TEXT BOOK

FOR OFFICERS
AT
SCHOOLS OF MUSKETRY

MILITARY BOOKS.

Published by Authority.

REVISED ARMY REGULATIONS.—VOL. II.

THE QUEEN'S REGULATIONS AND ORDERS FOR THE ARMY.

Adjutant-General's Office, Horse Guards, 1st January 1868.
Royal 8vo. edition, cloth boards. Price 3*s*. 6*d*.
Do. do. interleaved, 4*s*. 6*d*.
POCKET EDITION, demy 16mo., in leather, with clasp. Price 1*s*.

REGULATIONS FOR THE DRESS OF GENERAL, STAFF, AND REGIMENTAL OFFICERS OF THE ARMY.

Dated Adjutant-General's Office, Horse Guards, 1864.
122 pp. demy 8vo., cloth boards. Price 2*s*.

INSTRUCTION, FORMATIONS, AND MOVEMENTS OF CAVALRY, Regulations for the.

Dated Horse Guards, 1st January 1865.
Demy 12mo., cloth boards. Price 3*s*.

MOVEMENTS AND FORMATIONS OF A DIVISION OR BRIGADE OF CAVALRY, Regulations for the.

Dated Horse Guards, 1st August 1863.
Demy 12mo., cloth boards. Price 3*s*.

THE SWORD, CARBINE, PISTOL, AND LANCE EXERCISE, WITH STANDING GUN DRILL,

For the use of the Cavalry.
Dated Horse Guards, 1st January 1865.

THE MANUAL AND PLATOON EXERCISES FOR THE SNIDER BREECH-LOADING CAVALRY CARBINE.

Horse Guards, August 1868. Price One Penny.

MANUAL OF ARTILLERY EXERCISES.

Dated Horse Guards, 1st January 1860.
304 pp. demy 8vo., cloth boards, with Plates. Price 2*s*. 4*d*.;
by Post, 2*s*. 10*d*.

POCKET EDITION of Ditto. Price 1*s*.

MANUAL OF FIELD ARTILLERY EXERCISES.

Dated Horse Guards, 1st August 1861.
246 pp. demy 8vo., cloth boards, with numerous Diagrams.
Price 5*s.*; by Post, 5*s.* 6*d.*
POCKET EDITION of Ditto. Price 1*s.* 6*d.*

THE MANUAL AND PLATOON EXERCISES FOR THE SNIDER BREECH-LOADING ARTILLERY CARBINE.

Revised Edition. Horse Guards, January 1868.
Crown 16mo., in wrapper. Price 2*d.*

STANDING ORDERS, DRESS REGULATIONS, AND TRUMPET AND BUGLE SOUNDS, FOR THE ROYAL REGIMENT OF ARTILLERY.

Dated Horse Guards, April 1864.
286 pp. demy 8vo., cloth boards. Price 5*s.*

FIELD EXERCISE AND EVOLUTIONS OF INFANTRY AS REVISED.

Dated Horse Guards, May 1867.
552 pp. demy 8vo., cloth boards. Price 4*s.*
POCKET EDITION. Price 1*s.*

REGULATIONS FOR THE MUSKETRY INSTRUCTION OF THE ARMY.

(*Revised Edition, March* 1868.)
Adjutant-General's Office, Horse Guards, 1st February 1867.
Crown 8vo., cloth boards. Price 1*s.*; interleaved, 1*s.* 6*d.*

TEXT BOOK ON THE THEORY OF THE MOTION OF PROJECTILES;

(*Revised Edition, January* 1868.)

The History, Manufacture, and Explosive Force of Gunpowder; the History of Small Arms; the Method of conducting Experiments; and on Ranges;

FOR THE USE OF OFFICERS SENT TO THE SCHOOLS OF MUSKETRY.

152 pp. crown 8vo., cloth boards, with Plates. Price 2*s.*; interleaved, 2*s.* 6*d.*

A MILITARY SYSTEM OF GYMNASTIC EXERCISES FOR THE USE OF INSTRUCTORS.

BY ARCHIBALD MACLAREN.

Dated Adjutant-General's Office, Horse Guards, Feb. 1862.
194 pp. crown 8vo., cloth boards. Price 1*s.* 6*d.*

MILITARY BOOKS, published by Authority—continued.

A SYSTEM OF FENCING FOR THE USE OF INSTRUCTORS IN THE ARMY.

By Archibald Maclaren.

Dated Adjutant-General's Office, Horse Guards, July 1864.

88 pp. crown 8vo., cloth boards. Price 1*s.*

A SERIES OF EXERCISES FOR THE REGULATION CLUBS.

Date—Horse Guards, July 1863.

20 pp. demy 12mo. Price 3*d.*

OR

GYMNASTIC EXERCISES, SYSTEM OF FENCING, AND EXERCISES FOR THE REGULATION CLUBS.

In One Book. Price 2*s.*

THE INFANTRY SWORD EXERCISE.

Horse Guards, 1842.

With Illustrations. Price 6*d.*

MILITARY TRAIN MANUAL.

Date—Horse Guards, June 1862.

72 pp. demy 8vo. Price 1*s.*

PURVEYORS' REGULATIONS.

Regulations and Instructions for guidance of Officers of Purveyors' Department of the Army.

Date—War Office, 22nd October 1860.

236 pp. demy 8vo. Price 3*s.*

FORMULARY OF PRESCRIPTIONS FOR USE IN MILITARY HOSPITALS.

Price 1*s.*

THE REVISED ROYAL CLOTHING WARRANT OF 1865,

For the provision of Clothing and Necessaries for the Army.

War Office, 2nd January 1865. Demy 8vo. Price 1*s.*

STRENGTH, COMPOSITION, AND ORGANIZATION OF THE ARMY OF GREAT BRITAIN.

Compiled by Captain MARTIN PETRIE, 14th Regt., Topographical Staff.

Prepared at the Topographical and Statistical Department, War Office,

Colonel Sir HENRY JAMES, R.E., F.R.S., &c., Director.

FIFTH EDITION, Corrected according to the Estimates of 1867-8,

By Lieutenant H. M. HOZIER, 2nd Life Guards, Topographical Staff.

PRINTED BY ORDER OF THE SECRETARY OF STATE FOR WAR.

12mo., cloth boards. Price 1*s.* 6*d.*

TEXT BOOK

ON

THE THEORY OF THE MOTION OF PROJECTILES; THE HISTORY, MANUFACTURE, AND EXPLOSIVE FORCE OF GUNPOWDER; THE HISTORY OF SMALL ARMS.

FOR THE USE OF OFFICERS SENT TO THE SCHOOL OF MUSKETRY.

By Authority.

Revised, January 1868.

LONDON:
Printed under the Superintendence of Her Majesty's Stationery Office,
AND SOLD BY
W. Clowes and Sons, 14, Charing Cross; Harrison and Sons, 59, Pall Mall; W. H. Allen & Co., 13, Waterloo Place; W. Mitchell, Charing Cross; Longman & Co., Paternoster Row; and Trübner & Co., Paternoster Row.
ALSO BY
A. and C. Black, Edinburgh;
Alex. Thom, Abbey Street, and E. Ponsonby, Grafton Street, Dublin.
AND BY
W. S. Paine, Bookseller, Hythe.

Price 2s., and interleaved 2s. 6d.

MILITARY BOOKS, published by Authority—continued.

A SYSTEM OF FENCING FOR THE USE OF INSTRUCTORS IN THE ARMY.

By Archibald Maclaren.

Dated Adjutant-General's Office, Horse Guards, July 1864.

88 pp. crown 8vo., cloth boards. Price 1*s*.

A SERIES OF EXERCISES FOR THE REGULATION CLUBS.

Date — Horse Guards, July 1863.

20 pp. demy 12mo. Price 3*d*.

OR

GYMNASTIC EXERCISES, SYSTEM OF FENCING, AND EXERCISES FOR THE REGULATION CLUBS.

In One Book. Price 2*s*.

THE INFANTRY SWORD EXERCISE.

Horse Guards, 1842.

With Illustrations. Price 6*d*.

MILITARY TRAIN MANUAL.

Date—Horse Guards, June 1862.

72 pp. demy 8vo. Price 1*s*.

PURVEYORS' REGULATIONS.

Regulations and Instructions for guidance of Officers of Purveyors' Department of the Army.

Date—War Office, 22nd October 1860.

236 pp. demy 8vo. Price 3*s*.

FORMULARY OF PRESCRIPTIONS FOR USE IN MILITARY HOSPITALS.

Price 1*s*.

THE REVISED ROYAL CLOTHING WARRANT OF 1865,

For the provision of Clothing and Necessaries for the Army.

War Office, 2nd January 1865. Demy 8vo. Price 1*s*.

STRENGTH, COMPOSITION, AND ORGANIZATION OF THE ARMY OF GREAT BRITAIN.

Compiled by Captain MARTIN PETRIE, 14th Regt., Topographical Staff.

Prepared at the Topographical and Statistical Department, War Office,

Colonel Sir HENRY JAMES, R.E., F.R.S., &c., Director.

FIFTH EDITION, Corrected according to the Estimates of 1867-8,

By Lieutenant H. M. HOZIER, 2nd Life Guards, Topographical Staff.

PRINTED BY ORDER OF THE SECRETARY OF STATE FOR WAR.

12mo., cloth boards. Price 1*s*. 6*d*.

TEXT BOOK

ON

THE THEORY OF THE MOTION OF PROJECTILES; THE HISTORY, MANUFACTURE, AND EXPLOSIVE FORCE OF GUNPOWDER; THE HISTORY OF SMALL ARMS.

FOR THE USE OF OFFICERS SENT TO THE SCHOOL OF MUSKETRY.

By Authority.

Revised, January 1868.

LONDON:
Printed under the Superintendence of Her Majesty's Stationery Office,
AND SOLD BY
W. Clowes and Sons, 14, Charing Cross; Harrison and Sons, 59, Pall Mall;
W. H. Allen & Co., 13, Waterloo Place; W. Mitchell, Charing Cross;
Longman & Co., Paternoster Row; and Trübner & Co., Paternoster Row.
ALSO BY
A. and C. Black, Edinburgh;
Alex. Thom, Abbey Street, and E. Ponsonby, Grafton Street, Dublin.
AND BY
W. S. Paine, Bookseller, Hythe.

Price 2s., and interleaved 2s. 6d.

CONTENTS.

THIS book has been compiled from the under-named works, on projectiles, ammunition, arms, &c., to furnish a key for further research, and to assist officers who are sent to the Schools of Musketry to qualify for the appointment of Instructor, in acquiring a knowledge of these subjects, that they may be enabled to carry out the instructions contained in paragraph 35, page 33, of the Musketry Regulations, viz. :—

" The commanding officer is to assemble the officers " of the battalion at least once in each half year, and to " cause the non-commissioned officers and men to be " assembled occasionally by squads or companies, at " other times than when the annual course is proceeding, " when the officer instructor, having previously explained " the theoretical principles detailed in the foregoing " lessons, will be at liberty to advance deeper into the " subject, developing, to a degree proportionate to the " rank and intelligence of his auditors, the whole history " of small arms, from the invention of gunpowder, and " the successive steps by which the rifle has attained its " present efficiency ; in order that the officers and " soldiers, by acquiring a thorough knowledge of the " subject theoretically, may take greater interest in the " practical part of this most important branch of their " duty."

The paragraphs on which officers will be examined are denoted by an asterisk.

Ancient Armour:—*Hewitt.* Ancient Armour:—*Meyrick.* Ancient Armour, Illustrations of:—*Skelton.* Annual Reports of Schools of Musketry. Artillerist Manual:—*Major Griffiths, R.A.* Dictionary of Dates:—*Hayden.* Dress of the British Soldier:—*Col. Luard.* Elementary Lectures on Artillery:—*Bt.-Major Owen and*

Capt. Dames, R.A. Engines of War:—*Wilkinson.* Gunnery in 1858:—*Greener.* Gunpowder:—*Major Baddely, R.A.* Heat considered as a mode of motion:—*Professor Tyndal.* Lectures at Royal and United Service Institutions. Manual of Fire-arms. —*Deane.* Manufacture of Gunpowder:—*Col. Anderson.* Mathematical Tracts:—*Benj. Robins.* Mechanical Subjects:—*Whitworth.* Military Antiquities:—*Grose.* Naval Gunnery:—*Sir H. Douglas.* Notes from Waltham Abbey, furnished by *Lt.-Col. Henry, R.A.*, by permission of *Col. Askwith, R.A.* Our Engines of War:—*Capt. Jervis, R.A.* Principles of Gunnery:—*Hyde.* Projectiles and Guns:—*Scott.* Remarks on National Defence:—*Major-General Gordon.* Rifles and Rifle Practice:—*Wilcox, United States.* The Artillerist's Manual:—*Gibbons, United States.* The Longbow of the Past and the Rifle for the Future:—*H. Brittanicus.* The Rifle Musket:—*Capt. Jervis, R.A.* The Motion of Projectiles:—*Major Owen, R.A.* Traité d'Artillerie:—*Piobert.* Treatise on Artillery: —*Col. Boxer, R.A.*

THEORETICAL PRINCIPLES.

1. Before entering upon the investigation of the theory of projectiles, it is necessary to understand the meaning of the several terms and expressions made use of in explaining the various subjects which will fall under consideration.

Definitions.

* 2. *Matter.*—The substance of which bodies are composed. Matter is of four kinds, three of which have weight. First, *solid;* second, *liquid*: third, *aeriform:* fourth, *imponderable*, or destitute of weight, such as light, caloric, electricity, magnetism.

* 3. *Body.*—Any definite portion of *matter*, of which the existence can be perceived by our senses, or which may act or be acted upon by other bodies.

* 4. *Particle.*—An atom, or a point so minute as to admit of no division.

* 5. *Mass.*—The quantity of *matter* in any body ; the sum of all the particles of a body ; it is estimated by weight.

* 6. *Cohesion.*—The force which holds together the particles of bodies ; it acts only between particles of the same kind and at insensible distances. Without cohesion all substances would be in the form of small dust.

* 7. *Volume or Bulk.*—The space a body occupies.

* 8. *Figure.*—The form or shape of a body ; thus, a globe and cylinder may have the same volume, but have entirely different figures.

* 9. *Density.*—The closeness of the particles of any body ; or the quantity of matter in any given bulk.

* 10. *Elasticity.*—An inherent property in bodies by which they recover, or partially so, their former figure or state after the removal of external pressure, tension, or distortion. Perfect elasticity and perfect non-elasticity do not exist.

* 11. *Inertia.*—A property of matter by which it cannot of itself put itself in motion, or, if in motion, has no

power within itself to alter the direction or magnitude of its motion. A body cannot produce action on itself.

* 12. *Motion.*—The opposite to rest; the passing of a body from one place to another.

* 13. *Velocity.*—The degree of swiftness with which a body moves over a certain space in a certain time. When a body passes through equal spaces in equal times, its velocity is said to be *uniform;* when through unequal spaces in equal times, it is *variable;* when through greater spaces in each equal successive portion of time, it is *accelerated;* and when through a less space in each equal successive portion of time, it is *retarded.* Accelerated and retarded velocities may be either uniform or variable.

* 14. *Initial Velocity.*—The velocity at the instant of the departure of the bullet from the muzzle. The initial velocity of the bullet fired from the Enfield rifle, pattern 1853, is 1265·1 feet per second.

* 15. *Final Velocity.*—The velocity of the bullet at the end of any given range.

* 16. *Terminal Velocity.*—The velocity attainable by falling bodies, which they cannot exceed on account of the resistance of the air becoming equal to the force of gravity. From this point, if the air were equally dense, the body would fall at a uniform rate. The terminal velocity of a spherical musket ball is said to be 213 feet per second.

* 17. *Relative Velocity* is that which has respect to the velocity of another body.

* 18. *Velocity of Rotation* (initial).—This depends upon the initial velocity and the inclination of the grooves or twist. In order to find the initial velocity of rotation of a bullet, divide the initial velocity in feet by the number of feet in which one complete turn is made by the bullet; thus, the initial velocity of the Enfield rifle being 1265·1 feet per second, and the turn one in 6·5 feet, the initial velocity of rotation of the bullet, fired from the Enfield, is 194·6 revolutions per second. The greater the initial velocity the greater the initial velocity of rotation from the same rifle, and *vice versâ;* therefore, projectiles fired from two rifles similar in all respects, with the exception of their spirality, may be impelled with the same initial velocity of rotation, the

initial velocity of the rifle with the greatest spiral being reduced, so that $\frac{\text{IN. VEL.}}{\text{L for 1 rot.}} = \frac{\text{in. vel.}}{l\text{ for 1 rot.}}$, or

$$\frac{1200}{6} = \frac{1000}{5}.$$

* 19. *Centre of Rotation.*—The point about which a body revolves.

* 20. *Momentum.* — The quantity of motion in a moving body. This is always equal to the mass multiplied by the velocity. The comparative momenta of moving bodies are in proportion to the products of the mass and velocity, when expressed in numbers ; thus a ball of 4 lbs. weight, moving at the rate of 18 feet in a second, has double the momentum, that is, it would strike against an object with twice the force that a ball 3 lbs. in weight, moving at the rate of 12 feet a second, would do, because the first product, 4 × 18, is double that of the second, 3 × 12. When the velocities of two moving bodies are inversely as their *quantities* of matter, their momenta are equal. The expression for momentum is WV., or, more properly, MV.

* 21. *Laws of Motion.*—Three in number :—

1st. Every body continues in its state of rest or of uniform motion in a straight line until a change is effected in it by the agency of some external force.

2d. When any force acts upon a body in motion, the change of motion which it produces is in the direction and proportional to the magnitude of that force.†

3d. Action must always be equal and contrary to reaction, so that in the case of one body impinging upon another, whatever momentum is lost by one is gained by the other, the sum of their momenta remaining unaltered.

* 22. *Force.*—Any power which moves or stops, or tends to move or stop a body. It is measured by weight, *e.g.*, forces which will bend a spring into the same positions as weights of 1 lb., 2 lb., 3 lb., &c. are called respectively forces of 1 lb., 2 lb., and 3 lb.

* 23. *Friction.*—The resistance which a body meets

---

† By the direction of a force is to be understood the line in which it tends to produce motion.

with from the surface on which it moves. This is due to the roughness or want of smoothness of the surfaces. It is a retarding force. Perfect smoothness can never be attained in practice.

* 24. *Gravitation.*—That force or universal law by which all bodies and particles of matter are attracted towards each other.

* 25. *Terrestrial Gravitation*, commonly known as the *Force of Gravity.*—The tendency of everything to fall in a straight line towards the centre of the earth. The measure of it is weight. Air gravitates towards the earth's centre with such a pressure that at the level of the sea, the barometer standing at 30″, its weight is $14\frac{3}{4}$ lbs. on the square inch. In vacuo everything falls to the earth at the same rate, but not so in nature. Things lighter than air, in consequence of the pressure of the atmosphere, ascend until they reach the strata of air of the same density as themselves; things heavier than the air descend at rates in proportion to their surfaces and densities; this is caused by the air's resistance. In vacuo, everything in the latitude of London falls nearly $16\frac{1}{12}$ feet in the first second, and it has been found by experiment that the fall increases according to the square of the time the body is exposed to the influence of gravitation. Gravity is thus an accumulating force, and at the end of the second second will have caused the body to have fallen four spaces of 16 feet (omitting fractions) or 64 feet, and so on. A uniformly accelerating force is measured by twice the space described from rest in one second. In dropping a bullet from a considerable height, we find that during the first second of descent it acquires a velocity of 32 feet per second. Its velocity at the commencement was 0, for it began to move from a state of rest; at every one of the instants into which we may conceive a second of time to be divided, it acquired more and more velocity until it attained the final velocity of 32 feet in a second. All these acquisitions of speed are equal in equal times, because the force of gravity is constant, and therefore exerts equal influences in equal times. Had the bullet descended during the whole second at the final velocity of 32 feet per second, it would have passed through 32 feet of space. Had it retained its initial velocity which was nothing, it would have descended through 0 feet; but

as the velocity began with 0 and ended with 32, its average throughout the second was 16 feet per second, and therefore the bullet descends in the first second through 16 feet. During the second second, the bullet starting with a velocity of 32, acquires an additional velocity of 32, and therefore ends with a velocity of 64 feet a second, the average being 48 feet per second, and therefore the descent is 48 feet in height; adding this to the space descended during the first second, 16 feet, we find that in the first two seconds the total descent is 64 feet, and so on. The velocities acquired in descending are in exact proportion to the times of descent, and the spaces descended are proportional to the squares of the times, and therefore to the squares of the velocities. The times being as the velocities, and the spaces as the squares of either

If the times are as - - 1 . 2 . 3 . 4 . 5 .
The velocities will be - - 1 . 2 . 3 . 4 . 5 .
And the total spaces as their squares - - - 1 . 4 . 9 . 16 . 25 .
And the spaces for each second 1 . 3 . 5 . 7 . 9 .

or the series of odd numbers, which are the differences of the squares, denoting the whole space ; so

The times being - - 1 . 2 . 3 . 4
The velocities in feet will be - 32 . 64 . 96 . 128
The spaces fallen in the whole times - - - 16 . 64 . 144 . 256
The spaces fallen in each second 16 . 48 . 80 . 112

of which spaces the common difference is 32 feet, the natural and obvious measure of the force of gravity.

In each second - - 1 . 2 . 3 . 4 . 5
A body falls - - - 1 . 3 . 5 . 7 . 9

spaces = 25 or 5^2, the square of the time 5 seconds.

These rules apply in vacuo. The resistance of the air materially retards velocities, if it did not, every raindrop, descending, as it does, from a height of several hundred feet, would strike with a force as great as a rifle bullet.

*26. *Centre of Gravity.*—The point in which the weight of the body centres, on which point, if supported, the whole body would balance in any position.

*27. *Specific Gravity.*—The weight of one body compared with that of another of equal bulk taken as a standard. Gases are referred to common air; other matter to pure distilled water at 60° temperature.

* 28. *A Concentric Body.*—A body whose centre of gravity and centre of figure coincide.

* 29. *An Eccentric Body.*—A body whose centre of gravity and centre of figure do not coincide.

* 30. *Resistance.*—In talking of the motion of projectiles, this refers to common air. The air is an elastic fluid which surrounds the earth to the height of 45 miles; the nearer the earth the greater the pressure of air from the attraction of gravity and the superincumbent strata, so that at the sea level, the barometer standing at 30 inches, the pressure of the atmosphere is $14\frac{3}{4}$ lbs. on the square inch. Now, the bullet in its course displaces the air, and this it cannot do without its flight being affected. The resistance varies with the velocity in the same body, the greater the velocity the greater the resistance. A body moving with an increased velocity encounters an increased number of particles and impresses upon them an increased amount of force; from this cause the resistances will be as the squares of the velocities. The resistance of the air is the cause of the irregularities which occur in the flight of rifle projectiles, as will be hereafter explained.

* 31. *Retardation.*—The effect of the air's resistance upon a bullet.

Theory of the Motion of Projectiles.

* 32. In early times various ideas prevailed as to the path described by a projectile in its flight:—

1st. That it went straight and then fell perpendicularly.

2nd. That it went straight for some distance, then in a curve, and then fell perpendicularly.

3rd. That its flight was curved throughout, but, according to Tartaglia in the 16th century, so slightly, that he compared it to the surface of the sea.

4th. That it described a parabola, as asserted by Galileo in the 17th century, except in so much as it might be diverted from that course by the resistance of the atmosphere. A parabola is the section of a cone cut by a plane parallel to one of its sides.

* 33. It remained for Robins, in 1742, to point out the actual path of the bullet, for he demonstrated the effect

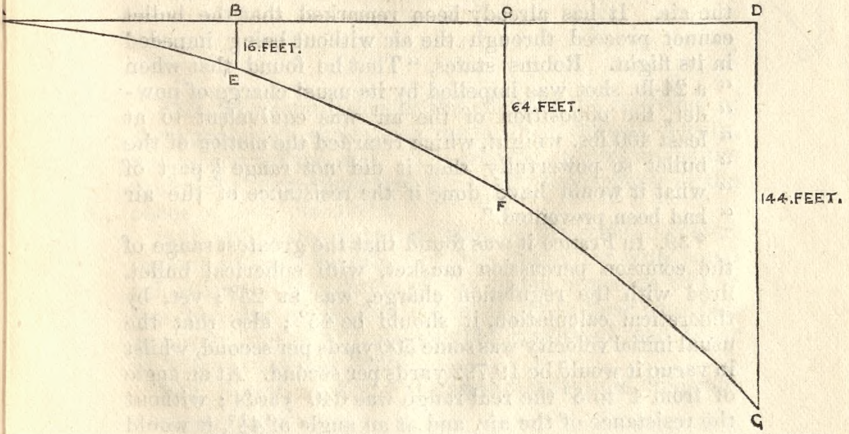
of the resistance of the air, which he stated to be as the squares of the velocities up to 1,200 feet a second, and this ratio to be trebled after that velocity, in consequence of the vacuum in rear of the projectile. Air rushes into a vacuum at the rate of 1,344 feet in a second.

* 34. Dr. Hutton, towards the end of the last century, came to the conclusion that the resistance was in a somewhat higher ratio than the squares of the velocities (V^2) up to 1,500 or 1,600 feet a second, and that then the ratio gradually decreased, but never fell below that ratio of increase.

* 35. The force of gravity having been explained, also the resistance of the air, we will now proceed to consider these forces as affecting the path of the bullet, which at the instant of starting from its position next the charge, is under the influence of three forces, viz., the exploded gunpowder;—the force of gravity;—and the resistance of the air.

* 36. We will commence by considering the effect of the first two forces. The bullet, although under the influence of gravity from its starting point, cannot commence to fall until it loses the support of the barrel and emerges from it. The bullet, from the impressed force of gunpowder, will travel forward equal spaces in equal times; thus in the first second from A to B (Fig. 1), in the second from B to C, and in the third from

Fig. 1.



C to D; but in obedience to the law of gravity, it will fall in the first second 16 feet B E, at the end of the second second it will have fallen 64 feet, C F, and at the end of the third second 144 feet D G, being at the end of these seconds at the points E F G respectively. Now this is the parabolic curve, which is not generally approached by projectiles except when moving with very small velocities. The existence of the force of gravity is the sole cause of the course of the bullet being in a curved line, and of the necessity of giving elevation to all arms, varying in an increasing ratio according to distance, if this force acted on the bullet in vacuo; but acting as it does in conjunction with the resistance of the air, which greatly increases the curve, the ratio of the elevation necessary is greatly augmented.

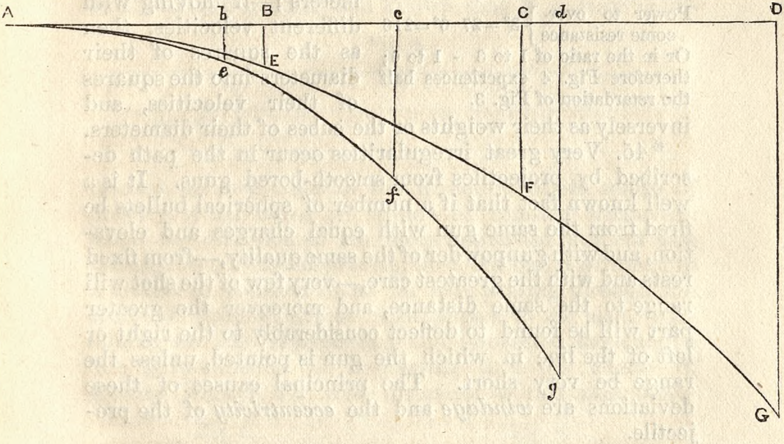
* 37. Having now established the general form of the trajectory, under the forces of gunpowder and gravity, we arrive at the following conclusion, that supposing a rifle is laid with its axis horizontal, it is immaterial with what charge it is loaded and with what velocity the bullet is projected, the latter will reach the ground in one second if 16 feet above it, and in two seconds if 64 feet, and so on; consequently if several rifles were laid with their axes in the same horizontal plane, the bullets projected from them at the same instant would reach the ground at the same moment irrespective of their velocities or height above the ground.

* 38. We will now take into account the resistance of the air. It has already been remarked that the bullet cannot proceed through the air without being impeded in its flight. Robins states, "That he found that when "a 24-lb. shot was impelled by its usual charge of pow-"der, the opposition of the air was equivalent to at "least 400 lbs. weight, which retarded the motion of the "bullet so powerfully that it did not range $\frac{1}{5}$ part of "what it would have done if the resistance of the air "had been prevented."

* 39. In France it was found that the greatest range of the common percussion musket, with spherical bullet, fired with the regulation charge, was at 25°; yet, by theoretical calculation, it should be 45°; also that the usual initial velocity was some 500 yards per second, whilst in vacuo it would be 19,792 yards per second. At an angle of from 4° to 5° the real range was 640 yards; without the resistance of the air, and at an angle of 4½°, it would

be 3,674 yards, or six times greater. The flight of the bullet will then be modified thus; it will not proceed equal distances in equal times, but the spaces traversed will be successively less and less; instead of the bullet travelling forward a space equal to A B (Fig. 2), in the first second of time, to B C in the second, and to C D in the third; the spaces will be, say, A b, b c, and c d; and the action of gravity being nearly the same as before, the bullet, at the termination of each second, will be respectively at e, f, g, the actual path of the bullet differing in a great degree from that of the parabolic curve.

Fig. 2.



*40. The retardation, or the effect of the resistance of the atmosphere, varies with the surface, content, density, and velocity of the shot. The areas of spheres are as the squares of their diameters; the contents of spheres as the cubes of their diameters.

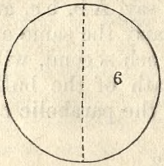
*41. With two spherical shot of the same diameter, the one of lead, the other of iron, travelling with equal velocities, the retardation of the leaden projectile will be less than that of the iron and inversely as their densities, or nearly as 8 to 11; the specific gravity of lead being 11·325, that of iron 7·425.

*42. Spherical shot of the same density, and diameter, travelling with unequal velocities, experience retardation in proportion to the squares of their velocities.

* 43. Spherical shot of different diameters, but of the same weight, moving with the same velocity, will be retarded in proportion to the squares of their diameters.

Fig. 3.

Fig. 4.



	Diameter, 3.	Diameter, 6.
Resistance - -	$3^2=9$	$6^2=36$
Power to overcome resistance	$3^3=27$	$6^3=216$

Or in the ratio of 1 to 3 - 1 to 6; therefore Fig. 4 experiences half the retardation of Fig. 3.

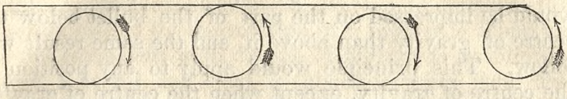
* 44. Spherical shot of different diameters, and of the same density, moving with the same velocity, will experience retardation as the squares of their diameters, and inversely as their weights or the cubes of their diameters ;—if moving with different velocities, then as the squares of their diameters into the squares of their velocities, and inversely as their weights or the cubes of their diameters.

* 45. Very great irregularities occur in the path described by projectiles from smooth-bored guns. It is a well known fact that if a number of spherical bullets be fired from the same gun with equal charges and elevation, and with gunpowder of the same quality,—from fixed rests and with the greatest care,—very few of the shot will range to the same distance, and moreover the greater part will be found to deflect considerably to the right or left of the line in which the gun is pointed, unless the range be very short. The principal causes of these deviations are *windage* and the *eccentricity* of the projectile.

* 46. In addition to the deflection caused by the bullet rebounding from that part of the bore against which it is irregularly and forcibly driven by the explosive force in consequence of its not filling the barrel accurately, there is a still more important deviation caused by the rotation which the bullet receives from its last impact on leaving the bore. Now no ball can strike on any substance, at an angle less than a right angle, without receiving in rebounding a rotatory motion, the velocity of this rotation being increased the smaller the angle of incidence. The bullet on its last impact, and in rebounding from the sides of the barrel, receives a motion of rota-

tion round an axis at right angles to its line of flight; if striking the left of the barrel at its last impact, it rotates from right to left, and so on. (Fig. 5.)

Fig. 5.



* 47. Rotation is also occasioned by the *eccentricity* of the spherical shot, which is thus explained. The shot being supposed to fit the gun, the force of the gunpowder may be said to act equally on its hinder part, the direction of the force being through the centre of the bullet (Fig. 6). It is well known that if a force is impressed on any body in the direction of its centre of gravity, it will cause no motion of rotation whatever; but if the direction of the force impressed does not pass through the centre of gravity, then the bullet will acquire a motion of rotation round an axis passing through the centre of gravity, and at right angles to the plane containing the line representing the impressed force and a line perpendicular to it passing into the centre of gravity (Figs. 7, 8). The direction of this axis, therefore, depends upon the position of the centre of gravity with regard to the centre of figure. Suppose the centre of gravity was directly above the centre of the figure (Fig. 7), then the half of the force acting upon the lower part of the bullet would have fewer particles to be dis-

Fig. 6.

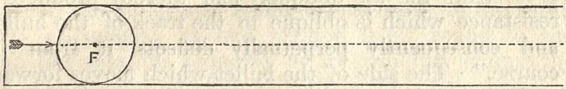


Fig. 7.

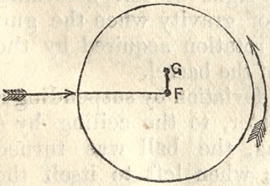
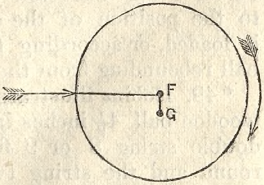


Fig. 8.



tributed over than the upper part, consequently the lower part would start with a higher velocity than the upper. This would cause the lower part to turn upwards, and the bullet to revolve in this direction on an horizontal axis ; or take it this way, a greater amount of force would be impressed on the part of the bullet below the centre of gravity than above it, and the same result will follow. This principle would apply to any position of the centre of gravity, except when the centre of gravity, although not in the centre of figure, was in the same direction or line with the impressed force and the centre of figure.

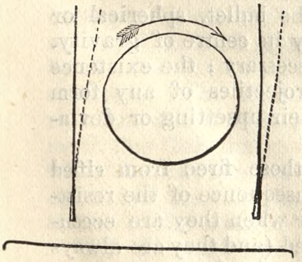
*48. The effect of the rotation, originating from windage (vide par. 46), or from the eccentricity of the projectile (vide par 47), is well explained by Robins,—who states " this whirling motion of the bullet occasions " it to strike the air obliquely and thereby produces a " resistance which is oblique to the track of the bullet, " and consequently perpetually deflects it from its " course." The side of the bullet which moves forward experiences an increased resistance, and the opposite side which retires experiences a less resistance than it would do if it received no rotation, the consequence naturally is that the bullet is deflected in the direction of the least resistance, which will be in the opposite direction to the deflection caused by the rebound of the bullet from its last impact upon leaving the bore, or in the direction to which the leading surface of the bullet spins. Thus the track of the spherical ball is not the curve depending simply on the three forces, viz., gunpowder, gravity, and the resistance of the air ; but becomes a double curve, being deflected to the right or left according to the position of the centre of gravity when the gun is loaded, or according to the rotation acquired by the ball rebounding from the side of the barrel.

*49. Robins illustrated this deviation by suspending a wooden ball, 4½ inches in diameter, to the ceiling by a double string 8 or 9 feet long, the ball was turned round and the string twisted ; when left to itself the ball rotated from the untwisting of the string ; but if drawn considerably from the perpendicular, it vibrated steadily at first in the same vertical plane in which it began to move ; but by the untwisting of the string, it acquired, after a short time, a sufficient degree of rotation, and began to deflect to the right or left of its proper track. This appeared to be entirely owing to the resistance being greater on one part of the leading surface of the globe than on the other. The same is visible in a racket ball when it is made to revolve by an oblique stroke of a racket.

* 50. Another experiment of Robins to elucidate the deflection caused by the rotation of a projectile round an axis not coincident with its line of flight was as follows: he took a barrel and bent it (about 4 inches from the muzzle) to the left, at an angle of 3° or 4°, he then fired it with a loose ball through two thin paper screens at a wall: the first screen was 50 feet from the barrel, the second 50 feet behind the first, and the wall 200 feet behind the second screen, and 300 feet from the barrel; he found that in the first screen the bullet had struck $1\frac{1}{2}$ inches to the left of the centre of it; in the second screen about 3 inches to the left; but on the wall the mark of the bullet was found considerably to the right, about 14 inches. It had worked itself round to the right, the rotation acquired by its rubbing against the bent side being from left to right. This he considered a convincing proof of the truth of the principle which he had been contending for.

51. Professor Magnus, of Berlin, a few years since demonstrated the unequal resistance of the air on the front of a rotating spherical bullet; the projectile was stationary, and a strong current of air directed upon it. A brass cylinder, $1\frac{1}{2}$ inches diameter, and 4 inches high, on a vertical axis, represented the projectile; this was made to rotate by machinery. A rotatory fan, with a nozzle 5 inches wide and $\frac{3}{4}$ inch deep, delivered the current of air (Fig. 9). Two light vanes were placed on each side of the cylinder, so that the pivots were equally distant from the orifice of the blower, and also from the plane passing through the axis of the cylinder by the middle of the current of air. When the blower was put in action the vanes placed themselves in the direction of the current, as shown by the continuous lines; but when in addition to the current of air produced by

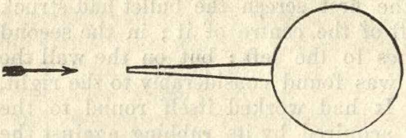
Fig. 9.



the blower, the cylinder was made to rotate with a certain velocity, the vane, on that side of the cylinder which moved in the same direction as the current, approached the cylinder, while on the contrary side the vane receded, as shown by the dotted lines. It followed that on the former side there was a diminished, and on the latter an increased pressure, compared with that which existed when the cylinder was at rest.

* 52. All other things being equal, the largest, most dense, and most perfectly formed balls will be the most accurate in their flight. Mons. Piobert mentions that in experiments which took place in France, a ball cast on the head of a wire tack about $1\frac{2}{11}$ inches in length had four times the accuracy of the ordinary ball; the rotation being prevented (Fig. 10).

Fig. 10.



* 53. For a long time the deviations observed in shot were not attributed to their eccentricity. When it became known that eccentricity was the cause of the resistance of the air producing such great deviations in the firing, every effort was put forth to make the projectiles as concentric as possible, with the view of increasing the accuracy of fire. It was not until quite recently that this very eccentricity was made use of to increase the accuracy and range of projectiles, and it was found that the accuracy and range could even be further increased by magnifying what had heretofore been regarded as the cause of the evils, viz., the distance between the centre of gravity and figure.

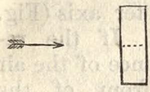
* 54. Whatever the form of the bullet, spherical or elongated, its path is described by its centre of gravity. In vacuo, no rotation would be necessary ; the existence of a medium, through which projectiles of any form must pass, is the sole cause of their upsetting or deviating from their true path.

* 55. All projectiles, except those fired from rifled barrels of sufficient pitch, in consequence of the resistance they meet with from the air when they are eccentric, whether spherical or elongated (and they are always one or the other), rotate naturally, the former round an accidental axis passing through the centre of gravity,

and the latter round the short axis also passing through the centre of gravity, so that at first sight it would appear advisable, if possible, so to construct projectiles that they might rotate round an axis in the natural direction. It must be remembered, however, that the rotation to correct the flight of the projectile should be round an axis coincident with its initial direction ; any rotation in any other direction acts as a disturbing force, and causes irregularities.

* 56. The most perfect form for rotation is that of the disc, for when its rotation is around any axis but the shortest, the constant tendency is to return to this. The disc, in consequence of the great retardation it would experience, would be useless as a projectile. (Fig. 11.)

Fig. 11.



* 57. The object of rifling is to give such a rotation to the projectile as to insure its stability for the longest ranges. That rotation does give stability is well known from the gyroscope, or patent top ; the weaker the rotation the less the stability, and *vice versâ ;* the longer the bullet the less the stability, and, consequently, the greater the rotation required. If the rotation becomes too weak at any part of the range, the bullet will wabble, perhaps turn over, and deviation must ensue.

* 58. It was thought, formerly, that a rapid twist would be detrimental and decrease the velocity ; but this has practically been disproved. A high initial velocity and a rapid rotation can be given without causing any injurious effects, except that the greater the velocity of rotation, with the same velocity of translation, the greater will be the drift.

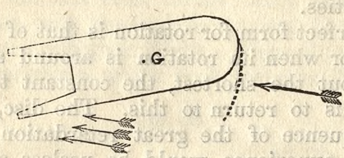
* 59. A quick twist will undoubtedly necessitate a stronger barrel than a slow one ; but this may be arranged in small arms, without increasing the weight, by the description of metal of which the barrel is constructed. The more rapid the twist, the more the ricochet will deviate ; the velocity of rotation, being much less than that of translation, diminishes but slowly, while the resistance of the air, being proportional to the squares of the velocities, diminishes rapidly the forward motion of the shot.

* 60. The velocity of rotation to be imparted to a shot is influenced not only by its length, but by other considerations, as explained in paragraphs from 61 to 65.

* 61. The greater the density the less will the velocity of rotation be impaired by the air's resistance, and the less will be the rotation required, *e.g.*, lead will require a smaller amount of rotation than iron, their specific gravities being as 11 to 8 nearly.

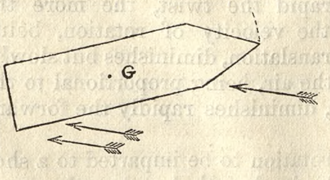
* 62. Upon the position of the centre of gravity.—An elongated shot, having the centre of gravity very forward, will have but little tendency to turn round its shorter axis (Fig. 12). If the resistance of the air in front of the centre of gravity caused the direction of the longer axis to be moved, it would be counteracted by the resistance of the air acting on that part of the bullet in rear of the centre of gravity. In this position of the centre of gravity, with a weak rotation, the shot would have the greatest tendency to lower its point, and to keep its axis a tangent to the trajectory, thereby causing the resistance to be kept on the front of the projectile, and the velocity of the shot to be less reduced than if the axis of the shot were kept parallel to its initial direction, and the resistance applied to the whole of its lower surface. With a weak rotation, however, the centre of gravity being forward, an irregular motion of the rear of the projectile will generally take place; hence a rapid rotation in this case is necessary.

Fig. 12.



* 63. The nearer the centre of gravity is to the rear of the bullet (Fig. 13), the greater the rotation required to keep the bullet point first, for while the resistance on that part of the bullet in rear of the centre of gravity is much reduced, the power of the direct action of the air on the front of the bullet is much increased in consequence of its distance from the centre of gravity and the greater leverage. In

Fig. 13.



this position of the centre of gravity the bullet is supposed to retair, or nearly so, its initial direction, unless the rotation is weak, when the bullet will turn over.

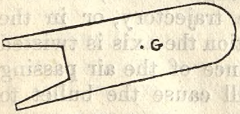
*64. In the case of an elongated projectile whose centre of gravity does not lie in the long axis of the bullet, an irregular rotation will take place round an axis passing through its centre of gravity, parallel to the long axis. The spin of the bullet will be impaired in proportion to the distance of the axis of rotation from the long axis, and consequently the greater their distance from each other the greater the rotation necessary.

*65. In windy or boisterous weather a powerful rotation is necessary to keep the axis in its true direction, for the lighter end of the bullet is more easily acted upon by the wind than the heavier. If the lighter end were in rear this part would be pressed to leeward, and the front and axis directed to windward; from the increased resistance on the forward side, the bullet would have a tendency to be driven to windward. If its lighter end were in front the bullet would turn on its short axis, and its heavy end would try to go first. For a military rifle to be serviceable, a rapid rotation is indispensable to keep the bullet stable under all circumstances.

*66. When the axis of the bullet is not a tangent to the trajectory, the resistance of the air ceases to act equally on the front of the bullet. It acts on its lower surface, and the more so, the more the bullet preserves its parallelism to the line of fire, and the farther it is from the muzzle ; so that the bullet meets with greater resistance than if the axis is kept in the direction of the trajectory, and the range will be lessened.

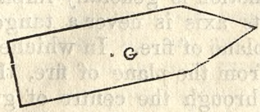
67. The more pointed the bullet the further is the centre of gravity thrown back, and the axis is more liable to injury. If the point is injured, and does not coincide with the axis of the bullet, an irregularity in the flight of the bullet must take place. The general mode of throwing the centre of gravity forward is by hollowing the base of the projectile, and by blunting the point.

Fig. 12.



G. Forward.

Fig. 13.

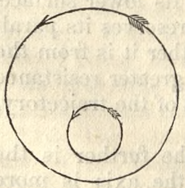


G. Backward.

*68. The direction of the rotation of all English rifling is to the right, so that the lower portion of the bullet passes from right to left. Now, the lower half of the bullet travels on compressed air, the upper on rarefied ; the result is, that the bullet rotates on the compressed air and works to the right, in the same way that a top would do if made to revolve in the same direction, and placed on its edge on the ground. If the rifling were to the left (the lower part of the bullet rotating from left to right), the drift would be to the left. The longer the range and the greater the angle of descent, the greater the drift ; but if the axis of the bullet continued to be a tangent to the line of flight, this deviation would not take place.

69. Another cause of deviation is the unequal pressure of the air upon the front of the bullet, and the twisting of the long axis from the plane of fire. It is accounted for thus. Suppose the rifling to be in the usual direction, and the elongated bullet to have a conoidal or rounded front, the greatest pressure would be on its lower front; the rotation from right to left below will cause the point to work round to the right, and the axis consequently to be turned in this direction. If pressure is exerted on the left front of the projectile, the point will fall ; if on the upper front, it will work to the left, and if on the right front, the point will rise (Fig. 14). Combining these effects, and supposing the air to commence acting with greater force on its lowest front, the point working round, the action would be transferred to the left, upper, and right fronts in succession, the point of the bullet describing a circle while the centre of gravity remains at rest. It is presumed that this motion is generally imparted to elongated shot, and that its axis is never a tangent to the trajectory, or in the plane of fire. In whichever direction the axis is twisted from the plane of fire, the resistance of the air passing through the centre of gravity will cause the bullet to deviate in the same direction.

Fig. 14.



70. If the rifles were cut in the opposite direction, the movement of the axis would be also changed. Professor Magnus, of Berlin, states that a flat-headed shot would deviate, with a right-handed rotation, to the left.

71. It has been supposed by some that the greatest drift occurs with projectiles which are without grooves (cannelures). Mons. Tamisier, as is noticed at page 116, originally placed these grooves on projectiles to correct their flight (fig. 15), to act as the feathers of an arrow, by creating resistances on the posterior end, and as the resistance of the air acts in the direction of a tangent to the trajectory, the moment the axis of the projectile ceases to remain a tangent, the air acts directly against these surfaces on one side, and the axis is forced back to its position as a tangent to the trajectory ; it was supposed that it had the same effect in correcting drift, but these resistances must reduce range.

Fig. 15.

72. It does not appear to be clearly known what angle to the trajectory the axes of elongated bullets preserve during their flight. It has been supposed by some that they preserve their primary direction, and by others that they form a tangent to the trajectory ; theory may be cited in favour of either assertion ; experiment may hereafter prove which is correct.

73. The following expressions were made use of at the Institution of Civil Engineers in February 1860,in a discussion on the construction of artillery. Mr. Conybeare says, "It was found in the experiments tried by the French
" Commission, that when the centre of gravity of an elon-
" gated projectile was near the front, the point of such
" projectile drooped below the trajectory, in its flight; that
" when the centre of gravity was near the rear, the tail
" drooped ; but that when the centre of gravity was in
" the centre of the length of the projectile, the axis of
" such projectile remained coincident with the line of
" trajectory, throughout its flight.

74. Sir William Armstrong says, " Experiments have
" been quoted, of rifle projectiles having been fired with
" such small charges, as to allow of the projectile being
" distinctly seen in its course through the air, and it
" was said to have been clearly perceived, in such cases,
" that the axis followed the curve" (possibly alluding to some experiments by a Royal Commission at Berlin) ;
" but in all my own experiments (he continues) the indi-
" cations attending the graze marks, and the form of the
" holes made in distant targets, led to a contrary con-
" clusion. In fact it was easy to understand, that the

" eye might be deceived, by the impression left on the " retina, by an object thus rapidly moving, and producing the illusion of a sort of tail following the direction " of the curve."

75. Major Owen, Royal Artillery, in a recent work says, " Many who are constantly employed in noting " the flight of shot, assert most positively that, when the " velocity is not too high, they can clearly see the projectiles descend with their points downwards. It is " difficult to say whether this is a mere optical illusion, " but the effects on targets, which can be examined at " leisure, are more satisfactory evidence than that of " the mere view of a shot during flight. Now it is " almost invariably found that the holes made in " targets are circular even when elongated shot descend " at considerable angles ; for instance, some 40-lb. shot " fired recently at 7° and 10° of elevation, the angles " of descent for which would be about 9° and 13° " respectively, cut circular holes out of vertical targets " made of thin wood covered with sheet lead, the most " probable explanation of this fact must evidently be " that the point of the shot had drooped during flight, " so that, on striking, the longer axis was nearly perpendicular to the plane of the target. . . . . This drooping of " the point is of importance, for did the axis remain " parallel during flight to its primary direction, the projectile would, most probably, when fired at any but a " very low angle, on striking an object of hard material " and solid structure, as a wall, &c., turn up against it " lengthways, and therefore produce but trifling effect. " This has not however, been found to take place in the " experiments hitherto made, but on the contrary the " penetrations of elongated shot at considerable ranges, " are always remarkably great. There is but little fear of " a shot turning up against an object unless the velocity " both of translation and rotation be very low, and the " angle of fire very high."

76. The deviations of flat fronted shot are not sufficiently ascertained to furnish any certain data.

77. The deviation caused by the rotation of the earth is so slight in the range of small arms that it is not necessary to consider it.

* 78. The effect of the density of the atmosphere on the flight of rifle projectiles, more especially apparent at long ranges, is now universally recognized. Our first rate

rifle shots have their pocket barometers, compensated for temperature, for target shooting. The denser the atmosphere the greater the resistance and retardation, consequently the lower the bullet will strike ; the rarer the atmosphere the less the resistance, and the higher the bullet will strike.

* 79. The velocity (initial) of a round shot is greater than that of an elongated one of the same diameter, taken transversely. Suppose the transverse sections of two shot, one spherical the other elongated, to be the same, and also the resistance, then the elongated projectile has much greater weight to overcome the resistance, or in other words the resistance is distributed over a greater number of particles, and its effect upon each particle is less than that upon the fewer particles of the spherical shot. Now although the spherical shot may have a much greater initial velocity than the elongated, yet it experiences a much greater retardation, and its velocity is much more rapidly diminished, the result is that the flight of the spherical shot is considerably less than that of the elongated shot, which latter travels at a more uniform speed throughout its flight.

Fig. 3.

Fig. 4.

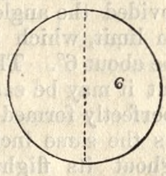


Fig. 16.

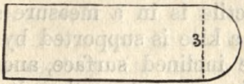


Fig. 16 an elongated shot, having the same frontage as Fig. 3, and the same mass or weight as Fig. 4. This shot thus experiences resistance as $3^2 = 9$, with power to overcome resistance, as $6^3 = 216$, or in the ratio of 1 to 24, thus experiencing $\frac{1}{8}$th of the retardation of Fig. 3, and $\frac{1}{4}$th that of Fig. 4. Vide para. 44.

* 80. Elongated projectiles fired from rifled pieces attain much longer ranges, combined with far greater accuracy, than spherical bullets of equal diameters, fired from the same pieces, with the same angle of elevation, and with equal initial velocities. For a given range, unless very short, the elongated projectile will require a less angle of elevation than the spherical shot, hence its trajectory will be lower, thereby increasing the chance of its striking the object.

81. Sir William Armstrong states, that at certain low elevations the range of an elongated projectile is greater in the atmosphere than in vacuo, and the following is the explanation given by him :—"In a vacuum the tra-
" jectory would be the same whether the projectile were
" elongated or spherical, so long as the angle of eleva-
" tion and the initial velocity were constant; but the
" presence of a resisting atmosphere makes this remark-
" able difference, that while it greatly shortens the range
" of the round shot it actually prolongs that of the
" elongated projectile, provided the angle of elevation
" does not exceed a certain limit, which in my experi-
" ments I have found to be about 6°. This appears at
" first very paradoxical, but it may be easily explained.
" The elongated shot, if perfectly formed and having a
" sufficient rotation, retains the same inclination to the
" horizontal plane throughout its flight, and conse-
" quently acquires a continually increasing obliquity to
" the curve of its flight. Now, the effect of this
" obliquity is, that the projectile is in a measure sus-
" tained upon the air, just as a kite is supported by the
" current of air meeting the inclined surface, and the
" result is that its descent is retarded so that it has
" time to reach to a greater distance."

Penetration.

* 82. The *vis viva* (mechanical effect, damaging effect, or power) of a projectile has been most ably explained in a recent paper by Professor Tyndal, from which the following is extracted :—" A sphere of lead weighing
" 1 lb. was suspended at a height of 16 feet above the
" theatre floor. It was liberated and fell by gravity.
" That weight required exactly a second to fall to the
" earth from that elevation, and the instant before it
" touched the earth it had a velocity of 32 feet a
" second. That is to say, if at that instant the earth
" were annihilated, and its attraction annulled, the
" weight would proceed through space at the uniform
" velocity of 32 feet a second. Suppose that, instead of
" being pulled downward by gravity, the weight is cast
" upward in opposition to the force of gravity—with
" what velocity must it start in order to reach a height
" of 16 feet ? With a velocity of 32 feet a second. This

“ velocity imparted to the weight by the human arm, or
“ by any other mechanical means, would carry the
“ weight up to the precise height from which it had
“ fallen.” . . . . “ Supposing now, that instead of imparting
“ a velocity of 32 feet a second to the weight,
“ we impart twice this speed, or 64 feet a second. To
“ what height will the weight rise? You might be
“ disposed to answer, ‘To twice the height;’ but this
“ would be quite incorrect. Both theory and experiment
“ inform us that the weight would rise to four
“ times the height; instead of twice 16, or 32 feet, it
“ would reach four times 16 or 64 feet. So also, if we
“ treble the starting velocity, the weight would reach
“ nine times the height.” . . . . “Now, the work done—
“ or, as it is sometimes called, the ‘mechanical effect’—
“ is proportional to the height, and as a double velocity
“ gives four times the height, a treble velocity nine
“ times the height, and so on, it is perfectly plain that
“ the mechanical effect increases as the square of the
“ velocity.” . . . . “In the case considered, I have supposed
“ the weight to have been cast upward, being
“ opposed in its upward flight by the resistance of
“ gravity; but the same holds true if I send the projectile
“ into water, mud, earth, timber, or other resisting
“ material. If, for example, you double the velocity
“ of a cannon ball, you quadruple its mechanical effect.”
. . . . “The measure then of mechanical effect is the
“ mass of the body multiplied by the square of its velocity.”
Thus, if the velocity of any number of shot of
agiven weight at any particular distance be known, their
comparative powers of inflicting mischief at that distance
are also known.

*83. The expression for the vis viva or mechanical effect is $W V^2$., or rather $M V^2$.

*84. The mechanical effect or penetrative power having been explained, it will be easily understood that an increase of velocity increases the penetration much more powerfully than an increase of weight, and that the final velocity of a shot must be great to produce great penetration.

*85. Round shot with equal charges leave the gun with a much higher initial velocity than elongated shot of the same diameter, and although their momenta $M V$. might be equal, their mechanical effect at a short range would be very unequal. The round shot in this case would have much greater power.

* 86. Round shot can generally be fired from a gun of the same diameter with a higher initial velocity than an elongated one.

* 87. We have already noticed that the retardation of shot of the same diameter and density is in the inverse ratio of their weight, and as all elongated shot greatly exceed in weight that of the round shot of the same diameter, it is manifest that the velocities of the round will, at a comparatively short distance, be reduced to that of the elongated shot, and then fall greatly below it. It is from these causes that the penetrative power of a round shot, exceeding that of an elongated at short ranges, becomes rapidly diminished. When their velocities are equal, the effect of the elongated projectile will be greater than that of the spherical one, and the former will retain in a greater degree its mechanical effect at the longer ranges, its velocity remaining comparatively unimpaired.

* 88. Major Owen, in a recent treatise, gives the following from a report of the Ordnance Select Committee :—
" The increased penetration of the rifled projectiles is
" in a far higher ratio than theory would assign them.
" It is plain, therefore, that we must look for some other
" cause than their superior '*vis viva*,' and this is fur-
" nished by their rotation on their longer axis. The
" 6-inch projectiles leave the muzzle of the gun spinning
" at the rate of about 63 turns per second. It is not
" probable that this rate diminishes as fast as the motion
" of translation. It will be very little reduced in three
" or four seconds, or at 1,032 yards, and must materially
" aid penetration."

* 89. If this be correct, which there appears to be no reason to doubt, it would follow that, as increased rotation gives increased penetration, decreased rotation will give decreased penetration, and for the same reason, an increased or a decreased rotation would produce increased or decreased range.

* 90. In small arms, the great object being to destroy human life, lead is sufficiently hard for the purposes of penetration, but for penetrating woodwork or defences a harder material than lead is necessary. Bullets hardened with $\frac{1}{10}$th of tin have a greater penetrating power than bullets made of pure lead, in the proportion of

35 to 13. This is due to the hardness of the metal, and not to the density, as the addition of tin reduces the density. Bullets of steel and iron might also be used with effect. These projectiles cannot, however, be used in the majority of rifles, which generally require bullets of an expanding character. The greater the velocity, the cleaner the cut. A low velocity would produce fracture, as may be observed in firing through glass or wood.

91. For penetrating water or iron, a flat front has been found the best.

*92. From what has been said, it will be seen that penetrative power depends upon velocity, density, and rotation, when the figures of the shot are similar, and the object fired at is the same ; but if the projectiles are of different diameters, and the object is of a different character, these circumstances have to be taken into account.

93. The following is extracted from Griffiths' Artillerist's Manual, 9th edition.

Maximum penetration of Enfield rifle bullet at ranges from 20 to 200 yards.

Determined by Captain Whitmore, Royal Engineers.

Sandbags - - -	12 inches.
Rammed sandy earth - -	16 „
Ordinary soil in parapet - -	3 to 4 feet.
Solid oak (across grain) - -	4 inches.
Ash, elm, beech - -	4 „
9-inch fascines - -	Not proof.
Full gabions, 2 feet diameter, earth rammed - -	Barely proof at diameter.
Full gabions, 2 feet diameter, earth not rammed - -	Not proof.

Rope mantlets, 13 lbs. to square foot, 3 bullets out of 9 stopped.

Sheet plates $\frac{1}{4}$ inch thick, 10 lbs. per square foot (homogeneous)	Bulged, but not cracked with lead balls.
Sheet plates $\frac{3}{8}$ inch thick, 15 lbs. per square foot -	Unaffected by lead balls, slightly marked by steel tips.

94. The following table records the result of trials which took place before the Ordnance Select Committee at Woolwich in the summer of 1862, to test the penetration of projectiles of pure lead weighing 530 grains, fired from large and small bore muzzle-loading rifles at elm boards half an inch thick and an inch apart, which had been well soaked in water for 48 hours previously; also that of a projectile composed of 19 parts of pure lead and one part of tin, fired from Westley Richards breech-loading rifles :—

Description of Rifle fired.	Number of Boards penetrated at			
	30* Yards.	60* Yards.	100* Yards.	200* Yards.
Enfield ·577″, 3 grooves; pitch, 1 turn in 6′ 6″ - - - - -	11·65	11·15	12·15	11·85
Enfield ·577″, 5 grooves; pitch, 1 in 6′ 6″	11·70	11·00	12·35	11·85
Enfield ·577″, 5 grooves; pitch, 1 in 5′ 3″	12·00	12·10	12·75	11·30
Enfield ·577″, 5 grooves; pitch, 1 in 4′ -	11·40	11·85	12·80	10·70
Lancaster $\frac{\cdot 580''}{\cdot 572''}$; ellipse; pitch, 1 in 3′ -	12·00	11·60	12·45	10·65
Enfield ·451″, 5 grooves; pitch, 1 in 20″ -	12·30	12·65	12·75	13·20
Whitworth ·451″; hexagonal; pitch, 1 in 20″ - - - - -	12·10	12·10	12·00	14·10
Lancaster $\frac{\cdot 462''}{\cdot 450''}$; ellipse; pitch, 1 in 20″ -	12·70	12·90	11·75	13·90
W. Richards $\frac{\cdot 480'}{\cdot 450''}$; octagon; pitch, 1 in 20′ - - - - -	19·95	20·05	19·45	19·95

From the above it will be seen that the greatest penetration obtained with the projectile fired from the large bore is at 100 yards, while that from the small bore is at 200 yards, at which distance the penetration is greater than that of the large bore at 100 yards.

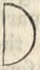
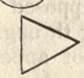
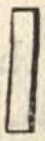
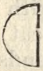
*95. From what has been already remarked concerning the great retardation experienced by spherical, and the comparatively small retardation experienced by elongated shot, it is very evident that for all practical purposes, the elongated is the best form that can be effectively used in rifles.

---

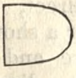
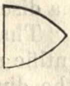
* The slightly increased penetration found to be attained in some cases at the longer distances is probably to be accounted for by the fact that the loss of velocity of the bullet (which has been observed to be 99 feet per second between 30 and 90 yards from the muzzle) is compensated for by the time given to the axis to become rigid, and thus to meet with less resistance.

96. The following tables of resistances to bodies of various forms, with very slow motions, have been constructed by Dr. Hutton and Captain Piobert; but with regard to very swift motions, such as those attained by shot, we have very little information.

FROM DR. HUTTON'S EXPERIMENTS.

	Form of Bodies.	Resistances expressed in Numbers.
	Hemisphere, convex side in front	119
	Sphere	124
	Cone angle, with axis 25° 42′	126
	Disc	285
	Hemisphere, flat side in front	288
	Cone as above, base in front	291

PIOBERT.

	Form of the Base of the Prisms.	
	Triangle, base foremost	100
	Triangle, point in front	52
	Demi ellipse	43
	Ogive	39

97. From the above it would appear that with very slow motions the form of the ogive is the best for pass-

ing through the air (the original Minié bullet was of this form), and that the demi ellipse and triangle, the apex foremost, experience less than one half the amount of resistance of bodies with flat ends in front.

98. Dr. Hutton's tables were established with velocities of only 10 feet per second, and Piobert's with velocities of from 3 to 25 feet in a second.

99. The triangular or conical point is seldom used as the front part of a projectile, in consequence of the weakness of the point and its liability to damage. This weakness the conoidal (the form of the front part of the Enfield bullet, and somewhat like that of the demi ellipse) and ogivale do not possess, and therefore these forms are preferred.

100. It is generally and naturally supposed that a pointed body is the best shape for passing through the air. Whether this is true or not does not appear to have been determined in any conclusive manner.

101. It is acknowledged that for penetration the flat front is the best, whether for penetrating metal, hard substances, or water; and it is a question if with the flat front for all purposes we shall not have great advantages. The action of the air on its front tends to lower its point and to keep the axis a tangent to the trajectory. It has already been observed that a projectile with a round front is disposed to twist its axis; with the flat front the pressure of the air would be more equally distributed on its front and also on its cylindrical portion; the axis of the projectile would deviate in a direction parallel to the plane of fire, and would not be so liable to have its axis twisted from this parallelism.

102. Supposing a flat-ended shot to preserve its parallelism to its initial direction, it may be conjectured that it would experience greater resistance from the air. At first the resistance would be direct, but if the shot preserve its initial direction, after a short distance the resistance would become more and more oblique to its front. Mr. Michael Scott, in a discussion at the United Service Institution, stated "That Mr. "Froude," (a gentleman of the highest scientific attainments,) "has shown that the resistance in the direction "of motion to a plane moving obliquely is the same as

" the resistance to the plane at right angles with the " line of motion, which is subtended by the oblique " plane if the angle of obliquity is not less than about " 60°. If so, we have the condition of a pointed shot " as compared with a flat-ended shot." " It would there" fore appear, that the resistance due to the pointed " shot is the same as, and no less, up to the limit of 60°, " than the resistance of the flat-ended shot. That seems " to be proved."

103. Mr. Whitworth, in his Papers on Mechanical subjects, states, " When the flat-fronted projectiles were fired " in comparison with those having rounded fronts, from " the same barrel and under precisely similar conditions " as to range (500 yards), charge, and weight, the " pointed projectiles were not found to possess any great " practical advantages over the flat ones, for the eleva" tion of the former was only a minute and a half better " than that of the latter. It was satisfactory to find " that so *slight* a difference existed between the two " shapes, for in other respects the flat-fronted projectile " has many advantages." Such as for firing against iron plates and for penetration through water.

*104. The base of the bullet for English rifles is generally more or less hollowed out to throw the centre of gravity forward, the hollow frequently being stopped up by a plug.

*105. Mr. Whitworth finds that with his solid shot tapered off towards the base, he obtains an increased range, viz., from a $\frac{1}{4}$ to $\frac{1}{3}$, compared with his projectiles, formerly used, with "non-tapering rears"; the shot is flat at the base, as giving greater steadiness to the projectile in flight.

106. The best shape, however, for the front and base of projectiles with high velocities is still undetermined.

* 107. The body of the bullet should on leaving the rifle be as near that of a cylinder as possible; this shape experiences the smallest resistance from the air in its rotation, and ought to produce the least drift; for the greater the projections the greater, theoretically, the drift; but it is probable that the resistances caused by uneven surfaces about the body of the bullet may prevent the twisting of the axis from the plane of fire.

*108. The longer the bullet, other things being equal, the less the retardation; also, the longer the bullet the greater the effect of a side wind, the less the initial velocity with the same charge, the greater the penetration at long ranges with the same initial velocity and the flatter the trajectory ; but greater rotation is required.

* 109. The length of projectiles for rifled small arms varies generally from two to three diameters, those for the small bores ($\frac{1}{2}$ inch)being of the greater length.

* 110. Mr. Whitworth found that all difficulty arising from the length of projectiles was overcome by giving sufficient rotation.

* 111. The initial velocity should be as great as possible consistent with recoil, the strength of the barrel, and the preservation of the shape of the bullet.

* 112. It would appear from all the considerations which have been advanced, that the great object of the present day must be to obtain arms from which the bullet can be projected with the greatest initial velocity, combined with the greatest possible power of overcoming the air's resistance, thus producing the lowest trajectory, and the greatest destructive power at all distances.

On Heat generated by arresting the Progress of Shot.

113. Professor Tyndal states, in his lecture on force, " In firing a ball against a target the projectile, after " collision, is often found hissing hot. Mr. Fairbairn " informs me that in the experiments at Shoeburyness " it is a common thing to see a flash of light, even in " broad day, when the ball strikes the target. And " if I examine my lead weight after it has fallen from a " height I also find it heated. Now here experiment " and reasoning lead us to the remarkable law that the " amount of heat generated, like the mechanical effect, " is proportional to the product of the mass into the " square of the velocity. Double your mass, other " things being equal, and you double your amount of heat; " double your velocity, other things remaining equal, " and you quadruple your amount of heat. Here then " we have common mechanical motion destroyed and " heat produced." . . . . "We, moreover, know the " amount of heat which a given amount of mechanical " force can develope. Our lead ball, for example, in

" falling to the earth generated a quantity of heat suffi-
" cient to raise the temperature of its own mass $\frac{3}{5}$ths of
" a Fahrenheit degree. It reached the earth with a
" velocity of 32 feet a second, and 40 times this velocity
" would be a small one for a rifle bullet ; multiplying
" $\frac{3}{5}$ths by the square of 40, we find that the amount of
" heat developed by collision with the target would, if
" wholly concentrated in the lead, raise its temperature
" 960 degrees. This would be more than sufficient to
" fuse the lead. In reality, however, the heat developed
" is divided between the lead and the body against
" which it strikes ; nevertheless, it would be worth while
" to pay attention to this point, and to ascertain whether
" rifle bullets do not under some circumstances, show
" signs of fusion."

ON METAL FOR BULLETS TO FIT BY EXPANSION.

1. In selecting a metal for expanding bullets, there are several conditions to be observed, 1st, the metal should be as non-elastic as possible ; 2nd, it should be sufficiently ductile that perfect expansion may be obtained by the action of the gunpowder ; 3rd, it should be of sufficient hardness that its form should not be destroyed by the action of the gunpowder, and that it may destroy animal life ; 4th, the metal should be of the greatest density possible ; 5th, it should be of moderate cost.

2. Lead, which is a very common metal and easily obtained, is one of the most inelastic substances with which we are acquainted ; it requires the least force of all the metals to perfect its expansion, and it makes but little effort to resume its former shape after it has been altered by any force impressed upon it. The mixture of any other metal with lead will affect its property of non-elasticity.

3. Lead penetrates sufficiently for the general purposes of war. The penetration of an Enfield bullet into a column of men is not known ; but it *is known* that it will perforate 12 half-inch elm planks half an inch apart, at a distance of 100 yards from the rifle.

4. For purposes of penetration into hard substances, however, a harder metal than pure lead is necessary, and in warfare cases may arise when it may be desirable to have an arm from which hardened bullets and hardened shells can be projected with accuracy, such as firing into ammunition waggons, palisades, and other enclosures. Mr. Whitworth's hardened mechanically fitting bullets, composed of lead and $\frac{1}{10}$th tin, fired from his rifle, penetrate 35 half-inch elm planks at a distance of 30 yards ; their powers of resistance to crushing force and their elasticity in comparison with lead are greater, consequently their forms are not so easily altered or damaged on impact.

5. Zinc and antimony are also frequently mixed with

lead to give greater hardness ; they however prevent the bullet from being expanded.

6. Bullets of lead tipped with zinc or cast iron have been made to effect increased penetration and to preserve the form of the projectile on impact.

7. In using a hardened material in combination with lead, care should be taken to use no more of it than is necessary to attain the required object, in order to retain as much density and expanding power as possible. By hardening lead its penetrating power in one sense is increased, and its power of expansion reduced; its density or specific gravity is reduced, and its elasticity is increased.

8. The greater the windage and depth of grooving, the greater must necessarily be the expanding property of the metal used in the manufacture of bullets. The windage of the Enfield rifle being ·027, pure lead is absolutely necessary for its projectiles.

9. Lead is more easily twisted than any other metal, and it possesses the greatest power of readily altering its shape, and in combination with its other properties already explained, is the most perfect metal for the formation of bullets for rifles having an increasing or decreasing twist or turn. Bullets made of a hardened metal cannot so readily conform to the constantly varying shape of the barrel, and would consequently be projected with difficulty.

10. Common small shot being made of hardened lead cannot be used in the manufacture of expanding bullets.

LEAD TESTING.

1. All lead received from contractors for the Royal Arsenal, Woolwich, previously to being melted down for bullets for the Government rifles, is subjected to certain mechanical and chemical tests in order to ascertain that it is equal to the standard and fit for the service required of it. The tests are very simple, and affect the purchase of lead, pure lead being a higher price than hard lead.

Mechanical test.

2. From every consignment sundry pieces are cut off from the bars, melted, and cast separately into upright lengths of 6 inches, from each of which a cubic inch is cut off, rather below the centre to insure its solidity, and submitted to a pressure of 28 cwt., which should reduce it to the thickness of half an inch; if this pressure has not this effect, the lead is too hard for the patent bullet making machine, and will not go up into the dies. The hard lead is only fit for bullets for use in spherical case.

Chemical test.

3. The chemical test is of such a simple nature that it can be adopted and practised by any rifleman desirous of making ammunition for himself. From each barge load supplied by the contractor five or six pieces are cut off from different pigs taken indiscriminately, marked both in pig and piece, and are sent to the chemical department, which is presided over by Mr. Abel (the chemist to the War Department), and are there subjected to the chemical test. Nitric acid (concentrated) is used in testing lead; it is necessary that this should be perfectly pure and free from sulphuric acid (oil of vitriol); if it is not pure, it would cause a white precipitate to form at the bottom of the test glass, and it might be fancied that the lead was impure, when in fact it would have been the nitric acid. Nitric acid is tested (with regard to purity for testing lead) by diluting a small quantity in five waters by bulk, and then pouring on it a few drops of chloride of barium; if it contains sulphuric acid a white precipitate would be produced (sulphate of baryta) insoluble in water. The presence of this acid (sulphuric) is the only thing that would interfere with nitric acid in testing the purity of lead.

Tested by nitric acid (con.).

Testing operations.

4. The nitric acid having been found to be pure, small portions are cut off the pieces of lead sent into

the laboratory, and flattened out so as to be readily weighed ; each piece is reduced to 200 grains ; the outside becomes clean by the hammering. Each piece of 200 grains is placed in a separate conical bottle, and six drams of concentrated nitric acid poured on it, this is diluted at once with 12 drams of distilled water. The bottle is then placed upon a dry sand bath, which is heated by gas underneath; the heat assists the solution in dissolving the lead. If watched, gas will be seen rising to the surface as the lead dissolves. The lead, when dissolved, if *pure*, leaves the solution quite clear ; but if antimony is present (that is, any appreciable quantity, sufficient to harden lead) a white powder will be left suspended in the liquid, giving it a milky appearance ; this powder is insoluble in water. Arsenic and antimony are the impurities which are generally found.

HISTORY OF GUNPOWDER.

1. Ignorance of the history of gunpowder may be received as a proof of its great antiquity. We have no certain information as to how, when, or by whom it was invented.

* 2. It appears, however, to have been first known in India and China, where it was used in the manufacture of fireworks, and possibly in warfare, several centuries before the Christian Era.

* 3. Wilkinson, in his book entitled Engines of War, says, "it has always appeared to me highly probable that " the first discovery of gunpowder might originate from " the primeval method of cooking food by means of wood " fires, on a soil strongly impregnated with nitre, as it is " in many parts of India and China." Now it cannot reasonably be supposed that the inflammable properties of saltpetre (nitre) could be long unknown after the substance itself was discovered, for the accidental dropping of any small part of it into the fire would prove its explosive force ; this being once observed, we can easily conceive that the invention of a more powerful composition of saltpetre and some other substance would naturally follow. Our present gunpowder is only the improvement and perfection of such a mixture.

* 4. The inflammable property of a mixture of nitre, charcoal, and sulphur was known long before its projectile force was discovered. Used in the form of dust, it is supposed by many to have been the substance of which the rockets and Greek fire of the ancients were made. Authors, however, differ respecting the composition used in Greek fire.

5. In Colonel Anderson's book on gunpowder the following appears :—" John Bell, of Antermony, on his " journey to Pekin, records, under date 1721, January " 1st :—The emperor's general of artillery, together with " Father Fridelly, and a gentleman named Stadlin, an " old German, and a watchmaker, dined at the ambassa- " dor's. He was by birth a Tatar, and by his conver- " sation it appeared he was by no means ignorant of his " profession, particularly with respect to the various

" compositions of gunpowder used in artificial fireworks. " I asked him how long the Chinese had known the " use of gunpowder ; he replied, above 2,000 years in " fireworks, according to their records, but that its " application to the purposes of war was only a late " introduction. As the veracity and candour of this " gentleman were well known, there was no room to " question the truth of what he advanced on this subject."

* 6. It is said that gunpowder was first used at the siege of Mecca, A.D. 690, by the Arabs, from whom the knowledge of it was conveyed to Europe on the return of the crusaders, and that the Arabs derived it from the Indians.

* 7. Kock mentions that it is probable that the Arabs first availed themselves of the advantages of gunpowder in their wars with the Spaniards ; that from Spain the use of gunpowder passed to France, and thence it gradually extended itself over the other States of Europe.

* 8. It is very difficult to ascertain when gunpowder was first used or made by the English ; but from certain records which have been left, it appears to have been manufactured in 1346, as King Edward III. ordered all the saltpetre and sulphur that was for sale to be bought for him; and again in 1349, 912 lbs. of saltpetre and 886 lbs. of quick sulphur were supplied to him for his guns. It is supposed that gunpowder was used at the battle of Cressy, in 1346. Villani, a Florentine historian, mentions it, also Froissart, whose manuscript runs freely thus, " and the English caused to fire certain " guns which they had in the battle, to confound the " Genoese." A passage in the chronicles of St. Denis mentions the use of cannon by the English at Cressy.

* 9. Although the manufacture of gunpowder in England commenced in the time of Edward III., it was not until the reign of Elizabeth that it was fairly established.

10. In the year 1377, being the first of Richard II., Thomas Norbury was ordered to buy, amongst other munitions, saltpetre, sulphur, and charcoal, to be sent to the castle of Brest.

11. In 1414 Henry V. ordered that no gunpowder should be taken out of the kingdom without special

licence; in the same year this monarch also ordered 20 pipes of powder of willow charcoal and various other articles to be prepared for the use of the guns.

* 12. Gunpowder at this period was but dust, and for sometime after the invention of artillery was of a composition much weaker than that now in use, or that ancient gunpowder mentioned by Marcus Græcus, who lived about the end of the 8th century, which was composed of six parts of saltpetre, two of charcoal, and two of sulphur.

* 13. Tartaglia, who lived about 1537, mentions 23 compositions as having been used at different times; the first, (the most ancient), contained equal parts of saltpetre, charcoal, and sulphur. The powder of his own time for cannon was made of four parts of saltpetre, one of charcoal, and one of sulphur, and the musket powder,—

Saltpetre.	Charcoal.	Sulphur.
48	8	7
or, 18	3	2

These compositions, Robins remarks (1742) to have been very near the standard in his time.

* 14. The change in the proportion of materials composing gunpowder was not the only improvement it received. At first it was always in the form of fine meal, such as it was reduced to by grinding the materials together. Graining was introduced, and it is doubtful if the first graining of gunpowder was intended to increase its strength, or only to render it more convenient for filling into small charges, and the charging of small arms, to which alone it was applied for many years, whilst meal powder was still continued for cannon.

* 15. The additional strength which grained powder was found to acquire from the free passage of the flame between the grains, said to be equal to $\frac{1}{3}$rd more, occasioned the meal powder to be entirely laid aside. The mealed powder was called serpentine powder in the time of Edward VI.

* 16. From the beginning of the reign of Elizabeth, when saltpetre was first manufactured in this country, less than one-third of the supply was made in England, the remainder was procured from Barbary, France, Poland, Hamburgh, and Germany.

* 17. About the year 1600 recourse was had to the

corn or grained powder. It was not generally in use until the reign of Charles I. the powder for priming remaining ungrained. At a later period one kind of powder was used both for priming and loading; this continued until the introduction of the percussion cap.

* 18. In 1623, in order to prevent the sale of weak or defective powder, a proclamation was issued by James I. prohibiting its manufacture, or that of saltpetre, except under the King's commission, and directing that all gunpowder should be proved and marked by the sworn proof master.

* 19. In Charles I.'s reign, about 1626, the East India Company had commenced the importation of large quantities of saltpetre, and had erected powder mills in Surrey.

* 20. Until the reign of Charles II. the quantity of gunpowder and saltpetre made in England was not sufficient for the service; large quantities were imported from various foreign countries.

* 21. In 1692 a company, formed for the purpose of making and refining saltpetre, was bound to furnish Government with a quantity, not exceeding 1,000 tons, yearly. According to the charter of 1693, in the reign of William III., the East India Company was bound to furnish Government with 500 tons of saltpetre annually. From this time forward we hear of no difficulty in procuring this, the chief ingredient of gunpowder.

* 22. In the early days of the European occupation in India, war and battle were too frequent to admit of the powder being long stored in the magazines. With native armies the powder makers followed the camp; the women of families often manufactured the article for the matchlocks of their husbands; such too at the present day is the custom in the wilds of Affghanistan, where the hand flour mills of the huts are occasionally seen grinding the sulphur and saltpetre, to fabricate a coarse powder for the use of the men on their sporting excursions or plundering forays.

MANUFACTURE OF GUNPOWDER.

* 1. Before proceeding to detail the process of the manufacture of gunpowder, it is desirable to consider the several properties of the ingredients of which it is composed, viz., *saltpetre*, *charcoal*, and *sulphur*, whence they are procured, &c.

* 2. *Saltpetre* is a compound of 54 parts of nitric acid and 46 of potash. It decomposes gradually at 800° when there is no combustible present; but with a combustible, such as charcoal, it decomposes suddenly, and an explosion takes place.

* 3. Saltpetre is a natural production, and is found on the surface of the earth in some warm climates, such as India and China. When it arrives in England it has only been partially separated from the earths and salts with which it was combined when found, and in such a state it is quite unfit for the manufacture of gunpowder; the salts especially, from their powers of absorbing moisture, are most injurious.

* 4. In Bengal saltpetre is found in greater abundance than in any other country.

* 5. In France and Germany nitre is produced artificially. Animal refuse of all kinds is mixed with old mortar and earth, and placed in heaps under sheds, exposed to the action of the air, but protected from rain. From time to time these heaps are watered with putrid urine, and the mass is turned over to expose fresh surfaces to the action of the air. Thus nitrate of lime is formed, and by a chemical process nitre (nitrate of potash) is produced.

* 6. The purification of the saltpetre (called grough saltpetre before purification) is so arranged that the earthy and saline matters are all abstracted. The purification at Waltham Abbey depends upon the natural laws of crystallization. Saltpetre is more soluble in hot than in cold water; while common salt is equally soluble in hot and cold water. Water at 212° holds about ten times as much nitre in solution as water at 60°. If, therefore, a saturated solution of nitre be made at a temperature of 212°, and salt is contained in the liquor,

as the solution cools to 60°, nine-tenths of the nitre contained in it will be deposited in the form of crystals, whereas the common salt will still remain suspended in the solution.

* 7. Whenever, in boiling or evaporating, the solution is saturated with salt, any additional evaporation will cause the surplus salt to be precipitated with the earthy matter ; thus in evaporating saturated liquor to one-fourth, three-fourths of the salt would be precipitated ; so that in the continual succession of boilings and evaporatings all the impurities are got rid of.

* 8. *Charcoal* is a form of carbon with a small quantity of impurities, chiefly earthy. It is best fitted for the manufacture of gunpowder when prepared from light but spongy wood, which should be sound, about an inch in diameter, and not more than three or four years old.

* 9. Wood charcoal is the woody fibre which remains after the liquid and more volatile parts have been driven off by charring. The object of charring wood is the removal of moisture, and, which is of great importance, the expulsion of those matters contained in it which become volatile before they are burned, and which would absorb a large amount of heat.

* 10. It may be charred in the ordinary way in pits ; but the usual mode of preparing charcoal for gunpowder is by distillation in large iron cylinders, as described in the manufacture of gunpowder, pages 46 and 47. By the latter method the operation is performed more completely, and the charcoal rendered more free from foreign substances.

* 11. The quality of the charcoal exercises great influence on the rapidity of combustion, so that the method of manufacture and description of wood used are of the greatest importance.

* 12. Dogwood produces the best charcoal, and is used for the Enfield rifle powder. It is procured from Sussex, Belgium, or Holland. Alder and willow are used for common service powder ; these are obtained from various parts of England.

13. Alder has a triangular pith, and is a reddish wood. Willow has a circular pith, and is a white wood. Dogwood is a much smaller wood than the other two, averaging in size the diameter of a thick osier ; its pith is circular, and large in proportion to the size of the wood.

* 14. The wood generally should give from 25 to 26 per cent. of charcoal ; dogwood rather more.

15. The wood should be cut in the spring when the sap is up, as it can then be more readily stripped of its bark. It is laid in open stacks for about three years, exposed to rains, which carry off the sap and soluble matter, when the wood is ready for charring.

* 16. *Sulphur* is insoluble in water, but is soluble in oils or alcohol, and suffers no change by exposure to the air. It begins to evaporate at 170°, giving out a disagreeable odour, and to melt at 216°. Between 230° and 270° it is perfectly liquid and of a bright amber colour ; between 300° and 400° it becomes glutinous or sticky, and of a deep brown colour ; at higher temperatures it again liquefies ; and about 600° it boils and sublimes in a yellow vapour.

* 17. Native sulphur is principally brought from Sicily, and is found there in large masses very nearly pure.

* 18. Sulphur is purified at Waltham Abbey by distillation.

* 19. The gunpowder used by the English forces is composed of 75 parts of saltpetre, 15 of charcoal, and 10 of sulphur; and in its manufacture at the royal factory at Waltham Abbey, passes through the following processes, which will be explained separately :—

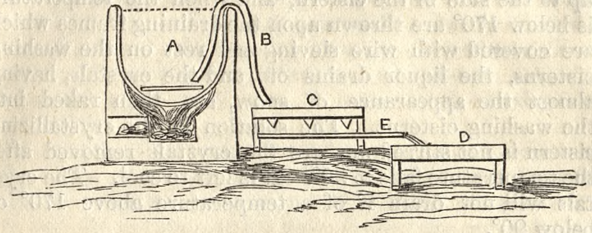
1. Purification of the ingredients, pulverizing and sifting the charcoal and sulphur.
2. Mixing the ingredients.
3. Incorporation and proof of the mill cake.
4. Breaking down the mill cake.
5. Pressing.
6. Granulating.
7. Dusting.
8. Glazing and dusting.
9. Stoving or drying.
10. Finishing or final dusting.
11. Proof.

1.—PURIFICATION OF INGREDIENTS.

20. *Saltpetre called grough saltpetre.*—The refining coppers are capable of holding 500 gallons each, and are fitted with false wooden bottoms, to prevent the saltpetre adhering to the coppers (Fig. 1). The coppers are each charged with 280 gallons of the second and third washings

of the purified saltpetre, and 40 cwt. of saltpetre, partly grough, say 25 cwt.; partly crystals from reduced liquors, 5 cwt.; partly crystals left in crystallized cisterns, 5 cwt.; and about 5 cwt. in the water.

Fig. 1.



A. Boiler, wooden bottom in.
B. Syphon, instead of pump.
C. Trough, with filtering bags.
D. Crystallizing cistern.
E. Conducting trough to D.

21. In about two hours after the fires have been lighted the greater part of the saltpetre in the copper will be dissolved, and the solution begin to boil ; just before boiling the thick scum formed on the surface is carefully skimmed off, and the false bottoms are pulled out ; while boiling, cold water is from time to time thrown in to precipitate portions of the chlorides, which would otherwise rise to the top ; the scum is removed as long as it forms. The boiling continues for half an hour, or until the scum ceases to rise ; the coppers are then filled up with cold water, and the solution is again made to boil briskly for a few minutes, when the furnace doors are opened and the fires allowed to go down.

22. In about two hours the solution will be at the proper temperature, 220° (specific gravity 1·53), for pumping out. A copper pump is then lowered into the boiler, and the solution pumped out into the wooden supply troughs, which are fitted with four or five brass cocks, having conical filtering bags of dowlas underneath, through which it filters into a long copper trough below, which conducts the solution to the crystallizing cisterns at a temperature of 180° or 190°.

23. These cisterns are each 12 × 7 feet and about 11 inches deep, the solution between 5 and 6 inches deep. The liquid is kept in agitation by a man with a long handled wooden hoe, and as it cools fine crystals fall to the bottom of the cistern. If not kept in agitation large crystals would form, which would enclose liquid and impurities. The crystals are from time to time drawn up to the side of the cistern, and when the temperature is below 170° are thrown upon the draining frames which are covered with wire sieving and rest on the washing cisterns, the liquor drains off, and the crystals, having almost the appearance of snow, are then raked into the washing cisterns. The solution in the crystallizing cistern is not stirred nor are the crystals removed after the temperature falls to 90°. It is left to cool. The crystals will not drain if of a temperature above 170° or below 90°.

24. The washing cisterns are about 6 feet long, 4 feet wide, and 3 feet 6 inches deep, and are fitted with a false bottom of wood pierced with holes, under which is nailed a sheet of fine copper mesh, to prevent the crystals from passing through the holes. Each cistern is fitted with a plug hole below.

25. The cisterns being full of saltpetre, the plugs are withdrawn, and the crystals are washed by sprinkling about 70 gallons of water by means of a rose over each cistern. The saltpetre is then left to drain for half-an-hour. The liquor which passes through is called the first washing, and runs into a tank. It is used in the evaporating pots. The plugs are now inserted, and enough water is permitted to run into the cisterns to cover the saltpetre. This water is allowed to stand half-an-hour, when the plugs are withdrawn, and the liquor runs into a tank, a separate one from that into which the first washing runs. This liquor is allowed to run off for half-an-hour, and is called the second washing. A third and final washing is then given by sprinkling about 100 gallons of water over each cistern, as at the first washing, the plug holes remaining open. It is desirable that distilled water should, when procurable, be used for this washing, to avoid the impurities which are contained in the best ordinary water. The water which runs from the third washing flows into the same tank which contains the second washing, and is used in the

refining coppers instead of water. Whatever remains in the tank after the coppers are filled is pumped into the evaporating pot. The saltpetre is now allowed to drain all night, and in the morning it is removed (with the exception of about 6 inches in depth, which contains a large amount of moisture) to one of the store bins, where it remains until required for use. After remaining there about three days it is ready for use, and contains from 3 to 5 per cent. of moisture, according to the season. The saltpetre should now be tested by the refiner. For test, see Explosive force, Purity of ingredients, par. 12. From each copper of 40 cwt., 25 cwt. of refined saltpetre is obtained.

26. On the following morning, the solution which was left in the crystallizing cisterns at 90° having become cold, the mother liquor is run off into the evaporating pot, and the crystals which have formed are set to drain. These are afterwards placed in the refining coppers with a fresh boiling.

27. The evaporating pots contain about 300 gallons each. The liquor to be evaporated consists of the mother liquor from the crystallizing cisterns, the mother liquor from the saltpetre crystallized in pans (hereafter explained), the first and part of the second and third washings. The liquor is kept briskly boiling, and is occasionally stirred to prevent the salts caking at the bottom. When the liquor is reduced to about one-fourth of its original bulk, the fires are allowed to go out, and about nine hours from the lighting of the fires the solution, just simmering, is ready for filtering. It is filtered in the manner already described, and run into crystallizing pans, containing about 17 gallons each, and left all night. In the morning the mother liquor is run off and sent back to the evaporating pot. The crystals formed (about 11 cwt.) are drained and sent to the refining coppers.

28. A constant process is going on of petre (saltpetre) to the coppers and of mother liquor to the evaporating pot. During every boiling and evaporating the scum is taken off as it rises, and when completed the boilers are cleaned out if necessary, and the residue (chiefly sulphate of potash), after all the petre is washed out, is sent to the refuse store.

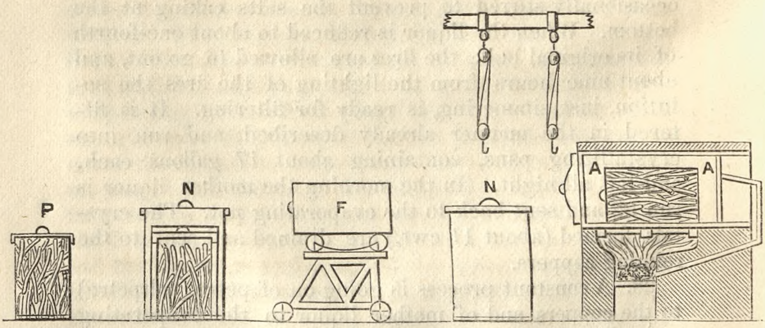
29. If grough saltpetre is very impure, it is soaked in

liquor (that from the crystallizing cisterns), which takes a great part of the impurity away. It then goes to the refining coppers.

30. The refined saltpetre required in the manufacture of rockets, fuses, &c., at the Royal Laboratory, at Woolwich, is dried at Waltham Abbey, at a heat of 270° gradually raised and lowered for about 48 hours. The same is done if the saltpetre is to be stored for any length of time.

31. Charcoal made in cylinders is the best for the manufacture of gunpowder. The wood is cut into lengths of 3 feet, and is packed into iron cylindrical cases called slips, which are 3 feet 7 inches long and 2 feet 4 inches in diameter, standing on one end (Fig. 2). If the wood differs much in size it is split up, in order that the charcoal may be evenly made. The lid is fastened on, two openings being left in the slip at the bottom, of about 4 inches in diameter. The slips are placed into horizontal cylindrical retorts, the end with openings (one being below the other above) first. The retorts, which have openings at the far end to correspond with those on the cylinders, are closed by tight-fitting iron doors.

Fig. 2.



P. Receiver or Slip. N. Extinguishers. F. Slip on Carriage. A. Retort.

32. The retorts are built in the wall with furnaces so arranged underneath as to admit of the accurate regulation of heat throughout the operation of charring, which occupies, for dogwood about 3½ hours, and for

alder and willow 4½ hours ; this time, however, would be increased if the wood was beyond the average size ; the furnaces are so arranged that the flames surround the retorts, and the heat acts as equally as possible on the whole surface of the cylinder. The gas from the wood passes out from the upper hole in the slip, and the tar through the lower hole (both holes corresponding with holes in the retort) into the furnace where they are burnt ; this saves fuel.

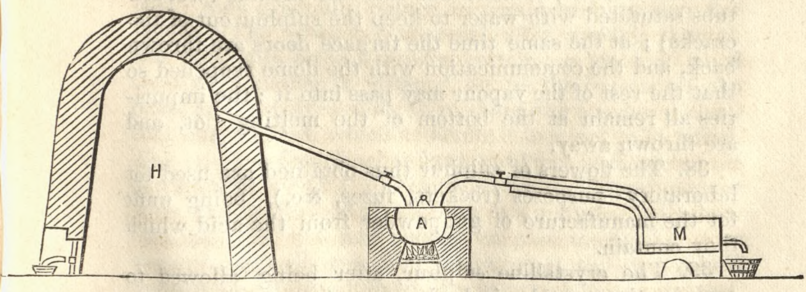
33. When it has been sufficiently charred, which is known by the violet colour of the flame from the burning gas, the slip is withdrawn by tackling, and placed in a large iron case or cooler, covered with a close fitting lid, and allowed to remain until all the fire is extinguished, which takes about four hours ; the charcoal is then emptied into smaller coolers and sent to store.

34. Dogwood, alder, and willow are each burnt exactly alike.

35. The charcoal is carefully looked over and picked, to see that all is properly burnt, and that no rivets from the slips have broken off. For charcoal test, see Explosive force, par. 13.

36. Sulphur is purified by distillation. A large iron melting pot, or retort, is set about three feet above the floor with a furnace underneath ; this retort has a movable lid, which is fixed into the pot with clay, and in the lid is an iron conical plug that can be removed at pleasure (Fig. 3.) From the melting pot lead two pipes,

Fig. 3.



H. Subliming Chamber. A. Melting Pot. M. Receiving Pot.

one to a large circular dome, and the other (five inch) to an iron receiving pot, rather below its level. The latter pipe has an iron casing or jacket round it, which can be filled with cold water when desired. The communication of these pipes with the melting pot can by a mechanical arrangement be shut off or opened as occasion requires.

37. The grough sulphur is broken into small pieces, and about 5¼ or 5½ cwt. of it is placed in the melting pot, and subjected to the action of the furnace. The plug hole in the lid, and the pipe leading to the dome are now left open, but the pipe leading to the receiving pot is closed ; after about two hours a pale yellow vapour rises, when the plug is put in and the vapour is conducted into the dome, where it condenses on the sides and floor in the form of an impalpable powder called "flowers of sulphur"; a small pipe leads from the bottom of the dome on the opposite side into a tub filled with water ; the air escapes by the former, and sulphuric acid is taken up by the latter. In about 1½ or 2 hours more, the vapour becomes a deep iodine colour, when the pipe communicating with the dome is shut, and that with the receiving pot opened, at the same time cold water from a tank above is allowed to pass into the jacket covering the latter pipe ; the vapour then passes through, is condensed in the pipe, and runs into the receiving pot below in the form of a thick yellow fluid. When nearly all has passed over into the receiving pot, which can be known by the jacket getting cold, the pipe communicating with the receiving pot is again closed, and the fluid sulphur left about an hour to get sufficiently cool (not below 220°) to ladle out into the moulds (wooden tubs saturated with water to keep the sulphur out of the cracks) ; at the same time the furnace doors are thrown back, and the communication with the dome reopened so that the rest of the vapour may pass into it ; the impurities all remain at the bottom of the melting pot, and are thrown away.

38. The flowers of sulphur thus obtained are used for laboratory purposes (rockets, fuzes, &c.), being unfit for the manufacture of gunpowder from the acid which they contain.

39. The crystalline sulphur, after being allowed to cool in the moulds, is broken up into barrels ready

to be ground. For sulphur test, see Explosive force, par. 14.

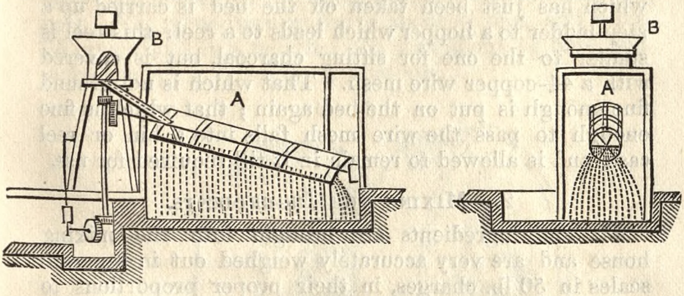
Pulverizing and Sifting.

40. Refined saltpetre required for fuses, rockets, &c., at Woolwich, is ground, 2 cwt. at a time, for 10 minutes under runners, similar to those used in the incorporating process hereafter described; it is then placed in a copper 60-mesh reel and sifted.

41. The refined saltpetre for gunpowder is not ground previous to mixing.

42. The charcoal mill in shape is like a very large coffee mill, 4 feet 6 inches in diameter at the top (Fig. 4).

Fig. 4.



B. Mill. A. Reel for Sifting.

The teeth of both the cylinder and cone are very large at the upper end, so as to readily admit the pieces of charcoal; they gradually reduce in size, becoming very fine below. The powdered charcoal, after passing through the mill, falls on to a wooden bottom; a piece of wood shod with leather is fastened on to the bottom of the cone, and revolves with it, pushing the powdered charcoal into a spout, which conducts it to a reel to be sifted. The reel is 8 feet 6 inches long and 3 feet in diameter, set at a slope of about 4°; it is covered with 32-mesh copper wire, and makes 38 revolutions in a minute. All charcoal which is not fine enough to pass the meshes goes through the reel and falls into a tub at the end, and is again passed through the mill; that which passes through the meshes falls into a bin or reel case, and is fit for use; the reel case is closed during the sifting, to prevent the charcoal from flying about the house. After the day's work the charcoal is taken out of the bin and placed in iron coolers, as before mentioned, and removed to the store for ground charcoal. This store is of corrugated iron, and stands by itself, as spontaneous combustion sometimes takes place with ground charcoal.

43. The sulphur as it comes from the store is in large pieces, and is ground under a pair of iron runners, similar to those in the incorporating mills; about 2½ cwt. is placed in the bed at a time; the runners are then set at work, and make eight revolutions in a minute. In about 8 or 10 minutes the sulphur will be ground fine enough for reeling; it is then taken off the beds, and a fresh charge is introduced; while this is grinding, that which has just been taken off the bed is carried up a step ladder to a hopper which leads to a reel; this reel is similar to the one for sifting charcoal, but is covered with a 44-copper wire mesh. That which is not ground fine enough is put on the bed again; that which is fine enough to pass the wire mesh falls into a bin or reel case, and is allowed to remain in it till required for use.

2.—Mixing the Ingredients.

44. The ingredients are brought into the mixing house and are very accurately weighed out in separate scales in 50 lb. charges, in their proper proportions to 100 lb., viz., 37½ saltpetre, with an allowance for the moisture in the saltpetre, 7½ charcoal, 5 sulphur. This is the largest charge authorized for the incorporating mill.

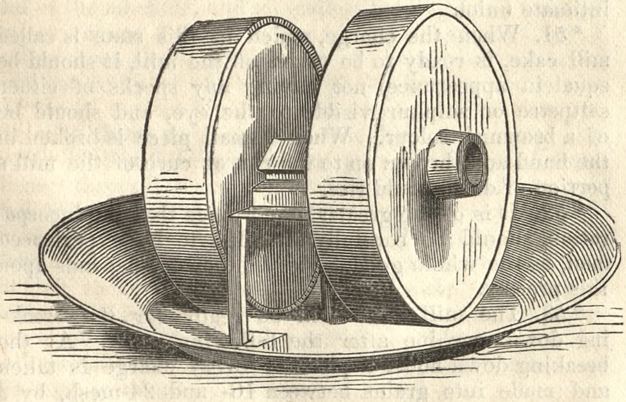
45. This charge is now placed in the mixing machine, which consists of a cylindrical gun metal or copper drum, about 2 feet 9 inches in diameter, and 1 foot 6 inches wide, with an axle passing through its centre, on which there are eight rows of gun metal flyers, like forks; the machinery is so arranged that the flyers and drum revolve in opposite directions, the drum making about 40 revolutions, and the flyers 120 per minute. The ingredients are thoroughly mixed in about five minutes; the machine then empties itself into a box, and the composition is passed through an 8-mesh hand copper sieve, in order to catch any bit of copper

or nail which may have got into the saltpetre in the refining; it is then placed in bags, and tied up ready for the incorporating mill. In this state it is called a green charge.

3.—INCORPORATION AND PROOF OF THE MILL CAKE.

46. The incorporating mill consists of an iron or stone circular flat bed, about 7 feet in diameter, fixed very firmly in the floor of the building, whereon the iron or stone cylindrical runners revolve; the old pattern beds and runners are of stone, the new of iron (Fig. 5). The stone runners are 5 feet 10 inches in diameter, the iron 7 feet; they are from 14 to 18 inches wide. Stone runs upon stone, iron upon iron. They have a common axle, and a vertical shaft passing through the centre of the bed connects this axle with the machinery, which is above the bed in the old apparatus, and beneath it in the new. The stone runners weigh about 3½ tons, and make 7½ revolutions in a minute; the iron about 4½ tons, and make about 8 revolutions in a minute.

Fig. 5.



* 47. The 50 lb. green charge is brought in the bag, and put on the bed of the mill evenly, and is worked for 5½ hours under the stone, or 4 hours under the iron runners for the Enfield rifle powder, which arrangement is considered to render the incorporation equal in every respect. Common service powder is 3½ hours under the stone and 2½ hours under the iron runners.

48. The bed has a rim outside, making it in shape like a barrack meat dish. The runners are not equidistant from the centre of the shaft ; one works the part of the charge nearest the centre of the bed, the other the outer part, but they overlap ; two ploughs of wood covered with leather, one working next the vertical axle, the other next to the rim, throw the composition as it is worked outwards under the runners.

* 49. The 50 lb. charge when placed on the bed of the mill contains about 2 pints of water (the moisture of the saltpetre), and a further quantity of from 2 to 6 or 7 pints of distilled water is required, according to the state of the atmosphere, to facilitate the incorporation, and reduce the effect of an explosion. If too wet the runners would take up the composition from the bed. During the time of working the charge, the millman takes a wooden shovel and pushes the outside of the charge into the middle of the path of the runners to facilitate the incorporation.

* 50. The action of the runners is threefold,—crushing, grinding, and mixing, which gives the charge a most intimate union.

* 51. When the charge, which in this state is called mill cake, is ready to be taken off the mill, it should be equal in appearance, not having any specks of either saltpetre or sulphur visible to the eye, and should be of a brownish colour. When a small piece is broken in the hand and thrown on to the rim or curb of the mill a portion of dust should rise.

* 52. It is of the greatest importance that the incorporation should be carefully attended to by experienced men, as the whole goodness of the powder depends upon this process.

* 53. The mill cake will be ready for the breaking down machine after the following proof. At the breaking down house a piece of every charge is taken and made into grains between 16- and 24-mesh, by a small corning frame ; it is put into proof pans and sent to the proof-house, where it is dried in an oven. Half a dram is accurately weighed and fired ; this should raise the vertical eprouvette (the ball and rod of which weigh $28\frac{1}{4}$ lbs.) at least 13 inches for the Enfield rifle and 11 for the common service powder. About half an ounce is also flashed on a glass plate ; if any white or yellow

spots are found, it is a sign that the powder has not been properly incorporated. This is a very excellent proof.

4.—BREAKING DOWN THE MILL CAKE.

54. The mill cake, on being taken off the bed of the mill, is placed in wooden tubs or boxes, moved to small magazines, and then to the breaking down machine, which is similar in principle to the granulating machine, vide Fig. 7.

55. The object of this machine is to reduce the cake to a convenient size for the hydraulic press box, and, that being again crushed to meal, it may get a more even pressure. The machine consists of a strong gun-metal framework, in which are fixed two pairs of fine toothed or plain gun-metal rollers, which revolve towards each other, one of each pair working in sliding bearings connected with a weighted lever (pressure about 56 lbs.), so that on any hard substance getting in by accident they would open and allow it to pass through, thereby preventing the dangerous friction which would otherwise result.

56. A hopper capable of holding 500 lbs. is fixed at one end of the machine, and an endless feeding band made of web or canvas 2 feet 6 inches wide, and having strips of leather sewn across at distances of about 4 inches, passes over one roller at the bottom of the hopper and one at the top of the machine. When set in motion it conveys the cake from the hopper to the highest point of the band ; it then falls into the first pair of rollers, and from thence through the second, which are directly below, passing in the form of meal into wooden boxes placed upon a carriage under the machine. These boxes, when they are filled, move forward by a self-acting motion, making room for others. The mill cake thus broken down is fit for the press, and is taken to an expense magazine until required for pressing. The Enfield rifle and common service powders are both broken down in the same manner.

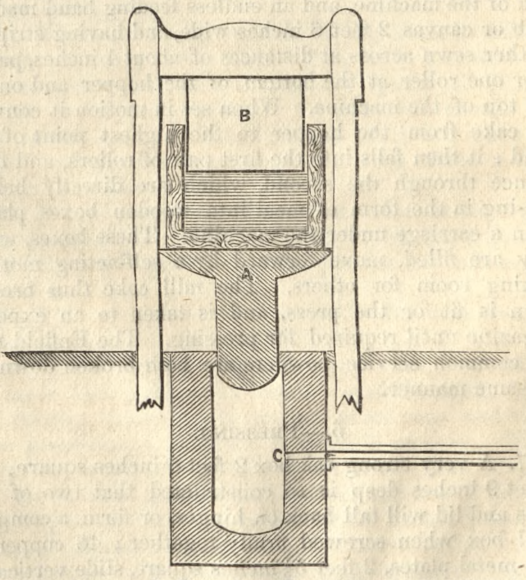
5.—PRESSING.

57. A very strong oak box 2 feet 6 inches square, and 2 feet 9 inches deep is so constructed that two of the sides and lid will fall back on hinges, or form a compact solid box when screwed firmly together ; 46 copper or gun-metal plates, 2 feet $5\frac{1}{2}$ inches square, slide vertically into this box, and are kept $\frac{5}{8}$ of an inch apart by two metal

slips (called racks) with corresponding grooves, which can be removed when necessary.

58. About 800 lbs. of the meal is put into this box, while the plates are in a vertical position; when full the racks are withdrawn, the plates are then only separated by the powder between them; the lid is now firmly screwed down, and by an arrangement of pulleys the box is turned over, so that the plates are now horizontal; the present upper side is taken off, and a travelling crane, moving on a rail overhead, is lowered until its claws hook on to two trunnions fixed on the sides of the box; it is now lifted by means of a hand wheel windlass, and the box being suspended, is pushed easily by means of the rail and deposited on the table of the ram under the press block. The pumps, which work the hydraulic press in a separate house, are now set in motion by a water wheel (or by hand if necessary) and allowed to work up to the required pressure, viz., about 41 tons on the square foot for the Enfield rifle powder, and 62 tons for the common service. (Fig. 6.)

Fig. 6.



A. Table of Ram. B. Press Block. C. Pipe leading from Pump.

59. After the required pressure has been obtained (which is known by the safety valve lifting, and the water making its escape), the box is allowed to remain under the press for a few minutes, a cock is then opened to allow the free passage of the water from the cylinder, when the ram and press box descend. The box is run from beneath the press by means of the crane and rail, and again turned over on its side. The amount of pressure depends in a great measure upon the judgment of the foreman of the press house, for when the mealed powder is a little drier than usual, or the weather is very dry or windy, the safety valve will lift before the powder is sufficiently pressed.

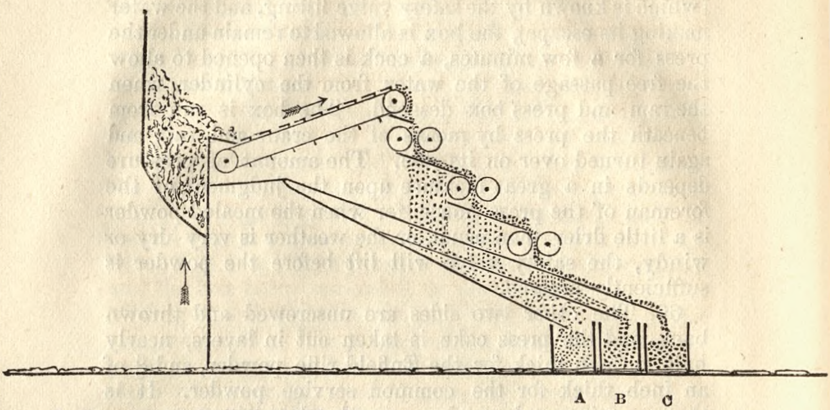
60. The other two sides are unscrewed and thrown back, and the press cake is taken out in layers, nearly half an inch thick for the Enfield rifle powder, and $\frac{3}{8}$ of an inch thick for the common service powder. It is then put into tubs or boxes and taken to an expense magazine until required for granulation. The press cake hardens by exposure to the air.

6.—GRANULATING.

61. The granulating machine is very beautifully contrived, and is entirely self-acting, to obviate the necessity of any one being in the building while it is in motion; it consists of a strong gun-metal framework fitted with three pair of teethed gun-metal rollers of different degrees of fineness. When making Enfield rifle powder, or fine grain only, the bottom pair are without teeth, the finest pair of teethed ($\frac{1}{8}$ inch) rollers are next above the plain ones; the teeth of the upper pair are half an inch long. The rollers work in sliding bearings of the same kind as those of the breaking down machine, so that they may open to allow any hard substance to pass through and prevent friction.

62. At one end of the machine is a wooden hopper filled with press cake, so contrived as to rise gradually by the motion of the machine, and constantly to supply an endless band similar to the one in the breaking down machine; when the press cake arrives at the highest point of the band, it falls over and is granulated by the first pair of rollers. Under each pair of rollers, except the bottom, is a screen (Fig. 7).

Fig. 7.



A. Dust. B. Enfield Rifle Powder. C. Large grain to be regranulated.

63. When making Enfield rifle powder the screens are covered with a 12-mesh copper wire ; all the powder which is not sufficiently small to pass through is carried by the screen to the next pair of rollers, and in like manner that which is not broken small enough by the *second* pair of rollers is carried to the third pair by *its* screen. In addition to these screens there are two others, the top one covered with 12-mesh and the under one with 20-mesh copper wire ; these are fixed in a frame at an incline below the whole of the rollers and about 2 to 3 inches apart. While the machine is in movement the screens have a shaking motion communicated to them, to cause the grain to pass through, or to fall to the end of the screens to be delivered to the next rollers or into the boxes. That grain which is broken small enough to pass through the 12-mesh screen leading from one pair of rollers to the next, will fall on to and pass through the 12-mesh long screen which runs from the top of the machine to the bottom ; that which passes the 12-mesh screen and is retained on the 20-mesh is the Enfield rifle powder. It falls into boxes which are made to move forward as they are filled, fresh ones taking their places; the grain which does not pass the 12-mesh screen falls off it into separate boxes and is again placed in the hopper to be re-granulated ; that which is fine enough to

pass through the 20-mesh screen falls on the bottom of the machine frame and is conducted into a box; this is called dust, and is sent back to the incorporating mill in 50-lb. charges to be run for one hour.

64. For the common service large grain and fine grain powder the screens leading from one pair of rollers to the other are covered with an 8-mesh copper wire, and there are three screens fixed in the frame below the rollers, the top one covered with an 8-mesh, the next with a 16-mesh, and the third with a 56-mesh silk, called Cyprus. That grain which is broken fine enough to pass the 8-mesh, but is retained on the 16-mesh, is the common service L.G. powder; that which passes the 16-mesh, and is retained on the 56-mesh silk, is the common F.G. powder; and that which passes through the silk is dust; this is weighed into 50-lb. charges, and sent again to the incorporating mill to be worked for one hour under the runners. That which is not fine enough to pass the 8-mesh is put into the hopper and passed through the machine again.

* 65. All grain from the granulating machine is called foul grain.

7.—DUSTING.

66. Dusting foul L. G. common service powder is performed by a horizontal cylindrical 24-mesh canvas reel, which makes about 38 revolutions in a minute; this reel is 8 feet 2 inches long, and 2 feet 2 inches in diameter. It works in a closed case, which catches the dust and prevents it from flying about the building. 270 lb. of foul L. G. are put into the reel at a time, and worked for 1½ hours. One end of the reel is then lowered, unscrewed, and the powder allowed to run into barrels. It is free from dust, and has a fine black appearance. The dust which remains in the reel case is sent to the incorporating mill, and run for one hour.

67. Dusting foul F. G. common service powder. The fine grain powder has a much greater proportion of dust in it when it leaves the granulating machine than the large grain; and it is necessary, on this account, to use a different kind of reel. These reels are called slope reels, on account of their being set at an angle of about 4°. They are about 7 feet 10 inches long and 1 foot 5 inches in diameter, open at both ends, and make 38 revolutions

in a minute. A continuous stream of powder fed by a hopper passes through while they revolve, and falls out at the lower end into barrels. The first slope reel this powder is passed through is covered with a 56-mesh silk "Cyprus." This takes away all the finer and light dust. It is then passed through another reel covered with 44-mesh cloth, called dusting cloth, when it is ready for glazing. The slope reel is also enclosed in a case to catch the dust, which is sent to the incorporating mill to be re-worked.

68. Dusting foul Enfield rifle powder. This is done by a similar slope reel to the before mentioned, covered with 24-mesh canvas. Passing once through this reel is sufficient for this powder ; it is then ready for glazing.

8.—GLAZING AND DUSTING.

69. The process of dusting imparts sufficient glazing to the L. G. common service powder without any further operation.

70. The common F. G. service powder, after passing through the two slope reels, is put into glazing barrels, which are horizontal, 5 feet in length and 2½ feet in diameter, and revolve 34 times in a minute. About 350 lbs. are put into each glazing barrel, with about 40 lbs. of a larger grain powder called *chucks*, and run for 3½ hours, when a fine black glaze is imparted, merely by the friction of the grains of powder against each other. It is then unloaded into barrels, passed again through another slope reel covered with 44-mesh dusting cloth, and afterwards sifted with a 12-mesh sieve, which retains the chucks and allows the F. G. to pass into barrels. It is then ready for drying.

71. Enfield rifle powder is glazed in the same barrels as the F. G. common service powder ; but is run for 5½ hours, and then passed through a slope reel covered with 28-mesh canvas, and afterwards sifted with a 10-mesh sieve, which retains the chucks. It is then ready for the drying process.

9.—STOVING OR DRYING.

72. All kinds of powder are dried in the same manner. A drying room, heated by steam pipes, is fitted with open framework shelves one above another, to 7 or 8 tiers in height, the steam pipes being underneath. Cop-

per trays, or wooden trays with canvas bottoms, about 3 feet long, 1 foot 6 inches wide, and 2½ feet deep, holding about 12 lbs. of powder, are placed on these shelves. About 4,000 lbs. are dried at one time, in about 20 hours. The powder in the copper trays is subjected to a heat of 120°, that in the wooden to 130° Fahr. The temperature is raised and lowered gradually. The ceiling and roof are fitted with ventilators, through which all the moisture escapes, so that there is a constant current of hot air circulating through the room. There are also ventilators at the bottoms of the doors. It is of the greatest importance that the vapour should be carried off, for if this is not effectually done, on the decrease of the temperature it would return to its liquid state, and form again on the powder.

10.—Finishing or final Dusting.

73. The drying process produces in all kinds of powder a small portion of dust, which it is necessary to remove.

74. The L. G. common service is again put into a horizontal reel covered with 24-mesh canvas, which makes about 37 revolutions in a minute. 270 lbs. are placed in each reel, and run for about 1½ hours, it is then taken out and put into barrels, and removed to an expense magazine until the next day, when it is again put into the reel, and run for about two hours ; it then presents a beautiful glossy appearance, and is ready for use. It is found that reeling the L. G. the second time increases the colour very much, and entirely frees it from dust. The dust which remains in the reel case is sent back to the incorporating mill to be re-worked.

75. F. G. common service powder is also put into a horizontal reel, covered with 44-mesh dusting cloth, which makes about 45 revolutions in a minute. About 200 lbs. are put into each reel, and run for about 2 or 2½ hours ; the powder is then taken out and sifted in a 36-mesh sieve, and that only which remains on the sieve (or between 16 and 36-mesh) is used as fine grain. This powder now presents a beautiful glossy appearance, and is perfectly free from dust. That powder which passed the 44-mesh, and is retained in the reel case, is again put into another horizontal reel covered with a 72-mesh

dusting cloth, making 45 revolutions in a minute. About 200 lbs. are put into each reel and run for 2 hours ; it is then taken out and sifted in a 36-mesh sieve ; all that passes this sieve is called R. A. medium, and is used for filling Colonel Boxer's diaphragm shells. The dust from the 72-mesh reel is sent to the incorporating mills to be re-worked.

76. Enfield rifle powder is finished by being reeled in a horizontal reel covered with 28-mesh canvas, making 45 revolutions in a minute. About 270 lbs. are put into each reel and run for about 2½ hours ; it is then taken out and barrelled up for use. This powder when finished has a very glossy appearance, but is of a browner colour than the common F. G. That which passed through the 28-mesh is put into another horizontal reel covered with 44-mesh dusting cloth, making 45 revolutions, and run for two hours ; it is then sifted in a 24-mesh sieve, and afterwards in a 32-mesh sieve ; whatever passes the 24-mesh and rests on the 32, is saved for Sir William Armstrong's bursters ; that which passes the 44-mesh is sent back to the incorporating mill to be re-worked.

11.—Proof.

* 77. After the powder is finished, 2 oz. are accurately weighed and fired in an 8-inch gomer mortar with a 68-lb. shot.

The L. G. should average 270 feet.
The F. G. „ 270 „
The E. R. „ 310 „

Half an ounce is also flashed on glass plates, which if not clean the powder would be rejected.

* 78. The eprouvettes are useless as instruments for testing the relative projectile force of different kinds of powder. The only use of these eprouvettes is to check and verify the uniformity of a current manufacture of gunpowder where a certain course of operations is intended to be regularly pursued, and where the strength should be uniform ; but as a means of proving gunpowder received (as in our service) from manufacturers pursuing entirely different processes, they may be pronounced worse than useless, since they may lead to erroneous results. Gunpowder should be tested for strength in the arms for which it is made.

*79. Gunpowder that may have become too much damaged in transport to re-dust is often worked over again in the same way as a dust charge, provided the nitre is found to be pure; should, however, the grains not be very much broken up, by reeling the powder for 1½ hours it will be perfectly freed from dust, and the original appearance and glaze nearly restored.

*80. Powder that may have imbibed an undue amount of moisture from damp magazines or exposure can be re-stoved and dusted, which partially restores it; it would, however, be advisable generally to use this powder for bursting shells or for salutes, as little dependence can be placed on its regularity of effect.

*81. Two drs. of F. G. or musket powder will send a steel bullet through 15 or 16 half-inch elm planks three-quarters of an inch apart, the first plank being 40 inches from the musket; when re-stoved only through from 9 to 12 planks.

*82. Powder much damaged is sent to Waltham Abbey to have the saltpetre extracted to be used again in the manufacture of gunpowder.

CHEMICAL TEST OF POWDER.

1. *For saltpetre.*—About 50 grains are dissolved in distilled water, and filtered through paper, which retains all the sulphur and charcoal (both being insoluble in water), the nitre passes through in solution ; the solution is then evaporated to dryness, and the saltpetre weighed; the petre should be 75 per cent. of the 50 grains.

2. *For sulphur or charcoal.*—It is only in special cases that the powder is tested for the proportion of sulphur and charcoal ; it is done by fusion.

3. *For sulphur.*—Gunpowder mixed with common salt is fused in a crucible ; it is then dissolved in water, and the sulphur, which is now in the form of sulphuric acid, is estimated as sulphate of baryta, chloride of barium having been added to the solution and the precipitate collected.

4. *For charcoal.*—After the process for saltpetre, the residue on the blotting paper is dried and weighed ; the weight of the sulphur found in the second process, together with the weight of the paper, is deducted, and the remainder is the weight of the charcoal.

EXPLOSIVE FORCE.

* 1. Gunpowder possesses several advantages over other explosive compounds, which render it better adapted for fire-arms of every description.

1st, the ingredients, saltpetre, charcoal, and sulphur are easily procured.
2nd, they are comparatively cheap.
3rd, gunpowder, under ordinary circumstances, and with ordinary precautions, is safe in manufacture, store, and in transport; it is also durable.
4th, its combustion is gradual and not instantaneous, as is the combustion of gun cotton and of the fulminates of gold, silver, mercury.

* 2. The action of the fulminates is so instantaneous, that if used in fire-arms the barrels would burst, and the shot be destroyed without any motion of translation being communicated to it; they give no time for their effect to be distributed over the particles at any great distance before those in the immediate vicinity of the explosion are forced out of the sphere of action of the cohesive force, and consequently rupture must take place. Even if fulminating powders are placed on a plate of metal and exploded, the plate may be perforated.

* 3. Owing to the gradual nature of the combustion of gunpowder, the force exerted by the gases overcomes the inertia of the projectile when but a small portion of the charge is burnt; consequently, by the time the whole charge is consumed, the projectile has moved some distance down the barrel, and the gases occupy a much larger space than they do when produced from a fulminate. Gunpowder thus becomes a safe compound for both small and large guns.

* 4. The great and ultimate object to be attained in the manufacture is not so much to produce a powder which gives the greatest propellant force, although that is a desideratum, as one that shall be durable, not easily deteriorated by atmospheric influence, or by

transport, and one with which equal charges shall produce equal effects.

* 5. One of the great arguments in favour of a Government factory is the production of an equal powder ; it being next to an impossibility to obtain this result when the great bulk is supplied by contractors working by different processes.

* 6. Gunpowder should present uniformity in the appearance of its grains, which should be angular, crisp, and sharp to the touch, not easily reduced to dust by pressure between the fingers, or be dusty in handling. Its specific gravity should not be less than 55 lbs. to the cubic foot (that of Waltham Abbey is generally 58 lbs.), taking water at 1000 ounces. It should communicate a sufficient velocity to projectiles, and be free from fouling ; for although fouling was of small import with the old musket, in rifled arms it is necessary that it should be reduced to the smallest possible quantity.

* 7. All these requirements are of paramount importance, particularly that which relates to the equal effect of equal charges, for on this condition is based all calculations connected with gunnery, and on it the accuracy of fire is entirely dependent.

* 8. It is worthy of remark, that during the six centuries throughout which powder has been known in Europe, the ingredients have remained the same, although the quality and proportions used in different countries have varied.

* 9. The improvement effected in the construction of fire-arms rendered indispensable a careful revision of the descriptions of gunpowder previously used. This has already led to the modification of several important points in the manufacture, whereby a greater uniformity in the action of the powder is insured, and its explosion regulated with special regard to the double work which it now has to perform in the greater number of rifled arms, namely, that of propelling the projectile, and of expanding it into the grooves.

* 10. The force of the gunpowder depends upon the rapidity with which it is converted into gas, and the small amount of residue. Both of these circumstances, however, depend upon a variety of considerations, among

which are the following :—1st, the purity of the ingredients ; 2nd, their proportions ; 3rd, the power to resist moisture ; 4th, the thorough intermixture of the ingredients ; 5th, the pressure under which the grain is formed and the glazing; 6th, the form and size of grain. Ignition and combustion depend on these six considerations.

* 11. 1st. *On the purity of the ingredients.*—Previous to the manufacture of gunpowder, it is absolutely necessary to purify the ingredients, to remove all foreign substances, absorbents of moisture, &c., which not only interfere with the keeping properties of the gunpowder, but also lessen its explosive force. Theoretically gunpowder when burnt should leave no residue, and the proportions of the ingredients should be so calculated as to effect this. Practically this condition cannot be completely fulfilled ; care is, however, taken to approach as closely as possible to it, by, in the first place, purifying the saltpetre, charcoal and sulphur, the tests of which are as follows.

* 12. (1.) *Saltpetre.*—About 50 grs. of saltpetre are put into a test tube, or clean oil flask, with half an ounce of distilled water ; on the application of heat the saltpetre is dissolved, a drop or two of a solution of nitrate of silver is then added, and the solution agitated. If any whitish or milky appearance is produced, the presence of muriatic acid or common salt is indicated, the density of the discolouration showing the degree of impurity. So very delicate is this test, that the presence of the most minute proportion of either of these substances will be shown.

*13. (2.) *Charcoal* charred to excess becomes very hard, and reduces greatly the strength of the gunpowder. In France it was found that when charred only a reddish brown the powder acted more as a fulminate, and seriously damaged the guns, so that it is evident that a great deal of experience is necessary in the manufacture of charcoal, which should be light and sonorous when gently dropped. On being broken it should be of even texture, either a dead black or a shining jet black, according to the nature of the wood. It should be so soft as not to scratch polished copper. To ascertain if charcoal contains alkali, pulverize a small portion, add some distilled water, boil and filter the solution, and apply litmus paper that has been reddened by any weak acid, when, if it contains alkali, the original colour will be wholly or partially restored. If charcoal is heated to a certain temperature, combustion takes place, and if perfectly pure no ash will remain. Charcoal is very porous, and greedily absorbs moisture ; no large store, therefore, is ever kept ; it is prepared as required for use. Ground charcoal absorbs moisture more readily than unground. Fresh pulverized charcoal often inflames spontaneously when left exposed to the air.

* 14. (3.) *Sulphur* is tested for purity by heating a small portion on porcelain or platinum foil. If pure it will evaporate without residue. If boiled in distilled water litmus paper should not be discoloured.

* 15. 2nd. *The proportion of the ingredients.*—Nitre is the substance which, possessing such a large per-centage of oxygen in a solid form, gives charcoal the ability to burn, whether in contact with the air or not. Charcoal by itself will not burn in vacuo.

* 16. Gunpowder made from saltpetre and charcoal only, in certain proportions, would have a certain explosive force, but not all that could be desired ; it is porous, friable, and possesses neither firmness nor solidity ; it cannot bear carriage, and it absorbs moisture readily.

* 17. The addition of sulphur quickens the combustion, raises the temperature of the gases, and increases their expansion. An excess of sulphur would, however, lessen the explosive force. Sulphur, from its non-absorbent qualities, makes gunpowder durable, compact, and capable of bearing transport. It closes the absorbent pores of the charcoal, and solidifies the gunpowder. Good gunpowder cannot be manufactured without sulphur, which is required as a conservative ingredient ; charcoal being a powerful absorbent of moisture, it is desirable to reduce its quantity as much as possible.

* 18. The durability of the gunpowder will depend upon the proportions of the three ingredients.

* 19. The French found that gunpowder composed of 76 parts saltpetre, 15 of charcoal, and 9 of sulphur, was the strongest as to its explosive power, and adopted it, but soon after found it was not sufficiently durable, and then altered it to 75 saltpetre, 12·5 charcoal, and 12·5 sulphur.

* 20. We however find, that for general service in

all climates, 75 parts of saltpetre, 15 of charcoal, and 10 of sulphur, form the best gunpowder.

21. The theoretical proportions are those in which the carbon will just consume the oxygen of the nitre, and the sulphur as much as will saturate the potash. Thus, in 100 parts, according to some authorities, these should be 75 saltpetre, 13·2 charcoal, 11·8 sulphur. Chemists, however, differ with regard to the exact proportion to carry out this theory.

*22. It has been mentioned by some writers, that on examining the residue of fired gunpowder, the unconsumed charcoal amounted generally to one-third of the quantity used. If this be correct, it would appear to be very desirable to reduce the amount of charcoal, especially as in our service the gunpowder is so much used on the coast and at sea.

23. Any alteration in the proportion or preparation of the ingredients which would reduce fouling without diminishing the explosive force of the gunpowder would be of the greatest importance. The more accurate the arm, the greater the desirability of paying attention to these points. Experiments on the residues of various powders would be highly interesting and instructive, and would probably result in diminishing fouling.

24. The following is the result of trials in France a few years since of charcoal made from various woods. The *number of volumes of gas produced* from 60 parts of saltpetre mixed with 12 of charcoal by weight was found to be as follows :—

	Vols. of Gas.
Black dogwood - - -	84
Willow - - - -	76
Alder - - - -	74
Filbert - - - -	72
Willow charcoal overheated - -	64

Other descriptions of wood, &c. were experimented with, none of which produced 70 vols. of gas.

*25. 3rd. *Power to resist moisture.*—This depends chiefly upon the purity of the ingredients, the proportion of sulphur, the incorporation, the amount of pressure to which subjected, and the glazing.

*26. 4th. *The thorough intermixture of the ingredients.*—The incorporating process is one of the most important in the manufacture of gunpowder, and it is one which requires the greatest attention and care, in order that the several ingredients may be most completely mixed.

* 27. Gunpowder is incorporated in a damp state, in order the more perfectly to further the operation, and to prevent an explosion, or lessen its force should it occur. If too damp, it will stick to and be taken up by the runners. If not thoroughly incorporated, the explosive force will be lessened, and the powder will be very dirty in use. If properly incorporated and afterwards dried and granulated, it will be serviceable for immediate use, the subsequent operations which it undergoes being to make it durable and capable of bearing transport. Should, however, the process of incorporation fail, the powder will be worthless.

* 28. The more the powder is incorporated the more dense it becomes, and up to a certain point the greater is the force of the powder ; but beyond this limit it is found that no increase of force follows the continued working.

* 29. 5th. *The pressure to which the gunpowder is subjected and the glazing.*—This pressure is necessary to prevent the deterioration of the powder from the moisture of the atmosphere, and to enable it to stand the friction in carriage.

* 30. Although the density of the grain is increased, a closer connexion of the ingredients effected, and a greater quantity of gas produced from an equal volume by increasing the pressure, the rapidity of combustion, and the explosive force is diminished. The more porous the powder the quicker the combustion.

* 31. The pressure for the Enfield rifle powder is 41 tons on the square foot. It is a question if this pressure is not too low, and if it does not in consequence become too easily deteriorated by the atmosphere. For the common service powder a higher pressure is used, otherwise it would not bear transport.

* 32. The density of powder should be great, and proportional to the size of the arm ; the larger arm has generally powder of a greater density than the smaller. The density, however, must not be too great if it is to produce the highest velocities.

* 33. Glazing makes the powder more durable, causes less dust to be formed in transport, and increases its preserving quality, being less liable to absorb moisture ; it, however, reduces the explosive force by removing the roughness of the surfaces and rounding the edges, and the powder is considerably longer in igniting and burning. When highly glazed powder is used in large charges, a portion may be blown out unfired.

* 34. It is said that by the operations of pressing and glazing gunpowder loses 25 per cent. of its strength. Gunpowder which has been neither pressed nor glazed will not retain its strength for any length of time, especially at sea, on the coast, or in a damp climate; and, although when new it is superior to that which has been subjected to these operations, it deteriorates rapidly, and soon becomes much inferior ; consequently the advantages of these operations greatly exceed the disadvantages.

* 35. 6th. *The form and size of grain.*— Ignition, the setting fire to a single grain or charge of powder, is influenced by the form of grain as follows :—If heat is applied to a grain of an angular form ignition is quicker than if it is applied to one of a round form, there being greater surface exposed.

* 36. Ignition of gunpowder may take place in various ways (but the heat must be raised to about that at which sulphur would sublime, viz., about 600° Fahr.), by percussion between copper and copper ; copper and iron ; lead and lead ; lead and wood, at a high velocity such as that given by a musket; on an anvil, or between copper and bronze, and bronze and wood ; but in the two last cases it is more difficult to ignite the powder. Mealed powder explodes more rapidly by percussion on an anvil than grained.

37. Even in the manufacture and employment of comparatively so safe an agent as gunpowder, which may be subjected, without ignition, to tolerably powerful friction or percussion, and to the direct application of heat below that which suffices to sublime sulphur, as before stated, the neglect of strict precautions for excluding the possibility of a particle of the powder being subjected to sudden and powerful friction, may and frequently does lead to accidental explosions.

* 38. Combustion, the complete burning of a grain

or charge, depends upon the form and size of grain ; the larger the grain the longer the time to consume it. Those round in form (the grains being of the same volume) are longest in burning, there being a greater distance for the flame to penetrate, and the smallest surface presented to the action of the flame. The elongated, cylindrical, or flat grains, having smaller diameters and larger surfaces, will generate gas more rapidly, and consequently their combustion will be quicker. Their time in burning will be in proportion to their minor diameters ; the smaller the grain the quicker its combustion ; and in small charges, in which the flame has to traverse but a short distance to complete the ignition of every grain, a small grain gives the quickest combustion and explosive force.

* 39. In small charges of large grain, the time taken to consume the grain will delay the combustion, decrease the rapidity of the formation of the gas, and consequently reduce the explosive force. In large charges of small grain, on the other hand, the delay in the transmission of the flame, from the smallness of the interstices, will delay combustion and reduce the explosive force. Large grain in large charges allow the quick passage of the flame through the charge ; and, although each grain is longer burning than small grain would be, the whole charge is much more rapidly consumed.

* 40. The shorter the gun the greater the necessity of rapidity of combustion to prevent a portion of the charge from being blown out unfired.

* 41. The rapidity of combustion of gunpowder may be regulated without altering its composition or the perfection of its manufacture, by simply increasing or diminishing the size of the grain, and by modifying the degree of compression to which the gunpowder is subjected, before or at the time of its conversion into grains. To attempt to retard combustion by altering the proper proportion of the ingredients, or by reducing the time of incorporation, would alter the chemical action and interfere with the explosive force.

* 42. The rounded form of grain is the most favourable for the transmission of the flame, the interstices being larger ; the elongated or flat grains, *if fitting into one another*, obstruct the passage of the flame, and retard combustion.

*43. Powder is a bad conductor of heat; hence, in a compact mass, as a rocket filled with mealed powder, or a cake, if one end only is lighted, combustion will take place very slowly.

*44. If the charge be composed of mealed powder, which ignites very readily, a longer time is found to be necessary for the complete combustion of the whole, in consequence of the minuteness of the interstices, than in the case when the powder is granulated, and the initial velocity of the shot is reduced about one-third. The following experiment was made some years ago:—A piece of pressed cake, weighing 1·06 oz., was put into a mortar, and a ball of a light substance placed upon it; and when fired the ball was not thrown out. An equal quantity broken into seven or eight pieces just threw it out; broken into 12 or 15 pieces the ball ranged 3·3 yards; broken into 50 grains, the ball ranged 10·77 yards; and when the ordinary powder was used, the ball was projected 56·86 yards. This experiment shows the advantage of graining powder.

*45. Hard ramming home will meal the powder, reduce the size of the interstices, and lessen the velocity of combustion.

*46. Dampness increases the time of combustion by separating the ingredients of the charge, and using up a portion of the heat. For these reasons it reduces the explosive force.

*47. Dust is removed after granulation, glazing, and storing, as its existence in a charge retards combustion by filling up the interstices between the grains.

*48. A greater difference will generally be found to exist in charges of powder when *measured* than when *weighed*. By measuring the same volume of powder is obtained, but not the same quantity. Weighing is the most accurate, as the same quantity is obtained, but not the same volume. From the powder not occupying the same volume in weighing a difference will take place in the explosive force, as will be seen by considering the next subject, viz., the formation of gas. Again, in measuring, there not being the same quantity of matter in each charge, an irregularity in the explosive force will also occur. In cartridge making at Woolwich the powder is measured; weighing would occupy too much time.

* 49. *Formation of the Gas.*—Suppose, which is not really the case, the charge of gunpowder to be without weight, and its combustion to be instantaneous, its explosion would generate a quantity of gas in a highly condensed state, which would exert on the internal surface of the gun a pressure equal in all directions.

* 50. In speaking of so many atmospheres, a term frequently made use of in alluding to the pressure of gases, each atmosphere is estimated at the ordinary pressure of $14\frac{3}{4}$ lbs. on the square inch, or say, in round numbers, 15 lbs.

* 51. The general properties of gases may be understood by considering those of the air, with which they are identical. Air under a constant pressure is uniformly expanded by an increase, and uniformly contracted by a decrease of temperature. The pressure to which any quantity of air is subjected remaining constant, its volume is doubled by an increase of temperature of 480° Fahr., and every additional 480° increases its original volume once. Again, its volume remaining constant, its elasticity or expansive pressure is doubled by an increase of temperature of 480°, therefore, the expansion and contraction being uniform, and the pressure remaining constant, the volume occupied by any quantity of air varies as the temperature; and the volume remaining constant, the pressure varies as the temperature.

* 52. The air is under a constant pressure of about 15 lbs. on the square inch; double this pressure and it will occupy one half its former volume; treble it and it will occupy one-third, and so on; and if in a vessel you condense double the quantity of air it naturally contains, you double the pressure, *i.e.*, from 15 lbs. to 30 lbs., or two atmospheres; condense treble the quantity in it and you treble the pressure, *i.e.*, from 15 to 45 lbs. on the square inch, or three atmospheres.

53. Heat is a great promoter of chemical action. In most cases, when substances having a tendency to combine are mixed together, the application of heat increases the rapidity of their combination, and in many cases combination will not ensue until the substances whose union is desired are heated to a considerable temperature.

* 54. The action of gunpowder is dependent upon a

purely chemical process, and Robins proved conclusively that the force generated by the combustion of gunpowder was owing to an elastic gas, which was suddenly disengaged from the powder, when it was brought to a certain temperature; and further, that this disengaged gas had its elastic force greatly augmented by the heat evolved by the chemical action; he found that the weight of the gas generated was three-tenths of the weight of the powder, and that its volume when cold and expanded to the rarity of common air (the barometer being at 30°) was 244 times that of the powder; therefore, if confined in the same space as the powder, the elastic force when cold would be 244 atmospheres. He also considered that the heat evolved by the chemical action was at least equal to that of a red hot iron, and that air heated to this temperature had its elasticity quadrupled, therefore he inferred that the force of the gas was at least four times 244, or in round numbers 1,000 atmospheres, or 15,000 lbs. on the square inch.

*55. Dr. Hutton thought that the volume of the gas when cold would be 250 times that of the powder which yielded it, and that its volume was increased in the combustion not less than eight times; thus estimating its force at 2,000 atmospheres, or 30,000 lbs. on the square inch.

56. Others thought that the heat generated by fired gunpowder was 4,000° Fahr., as pure or red copper which fuses at 4,622°, was not always affected by the gases, while yellow copper, which melts at 3,898°, was constantly so.

57. Lieut.-Col. Boxer and Mr. Hyde give the probable heat at 3,000°; Colonel Anderson supposes it to be 2,196°. Different authors give different quantities of permanent gas obtained from a measure of gunpowder, varying from 244 to 450.

58. By taking Mr. Robins' and Dr. Hutton's data of about 250 volumes, we have seen that their total estimated pressure is—Mr. Robins 1,000 atmospheres, or 15,000 lbs. on the square inch;—Dr. Hutton 2,000 atmospheres, or 30,000 lbs. on the square inch; and assuming the same volume, which is the lowest estimate, and applying to it the amount of heat generated, as mentioned in paragraphs 56 and 57, and deducting the temperature

of the atmosphere 60°, we obtain the following increase of volume and the pressure :—

—	Supposed heat of fired Gunpowder.	Increase of Volume in combustion.	Original volume of Gas increased in combustion.	Atmospheres.	Pressure on square inch.
		Vol. Vol.			lbs.
Col. Anderson -	2,196°	480° : 1 : : 2,196°–60° : 4·45	250 × 4·45	1,112·5	16,687·5
Col. Boxer and Mr. Hyde -	3,000°	480° : 1 : : 3,000°–60° : 6·12	250 × 6·12	1,530	22,950
Some authors -	4,000°	480° : 1 : : 4,000°–60° : 8·2	250 × 8·2	2,050	30,750

* 59. In order to arrive at any satisfactory result, it is necessary to investigate, as far as possible, the condition under which powder is fired. Suppose a charge of powder to be ignited behind a ball, it is gradually but quickly converted into a large quantity of gas in a state of extreme condensation. During the first moment of ignition the pressure rapidly increases from nothing to its greatest amount, and again diminishes as its volume is increased by the motion of the ball along the bore. From the commencement of ignition a portion of the force of the gas is expended in moving the unburnt portion of the charge and the bullet, so that by the time the combustion of the charge is complete, the gas occupies a space far greater than that originally occupied by the powder. If the barrel is cold a portion of the heat will be absorbed by it, and the volume of the gas be proportionately reduced ; the hotter the barrel the less the absorption of heat, and the greater the volume of gas and the explosive force. The more regular the heat of the barrel the more regular the effect.

* 60. If gunpowder be heated and fired when hot, its effects are greatly increased. One ounce *troy* of powder, fired in a 4½ inch mortar with a shell weighing 8 lbs., gave a medium range of 144 yards, and when heated to about 400° Fahr. 242 yards.

61. No definite idea can be given of the absolute force of gunpowder. The expansion of the gas of gunpowder, like everything else, has its limit, and the idea formerly entertained that a thimbleful of gunpowder completely confined at the centre of the earth, would, if ignited, produce a general earthquake, is now exploded. During some experiments with concussion fuses an 8-inch shell was charged with half-a-pound of fine rifle powder and a bronze fuse plug screwed in. It did not explode, and the plug could not be removed except with a "cold chisel"; on an opening being made, the chisel was blown from the workman's hand, and he was knocked back with a feeling as if his hand and arm were burnt, and the escaping gas made a noise like the escape pipe of a small steam engine. This powder, therefore, in a gaseous form, had been confined for several hours in the shell.

*62. The absolute velocity of the expansion of the gas, from the causes already mentioned, and from a large portion not being converted into permanent gas, also from the gas not being of uniform density, cannot be ascertained with any accuracy; but it must be very much greater than the velocity of combustion. Robins estimated the velocity of expansion at the muzzle at 7,000 feet per second. Piobert, the velocity of the transmission of the flame at 38 feet per second.

HISTORY OF ARMS.

1. The word *arms*, in a general sense, includes every description of warlike weapon whether for offence or defence ; the following history will, however, refer principally to an account of the former, and show, as far as can be ascertained, the time and place of their invention, and when introduced into England.

2. It is supposed that the first artificial arms of offence were of wood, and that the *club* was the first weapon of the kind.

3. Arms of stone, of bone, and of brass appear to have been used before recourse was had to those of iron or steel.

4. Josephus assures us that the patriarch Joseph taught the use of iron arms in Egypt among the troops of Pharaoh.

5. Speaking generally, the leading nations of Europe have adopted improved weapons, whether invented in their own country or not. This policy contributed in a great measure to render the Romans masters of the world ; for, having successively warred against all nations, they constantly renounced their own methods of warfare, arms, &c. whenever they met with better.

6. In England we have adopted continually the inventions of other nations ; whatever arm we refer to, we cannot trace its origin to the conceptions of our own countrymen, although, after its adoption, we have generally improved and perfected it.

7. Arms of the *spear* kind reach into the past far beyond our powers of tracing.

8. *Swords* have also been known from time immemorial.

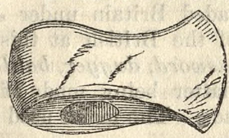
9. *Bows and arrows* are likewise of ancient date, for we read of them in Scripture as early as 1892 B.C. in Genesis xxi., in which it is said that "Ishmael grew, "dwelt in the wilderness, and became an archer."

10. Until the Second Punic War the Romans had no archers in their armies, except among their auxiliaries ; afterwards they had them as mercenaries only.

11. The arms of the inhabitants of Britain previous to

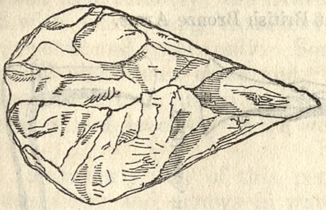
1100 B.C. were *bows*, with *arrows* of reed headed with flint or pointed bone ;—*spears* and *javelins* made of long bones ground to a point and inserted in oaken shafts ;—*battle-axes* of flint ;—and *clubs* of four points or edges called " cats " made of oak.

Ancient British Stone Arms (reduced size).



Battle axe head of marl containing silex.

Stone blade of spear let into wooden shaft.



A kind of Tomahawk, blow given by point, of brown or black silex.

Battle axe head. Silician stone, broad end sharpened to an edge.

Flint arrow head inserted in reed.

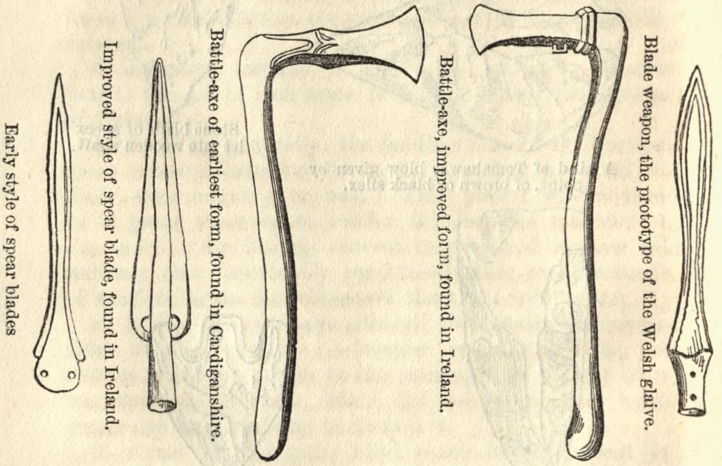
12. Upwards of 11 centuries before the Christian 1100 B.C.
Era Phœnician merchants were attracted to the south-
western coasts of Britain, and especially towards the
Scilly islands, by the abundant supply of tin, which was
extensively used abroad in the manufacture of bronze,
both for weapons of war and for implements of peace.

13. From the Phœnicians the Britons learnt the art of manufacturing warlike implements of metal.

14. In the Tower Armoury may be seen several ancient stone weapons, which have been found in Norfolk, in Ireland, and in various parts of the world ; also bronze weapons, ancient British swords, ancient Irish swords, daggers, bronze spear heads, and celts, found in England, Ireland, and abroad.

55 B.C. 15. The Romans first invaded Britain under Julius Cæsar 55 B.C. The arms of the British at this time were the *spear* or *lance*, the *sword*, *dagger*, ***battle-axe***, and ***bows*** and *arrows*, the latter being made of reed, with flint, bone, or metal heads. The metal used in the construction of arms was bronze.

Ancient British Bronze Arms.



Early style of spear blades

Improved style of spear blade, found in Ireland.

Battle-axe of earliest form, found in Cardiganshire.

Battle-axe, improved form, found in Ireland.

Blade weapon, the prototype of the Welsh glaive.

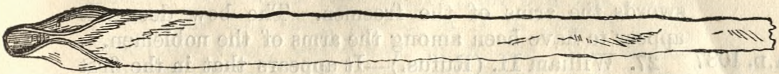
A.D. 78 to 400. 16. On the Romans obtaining a footing in England, the British exchanged their bronze weapons for steel.

17. The Roman cavalry and infantry were armed with swords, shields, and javelins pointed at both ends.

Ancient Roman Arms.

Broken blade of a Roman iron lance, found in Suffolk.

Roman spear head of iron, found in Lincolnshire.



Broken blade of Roman javelin, found in Roman entrenchment in Gloucestershire.

18. During the Anglo-Saxon period, the Saxons, who were all soldiers, used the sword, the spear, and the axe, which were all formed of iron. A.D. 450 to 1066.

19. The Saxon military force consisted principally of heavy and light infantry; the former carried large shields armed with spikes, long broad swords, and spears; the latter, swords and spears only. Some of the spears were "barbed," and others broad and "leaf shaped." They had, moreover, men armed with clubs, and others with battle-axes and javelins. Axes were hurled about this time.

20. In the early part of this period the Saxons may have used bows and arrows in war; if so, in the latter part they had discontinued their use except in the chase, for Henry of Huntingdon makes William the Conqueror speak of the Saxons as a nation not even having arrows; they were however celebrated for their expertness with the *mace* and *battle-axe.*

21. There was a severe penance prescribed in the ancient canons for going unarmed, and the sword consequently was almost generally worn.

22. Harold II. having observed that the heavy armour of the Saxons prevented them from pursuing the Welsh into their recesses, commanded them to use lighter weapons, and armour made of leather only.

23. At the battle of Hastings the Saxons used the battle-axe, javelin, sling, spear, and lance.

24. Under the Normans the archers were a most important body; they did the Conqueror invaluable service at the battle of Hastings, which was decided by them. A.D. 1066 to 1087.

25. The bow from this time, and for many centuries after, was the chief arm of the English. Archers were both mounted and on foot.

26. The weapons carried by the infantry from the time of the Conquest were bows and arrows, half pikes, spears, halberds, maces, various kinds of battle-axes,

swords, daggers, and piles, *i.e.* pieces of wood smaller at one end than the other; these arms continued in use, with little variation, to the close of the 12th century. Piles and maces were the arms of the serfs; lances and swords the arms of the freemen. The bow does not appear to have been among the arms of the noblemen.

A.D. 1087 to 1100. 27. William II. (Rufus.)—It appears that in the first Crusade in 1097 the Turks used the bow, and by the rapidity of their fire caused great havoc among the crusaders.

28. The Welsh in this reign used arrows and javelins as missile weapons; the Irish used javelins only.

A.D. 1100 to 1135. 29. In the reign of Henry I., archery was much cultivated, and great numbers of bowmen were brought into the field; and to encourage practice with the bow, a law, the first of its kind, was passed freeing from the charge of murder anyone, who, in practising with arrows or darts, should kill a person standing near.

30. The cross-bow appears to have been used in the chase in this reign.

A.D. 1135 to 1154. 31. Stephen.—No improvement in arms appears to have been made in this reign.

A.D. 1154 to 1189. 32. Henry II.—The Irish at this period were still without the bow, and the English conquests in Ireland were due to its use.

33. The Welsh were celebrated for expertness in the use of their bow, which was made very stout and of wild unpolished elm; their arrows inflicted severe wounds at close quarters.

A.D. 1189 to 1199. 34. To the sword, the spear, the battle-axe, and the bow, we have to add the *arbalest* or cross-bow, which was adopted as a weapon of war in England during the reign of Richard I.

35. The cross-bow was not a new invention, for by some it is said to have been of Sicilian origin, by others of Cretan, and that it had been previously introduced into England by the Saxons at the time of Hengist and Horsa, about A.D. 457. The cross-bow, however, does not appear on any of the early Roman monuments.

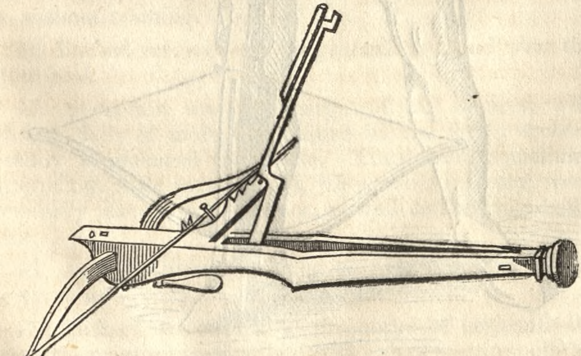
36. The use of the cross-bow was forbidden by the second Lateran Council, A.D. 1139, as fatal and cruel, and again by Pope Innocent III., about A.D. 1200.

37. The bow of the cross-bow was fixed crosswise on the top of a sort of staff or stock of wood, and was

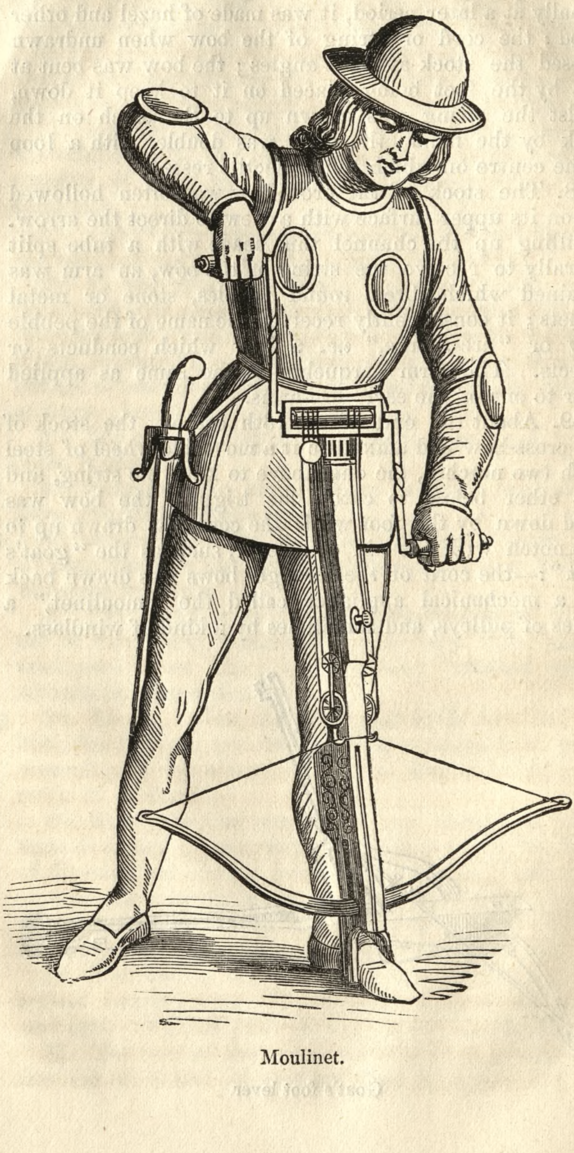
commonly made of steel, although at first, and occasionally at a later period, it was made of hazel and other wood ; the cord or string of the bow when undrawn crossed the stock at right angles ; the bow was bent at first by the foot being placed on it to keep it down, whilst the string was drawn up to the catch on the stock by the hand ; the cord was double, with a loop in the centre on which the projectile rested.

38. The stock of the cross-bow was often hollowed out on its upper surface with a view to direct the arrow. In filling up the channel thus made with a tube split laterally to receive the string of the bow, an arm was obtained which threw round pebbles, stone or metal bullets ; it consequently received the name of the pebble bow or "arc-a-buse," *i.e.* a bow which conducts or directs. The term harquebus is the same as applied later to one of the early fire-arms.

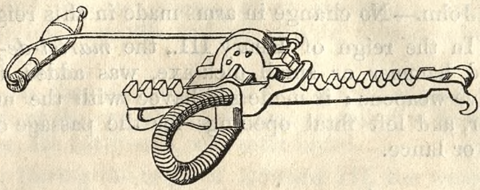
39. About the end of the 13th century the stock of the cross-bow had affixed to it a moveable wheel of steel with two notches, the one above to hold the string, and the other below to catch the trigger ; the bow was held down by the foot while the cord was drawn up to the notch with the aid of a lever, such as the "goat's foot" :—the cord of the stronger bows was drawn back by a mechanical appliance called the "moulinet," a series of pulleys, and sometimes by a kind of windlass.



Goat's foot lever.



Moulinet.



Windlass.

40. Many of the cross-bows were provided with sights.

41. The cross-bow continued in use until small arms superseded it, and the cross-bowmen were some mounted and some on foot, and their place in battle was in the van.

42. The long bow for infantry was of the most simple construction, and a far superior weapon to the cross-bow, inasmuch as half a dozen arrows could be discharged from it in the time taken to wind up the cross-bow and fix its projectile.

43. The long-bow was lighter than the cross-bow, and being held vertically, the soldier required but little space to work in. It however required the most careful training to use the long-bow dexterously, whereas the cross-bow could be charged and discharged by a boy, or without training.

44. Barbed arrows were in general use, and were the most fatal.

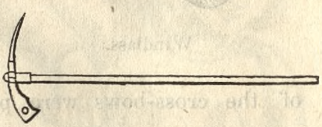
45. A captain was in charge of 20 archers, who became daily of more importance in the field ; archers usually commenced the battle. They were sometimes intermixed with cavalry, and, when with infantry, were generally placed on the flanks, as well as the cross-bowmen.

46. Archers were preferred as infantry, and cross-bowmen as cavalry.

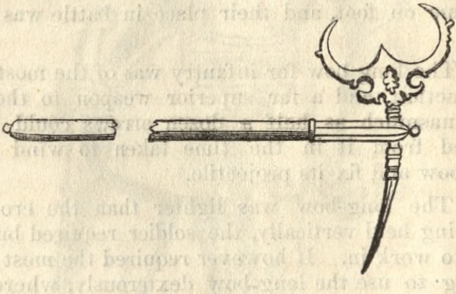
47. Richard I. established the corps of serjeants-at-arms, the original number being 24 ; they were appointed for life, and were armed with the mace, sword, and bows and arrows.

A.D. 1199 to 1216. 48. John.—No change in arms made in this reign.

A.D. 1216 to 1272. 49. In the reign of Henry III., the *martel-de-fer*, a pointed hammer or small pick-axe, was added to the offensive weapons; it made sad havoc with the mail or armour, and left fatal openings for the passage of the sword or lance.



Martel-de-fer, time of Henry VIII.



Martel-de-fer, time of Edward VI.

50. The infantry were of three kinds, viz., the men at arms or dismounted knights; the spearmen; the light armed, having light spears or axes: and besides these there were the slingers; the archers; and the cross-bowmen.

51. The archers at this period carried their arrows for immediate use in a belt or girdle.

A.D. 1272 to 1307. 52. During the reign of Edward I., the *falchion*, a peculiarly shaped broad bladed sword; the *estoc*, a small stabbing sword; the *anelas*, a broad dagger tapering to a small point; and the *cuttelas* (whence cutlass), a military knife, were added to the offensive weapons.

53. Edward I. commanded every man to be armed according to his property; some to have sword, knife,

bow and arrows; some, other weapons; and those having less than 40*s*. in land, if able, to have a bow and arrows.

54. In the reign of Edward II. a kind of pole-axe, *i.e.* an axe at the end of a pole, and so called to distinguish it from the battle-axe, was introduced.

A.D. 1307 to 1327.

55. During the reign of Edward III. the weapons of the knights were chiefly lances, swords, maces, and battle-axes.

A.D. 1327 to 1377.

56. Although Edward III. found it necessary to enjoin practice with the long-bow by two mandates, in consequence of its superiority over the cross-bow in length of range and rapidity of fire, he, having observed the great exactness of the shot discharged from the cross-bow, and the convenience with which it was used on horseback, wrote to the sheriffs of London to encourage its use; it does not, however, appear that cross-bowmen were raised in England in this reign; those in the English service were mercenaries.

57. The Genoese were the most celebrated cross-bowmen in Europe, and were employed by the English and the French at various periods.

58. The English archers did great execution at, and may be said to have gained the battle of Cressy in 1346, at which the French had 15,000 Genoese cross-bowmen, the greatest number of these troops ever known to have been in the field at one time. The English archers did great havoc also at the battle of Poictiers in 1356.

59. While the long-bow was the chief arm of the English, the cross-bow was that of foreign powers: and our great successes in war at this period may be attributed, in a great measure, to the very rapid fire of the long-bow: the cross-bow, however, was constantly used by the English in the defence of places, and various missiles were propelled by it.

60. In this century archery was at its zenith; a painted bow sold for 1*s*. 6*d*.; a white bow for 1*s*.; arrows, with sharpened points, 1*s*. 2*d*. per sheaf of 24; if blunt headed, 1*s*. per sheaf.

61. Infantry were employed in preference to cavalry, in consequence of the great slaughter of horses, &c. by the archers and cross-bowmen.

62. The knights often performed their chief service in the field when dismounted, and then mounted to pursue the enemy.

63. The cavalry in this and the previous reign were composed of men-at-arms (heavy cavalry), hobilers (light cavalry), and mounted archers. The hobilers were in great repute at this time ; they were armed with a sword, knife, and lance ; the infantry consisted of spearmen, archers, and cross-bowmen.

64. Pavisers, men carrying pavises or shields, were employed about this period ; they were of three kinds, viz., those who fought on horseback ; those who fought on foot ; and those who carried pavises in front of archers or cross-bowmen, to defend and shield them from the enemy.

* 65. Fire-arms were introduced in this reign. Authors differ in their statements as regards the exact year and country in which they were invented ; the actual date, &c. of the first portable fire-arm, the *hand gun*, is involved in obscurity.

66. An inquisition taken at Huntercombe in Yorkshire, in 1375, the record being in the Chapterhouse Westminster, mentions the attack on the manor house of Huntercombe by 40 men armed, among other weapons, with "gonnes," supposed to be the hand gun.

67. We read of the "*Arquebuse à Mèche*" in Germany in 1378, so that the invention probably occurred some years earlier.

68. Gunpowder having been first manufactured in England in 1346, it is not probable that the actual introduction of cannon and hand guns could be of a later date.

69. Cannon are said to have been used in the English expedition against Scotland in 1327, and at the battle of Cressy in 1346. In 1360 there were four copper guns in the tower. Cannon were first used for siege purposes, but were rarely used, even at the end of this century, in the field.

70. Cannon balls were chiefly of stone, but sometimes of iron or lead.

71. Stones thrown by hand were used in the defence of places, in the field, and on board ship in this reign.

72. Richard II. commanded the practice of archery on Sundays and holidays by servants, labourers, etc., and the leaving off by them of games of quoits, ball, etc. A.D. 1377 to 1399.

73. In the excavation of the castle of Tannenberg, dismantled in 1399, there was found a hand gun of brass, with part of the wooden stock remaining, and the iron rammer belonging to it.

74. By an Act of Parliament in the reign of Henry IV. it was enacted that the heads of arrows and quarrels should be boiled, or brazed and hardened at the points with steel, and that every arrow head or quarrel should bear the name of the maker under pain of imprisonment. A quarrel was an arrow with a four-sided or pyramidal head; they were sometimes feathered with wood or brass. A.D. 1399 to 1413.

75. The archers did great execution at the battle of Shrewsbury in 1403, at which cannon were used.

76. Henry V., in order that there might be no want of arrows, ordered the sheriffs of the several counties to procure feathers from the wings of geese by picking six from each goose. A.D. 1413 to 1422.

77. The bows were of great strength, and the arrows a yard in length besides the head; and every archer had a good bow, a sheaf of arrows, and a sword.

78. The victory of Agincourt in 1415, where cannon were used both by the French and English, is in a great measure ascribed to the English archers, who at this time bore on their shoulders a stake six feet in length, sharpened at both ends, to be fixed in the ground before them in a slanting direction, as a defence against cavalry.

79. Cross-bowmen, who had a paviser in attendance, carried their bolts or quarrels in a case at the right hip; at this period, and for some time previously, the English had but little confidence in the cross-bow, so much so, that with the force of 10,000 men which left England in 1415, there were not more than 98 cross-bowmen.

Cross-bowman with paviser.

*80. Hand guns are mentioned as having been first used at the siege of Arras, in 1414.

A.D. 1422 to 1461. *81. Henry VI.—In 1430 hand guns were used at the siege of Lucca; this is mentioned by some authors as the most reliable date of the first use of small arms in the field. In 1446 they came into more general use.

*82. Spanish historians state that Spain was the first power which armed the foot soldier with hand guns.

Hand gun and axe combined.

Hand gun being fired.

* 83. The hand gun was of very rude construction ; it consisted of a simple iron or brass tube with a touch hole at the top, this tube was fixed in a straight stock of wood, about a cubit and a half long, called the frame of the "gonne ;" it had no lock, and, when about to be fired, the end of the stock passed under the right armpit.

84. The hand gun used by the horse soldier was similar to that above described ; it had a ring at the end of the stock, by which it was suspended by a cord round the neck ; a *forked rest*, fitted by a ring to the saddle bow, served to steady the gun, which, when not in use, hung down in front of the right leg.

85. A match and ammunition of very inferior quality formed the appurtenances of the hand gun.

* 86. The match was made of cotton or hemp spun slack, and boiled in a strong solution of saltpetre, or in the lees of wine.

* 87. It was soon found that the priming fell off the touch hole by being on the top of the tube or barrel of the hand gun ; a hole was therefore made at the side, and a small pan placed under it to hold the priming, with a cover moving on a pivot to turn off or on with the hand. The hand gun was thus used in England as early as 1446.

88. The English continued to encourage archery, for

in 1453 the Parliament voted an army of 20,000 bowmen for service in France.

89. The battle of St. Alban's, in 1455, during the wars of the Roses (York and Lancaster), seems to have been won entirely by archers.

90. Cross-bow stocks in this reign were made of hard wood ; they were ornamented with ivory, and were 3 ft. 3 in. in length, and the steel bow was 2 ft. 8 in. from end to end, all weighing 15 lbs.

91. An Act was passed in the reign of Edward IV., ordering every Englishman to have a bow of his own height, and butts to be erected in every township for the inhabitants to shoot at on feast days ; also that bows of yew were to be sold for 3*s.* 4*d.* **A.D. 1461 to 1483.**

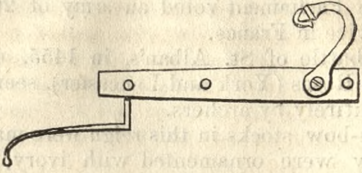
92. Bows became so scarce, and dear, that all vessels bringing merchandise to England were compelled by law to land four bow staves with every ton of goods.

* 93. The landing of Edward IV. at Ravenspur in Yorkshire, in 1471, with 300 Flemings armed with hand "gonnes," has been quoted by authors as the first introduction of hand guns as military arms into England. While this circumstance may be considered as the first instance of a force having been landed in England armed with hand guns, it cannot be received as proving that this description of warlike weapon only made its first appearance in this country in 1471.

94. Edward V.—Nil. **A.D.1483.**

95. In consequence of a seditious conspiracy of the Lombards, by which the bow staves were raised from 2*l.* the 100, the usual price, to the outrageous sum of 8*l.* the 100, it was enacted in the reign of Richard III. that 10 bow staves should be imported with every butt of Malmsey or Tyre wines brought from Venice, under a penalty of 13*s.* 4*d.* for every butt of the said wines in case of neglect. **A.D. 1483 to 1485.**

* 96. An improvement in fire-arms took place in the first year of the reign of Henry VII., or as some say, perhaps at the close of Edward IV., by fixing a cock on the hand gun to hold the *match,* which was brought down to the priming by a trigger, whence the term matchlock, or *arc-a-bouche*, a bow with a mouth, which was afterwards corrupted to harquebus, the same name that was occasionally applied to the cross-bow. **A.D. 1485 to 1509.**



Matchlock.

* 97. It is supposed that the harquebus or matchlock was invented in Italy. The weapon is still in use among the Chinese, Tartars, Sikhs, Persians, and Turks.

98. Henry VII. in establishing his body guard of 50 men (now the yeoman of the guard) in 1485, armed them with swords, and half with bows and arrows, and the other half with the harquebus. This was the first regular standing force in England, with the exception of the corps of serjeant-at-arms established by Richard I.

99. The cross-bow of this reign was of two kinds, the *latch* with its grooved stock for quarrels, and the *prodd* for bullets, which latter was in use by the Genoese at this period. The service cross-bow would kill point blank at from 40 to 60 yards, and when elevated at from 120 to 160 yards.

100. At the battle of Fornone, in 1495, there were German harquebusiers mounted, and on foot.

* 101. The harquebus underwent an improvement during this period; hitherto, like the cross-bow, it had a straight stock, but now it was formed with a wide butt end which might be placed against the right breast. Subsequently the stock was bent or crooked, a German invention, when the arm was called a hackbutt, or hagbut, and the smaller sort demihags.

102. By a statute of Henry VII., in 1508, the use of the cross-bow was forbidden, except among the nobility, the object being to induce the more frequent practice of archery.

A.D. 1509 to 1547. 103. Henry VIII., to enforce the practice of archery, enacted "that every man under the age of 60, not "labouring under some bodily incapacity (ecclesiastics "and judges excepted) should use the exercise of "shooting in the long-bow, that fathers, governors, and

" masters should instruct and bring up their sons and " youths under their charge in the knowledge of shooting, and that every man having a boy or boys in his " house should provide for each of them of the age of " seven years, and until he came to that of 17, a bow " and two shafts to induce him to learn archery ;" also, " that the young archer might acquire an accurate " eye and a strength of arm-bone, none under 24 years of " age might shoot at a standing mark . . . . . . under " the penalty of 4*d.* for each shot made contrary to this " regulation," and that " no person above the said age " should shoot at any mark that was not above eleven " score yards (220) distance under pain of forfeiting for " every shot 6*s.* 8*d.*" The range of the bow is said to have been from 320 to 400 yards.

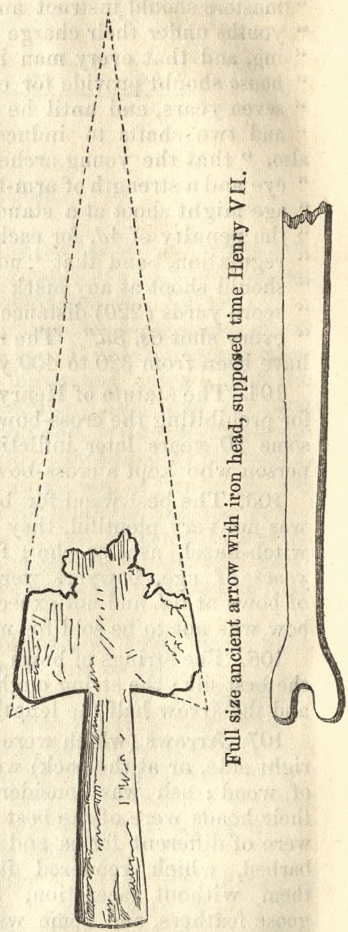
104. The statute of Henry VII. (1508) was renewed for prohibiting the cross-bow, and another was enacted some 20 years later inflicting a fine of 20*l.* on every person who kept a cross-bow in his house.

105. The best wood for bows was yew ; but as this was not very plentiful, they were ordered to be made of witch-hazel, ash, or elm ; for people from seven to 17 years of age, bowyers were bound to keep a supply of bows at 6*d.* and not exceeding 1*s.* each ; a yew wood bow was not to be sold for more than 3*s.* 4*d.*

106. The strings of bows were made of hemp, or of the best silk; the string ought to be the height of a man, and the arrow half the length of the string.

107. Arrows (which were carried in a quiver at the right side, or at the back) were made of different kinds of wood ; ash was considered the best for warfare ; their heads were of the best iron pointed with steel, and were of different forms and denominations ; some were barbed, which rendered it impossible to withdraw them without laceration, they were feathered with goose feathers, and some were tipped with combustible matter for setting fire to houses, ships, &c.

108. The latch cross-bow in this century had a windlass let into the stock to draw up the string to save the trouble of putting it on and taking it off, as was the case with the "moulinet ;" as this measure, however, weakened the handle or stock, recourse was had to the " goat's foot lever."



Full size ancient arrow with iron head, supposed time Henry VII.

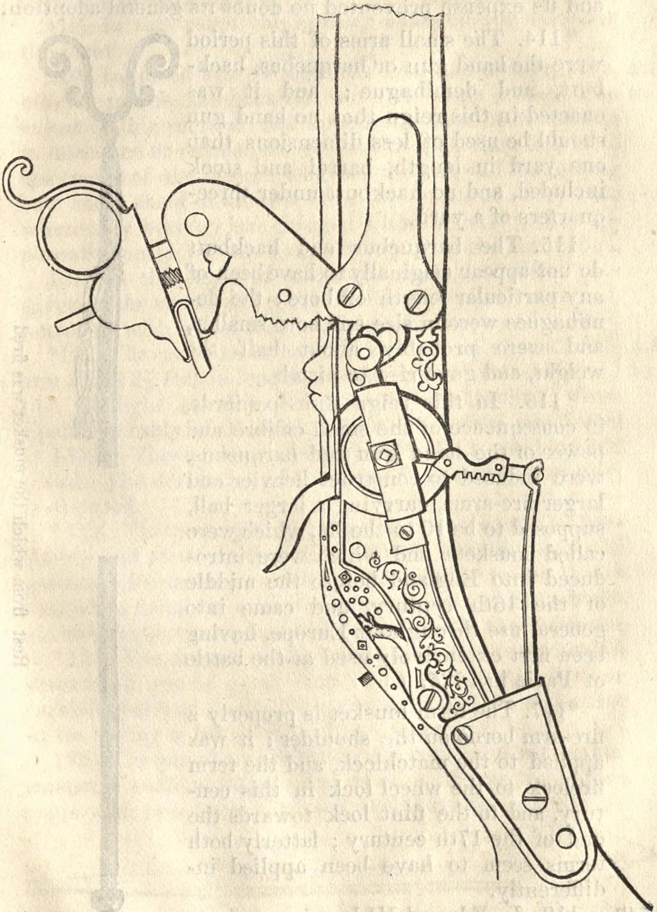
109. In the reign of Henry VIII. the infantry were chiefly archers, cross-bowmen, halberdiers, pikemen, and harquebusiers. Pikemen formed the principal portion of the English army from this reign to that of William III.

* 110. The pistol, invented by Camillo Vitelli, an Italian, and so named from having been made at Pistoia, with its variety the "dag" or "tache," is of this period, and was first used by cavalry in England in 1544.

* 111. The wheel lock, an improvement on the matchlock or harquebus, was invented at Nuremberg in 1517; was first used at the siege of Parma in 1521; was brought to England in 1530, and continued in use in this country, although not generally, until the time of Charles II.

* 112. The wheel lock consisted of a steel wheel rasped at the edge, which protruded into the priming pan; a strong spring; and a cock into which was fixed a piece of pyrites (sulphuret of iron); the wheel fitted on the square end of an axle or spindle, to which the spring was connected by a chain swivel; and the cock was so fitted that it could be moved backwards or forwards at pleasure, a strong spring being connected with it to keep it firm in its position. When it was required

to discharge the gun, the lock was wound up by means of a key or spanner which fitted on the axle or spindle, and the cock was let down to the priming pan, the pyrites resting on the wheel; on the trigger being pressed the wheel was released and put in motion, when sparks were emitted which set fire to the powder in the pan.



German wheel lock.

* 113. The wheel lock frequently missed fire, as the pyrites, which is of a friable nature, broke in the pan,

and forced it back from the pan, evolving at the same time sparks, which fired the priming.

* 132. There were three kinds of locks applied to the harquebus at different times; the exact period of their invention, however, cannot be ascertained.

1st. The cock was fixed on the far side of the priming pan, and was made to move towards the firer.

2nd. The cock was fixed between the priming pan and the firer, and was made to move from the latter.

3rd. The cock was propelled forward by a snap.

133. In this reign each company of infantry usually consisted of men armed in five different ways.

"Men-at-arms"	40	10 halberdiers or battle-axe men. 30 pike men, pikes 14 to 18 ft. long.
"Shot" -	60	20 archers. 20 harquebusiers. 20 musketeers.

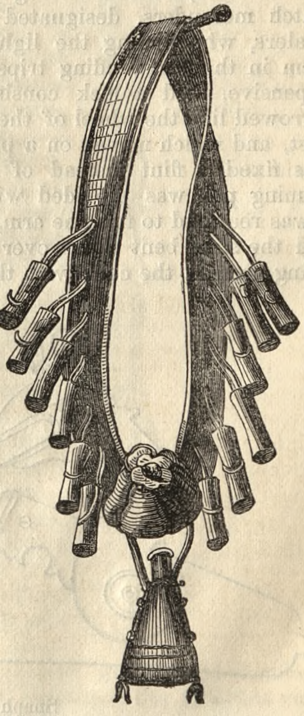
Each man carried, in addition, a sword and a dagger.

134. There existed a law at this time against shooting with hand guns and harquebuses; but those appointed by the authorities to be harquebusiers were to use their weapons without danger from this law.

A.D. 1603 to 1625. 135. In the reign of James I. the increasing use of fire-arms brought armour into disrepute, and before the close of it that of the heaviest cavalry terminated at the knees.

* 136. As bows and arrows fell into disuse, the infantry became reduced to two classes, viz., musketeers (armed with matchlock musket, sword and dagger), and pikemen.

* 137. The musketeer in England in this and the following reign carried



Bandolier, bullet bag, touch box.

his powder in small wooden, tin, or leather cylindrical cases, each containing a charge; twelve of these were fixed to a belt, worn over the left shoulder, and were called bandoliers, to which was also attached a bag for bullets; they also had two flasks, a small one, called a touch-box, containing powder of a fine description for priming, which was carried in front, and a larger one, which contained the reserve of loading powder. The musket was carried on the left shoulder, and the rest in the right hand.

* 138. In 1621 the length of the barrel of the musket was 4 ft., and the size of the bore 12, *i.e.* 12 bullets to the pound.

139. To prevent the match from being seen in the night, small tubes of tin or copper pierced full of holes were invented by a Prince of Orange. Walhuysen describes them, and says, "it is necessary that every " musketeer know how to carry his match dry in moist " and rainy weather, that is in his pocket or in his hat, " by putting the lighted match between his head and " hat, or by some other means to guard it from the " weather; the musketeer should also have a tin tube, " about a foot long, big enough to admit a match, and " pierced full of little holes, that he may not be dis- " disturbed by his match when he stands sentinel." This was the origin of the match boxes carried by grenadiers.

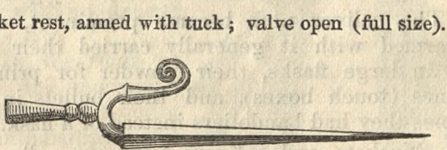
140. The caliver now became prominent, and the troops armed with it generally carried their loading powder in large flasks, their powder for priming in small ones (touch boxes), and their bullets in a bag. Sometimes they had bandoliers instead of a flask.

* 141. Muskets and calivers were generally matchlocks; the wheel-lock was too expensive for the common soldiery, and was confined to cavalry, who carried carbines, pistols, the butts of which were now elongated, and swords.

* 142. The musket rest underwent a change in the latter part of this reign; instead of a wooden shaft it was made of a thin tube of iron covered with leather; it had a tuck, *i.e.* a thin rapier blade enclosed in it, which, on touching a spring to open a small valve, flew out. Rests thus armed were said to contain Swedish or swine's feathers, and were used as a defence against cavalry, like archers' stakes. Sometimes instead of swine's feathers a

spike projected from one of the prongs of the fork of the rest.

Musket rest, armed with tuck; valve open (full size).



Spike on prong of fork.

* 143. In the early part of the 17th century Gustavus Adolphus, King of Sweden (1611–33), caused the gunpowder, which had hitherto been carried in flasks or bandoliers, to be made up into cartridges and carried in pouches.

A.D. 1625 to 1649. 144. During the reign of Charles I. the harquebus, matchlock musket, caliver (until about 1635), dragon, carbine, and pike were in use. Great reliance was placed on the pikemen, whose pikes were now 18 feet in length.

*145. In 1629 we hear of the "tricker lock," which appears to imply the hair trigger. A tricker wheel lock of Charles I., a tricker matchlock of Charles II., and a tricker firelock of James II., with hair triggers, are in the collection at Goodrich Court.

146. In this reign there was an additional case added to the bandoliers, which hung down lower than the rest, to hold the fine powder for priming, supplying the place of the touch-box, and called by the French la pulverain.

147. The following dimensions of arms at this period are given by Hewitt :—

	Length of barrel.	No. of bullets to the pound.	Nature of lock.
Harquebus	2½ ft.	17	Wheel
Musket	4 ft.	10	Match
Carbine	2½ ft.	24	Flint

148. The dragoons in 1632 carried short muskets hung at their backs ; in 1645 they carried dragons of musket bore, barrel 16 in. long, having wheel, or flint locks ; and in 1649 a caliver ; they also carried a flask, a priming flask (touch-box), bullet bag, and sword ; they served on foot as well as on horseback.

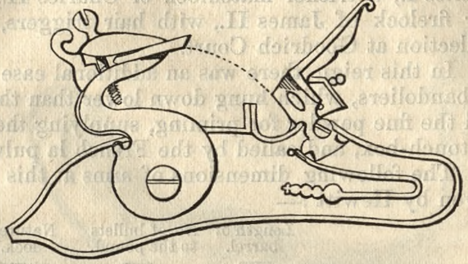
149. In 1632 the cuirassier is said to have carried two wheel-lock pistols, barrel 18 in. long and 20 bore, *i.e.* 20 bullets to the pound, and a sword ; and the harquebusier the same kind of pistol, in addition to his own weapon, and of whom it is also recorded, that he "had "his purse and his mouth for his bullets, and in his "left hand his match and harquebus."

150. In the directions for the arming of the Scots in defence of the King in 1643, the cavalry were ordered to be armed with pistols and swords ; the infantry with muskets and swords, or pikes and swords, and failing these weapons, they were to have halberds and lockaber axes.

151. In 1625 the stocks of guns were made of beech and walnut, and about this period browning barrels was in practice.

*152. The modern firelock, the *flint lock*, was invented about 1635, suggested, no doubt, from the snaphaunce already described, and from which it only differed by the cover of the pan forming part of the steel or hammer, which retained its furrows until the 18th century.

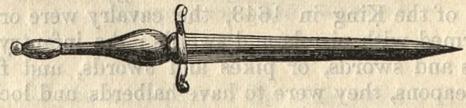
Before the invention of the flint lock, the wheel lock was frequently called the firelock.



Flint lock.

A.D. 1649 to 1660. * 153. During Cromwell's protectorate, or shortly after, the musket rest fell into disuse.

A.D. 1660 to 1685. * 154. In the reign of Charles II. the swine's feathers and rest were laid aside, and the infantry soldier was armed with a dagger which he stuck in the muzzle of his gun or firelock to serve as a pike ; this appears to have been the origin of the bayonet, which is said to have been invented at Bayonne, and called by the French " bayonet à manche." Although said to have been used abroad as early as 1646, it was not introduced into our army until 1672. The bayonet at first consisted of a wooden handle 8 or 9 in. long, to fix in the muzzle of the gun or firelock, with a two-edged blade 1 ft. in length and " a broad inch " in breadth. This invention was considered a great improvement, as it gave the musket a second means of offence.



155. In 1673 the infantry were armed by statute as follows : the musketeer had a matchlock musket, the barrel not less than 3 ft. in length carrying 12 bullets to the pound, a sword, and bandolier ; he was ordered to bring with him at every muster $\frac{1}{2}$ lb. of powder, $\frac{1}{2}$ lb. of bullets, and three yards of match. The musket was occasionally furnished with a flint lock. The tallest men were chosen for pikemen, who carried a pike 16 ft. in length, head and foot included.

*156. In 1678 each company of 100 men consisted of 30 pikemen, 60 musketeers, and 10 men armed with lighter firelocks, supposed to be the fusil, a firelock lighter than the musket invented in France about 1635, and deriving its name from the Italian word "focile" a flint. In 1678 a British regiment was armed with the fusil, and the King added a company of men armed with hand grenades to each of the old British regiments, which was designated the grenadier company. The grenadier had a pouch of grenades, match firelock with bayonet to fit into the barrel, cartridges and primer.

157. Previous to 1670 the use of the bandolier began to decline ; it was found impossible in wet weather, without a cloak, to keep the cases attached to the bandoliers dry, hence the powder very often became spoiled ; besides which, the noise occasioned by these cases knocking against each other betrayed those who carried them in all surprises, onslaughts, and sudden enterprises.

*158. Cartridges and cartridge boxes, *i.e.* pouches, appear to have taken the place of bandoliers in this reign, and were brought into general use about the same time as the introduction of the flint lock. They are said to have been invented by Gustavus Adolphus, King of Sweden, and to have added very much to the efficiency of the soldier, who was enabled thereby to fire three times the number of shots he could discharge when loading from bandoliers. Their use at first was chiefly confined to dragoons and grenadiers.

*159. The flint lock does not appear to have been employed in England until 1677, although used in the French army about seven years earlier.

*160. The Earl of Orrery, in 1677, describes the superiority of the flint lock over the matchlock in the following words:—"First, it is exceedingly more ready; " for with the firelock you have only to cock, and you " are prepared to shoot ; but with your matchlock you " have several motions, the least of which is as long a " performing, as but that one of the other, and oftentimes " much more hazardous ; besides, if you fire not the " matchlock musket as soon as you have blown your " match (which often, especially in hedge fights and " sieges, you cannot do), you must a second time blow " your match, or the ashes it gathers hinders it from " firing. Secondly, the match is very dangerous, either

" where bandeleers are used, or where soldiers run hastily " in fight to the budge-barrel, to refill their bandeleers ; " I have often seen sad instances thereof. Thirdly, march- " ing in the nights, to avoid an enemy, or to surprize one, " or to assault a fortress, the matches often discover you, " and inform the enemy where you are, whereby you " suffer much, and he obtains much. Fourthly, in wet " weather, the pan of the musket being made wide open, " for a while the rain often deads the powder, and the " match too ; and in windy weather, blows away the " powder, ere the match can touch the pan; nay, often in " very high winds, I have often seen the sparks blown " from the match, fire the musket ere the soldier meant " it ; and either thereby lose his shot, or wound or kill " some one before him. Whereas in the firelock, the " motion is so sudden, that what makes the cock fall on " the hammer, strikes the fire, and opens the pan at once. " Lastly, to omit many other reasons, the quantity of " match used in an army, does much add to the baggage, " and being of a very dry quality, naturally draws the " moisture of the air, which makes it relax, and conse- " quently less fit, though carried in close waggons : but " if you march without waggons, the match is the more " exposed ; and without being dried again in ovens, is " but of half the use which otherwise it would be of : " and which is full as bad, the skeans you give the " corporals, and the links you give the private soldiers " (of which near an enemy, or on the ordinary guard duty, " they must never be unfurnished), if they lodge in huts " or tents ; or if they keep guard in the open field (as " most often it happens) all the match for instant ser- " vice is too often rendered uncertain or useless ; " nothing of all which can be said of the flint, but " much of it to the contrary. And then the soldiers " generally wearing their links of match near the " bottom of the belt, on which their bandeleers are " fastened, in wet weather generally spoil the match " they have, and if they are to fight on a sudden, and " in the rain, you lose the use of your small shot, which " is sometimes of irreparable prejudice."

161. The dragoon in 1682 carried a flint lock fusil, bayonet to fit into the barrel, sword, cartridges, and primer.

162. Archery was still continued for amusement, but

in England, at this period, archers seem to have disappeared from the national force.

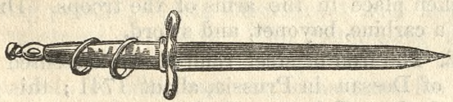
163. In James II.'s reign two regiments of dragoon guards were raised, which were armed with firelocks and bayonets, in addition to swords and pistols, and were trained to act either on foot or on horseback. A.D. 1685 to 1688.

164. The pike, in the last half of this century, was falling into disuse, and by the end of it appears to have been discontinued, the musket having become by the addition of the bayonet a weapon of the pike kind.

165. In 1686 the grenadiers appear to have changed their matchlocks for firelocks or snaphaunce muskets.

166. In William and Mary's reign most of the troops were armed with muskets or firelocks in the place of matchlocks ; the bayonet was still a kind of dagger, but the ring added to the guard or handle, at first for defence, was brought into great use at this time on the continent. A.D. 1688 to 1702.

*167. In one of the campaigns in Flanders the British 25th regiment, whose bayonets were made to screw into the muzzle of their firelocks, was attacked by a French regiment which, having their bayonets fitted by a ring over the muzzle, fired a volley and immediately charged them, greatly to their astonishment.



Original bayonet with two rings.

*168. Macaulay states that at the battle of Killiecrankie, fought in 1689, between the forces of William III. under General Mackay, and the adherents of James II. under Graham of Claverhouse, Viscount Dundee, "When "only a space was left between the armies, the Highlanders suddenly flung away their firelocks, drew "their broadswords, and rushed forward with a fearful "yell. The Lowlanders prepared to receive the shock : "but this was then a long and awkward process ; and "the soldiers were still fumbling with the muzzles of "their guns and the handles of their bayonets when "the whole flood of Macleans, Macdonalds, and Camerons came down. In two minutes the battle was lost "and won." The English were completely defeated, the immediate cause of which was mainly to be attributed to the difficulty of fixing bayonets, or of converting the firelock into a pike for close combat.

* 169. Macaulay again states, "the firelock of the
" Highlander was quite distinct from the weapon which
" he used in close fight. He discharged his shot, threw
" away his gun, and fell on with his sword. This was
" the work of a moment. It took the regular mus-
" keteer two or three minutes to alter his missile weapon
" into a weapon with which he could encounter an
" enemy hand to hand ; and during these two or three
" minutes the event of the battle of Killiecrankie had
" been decided. Mackay therefore ordered all his
" bayonets to be so formed that they might be screwed
" upon the barrel without stopping it up, and that his
" men might be able to receive a charge the very instant
" after firing."

* 170. The socket bayonet was adopted from this time, and was in general use in 1703.

A.D. 1702 to 1714. 171. In the reign of Queen Anne every infantry soldier was armed with a musket, bayonet, and sword, and the grenadier ceased to carry grenades.

A.D. 1714 to 1727. 172. In the reign of George I. no change appears to have taken place in the arms of the troops. Dragoons carried a carbine, bayonet, and sword.

A.D. 1727 to 1760. * 173. The iron or steel ramrod was invented by the Prince of Dessau in Prussia, about 1741 ; this greatly increased the efficiency of the musket, and was an improvement on the scouring stick, which was very liable to be broken on service. Previous to this invention the corporals of the Prussian and Austrian infantry were provided with spare iron ramrods in two parts, which, when required, were screwed together.

* 174. In the reign of George II. light companies were added to infantry regiments ; in 1745 the men of battalion companies of infantry, and in 1746 of grenadier companies, ceased to carry swords. From this period the arms of the infantry soldier have been confined to the musket and bayonet.

A.D. 1760 to 1820. 175. George III.—In 1800 the light and heavy dragoons carried a sword and fusil ; in 1808 the light dragoon had a carbine with a bayonet.

176. At the commencement of the present century the English musket with its ammunition was as follows :—

Weight of musket with bayonet - - 11 lb. 4 oz.
Do. bayonet - - - - 1 „ 2 „
Length of barrel of musket - - 3 ft. 3 in.
Diameter of bore of barrel ·753 in., or $14\frac{1}{2}$ bullets to the pound.
Charge of powder 6 drs. F. G., with 3 flints to every 60 rounds.

* 177. There had been, at different periods, various methods of priming small fire-arms. Originally the priming was put into the pan from a flask containing a fine-grained powder called serpentine powder ; in the early flint-lock musket this was rendered unnecessary, as, in loading, a portion of the charge passed through the vent into the pan, where it was prevented from escaping by the hammer ; latterly, the top of the cartridge was bitten off, and the pan filled therefrom before loading, which was very unsafe.

* 178. The objections to the flint lock were that it did not entirely preserve the priming from wet, and that the flint failed sometimes to ignite the charge.

* 179. To remedy these imperfections, the Rev. Mr. Forsyth, in 1807, obtained a patent for priming with fulminating powder, which, when struck with any metal or hard substance, exploded. This fulminating powder at first consisted of chlorate of potash with sulphur and charcoal ; it was, however, considered too corrosive, and was subsequently improved.

180. George IV. — No change in small arms took place during this reign. A.D. 1820 to 1830.

* 181. In William IV.'s reign Mr. Forsyth's invention was tested at Woolwich (1834) by firing 6,000 rounds from six flint-lock muskets, and the same number from six percussion muskets, in all weathers ; the result of this trial proved exceedingly favourable to the percussion principle ; the shooting was more accurate ; the recoil was less, the charge of powder having been reduced from 6 to $4\frac{1}{2}$ drs. ; the rapidity of firing was greater ; and the number of miss-fires considerably reduced, being as 1 to 26 nearly in favour of the percussion system. A.D. 1830 to 1837.

* 182. Victoria.—In consequence of the success mentioned in the foregoing paragraph, the flint lock in 1839 A.D. 1837.

was altered to suit the percussion principle ; this was easily accomplished, as the interior of the lock remained the same, by removing the hammer with the spring and pan, and replacing the cock which held the flint by a small conical-shaped hammer with a hollow to fit on the nipple when released by the trigger ; this nipple is a small pillar screwed into the side of the barrel, with a hole through its centre communicating with the vent or touch-hole, to hold the copper cap containing the detonating composition, which now consisted of three parts of chlorate of potash, two of fulminate of mercury, and one of powdered glass.

* 183. In 1840 the Austrian army was supplied with the percussion musket, which does not appear to have been generally issued to the English army until 1842.

184. In 1842 a new model musket on the percussion principle was adopted, with a block or back sight for 150 yards, its weight, &c., being as follows :—

Weight of musket and bayonet, 11 lbs. 6 oz.
Weight of bayonet, 1 lb. 8 oz.
Length of musket with bayonet fixed, 6 ft. 0 in.
Length without bayonet, 4 ft. 6¾ in.
Length of barrel, 3 ft. 3 in.
Size of bore, ·753 in., 14½ bullets to the lb.
Charge of powder, 4½ drs.

* 185. The bore of the English musket being larger than that of France, Belgium, Russia, and Austria, was considered an advantage, because their balls could be fired out of our barrels, whilst our balls could not be fired out of theirs. It was also thought that the greater weight of the English ball produced an increased range and momentum ; this was however counteracted by the excess of windage.

* 186. The shooting powers of the percussion musket 1842 are shown in a report on " experimental musketry " firing " carried on by Captain (now Colonel) McKerlie of the Royal Engineers, at Chatham, in 1846, which concludes as follows :—

" It appears by these experiments that as a general " rule musketry fire should never be opened beyond " 150 yards, and certainly not exceeding 200 yards ; " at this distance half the number of shots missed the

"target, 11 ft. 6 in., and at 150 yards a very large pro-
"portion also missed; at 75 and 100 yards every shot
"struck the target 2 ft. wide, and had the deviation
"increased simply as the distance, every shot ought to
"have struck the target 6 ft. wide at 200 yards; in-
"stead of this, however, some were observed to pass
"several yards to the right or left, some to fall 30 yards
"short, and others to pass as much beyond, and the
"deviation increased in a still greater degree as the
"range increased. It is only then under peculiar cir-
"cumstances, such as when it may be desirable to bring
"a fire on field artillery, when there are no other means
"of replying to it, that it ought ever to be thought of
"using the musket at such distances as 400 yards."

187. The foregoing forms a true account of the value of the percussion musket 1842, which continued in use in our army until superseded partially in 1851 by the Minié rifle, and altogether by the Enfield rifle in 1855.

RIFLES.

A.D.1498. *1. The invention of rifling has been attributed to Gaspard Zoller, or Zollner of Vienna, about the end of the 15th century.

*2. The grooves were at first cut straight down the bore, for the purpose, it is supposed, of receiving and decreasing the effect of the fouling. It also tended to increase the accuracy of shooting of the arm, inasmuch as the bullet was directed in a straight line down the barrel. The citizens of Leipzic used rifled barrels with straight grooves at target practice about this period.

A.D.1520. *3. About the year 1520, Koster of Nuremberg is said to have adopted the spiral form of grooving ; whether from fancy, or from understanding the value of the change, does not appear at all certain.

*4. Rifles were at first used for amusement, and were not employed in warfare until about the middle of the 17th century.

5. A snaphaunce rifled gun, 4 ft. 9 in. in length, of the time of Charles I., is to be found in Sir Samuel Meyrick's collection of arms.

6. In the official catalogue of the Tower armouries it is stated that "rifling barrels commenced about the "beginning of the 17th century," and that the earliest patent preserved in the Patent Office for rifling small arms, is dated 24th June 1635, which reads as follows :—"The gunsmith undertakes to rifle, cutt out, and screwe "barrels as wide, or as close, or as deepe, or as shallowe, "as shall be required, and with great care."

A.D.1610. 7. In the Tower armouries may be seen a tricker wheel-lock rifled birding piece, dated about 1610 ;—a hunter's wheel-lock rifle, dated 1613, the barrel has seven grooves with double lines between the grooving ;—a tricker flint-lock forest rifle, about 1630 ;—and a German wheel-lock rifle, dated 1797.

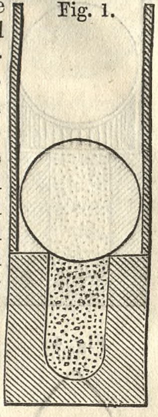
A.D.1680. *8. In 1680 each troop of Life Guards was supplied with eight rifled carbines.

A.D.1800. *9. In 1800 the 95th Regiment, now the Rifle Brigade, was armed with a rifle known by the name of "Baker's "rifle," which weighed 9½ lbs. The barrel of this rifle was 2½ feet in length ; it had 7 grooves, making a quarter turn in the length of the barrel, and its calibre was a 20 bore. A small wooden mallet was supplied with this rifle, to make the ball enter the barrel; this mallet was in use only a short time when it was withdrawn. This rifle was loaded with great difficulty.

A.D.1826.

* 10. The great objection to the use of the rifle in war was the difficulty experienced in loading it. To remedy this evil, M. Delvigne, a French infantry officer, in 1826, proposed to place at the bottom of the breech a small chamber having an abrupt connexion with the bore (fig. 1). The charge of powder nearly filled this chamber, and the ball, which was spherical in form and fitted the barrel loosely, rested on it and was forced into the grooves by several sharp strokes with a heavy rammer having a conical head, in order that it might receive a spiral motion during its projection from the barrel; this hard ramming also forced the ball into the chamber to the injury of the powder.

Fig. 1.



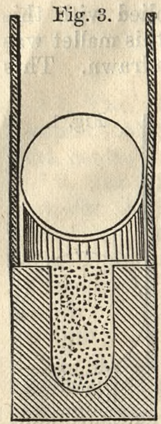
* 11. Although easy loading and increased accuracy in shooting, (which at 600 yards was double that of the smooth-bore musket at 350 yards,) resulted from this invention, it was soon abandoned, as it was found that the fouling increased so rapidly as to cause the powder, after a few shots had been fired, to project beyond the chamber, when the ball, resting on the powder instead of the chamber, was not so easily dilated into the grooves, but was,—by hard ramming to overcome the obstacle,—forced out of shape by being flattened in front, which caused irregularities in its flight.

Fig. 2.

A.D.1828.

*12. In 1828, Colonel Thouvenin, of the French artillery, proposed a rifle on the tige principle. It consisted in substituting for the Delvigne chamber a small cylinder or pin of steel, fixed in the bottom of the bore, around which the powder lay, and on which the ball rested when loaded, thereby allowing the latter to be expanded more easily and without so much detriment to its shape (fig. 2). The ball when in the barrel was quite firm, and could not

Fig. 3.

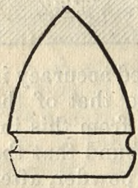


be easily displaced by marching, or the ordinary movement of the rifle ; but being spherical it received obliquely the impulse of the charge, and was consequently propelled with diminished force. The tige rifle was therefore not adopted at this time.

A.D. 1833.

* 13. In 1833, Colonel Poncharra suggested placing a "sabot" of hard wood underneath the ball with a greased patch, which, resting on the offsets of the mouth of the chamber (fig. 3), was prevented from entering it. The Delvigne-Poncharra rifle was objected to as a war weapon on account of the complicated nature of its ammunition, and the difficulty of procuring it in the field ; besides which, the sabots frequently broke in loading, from the ramming necessary to expand the bullet into the grooves.

Fig. 4.

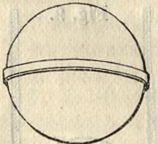


* 14. Colonel Thierry, of the French artillery, about this time proposed a rifle from which cylindro-conical bullets, suggested by Delvigne, were to be fired; they were to be flat at the bottom, cylindrical in the body, with a conical point (fig. 4). This rifle was not found to answer with these projectiles.

A.D. 1836.

* 15. In William IV.'s reign the Brunswick rifle, with back action hook lock, was introduced into the army ; its weight with sword bayonet and scabbard was 11 lbs. 5½ ozs ; weight of barrel, 3 lbs. 14 ozs. ; length of barrel, 2 ft. 6 in. ; number of grooves, two, making one turn in the length of the barrel ; weight of bullet (which was spherical and belted) (fig. 5), 557 grs. ; diameter, ·696 in. ; charge of powder, 2½ drs.

Fig. 5.

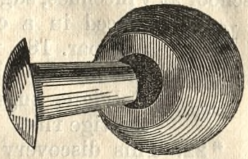


* 16. This rifle, from the ball having a belt round it, with a patch to prevent its "stripping," *i.e.* passing out of the grooves, was found an inconvenient weapon, in consequence of the delay experienced in placing the belted ball properly in the grooves, without which loading was impossible. The rifle soon fouled, and its shooting beyond 400 yards was wild.

* 17. In 1836 Mr. Greener invented and submitted for trial at Tynemouth, under the authority of the Master

General and Board of Ordnance, a bullet to expand by the action of the powder; it was shaped like an egg, having an opening at one end to receive a "taper plug, with a head like a "round-topped button, of a "composition of lead, tin, and "zinc" (fig. 6); this plug, which was rather larger near the head than the opening, was driven home on the explosion of the powder, when the sides of the bullet were dilated, and forced into the grooves of the rifle, thereby stopping all windage, and increasing the accuracy of shooting as compared with the Government bullet. The Board of Ordnance rejected this invention on the ground of the bullet being a compound; in 1857, however, Mr. Greener was awarded 1,000*l*. "for "the first public suggestion of the principle of expansion, "commonly called the Minié principle, "for bullets, in 1836."

Fig. 6.



A.D.1841.

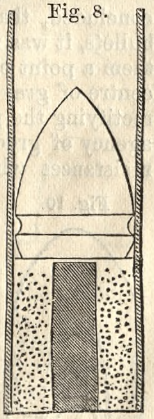
* 18. Delvigne was the first of recent date in France to announce the fact, that elongated bullets, hollowed at the base, were expanded and forced into the grooves of the rifle by the gas evolved in the explosion of the powder, and in 1841 he obtained a patent for a bullet consisting of a cylinder terminated by a cone (fig. 7).

Fig. 7.

A.D.1844.

* 19. In 1844 Colonel Thouvenin's tige rifle was again brought forward to be tried with the elongated bullet already proposed by Delvigne (see par. 14), and was adopted (fig. 8). The size of the tige, stem, or pin, was such as to leave a sufficiently large space between the powder and the ball for the fouling accumulating in the barrel from 50 rounds.

Fig. 8.



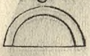
20. The tige rifle was difficult to clean, a special instrument being required for the purpose; it appears to have been the first military arm in which an elongated projectile was successfully used, and to have been adopted in France as the arm for the Chasseurs.

A.D.1847.

21. No practical result appears to have flowed from these discoveries until some

time in 1847, when Captain Minié, an instructor of the school at Vincennes, suggested an iron cup (fig. 9) being placed in a cavity at the base of the bullet (see par. 18), which was found to be expanded thereby as well as, if not better than, the bullet Delvigne suggested, and which was used for the tige rifle.

Fig. 9.



Cup.

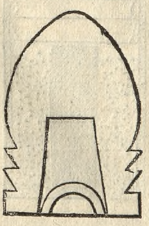
*22. This discovery caused the manufacture of the tige or stem to be discontinued, and the Minié rifle (an ordinary rifle firing a Minié bullet) to become the favourite arm ; and the smooth-bore musket was, by the simple operation of rifling, transformed into the long range rifle with which the Imperial Guard and some of the other troops of the line in France were armed.

23. After Captain Minié's suggestion of an iron cup in the base of the bullet, it was considered that a practical and definite solution of the principle of expansion had been obtained.

24. One of the early bullets of Captain Minié's principle was a cylindro-ogive in form, with a groove on its cylindrical portion intended to receive a greased patch ; this groove having been dispensed with, it was found that the rifle lost much of its accuracy; it was therefore re-adopted, when it was discovered that any variation in the shape or position of the groove materially affected the shooting.

*25. Captain Tamisier, another instructor of the school at Vincennes, after trying bullets of a cylindrical form of different lengths with conical points of various angles, concluded, that to increase the precision of elongated bullets, it was necessary to ascertain the means of giving them a point of resistance as far as possible behind their centre of gravity ; he accordingly adopted the plan of rectifying the path of the bullet by creating, through the agency of grooves or cannelures at the posterior end, resistances which should act when its *axis did not coincide* with the direction of motion (fig. 10). He tried to carry the centre of gravity of his bullet as far forward as possible, which compelled him to flatten the front of the projectile.

Fig. 10.



*26. In the first elongated bullets made for the tige rifle, the centre of gravity being near the base, the rear end had a tendency to fall before the front, this was rectified by the cannelures.

*27. In 1851 a rifle musket of the Minié pattern was introduced into the English army; it was never generally issued, although used by our troops during the Caffre war in 1851, and in the Crimea, at the battles of the Alma and Inkerman; its weight, &c. was as follows:— **A.D.1851.**

Weight of rifle, musket with bayonet, 10 lbs. 8¾ oz.
Weight of barrel, 4 lbs. 10 oz.
Length of barrel, 3 ft. 3 in.
Diameter of bore, ·702 in.
Number of grooves and turn, 4, making 1 turn in 78 in.
Diameter of bullet, ·690 in.
Weight of bullet, 680 grains.
Windage, ·012 in.
Charge of powder, 2½ drs.
Point blank range, 177 yards.
Sighted from 100 to 1,000 yards.

*28. The form of bullet first used with the English Minié rifle was conoidal (fig. 11). It soon became apparent that this form was defective, as there was little chance of the axis of the bullet coinciding with that of the barrel during its passage out; hence it was changed to a cylindro-conoidal form (fig. 12), with an iron cup of nearly hemispherical form. These bullets were made up into cartridges, which had to be reversed by the hand (after pouring the powder into the barrel), to insert the bullet; the paper surrounding the cylindrical portion and base of the bullet was greased with a lubrication composed of five parts of tallow and one of beeswax; the paper above the point of the bullet and that forming the powder case was torn off before drawing the ramrod to place the projectile home on the powder.

Fig. 11.

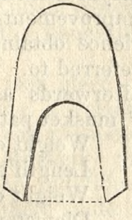
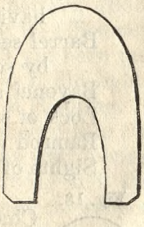


Fig. 12.



29. Many complaints having been made of the difficulty of loading the Minié rifle with its regulation bullet, the Commandant of the School of Musketry, Hythe, suggested, in March 1854, a reduction in the diameter of the bullet, and a change in the form of the cavity at its base to receive the iron cup; these alterations were

made, as it was found that the loading of the rifle was thereby rendered more easy, while, at the same time, the accuracy of its shooting was not in any way impaired.

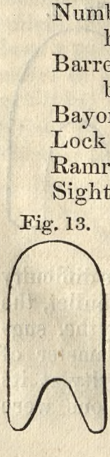
30. A large number of percussion muskets, pattern 1842, were converted into rifles by being grooved, and were issued to the Royal Marines, and made available for sea-service, whence the term "sea-service rifle;" the bullet was of the Minié pattern, its diameter was ·731 inch; weight 825 grains; and the charge of powder 3 drs.

A.D. 1852. 31. In the early part of 1852 experiments were carried on at Enfield, by order of the late Viscount Hardinge, when Master-General of the Ordnance, to test the merits of different rifles submitted for trial by some of the principal gunmakers of England, with a view to ascertain the best description of fire-arm, combining lightness with efficiency, for military purposes.

* 32. In August 1852 two muskets were made at the Royal Enfield Manufactory in which were embodied the improvements and alterations suggested by the experience obtained during the course of the experiments referred to. The weight, &c., of these muskets, known afterwards as the Enfield 3-grooved rifle, "or rifle " musket pattern 1853," was as follows:—

Weight of rifle musket, with bayonet, 9 lbs. 3 oz.
Length of barrel, 3 ft. 3 in.
Weight of ditto, 4 lbs. 1½ oz.
Diameter of bore, ·577 in.
Number of grooves and turn, 3 and equi-distant, having 1 turn in 78 inches.
Barrel secured to stock by three steel bands fastened by screws and breech nail.
Bayonet secured with locking ring.
Lock of swivel pattern.
Ramrod with swell near the head.
Sights of Mr. Westley Richards' pattern capable of folding down either way.
Charge, 2½ drs.

Fig. 13.



* 33. A bullet of cylindro-conoidal form (fig. 13), made up into cartridges and lubricated as for the Minié rifle, was adapted to these arms by Mr. Pritchett, for which he was awarded by Government 1,000*l.*; the weight of this bullet was 530 grains; its diameter ·568, and windage, ·009 in.

34. In December 1852 a trial of these muskets was made, for the first time, at distances from 100 to 800 yards, when it was found that the shooting produced was equal in accuracy at the several distances to any hitherto obtained by the arms previously tried.

*35. In October 1853 the Enfield 3-grooved rifle was tried at Hythe in competition with the Minié, or rifle musket 1851, and Lancaster's smooth-bore elliptical rifle, with increasing spiral or gaining twist, freed at the breech. The Pritchett bullet was used with the Enfield and Lancaster rifles. The result of this trial was in favour of the Lancaster. **A.D.1853.**

36. In December 1853 another trial was made between the Enfield and Lancaster rifles, when the former, on the whole, proved to be superior, the latter evincing a tendency to "strip," especially at the longer ranges.

37. In January 1854 the Lancaster and Enfield rifles were again tried, the barrels of both arms, on this occasion, having been reduced from 3 ft. 3 in. to 2 ft. 6 in, ; the result was a second time favourable to the Enfield system of rifling, and the stripping tendency of the Lancaster clearly established. **A.D.1854.**

38. A further trial of the Enfield rifle took place in October and November 1854, by placing a certain number of these arms in the hands of non-commissioned officers and privates sent to the School of Musketry for instruction, and comparing the results of the individual shooting and file and volley firing, with those made in the same practices with the Minié rifle, pattern 1851, when the superiority of the Enfield rifle, pattern 1853, was confirmed, thus placing beyond a doubt its efficiency for military service over any arms that had yet been put into the hands of the infantry, combining as it did lightness and strength with increased accuracy of shooting.

*39. In 1855 the Enfield rifle was introduced into the English army; was used during the Crimean war, having there replaced the Minié rifle pattern 1851, and the Percussion musket 1842; and is now the general weapon of the entire infantry. Short rifles of the same pattern, with barrels 2 ft. 9 in. long, and a sword bayonet, were supplied to the 60th and Rifle Brigade. About this time two small carbines, constructed on the same principle as the Enfield rifle, were introduced for the artillery and cavalry, also a rifled pistol. **A.D.1855.**

*40. In 1855 the Lancaster smooth-bore elliptical rifle, barrel 2 ft. 8 in. long, became the arm of the corps of Sappers and Miners, now the Royal Engineers.

*41. Several improvements have been made in the Enfield rifle since its first appearance, *e.g.*—

In 1854 a new back sight was adopted which combined the principles of Mr. Westley Richards and Mr. Lancaster with that of the Ordnance pattern 1851 fitted to the Minié rifle.

In Mr. Westley Richards' sight the flap can be put down on the barrel from or towards the muzzle ; in Mr. Lancaster's the flap is protected by flanges ; and in the Ordnance pattern the flap is kept in a perpendicular position by a spring.

In 1855 a new ramrod was recommended and adopted, having a jagged head, the suggestion of Mr. Aston, the armourer of the School of Musketry, which facilitated the drawing of it from the stock, and removed the necessity for the brass jag issued with each rifle, and used for sponging out the barrel.

In the same year, a new turnkey, which dispensed with the "cramp," and furnished an oil bottle, was recommended and adopted, the suggestion also of Mr. Aston.

In 1858 the grooves which were at first of uniform depth, were made progressive, being at the breech ·015 in. and at the muzzle ·005 in.

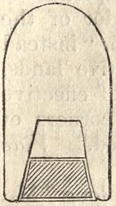
In 1860 all the parts of the rifle and lock were made to interchange, an incalculable advantage for a military arm, particularly in the field, and it was directed "that "the army shall be equipped exclusively" with rifles of the interchangeable pattern.

42. Whilst the Pritchett bullet will shoot well from the Enfield rifle when the diameter of the former is ·568, and that of the latter ·577 in., no dependence can be placed on it when these conditions are not maintained, as was satisfactorily proved in a long course of experiments at the School of Musketry, Hythe, in 1855, Captain Fraser, Royal Artillery, being present. When it is considered that three-thousandths of an inch are allowed as a margin in boring the barrel, and one-thousandth in manufacturing the bullet, it will be seen that it is next to impossible to maintain the conditions mentioned. With a view therefore to correct any imperfections which might exist either in the diameter of bullet or bore of rifle, the cavity in the base of the bullet was

altered, and an iron cup placed there as an auxiliary to expansion, on the strong recommendation of Colonel, now Major-General Hay.

43. To determine the best material and shape for the cup or plug, further experiments took place in 1855, which resulted in a new form of bullet, with a boxwood plug (fig. 14), being recommended and adopted; the advantages claimed for it were :—

Fig. 14.



1st. Greater, more certain, and uniform expansion, leaving at the same time a sufficient margin to cover any trifling inaccuracy in diameter either of bore or bullet of rifle, caused by imperfect manufacture.

2nd. Great decrease of fouling, with corresponding facility of loading.

3rd. Increased accuracy of shooting.

44. In August 1857 it was directed that the lubricating mixture for the Enfield rifle was in future to consist of five parts of beeswax, and one of tallow, instead of five parts of tallow and one of beeswax, and in April 1859, in consequence of complaints of the difficulty experienced in loading this rifle during the Indian mutiny, the diameter of the bullet having enlarged from the incrustation of a white deposit, occasioned, it is said, by the acids of the fatty matter of the lubrication, an entire change of the ammunition for arms of the Enfield ·577 bore pattern was ordered, viz. :—

1st. The bullet to be ·55 in diameter and 1·09 in. in length, instead of ·568 in. in diameter and 1·05 in length.

2nd. The lubricating mixture to be beeswax, instead of beeswax and tallow.

3rd. The outer envelope or paper which contains the bullet to be fastened to the inner envelope or bag which contains the powder by a strip of gummed paper, instead of the two being twisted together beyond the stiff cylinder of the powder bag, to facilitate tearing off the end of the cartridge.

* 45. In 1858 a short rifle ·577 in. in diameter of bore, and having five progressive grooves with a turn in 4 ft., was made at Enfield for the Royal Navy to replace the sea service rifle pattern 1842. A similar rifle is now being supplied to the 60th Rifles, Rifle Brigade, and to serjeants of infantry of the line; it is a superior

weapon, as regards accuracy of shooting, to either the long or short rifle of pattern 1853.

*46. In 1854 Mr. Whitworth, the distinguished mechanist, was induced by the late Lord Hardinge, then General Commanding in Chief of the army, to consider the subject of rifling ; after a long series of experiments he adopted that system in which "the interior of the " barrel is hexagonal," and which, "instead " of consisting partly of non-effective lands, " and partly of grooves, consists of effective " rifling surfaces. The angular corners of " the hexagon are always rounded." *Vide* fig. 15.

Fig. 15.

*47. " For an ordinary military barrel 39 in. long " Mr. Whitworth " proposed a ·45 in. bore, with one turn in " 20 ins.," which he considered the best for this length.

*48. " Either cylindrical or hexagonal bullets may be " used " with this rifle. " Supposing a bullet of a " cylindrical shape to be fired, when it begins to expand " it is driven into the recesses of the hexagon. It thus " adapts itself to the curves of the spiral, and the inclined " sides of the hexagon offering no direct resistance, " expansion is easily effected." Vide fig. 16.

*49. " While the ordinary grooved rifle depends upon " the expansion of the soft metal projectile, in the " hexagonal system rifling may be effected independently " of expansion, by making the projectile of the same " shape as the interior of the barrel (fig. 17), in other " words, by having a mechanical fit between them. The " projectile may be used naked, and be made of metal of " any degree of hardness." " The expansion principle " may also be combined with an easy mechanical fit, so

Fig. 16.

Fig. 16.

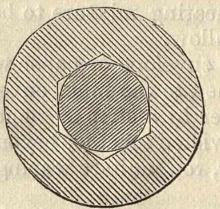


Fig. 17.

" that a projectile of metal harder than lead, as an alloy " of lead and tin, may be used, which, while it loads " easily, will expand sufficiently to fill the bore, and give " more than double the penetration."

50. In April 1857 a trial of the Whitworth rifle against the Enfield rifle pattern 1853 took place at Hythe, in the presence of Lord Panmure, then Secretary of State for War, when the former proved greatly superior to the latter both in accuracy of shooting and penetration. It has since then been under trial before two committees at different times in competition with small bore rifles; the last committee, in their report of the 26th November 1862, state in paragraph 69 that " the " makers of every small-bore rifle having any pretension to special accuracy have copied to the letter the " three main elements of success adopted by Mr. Whit-" worth, viz., diameter of bore, degree of spiral and " large proportion of rifling surface, it is not probable " that any further modifications or *quasi* improvements, " that might result from the question being now thrown " open to the gun trade would be attended with any practical advantage." The result of this trial will be best conveyed in the words of the committee's report, par. 68, viz., " They think it only just to Mr. Whitworth to " acknowledge the relative superiority of his small bore " rifle even as a military weapon, over all the other rifles " of similar calibre that have been under trial," viz., the Enfield, Lancaster, and Westley Richards' breech loader; and again, in par. 70, " With the exception of " the defect already noticed as to wear, and the difficulty " of obtaining ammunition suitable for the rifle as well " as the service, the Committee are of opinion that the " Whitworth rifle, taking all other points into consideration, is superior to all other arms as yet produced, and " that this superiority would be retained if Mr. Whit-" worth could ensure all the arms being made with " equal mechanical perfection."

51. It is worthy of record that the first meeting of the National Rifle Association at Wimbledon, on the 1st July 1860, was opened by Her Majesty Queen Victoria firing the first shot from a Whitworth rifle rest at 400 yards, the bullet hitting within 1½ inches of the centre of the target; and that the Queen's prize of 250*l*. has been shot for yearly at the said meeting with the Whitworth rifle,

which has carried off the palm of victory in all the contests opened by the National Rifle Association to the gunmakers of the United Kingdom to determine the rifle with which the Queen's prize is to be shot for at the "*Tir National*" of England.

52. In July 1861 a new back-sight for the naval rifle, pattern 1858, and short rifle, pattern 1860, was introduced, and the fore-sight was ordered to be made of cast steel, and in November 1861 a new back-sight for the Enfield rifles, pattern 1853, graduated up to 1,000 yards instead of 900.

53. In December 1861 a carbine with five grooves and pitch of one turn in four feet was introduced for the Royal Artillery; also a pistol of reduced weight for the Cavalry; length of barrel, 8 inches; calibre, 0·577 inches; weight, about 2 lb. 10½ oz.

54. In November 1863 Metford's explosive bullet was introduced, and in December 1863 plugs of baked clay were adopted for the hollow in the base of the elongated bullets instead of boxwood, in consequence of the difficulty of procuring the requisite supplies of the latter.

55. In December 1863 a pattern Whitworth rifle was approved to guide a supply of 8,000 ordered to be made at Enfield; calibre across angles, 0·4895 inch; sides, 0·4495.

56. In February 1864 an improved snap cap for small arms was introduced.

In May 1864 an alteration was made in the shape of the toe of the butt for long butt Enfield rifles to give greater strength to this part of the stock.

* 57. In June 1864 a committee of officers was ordered to consider and report on the expediency of introducing breech-loading arms for general adoption by the British Army, who, after a very few sittings, unanimously recommended that the system should be at once introduced, and the Secretary for War invited the various gunsmiths and manufacturers of fire-arms to send in to the Ordnance Select Committee patterns of the modes in which they might propose to convert the existing stock of Enfield rifles, pattern 1853. Nearly 50 different methods of conversion were proposed, the great majority of which were disapproved of on account of their requiring the stock to be materially altered or cut away; and the Committee after most laborious and protracted

experiments, recommended the plan proposed by Mr. Jacob Snider.

The rifles converted on this plan did not at first appear to produce accuracy in shooting at all equal to that of the unconverted arms, but Colonel Boxer, R.A., having devoted much time and attention to the subject, invented a cartridge for them which rendered their shooting at least equal if not superior to that of the muzzle-loading arm.

* 58. In the early part of 1866 Lord de Grey, then Secretary of State for War, gave orders for the conversion of a considerable number of the Enfield rifles into breech-loaders on the Snider principle ; and later in that year Lieut.-General Peel, who became Secretary for War on a change in the Cabinet, ordered the conversion on the same principle to be pressed on more rapidly. A number of these rifles were sent for experiment to the Schools of Musketry at Hythe and Fleetwood in September 1866. The shooting with those sent to Hythe with the first supply of ammunition furnished not having proved satisfactory, Colonel Boxer again turned his attention to the construction of the cartridges, and with his later ammunition, pattern No. 3, the results have been remarkably good, the number of miss-fires much less than with the muzzle-loaders ; and this principle of conversion is being generally adopted for the small arms of the British service.

On the 30th Oct. 1866 the Lancaster oval-bore rifles of the Royal Engineers were ordered to be converted on the Snider principle.

On the 1st May 1867 the cavalry carbine, pattern 1861, was ordered to be converted on the same principle.

In May 1867 the artillery carbine, pattern 1861, was ordered to be converted on the Snider principle.

In August 1867 the naval rifle, pattern 1858, was ordered to be converted on the Snider principle.

It will have been observed in the perusal of the foregoing pages on arms, that very little real improvement or alteration took place in fire-arms after the appearance of the *flint lock* in the 17th century until towards the middle of the present century, in which the changes from one description of arm to another have been most rapid in the English and foreign armies.

RIFLING.

* 1. " Fire-arms are rifled to give rotation to the pro-
" jectile round its axis of progression in order to insure
" a regular and steady flight." This object was fully pointed out by that celebrated mathematician Benjamin Robins in his Tracts on Gunnery in 1745, who, foreseeing the great advantages to be derived from the use of rifled arms, recorded in the last paragraph of these tracts the following prediction:—" Whatever state shall thoroughly
" comprehend the nature and advantages of rifled barrel
" pieces, and, having facilitated and completed their
" construction, shall introduce into their armies their
" general use with a dexterity in the management of
" them, they will by this means acquire a superiority
" which will almost equal anything that has been done
" at any time by the particular excellence of any one
" kind of arms, and will perhaps fall but little short of
" the wonderful effects which histories relate to have
" been formerly produced by the first inventors of fire-
" arms."

2. " Various plans have been proposed for furnishing
" the projectile itself with vanes, wings, grooves, or
" other configurations intended to give it rotation during
" its passage through the air ; but the only practical
" method hitherto adopted has been to make the barrel
" of a fire-arm of such a shape in its interior, that the
" projectile while being propelled from the breech to the
" muzzle may receive a rotatory combined with a forward
" motion."

* 3. The systems of rifling in general use may be classified under three headings. It would be useless to attempt to describe all the rifles now in existence.

First,—*The Grooved Cylinder.*—Rifling by grooves is a system that has been generally adopted by gunmakers of all countries and in all periods since the introduction of rifled arms, and is that which is adopted at the Royal Small Arms Factory, Enfield, in the manufacture of rifles for the army and navy.

Second,—*The Elliptical or Oval Bore.*—The distinctive character of this system, as adopted by Mr.

Lancaster, is that the barrel is cut in its interior in the form of an ellipse, the difference between the major and minor axes being ·012. The barrel being a smooth bore is easily cleaned; there are no recesses for the collection of fouling, and the bullet does not act upon the air with any sharp edges.

Third,—*The Polygonal System.*—This has been adopted by Mr. Whitworth in the construction of his rifle, the bore of which is hexagonal and measures across the flats, *i.e.* the minor diameter, ·451, and across the angles, *i.e.* the major diameter ·503 inch;—and by Mr. Westley Richards in his breech-loader, the bore of which is octagonal;—also by Mr. Henry, of Edinburgh, the bore of whose rifle is heptagonal with a rib in each of the angles.

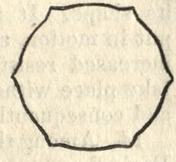
4. The form, depth, and number of grooves adopted by different gunmakers are various and capricious.

* 5. As regards form, they have been made—

Round, thus—

Circular, thus—

Angular, thus—



The proportion that the grooved should bear to the land or unrifled surface is still unsettled; but opinion appears to be generally tending to an excess of groove.

*6. As regards depth of grooves, those of the early rifles were very deep and uniform;—those of more modern date are shallower and uniform;—lately they have been made progressive, *i.e.*, increasing in depth from muzzle to breech. Among the old rifles in the Artillery Museum at Paris, none of them have grooves decreasing in depth, a system first practised by Tamisier in 1846, when smooth-bore muskets were being converted into rifles.

* 7. As regards number of grooves, some rifles have had upwards of 100; these poly-grooved rifles are out of date; the number usually adopted varies from two to seven. It is absolutely necessary to have two grooves: one only would cause error.

8. There have been rifles with a portion of the barrel only rifled.

* 9. The pitch of the rifling, the degree of spirality or turn are the terms generally given to the twist in the grooving, which may be classed under three headings, uniform;—gaining;—and decreasing.

* 10. In the beginning of the 16th century Koster of Nuremberg was led to make use of inclined instead of straight grooves. The uniform spiral is in general use.

* 11. The gaining twist, *i.e.* increasing towards the muzzle appeared first in America; it has been adopted by Mr. Lancaster in the construction of his elliptical rifling.

* 12. The decreasing twist towards the muzzle was advocated by Mr. Greener.

* 13. The bullet in a barrel with a gaining or decreasing spirality receiving its expansion at the breech, is moulded into the shape of the barrel at that part, but on proceeding down the barrel under the force of the powder it is obliged, in order to make its way out, to alter its shape. It is never, therefore, from the instant it is put in motion, at any two spots of the same form. This increased resistance to the passage of the bullet cannot take place without loss of power, loss of initial velocity, and consequently loss of rotation.

14. Among the old rifles in the Artillery Museum at Paris there are to be found :—

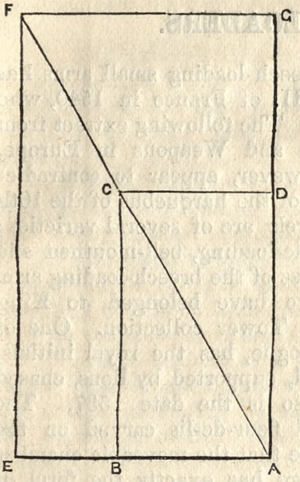
19	rifles	with straight grooves.
131	,,	with grooves uniformly inclined.
87	,,	with an increasing twist near the breech.
29	,,	do. do. towards the muzzle.
83	,,	do. do. towards the *middle* of the barrel.
67	,,	had grooves making half a turn and under in the length of the barrel.
219	,,	had grooves making from half to a whole turn in the length of barrel.
55	,,	had grooves making from one to two entire turns in the length of the barrel.

The calibres of the above arms were 311 of ·68 and under, and 32 above ·68 in.

15. The most convenient way of expressing the pitch or turn of the rifling is to represent it as having one turn in so many diameters.

*16. The pitch of the rifling is said to be the same in two rifles of different diameters, when the angle formed by the grooving and the circumference of the bore are equal, *e. g.*: Suppose two barrels of different diameters to be cut in lengths, the distance in which the grooving takes one turn (fig. 18); A D or B C to represent the length of the smaller; A G or E F the length of the larger; suppose each to be slit lengthwise at the point at which the grooving meets the ends, and the barrels to be spread open flat, then each will be a parallelogram, A B C D the smaller and A E F G the larger barrel; A B and A E the circumference of the bores; A is the point at which the rifling commences; and A C, the diagonal, represents the rifling of the smaller barrel; the angle C A B is the pitch of the rifling. In the case drawn, the same line continued, or A F, is the rifling of the larger barrel; and the angle F A B, the same as C A B, is the pitch of the rifling of the larger barrel, thus both barrels have the same pitch or turn. In a rifle in which the angle C A B approaches nearer to a right angle, the twist is slower, and when more acute it becomes a quicker turn.

Fig. 18.



BREECH LOADERS.

*1. The invention of breech-loading small arms has been attributed to Henry II. of France in 1540, who applied it to the harquebus. The following extract from Hewitt's Ancient Armour and Weapons in Europe, p. 624, vol. iii., would, however, appear to contradict this assertion; for speaking of the harquebus of the 16th century, he says, " The barrels are of several varieties; " breech-loading and muzzle-loading, bell-mouthed and " cylindrical. Two examples of the breech-loading arm, " both of which appear to have belonged to King " Henry VIII., are in the Tower collection. One of " these, No. $\frac{12}{1}$ of the catalogue, has the royal initials, " H. R., and a rose crowned, supported by lions, chased " on the barrel, where also is the date 1537. The " No. $\frac{12}{3}$ has the rose and fleur-de-lis carved on the " stock, and it is remarkable that the moveable chamber " which carries the cartridge has exactly the form of " that in vogue at the present day. These two examples " appear to be the arms named in the Tower inventory " of 1679 :—' carbine, 1, and fowling-peece, 1, said to " ' be King Henry the VIII.'s.' "

* 2. Breech-loaders have not been introduced into the armies of Europe except in Prussia and in a few special corps in other countries until within the last year.

* 3. Within the last six years breech-loading carbines on Green's and Sharp's principle, both Americans, and Westley Richards', of Birmingham, have been issued to some of our cavalry regiments, all of which, Lancers excepted, were to have been armed with the Westley Richards breech-loading carbine. One thousand Westley Richards' breech-loading muskets were supplied to the Government in 1862, and have been issued in small numbers to several battalions for practical trial.

It is now intended to arm the cavalry with the carbine, pattern 1861, converted on the Snider principle.

*4. The difficulties attending the construction of breech-loaders are chiefly mechanical, and that of closing the breech effectually to prevent the escape of gas is the principal. This, however, has been overcome in some systems, first by Colonel Green, of the United States army.

*5. Any breech-loading gun which can, by accident or design, be fired before all its parts are properly in place, is a defective and highly dangerous arm to those who use it, and totally unfit for any practical purpose in warfare.

*6. The advantages of breech-loaders are, 1st, celerity of fire ; 2nd, easy loading in any position; 3rd, generally more easily cleaned and examined.

*7. The disadvantages of breech-loaders are, 1st, the disposition of the gas to escape at the breech ; 2nd, generally cannot be loaded with loose powder ; and 3rd, they do not shoot as strong as muzzle-loaders.

*8. Breech-loaders, as a rule, require a special cartridge. The escape of gas round the joint at the breech is generally prevented by placing a wad at the base of the cartridge, which consequently rests against the breech and receives the force of the explosion, whereby it is detached from the cartridge and retained in the barrel. This wad, on the introduction of the next cartridge, is pushed in front of the bullet, and in its passage out, tends to clean the barrel.

*9. The breech-loading arms in general use are as follows :—

Prussian needle gun, Zündnadelgewehr.
*Green's, } barrels move forward, junction behind
*Prince's } the cartridge.
*Sharp's, junction behind the cartridge, breech drawn down by the trigger guard.
*Calisher and Terry's, junction behind the cartridge; the barrel projects above the stock ; breech moveable by a backward motion.
Storm's, junction in front of the cartridge; the chamber to receive the charge hinges on the upper part of the barrel, and is turned back towards the muzzle to load.

---

* Note.—These are falling into disuse in the British service, and the Snider principle superseding them.

Westley Richards', junction behind the cartridge; breech moveable by an upward motion.

Snider's, breech closed by a block moving on a hinge at the right side parallel to the axis and fitting in a shoe.

The "Chassepot," a modification of the Prussian needle gun.

WEIGHT and DIMENSIONS of ARMS, AMMUNITION, &c., now used in the BRITISH SERVICE.

DESCRIPTION OF ARM.		MUSKET.								BAYONET OR SWORD.					BARREL.															Sighted up to	AMMUNITION.						Weight of 60 Rounds and 75 Copper Caps packed.		REMARKS.
		Weight.				Length.				Length beyond Muzzle.		Weight.		Weight of Scabbard.	Dimensions, &c.									Grooves.							Bullet.					Charge of Powder.			
		With		Without		With		Without							Weight.		Length.		Diameter of Bore.	Lancaster, Whitworth, and Westley Richards' Rifles. Diameter of — At Muzzle.		At Breech.		Number.	Width.	Depth at Muzzle.	Depth at Breech.	Description.	Degree of Spirality.		Description.	Weight.	Diameter.	Length.	Windage.				
		Bayonet or Sword.																		Major Axis or across Angles	Minor Axis or across Flats.	Major Axis or across Angles.	Minor Axis or across Flats.																
		lbs.	oz.	lbs.	oz.	ft.	in.	ft.	in.	ft.	in.	lbs.	oz.	oz.	lbs.	oz.	ft.	in.												yards.		grs.	in.	in.	in.	drs.	lbs.	oz.	
Converted to Breech-loaders on the Snider system.	Long Enfield Rifle, Pattern 1853 (1)	9	12¼	8	14¾	5	11½	4	6	1	5½	-	13½	4½	4	10½	3	3	·577 to ·580	—	—	—	—	3	·235	·005	·013	progressive	1 in 6 ft. 6 in.	950	plug with 4 saw-shaped cannelures.	480	·573	1·04	(a)	2½	6	3	The following marks are on the action of these arms:— Original pattern in which countersink has been squared.—I.* Arms with squared countersink, but without other minor improvements.—II.* Arms with all the improvements.—II.** (a) The cylindrical portion of bullet is made to equal the diameter of bore by being coated with beeswax.
	Short Enfield Rifle (Naval), Pattern 1858 (2)	11	0¼	8	10¼	6	3⅜	4	0½	2	2⅞	2	6	10¼	4	8¼	2	9	do.	—	—	—	—	5	·235	·005	·013	do.	1 in 4 ft.	1,000	do.	480	·573	1·04	(a)	2½	6	3	
	Short Enfield Rifle, for Serjeants and Rifle Corps, 1860	10	7½	8	12	5	11½	4	0¾	1	10¾	1	11½	7½	4	8¼	2	9	do.	—	—	—	—	5	·235	·005	·013	do.	do.	1,000	do.	480	·573	1·04	(a)	2½	6	3	
	Royal Engineers' Rifle Carbine (Lancaster)	9	12¼	8	1¾	5	11½	3	11½	2	0	1	10½	9¾	4	2¼	2	7½	do.	·593	·577	·598	·580		oval	bore		do.	variable (7)	1,150	do.	480	·573	1·04	(a)	2½	6	3	
	Cavalry Rifle Carbine, Pattern 1861 (3)	-	—	6	10¼	-	—	3	0¾	-	—	-	—	—	3	2¾	1	9⅝	do.	—	—	—	—	5	·235	·005	·013	do.	1 in 4 ft.	600	do.	480	·573	1·04	(a)	2½	6	3	
	Royal Artillery Rifle Carbine, Pattern 1861 (3)	9	3	7	7	5	3	3	4¼	1	10¾	1	11½	12	3	6¼	2	0	do.	—	—	—	—	5	·235	·005	·013	do.	do.	600	do.	480	·573	1·04	(a)	2½	6	3	
Muzzle-loaders.	Long Enfield Rifle, Pattern 1853 (1)	9	12	8	14½	5	11½	4	6	1	5½	-	13½	4½	4	4	3	3	do.	—	—	—	—	3	·235	·005	·013	do.	1 in 6 ft. 6 in.	1,000	plug	530	·55	1 1/10	·027	2½	5	10¼	None of these muzzle-loaders, with the exception of the Cavalry Pistol, will in future be issued to the regular forces.
	Short Enfield Rifle, Pattern 1856	9	14½	8	2½	5	11½	4	0¾	1	10¾	1	12	7½	3	10½	2	9	do.	—	—	—	—	3	·235	·005	·013	do.	do.	1,100	do.	530	·55	1 1/10	·027	2½	5	10¼	
	Short Enfield Rifle (Naval), Pattern 1858 (2)	10	14	8	8	6	3⅜	4	0½	2	2⅞	2	6	10¼	4	1½	2	9	do.	—	—	—	—	5	·235	·005	·013	do.	1 in 4 ft.	1,250	do.	530	·55	1 1/10	·027	2½	5	10¼	
	Short Enfield Rifle, for Serjeants and Rifle Corps, 1860	10	4	8	8½	5	11½	4	0¾	1	10¾	1	11½	7½	4	1½	2	9	do.	—	—	—	—	5	·235	·005	·013	do.	do.	1,250	do.	530	·55	1 1/10	·027	2½	5	10¼	
	Royal Engineers' Rifle Carbine (Lancaster)	9	0¾	7	6¼	5	11½	3	11½	2	0	1	10½	9¾	3	9	2	7½	do.	·593	·577	·598	·580		oval	bore		do.	variable (7)	1,000	do.	530	·55	1 1/10	·027	2½	5	10¼	
	Cavalry Rifle Carbine, Pattern 1861 (3)	-	—	6	11	-	—	3	0¾	-	—	-	—	—	2	9¾	1	9	do.	—	—	—	—	5	·235	·005	·013	do.	1 in 4 ft.	600	do.	530	·55	1 1/10	·027	2	5	7½	
	Royal Artillery Rifle Carbine, Pattern 1861 (3)	9	4	7	8	5	3	3	4½	1	10¾	1	12	12	3	0	2	0	do.	—	—	—	—	5	·235	·005	·013	do.	do.	600	do.	530	·55	1 1/10	·027	2	5	7½	
Pistols.	Cavalry Rifle Pistol, 8-inch	-	—	2	10¼	-	—	1	2	-	—	-	—	—	-	15¾	0	8	do.	—	—	—	—	5	·235	·005	·013	do.	do.	100	hollow	390	·568	11/20	·009	1	3	15¾	Pattern prepared to supersede 10-inch pistol; but none of this pattern have yet been manufactured.
	Do. do. 10-inch	-	—	3	2	-	—	1	3¾	-	—	-	—	—	1	4½	0	10	do.	—	—	—	—	5	·235	·005	·013	do.	do.	300	do.	390	·568	11/20	·009	1	3	15¾	Issued to Lancer Regiments, Staff Serjeants, Troop Serjeant Majors, and Trumpeters of all Cavalry Regiments.
																					Diam. of chamber.																		
	Dean and Adam's Revolver Pistol, 54 gauge (6)	-	—	2	6½	-	—	1	8	-	—	-	—	—	-	—	0	5¾	·434	—	·451	—	—	3	·305	·009	·009	uniform	1 in 20 in.	No sight	plain	191	·45	·55	*	15 grs.	1	15	For the Navy and Coast Guard.
	Do. do. do. 38 gauge	-	—	4	7½	-	—	1	11⅝	-	—	-	—	—	-	—	0	7½	·470	—	·494	—	—	3	·016	·009	·009	do.	1 in 18 in.	do.	do.	245	·490	·66	*	20 grs.	2	7¼	
	Colt's Revolver Pistol, 84 gauge	-	—	2	9½	-	—	1	1¾	-	—	-	—	—	0	11	0	7½	·358	—	·374	—	—	7	·080	·010	·012	progressive	1 in 3 ft.	do.	do.	131	·383	·63	*	11 grs.	1	6¾	
	Naval Smooth-bore Pistol	-	—	2	3½	-	—	0	11⅝	-	—	-	—	—	0	12¼	0	6	·570	—	—	—	—	-	—	—	—	—	—	do.	spherical	203	·515	—	·055	2	-	--	For the Navy, but gradually being withdrawn.
Obsolete.	Whitworth Rifle, Pattern 1862	10	10¾	9	13¼	5	8½	4	3	1	5½	-	13½	4½	4	15½	3	0	·451	·49	·450	·49	·450	6	·196	·037	·037	uniform	1 in 20 in.	1,250 (b)	hollow (8)	480	·442	1·29	·009	75 grs.	5	9½	(b) When fired with cylindrical bullet.
	Westley Richards' Breech-loading Nº 4 Carbine (4)	-	—	6	8	-	—	2	11⅞	-	—	-	—	—	2	5	1	8	·449 to ·452	—	—	·485	—	8	—	·008	·008	do.	do.	800	plain	402	·467	1 1/25	*	2	4	7½	
	Sharp's Breech-loading Carbine (5)	-	—	7	7	-	—	2	11½	-	—	-	—	—	2	8½	1	6	·551	—	—	—	—	3	·214	·013	·013	do.	1 in 6 ft.	600	do.	545	·568	1·09	*	62 grs.	6	—	
	Green's Breech-loading Carbine (5)	-	—	7	7	-	—	2	10½	-	—	-	—	—	3	11½	1	6	·551	—	—	—	—	3	·250	·013	·013	do.	do.	600	The makers of these carbines supply ammunition for them.								
	Terry's Breech-loading Carbine (5)	-	—	6	3½	-	—	3	1½	-	—	-	—	—	3	0	1	9	·539	—	—	—	—	5	·175	·013	·013	do.	1 in 3 ft.	500									

---

(1) There are some pattern /53 Rifles (those made before December 1859) which are 1 inch longer in the stock than the present ones.

(2) The Naval Rifle has a "cutlass sword bayonet."

(3) There is an old pattern Cavalry and Artillery Carbine, with 3 grooves and pitch of 1 in 6 ft. 6 inches; in other respects they are the same as the present patterns.

(4) Nº 4 pattern of Westley Richards' Carbine is the pattern now adopted; ·485 is the diameter of the chamber.

(5) No more of these will be issued.

(6) The barrel and stock being in one, the weight of the barrel cannot be given separately.

(7) A quicker pitch at the muzzle than at the breech.

(8) This refers to the conical bullet. The hexagonal weighs 530 grs., measures ·438 across flats, and ·469 across angles, 1·47 inches in length; charge, 85 grains; weight of 60 rounds, 6 lbs. 3¼ ozs.

* In these cases the bullet is larger than the bore.

(Signed) H. T. ARBUTHNOT, Bt.-Major, R.A.,
Assistant Superintendent R.S.A. Factory.

HISTORY OF ARMS.

INDEX.

INDEX TO RIFLES.

LONDON:
Printed by GEORGE E. EYRE and WILLIAM SPOTTISWOODE,
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.
[P. 1895.—500.—2/69.]

MILITARY BOOKS, published by Authority—continued.

ARMY EQUIPMENT.

Prepared at the Topographical and Statistical Department, War Office.

COLONEL SIR HENRY JAMES, R.E., F.R.S., &c., *Director.*

PART I.—CAVALRY.

Compiled by LIEUT. H. M. HOZIER, 2nd Life Guards, F.C.S., F.G.S., Topographical Staff.

Royal 8vo., cloth boards. Price 4*s.*

PART IV.—MILITARY TRAIN.

Compiled by LIEUT. H. M. HOZIER, 2nd Life Guards, F.C.S., F.G.S., Topographical Staff.

Royal 8vo., cloth boards. Price 2*s.* 6*d.*

PART V.—INFANTRY.

Compiled by CAPTAIN MARTIN PETRIE, Topographical Staff.

Royal 8vo., cloth boards. Price 5*s.*, with Plates.

PART VI.—COMMISSARIAT.

Compiled by LIEUT. H. M. HOZIER, 2nd Life Guards, F.C.S., F.G.S., Topographical Staff.

Royal 8vo., cloth boards. Price 1*s.* 6*d.*

PART VII.—HOSPITAL SERVICE.

Compiled by CAPTAIN MARTIN PETRIE, Topographical Staff.

Price 5*s.*, with Plates.

REGULATIONS FOR THE VOLUNTEER FORCE.

Dated War Office, 18th September 1863.

212 pp. demy 8vo., cloth boards. Price 1*s.* 6*d.*

MANUAL OF DRILL FOR MOUNTED RIFLE VOLUNTEERS,

OR VOLUNTEER IRREGULAR CAVALRY.

By Lieut.-Col. J. BOWER and Captain 1st Hants Mounted Rifle Volunteers.

Demy 12mo., cloth boards. Price 1*s.* 6*d.*

REGULATIONS APPLICABLE TO THE CORPS OF YEOMANRY CAVALRY.

26 pp. demy 8vo. Price 6*d.*

LONDON:
Printed under the Superintendence of H.M. Stationery Office,
AND SOLD BY
W. CLOWES & SONS, 14, Charing Cross; HARRISON & SONS, 59, Pall Mall;
W. H. ALLEN & Co., 13, Waterloo Place; W. MITCHELL, Charing Cross;
And LONGMAN & Co., and TRÜBNER & Co., Paternoster Row;
Also by A. & C. BLACK, Edinburgh; D. ROBERTSON, 90, St. Vincent Street, Glasgow;
ALEX. THOM, Abbey Street, and E. PONSONBY, Grafton Street, Dublin.