\frac{1}{2}$ lb. of alum to $2\frac{1}{4}$ lb. of resin to 2 cwt. of rags, which is about the charge for this engine.

In this vat the rags are beaten up into a rough pulp, and cut up at the same time; but to render this of a consistency required for the manufacture of the paper bags, it is allowed to pass into another machine of a similar description, in which the pulp is cut up finer and reduced to the required consistency. In this machine, the distance between the fixed cutters and those on the cylinder is regulated by a lever, by which the cylinder is raised or depressed as occasion requires.

The pulp is now prepared, and runs from hence into the reservoir, in which it is kept for use, technically called the stuff-chest. To prevent its settling in this reservoir, it is kept constantly in motion by means of a spindle, with long arms or agitators attached to it. By an ingenious arrangement of tubes and valves, the pulp is pumped from this "stuff-chest" into the vats for use, and the liquid portion repumped again into the "stuff-chest" after being used.

The bags for the cartridges are made in the following manner. Upon a circular frame, composed of a double row of tubular rings, are fixed the "moulds," or small perforated tubes, closed at the top, the other end opening into the tubular rings composing the frame. These moulds are of the same size and shape as the required paper bag. The moulds are covered with little bags of woollen cloth called "mould-covers," and fitting accurately. This frame is then screwed on to the pipe of a powerful suction-pump, of which it forms the spout. (The pump has four valves to keep it constantly in action.) The whole frame is then plunged into the vat containing the pulp. There are two of these vats; one containing pulp of a thicker consistency than the other, in event of any of the bags requiring a second and thicker coating. The frame being thoroughly immersed, the suction-pump to which it is attached is set in motion. By this means the water is drawn through the mould-cover, leaving the pulp on the surface. The pulp has only to be dried after this has been done, and a perfect paper bag is formed.

The bags for Sharp's breech-loader cartridge being conical, require a second dipping at the points, the threads of the

" mould-covers" of this shape being drawn together so tightly that they are less porous at the top than at the other part.

The inner bags, or inside cylinders of the Enfield rifle cartridge, always receive a second coating, about half the length, making them sufficiently strong where the powder rests, but thin enough at the upper part to be easily twisted. After this process, the tubular frame, containing the moulds, is taken off from the pipe of the suction-pump (on to which it is fastened by means of a bayonet-catch), and the mould-covers are then dipped into animal size, kept at a warm temperature by means of steam-pipes passing through the pans containing it. After this the " mould-covers" are taken off the moulds, with the pulp adhering, and transferred to the drying formers,—tubular cylinders of the same form as the moulders, but not perforated. These drying " formers" are all fixed to a large circular and tubular frame, heated by steam, and which revolves slowly. A boy standing in one place ascertains by the touch if the bags are dry, and, if dry, he takes off each as they pass, and separates the paper bag from the woollen " mould-cover" (it easily comes away when dry); he then throws the paper bag into a basket at one side, and the mould-cover into another receptacle, so that they may be used again.

The bags intended for the Enfield rifle cartridge are made in two forms, the inside cylinder for the powder, and the outer cylinder to receive the bullet. The inside cylinder, which is formed from the pulp with a flat top, has a hollow afterwards formed at the top by means of a steel former: this hollow is made to receive the point of the bullet when the cartridge is formed.

The " outside cylinder" is flat at one end. Previous to being made up into cartridges, these bags are " glazed," which is done by passing them (when fitted upon steel formers of the exact dimensions of the bag) between a circular revolving roller and the smooth steel frame of the machine. By this process the pores of the paper are closed, and a slightly polished appearance is given. This done, the bullet is pushed down into the " outer cylinder," base downwards, by means of a former; the "inner bag" being then placed upon the former, is pushed down and firmly pressed upon the point of the bullet. The cartridge is now ready for the operations of filling, twisting, and lubricating, which are carried on in separate buildings, and which operations are precisely similar to those in practice for the Enfield rifle cartridge.

At present, this branch of manufacture has not been quite perfected; the bags are slightly porous, and liable, therefore, to absorb moisture, it being found a difficulty in this process of manufacture to work the pulp in an advantageous manner, or to introduce much size. The cartridges are, moreover, weak at that part where the inner cylinder fits upon the apex of the bullet, no doubt owing to the porosity of the paper as it is at present made by this process.

The "outer bag" of the cartridge for the Enfield rifle, after the cartridge has been made up, is cut from the shoulder to the base of the bullet with a longitudinal slit, so that it may free itself easily from the bullet when discharged from the rifle.

Filling, Twisting, Lubricating, and Packing Cartridges, and the Precautions taken in the Royal Laboratory.

The empty cartridges are conveyed in boxes by means of waggons to the cartridge-sheds, which are small isolated buildings. When in the vicinity of these sheds, they are wheeled in trucks moving on copper rails; great care being taken that these are rolled slowly and steadily.

The boxes are taken out and conveyed to the shed, that the cartridges may be filled. This is done by means of filling-machines, one of which is shown in fig. 1, diagram 10; the box being placed immediately underneath the hoppers of the machine, which ought never to be kept more than half full, and but two barrels of powder ought to remain at any one time in any of these sheds.

Each cartridge having been filled, the boxes are taken to be examined by a man well accustomed to the duty. He glances down upon them, and if he has any doubts concerning a cartridge, he empties it into a small tin measure, to prove if his suspicion be correct. A slight excess of about two grains above the regulation charge is desirable, to allow for that portion of the powder the effect of which is usually lost by its adhering to the bottom of the powder-cylinder.

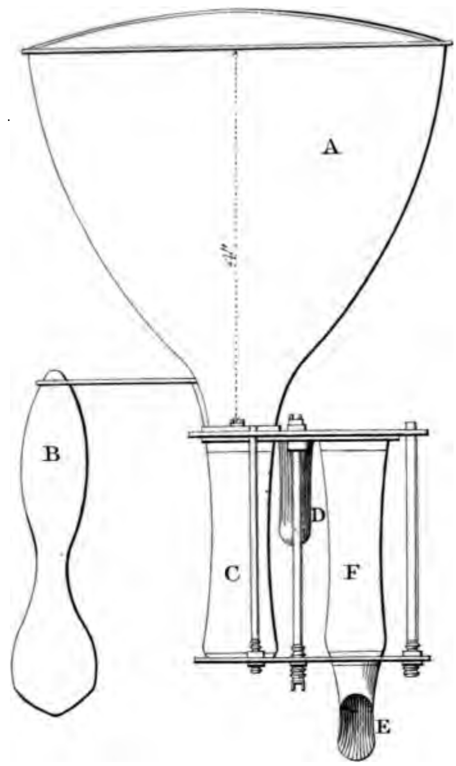
The filling-machine requires testing constantly, allowances being carefully made for any variations in the powder. When the man who has examined the box is satisfied as to the correctness of its contents, he affixes a mark to it and passes it on, that the cartridges may be twisted; an operation performed by twisting from left to right the superfluous paper at the top completely round, pressing it down upon the powder at the same time. This done, the cartridges are taken to be lubricated, or dipped, and for this purpose are fixed in trays so contrived that each cartridge fits into a small cylinder, leaving that portion alone projecting at the bottom which it is necessary to lubricate. The lubrication, or anti-fouling composition, at present composed of wax alone, is carefully weighed out, and stirred whilst melting in steam-heated pans until thoroughly incorporated. When it is required for use, it is heated and kept by means of steam at a temperature of 230° Fahrenheit. At the side of the dipping-pans are slabs or metal plates heated by steam. Upon these the trays containing the cartridges are placed until the cartridges are thoroughly dried and have acquired some slight degree of heat. Of course the heating of these is carefully regulated. Each tray is then successively dipped into the composition, in such a manner that the bases of the cartridges touch the bottom of the dipping-pans, which are adjustable so as to regulate the required depth. A reservoir of the composition is fixed at the back part of the pan, with a cock, so that the quantity in the dipping-pan may be regulated. In front of the dipping-pan there is a small copper cylinder running across horizontally, upon which, after having been dipped, the bases of the cartridges are just touched or lightly drawn across, taking off the superfluous composition which may adhere. The cartridges are then left to cool, and until they are thoroughly so, the operation of packing is not ventured upon. When this more cumbersome apparatus for dipping cartridges is not available, or for field service, a portable apparatus is used, in the form of the lubrication-kettle shown in fig. 2, diagram 10. A is a copper kettle, with a handle D; B a saucepan or pot, in which the composition is placed; it fits into A, into which hot water is placed after the fashion of a glue-pot. E is a perforated piece of copper, tinned; it forms a bottom for the dipping-pan, and is adjustable by sliding upon a small rod, and being fixed by means of the screw F. C is the handle of the dipping-pan. G is a small brass cylinder, in which the cartridge is placed after having been dipped, so that it may be gauged; the hole to receive it is ·582 of an inch in diameter for the Enfield rifle cartridge. There is a small orifice at the bottom of this gauge, to allow the composition to flow out. The filling-machine is shown in fig. 1: A is the receptacle for the powder; B is a handle, by turning which the powder is allowed to escape into either the tube C or F; D is a handle, by means of which either C or F is alternately brought underneath the receptacle A and over the funnel E, by which the charge is introduced to the cartridge.

Packing Small-arms Cartridges.

For this purpose the "slip," or packing-paper, is laid upon the table; a cartridge is laid parallel to the nearest end, bullet to the right; the "slip" is then rolled once round. The second cartridge is then laid under it close to the first, the bullet towards the left; the remainder, up to the first five, are thus laid alternately over, and under the "slip," the bullets' ends alternately reversed. When five have been thus laid, the remainder of the slip is passed over and the sixth cartridge placed at the same time in the double; the seventh is then placed over the second, the bullet towards the right, and the rest are alternately placed over and under, as before, until ten have been laid; the remaining portion of the slip is then passed over; the whole are then gently pressed with the hand, and packed in the wrapping-paper, the dimensions of

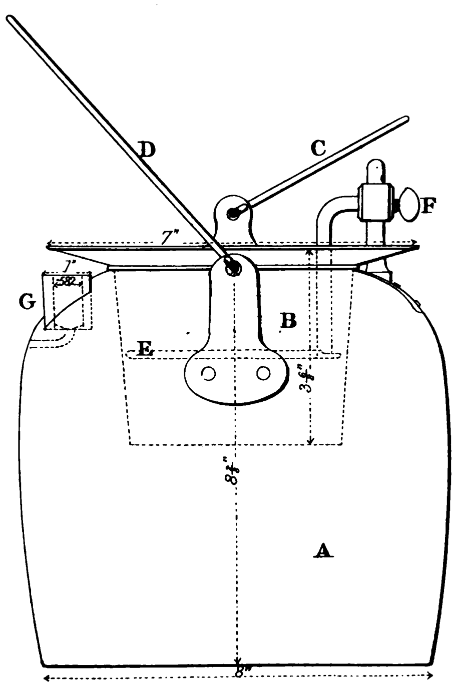
DIAGRAM 10.

Fig. 1.



CAFFIN'S FILLING MACHINE ¼ Size.

Fig. 2.



Arthur B Hawes Capt. delt.

Cox & Wyman, Printers, Great Queen St. London.

LUBRICATION KETTLE ¼ Size.

which are given in the tables of dimensions of cartridge-papers; upon which paper the description of cartridge contained is marked. Packets of cartridges of ·55 diameter are labelled as follows:—

For Rifle Musket /53. Bullet ·55 diameter, WAX ≡ Powder 2½ drs. Wood Plug.

The word "wax" signifies that the lubrication is composed of wax unmixed, and the three lines represent that the outer forming-paper, or "outside," has received the three cuts before described.

The packets are then fastened with strong twine, and carefully packed in barrels, by being built up round the sides; a cylinder of caps being placed in the centre, in the proportion of 75 caps for every 60 rounds: this proportion, however, it is in contemplation to alter, by increasing the number of caps. Previous to the packing, however, each bundle is weighed against a standard bundle, and if found light, is immediately rejected. They are also examined to see that they have been properly packed. Packing and fastening the barrels are operations performed in the same building as filling and dipping, and from thence, when the barrels have been marked with the contents, they are conveyed to the several magazines to which they are destined.

The New Blank Cartridge.

This ingeniously-contrived cartridge, a sketch of which is shown in diagram 1, enables the soldier to go through all the motions of loading in exactly the same manner as if loading with ball-cartridge, and has been devised by Captain Boxer, to obviate the difficulty of the soldier having to practise on parade, or at reviews, a different plan of loading than he would have to do when before the enemy.

With the old blank ammunition, he merely poured the powder into the musket from the paper bag, and then rammed the paper down upon the top of it. With the new one, he goes through the motions of reversing the cartridge, after pouring in the powder, thereby lessening the chances of the soldier's obliviously loading his rifle in action with the bullet point foremost, a mode of performing this operation which is obviously calculated to prevent any good results being obtained in practice, and to cause the grooves of the rifle to become leaded.

These cartridges are made with bags manufactured as described before from the pulp. There are two cylinders similar to those in the ball-cartridge made from bags; the inner bag has a hollow in its base, the outer bag is a cylinder with a flat base. There is also a small bag or cup, somewhat of the form of the conical bullet, and of the same length and diameter. These three bags are conveyed to the filling-sheds, the filling and making this cartridge being simultaneous operations. The ragged edges at the mouth of the bags are first cut off; the outer cylinder being about 3½ inches in length after this operation. These outer cylinders are then dipped in the lubricating composition, and for which purpose are fitted upon boxwood formers, seventy-two of these formers being fixed perpendicularly, and in six rows, upon square brass plates, with handles to each side. These plates, or dipping-trays, are then reversed and dipped in the pans, which are in every respect, as regards arrangement, and also the composition and temperature, similar to those already described.

The former are constructed larger at the top, so that, where the lubrication is required on the bag, it fits tightly; a small groove up the side allows the air to pass in in removing the bag, and enables that operation, therefore, to be easily performed. After the lubrication has hardened by being allowed to cool, the bags, or "outside cylinders," are brought to a boy, who, fitting them upon a brass former with a box-wood top, by means of a small punch attached to a lever, punches a small hole from the bottom of each bag. This done, a small piece of coarse muslin, cut into a circular shape of about the same diameter as the cartridge, after being well pasted, is inserted by means of a former into the cylinder, and pasted over the hole punched out in the bottom of the cylinder. These pieces of muslin are cut out by means of a common circular punch, or patch-cutter, and mallet.

The next process is to place within these cylinders the small bags or cups before mentioned, and which have been previously filled with $1\frac{1}{2}$ dram of powder. These are reversed, and pressed in by means of a former, the muslin being too fine to allow of the powder escaping through the interstices. Upon this imitation bullet the inner bag is then firmly pressed by means of the former. The cartridges are then put on one side to be examined by placing a former in them to ascertain if these mock-bullets are placed in, as also to open the mouth to receive the charge.

The trays are now placed under the filling-machine, and each cartridge receives its charge of 2 drams; and after this a small strip of purple paper, $2\frac{1}{4}$ inches × $\frac{4}{8}$ of an inch, is pasted round each as a distinguishing mark. The twisting is performed in the same manner as other cartridges already described.

They are packed in the same way as the ball-cartridge, 10 in each packet, the wrapping-paper being, however, purple, and labelled as follows:—

BLANK.

The operations for loading with the new pattern blank and with the service-ball cartridge are the same. The portion of the blank cartridge which is lubricated, represents the bullet in the service cartridge.

1858.

A paper containing these directions is also inserted into each barrel.

They are packed in half-barrels, marked in the following manner:—

W.
BLANK.
For Pattern /53.
And all arms.
·577 bore.
No. ... ... 1,400.
Caps... ... 1,540.

On "firing," the powder of the charge ignites through the interstices of the muslin the powder in the bag or cup; thus blowing it to pieces, and preventing the contingency of any part "balling," or being expelled *en masse.*

The old form of Blank Ammunition.

Blank ammunition for all arms is made of purple paper; one forming-paper alone is used, of the dimensions given in one of the tables.

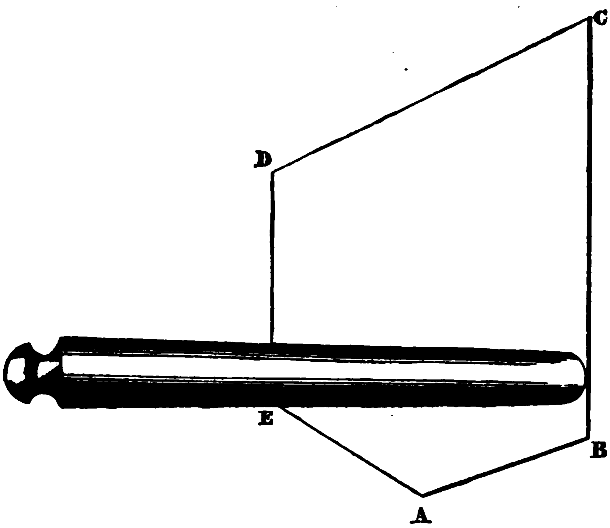
The paper is rolled upon a former in precisely the same manner as the outer forming-paper of the ball-cartridge; the former is ·65 of an inch in diameter, and rounded convexly at the end. After being rolled, they are choked, and tied with twine; thus forming bags.

They are then filled at the filling-sheds with 3½ drams of powder, then twisted and tied, as shown in diagram 2, fig. 8.

They are packed in half-barrels containing 1,800, and the proper proportion of caps, *i.e.* 1,980.

Mode of forming Sharp's Breech-loading Carbine Cartridge.

The charge for this cartridge is the same as for the Enfield rifle cartridge, *viz.* 2½ drams. The bullet is the same externally, the difference being in the hollow at the base, which is not so deep, and the surface of which is roughed; the weight is 530 grains, diameter ·568. The former for making this cartridge is 0·5 inch in diameter, and tapers slightly towards the end, which is rounded off, so that it may fit the hollow of the ball. A piece of white fine paper is cut to the pattern A B C D E, shown in the diagram half size.



The "former" is then placed upon the "forming-paper," as shown in the diagram, and the part A is laid over it, and the whole rolled tightly up. The projecting part of the paper, after this has been done, is twisted close on to the rounded end of the "former" by the finger and thumb, assisted by a "choking twine" fixed to the table. The twisted end of the cartridge is then dipped into a cement of the consistency of thick glue, consisting of shell-lac dissolved in spirits of wine, and then pressed into the hollow of the ball, which is roughed. The "former" is now taken out, and the cartridge is left for about two hours to dry. A slip of "white fine" paper, 0·7 in. wide, is then pasted round the lower part of the ball and cartridge. When the whole is dry, the powder is put in, and to insure the cartridge being made of the proper length (a matter of great importance), it is placed in a small block of wood having a cavity of the same diameter as the shoulder of the ball, and 2½ inches in length; the end of the cartridge is folded down as flat as possible. A small quantity of lubrication is then put round that portion of the paper band that covers the ball, and the cartridges are packed in bundles, as before described.

Appliances required for rolling these Cartridges.

A board for a table; (W. F.) paper; tin patterns; choking-pin; former; block of box, or any hard wood, with the required hollow for gauging; paste; twine; lubrication-kettle; and the lubrication.

Sharp's Breech-loader Cartridge.

The cartridges generally used for Sharp's breech-loading carbine are made from the pulp. The bags are made tapering to a point between ·28 and ·29 of an inch in length; these bags are brought to the filling-sheds, and are, in the first place, placed in trays, mouth upwards, and filled with the regulation charge of 2½ drams, by means of the filling-machine. After this the bullets are placed in, base downwards. The hollow in these bullets is slightly different from the Enfield rifle bullet, the inside surface being roughened. The bullet having been placed in, the cartridges are gauged in a small gun-metal gauge, to see that they are the required length, a very important point with the cartridges for Sharp's breech-loading carbine.

Formers with cups are used in forcing the bullet into the cartridge-bag. If it does not readily go down, the small end of the cartridge is inserted into a hole in a block of wood, and a few smart taps with the former serve to settle the powder, and to allow the bullet to fit in; the superfluous paper which projects beyond the point of the bullet is then cut or torn off roughly. The cartridge is after this taken to a boy, who, placing the point of the bullet in a gun-metal mould made to receive a certain length, passes a knife round it, and cuts off the paper neatly round the cylindrical part of the bullet. After this has been done, but ·1 of an inch of paper in breadth ought to overlap or hold the base of the bullet. A small strip of paper (W. F.) 1·5″ × ·3, is now pasted round the junction of the paper and the bullet, ·2 of an inch being on the bullet, and ·1 of an inch on the paper; so that, when this is pasted on, ·3 of an inch of the bullet in depth is held by the cartridge. This has been found to be quite sufficient.

After this process, technically called "banding," has been completed, the cartridge is again gauged to see if it is correct as to length; it is then placed with others in the dipping-trays. These trays, made of copper, tinned, are constructed with 90 small cylinders or cups, ·917 of an inch in depth, into which the point of the bullet fits. When all the cartridges have been arranged, bullets downwards, in these cups, the tray is dipped into the lubrication-pan, which, in arrangement, is precisely similar to those in use which have been already described; the composition is also the same. The tray should touch the bottom of the pan, as the lubrication is kept at a fixed depth, regulated by a mark or gauge at the side of the pan. The temperature at which it is kept is 180° Fahrenheit. In thus dipping them, a small rim of lubrication adheres to the part of the cartridge just above the cup or cylinder (if the point of the bullet touches the bottom of the cup or cylinder, this should be the broadest part of the bullet), an important point; for if the bullet is not lubricated at its broadest part, it will invariably foul the carbine by leading the grooves. The rim of lubrication is about ·2 of an inch in depth. After the lubrication has been cooled, the cartridges are packed in the same way as other descriptions of cartridges, *viz.*, ten in a packet, and labelled as follows:—

SHARP'S
Breech-Loading
Rifle Carbine,
·577 Bore, W.T.
2½ Drs. F.G.
1858.

These packets are then packed in quarter-barrels, which are marked thus—

W.
Cartridges.
Sharp's
Breech-Loading
Rifle Carbine.
W. ·577 T.
$2\frac{1}{2}$ drams F.G. 800.
Caps 1000.

It is contemplated to alter the proportion of caps for all arms from five to four rounds to six to four.

TABLE 1.—SMALL-ARM CARTRIDGES.

NATURE OF CARTRIDGE.	Charge.	Number of Bullets to a Pound.	Diameter of Bullet.	Diameter of Former.	Number of Cartridges (ten in a Bundle) packed in Barrels, Cases, &c.									REMARKS.
					¼ Barrel.		½ Barrel.		Box.		Sea Service.			
					Cartridges.	Caps.	Cartridges.	Caps.	Cartridges.	Caps.	Copper-lined Cases half.	Dell's Cases, Sectional.	Quarter Hexagon.	
	Drams.		Inches.	Inches.										
Blank for all arms	3½	..	..	·65	..	..	1,800	1,980					Quarter Hexagons are only packed with fractions, but will hold about 500.	
Rifle Musket (1842) Sea Service	3	8½	·746	·65	500	625	..	..	..	..	1,300	1,300		
Ditto (1851) Ditto	2½	10	·691	·6	500	625	..	..	500	625				
Ditto (1853) Ditto	2½	13½	·568	·5	700	875	..	..	560	700				
Artillery Rifle Carbine	2	13½	·568	·5	800	1,000	..	..	560	700				
Lancaster's Rifle	2½	10	·28	·65	500	625								
Rifle Musket (1853) New Diameter	2½	13½	·55	·472	700	875	..	..	700	875				
Carbine (Carbine bore)	2½	20	·610	·59	700	875								
Carbine (Musket bore)	3½	14½	·680	·65	600	750								
Carbine (Victoria M.B.)	2½	14½	·680	·68	700	875								
Carbine (Paget's Rifle)	1¾	10	·674	·59	700	875								
Musket, Common	4½	14½	·680	·65	500	625	..	..	500	625	1,400	1,400		
Musket, Ordnance	3½	14½	·680	·65	600	750								

NOTE 1.—Caps are not packed in copper-lined cases, or in Dell's sectional cases, but are sent separately, in stone jars containing 1,000 each (Sea Service).

NOTE 2.—Wood Formers are made of boxwood, of a uniform length of six inches, with a hole pierced through, and one end concave, *except* those for blank and Sharp's breech-loading cartridge, which are convex.

SMALL-ARM CARTRIDGES.

NATURE OF CARTRIDGE.	Charge.	Number of Bullets to a Pound.	Diameter of Bullet.	Number of Cartridges (ten in a Bundle) packed in Barrels, Cases, &c. — ½ Barrel. Cartridges.	½ Barrel. Caps.	Sea Service. Dell's Sectional.	Sea Service. Remarks.
	Drams.		Inches.				
Pistol (Musket bore)*......	2½	14½	·680	700	875		Balls lined with a fustian patch for Coast-Guard Service.
Pistol (Carbine bore)*......	2	20	·610	800	1,000	..	
Pistol (Percussion)†........	2	34	·511	..	..	2,400	

* The "formers" the same as Carbine M.B. and C.B.
† The "former" ·5 of an inch in diameter.

DIMENSIONS OF PAPER, &c. FOR SMALL-ARM CARTRIDGES.

DESCRIPTION OF CARTRIDGE.		Forming Paper. Description.	Forming Paper. Breadth.	Forming Paper. Longest side.	Forming Paper. Shortest side.	Slip or Packing. Description.	Slip or Packing. Length.	Slip or Packing. Breadth.	Wrapper. Description.	Wrapper. Length.	Wrapper. Breadth.
			In.	In.	In.		In.	In.		In.	In.
Blank for all arms......		Purple.	4·4	5·8	3·25	..	..	..	Purple	11	5·75
Rifle Musket (1842)	1st Cylinder	Yellow wrapping	1·66	5·0	4·55						
	2nd Inside..	Yellow fine	4·3	5·6	3·5	Yellow fine	17·5	4	Yellow wrapping	9·75	6·25
	3rd Outside ..	Y.F.	4·52	5·6	3·4						
Rifle Musket (1851)	1st Cylinder	Red wrapping	1·65	4·97	4·57						
	2nd Inside....	Red fine	4·05	4·65	2·52	Red fine	17·5	4	Red wrapping	9·75	6·25
	3rd Outside ..	R.F.	4·45	4·57	2·33						
Rifle Musket (1853)	1st Cylinder..	Wrapping	2·05	5·05	4·5						
	2nd Inside....	W.F.	4·5	3·85	2·03	White Brown	17·5	4	Wrapping	9·75	6·25
	3rd Outside ..	W.F.	4·65 4·65	3·81 3·67	1·95 1·95 for ·55 bullet.						
Musket (Ordnance) .. Carbine (Victoria) M.B.		W.F.	4·3	6·65	5·25	White Brown	17·5	4	Wrapping	9·75	5

DIMENSIONS OF PAPER, &c. FOR SMALL-ARM CARTRIDGES.

DESCRIPTION OF CARTRIDGE.		Forming Paper.				Slip or Packing.			Wrapper.		
		Description.	Breadth.	Longest side.	Shortest side.	Description.	Length.	Breadth.	Description.	Length.	Breadth.
			In.	In.	In.		In.	In.		In.	In.
Musket (Common)......		White fine	4·7	6·8	4·8	White fine	17·5	3	Wrapping	9·75	6·25
Artillery Carbine (1853)	1st Cylinder..	Wrapping	1·7	5·0	4·55						
	2nd Inside....	W.F.	3·42	3·8	2·45	W.B.	17·5	4	do	8·3	6·25
	3rd Outside ..	W.F.	4·15	3·8	2·2						
Lancaster Rifle	1st Cylinder..	Wrapping	1·7	5·05	4·6						
	2nd Inside....	W.F.	4·35	5·6	3·5	W.B.	17·5	4	do	9·75	6·25
	3rd Outside ..	W.F.	4·55	5·6	3·4						
Paget's Rifle Carbine	1st Cylinder..	Wrapping	1·33	5·0	4·73						
	2nd Inside....	W.F.	4·05	4·6	2·5	W.B.	17·5	4	do	9·75	6·25
	3rd Outside ..	W.F.	4·4	4·6	2·33						
Carbine (Carbine bore)..		W.F.	4·5	5·25	3·15	W.B.	17·5	4	do	9·75	5·0
Carbine (M.B.)		W.F.	4·5	7·4	5·25	W.B.	17·5	4	do	9·75	5·0
Pistol (M.B.)		W.F.									
Pistol (C.B.)............		W.F.	4·5	6·35	4·0	W.B.	17·5	4	do	9·75	5·0
Pistol percussion........		W.F.	3·75	5·2	3·6	W.B.	14·25	3	do	8·3	5·0

METALLIC TUBES.

Manufacture of Metallic Tubes for preserving Cartridges from damp.

THESE are waterproof covers of thin tin tubing, for preserving the cartridges on boat-service, or any service in which they would be greatly liable to be exposed to the action of damp. The mode of making these tubes is so peculiar and so exceedingly beautiful, that a detailed description of it will, I am sure, prove very interesting. It is performed in the following manner:—A circular piece or pellet of block tin, ·63 of an inch in diameter, somewhat resembling a thick fourpenny-bit, being ·1 of an inch in thickness, is punched out. This is put into a small circular hollow or die, sunk into the bed or lower part of the frame of a fly press. The sides of this hollow or bed are slightly raised above the small tin pellet, and the die is also, in a very small degree, of a larger diameter than the piece of tin. A punch fixed to a spindle is, by means of the fly press, brought with considerable force down upon this piece of tin. The diameter of the punch is about ·005 of an inch less than that of the hollow in the frame in which the piece of tin rests. By the force of the blow, the metal is forced or squirted up, and forms a tube round the punch. To enable this tube to be drawn off easily, and to prevent its being rendered useless by collapsing in so doing, the air is allowed to pass down the punch through a small hole drilled through the centre, and in which a delicately-constructed steel bar is placed. This is so formed (being larger at the bottom) that, when forced upwards, it closes the opening in the lower part of the punch; thus, on the punch descending, the blow closes the air-hole, allowing the air first to escape, and preventing, at the same time, the tin being forced up into the hole. On withdrawing the tube from the punch, the rod falls downwards, allowing the air to enter from above, and thus permitting it to be easily drawn off with the hand without the danger of a collapse.

The tube is 3 inches in length, ·63 of an inch in diameter, and about ·005 of an inch in thickness. Into it the cartridge is inserted, the bullet-end being uppermost. Upon the top of this, again, is placed a small beech-wood cork or plug, ·61 of an inch in diameter, and about ·25 of an inch thick; it has a groove round its circumference, into which the tin sides of the tube being pressed with the nail, it is held firmly in its place, and the sides of the tube protected from being pressed in or flattened; over this another tube or cap (manufactured in the same manner, but, being made from a smaller piece of tin, it is shorter) is fitted, forming, as it were, a cap for the larger tube: a little shellac between these insures an adhesion of the two surfaces. The sides are then pressed into the groove in the cork with the nail, and finally the whole cap receives a coat of black varnish; thus effectually preventing any moisture from entering and spoiling the cartridge.

These tubes are opened by tearing off the bottom or unvarnished end, and drawing out the cartridge by its twisted top. All packets containing cartridges thus protected are marked "Metallic Covers."

LUBRICATION.

The Lubrication, or Anti-fouling Agent,—Material used and Tests for it.

The best anti-fouling agent known at present is beeswax; its freedom from acid and fatty substance, and the comparatively high temperature of its melting-point, constitute it a much more permanent material, for this purpose, than other substances.

In a hot climate, grease is inadmissible as a lubrication; a high temperature causing the grease to disappear from the surface of the cartridge, and some penetrating the paper to the surface of the bullet, frequently corrodes the lead, rendering the cartridge unserviceable, and fouling an inevitable consequence.

The beeswax used, therefore, ought to be free from all acids, and the tallow and grease should be equally pure. Beeswax may be adulterated with fatty matter. The presence of a considerable quantity of this can be tested by rubbing it between the finger and thumb. If it becomes very soft or sticks to the fingers, and is greasy; the presence of some fatty matter may be assumed.

If the wax be heated to a heat of 220° Fahrenheit, and shows signs of frothing, water is present: this may be expelled by keeping the heat up and allowing it to evaporate.

The subject of the lubrication of the cartridge would seem to the casual observer, or to one not closely acquainted with the practical expenditure of ammunition, to be a matter of small importance, and that the object was gained, when there was a something on the cartridge to grease the grooves in the barrel and to facilitate loading.

But these are only secondary objects in the choice of a lubricating agent; its real duty being to reduce fouling, and render the rifle, after many rounds, an efficient weapon.

The choice, therefore, of a lubricating agent becomes a very large and important question. It is stated that the rifles in the service vary nearly $\frac{3}{1000}$ of an inch; some taking the rejecting-plug ·58 of an inch nearly halfway down the barrel.

If no difficulty existed in the field, such as rust, dirt, and fouling of the barrel, then, the components of the lubricating composition would not affect to the same extent the efficacy of the Enfield rifle on service. But such minute accuracy either in the manufacture, or in the examining of large quantities, is hardly to be attained and scarcely to be expected, wonderful as is the precision and amount of perfection already arrived at in this branch of manufacture.

It is difficult to over-estimate the loss in efficiency of a corps in the field, consequent upon the issue of ammunition which has been imperfectly or improperly lubricated, or which has been defectively made up. It is not merely a question whether more or less accuracy is attained, but whether *any firing at all* can be maintained against the foe.

It is thus easily seen that the careful selection of a lubricating agent becomes a very important part in the manufacture of the ammunition; for, besides its adaptability in obviating fouling, its keeping properties when in store must be taken into the deepest consideration; as, in most cases, troops on service must be supplied with ammunition which has been some considerable period in store.

If, then, the lubricating agent is one that deteriorates or injures the cartridge, its rejection becomes not merely a matter of expediency but an imperative duty.

Tallow, or other similar substance, either by itself, or when combined with other material, will not remain permanent, but will gradually pass away into the paper of the cartridge; and, in cases where the tallow preponderates in a large degree over the beeswax, a portion of the tallow will remain on the cartridge, in the form of a dry powder.

The superintendent of the Royal Laboratories and the chemist of the War Department remark, that, having examined some bullets which had been to India, in cartridges made up in the Royal Laboratory some time previous (the lubrication containing tallow), they discovered an incrustation upon the surface of the bullets, resulting from a corrosive action set up by the acid matter, caused by the change which tallow undergoes, and that the rapidity of this action would be regulated by the nature of the climate to which the ammunition is exposed.

Tallow in a state of mixture with beeswax is easily alterable, and being fused by a tropical climate, a very small proportion is sufficient (absorbed through the paper) to reach the bullet and corrode it; and when once the corrosive action has been set up, simple atmospheric exposure will continue it.

These facts are very important, as they are sufficient to condemn the use of any fatty matters as lubricators, where the windage allowed is small.

The two substances with which experiments (as to the proper description of lubricator) have been carried on, are beeswax and tallow, and the proportions of each have been from time to time altered; at one time a preponderance of tallow at others beeswax alone.

In 1857 Captain Boxer, R.A., Superintendent of the Royal Laboratories, proposed beeswax as the agent, and urged its valuable properties of not injuring the cartridge in store. A committee, composed of General Hay, commandant School of Musketry, Hythe; Colonel Gordon; Mr. Abel, chemist to the War Department; and Mr. Gunner, inspector of small arms, assembled in the beginning of July, 1857, and were fully satisfied of the advantages possessed by beeswax over tallow in the keeping properties of the cartridge; but they qualified their consent to the introduction of beeswax *alone*, —"That, by adding a very small proportion of tallow, the operation of loading would be facilitated." The mixture adopted into the service, resulting from the report of this committee, was one part tallow to five beeswax.

At a subsequent period, however, difficulties arose in loading in cold weather, when the temperature was below 40° Fahrenheit, which, however, usually vanished after the third or fourth round. General Hay, in January, 1858, expressed his opinion that beeswax would *not* do as a lubricating agent, and he also condemned the admixture of beeswax recommended in the first instance: his opinion, based as it was upon the practical expenditure of ammunition, demands very serious attention. He anticipated great difficulties in loading in any but the hottest weather, and also objects to this lubrication, from its being apt to chip off in handling during very cold weather; and he came to the final conclusion, that where rapidity and facility of loading, combined with accuracy of shooting, is required, tallow must be the preponderating ingredient from of at least four parts tallow to one beeswax. Fresh inquiries were now pursued into this subject, and Captain Boxer having given it his careful attention, came to the conclusion that by a particular mode of applying the mixture of five parts beeswax and one tallow, the defect of peeling off would be removed, and that loading would not be seriously inconvenienced, even in the coldest weather.

He also became convinced that the mixture containing a preponderance of tallow would not meet the requirements of the service.

In February, 1858, Captain Rowland, musketry instructor, H.M.'s 25th foot, was instructed to enter into a series of experiments on the subject, and, together with Captain Boxer, carried on a series of elaborate and practical experiments.

The composition and proportions experimented on were as follows:—

1st.	5	wax	to	1	tallow
2nd.	2	do.	to	1	do.
3rd.	1	do.	to	4	do.

The two first were raised to a temperature of 230° Fahrenheit before the cartridges were dipped, and the bullet or cartridge itself warmed. The last mixture, owing to the large quantity of grease contained in it, was only raised to a temperature of 210° Fahrenheit.

The cartridges when dipped were forced into a gauge ·582 of an inch in diameter, raised to a temperature of 130°: this removed the superfluous lubrication, and the cartridges were thus enabled to be entered into the barrel without any considerable force being required.

The object gained in warming the cartridges and raising the temperature of the composition previous to dipping, is to cause it to adhere the more firmly and evenly.

The experiments being carried on during a cold easterly wind, were useful in testing the several merits of the compositions in cold weather.

The result of the trials was, that a composition of five parts wax and one tallow was found to answer both as regards fouling and loading in very cold weather, and at the same time it was decided, 1st, That to obtain a good result with this mixture, it was necessary to raise it to a temperature of 230° Fahrenheit before applying. 2nd, That the cartridges should be previously warmed on a hot plate; and 3rd, That, after dipping, the cartridges should be passed through a warmed gauge ·582 of an inch in diameter; these operations being very inexpensive, increasing the cost of the cartridge only ·333 per cent., and therefore so trifling as not to be taken into consideration.

However, with all these precautions in the preparation of ammunition, unless the soldier assists by careful loading, the result will be unsatisfactory.

He should be careful to press firmly, and by *direct* pressure, the *whole* of the cylindrical part of the bullet (up to the top of the shoulder) into the muzzle before tearing off, and at the same time take the greatest care not to twist the cartridge when inserted, so as to ruck up the paper.

But the reduction in the diameter of the bullet proposed by Captain Boxer entirely removes every objection as regards the loading with beeswax upon the cartridge.

At first thought, this would appear to those who have studied musketry theoretically, as a mode of procedure calculated to injure the efficacy of the weapon; as, increasing the windage from ·001 to ·018 of an inch in a weapon like the Enfield rifle becomes, a very serious question.

The advantages gained, however, were easy loading and apparent diminution of fouling. The disadvantages fully anticipated were loss of range, less accuracy of fire, and the contingency of the bullets being liable to be displaced, or not remaining "home," after loading, when the rifle was reversed or shaken.

All these points were most carefully gone into in July, 1858, by a committee, of which Colonel Norcott, C.B., was president, and to the surprise of most theorists, it was found practically that the target results were not in the slightest inferior to those of the bullet ·568 inch diameter: the range appeared precisely the same, and the elevation required being in both cases similar. If anything, it appeared that the bullet with the diminished diameter had the lowest trajectory; one slight tap with the ramrod, after the bullet had slipped down, was found sufficient to retain it in its place, although subjected to severe trials (the rifle being jolted and struck with the barrel reversed). In fact, it seemed apparent to all, that sufficient expansion was obtained to enable the projectile to fill the grooves instantaneously upon ignition, and therefore to acquire the necessary rotation; and perhaps the friction being diminished from the particles of discomposed lead being less dense when forced into the grooves, would account for the trajectory being lower. No experiments were gone into as to the penetration; but having carried on a few with a rifle of *larger* diameter in bore than the Enfield, I found that it was precisely the same with bullets of both diameters. And with the Enfield rifle I found no difference.

It was thus proved beyond all doubt the fact that General Hay's wood plug acts as an immediate expander even to the extent of more than ·018 of an inch. Whether the same amount of expansion can be obtained by altering the shape of the hollow or not, or by any other means, remains to be seen. The wood plug has proved itself indubitably fully able to perform the duty required of it.

The facility with which loading is carried on even with rifles seriously fouled, with cartridges of this new diameter, and the great diminution in "fouling" itself, became so evident, that on the 26th July, 1858, it was adopted into the service for India, and on the 21st February, 1859, throughout the whole army, as also the adoption of beeswax alone as the lubricator.

A cartridge also slightly modified from that described in a former part of this book, has been introduced; the object being to facilitate the "tearing of," by reducing the number of folds of paper in the upper portion or powder-cylinder. This is attained by shortening the "forming," or outside paper; and to secure it at the junction to the second or inside paper, a small strip of gummed paper is fastened round the cartridge at this place. The bullet is 0·55 inch in diameter and 1·09 inch in length, instead of 0·568 and 1·05.

Breaking up Ammunition.

Unserviceable ammunition is broken up, the powder being sometimes good, and always valuable for the purpose of extracting the saltpetre.

The bullet is first broken from the cartridge, and allowed to roll into a receptacle to receive it; the powder is emptied through a funnel and wire sieve into a separate compartment. The only papers used again are the slip, and some of the wrapping-paper; in some cases, the cylinder or stiff.

THE CAP.

The Materials used, and Tests for them.

PERCUSSION caps used in the service are made of copper, a metal, both as to its chemical as well as physical qualities, admirably adapted to meet the requirements of this particular manufacture. The copper used must necessarily be very fine, as a very small proportion of foreign matter, such as antimony, lead, tin, &c., will affect injuriously its malleability.

As the lead, so the copper is procured by a broker, and costs on an average about 1*s*. per lb.

Test for the Copper.

The presence of antimony may be readily determined by boiling a small quantity of copper in concentrated nitric acid; for, in so doing, the antimony will not be dissolved by the acid, but merely oxidized. Tin will be affected in a like manner; but lead and iron will dissolve with the copper in the nitric acid, and must be tested for by a regular analysis. Samples from a certain percentage of the metal sent are tested in this way:—The copper arrives in sheets, 5 × 2 feet; 16 oz. by weight to the square foot. To insure the sheets being clean, before they are used in manufacture (a point of the utmost importance, as the fact of any impurities remaining upon them greatly affects the serviceableness of the caps when made up), they are taken to a building in which are erected leaden vats, containing dilute sulphuric acid. The sheets are dipped into this solution and allowed to remain in it a short time, according to the strength of the acid. By this process they are cleansed from all oxide, and if any dirt remains after this, the plates are further scrubbed with sand until quite clean; they are finally rubbed with a cloth, and carried to the manufactory to be made up into caps, or friction-tubes, &c. Previous to being cut up into strips of the requisite size for the cap-machines, the sheets are rubbed over with an oiled cloth, to render their passage through the machine easy. The sheets are then passed between revolving circular cutters, and cut into strips two inches wide, and of the same length as the sheet. The width of these slips varies, according to the machine for which they are intended: for Abraham's cap-machine, with four punches, the width of each strip is 2 inches and ⅝. The strips are then ready for the machines. Of these there are several kinds still working; but the more recently-constructed machine (Abraham's) has so many decided advantages over the others (which are of American invention and manufacture), that the universal adoption of machines of this pattern cannot be at any very distant period. The cost of Abraham's cap-machine is about £400; and the rate of manufacture, on an average, somewhere about 130,000 caps in a day of 10 hours; whilst the American machines can only make 60,000 in the same time: they are, however most ingeniously contrived, and very beautiful in appearance. In Abraham's machine the motion is continuous, whilst the American is so constructed that it is necessary to stop the machine when each strip of copper has been worked up, for the purpose of supplying the machine with a fresh strip of copper. Broken pieces of copper do not necessitate the stoppage of Abraham's machine; but the least obstruction of this sort in the American machine renders it necessary to stop the machine to pick it out. The speed at which the American machine can be worked is, owing to its peculiar construction, limited; whilst Abraham's can be worked at any speed. I will endeavour to describe the principles and working of Abraham's machine.

Abraham's Cap-Machine.

The strips of copper sheet are brought to the cap-machine, and one end is inserted between two horizontal rollers, by the rotation of which the strip is drawn forward into the machine. These rollers have motion imparted to them by means of an eccentric, connected by a rod and band to the rollers, and thus giving an intermittent movement to spur-pinions attached to the rollers.

The strip is thus brought under three or four (according to the construction of the machine) cross-shaped punches, and over three holes in a revolving circular disc; these holes being immediately under and coinciding with the position of the punches. The punches are attached to a spindle, to which a vertical reciprocating motion is given by an eccentric and band on the main shaft: by these punches small cross-shaped pieces of copper are stamped out, of the following shape and dimensions:—

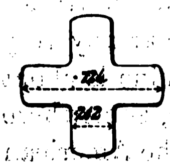


Fig. 1.

After being punched, these crosses or blanks fall into the holes in the revolving circular disc: this disc rests upon a flat plate, which forms a bottom for these holes; it then makes a quarter-revolution, and, taking the crosses along with it, brings them exactly under three punches with cylindrical ends, of the same size and shape required for the cylindrical portion of the cap. These punches are fixed to the same spindle with the cross-shaped punches; and, vertically descending, the cross-shaped pieces are punched into beds or recesses in the lower plate, of the same shape and dimensions as the cylindrical part of the cap: after being punched into these beds, the caps are ejected from below. A movable socket on each punch, sliding down as the punch rises, throws the cap off, in event of its adhering to the end of the punch. The caps thus formed remain in the holes in the disc; and, the disc again making a quarter-turn, they are brought over an opening through which they fall into a barrel, or any receptacle placed underneath the machine to receive them.

The Finished Cap.

Diameter of flange	·43 of an inch.	
Greatest diameter	·230	,,
Least diameter	·212	,,
Depth inside	·248	,,

The original machine of this description, in the Royal Laboratory, has been greatly modified, and much improved by the addition of some most ingenious contrivances by Mr. Campbell, of the Royal Laboratory Department.

One of these is the addition of a piece of mechanism, by which, in event of the disc not revolving truly, *i.e.* not making a complete quarter-revolution, the punches are checked from descending. If some such precaution were not taken, not only would the punches themselves be broken, but the disc would be greatly injured, and the whole machine receive a most injurious shock. Other additions, equally ingenious, have been added by Mr. Campbell, to various parts of the machine, rendering it very perfect, and beautifully adapted to its requirements.

After the cap has arrived thus far in the process of its manufacture, it has to go through the several operations of cleaning, filling, pressing, varnishing, drying, examining, further drying, and finally packing. In this order I will describe them, being the same in which the operations are conducted.

Cleaning.

The caps are taken away, after being formed in the machine, and thrown into a wooden cylinder, or drum, containing saw-dust. This cylinder is driven by steam power; and, slowly revolving, the caps in this way become thoroughly scoured. When taken out of this drum, they are placed in a sieve, to which a rapid reciprocating motion is given, and any sawdust that may adhere to them is thrown off and falls through; after they have gone through this process, they are thrown in a heap upon a large open tray or table, with raised sides, and from this they are placed in trays ready for filling in the following manner:—

Filling.

To enable the caps to be easily and quickly placed, mouth upwards, in the trays, in a position for filling, they are thrown, by a boy, upon this tray, which is a plate of brass containing 1,000 holes or perforations, coinciding in diameter to that of the cylindrical part of the caps. He rests it upon a loose roller fixed across a table, with raised sides, on which are thrown the caps, and, by a peculiar motion, *viz.*, by shaking or jerking the tray on this rolling bar backwards and forwards, and heaping fresh caps upon it, continues this operation until the caps fall into it, filling each hole and adjusting themselves with their mouths upwards.

These trays are then carried to the filling-machine, which is constructed in the following manner:—It is made in the form of an oblong table, with two metal tops and a raised edge; the tray of caps sliding in, in the manner of a drawer. The double top to this table is formed of two metal plates, both perforated with 1,000 holes, exactly corresponding to those in the tray of caps underneath. The lower plate is movable, sliding backwards and forwards; motion is given to it by turning a handle, connected to it by a rod, working within a fine female screw; thus preventing any rapid or sudden motion being given to the lower plate.

To prepare the machine for filling, the cap tray is slipped underneath the two plates, the lower one being so adjusted that the holes in it do *not* coincide with those in the upper plate; thus forming, as it were, a bottom for them.

The composition, in the form of a fine white powder, a description of which is given further on, is carefully spread over the upper plate with a pasteboard slice (12 oz. of this composition only is permitted to remain at any one time in the factory, and this fills between 17,000 and 18,000 caps); when each hole on the upper plate has been filled, the superfluous composition is carefully removed. The handle is now turned, the lower plate thereby being slowly moved, until the holes coincide, when a few smart taps on the frame or edge of the table suffice to cause the composition to fall into the caps below, each cap obtaining a charge of about one-third of a grain.

By the contrivance for moving the lower plate, it is rendered impossible for a hasty or careless workman to move the plate rapidly, which might cause friction sufficient to ignite this highly-explosive composition. The caps thus filled, the trays are conveyed to the pressing-machine.

Pressing.

The tray, whilst in this machine, is placed upon a slab or table, and, at each stroke of the machine, by means of a rack-movement, it is drawn forward, when, at the same time, punches corresponding to the cylindrical portion of the cap gently descend, pressing the composition in each cap with a pressure of about 65 lb., there being a row of punches corresponding to a row of caps in the tray. Thus, at each stroke, the tray is advanced, and a row of caps brought underneath the line of punches; the tray is thus advanced until all the caps being pressed, it is brought against a lever, when, by an ingenious contrivance, the machine is stopped and the punches checked from descending, thus enabling the tray to be easily withdrawn. This machine, until very lately, was worked by hand; but Mr. Campbell, of the Royal Laboratory Department, has so adapted it, that it may be worked by power, besides adding the ingenious arrangement above mentioned. The composition, although pressed into the bottom of the cap, is still liable to imbibe moisture and fall out; and to secure it from either of these contingencies it is varnished.

Varnishing.

For this operation the caps still remain in the same tray, which is now brought to a machine and laid upon a slab or table; and, by a similar rack-movement to that on the pressing-machine, is drawn forward, at each stroke of the machine, the exact distance of the space between each row of caps. Upon a rod connecting two movable or hinging arms, one on each side of the machine, are fixed a number of small pins, corresponding in number and position to one row of caps in the tray. This arm is so arranged, that the boy in charge of the machine is enabled to dip the pins into a reservoir of shellac and methyllated spirits of wine, and then passing them over, the amount of varnish adhering to each pin is deposited in each cap, sufficient quantity being taken up, in the act of dipping, to secure the composition within the cap. By the motion of bringing the arm back for a fresh dip into the reservoir, the tray is again drawn forward, and a fresh row comes under the place where the pins fall to receive their supply; and this is continued until the whole tray is finished and each cap receives its quantum.

Drying.

This operation completed, the tray is placed upon a steam-heated table, so that the varnish may be thoroughly dried; the temperature of this table necessarily being carefully regulated. They remain some time upon this table; and when quite dry they are examined.

Examining.

The tray is raised from the drying-slab, and each cap carefully glanced at, to see if any defect either in filling or in the manufacture is visible. The tray is then gently reversed upon a smooth table, and each cap remains standing mouth downwards. The tops are then examined to detect if any flaw exists, or any crack is visible. The slightest defect entails the rejection of the cap, when it is melted down.

Second Drying.

Previous to packing, the caps are subjected to a second and more complete process of drying, so that all moisture may be thoroughly expelled. If they do not undergo this process soon after filling, and the other processes, they seldom remain so long in a serviceable state.

For this final drying, they are ranged round a room on shelves, the temperature of this room being carefully maintained at a heat between 100° and 110° Fahrenheit. They issue, from hence, ready for packing and use. A certain percentage are gauged with two gauges, a high and a low one, to ascertain their correctness. These gauges are simply two gun-nipples: upon one the cap should slip on easily, upon the other with difficulty.

Packing.

A number of small flat square blocks, each perforated with 25 holes, coinciding with the cylindrical part of the caps, are placed together so as to form one tray, similar to those already described. The caps are scattered over this, and, by a process precisely the same as previously mentioned in the operation of filling the trays, are shaken until they adjust themselves in the holes. This operation complete, a boy, employed on this duty, takes up one block after another; and, after examining each separate cap, empties the 25 into a small tin box placed at his side; to facilitate his doing this speedily, he is provided with a funnel. This tin box is now given to the packer, who rolls the caps up into little brown-paper parcels, containing 25; and, further, three of these packets into one parcel, which, therefore, contains 75 caps, the proportion at present issued for 60 rounds ball cartridge; for 60 rounds blank but 66 caps are allowed. These larger packets, being secured with twine, are packed in zinc cylinders, of various sizes. Some are also packed in flat zinc boxes.

Composition used in Filling Percussion Caps.

This composition is formed of three ingredients, mixed in the following proportions, in a mannner that will be described hereafter:—

Chlorate of potash,	6	parts.
Fulminate of mercury,	4	,,
Powdered glass,	2	,,

Before entering into the manner of incorporating them, I will give a description of each ingredient.

The Chlorate of Potash.

Potash or potassa, so called from the original mode of preparing it being conducted by evaporating in iron pots the lixivium or salts of the ashes of wood fuel, consists in its crude state, therefore, of those constituents of burned leaves, twigs, vegetables, &c., which are "fixed" when subjected to the action of fire but soluble in water. The potash salts of vegetables or plants, which had contained vegetable acids, will be converted into carbonates, forming carbonate of potash.

If quick lime be added to a solution of these ashes, a proportion of caustic potassa will be the result.

This caustic potassa, or hydrate of potassa, is generally prepared from the carbonate by dissolving one part of the carbonate with ten parts water, in a clean iron pan, boiling, and then adding small quantities of quick lime slaked with boiling water.

There are several methods of preparing the chlorate of potash, the following seems, however, to rank among the best:—

A solution of caustic potash mixed with hydrate of lime (slacked) is heated, and a current of chlorine gas transmitted through a tube into the solution, which when saturated with the gas, is filtered and evaporated to crystallization; the result of which being the chlorate of potash.

Chlorate of potash or potassa is used in the manufacture of lucifer-matches. It has been tried, mixed with other substances, as a substitute for saltpetre, in the manufacture of gunpowder; but the decomposition was found to be too instantaneous, resembling the action of fulminates more than that of gunpowder; the strain, consequent on the sudden formation of the gas, being too great for a gun to stand for any length of time.

For mixing with detonating compounds the chlorate of potash has no equal; it therefore forms, as will be seen by the table, a larger proportion of the ingredients for making the composition for percussion caps, and is also used in the composition for friction tubes for firing cannon.

It is procured in small colourless and thin and tabular crystals, and is unaltered by exposure to the air; and is soluble in seventeen parts cold water to one of the chlorate; it is, however, dissolved in 1·5 parts of boiling water.

The principal substance with which commercial chlorate of potash is contaminated, is chloride of potassium; this substance may be readily discovered by the nitrate of silver.

The Fulminate of Mercury.

It consists of small brownish grey crystals, which sparkle in the sun, and are transparent when applied to a slip of glass, with a drop of water, and viewed by the transmitted light. An imperial pint of boiling water will dissolve 67 grains of the pure fulminate: whatever remains, after dissolution, indicates impurities.

Preparation.

100 parts by weight of mercury should be dissolved in 1000 parts nitric acid, also by weight (specific gravity 1·4), in a glass retort, the beak of which ought to be inserted into a large bottle, to collect the offensive fumes of nitrous gas, which are condensed into a liquid acid.

When all the mercury has been dissolved, and the solution has acquired a heat of 130° Fahrenheit, it should be poured slowly through a glass funnel into a largish bottle containing 830 parts by weight of alcohol, specific gravity 0·830.

The mixture now froths and bubbles, and a very inflammable white and voluminous gas escapes.

As soon as this effervescence is over, the contents of the bottle should be turned out upon a paper filter in a glass funnel, and washed through until the drainings no longer redden litmus paper.

The paper filter is then opened upon an iron or earthenware slab (carefully heated), and the contents, being the fulminate, are thus dried. The slab ought to be maintained at a temperature of 212° Fahrenheit, by means of steam or hot water.

This powder is packed up in parcels, 100 grs. in each, and after that in bottles or jars. The heat required to explode this fulminate is 367° Fahrenheit, and no inferior heat will do so. It detonates with a blow, or by any temperature above that mentioned, when azote, carbonic acid gas, and other vapours, are disengaged, to the sudden formation of which is due the report. It detonates even in a moist condition; and in a dry state it explodes readily when struck between two pieces of iron; less so between a piece of iron and gun-metal, with greater difficulty still between marble and glass, and even with more difficulty between iron and lead.

The larger the crystals the more readily they explode. When damped with 5 per cent. of water, it becomes less fulminating; the part struck will detonate, but ignition will not be communicated to the adjoining portions. Though moistened with 30 per cent. of water, it will occasionally detonate by trituration between a wood muller and a marble slab, but without any danger.

If a train of fulminate is laid as thick as a quill in a long line, and this covered over with gunpowder, with the exception of a short distance at one end, and then ignited at this end, not a grain of the gunpowder will be exploded, but may be collected afterwards from the places to which it has been blown, and ignited; the explosion of the fulminate being too rapid to raise the component parts of the powder to 600° Fahrenheit, the temperature needful for their explosion.

The Operation of Mixing.

In dealing with such explosive and dangerous substances as the fulminate of mercury and chlorate of potash, the greatest care and precautions have to be observed.

The buildings in which the processes of mixing are carried on, are isolated and lightly built.

The following is a list of most of the requisite appurtenances:—

A drying slab, or table of copper constructed so as to be heated by steam and regulated to a fixed degree of heat; three sieves, of the different sizes of mesh required for the different ingredients; a pair of scales; India-rubber bags to carry the composition; and brushes of the same form and size as painters' large-sized brushes. The floor of the shed in which the operations of mixing and drying are carried on is covered with a felt matting and the usual precautions of encasing the feet in nail-less over-shoes are insisted on.

The fulminate, which is kept in a moist state, in jars, in a magazine, is brought into this shed to be dried, which is done by exposing it, spread out, upon the drying table or slab; this is heated by steam, which is generated by means of gas in a building at some distance.

When the fulminate is dry, it is passed through a sieve (42 meshes to an inch) by means of a brush.

The chlorate of potash and powdered glass are then passed in the same manner through a sieve, 120 meshes to the inch. After this the three ingredients are brushed through a sieve of 80 meshes; all of these operations being carried on by means of a brush, the operative employed having to cover his mouth during the process of brushing them through the sieves, to prevent his inhaling any of the particles, especially of the powdered glass.

The composition thus complete is conveyed in India-rubber bags to the factory, for filling, as before mentioned, in quantities not exceeding 12 oz. at any one time.

AMMUNITION BARRELS.

Manufacture or Cooperage of Ammunition Barrels.

The barrels in which ammunition is packed, require to be of sufficient strength to resist the hard treatment to which at times they must necessarily be exposed, and also to a great extent waterproof. The wood of which they are made must be dry and well seasoned, the hoops as strong as possible; and with all these requirements, the cost of manufacture is a serious consideration to a nation whose ammunition is always travelling to and fro, through every possible temperature and climate, over a greater portion of the globe.

Various kinds of materials have been used in this manufacture, such as copper and thongs of various woods; but ashen thongs have been found to be the most economical, as well as durable; though more clumsy in appearance, nor presenting such a smart exterior as those barrels hooped in a more costly manner with copper.

The barrels used in the service, for all service ammunition, are called quarter-barrels, and are made of well-seasoned oak. The wood mostly used is American. The operations in making these barrels may be divided into six different parts, each of which I will endeavour to render clear, and in the following order.

1st. Making the staves, for which there are four distinct operations.

2nd. Making the heads, for which there are five operations.

3rd. Bending the thongs, one operation.

4th. Forming the barrel, two operations.

5th. Heating and preparing the barrel for the head, two operations.

6th. Hooping and fixing the heads, and finishing.

1.—*Making the Staves.*

The oak is brought to the manufactory in blocks or logs, about 5 feet long, and 3 × 6 inches, and firstly cut up into pieces $15 \times 3 \times 6$ inches. This is done in a machine technically called a circular cross-cutting saw. The wood is stationary on the frame of the machine, and the circular saw is mounted upon a movable and nicely-balanced frame, so that it is easily moved by the hand and brought down upon the piece of wood, which is placed upon the main frame at right angles to the saw. The log, thus cut to the above-mentioned length, is again brought to a circular saw, fixed in a machine of different construction, and is then squared or cut into pieces $15 \times 3 \times 3$ inches; these pieces are then brought to a *cylindrical* saw constructed or being of such a diameter as to give to the stave the curve required. The cylinder, which is fixed horizontally, revolves rapidly, and the square piece of oak is guided by the hand, being held horizontally towards the saw: by this means from each of these pieces before-mentioned five staves are cut, of uniform thickness and of that curve or convexity which is required for the shape of the barrel.

These curved staves are next brought to another machine having circular saws, fitted with copying slide motions, set so as to give to the staves that peculiar parabolic form required to make them up into barrels; viz., tapering to the ends and swelling towards the centre. There are two saws fitted into slides adjusted so as to give the curve for the right and left sides of the staves; and at the same time they give to the sides of the staves that necessary bevel to enable them to fit accurately together. The staves are now complete.

2.—*Making the "Heads."*

The "heads" are formed of oak in two pieces pegged together. The wood is cut out in the circular saw, before described in operation No. 2, in *making the staves*, into small oblong pieces about half an inch thick; these have two small holes, called "dowel-holes," drilled into one side by means of a horizontal "double spindle" drilling-machine. These sides are then planed, in a small planing-machine with a reciprocating action; this makes the surfaces of the sides coincide accurately. Then, by means of small wooden pegs placed into these "dowel-holes," the pieces are pegged together, thus forming one square piece; this piece is fixed between two face-plates, and nipped lightly, by means of screws, and then set in rapid motion. A tool working on a slide is brought up to it by means of a lever-handle; and, as it revolves, cuts it into a circular piece of the required diameter. Two other tools, set so as to bevel the edge that has been just cut (giving the head the double bevel and sharp edge, to enable it to fit accurately into the groove in the barrel), are now brought forwards on a slide up to the circular piece whilst rapidly revolving.

This done, the operation of "facing" the ends, as it is technically called, is performed. The head is fixed into the chuck of a lathe, and nipped by screws at the sides or edges; the head revolves, and a small tool fitted on to a *curved* slide planes the surface, and at the same time gives the head a convex surface thicker in the centre than at the edges, the object being to give strength to it.

The head is now taken from the chuck, and is ready to be fitted into a barrel.

3.—*Bending the Thongs.*

The thongs used, as before mentioned, are made of ash. They are brought in bundles split into the size required for barrel-thongs. The only process through which they pass is that of passing them through three revolving rollers, bending them, and at the same time testing their capabilities of torsion; for, if they are of unsound wood, they are at once crushed or broken. This done, they are twisted up into a loop, and are ready for use.

4.—*Forming the Barrel.*

The staves, formed as described in the first operation, are brought to the machines constructed for this purpose, and by means of which, by a pretty and ingenious arrangement, the staves are forced up together into the shape of a barrel.

This operation requires, however, a detailed description, to be clearly understood.

Upon the top of the ram of a vertical hydraulic press is fitted a circular plate, with a raised edge. The diameter of the plate being sufficiently large to allow of the staves being ranged upright all round it close to each other. Directly above this plate is a circular frame, formed by two semicircular pieces, which open and close by means of a screw. In the inside of these semicircular frames is a groove of a size to receive a temporary iron hoop or truss. To place this in, the frame is opened; and when done, it is screwed up. Thirteen staves are then arranged upright round the edge of the lower plate, their top resting within the upper frame. The press is then set in motion, and the lower plate consequently raised, forcing the staves up into the upper frame, which, being of a conical form, diminishing towards the upper part, causes the staves to be forcibly pressed together. The frame is then opened, the staves being held jointed together by means of the temporary truss which adheres. The barrel is then reversed, another temporary truss is fitted into the upper frame; and the same operation being repeated, the two middle hoops are thus fitted on to the barrel, which now is taken to a similar machine, contiguous to the above, and by means of which two other trusses are fitted on to the ends of the barrels; thus forming headless barrels with the temporary iron hoops. We now come to the next process.

5.—*Heating the Wood, and Preparing the Barrel for the Heads.*

For the purpose of drying and shrinking the wood pressed into this new form, the barrels are placed over a vertical pipe, with a number of gas-jets; and, to protect the barrel from becoming burnt, these jets are covered by an iron cylinder, with small holes in it. The barrel remains some time here, until thoroughly dried by the heat generated, when it is taken away, and the top and bottom temporary hoops are knocked off, and the barrel is fitted horizontally into a lathe, in which it is held at one end by means of a face plate, which slides backwards and forwards so as to allow of the barrel being slipped into a circular stay, to support it at the other end.

In this lathe, the barrel being made to revolve rapidly, one set of cutters fitted to slides are arranged so as to bevel off the staves at the ends, and another cutter cuts the groove in the interior of the barrel to receive the heads; the barrel is then reversed, and the same operation performed at the other end.

6.—Hooping and Fixing the Heads in the Barrel.

The two remaining iron hoops are now knocked off; the thongs, twisted to the proper size, are driven on by means of a mallet and a piece of wood, chalk being used to facilitate the operation of slipping them on; the head is put in, the remaining thongs fastened on, and the barrel is then complete.

To open the barrel it is only necessary to knock off a thong or two, and the head will fall in. The completed barrels are now taken to the sheds, in which the packing is carried on as occasion requires.

RIFLE-PRACTICE TARGETS.

The targets used for rifle-practice are made in the Royal Gun Foundry. They are made of one plate of the best cast iron, 6 × 2 feet and ½ inch thick, riveted to angle-iron sides; its surface or face is divided into 6-inch squares by lines cut on it. A circular bull's-eye also is cut in the centre, 8 inches in diameter, and two circles, the outer one 2 feet in diameter, the inner one about an inch less; these are to facilitate the painting of the targets. To the back of the plates two cast-iron blocks are riveted, with loops in them to receive the iron supports of the targets.

EXPERIMENTAL TARGETS.

These are usually made of the best cast-iron plates, 6 × 2 feet, and ½ inch thick. A number of these are built up and riveted together by means of angle iron, so as to form one large target, of course the larger the better, so that all shots at long ranges may be collected upon it. They require to be built up with care, and to have numerous and strong supports, and to be protected by a lofty butt, if possible, in places where much exposed. The surface is marked off into 6-inch squares, by means of lines cut upon it.

This is to facilitate the marking of the diagrams, which are copies of the target on a much smaller scale, one of which is shown in diagram.

The largest experimental target at Woolwich is 36 feet square.

MANTELETS.

These are places of safety for markers and others engaged in watching practice or experiments with small arms. They are placed in front of the butt and target, about 18 yards to the front of the latter, and to one side, and therefore enabling those in them to see the face of the targets.

Those used at present in the service are made in the Royal Carriage Department of the Arsenal, of best wrought iron, ½ inch thick; the plates are bent over, punched, and riveted in the same manner as boiler-plates, and then riveted to angle iron. The back is formed of two three-foot plates bent over, and therefore 6 feet in breadth, and the sides of plates 1 foot 6 inches wide. They have strong iron supports, fixed to the ground by iron bolts.

RIFLE RESTS.

The "Shoulder Rest."

In experimentalizing upon either the rifle, the ammunition, the powder, or the lubrication, it is necessary to obtain a more certain degree of accuracy than can be obtained by merely firing from the shoulder in the usual way.

To obtain the requisite steadiness, various stands or tables have been devised, and with these the best plan seeming to consist in securing a firm support for the left elbow, and for that part of the rifle nearest the muzzle.

These requirements are provided for in the table rest, which consists of a table supported by four legs, strengthened by cross-pieces, so as to render it firm and steady.

For the convenience of transport, brackets are made at the side for poles to slip into, and also racks for the various arms under trial. A place is shaped out in the table so that the body of the firer may come well up to it, and enabling him at the same time to rest his left elbow securely upon the table without any constraint or painful posture of the body. A Y, rest or a sandbag, is placed at the further end of the table, to allow the muzzle of the rifle to rest upon it. It is convenient to have a small hole at the left side of the table, with a drawer underneath, for the purpose of dropping the old caps into, and thus saving them. This rest or stand should be made adjustable to the height of the experimentalizer, or he should be raised or stand in such a way as to be perfectly without constraint whilst carrying on the experiments. In recording trials from this rest, it is necessary to insert in the margin of the diagram the words 'shoulder rest,' indicating that the rounds were fired from the shoulder and from the rest.

The Fixed Rest.

The foregoing method, although insuring a greater degree of steadiness, has been found, however, to vary too much to allow of certain deductions being made from the results of the experiments.

And for this reason a rest was constructed in which the rifle itself could be firmly secured; and, at the same time, to prevent the destructive effect of the recoil from injuring the rifle, a recoil slide was introduced.

The Americans, in their experiments on small arms in 1855, used a fixed rest of the following description:—

The rifle was held by a strap and bolt at the middle band, and also fixed by screws, so as to be firmly held at the butt, into a cast-iron carriage. This carriage, formed so as to slide freely in horizontal grooves, prevented the recoil from injuriously shaking the rifle.

When this rest had been levelled, it was screwed down to a heavy foundation of timber embedded in the earth below the disturbing influences of change of temperature.

Among the best rests used in England at the present time, is one formed much on the same principle; the butt, however, is left free to be pressed against the shoulder of the operator, the rifle being fixed by means of two brackets on the barrel.

By reference to the diagram No. 11, some idea may be formed of the construction of this apparatus. The diagram represents one of these rests constructed for India; and, for convenience of transmission, the frame was constructed rather lighter than there is any necessity for.

F, F, F, F, is the main frame of cast-iron, and made as strong as possible, or compatible with the portability required.

B is a movable piece or slide-rest. There is a groove running through the centre, into which the rifle-holder fits and freely slides. This slide-rest is so constructed that it may be elevated, being hinged on to the frame at *n*, and its direction laterally is also adjustable. The amount of elevation given is indicated on a vertical scale at the side of the frame, and the lateral direction by a horizontal scale in the fore part of the frame.

V a thumb-nut, to check the elevating screw; this must be unscrewed before attempting to elevate.

P is the elevating screw.

A, A, thumb-nuts, for the purpose of fixing the slide-rest; these must be unscrewed before attempting to alter either elevation or direction.

C, a thumb-nut to check the lateral movement of the slide-rest; this must be unscrewed before the direction can be altered.

D is a wheel for the purpose of turning a tangent screw working upon a female screw in the slide-rest, and by this means altering the direction.

S, a screw, of which there are two, for regulating the tangent screw, and so adjusting it, if required, as to prevent its working into the female screw in the slide-rest.

T, T, pins for resting the rifle-holder upon before fitting it into the groove.

H, groove in the slide-rest, into which the rifle-holder slides freely.

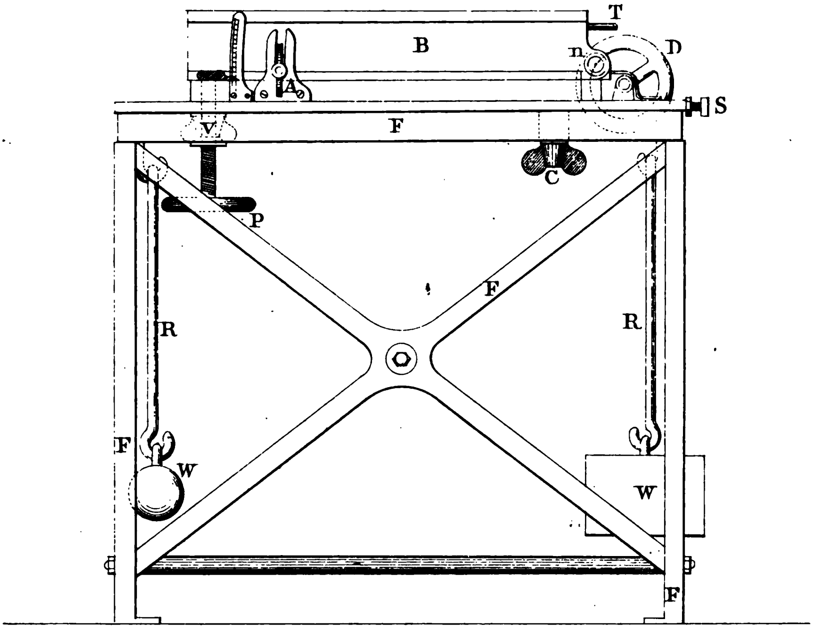
The rifle-holder is composed of two brackets constructed so as to coincide exactly in the groove H, and to nip the rifle-barrel firmly, without coming in contact with it, but pressing against the top edges of the stock. These two brackets are joined together by a metal bar. The greatest care should be taken in fixing a rifle into the holder, that the barrel is not twisted. The front screw of the lock-plate should be taken out and passed through the bracket, and then through the lock-plate and stock.

R, R, are rods, at the end of which weights, W, W, are suspended, for the purpose of steadying the rifle-rest. These should be about 100 pounds each. In diagram 11, the same lettering applies to both figures; the lower being upon a larger scale of three inches to a foot, and representing an end elevation of the upper part of the slide-rest. The position of the pins, T T, at the other end of the slide-rest, are also shown.

In using this rest, the butt of the rifle should be pressed into the shoulder of the firer, who ought to be seated on a

DIAGRAM II.

Fig. 1.



Scale of Feet. 0 1 2 3

FIXED RIFLE-REST.

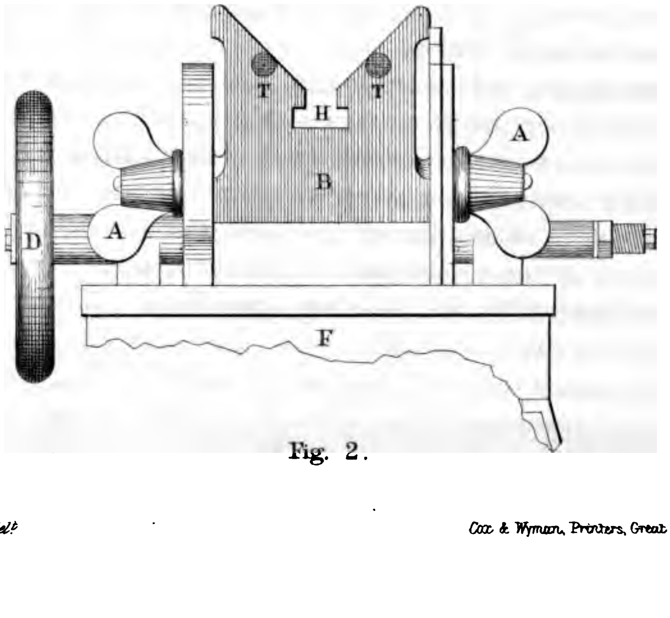


Fig. 2.

Arthur B. Hawes, Copt. del^t. *Cox & Wyman, Printers, Great Queen S^t. London.*

low stool; he should then pull the trigger steadily by means of a small lanyard.

The operation of loading is performed by sliding the rifle-holder out of the groove, and bringing the butt of the rifle (still attached to the holder) to the ground, and loading in the usual manner.

THE MICROMETER.

Micrometer, or Spherometer, used for Measuring the Diameter of Bullets, Cartridges, &c.

This delicately-made instrument is used for the purpose of ascertaining correctly to the thousandth part of an inch the diameters of bullets or cartridges, and of course other measurements may be made by means of it. To measure a bullet, it is necessary to hold it in such a manner that it shall be lightly touched by the two steel straight-edges that are fixed to the instrument; the space between these is the required diameter or measurement of whichever part of the bullet is desired to be taken.

This measurement is indicated to three places of decimals by means of a vernier and scale; the vernier being engraved upon a movable plate, to which one of the straight edges is fixed, and the scale upon the frame of the instrument, which is therefore fixed. The vernier is adjustable by a delicate screw, by means of which the steel straight-edge fixed to the plate is moved forwards upon the bullet. To save time, and to prevent the wearing out of the screw, this plate is so constructed that it can be moved back with what is called a quick movement, a spring within a small tube keeping a constant forwards pressure upon it.

By referring to diagram No. 12, which shows a plan of the instrument, full size, this instrument may be easily understood.

F, F, F, F, the frame supported upon pillars.

A is a plate sliding in the frame upon which the vernier is engraved.

V, the vernier.

D, D, D, D, screws for fixing the pillars to the frame.

E, E, steel straight edges, one fixed to the frame, the other to the sliding plate.

S is the scale of inches, each inch being divided into 50 parts, and the vernier having 21 divisions equal to 20 of those on the scale. The measurement is thus read off to the 20th of the 50th of an inch, or $\frac{1}{1000}$.

B, a handle to the screw *b*, by means of which the plate A is caused to advance or recede, and so constructed that by one complete revolution of it the plate advances $\frac{1}{1000}$ of an inch.

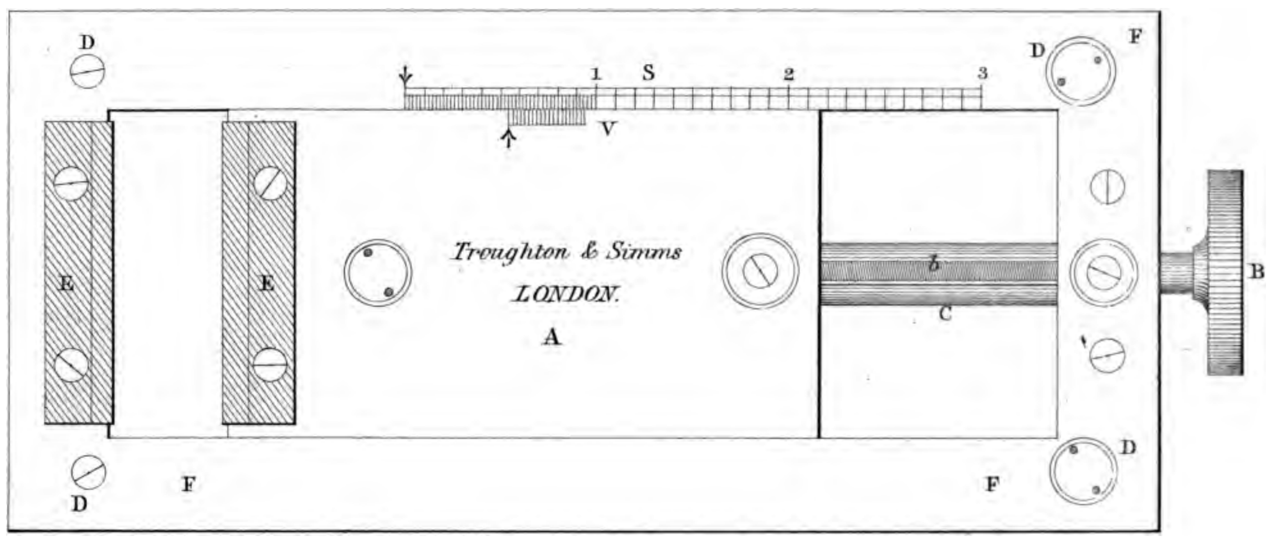
C is a tube in which is a spring acting upon the plate A, and which maintains a pressure upon it calculated to keep it closed upon the fixed straight-edge. The sliding plate can be pushed back without the necessity of turning the screw, a tedious operation, and one calculated to wear out the fine threads.

PENETRATION OF RIFLE-BULLETS.

Testing the Penetration of Projectiles.

To ascertain many points having reference to the description of rifling in a piece, shape and composition of the projectile, explosive force and quantity of powder in the charge, and description of lubrication, it is necessary to test the penetrative powers of projectiles fired at several distances, and under different circumstances.

For this purpose a stand is fitted up with grooves, the space of an inch between each; into these square boards of elm, ½ inch thick, and about 18 inches square, after being soaked in water, are fitted so as to slide in and out easily.



Arthur B. Hawes, Capt. del.

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PLAN OF MICROMETER

Used for measuring Bullets.

DIAGRAM 13.

Arthur B. Hawes Capt. delt.

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STAND TO TEST THE PENETRATION OF PROJECTILES.

Twenty of these are fitted into a frame, a sketch of which is given in diagram 13.

The firer places himself and rest in front of this stand at the desired distance, and, after firing, the boards are slipped out to ascertain the extent of the penetration, which is at once recorded. Three shots are usually fired from each description of rifle, &c., and the mean taken as the result or penetrative power.

The accompanying form is a convenient mode of recording the results of any experiments on penetration for the sake of comparison with other trials:—

Description of Rifle, Projectile, &c.	Rounds fired.	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20	Remarks.
Enfield Rifle.	1		Through the 11th.
Charge 2¼ drams.			
Service Ammunition.	2		Indented the 12th.
Lubrication.			
W 5. T 1.	3		Broke the 12th.
			Distance 200 yards.

First Round	11·0
Second Round	11·5
Third Round	11·7
Total divided by 3, or mean	11·4

Thus the first round the projectile penetrates 11 boards, which is recorded as 11; the second round indents the 12th, and is recorded as 11·5; the third goes a little further still, it breaks the 12th without penetrating, and is recorded as 11·7; these added together, and divided by 3, give us the mean of the three rounds, or value of the rifle or projectile, as far as penetration is concerned.

EXPERIMENTAL PRACTICE.

Manner of Carrying on Experimental Practice with Small Arms.

In carrying on experiments with the view of testing either the projectile, the powder, lubrication, or cartridge, or the merits of a weapon or cartridge, as to its fouling properties, the greatest care must be taken to secure a similarity and concordance in all the other components and influencing points, besides that for which the result is sought.

For instance, if it be a peculiar form of projectile that is under trial, the most scrupulous precautions must be taken to ascertain, as far as possible, that the description of powder, quantity of charge, lubrication, cartridge; and that the rifle should be an ascertained first-rate weapon, in good order, and clean; and lastly, but not least, that the experiments be carried on under similar circumstances as regards the temperature, state of the atmosphere, &c.

In experimenting upon ammunition or a rifle with a view of ascertaining its fouling properties, care must be taken that the operation of loading is performed in all cases in a similar manner, as the mode of doing this materially affects the accumulation of fouling.

All these experiments ought to be carried on from a fixed rest, otherwise the results are very little to be depended upon. And if such a rest is not procurable, diagrams showing the firer's average skill from the shoulder ought necessarily to be kept with the experimental diagrams, so that some comparison may be made; but even this does not invariably insure a correct result, as the slightest bias or inclination to any particular result on the part of the firer will frequently affect his aim, and, although to him unconsciously, will alter the result in a very marked degree.

In carrying out such experiments, the following is a list of the principal requirements :—

A fixed rest or shoulder-rest.

Experimental targets, the larger the better. If none can be procured, three or more (according to the distance) regulation practice-targets side by side.

Diagrams of the target, on a reduced scale, one form of which is shown in diagram 15. A convenient form of keeping these is adopted at Woolwich, of having them made up after the manner of artists' blocks, and with a frame for fixing them. When filled up, the sheet is easily removed by means of a penknife.

A micrometer, as described previously.

A telescope, mounted so as to be steady on a tripod stand, is a useful addition to the apparatus, as the exact mark of each shot on the target can be easily seen at long ranges, and marked at once on the diagram, which can be thus kept at the firing end of the range, and is at the same time a check upon the marker in the butt.

A barometer.

A maximum and minimum registering thermometer.

A thermometer to test the solar heat.

A hygrometer.

The marker in the butt should be provided with a brush at the end of a pole, and paint so as to effectually erase the mark left by each shot when it has been recorded. A stick with a flat end painted black is useful also, to enable him visibly to show the point struck to those at the other extremity of the range.

Signals of communication, by flags, bugle, or otherwise, between each end of the range should be prearranged, and strictly adhered to, so as to prevent the chance of a casualty. The range also should be kept clean, and as level as possible, ricochets from an uneven surface being dangerous in the extreme. All particulars as to temperature and amount of moisture, &c. should be frequently noted during the trials, as they very much affect the inferences to be drawn from the results.

The wind, as to direction and strength, ought to be frequently and carefully watched; as a strong wind, blowing at right angles to the range, is said to deflect the bullet 12 feet in 1,000 yards, and about 6 inches in 200.

For the convenience of registering on the diagram, it is not advisable to fire more than 25 rounds, or at the most 40, at a time; the distances to be of course varied for each series.

The merits of the several series are determined by comparing the mean absolute deviations of the rounds. To enable this to be obtained with perfect accuracy, it is necessary to measure them from a new centre than that of the target or that aimed at; as in most cases, either from wind or other causes, there is a drift or deviation to one side or other of the centre aimed at. This new centre is called the centre of mean impact, and is found by measuring the distance of each shot from one side of the target, being the horizontal measurement; and also that of each shot from the top or bottom of the target, being the vertical measurement. It must, of course, be previously decided as to the manner of taking these measurements, it being necessary to adopt some rule, such as that all vertical measurements be taken from the bottom of the target, and all horizontal from the left-hand side, or *vice versâ*. By adding up the vertical measurements, and dividing the sum by the number of shots divided, the mean vertical measurement is found: the mean horizontal is found in the same manner. These two measurements projected upon the diagram, the point of intersection of the lines is their centre of mean impact or origin of co-ordinates. The direct distance of each shot from this centre added together, and the sum divided by the number of shots fired, gives the mean absolute deviation or figure of merit.

If with this mean absolute deviation as a radius, and the point of mean impact as a centre, a circle is described; this circle will exhibit, in a tabular form, the merit of the result, and by comparing the circles of different series, a very good idea may be formed at a glance of the merits of each.

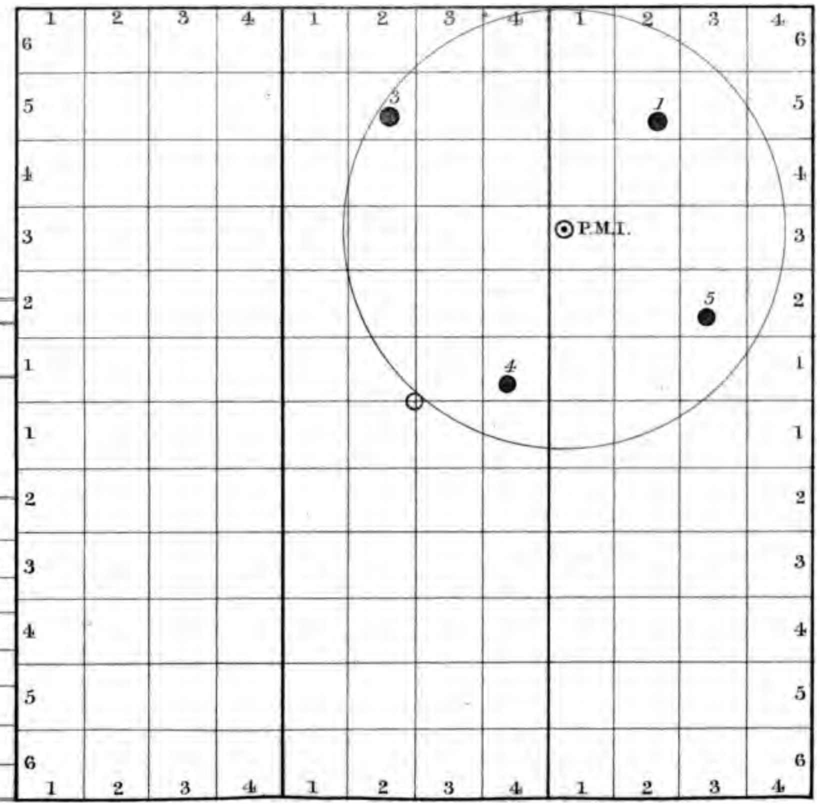
The mean absolute deviation may be found either by

IAGRAM 14.

REGISTER OF THE PRACTICE.

Date

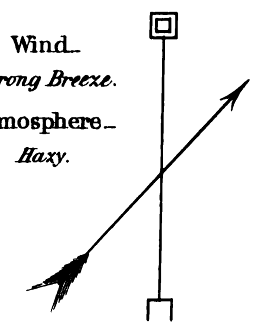
Shots with the Enfield Rifle at a range of 400 yards.



General Remarks.

Showing the deviation of each Shot						
	Measured from bottom & left of Target		*Measured from point of Mean Impact*			
Number of Shots	*Horizontal Measurement*	*Vertical Measurement*	*Horizontal Deviation*	*Vertical Deviation*	*Absolute Deviation*	*Remarks*
1	4.80	5.20	.67	.88	1.10	
2	"	"	"	"	4.24	*Miss*
3	2.80	5.20	1.33	.88	1.59	
4	3.75	3.20	.38	1.12	1.18	
5	5.20	3.68	1.07	.64	1.24	
Total	16.55	17.28	3.45	3.52	9.35	
Mean	4.13	4.32	.85	.88	1.87	

Wind—
Strong Breeze.
Atmosphere—
Hazy.



direct measurement on the target or diagram, and referring to a scale, or by the following arithmetical process :—

Take the horizontal and vertical measurement of each shot from the centre of mean impact, that is, the difference between the vertical and horizontal measurement of each shot, and *mean* vertical and *mean* horizontal.

Square these measurements of each shot, add them together, and extract the square root of the sum. And as the sum of the squares of two sides of a right-angled triangle is equal to that of the hypothenuse, this will be the required absolute deviation or direct distance of each shot from the mean point of impact.

These, added together and divided by the number of shots fired (and, if there should have been a miss, adding some fixed distance for its absolute deviation), give the mean absolute deviation.

When small targets are used, misses will be likely to occur, and in that case some distance must be taken for granted to be the deviation of a miss; in some cases it is supposed to have occurred in a circle described with half the diagonal of the target as a radius, and the centre of the target as a centre; this of course varies with targets of different sizes, and the amount allowed is varied according to different circumstances. A diagram of a target, or, more properly, three practice-targets placed contiguous, is given to explain this (*vide* diagram 14); but to all intents and purposes direct measurements from the target or from the diagrams, if very carefully kept and correctly ruled, are as valid as the above-mentioned method.

Scrupulous correctness in recording, and a multiplicity of trials, are the chief points to be observed before a result can be obtained, from which a reliable inference can be fairly drawn.

THE VERNIER.

The vernier that is shown on the micrometer, diagram 12, being incorrectly engraved and on too small a scale, is apt to mislead. I am of opinion, therefore, that a short and plain description of this ingenious contrivance (whereby we are enabled to measure and read off accurately to a far greater nicety than a scale could be graduated) will prove interesting, if not useful, to many; for although such an arrangement is attached to most barometers and other scientific instruments, yet there are many who are unaccustomed to their use, having seldom, if ever, recourse to such instruments for very minute measurements, and consequently, when called upon suddenly to read such, are scarcely *au fait*. For these, then, I will venture a simple, concise, and practical explanation of the vernier, having reference particularly to that attached to the instrument for measuring bullets, a description of which is given at page 79.

The vernier derives its name from one Peter Vernier, a Frenchman, who announced the discovery in Brussels more than 300 years ago. The necessity for some such contrivance to enable minute measurements to be taken had long been felt, owing as much to the difficulty and great expense of dividing and graduating a scale very finely, as to the fact that, if even done, the assistance of a powerful microscope was required to read it off.

Now it will be seen how, by means of the vernier, or nonius, as it is sometimes called, these difficulties are entirely overcome, and how that, by the aid of two scales with no division smaller than the 50th of an inch, measurements can be accurately made to the 1000th part of an inch.

The vernier itself is a smaller scale attached to another, and constructed so as to slide contiguous to this other scale.

For the purpose of rendering clear to those desiring to comprehend it, the best and simplest plan will be to commence constructing one under the following directions.

Take a slip of smooth card-board or drawing-paper

2 inches broad by about $5\frac{1}{2}$ or 6 inches long; measure and prick off upon it 5 inches. Subdivide each inch into 10 equal parts, in the same manner as the scale in diagram. For the sake of perspicuity, let this length of 5 inches represent one inch; enlarged five times then, each of these smaller divisions will represent the 50th part of an inch; lengthen the division line of each five of these divisions to denote the 10th of an inch, and commence numbering each 10th from left to right, 1, 2, 3, to 10.

Take another piece of card-board about the same width, and measure off upon it the length of 20 of these smaller divisions on the other scale, representing 50ths of an inch; divide this length with lines into 21 equal parts, place a lozenge or arrow at the first division on the left hand, as in the diagram, and number off the division from the left, 5, 10, 15, 20. You now have the vernier, and the next process is how to apply it to record measurements; and this is done as follows:—Place the edge of the vernier against the lower edge of the larger scale, as represented in the diagram of the micrometer; slide it along, so that the 1st line in the vernier (the line with the arrow) coincides with line No. 1 of the scale, and it will be seen at once that no other line in the vernier coincides but the last; move the vernier gradually towards the right, and it will be observed that as it is advanced, the 1st, 2nd, 3rd, &c. lines of the vernier coincide with another line on the scale, and according as the 1st, 2nd, 5th, or 6th, &c. line of the vernier coincides with another line upon the scale, so is the distance between the 1st line on the scale and arrow-head on the vernier $\frac{1}{1000}$, $\frac{2}{1000}$, $\frac{5}{1000}$, or $\frac{6}{1000}$ of an inch.

For as the length of the vernier is equal to $\frac{20}{50}$ of an inch, and it is subdivided into 21 equal parts, it stands to reason that each division on the vernier is $\frac{1}{20}$ of a 50th less than each division on the scale; that is, each vernier division is equal to $\frac{1}{50}$ of an inch, minus $\frac{1}{20}$ of a 50th, or $\frac{1}{1000}$, and this $\frac{1}{1000}$ of an inch is the difference between the divisions. For if you make one line on the vernier coincide with another on the scale, you will see that the lines of the vernier on each side fall short of the next divisions on the scale; the first lines on each side are, therefore, $\frac{1}{1000}$ short, the second pairs $\frac{2}{1000}$, and so on, until the last is as many short of a division as it is distant from the coinciding lines. If the 10th line on the vernier is made to coincide with another line, it will be seen that the indicating arrow is halfway through one division on the scale; that is, in advance with that division $\frac{10}{1000}$, or $\frac{1}{2}$ a fiftieth, or $\frac{1}{100}$ of an inch. The main point to be constantly remembered is, that the difference between a division on the vernier and one on the scale is exactly $\frac{1}{1000}$ of an inch, and as many thousandths as the arrow on the vernier is past a line on the scale, so many is denoted by the number of the coinciding line on the vernier.

For an example in recording, move the vernier until the arrow has past the fifth 10th on the scale and beyond the third 50th farther still, until the 8th line in the vernier coincides with another on the scale. Read off thus: firstly, the arrow is past the fifth 10th of an inch, or half an inch, and not up to the sixth 10th;—so record ·5. Secondly, it is 1, 2, 3 50ths beyond the fifth 10th;—record that as ·06. Now go to the vernier for the third place, and it is seen the 8th line coincides with another;—record that ·008; add these together thus:

$$\begin{array}{r} \cdot 5 \\ \cdot 06 \\ \cdot 008 \\ \hline \cdot 568 \end{array}$$

5 tenths, 6 hundredths, and 8 thousandths of an inch, the diameter of the large Enfield rifle bullet. If, however, the coinciding line was the 18th instead of the 8th, it would be recorded ·578, as 18 thousandths is 1 hundredth and 8 thousandths; and whenever, therefore, the coincidence is past 10 on the vernier, add one to the hundredths.

Of course the vernier can be varied to suit different measurements. Either the vernier divisions are less than those on the scale, or greater; in most barometers, 10 divisions on the vernier are equal to 11 on the scale, reading of course to the $\frac{1}{100}$ of an inch.

The difference between the divisions, whatever it be, is that which is indicated by the 2nd division on the vernier, when the first line coincides with a line on the scale. Two formulæ given by Heather, in his treatise on mathematical instruments, show both these descriptions of verniers. Let $n-1$ be the length of the vernier, or of a certain number of divisions on the scale,

n. . . the numbers of divisions on the scale,

L . . the length of a scale division,

V . . the length of a vernier division;

Then $(n-1)L=nV$;

And therefore $L-V=L-\frac{n-1}{n}L=\frac{1}{n}L$;

or, the defect of a division upon the vernier from a division on the scale is equal to the nth part of a division on the scale, n being the number of divisions on the vernier.

The other description of vernier, in which its divisions exceed in length those on the scale, is shown thus:—

$n+1$ length of the vernier, or certain number of divisions on the scale.

(The rest as before.)

Then would $(n+1)L=nV$,

$$V-L=\frac{n+1}{n}L-L=\frac{1}{n}L.$$

This arrangement entails reading the vernier backwards.

It can now be easily understood how, by means of delicate mechanism and beautifully-divided scales, the most minute measurements can be made. And indeed it is to the vernier that we owe those marvellously-correct measurements whereby the positions of ships in mid-ocean are ascertained and registered to within less than a mile, and also the positions and distances of the heavenly bodies themselves defined and recorded. How subtle is the mind of man to devise a scheme to unravel such measurements; but how much the more must we marvel at the infinite mind of Him to whom all is known,—measurements are not required,—and who himself has created this mind, and given all intellect to be used for himself.

Remarks *on Alterations which have taken place, or Improvements adopted into the Service, having reference to Small-Arms Ammunition or their Manufacture.*

THE BULLET.

Date.	Nature of Alteration and Remarks.
18	

Date.	Nature of Alteration and Remarks.
18	

Remarks *on Alterations which have taken place, or Improvements adopted into the Service, having reference to Small-Arms Ammunition or their Manufacture.*

THE PLUG.

Date.	Nature of Alteration and Remarks.
18	

Date.	Nature of Alteration and Remarks.
18	

Remarks *on Alterations which have taken place, or Improvements adopted into the Service, having reference to Small-Arms Ammunition or their Manufacture.*

THE CARTRIDGE.

Date.	Nature of Alteration and Remarks.
18	

Date.	Nature of Alteration and Remarks.
18	

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