RIFLES

AND

RIFLE PRACTICE:

AN

ELEMENTARY TREATISE

UPON THE

THEORY OF RIFLE FIRING,

EXPLAINING THE CAUSES OF INACCURACY OF FIRE, AND
THE MANNER OF CORRECTING IT.

WITH DESCRIPTIONS OF THE

INFANTRY RIFLES OF EUROPE AND THE UNITED STATES,
THEIR BALLS AND CARTRIDGES.

BY C. M. WILCOX,
UNITED STATES ARMY.

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In Memoriam
George Davidson
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PREFACE.

The following pages contain, in part, an elementary treatise upon the theory of Rifle-Firing; and in part, a description of the rifles, their balls and cartridges, with which the infantry of European armies and of the United States are at present armed.

In order that the theory of Rifle-Firing, as given, may be intelligible to all, it is preceded by the elementary principles of Arithmetic and Geometry indispensable for this purpose; and it is explained in a plain practical manner, dispensing, as far as possible, with the use of scientific and technical terms. It is proper to state that but little of this work is claimed as original, it being composed mostly of translations from recent, and what are regarded as the best French publications, and such as form a part of the course of instruction at their school at Vincennes.

It is hoped that this book may prove to be both interesting and useful to the United States Militia and Volunteers, for whose use it was principally prepared.

C. M. Wilcox,
1st Lieut. 7th U. S. Infantry.

New York, May 20, 1859.

(COPY.)

ADJUTANT GENERAL'S OFFICE,
Washington, June 28, 1859.

SIR—

I am instructed to inform you that the War Department will take one thousand copies of WILCOX'S Treatise on "RIFLES AND RIFLE PRACTICE," now being published by you.

I am, Sir, very respectfully,
Your ob't serv't,
G. D. TOWNSEND,
Ass't Adj't General.

D. VAN NOSTRAND, ESQ.
Publisher,
City of New York.

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RIFLES AND RIFLE PRACTICE.

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CHAPTER I.

ARITHMETIC.

Quantity is that which admits of increase or diminution. A quantity taken arbitrarily to serve as a term of comparison for all other quantities of the same species, is called a *unit.*

A *number* is a collection of units. There are two kinds of numbers: the number *abstract*, and the number *concrete.* The first does not designate the kind of unit, as for example, 20, 30, 35, &c., &c. The second, on the contrary, does designate the unit, as 20 yards, 30 men, &c., &c.

To MEASURE A QUANTITY is to compare it with its unit, to see how many times it contains the unit, or what part of the unit it would take to form a quantity equal to it. When the comparison can be made with exactness, the quantity is said to be *commensurable;* if the comparison cannot be thus made, it is called *incommensurable.*

The first four rules of Arithmetic are Addition, Subtraction, Multiplication, and Division.

Addition of Whole Numbers.

Addition is an operation by which many numbers of the same species are united into one, called the *Sum*, or total. To add whole numbers, first write them down one under another, in such a manner that units of the same kind shall be under each other.

Subtraction.

Subtraction is an operation by which the difference between two numbers of the same species is ascertained; the result is called the *remainder.* To subtract one number from another, first write the smaller under the greater, in such manner that units of the same kind shall be under each other.

Multiplication.

Multiplication is an operation by which a number, called the *multiplicand*, is repeated as many times as there are units in another number, called the *multiplier;* the result is called the *product*, the multiplicand and multiplier are called *factors.*

Division.

Division is an operation by which having a *product*, called *dividend*, and one of its factors, called *divisor*, we seek the other factor, called *quotient*. The quotient is not always a whole number, for this it would be necessary that the dividend be an exact multiple of the divisor. It may be said, then, that the object of division is to see if the dividend is a multiple of the divisor, and if so, to find the number by which it would be necessary to multiply the divisor to produce the dividend. If the dividend be not a multiple of the divisor, the quotient will be comprised between two consecutive whole numbers, and will be composed of a whole number and part of a number (or fraction).

Fractions.

A fraction is one or more equal parts of a unit, thus, $\frac{1}{5}$, $\frac{2}{3}$, $\frac{3}{4}$, are fractions: the fraction $\frac{1}{5}$ expresses that the unit has been divided into five equal parts, and that one of those parts has been taken; the fraction $\frac{3}{4}$ expresses that the unit has been divided into four equal parts, and that three of those parts have been taken.

Every fraction is composed of two terms: one, called the *denominator*, indicates into how many equal parts the unit has been divided; the other, called the *numerator*, indicates how many of those parts have been taken. Thus in $\frac{3}{4}$, 4 is the denominator, and 3 the numerator.

The more the numerator of a fraction increases, the denominator remaining the same, the greater the fraction becomes; the more the denominator diminishes, the numerator remaining the same, the more the fraction increases. As the numerator of a fraction diminishes, the denominator remaining the same, the fraction diminishes; as the denominator of a fraction augments, the numerator remaining the same, the fraction diminishes.

We can multiply or divide the two terms of a fraction by the same number, without changing the value of the fraction; its form only changes. From what has been said, it is seen that to make a fraction four times greater, we may either multiply its numerator by 4, or divide its denominator by 4. The fractions $\frac{2}{3}$ and $\frac{3}{4}$ are not of the same kind: one expresses thirds, the other fourths. We can, without changing the value of these fractions, cause them to express the same kind of units, by giving them the same denominator; this is done by multiplying the two terms, 2 and 3, of the first fraction, by 4, the denominator of the second, and the two terms, 3 and 4, of the second fraction, by 3, the denominator of the first. We obtain by this operation, $\frac{8}{12}$ and $\frac{9}{12}$. Thus, to reduce two fractions to the same denominator, multiply the two terms of the first by the denominator of the second, and the two terms of the second by the denominator of the first. To reduce many fractions to the same denominator, multiply the two terms of each fraction by the product of all the denominators of the other fractions.

Addition of Fractions.

To add the fractions $\frac{2}{7}$, $\frac{3}{7}$, and $\frac{5}{7}$, having a common denominator, add the numerators together, and for the denominator of this sum, write the common denominator; if the fractions to be added have different denominators, as $\frac{2}{3}$, $\frac{4}{5}$, $\frac{2}{9}$, first reduce them to a common denominator, and then add as above.

Subtraction.

To subtract one fraction from another having the same denominator, subtract the less numerator from the greater, and write under this remainder the common denominator; if the two fractions have not the same denominator, reduce them to a common denominator first, and then proceed as above.

Multiplication.

To multiply $\frac{3}{4}$ by $\frac{2}{7}$, the multiplier $\frac{2}{7}$, being composed of the $\frac{2}{7}$ of unity, the product will be composed of the $\frac{2}{7}$ of the multiplier, in virtue of the definition of multiplication; to take the $\frac{2}{7}$ of a number, take first the $\frac{1}{7}$, and then multiply this seventh by two. The seventh of $\frac{3}{4}$ is $\frac{3}{4\times 7}=\frac{3}{28}$; the $\frac{2}{7}$ will then be twice this, or $\frac{3\times 2}{4\times 7}=\frac{6}{28}$. It is seen, then, in order to multiply two fractions, one by the other, multiply the numerators together for a new numerator, and the denominators for a new denominator.

To multiply two proper fractions (that is, fractions less than unity), the product will always be less than the multiplicand; it is the reverse of this when two whole numbers are multiplied.

Division.

To divide $\frac{4}{5}$ by $\frac{3}{7}$, suppose the division made, and represent the quotient by the letter q. To prove this operation, multiply the quotient by the divisor; this should give the dividend. We would then have,

$$q \times \tfrac{3}{7} = \tfrac{4}{5}.$$

To multiply the quotient by $\frac{3}{7}$, is to take the $\frac{3}{7}$ of the quotient; we may then write the above expression under this form: $\frac{3}{7}$ of $q = \frac{4}{5}$. If the $\frac{3}{7}$ of the quotient equal $\frac{4}{5}$, $\frac{1}{7}$ would be three times too small: $\dfrac{1}{7}$ of $q = \dfrac{4}{5 \times 3} = \dfrac{4}{15}$; then we have $\frac{1}{7}$ of the quotient; the entire quotient should be seven times greater, or $q = \dfrac{4 \times 7}{5 \times 3} = \dfrac{28}{15}$. By comparing this result with the two fractions proposed, we will deduce this rule, viz.: *To divide two fractions*, one by the other, *multiply the terms of the dividend by the terms of the divisor inverted.* In dividing proper fractions one by the other, the quotient obtained will always be greater than the dividend; the reverse of this takes place with whole numbers.

A fraction is the more simple as the terms composing it are the more simple. To simplify operations with fractions, it is well to reduce their terms as much as possible.

It is indispensable in writing down fractions, such as have been spoken of above, to write the two terms composing them; for other fractions, it suffices to write the numerator in a certain manner, the denominator remaining always understood; these fractions, much more simple than vulgar fractions, are called decimal fractions.

Decimal Fractions.

In decimal fractions the unit admits only of subdivisions of tens, hundreds, thousands, &c., &c.; that is, for decimal fractions, the denominator is always 1, followed by one or more zeros; thus $\frac{32}{100}$, $\frac{219}{1000}$, are decimal fractions, written under the form of vulgar fractions. In general, a decimal fraction is written as if it were a whole number.

We know that a figure placed to the right of another expresses units ten times smaller than that figure. If, then, to the right of a figure expressing units we write another, it will express tens; and if to the right of this we place another, it will express hundreds, and so on.

In every decimal number, the whole part is separated from the decimal part by a period.

If the decimal number has no units, place a zero to the left of the period. Thus the number, twenty-four units three hundred and nine one thousandths, is written 24.309; three hundred and twenty-two one thousandths, is written 0.322; seven one hundredths, is written 0.07; four and thirty-two one hundredths, is written 4.32.

A decimal number does not change its value, whatever may be the number of zeros added or suppressed on its right.

To make a decimal ten times smaller, place the period one figure more to the left; to make it a hundred times smaller, move it two figures to the left, &c., &c.

To make a decimal ten times greater, move the period one figure more to the right; a hundred times greater, two figures to the right, &c.

To divide a whole number by a unit, followed by one or more zeros, it will suffice to separate from the right of the number as many figures as there are zeros to the right of the unit. The decimal number thus obtained expresses the quotient required; thus, 18729 divided by 1000 gives 18.729.

Addition of Decimals.

The addition of decimal numbers is made in the same manner as that of whole numbers; taking care, however, before commencing the operation, to write down units of the same kind under each other.

Subtraction.

The subtraction of decimal numbers is as that of whole numbers.

Multiplication.

To multiply 8.23 by 5.17 proceed as if they were whole numbers, leaving out the periods, and we obtain for product 425491. But in suppressing the period in the multiplicand, the multiplicand, and consequently the product, is 100 times too great; and in suppressing the period in the multiplier, the multiplier, as well as the product, is 100 times too great. The product will then be 100 times multiplied by 100, or 10,000 too great; to give it its proper value, divide it by 10,000, and it becomes 42.5491.

To multiply two decimal numbers, proceed *as if they were whole numbers, by suppressing the periods, and in the product point off as many figures from the right as there were decimals in the two factors.*

Division.

To divide 7.43 by 3.8, commence by making the number of decimal figures the same in the dividend and in the divisor. In this case, place a zero to the right of 3.8 which becomes then 3.80; then suppress the periods in each number, and proceed with the division as if they were whole numbers. The quotient thus obtained will require no modification, it will be correct; for in leaving out the period in the dividend, the dividend becomes 100 times too great; the quotient will then become 100 times too great. In leaving out the period in the divisor, the divisor becomes 100 times too great; the quotient will then be 100 times too little. The quotient then, in the one case, being 100 times too small, and in the other 100 times too great, will be found to be correct.

With the same number of decimal figures divide as in whole numbers; if they have not the same number of decimals, cause them to have by adding zeros to the right of the one with the less number, and then divide as in whole numbers.

To convert Vulgar into Decimal Fractions.

To convert a vulgar into a decimal fraction, divide the numerator of that fraction by its denominator; the quotient will be the required decimal. Thus, to convert $\frac{3}{4}$ into decimals, divide 3 by 4, and we get 0.75, which is nothing but $\frac{3}{4}$ transformed into a decimal.

It will frequently occur, in converting vulgar fractions into decimals, that the quotient obtained will be indefinite: thus, for example, $\frac{2}{3}$ transformed into a decimal, becomes 0.666 . . . ; the number 6 has no limit; $\frac{8}{11}$ becomes 0.727272, $\frac{2}{7}$ becomes 0.285714285714 . . . . ; the figures 2, 8, 5, 7, 1, 4, are produced indefinitely in the division.

In the same manner, a decimal having this form, 0.4562727 could be obtained.

The decimal figures that are continually produced in the same order and indefinitely, form what is called a *period;* the decimal figures which precede the first period, form what is called the decimal part, *non-periodic;* thus, 456 in 0.4562727 . . . . ; when the period commences immediately after the dot, the decimal number is called *periodic simply;* the decimal number is *periodic mixed,* when the period commences only after a certain number of decimal figures.

Squares and Square Roots of Numbers.

The square of a number is the product of this number multiplied by itself: thus, 8, multiplied by itself, gives 64; 64 is then the square of 8, and 8 is called the *square root* of 64.

To indicate that a number should be squared, write it thus $(124)^2$, which indicates that 124 is to be squared, that is, multiplied by itself. The squaring of a number presents no difficulty, whether it be an entire number or a fraction; thus, to square 24, it suffices to multiply it by itself; the product, 576, is the square sought. To square a vulgar fraction, square successively its numerator and denominator; thus, the square of $\frac{3}{4}$ is $\frac{9}{16}$; the square of the decimal 0.02 is 0.0004.

The squares of the first 10 numbers are as follows:

1, 2, 3, 4, 5, 6, 7, 8, 9, 10.
1, 4, 9, 16, 25, 36, 49, 64, 81, 100.

Knowing these ten squares, it is easy to find the square root of any number between 1 and 100; thus, for example, if we wish to find the square root of 42, we know that 42 is greater than 36, and less than 49, its square root will then be between 6, the square root of 36, and 7, the square root of 49; that is, it will be 6 and a fraction. The squares of the numbers

	1,	10,	100,	1,000,	10,000,
are:	1,	100,	10,000,	1,000,000,	100,000,000.

All numbers between 1 and 100 have their square roots comprised between 1 and 10; those between 100 and 10,000 have them between 10 and 100, &c.; but all numbers between 1 and 10 have but a single figure for their square roots; all between 10 and 100 have only two, &c.; consequently when a whole number has but two figures, the whole part of its square root will have but one figure. When a whole number has five or six figures, the whole part of its square root has three, and so on.

We know at once that the whole part of the square root of 72434 has three figures, that 3829437 has four figures, &c.

Before proceeding to extract the square root of a number, let us see what are the parts composing squares in general.

Suppose we wish to square the number 24, every number composed of two figures can at least be decomposed into *tens* and *units;* we may then write 24 under this form, 20+4, now we will square it under this form (multiply it by itself) in the following manner, taking care to show the different partial products:

$$\begin{array}{r}
20+\ 4 \\
\underline{20+\ 4} \\
4\times\ 4=\ 16 \\
20\times\ 4=\ 80 \\
20\times\ 4=\ 80 \\
20\times 20=\underline{400} \\
576
\end{array}$$

In examining the different parts of which 576 is composed, we see first 4×4, that is the square of the units; then, 20×4 and 20×4, that is twice the product of the tens by the units; and, lastly, 20×20, that is the square of the tens. It is seen, then, that the square of a number composed of tens and units is composed of three parts: 1st, the square of the units; 2d, the double product of the tens by the units; 3d, the square of the tens.

Let us now extract the square root of 729; it will be done in the following manner:

$$\begin{array}{r|l}
7.29 & \underline{27} \\
3.29 & 4
\end{array}$$

Since the given square is composed of three figures, the square root will have two, tens and units. To find the tens:—The square of tens giving hundreds cannot be found in the units 29; separate then the hundreds 7 by a dot or period; the given square will then be divided into two parts. The greatest square contained in 7 is 4, the square root of which is 2; 2 being squared gives 4, which being subtracted from 7 gives 3, bring down by the side of 3 the second part of the given square 29, we will then have 329, this number contains the double product of the tens by the units and the square of the units. We know the tens (2, or 20 units). To find the units:—We know that the double product of the tens by the units will at least give tens, and that they can then be found in the tens of 329, separate the hundreds 3 by a dot, and double the tens 2, and divide 29 by the product 4, we will obtain 7 for the units. Let us see if 7 is the proper number. We know that 329 contains the double product of the tens, 2, or 20 units, multiplied by the units 7, the product of the tens by the units is 140, this doubled is 280, the square of the units 7 is 49; then $280+49=329$, which subtracted from 329, leaves 0; the figure 7 is the figure desired, and 27 is the exact square root of 729.

In order that the whole number obtained for the square root may be the square root of the greatest square contained in the given number, it suffices that the last remainder may be less than double the whole number obtained for the root increased by a unit. To extract the square root of a vulgar fraction, extract separately the square root of its numerator, and then that of its denominator.

No further details, with reference to the extraction of square roots of numbers, will be given. What has been explained will be sufficient to understand any question of the kind, that may appear in the subsequent part of this course.

CHAPTER II.

RATIOS BY DIFFERENCE AND BY QUOTIENT.

We call ratio by difference, the result of the comparison of two numbers by subtraction; and ratio by quotient, the result of the comparison of two numbers by division. Thus the ratio by difference of 16 to 4, is 12; the ratio by quotient of 24 to 8, is 3. Every ratio is composed of two terms, the antecedent and its consequent. In the above ratio, 16 and 24 are the antecedents, 4 and 8 the consequents.

Two ratios, either by difference, or by quotient, are equal when the results of their comparison are the same. Thus the ratios by difference, $7-5=2$, $12-10=2$, are equal; so also are the ratios by quotient, $\frac{18}{6}=3$, $\frac{27}{9}=3$, equal.

Proportions by Differences.

We give the name of *proportion by differences*, to the union of two ratios equal by difference. The two ratios by difference, $7-5=2$, $12-10=2$, written in the following manner, form a proportion by difference, $7 : 5 :: 12 :$

10; this proportion is read in the following manner, 7 is to 5 as 12 is to 10. In every proportion of this kind, the first and third figures (7 and 12), are called antecedents; the second and fourth (5 and 10), consequents. 7 and 10 are also called extremes; 5 and 12, means. The difference between 7 and 5, or between 12 and 10, is called the ratio of the proportion. In every proportion by difference, the sum of the extremes is equal to the sum of the means.

Proportions by Quotients, or simply Proportions.

We give the name of *proportion* by *quotient* to the union of several ratios equal by quotient; thus the two equal ratios by quotient, $\frac{18}{6}=3$ and $\frac{27}{9}=3$, written in the following manner form a proportion by quotient, 18 : 6 :: 27 : 9; this proportion is read in the following manner, 18 is to 6 as 27 is to 9. The terms composing a proportion by quotient, bear the same names as those composing a proportion by difference.

Proportions will be frequently used in the subsequent part of this course. Thus it becomes necessary to know well how to establish them, and to know their principal properties, and to solve easily and rapidly all questions depending or flowing from them.

We know that in division the more the dividend increases, the divisor remaining the same, the greater becomes the quotient; on the contrary if the divisor augments, the dividend remaining the same, the quotient is diminished, and the reverse is the case if we diminish either the dividend or the divisor.

If the dividend and divisor augment in the same manner, the quotient does not change; thus, $\frac{18}{6}=3$. If we multiply the dividend 18 by 10, and the divisor 6 by 10, we will have $\frac{180}{60}=3$. It is easy to understand, then, that we do not change the value of a ratio by multiplying or dividing the two terms by the same number; a ratio being really a division indicated under a particular form.

In every proportion the product of the extremes is equal to that of the means. Let 18 : 6 : : 27 : 9, and then write the proportion under this form, $\frac{18}{6}=\frac{27}{9}$; from what has been said above, we can multiply without changing the value of the ratios, $\frac{18}{6}$ above and below by 9, and multiply $\frac{27}{9}$ above and below by 6, which will give us $\frac{18\times 9}{6\times 9}=\frac{27\times 6}{9\times 6}$. Suppressing the denominators in the two cases, we will have $18\times 9=27\times 6$, which we wished to show. This property is indispensable to the existence of proportions. It can be shown that when the product of the means is equal to that of the extremes, the four numbers are in proportion, and they are not in proportion when this is not the case.

Knowing Three Terms of a Proportion to find the Fourth.

Let us suppose that it is one of the extremes that is unknown, and let us represent it by x, for example; the three known terms being 18, 6, 27; we will then have

$18:6::27:x$. We know that in every proportion the product of the extremes is equal to that of the means; then $18\times x=6\times 27$. If $18x$ equal 6×27, x alone will equal the 18th part of 6×27; or, x (will equal)$=\frac{6\times 27}{18}$.

Then knowing the three terms of a proportion to find the fourth, if the unknown term is an extreme, divide the product of the means by the known extreme, the quotient will be the other extreme that we seek.

If the fourth unknown term is a mean, divide the product of the extremes by the other, or known mean. In a proportion of this form, 16 : 8 :: 8 : 4, the term 8 is a geometric mean to 16 and 4. *To find the geometric mean of two numbers, multiply them, and extract the square root of the product; it will be the geometric mean sought.*

Thus, to find the geometric mean of 16 and 4, multiply 16 by 4, giving 64, and extract the square root of 64, which is 8; 8 will be the mean sought. *To find the arithmetic mean of two numbers, add them, and divide their sum by* 2: thus, the arithmetic mean of 17 and 23 is $\frac{40}{2}$, or $=20$. *To obtain the mean of several numbers, add these numbers together, and divide their sum by the given number of numbers;* thus the mean of 12, 21, and 36, is $\frac{69}{3}=23$; the mean of 17, 22, 29, 31, and 46, is $\frac{145}{5}=29$.

By the aid of the property in all proportions, that the product of the extremes is equal to that of the means, we can easily show that if four numbers are in proportion, they will be so if the means are made the extremes, and the extremes the means; if we multiply or divide the four terms of a proportion by the same number, the terms will still be in proportion; if we multiply the first or last two terms of a proportion by the same number, the result will still be in proportion.

CHAPTER III.

GEOMETRY.

GEOMETRY is a science having for its object the measurement of *extension*. Extension has three dimensions,—*length*, *width*, *depth* or *height*.

A point is that which has none of the elements of extension; thus, mathematically speaking, a point is not visible.

A right line has neither depth or breadth, but length simply; a right line may be regarded as composed of a series of points, placed infinitely near each other, one after another.

FIG. 1.

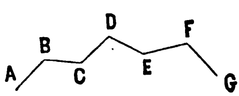


FIG. 2.

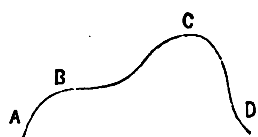


FIG. 3.

There are three species of lines: a right line, which is the shortest distance between two points, as in Fig. 1; a broken line, composed of right lines, making angles with each other, as in Fig. 2; and a curved line, which is neither straight nor broken, as in Fig. 3.

A surface has length and breadth, but no thickness; every surface can be regarded as made up of a series of lines, straight or curved, placed by the side of each other, and infinitely near, as in Fig. 4. We distinguish three kinds of surfaces—as plane, broken, and curved.

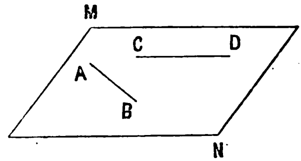


Fig. 4.

A plane surface, or simply a plane, is a surface such that if we take any two points in it at pleasure, and join them by a right line, the line will lie wholly in the surface, as the lines AB, CD, in the surface MN.

A broken surface is composed of plane surfaces, which make angles with each other, or which cut each other, as in Fig. 5.

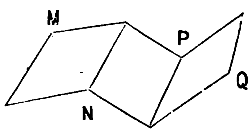


Fig. 5.

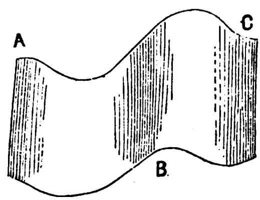


Fig. 6.

The curved surface is neither plane nor composed of plane surfaces, as in Fig. 6.

A solid unites the three elements of extension,—breadth, depth, and thickness.

Every body may be considered as composed of a series of planes, placed by the side of each other, and infinitely near: we may define a *point* to be the intersection of two lines; a *line* to be the intersection of two surfaces, and a *surface* the intersection of two solids.

An *angle* is the space, more or less great, which separates two lines cutting each other. The point where the two lines cut is called the vertex of the angle; the two lines are called sides of the angle. The size of the angle does not depend upon the length of the sides, but upon the width of the space between them. An angle is sometimes designated by a single letter placed at the vertex; at other times, and more generally, by three letters, the one at the vertex being placed in the middle.

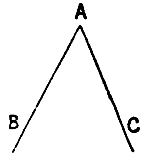


FIG. 7.

A perpendicular is a right line, which, falling upon another right line, forms with it two equal adjacent angles. ABC, ABD, being equal adjacent angles, AB is a perpendicular to CD.

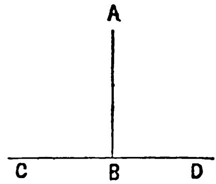


FIG. 8.

There are three kinds of angles: 1st, the *right* angle, which is the angle formed by a right line falling perpendicularly upon another right line; 2d, the *acute* angle, less than a right angle; and 3d, the *obtuse* angle, greater than the right angle; thus, ABC is a right angle, KBD an acute, and FBD an obtuse angle.

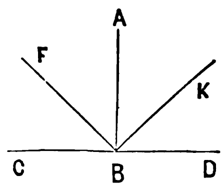


FIG. 9.

Parallel lines are lines which, being situated in the same plane, and being indefinitely produced, never meet; a right line cutting the parallel lines is called a *secant;* thus, AB, CD, EF, are parallel lines, and PR a secant.

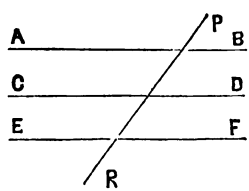


FIG. 10.

A polygon is that part of a surface bound by several right lines, which cut each other; the lines are called sides of the polygon, and taken together, they form and are called the *perimeter*.

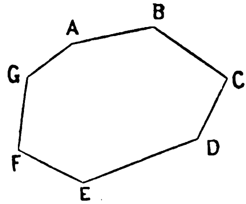


FIG. 11.—Polygon.

There are many kinds of polygons: one with three sides is called a *triangle*; one with four sides, a *quadrilateral*; one with five sides, a *pentagon*; and one with six sides, a *hexagon*, &c., &c.

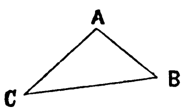


FIG. 12.—Triangle.

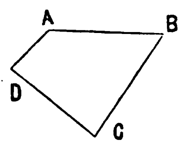


FIG. 13.—Quadrilateral.

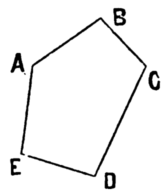


FIG. 14.—Pentagon.

Among the three-sided polygons or triangles are—

1st. The *equilateral* triangle, which has its three sides equal.

2d. The *isosceles* triangle, in which two sides are equal.

3d. The *scalene*, in which the three sides are unequal.

4th. The *right-angled* triangle, which has one of its angles a right angle: in a right-angled triangle, the side opposite to the right angle is called the *hypóthenuse*. Thus are seen the four species of triangles (p. 22):

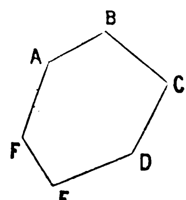


FIG. 15.—Hexagon.

In a triangle, the base is any side taken arbitrarily; the vertex of the triangle is the vertex of the angle opposite to the base, and the altitude of the triangle is the perpendicular let fall from the vertex on the base.

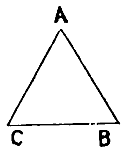


FIG. 16.—Equilateral.

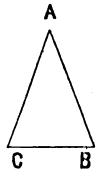


FIG. 17.—Isosceles.

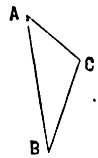


FIG. 18.—Scalene.

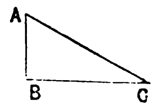


FIG. 19.—Right-angled.

Every polygon has as many angles as it has sides: thus, a polygon of six sides has six angles; one of four sides, four angles, &c., &c. A polygon is designated by letters placed at the vertices of the different angles. Among the quadrilaterals are, 1st, the *square*, which has

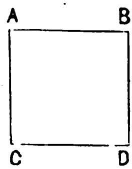


FIG. 20.—Square.

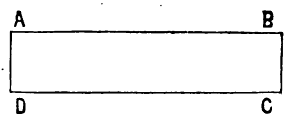


FIG. 20′.—Rectangle.

its four sides equal, and its angles right angles; 2d, the *rectangle*, which has its four angles right angles, and its opposite sides equal; 3d, the *parallelogram*, which has

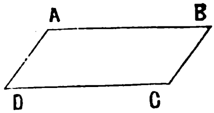


FIG. 21.—Parallelogram.

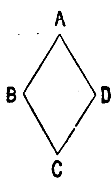


FIG. 22.—Lozenge.

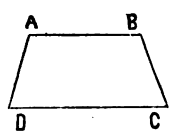


FIG. 23.—Trapezoid.

its opposite sides parallel; 4th, the *lozenge*, which has its sides equal, without having its angles right angles; 5th, the *trapezoid*, which has only two of its sides parallel. The *diagonal* in a quadrilateral is the right line joining the vertices of two opposite angles. Every quadrilateral has a base and altitude.

In a square, the base is any given side, and the perpendicular is an adjacent side; it is the same for the rectangle. The paralellogram has for base any one of its sides; the altitude is the perpendicular let fall upon the base from the opposite side: it is the same for the lozenge.

The trapezoid has for base one of the two parallel sides; the altitude is a common perpendicular to the two parallel sides.

In general, a figure is regular which has its sides and angles equal. Two figures are equal when, being laid one upon the other, the parts coincide perfectly. A triangle is *equiangular* which has its three angles equal. Two triangles are called equiangular when the angles of the one are respectively equal to the angles of the other; the sides opposite to these equal angles are called *homologous* sides.

An *exterior angle* of a triangle is formed by prolonging one side of the triangle; it is equal to the sum of the two angles of the triangle, *not* adjacent.

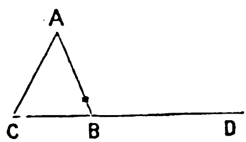


Fig. 24.—Exterior Angle ABD.

An *axiom* is a self-evident proposition which requires no demonstration. A *theorem* is a truth which only becomes apparent by a process of reasoning called a de monstration. A *problem* is a question proposed which requires a solution; thus, we *demonstrate* a theorem and *solve* a problem. The word *hypothesis* replaces, mathematically speaking, the word *supposition*.

CHAPTER IV.

The Circle and the Measuring of Angles.

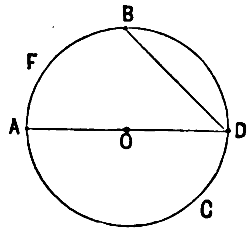


Fig. 25.—ABC, circumference; O, the centre; AO, radius; AD, diameter; AFB, arc of circle; BD, chord.

We give the name of *circumference* to a curved line, all the points of which are equally distant from a point within, called the *centre.* The part of the surface contained in the circumference is called the *circle.* Every right line joining the centre and any point of the circumference is a *radius* of the circumference; and as all points of the circumference are equally distant from the centre, all the radii are equal. The *diameter* of the circumference is the right line passing through the centre, and terminating at the circumference; the diameters are double the radii. An *arc* is any given portion of the circumference. A *chord* is a right line joining the extremities of an arc. The *sector* of a circle is the portion of the surface included by the radii of an arc; and an *inscribed figure* is one that has all of its vertices upon the circumference.

A *secant* is a right line, which cuts the circumference in two points. A *tangent* is a right line, which has but one point in common with the circumference; this point is called the *point of tangency.* A *circumscribed* *figure* is one in which all of its sides are tangents to the circumference. Every circumference is divided into 360 equal parts, called *degrees;* each degree is subdivided into 60 equal parts, called *minutes;* each minute into 60 equal parts, called *seconds.* To measure an angle, we use the arc of a circle, or degrees, &c., &c.; thus we say that an angle is equal to 30 degrees, 27 minutes, 32 seconds, &c. When we wish to measure an angle, or to find how many degrees it contains, with the vertex of the angle as a centre, describe an arc of a circle between its two sides, and then measure, by the aid of an instrument called a *quadrant,* how many degrees this arc contains; this gives the measure of the angle.

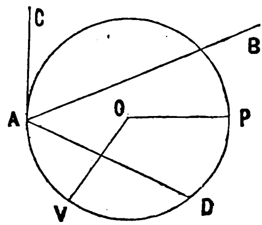


FIG. 26.—C, tangent; POV, angle at the centre; BAD, angle at the circumference, or angle inscribed; AB, secant.

If in a circumference two diameters at right angles to each other be drawn, they will divide the circumference into four equal parts, and form four angles at the centre, which are called *angles at the centre;* each of these angles is measured by the arc of the circle included between its sides. Now this arc is the fourth of 360°, or 90°; then each of the angles formed at the centre has for measure 90°. It has been seen that angles formed by perpendiculars are right angles; then every right angle has for measure 90°. An *inscribed angle* is one formed on the circumference by two chords. Every inscribed angle has for measure *half of the arc* included by its sides. An angle inscribed in a semi-circumference is measured by half the arc included by its sides, or the half of 180°, or 90°; or, in other words, it is a right angle.

In a triangle the sum of the three angles is always equal to two right angles, or to 180°. If one of the angles be a right angle, the sum of the other two will be equal to 90°. From this it is seen that a triangle can have but one right angle, or but one obtuse angle. In an equilateral triangle, the three sides being equal, the three angles are also equal; and as their sum is 180°, each one of them is $\frac{180}{3}=60°$. In a right-angled isosceles triangle, the angles opposite to the equal sides are equal, and as their sum is 90°, each one of them is 45°. Thus, knowing two angles of a triangle, it is easy to find the third.

Problem.

1st. To divide a straight line into two equal parts, let AB be the given line. From the point A, with a radius greater than the half of AB, describe two arcs of circles, the one above the other below AB. From the point B as a centre, with the same radius describe two other arcs; cutting the first two in the points D and E, join the points D and E. The line AB will be divided at the point O into two equal parts.

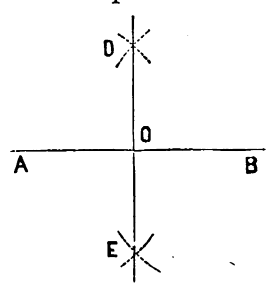


Fig. 27.

2d. Through a given point on a right line, to draw a perpendicular to that line, let O be the given point on the line AB; then take the two equal distances, OA, OB; from the point A, as a centre, with a radius greater than the half of AB, describe two arcs of circles; from the point B, as a centre, with the same radius, describe two arcs, which cut the first two in the points D and E; join the point D to E; the right line, DE, will be the perpendicular required.

3d. From a point without a given line, to let fall a perpendicular upon the line, let O be the given point without the line AB; from O, as a centre, with a radius greater than the distance from O to the line AB, describe an arc of a circle which cuts AB in the points D and F; from the point D, as a centre, with a radius greater than the half of DF, describe an arc of a circle below AB, and from the point F, with the same radius, describe a second arc, cutting the first at the point P; join O and P; OP will be the perpendicular required.

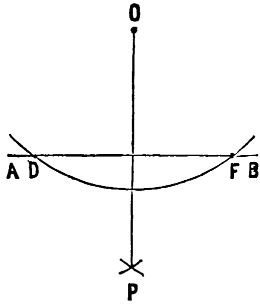


FIG. 28.

4th. To divide a given angle into two equal parts: let A be the angle; from the A, as a centre, describe between the sides of the angle, with any given radius, an arc of a circle, which shall cut the sides of the angle at the points B and C; from the point B, as a centre, with a radius greater than the half of BC, describe the arc of a circle; from the point C, as a centre, with the same radius, describe a second arc, which will cut the first at the point O, then join the point A with O. The line AO will divide the given angle into two equal parts.

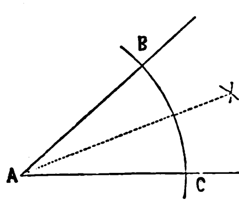


FIG. 29.

5th. To find the centre of a given circle: In the circle draw at will two chords, AB and CD; at the middle point of each of these chords erect a perpendicular, after the construction given above. The point of intersection of these two perpendiculars will be the centre of the circle.

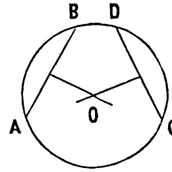


Fig. 30.

CHAPTER V.

Figures Similar and Figures Equivalent.

Two or more figures are *equivalent* when their surfaces are equal. Thus it can be conceived that a square, a triangle, a circle, although being different figures by their forms, can nevertheless inclose the same number of square yards; for example, those figures are then said to be equivalent, that is to say, of equal surfaces.

Two figures are *similar* when the angles of the one are equal to the angles of the other, and the homologous sides (sides opposite to the equal angles) are proportional. Two figures can be similar and yet have surfaces very different one from the other—the one being very large, the other, on the contrary, quite small.

To say that the triangles ABC, DEF, are similar, is to say that the angles of the one are respectively equal to the angles of the other, and that the sides are proportional.

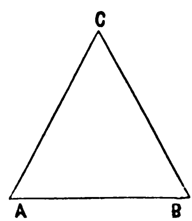


Fig. 31.

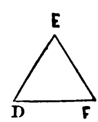


Fig. 32.

AB : DF : : AC : DE : : BC : EF. When two triangles are similar, the base and the altitude of the one are proportional to the base and altitude of the other.

The Measure of Surfaces.

To measure a line is to ascertain how many times the line contains the unit of length, the foot, or yard; to measure a surface is to ascertain how many times the surface contains the unit of surface, the superficial unit of surface, the square foot, or square yard. The surface of a triangle is equal to its base, multiplied by one half of its height.

Suppose, for example, that the base AC, of the triangle ABC, is 6 feet, and that its height BO is 4 feet, to ascertain how many times this triangle contains the unit of surface (square foot), multiply the base (6 feet) by the half of the height (4 feet), 2 feet, and we will have 12 feet for the surface, or the unit of surface is contained 12 times in the triangle ABC.

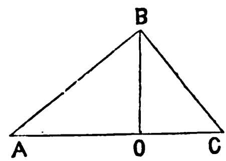


Fig. 33.

The surface of a trapezoid is equal to its height, multiplied by half the sum of its parallel sides; thus, to measure the surface of the trapezoid ABCD, add the two parallel sides AB,CD; divide their sum by 2, and then multiply the quotient by the height. If we suppose AB = 5 feet, CD = 7 feet, and AO = 4 feet, the surface of the trapezoid will equal $\frac{5 + 7}{2}$ multiplied by 4 feet, or

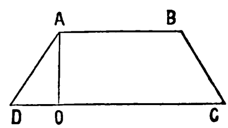


Fig. 34.

24 square feet. To measure the surface of a square, multiply the number indicating the side of the square by itself; thus, if the side of a square be 3 feet, its surface will be 3, multiplied by 3, or 9 feet. The surface of a parallelogram is equal to its base, multiplied by its height. The surface of a rectangle is equal to its base, multiplied by its height.

Problem.

To divide a straight line into any number of equal parts: let AB be the given right line, to be divided into three equal parts. From the point A, draw the right line AC, making an angle with AB; take upon AC three equal parts, AF, FG, GR; join the point B with R, through each of the points, F, G, &c.; draw the right lines GM, FO, parallel to BR, and the line AB will thus be divided into three equal parts, AO, OM, MB.

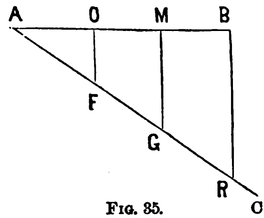


Fig. 35.

To Measure a Circle.

To measure approximatively the length of a circumference, the number of feet that it contains, repeat three times, and one-seventh its diameter. Suppose we wish the length of a circumference whose diameter is 7 feet, to find this length, multiply 7 by 3, giving 21, and then add the $\frac{1}{7}$ of 7, which is 1, thus giving 22 feet for the length of the circumference.

The measure of a circle is its circumference, multiplied by the half of the radius.

To find how many square feet a circle of 14 feet radius contains, first find the length of the circumference, which is equal to 28 feet $\times 3 + \frac{28}{7} = 88$; then multiply this by half of the radius, or 7: the product is 616 square feet.

Planes and Projections.

A plane has already been defined to be a surface, such that, taking two points in it at pleasure, and joining them by a straight line, that line will lie wholly in the surface.

A straight line is perpendicular to a plane when it is perpendicular to all the right lines (in that plane) drawn through its extremity in the plane. The name of *vertical* is given to every straight line which has a direction parallel to the plumb-line.

Every line is *horizontal* which is perpendicular to the plumb-line. A plane passed through a vertical line is a vertical plane: in order, then, that a plane may be a vertical plane, it should contain a vertical line. Every plane perpendicular to a vertical line is a horizontal plane. The *projection* of a point is the point where the perpendicular through this point pierces the plane (either vertical or horizontal).

Thus, to find the projection of the point A upon the plane M N, draw through the point a perpendicular AB, upon the plane MN; the point B, where this line meets the plane, is the projection of the point A. The projection of a point upon a

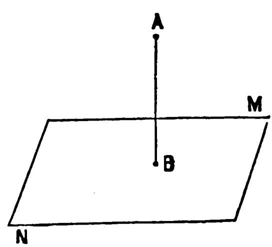


Fig. 36.

horizontal plane is called the horizontal projection; and upon the vertical plane, its vertical projection.

CHAPTER VI.

ROUND BODIES.

Sphere.—A volume, or solid, bound by a curved surface, all the points of which being equally distant from a point within called the centre, is called a *sphere.*

The radius of the sphere is a right line drawn from the centre to any point on the surface; the diameter or axis is the right line passing through the centre, and terminating at the surface. All the radii of a sphere are equal; the diameters are also equal, and double the radii.

A *cylinder* is a solid, generated by the revolution of a rectangle about one of its sides, as an axis. In this revolution, the sides, perpendicular to the side about which the revolution is made, describe circles called the *bases* of the cylinder, and the parallel side describes a surface called the *convex surface* of the cylinder.

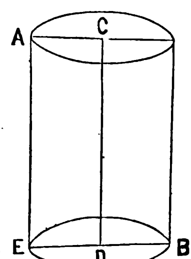


FIG. 37.—Cylinder. CD, axis; AE, generatrix.

The side about which the revolution is made, is called either the *axis* or *altitude;* the side describing the convex surface is called the *generator* or *generatrix* of the cylinder.

A *cone* is a solid, generated by the revolution of a right-angled triangle about one of the sides of the right angle: this side is called the *axis* or *altitude.* In the revolution that the rectangled triangle makes, the second side of the right angle describes a circle called the *base* of the cone; and the hypothenuse a surface, called the *convex surface* of the cone.

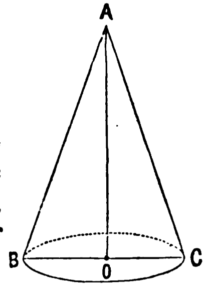


FIG. 38.—Cone. AO, axis or altitude; AB, AC, convex surface.

If we roll out or develop a cylinder upon a plane, we get a rectangle; but if we develop a cone, we get the sector of a circle.

HELICES.

Let a point on the surface of a cylinder be submitted to two motions, one upwards, parallel to the generatrices of the cylinder, the other a motion of rotation about the cylinder, parallel to the bases, and the two motions continuous and uniform; the point will take a motion resulting from the two motions acting upon it, and will describe in its movement a curve of a particular form, called a *helix.* This curve can be represented by means of a figure easy to construct. In a rectangle, draw a diagonal, and roll up this rectangle so as to form a cylinder. This having been done, the diagonal will describe upon the surface of the cylinder a curved line, which is the

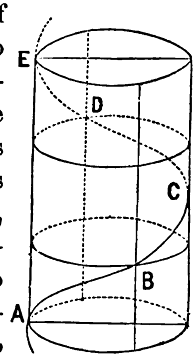


FIG. 39. ABCDE, helix.

helix. From what has been said, it is seen that if upon a plane we roll out or develop a cylinder, upon whose convex surface the helix has been traced, the base of the cylinder will be developed in a right line perpendicular to the generatrices, and the *helix* will be developed in a right line oblique to these generatrices. The distance in a right line which separates the two nearest points of the helix upon the same element or generatrix of the cylinder, is called the *turn* or *twist* of the helix, or measures this turn or twist. The *inclination* of the helix is the angle formed by the diagonal of the rectangle (obtained by the development of the cylinder), with one of the generatrices, or one of the sides of the rectangle. The *turn* or *twist* of the helix should not be confounded with its *inclination.* A helix is sometimes called a *spiral.* It will be seen that *grooves* of rifles are *spirals* or *helices.*

PART SECOND.

CHAPTER I.

General conditions to be fulfilled by the arm to be used by infantry.

THE musket or rifle, the only weapon with which infantry of the present time are armed, fulfils the double conditions of an arm of projection and of an arm of manual offence and defence. First, as an arm of projection, to destroy the enemy at a distance by means of projectiles; secondly, as an arm of manual offence and defence, in hand-to-hand combat with the bayonet. To satisfy properly the first condition, it should be easily and conveniently charged, and its fire should be certain and effective: for the second purpose, it should be strong, of simple construction, and easily handled.

Before the time of Vauban, muskets were used only as weapons of projection; and tactics prescribed the formation of six ranks for infantry, the two rear ranks being armed with long pikes, which projected beyond the front rank and formed the defence against cavalry. The invention of the bayonet restricted the use of pikes, and caused them to be abandoned in 1703. The first bayonets were nothing more than iron spikes with wooden handles: these were inserted in the muzzle of the musket, which for the time could not be fired. The adoption of this rude bayonet caused the infantry formation to be reduced from six to four ranks. Finally, Vauban invented the bayonet, which could be attached somewhat after the manner of the present one, which permitted the musket to be used at the same time, both as a weapon of projection and for hand-to-hand combat: from this time the formation of infantry was reduced to three ranks.

The length and weight of the arm should be such as not to fatigue or embarrass the soldier in his manœuvres, his march, or its general use, and should be easily kept in order.

The total length, with bayonet fixed, is about *six feet.* The English musket has less length, the Prussian the greatest, Austrian and Russian the same.

The weight of the English musket is 11 lbs. 3 oz., and the heaviest in Europe; the Spanish musket is the lightest, and weighs 9 lbs. 8 oz.

The total length of musket is such that, with three ranks, the bayonets of the first rank project at *charge bayonets* about four feet to the front; those of the second rank, near two feet; and those of the third rank, sufficiently far to render the first rank free of accidents. This total length is made up of the bayonet, the barrel, and the stock. The length of stock is nearly the same in all countries. There is greater variety in the length of the barrel and bayonet: the English have the shortest barrels, the Austrians and Russians the longest; the Saxons have the longest bayonet, Holland the shortest. In general, the total length is near *six feet,* (the stocks being equal in length): where the bayonets are longer the barrels are shorter; and with short bayonets the barrels are lengthened so as to keep to the length above mentioned, it being found proper for the formation in three ranks, which is the general formation of infantry in Europe.

As to the weight, there is a maximum and minimum limit: a weapon too heavy wearies the soldier in long marches, and in the manœuvres and exercises; one too light will be deficient in strength, and will be inaccurate in fire, from its strong recoil. Experience has given 9 to 10 lbs. as the most efficient and convenient weight.

The above weights and lengths are those of the smooth-bored muskets of the European powers (no longer used). In a subsequent part, the comparative lengths and weights of the rifles that are now in service will be given.

As the instruction of the soldier in the use of the rifle with the bayonet, as an arm of offence or defence, forms no part of our present purpose, it is unnecessary to enlarge upon it. It may, however, be observed, that the ability to use the bayonet may under many circumstances be of great importance, and a course of instruction and drills with this view will furnish the soldier with a means of defence, when exposed in single combat with an enemy, or when engaged in siege operations, that may often save his life.

CHAPTER II.

Determination of the trajectory of a projectile in vacuo.—Different kinds of motion.—Line of sight.—Line of fire.—Angle of sight.—Angle of fire.—Principal properties of the trajectory.

All bodies in nature have two distinct conditions; viz., that of *rest*, and that of *motion*. A body is said to be at *rest* when it preserves the same relative position with reference to other bodies with which it is compared. A body is said to be in *motion* when it occupies at successive instants of time different points in space.

Inertia.—There is an inherent property in bodies which prevents them from passing from a state of *rest* to that of *motion*, or the reverse, without the aid of some foreign cause. This property is called *inertia.*

If a body at *rest* be acted upon by a force which tends to impart *motion*, and at the same time by an equal force tending to check motion, the body remains at rest; but if the two forces are unequal, and the former the greater, the body is set in motion. *The kind of motion*, *the space passed over by a body*, *its velocity*, *and the direction of its movement*, depend upon the number and nature of the forces that act upon it. *The kind of motion* is ascertained by a comparison of the distances passed over by a body in equal portions of time.

Uniform motion.—If the spaces passed over in equal portions of time are equal, the motion is said to be *uniform. Uniform motion* can only be produced by a force of impulsion which acts but for an instant, and then ceases to act.

If, upon the contrary, the spaces passed over in *equal portions of time* are *unequal*, the *motion* is said to be *varied.*

Motion sometimes varies in an uniform manner; that is, it increases or diminishes in an uniform manner. In this case it is called *uniformly varied motion.* In *uniformly varied motion*, the spaces passed over in *equal* times are *unequal*, and the velocity is proportional to the time employed.

The cause producing *uniformly varied motion* is a *force* which acts constantly upon the body, and at each instant adds a new increase to, or diminishes by the same, the rate of motion: it is called a constantly *accelerating* or *retarding force.*

Manner of measuring velocity.—If two bodies of different volumes, but of the same substance, be acted upon by the same force, the smaller of the two bodies will have the greater velocity; but if they are of different substances, this will not always be the case. It is, therefore, necessary to consider the *mass* (to be explained hereafter) of each body.

Thus, in investigating the motion of bodies, we have to consider *the space passed over*, *the time employed*, *the mass*, and *the forces.* Each of these elements has its unit of measure. The ratio of a quantity to its unit of measure is expressed in numbers. The unit of measure for the *space* is a *foot;* for the *time*, a *second;* for the *mass*, a *cubic foot of distilled water*, at a temperature of 62° (Far.); for the *force*, it is the *force* necessary to cause the unit of mass to pass over the unit of space in the unit of time.

Velocity of uniform motion—Manner of measuring it.—The *rapidity* or *rate* of motion is estimated by the *velocity* that it imparts to a body. When this motion is *uniform*, the velocity is constant, and is measured by the *space* that the body passes over in a certain time; for the greater the space in this time, the greater will be the velocity. It results from this, that if there be taken for the unit of measure of velocity, the *velocity necessary to pass over a foot in a second*, it will suffice to ascertain the rate of any velocity,—or the number of units that it contains,—to divide the *space* passed over by the *number* of seconds of time employed to pass over it. The quotient will indicate the space passed over in a second, and the velocity required will contain as many units as there are feet in this space (since the unit is the velocity which passes over a foot in a second). From this it is seen, that the number which represents the *velocity of uniform motion* is equal to the quotient obtained by dividing the space passed over by the time employed to pass over it. So that, representing the *velocity* by V, the *space* passed over by E, and the *time* employed by T, the expression for the velocity will be $V = \frac{E}{T}$.

Expression for the space passed over.—From the expression, or equation $V = \frac{E}{T}$, we have $T = \frac{E}{V}$, and $E = VT$, which serves to calculate either the space passed over, or the time necessary to pass over it. The space passed over by a body which moves uniformly for a time T, is represented by VT; that is to say, the velocity multiplied by the time employed. From this it results, that velocity may be represented by a line containing the number of feet passed over in a second of time; or, if T = AB, and V = BC, it will be seen that the number indicating how many times the rectangle constructed on the lines AB and BC contains the unit of surface, will express the space passed over in *uniform motion* by the body under consideration.

Velocity of motion uniformly varied—Expression for this velocity.—In motion uniformly varied the velocity is not uniform, nor can it be estimated by the same means, or have a constant unit. We can, consequently, only ascertain its intensity at a given instant. To measure this velocity, suppose that the accelerating force which acts upon the body ceases its action at the moment considered; then the body takes a uniform motion, whose velocity *equals that which it had at the moment the force ceased to act*, and it is easy to calculate it. The force which produces uniformly varied motion acts continually, and with the same intensity, during all the time considered: the effect, then, that it produces at any given moment is doubled at the succeeding moment, tripled at the third succeeding, and quadrupled at the fourth succeeding moment, &c., &c.; that is, it increases proportionally to the time, so that if g represents the constant increase of velocity that the force impresses upon the body, the velocity will be g at the end of the first moment after its departure, $2g$ at the end of the second moment, $3g$ at the end of the third, and so on: at the end of a given time t it will be represented by tg; then the expression is $v = gt$, *for velocity uniformly varied.*

Expression for the space passed over in motion uniformly varied.—Upon the indefinite right line AM (Fig. 1), drawn through the point A, take the distances Aa, Aa', Aa'', &c., &c., proportional to the time employed by the body to run over the unit of space (the foot), that is to say, proportional to 1″, 2″, 3″, &c., &c. At the point a erect a perpendicular equal to g—that is, equal to the velocity acquired at the end of the first second; then, at the point a', a perpendicular equal to $2g$, the velocity acquired at the end of the second instant; at a'' a perpendicular equal to $3g$, &c., &c.; draw the lines bc, $b'c'$, $b''c''$, &c., parallel to AM, and we will have the rectangles $baa'c'$, $b'a'a''c'$, $b''a''a'''c''$, &c., &c., which

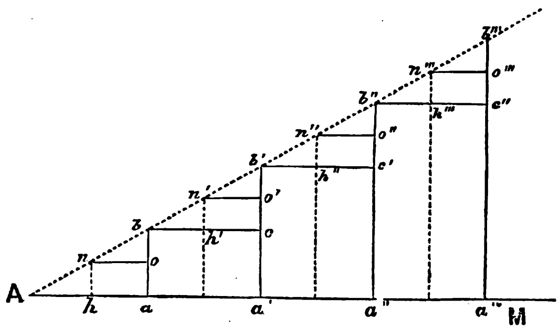


Fig. 1.

will represent, evidently, in virtue of the expression $E = VT$, the spaces pased over during the 2d, 3d, and 4th seconds. Thus, if it be supposed that the constantly accelerating force which acts upon the body, only acts by successive impulses from one second to another, the motion will be uniform; so that, as has been seen, the space passed over from one second to another will be represented by one of the rectangles that have been constructed; and finally, the total space passed over by the body will be the sum of these rectangles. It may be remarked, that in consequence of the proportionality of the right lines bc and Aa', $b'c'$ and Aa'', $b''c''$ and Aa''', &c., &c., the points b, b', b'', are in the same right line AK. Let only the first three rectangles be considered: their sum differs from the large rectangle by the four small triangles, Aab, bcb', $b'c'b''$, $b''c''b'''$. Now the sum of these rectangles is evidently inferior to the space passed over, since it has been supposed that during the first second it had no velocity, and that during the second it had only the velocity $2g$ that the body already had at the commencement of this second. We will approximate the truth by supposing that the increase of velocity takes place from half second to half second. Construct, then, the new rectangles $n\ h\ a\ o$, $n'h'c'o'$, $n''h''c'o''$, $n'''h'''c''o'''$, which add to the first rectangles, to give the space. In this manner, if we suppose the force to act from $\frac{1}{4}$ second to $\frac{1}{4}$ second, and construct rectangles, it will be seen that their sum will differ less from the large triangle $Ab'''a'''$; and if we suppose that this force should act at indefinitely small intervals, and rectangles be constructed, we will have their sum equal to the large triangle; and thus the space passed over by the body will have for measure a triangle whose base will be equal to the time (employed to run over the space), and whose altitude will be equal to the velocity (acquired at the end of the time t). The surface $Ab'''a''' =$ the space passed over, $e = Aa''' \times \frac{a'''b'''}{2}$, $Aa''' = t$, and $\frac{a'''b'''}{2} = \frac{v}{2}$; but we have $v = gt$, and then $\frac{v}{2} = \frac{gt}{2}$, or $e = \frac{gt^2}{2}$.

The equations $V = \frac{E}{T}$, $E = VT$, $v = gt$, $e = \frac{gt^2}{2}$ include every thing applicable to *uniform motion* and *uniformly varied motion.*

Gravity.—The force that draws bodies to the earth's surface, when not sustained, is called *gravity;* the direction that bodies take under the action of this force is that of the plumb-line, and is called *vertical;* the direction perpendicular to this is called *horizontal.* Experience teaches that the velocity of a falling body does not remain constant, and that the greater the height from which the body has fallen, the greater will be the shock produced. The velocity of a falling body is, therefore, proportional to the time it is falling; *gravity* is, then, a constantly accelerating force, and we can apply to it the equations $v = gt$, $e = \frac{gt^2}{2}$. The increase of velocity due to *gravity* has been determined as nearly as possible, and is $g = 32\frac{1}{6}$ feet. Substituting this value of g in the equation $e = \frac{gt^2}{2.}$, we have, after the first second, for the space passed over, $\frac{1}{2}\ g = 16\frac{1}{12}$ feet; after the second second, $\frac{1}{2}\ gt^2 = 64\frac{1}{3}$ feet; after the third second, $\frac{1}{2}\ gt^2 = 144\frac{3}{4}$ feet. Such are the elements necessary to understand in order to study the motion of bodies *in vacuo;* and now that they have been briefly described, we will proceed to that part of the subject.

The path described by a body moving in vacuo.—A projectile moving in vacuo—a musket or cannon ball for example—is subject but to the action of two forces: the *moving force*, which tends to urge it along with a uniform velocity in the direction of the axis of the piece· and *gravity*, which draws it from this direction towards the centre of the earth with a velocity progressively increasing; so that the projectile obeys neither one of these forces, but takes an intermediate direction, which is called the *trajectory*, and which will now be determined.

Through the point A (Fig. 2), draw the indefinite right line AX, and AY at right angles to it; then the oblique line AZ, indicating the direction of the moving force. If the projectile was only acted upon by the moving force, it would arrive, at the end of each unit of time, at the points A′, A″, A‴, A⁗, on AZ, at distances equal to the space passed over in a unit of time (second), and consequently

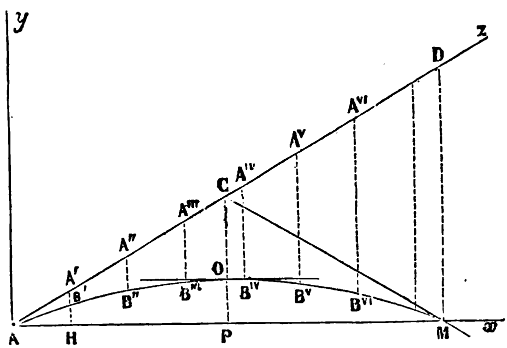


FIG. 2.

equal to each other. Now, during the time of the passage of the projectile from A to A′, that is to say, during a second, it has been acted upon by *gravity*, and has been drawn towards the earth by a quantity $e = \frac{gt^2}{2} = 16\frac{1}{12}$ feet, and will be found on the vertical A′H at the point B′, situated $16\frac{1}{12}$ feet below A′; the same at the end of the 2d second, instead of being at the A″, it will be at

$\frac{gt^2}{2}$, or $64\frac{1}{3}$ feet below, that is at B″, &c., &c. Thus B′, B″, B‴, &c., are the points through which the projectile has passed. If units of time be taken one half as great as those just considered, and operated on as have been done, we will find intermediate points of the trajectory; and if the process is carried on indefinitely, we will find an infinite number of points of the trajectory, and it will be found to be a curved line: this curve is called a *parabola*. Before discussing the properties of this curve, we will explain what is meant by *line of fire*, *line of sight*, *plane of fire*, *angle of sight*, and *angle of fire*.

The general principles of firing applicable to all fire-arms are deduced from the relative positions of three lines, one of which is this *trajectory;* the other two are the *line of fire*, and the *line of sight.*

Line of fire is the axis of the barrel, indefinitely prolonged; it is the line along which the centre of the ball is directed, and which it would never leave if it were acted upon by no other force but that of the powder.

Line of sight is the line passing through the bottom of the notch in the rear sight and the upper edge of the front sight. This line of sight is called the *artificial line of sight*, to distinguish it from the *natural* line of sight, which passes along the upper edge of the barrel, from the most elevated point at the breech, through the highest point at the muzzle. To *aim* is to direct the line of sight of an arm upon a given point; and in order that this may be exact, it is necessary that the two points determining the line of sight and the point aimed at may be in the same right line.

The *trajectory* is the curved line described in the air by the centre of the ball. While the ball is in the barrel, the trajectory coincides almost with the line of fire; but as soon as the ball leaves the piece the trajectory leaves the line of fire, and becomes more and more separated from it as the ball moves further and further from the piece. The line of fire is entirely above the trajectory, but tangent to it at the muzzle of the piece. The projectile, as has been seen, during its flight through the air, is submitted to the action of three forces,—*that of the powder*, *resistance of the air*, and *gravity*.

Plane of fire is the vertical plane passing through the line of fire; theoretically, the trajectory ought to be in this plane, but owing to many causes of deviation (as will be seen) in the projectile, it is never really in it, or if so, but for an instant.

Angle of sight is the angle formed by the line of sight and the line of fire.

Angle of fire is the angle formed by the line of fire with the horizontal. If the object aimed at is on the same level with the muzzle of the piece, the angle of sight will be equal to the angle of fire.

We will illustrate by a figure the different lines and angles that have been defined. Suppose CR to represent the barrel of a musket or rifle, RM will be the *line of fire*, AB the *line of sight*, ROTZ the *trajectory* (Fig. 3). The angle AOR, formed by the line of fire and the line of sight, will be the angle of sight; and the angle ORS, formed by the line of fire and the horizontal, will be the angle of fire.

If we consider the position of the trajectory with reference to the line of sight it will be seen, that on leaving the muzzle of the piece it is below the line of sight for a short distance, then it cuts it at the point L, near the muzzle: this point is of no consequence in considering the the firing of arms. Beyond the point L the trajectory rises above the line of sight for some distance, then it falls and cuts it again at V. This second point of intersection is called the *point blank;* the distance CV of the *point blank* from the muzzle, is called the *range of the point blank;* beyond the point V the trajectory falls below the line of sight, and continues to do so indefinitely.

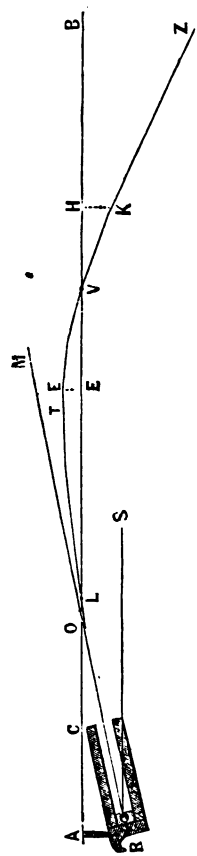


FIG. 8.

By inspecting this figure, it will be seen that if we wish to strike an object F, between the piece and the point blank, and aim directly at it, the ball will pass above it a certain distance FE, and it will be the same for all points between L and V; if to strike a point H, beyond the point blank, we aim directly at it, the ball would pass below by a certain quantity HK; and it will be thus for all points beyond the point blank. In order, then, to strike an object within the point blank, aim as much below it as the trajectory would be above it at that distance; to hit an object at the point blank, sight directly at it; for a point beyond, aim as much above as the trajectory would be below the point at this distance.

The *point blank* or *range* of an arm depends upon the angle of sight. The more this angle is increased, within certain limits, the greater will be the range; and on the contrary, the range will be diminished if we decrease this angle. (Fig. 4.) As will be seen in the figure, if

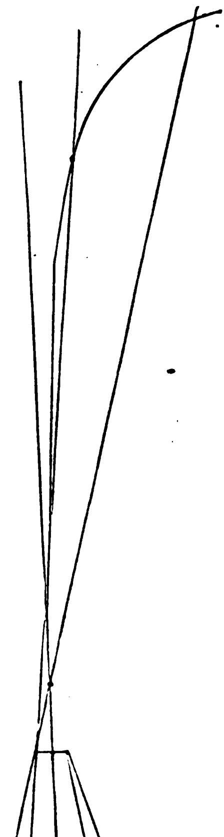


Fig. 4.

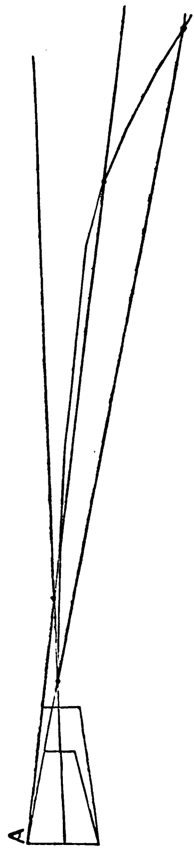


Fig. 5.

we increase or diminish the thickness of metal at the breech, we will make the angle of sight vary; if, instead of increasing the thickness of metal, we place a sight on the piece, near the breech, and raise or lower the point A, which is in the line of sight, we will increase or lessen the angle of sight. This sight, so arranged, is called an *elevating sight*, and by means of it we can vary the angle of sight, and consequently the point blank, or range.

The *angle of natural sight* does not depend entirely upon the thickness of metal at the breech and muzzle, but also upon the length of the barrel. If we diminish the length of the barrel, retaining the same thickness at the muzzle and breech (Fig. 5), we see by the figure that we increase the angle of sight; thus, of two barrels with the same thickness at the breech and muzzle, the longest one will have the less angle of sight. We see, from this, that a shorter arm, with less powder, and a range absolutely less, can, however, have a point blank more distant.

Principal properties of the Trajectory.—From the theorem, *If a force acts upon a body, we can decompose it, or replace it by two others forming the sides of a parallelogram, the diagonal of which is the given force*, we can decompose the force, or initial velocity with which the projectile moves at the moment of its departure, into two components, Ax and Ay (Fig 6). Thus the unit of velocity AA′ may be decomposed into two forces, one horizontal and the other vertical. Call a the horizontal unit A′H, and b the vertical unit A′V. The horizontal velocity will always be a, gravity which acts vertically cannot modify it, but as to the vertical velocity b, it is constantly modified by it; it is necessary, then, to subtract from b the influence of gravity $v=gt$, the vertical velocity will then become $b-gt$. The two velocities are, then, horizontal velocity a, vertical velocity $b-gt$.

Now to consider the spaces passed over. Since the projectile obeys a horizontal force a, the space passed

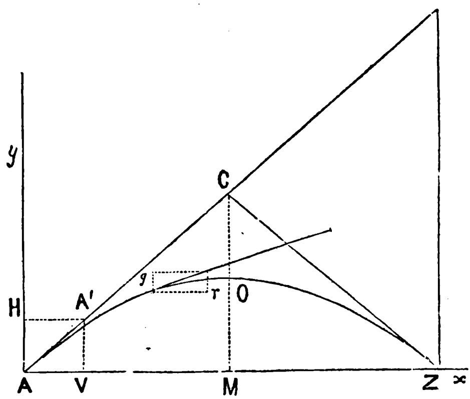


Fig. 6.

over after a time t will be at; as to the vertical force it may be remarked, that if the projectile was acted upon alone by the force of ascension the motion would become uniform, and after a time t, the space passed over, would be bt. But the action of gravity modifies this value, and the space passed over vertically will be represented by $bt-\frac{gt^2}{2}$. The *spaces passed over*, then, will be horizontal space at, vertical space $bt-\frac{gt^2}{2}$. Draw a line tangent to the trajectory at the point P, for example, the components at this point will be for the horizontal always a, since the horizontal motion is uniform; the vertical component will be $b-gt$. Let us take $Pr=a$, and $Pq=b-gt$, then we have the parallelogram whose diagonal is this tangent required.

To seek the position of this tangent at different points of the trajectory.—It will be found as the curve ascends, the tangent approaches more and more the horizontal, until at length the vertical component becomes *zero*, the tangent is then entirely horizontal; and this is the highest point of the curve, and called the *culminating point*. The vertical component becomes equal to *zero* when the force b, or velocity of ascension becomes equal to *gravity*, or the velocity of fall gt; then $b=gt$, or $t=\frac{b}{g}$. Now, if in $bt-\frac{gt^2}{2}$, the expression for the height of a body after a time t, we replace t by its value that has been found, there will be for the *culminating point* the expression $H=\frac{b^2}{g}-\frac{b^2}{2g}=\frac{b^2}{2g}$. Let us prolong the vertical through this point to C, it is evident that if the projectile had moved without yielding to the force of gravity, it would have arrived at the point C in the same time that it was necessary for it to reach the point O.

To find the height of the point C.—The space passed over would have been bt. In substituting for t its value $\frac{b}{g}$, we have for the point C, $\frac{b^2}{g}$ which is double the height of the culminating point. The projectile would require as much time to descend as to ascend, for at the point A of departure, as well as at the point Z, the vertical component would be *zero*. Then $bt-\frac{gt^2}{2}=0$, or $bt=\frac{gt^2}{2}$, and finally $t=\frac{2b}{g}$. Now at the culminating point $t-\frac{b}{g}$, then when the projectile arrives at Z, the expression for t is double what it is at the culminating point. The projectile to reach Z requires double the time it requires to reach the point O (culminating). And moving on from O the projectile will pass points symmetrically situated to those it did before arriving at O. When gt becomes greater than b, the quantities will be the same, but with contrary signs.

Range.—Now to find the value of the range of the trajectory, that is the length of AM. (Fig. 7.) If the horizontal component of the impulsive force be designated by a, the space passed over will be at. But as has been seen, the value of t at the point of fall was $t=\frac{2b}{g}$, then the range $P=at=\frac{2ab}{g}$, thus the range depends at the same time (Fig. 7), both upon the horizontal a, and the vertical b, and is proportional to the surface of the rectangle ab. The product ab can be obtained in different ways, by assigning different values to a and b. The components a and b depend on the initial velocity, and the angle of projection. If we suppose the initial velocity constant, the product ab can only be obtained in two ways. 1*st.* In supposing a the horizontal, and b the vertical component. 2*d.* In taking b for the horizontal, and a for the vertical component.

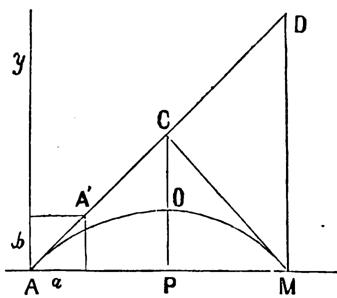


Fig. 7.

To examine the angles of projection corresponding to these two cases.—Let us first take AB=b, AD=a (Fig. 8); in this case the *line of fire* will be AC; then take AF=b, and AG=a; in this case the line of fire will be AE. These two lines of fire are equally distant from AM (45°). Now the angle BAM=MAF, since AM is the diagonal of a square. Besides the triangles ABC, EAF are equal, since they are right angled, and have the two adjacent sides equal each to each, then the angle BAC=EAF. Now BAM=MAF, BAC=EAF, then BAM−BAC=MAF−EAF; that is to say CAM=MAE. Thus the direction of the fire, in the two cases, is equally distant from 45°. And the ranges will be equal when we fire with the same initial velocity, under angles equally distant from 45°. Thus angles of fire 35° and 55° will give the same range.

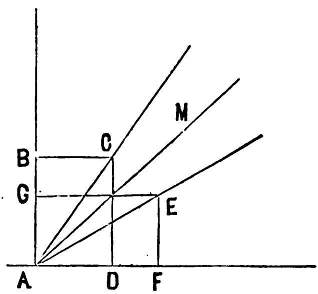


Fig. 8.

The maximum range.—In the equation $P=\frac{2ab}{g}$, 2 and g being constant, P will be the greatest possible when the product ab is at a maximum, and this will occur when $a=b$. Now upon $a+b=$ MP+PQ describe a semicircle, and erect at the point P a perpendicular PC; we know that $PC^2=MP\times PQ$. (Fig. 9.) Then MP×PQ will have the greatest value when

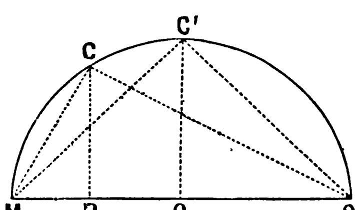


Fig. 9.

PC shall have its greatest value; the greatest value of PC is the radius OC′, and in that case $a=b$. Thus the maximum product of the two quantities a and b is obtained when those two quantities are equal, and as the rectangle thus constructed is a square, and the diagonal makes, with the adjacent sides, an angle of 45°, the greatest value of P will be obtained when the fire is under an angle of 45°.

The culminating point when the fire is under an angle of 45°.—If in the equation $P=\frac{2ab}{g}$, $a=b$, $P=\frac{2a^2}{g}$. Now, as has already been seen, the expression for the culminating point is $\frac{b^2}{2g}$, and since $a=b$, the height of the culminating point in the case of 45° is, $\frac{a^2}{2g}$. But $\frac{a^2}{2g}$ equals one-fourth of $\frac{2a^2}{g}$; that is, when the fire is with 45°, the height of the culminating point of the curve is equal to one fourth of the range. Thus far it has been seen how the ranges vary with different angles of fire, the initial velocity remaining constant.

The ranges vary with the same angle of fire, but with different initial velocities.—M being the constant angle of fire, consider two different initial velocities, $V=MB$, and $V'=MB'$, which we will decompose into $MA=a$, $AB=b$, $MA'=a'$, $A'B'=b'$; from the similar triangles (Fig. 10) we have $MB:MB'::MA:MA'$, and $MB:MB'::AB:A'B'$, or

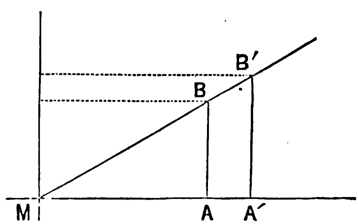


Fig. 10.

$V:V'::a:a'$, and $V:V'::b:b'$, and from these two proportions we have $V^2:V'^2::ab:a'b'$. Thus ab, $a'b'$ vary as the squares of the velocities. But since the ranges vary as the products ab, $a'b'$, we can say that the ranges vary as the squares of the velocities. Thus firing with the same angle and double velocity we will have a quadruple range, and with triple velocity a nine-fold range, &c., &c.

In Fig. 7, join the point M to C; the line CM will be tangent to the trajectory at the point M; since its symmetrical CA is tangent to it at the point A symmetrical to M, the angle CMP is called the *angle of incidence.* Now, the angle CMP is eqtual to PAC; since the triangles CMP, PAC, are equal, then the angles of incidence and departure (fire) are equal. If the angle of departure (or fire) is *zero*, or the line of fire horizontal, the trajectory will remain tangent to this line, and will be entirely below it; consequently, there will be no *point blank*, or the range is *zero.* If the line of fire is vertical, the projectile moves following this line, and gravity, which acts in the same line, but opposite direction, only serves to diminish its force, without varying its course; the trajectory coincides with the vertical, and there is no range; but as the line of fire departs from either of those directions, there is a range, and this range continues to increase, in each case, until it reaches its maximum at 45°, equidistant from the vertical and horizontal. The conclusions deduced from the discussion of the length of range, with a constant initial velocity, and variable angle of departure (or fire), are: 1st. With an angle of departure 0, the range is 0; 2d. That the range augments as the angle increases; 3d. That it is a maximum at 45°; 4th. That it diminishes beyond this limit as the angle increases; 5th. That it is 0 when the angle is 90°; 6th. That angles of departure greater or less than 45°, by the same number of degrees, give the same range. It is also seen that ranges with the same angles of fire vary as the squares of the initial velocities.

Such are the laws of motion of a projectile in vacuo. It will now be seen how these laws are modified when the projectile moves through the air.

CHAPTER III.

Flight of projectiles in air.—Modifications in the form of the trajectory, in consequence of the resistance of the air, mass, density, &c.

Resistance of the air.—The air is a colorless, invisible, and impalpable fluid, surrounding the earth. It is composed of particles infinitely small, but which, nevertheless, oppose to the movement of bodies a certain resistance.

Definition of resistance of the air—Mode of action of this force.—When a body moves through the air with a constant velocity, its forward surface encounters a certain number of particles, and pushing them, condenses them before it, forces them to deviate from the direction that they had, or to change their primitive positions. These particles react some against others, forming currents upon the sides of, and in rear of the projectile, and are replaced by other particles upon which the body acts in its turn in the same manner; in this continued action the projectile communicates to each particle of air touched (to the prejudice of its own) a certain velocity more or less. It is this loss of velocity which produces the effects that are now to be investigated, and the manner in which it is produced causes it to be called *the resistance of the air.* It may be defined to be the *inertia* that the particles of air oppose to the movement of a body, to overcome which, it is forced to use or to lose a certain part of its own velocity. The resistance of the air may be regarded as a real force—a powerfully retarding force—the intensity of which is represented by the quantity of velocity that the projectile imparts to its particles.

The resistance of the air is proportional to the square of the velocity with which the body is moving at the time considered. Thus, for example, if the velocity is double, the resistance will be quadruple; for when a body is moving with a double velocity, it ought to encounter in the same time a double number of particles of air, it loses then a double quantity of velocity; but to this double quantity of particles it impresses a velocity double that in the first case. Then, as in the one case it encounters double the number of particles, and in the other imparts twice the velocity, it is seen that the resistance is quadruple. The enunciation of the law of this resistance is not rigorously correct; it is more exact to say, that the resistance of the air is proportional to the product of the anterior surface of the body by the density of the air, and by the square of the velocity with which the body is moving at the time considered.

Modifications that the resistance of the air causes in *the trajectory.*—In regarding the resistance of the air as proportional to the square of the velocity, density of the air, and surface of the projectile, it is easy to account for the modifications that it gives rise to in the form of the trajectory. In this important matter it is not possible to demonstrate in an exact manner, what actually takes place; it is for experiment alone to determine the modified form of the trajectory. As has been seen, in vacuo, the trajectory was composed of two symmetrical parts; in the air it is not thus. If the fire is under small angles, the differences of the action of gravity are not very great, but the ranges vary considerably. In air the spaces passed over in equal times, go on constantly and rapidly diminishing, the successive lowering of the projectile tends, then, to deform completely the curve, which approaches rapidly its culminating point from its departure. Thus in air the range becomes much less than in vacuo. The tangents are not symmetrical, and the angles they make with the axes are much greater in the descending than in the ascending branch. The angle of the greatest range in the air, for the musket, is 28°; in the air it is not as it is in vacuo, an equality of range, when the fire is with an angle greater or less than 45° by the same number of degrees.

Let AM be the trajectory of a ball in vacuo, and g, already known, the constant increase of gravity. This increase (g), and the progressive velocity that it gives to the fall of the ball, being much less rapid than the initial velocity, the resistance opposed by the air to the descent of the ball will be much less than that offered by it to the ball, in its motion of translation along AZ, for the two resistances are as the squares of the velocities.

From this it results that when the ball would have been at A′, A″, A‴, A⁗, &c., without this resistance it will really only be at the points *c*′, *c*″, *c*‴, &c., all in rear of their corresponding points (Fig. 11), A′, A″, A‴, &c., by

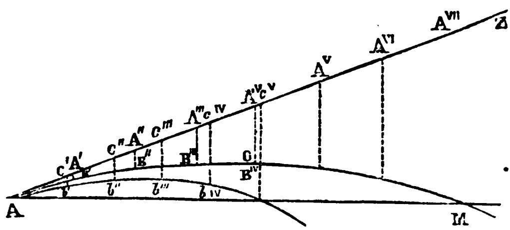


Fig. 11.

a quantity the greater as it is at a greater distance from its point of departure; for the spaces A*c*′, *c*′*c*″, *c*″*c*‴, *c*‴*c*ⁱᵛ, *c*ⁱᵛ*c*ᵛ, passed over during the unit of time become progressively smaller and smaller. On the other hand, the resistance to the vertical movement being far from proportional to the preceding resistance modifies the action of gravity in a scarcely perceptible manner, and the body falls almost the same distances as if this resistance were nothing. It results from this, that the point at which the body will be after the first second will be *b*′ below, and in rear of the corresponding B′; for the same reason *b*″ will be below, and in rear of the corresponding point B″, and so on. Then the trajectory in air will be constantly below, and in rear of its place in vacuo; and as the points *c*′, *c*″, *c*‴ are nearer and nearer the point of departure, the culminating point will be also nearer to A than O. The curvature of the line itself will be changed; for the right branch tends more and more to approach the vertical, while the left presents a flattened form. Thus the action of the air destroys the symmetry of the curve. It results from this tendency of the curve to approach the vertical that the angle of fall is greater than the angle of ascent, and in proportion as it is distant from the origin it becomes more considerable; lastly, the culminating point is lowered and the range considerably diminished.

Mass.—The resistance of the air changes materially the movement of bodies, however, as has already been stated, the difference becomes less as the projectile becomes heavier, and presents under the same volume a greater number of particles. This leads to the discussion of a new element, the *mass.* The mass of a body represents the quantity of molecules, or particles, contained in the body. In a body set in motion by a force the velocity imparted is divided or shared by all the molecules contained in the body, the force may be regarded as diffused through all the molecules in a uniform manner; then the force, or velocity can be considered as proportional to the quantity of molecules the body contains. The product of the velocity of a body by its *mass* gives what is called the *quantity of motion.*

Density.—To estimate the mass of a body, it is necessary to count all the molecules that it contains, an operation quite impossible; it is usual, then, to estimate the number of molecules contained in the particular volume that is taken as the *unit,* and to which is referred the volume that we wish to estimate. The ratio of the quantity of molecules contained in the total volume of the body, to those contained in the volume taken for the unit is called *density.* The *mass* of a body is equal to its total volume multiplied by its density, $M = v \times d$ (d being its density and v its volume). The influence of the mass and volume on the loss of velocity in projectiles can now be estimated.

The loss of velocity of two projectiles is in the inverse ratio of the densities of those bodies.—If there be two projectiles of the same form and dimension, moving with the same velocity, and experiencing consequently the same resistance, but having different densities, those two projectiles will not lose equal quantities of velocities. For, the resistance of the air being a force which acts upon all the elements of each projectile, its effect is less as those elements are the more numerous. If one of the projectiles has a density double or triple that of the other, it contains double or triple the quantity of elements of that body; then the effect of the resistance of the air upon the projectile is twice or three times less than upon the other. The effect of the resistance of the air is the loss of velocity which it occasions. The loss of velocity of two projectiles is in the inverse ratio of their densities, and we have then $V : V' :: D' : D$; V and V' being the velocities lost, and D and D' the corresponding densities.

The loss of velocities of two projectiles is in the inverse ratio of their diameters.—Again, of two spherical projectiles, of the same material and velocity, but of different diameters, it is easy to see that it is the larger projectile that loses less velocity, although it experiences the greater resistance. For the surface of a sphere augments as the square of its diameter; that is, for a diameter double or triple, the surface becomes *four* or *nine* times greater. But the volume of this body increases as the cube of the same diameter; that is to say, for a diameter *double* or *triple*, the volume becomes *eight* or *twenty-seven* times greater. Thus, when a spherical projectile has a diameter double that of another, its anterior surface is four times greater than the other, and the loss of velocity that it experiences is four times that of the other. But the first having a volume *eight* times greater than that of the second, contains *eight* times more material elements moving with the same velocity as those of the second. Then the resistance, *four* times greater, is spread over a number of molecules *eight* times greater. Thus the projectile with the double diameter experiences, in consequence of its surface, a resistance *four* times greater; but on account of its volume the effect of this resistance, or the loss of velocity, is *eight* times smaller than that of the projectile of half or single diameter. Thus the gain is double the loss, that is, the loss of velocity of the projectile of the larger diameter is the half of that with the smaller diameter; in the same manner it can be shown that the loss of velocity of a projectile of triple diameter is the *third*, &c., &c.; it is true, then, that all things being equal, the loss of velocities of two projectiles is in the inverse ratio of their diameters, and that $V : V' :: \Delta' : \Delta$, Δ and Δ' being diameters corresponding to V and V'.

The loss of velocities of two projectiles is in the inverse ratio of the products of their diameters by their densities.—In comparing the two proportions $V : V' :: D' : D$, and $V : V' :: \Delta' : \Delta$, we deduce, in consequence of the common ratio, the proportion $D' : D :: \Delta' : \Delta$; from which $D' : D :: D'\Delta' : D\Delta$, and finally $V : V' :: D'\Delta' : D\Delta$, which proves that for any projectiles whatever, the loss of velocity is in the inverse ratio of the products of their diameters by their densities.

If $V = V'$, then also $D'\Delta' = D\Delta$, an equality which serves to determine the diameters of two projectiles of different metals that ought to have the same range.

To recapitulate: the resistance of the air changes completely some of the conditions of the trajectory in vacuo, while it only modifies others; thus leaving only a certain resemblance to what it is in vacuo. It is this resemblance only of what takes place in vacuo to that in air, which has rendered the study of this chapter necessary, and which enables us to complete by comparison the discoveries made in the trajectory in air.

1st. A projectile launched in air follows a different path from what it would in vacuo if it had the same velocity.

2d. That this trajectory is an irregular curve, divided by the vertical passing through the highest point into two dissimilar and unequal parts, the left branch being of an elongated form, and that of the right a curve more and more bent or inclined as regards the vertical.

3d. That the range of this curve varies with the angle of fire and the initial velocities, and depends at the same time upon the diameter and density of the projectiles.

4th. That the maximum range is no longer 45°, but with an angle variable, depending upon the arm and projectile.

5th. That a moving force progressively increased, gives ranges that increase up to the limit at which the increased resistance of the air becomes equal to that of the initial velocity itself.

6th. That the range is greater as the projectile is larger; that it augments with the density of the projectile, and consequently with the product of the diameter by the density.

CHAPTER IV.

Estimating distances.—Necessity of properly appreciating distances.—Point blank.—Dangerous space.—Instruments for measuring approximatively distances.—The graduated tige.—Stadia.—The stadia of Corporal Malphet.—Advantages and defects of different stadia.

The trajectory, as above described, is not exactly such as a ball fired from the musket would give, but resembles it so closely that we can deduce certain conclusions from its form.

This form shows: 1st, that the point blank can be made to approach or recede from the piece, according as the line of fire makes a smaller or greater angle with the horizontal. 2d. That, in the first case the curve being more flattened stretches out almost parallel to the horizontal, while in the second it is more bent, and falls almost perpendicularly upon this line. 3d. In order to strike a point it is necessary that it should be precisely at the point blank. Now, as in practice the object to be struck has a certain height, the ball will strike it not only when it is at point-blank, but also when it shall be at such points in rear or in front of the point blank that the vertical distance of the trajectory from such points shall be equal to or less than the height of the object. In the first case, or flattened trajectory, as indicated (Fig. 12), these points are at a considerable distance MD (called the *dangerous space*) from each other; while in the second case (Fig. 12′, bent trajectory) they are near each other, being separated only by the small space M′D′ (*dangerous space*). It results from this, that to fire with accuracy, the soldier should be capable of appreciating the distance of the objects (point blank) with an accuracy such as to commit an error less than M′D′. The two figures indicate an infantry-soldier placed at point blank, and the men aim at his waist; the points D and D′ are the places at which, if he were standing, he would

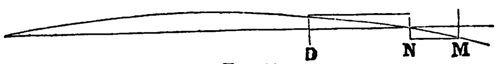


FIG. 12.

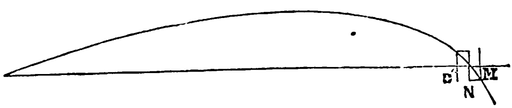


FIG. 12′.

be struck in the head, and the points M and M′ the places where he would be struck in the feet, these points limit the *dangerous space*. From this it is seen that the errors of appreciating distances can be either in front or in rear of the point blank; that is, that we may estimate in the one case the object to be at a greater distance than it is, or in the other, at a less distance; in the first case the error will be NM, N′M′, and in the second ND, N′D′, the latter are generally greater than the former; but each error being smaller than MD and M′D′, if, in the estimating of the distance, the man commits an error of MD or M′D′, or an error greater or less than MD or

M'D', he would miss the object, the *greater the dangerous space the more accurate the arm.*

This serves to show that the correct measuring of distances is one of the most delicate, as well as important points, in order to obtain accuracy of fire; especially when firing at long distances, for a certain error in estimating the distance would carry the ball a long distance in rear or in front of the point blank: officers should, therefore, attach the greatest importance to this point, and exercise the soldier at it constantly, for it is not possible to apply effectively *the rules of fire* (to be explained hereafter) if it is not known how far distant is the object to be struck. The rules of fire for such or such distances, only apply exactly to those distances.

The French chasseur-rifle with *tige*, or rifle-musket with wedge-ball (*bal à culot*), have the following limits of error or dangerous space.

Distance in yards.	Less, or ND.	Greater, or NM.	Total, MD.
At 273	54½	33	87½ yds.
" 328	49	31	80 "
" 372	41½	27	68½ "
" 437	33	22	55 "
" 546	25	17½	42½ "
" 655	20½	14	34½ "
" 764	16	11	27 "
" 872	13	7½	20½ "
" 983	8¾	5½	14¼ "
" 993	6½	4¼	10¾ "

Methods of appreciating distances.—There are two ways of appreciating distances: 1st, by the eye alone; 2d, by the aid of instruments. The first is the one to which the most importance is to be attached, and at which the soldier should be most constantly practised, as in the excitement of battle he would not be capable of using an instrument, were he provided with one. Numerous trials, and prolonged observations in the appreciation of distances can alone give the habit, or *coup d'œil*, which enables the soldier to estimate distances with sufficient accuracy. The best course of instruction on this point is that contained in the *Instruction sur le Tir*, approved by the French Minister of War in 1843, and approved again in 1849, with additions. The English course of musketry instruction contains almost literally the same. The system of target practice recently adopted in our army is the same substantially. The second method of estimating distances is more particularly applicable to the officer, and permits a more accurate estimate of the distance. Instruments used for this purpose are of two classes: 1st, those which serve to estimate distances by means of the apparent size of the objects; 2d, those that serve to estimate by doubling the images. Instruments of the first kind are alone applicable to army use, and are two in number, the *graduated tige* and the *stadia*. The graduated tige is the simplest of the two in its construction; and it is, like the stadia, based upon the fact that an object appears smaller as it is more distant. From this we see, that if we have the means of measuring the apparent height of an infantry soldier, equipped and of the medium height, we can by this means determine the distance of the soldier from us, if it be previously determined that such an apparent height corresponds to this distance.

Let O (Fig. 13) be the position of the eye; AC the soldier; BD the object on which it is wished to measure his apparent height—for example, a piece of ivory or wood (tige) placed vertically two feet from the eye. The apparent height of the soldier is evidently marked on the instrument (tige) BD by the visual rays, that, leaving the eye, pass tangent to the soldier's head and feet.

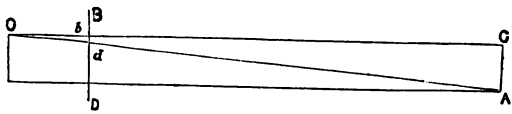


FIG. 13.

Now those two rays form a right-angled triangle, in which the apparent height *bd* is parallel to the base AC. From this we have the proportion OA : O*d* : : AC : *db*. If O*d* be 2 feet, the distance OA 200 yards, and the height of the soldier 6 feet, the preceding proportion becomes 200 yds. : 2 ft. : : 6 ft. : x, (*db*);

or, $x = \frac{2 \text{ ft.} \times 6 \text{ ft.}}{200 \text{ yds.}} = \frac{12 \text{ ft.}}{200 \text{ yds.}} = \frac{4 \text{ yds.}}{200 \text{ yds.}} = \frac{1}{50}$.

A similar calculation would, for all distances, give the apparent height desired.

These heights may then be marked on a piece of ivory or wood (tige), beginning at one extremity of it, and marking at each line the corresponding distance. To use this instrument, hold it vertically at two feet from the eye (Fig. 14), so that the beginning of the graduation may be upon the visual ray which is tangent to the head of the soldier; then lower the thumb until it becomes tangent to the ray which strikes the feet of the soldier;

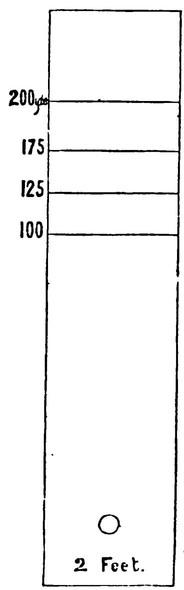


FIG. 14.

the graduation on the tige under this angle will give the distance of the man from you. This instrument, so simple, unfortunately is not very exact, if the distance exceeds 225 or 250 yards. We obtain the best results, and most promptly in marking the apparent height upon the following instrument, the *stadia*.

Upon an ivory, or metal plate, cut an isosceles triangle, whose base is equal to the apparent height of an infantry soldier at 200 yards, for example. Then the different distances, marked on the long sides of the triangle, will represent the continued and decreasing apparent height from 200 yards, up to the greatest distances. It is easy, then, always to find on it an interval equal to the apparent height of a soldier at a determined distance. For that, it will suffice to remark, that

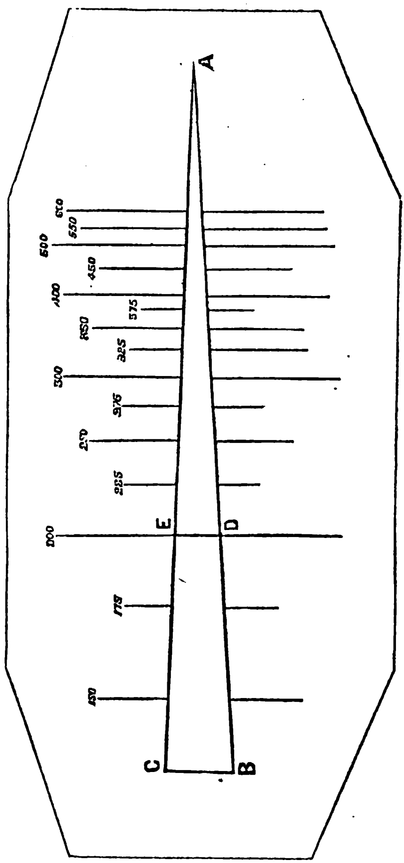


Fig. 15.

the triangles (Fig. 15) ADE, ACB, are similar, and give the proportion AD : AB : : ED : CB, which give $AD = \frac{AB \times ED}{CB}$; three terms of this proportion being known give easily the fourth. To use this instrument hold it vertically, at the distance from the eye for which the apparent heights have been calculated (that is ordinarily 2 feet), move it horizontally until the two extreme visual rays, which bound the soldier, are tangent to the two long sides of the triangle. Then the graduation corresponding to the points of contact gives the distance sought. The apparent height of a cavalry soldier, mounted, should also be marked on these two instruments. Then the distance at which a troop may be seen, either mounted or on foot, could be estimated.

Table, showing the values of CB and AD at various distances.

Distances in yards.	Values of CB.	Values of AD.	Distances in yards.	Values of CB.	Values of AD.
164	0.3070 in.	3.9370 in.	601	0.0820 in.	1.0590 in.
191	0.2817 "	3.3818 "	656	0.0748 "	0.9567 "
218	0.2222 "	2.9291 "	710	0.0708 "	0.9094 "
246	0.2046 "	2.6269 "	765	0.0669 "	0.8582 "
273	0.1850 "	2.3740 "	820	0.0630 "	0.8070 "
328	0.1535 "	1.9685 "	874	0 0590 "	0.7558 "
382	0.1299 "	1.6653 "	929	0.0551 "	0.7047 "
437	0.1141 "	1.4645 "	984	0.0512 "	0.6535 "
492	0.0983 "	1.2598 "	1038	0.0472 "	0.6023 "
546	0.0905 "	1.1613 "	1093	0.0433 "	0.5551 "

The stadia of Corporal Malphet, of the 67th Regiment of Infantry (French army).—The uncertainty that the two preceding instruments present, when distances to be measured are very great, has caused others to be sought for, which would give a nearer approximation. An instrument (Fig. 16) invented by *Corporal Malphet*, offers a very noticeable improvement. It is composed of a small cylindrical metallic tube, a slit following one of its longitudinal elements, and having at one end a hole to which the eye is applied; it limits and circumscribes the rays of light, and avoids thus the inconvenience resulting in the others from the trembling of the hand, and the uncertainty which too strong a light produces in judging of the coincidence of the extremities of the object, with the sides of the metallic triangle, or the graduated tige. A second cylinder of smaller diameter is placed in the first, and can be moved backwards and forwards by means of a ring which is attached to it, and which passes along the longitudinal slit in the first.

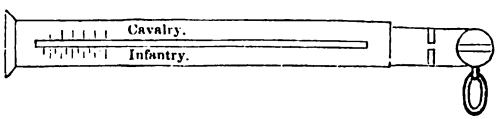


FIG. 16.

This small cylinder is opened towards the eye, and closed towards the other end by a circle, in which is cut a narrow transversal slit. When the instrument is applied to the eye, the soldier perceives, through the transversal slit, the object, the distance of which is to be measured. This object is in part concealed, or completely uncovered, according to the position of the slit in the instrument, and it is necessary to move this until the two edges of the transversal slit become tangent to the object at its extremities. Then the apparent height corresponding to the distance of the object is given by the position of this transversal slit, and is marked by lines graduated on the edge of the longitudinal slit, on the exterior of the outer cylinder. We can in the same manner obtain the apparent heights corresponding to all other distances, whether for infantry or cavalry; and the instrument completely graduated can be employed according to the previous explanations. The distance sought is read upon the line corresponding to the position of the transversal slit.

M. Porro, a Sardinian officer, has invented a very ingenious lunette for the measuring of distances; but it is expensive, and gives rise easily to errors, the trembling of the hand, and blowing of the wind, producing them. And when we look in the direction of a forest, the threads in the interior of it cannot be distinctly seen. M. Minié has also invented an interesting and ingenious lunette; it is graduated upon the principle of the superposition of images.

Advantages and disadvantages of different Stadia.— The graduated tige, and the stadia, properly called, are instruments simple in construction and easily to be used, but unfortunately they are far from fulfilling all the conditions that are requisite in an instrument to be used for the estimation of distances. Among the inconveniences presented by them are the following: 1st, the least inclination of the tige or the stadia causes great errors; 2d, it is almost indispensable that each instrument be graduated for the particular soldier who is to use it, for the length of the arm, and consequently the distance of the eye from the instrument, varies with each individual. And again, the apparent height of objects varies with the degree of perfection of sight.

Some of these defects have been obviated by Malphet's instrument, and in addition, it has the advantage, or is capable of being used by weak-sighted persons, by placing a concave glass at the open end of the large cylinder. The last two instruments are expensive, and that of Porro is easily injured.

CHAPTER V.

Construction of the trajectory of a musket or rifle.—The practical method of constructing the curve.—Calculation and definition of the *mean point of impact*.—Rules of fire for the rifle or musket.

It has been seen how the resistance of the air modifies the form of the trajectory; it will be necessary to complete the study of this curve to show how this modification may be introduced in the determination of the path of the ball; but as it is impossible to do this mathematically, recourse must be had to experiment. This consists in firing the arm whose trajectory is to be found, and in then tracing or drawing the trajectory thus obtained.

Different ways of firing an arm.—There are three methods of firing. The *first*, is to fix the piece in a vice, firmly, and to fire it thus; the *second*, to fire it supported against the shoulder, having at the same time the muzzle resting on some fixed object; the *third*, to fire from the shoulder, the muzzle not supported by any object. Of these three ways, the second is the one generally employed; it is less long and tedious than the first, and more accurate than the third, and resembling sufficiently what actually takes place in service, to give good results in practice.

Definition of the mean trajectory.—If at each time that an arm is fired, without changing the charge or the direction, the trajectory should be the same, it would be easy to determine its form and position relative to the line of fire. But it is not so. Numerous causes, which produce irregularity, and have each a particular effect, cause the projectile to follow at every fire a different path. These different curves are near each other during the first instant of the ball's flight, but become more and more separated as their flight continues, and form in space a number of curves, among which is one occupying a *central position* with reference to the others. This is the *mean curve*, by its position and form, that is sought and used for the determination of the rules of fire of an arm; for it is that one with which we are less apt to commit errors.

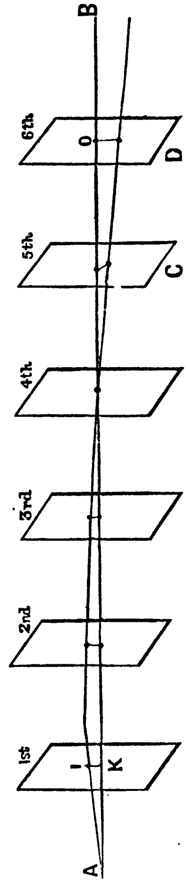


FIG. 17.

Manner of constructing this curve.—To trace this curve, place at different distances, upon the same line and level, screens of canvas, and fire upon them in the direction of the line a number of shots, aimed in the same manner; then find upon each screen the point that occupies a mean position with reference to all the points struck. These different *mean points* will belong to the mean trajectory, and will cause it to be easily constructed. But it may be obtained in a similar manner, and quite as exact, in determining successively each of those points, by placing in succession at different distances a target, and firing upon it, and finding at each position the mean point struck.

Manner of measuring the distance of the points struck from the centre of the target.—The target used in this experiment is square, and divided off into square feet, and numbered from the centre. The centre of the tar-

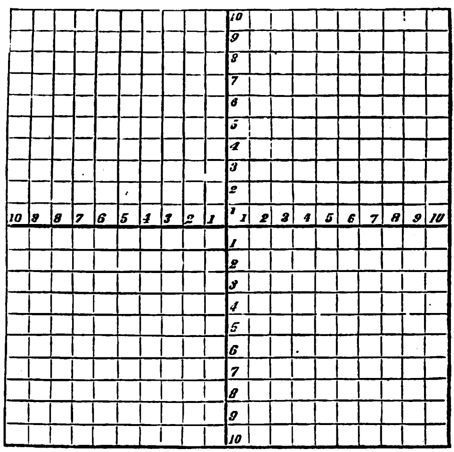


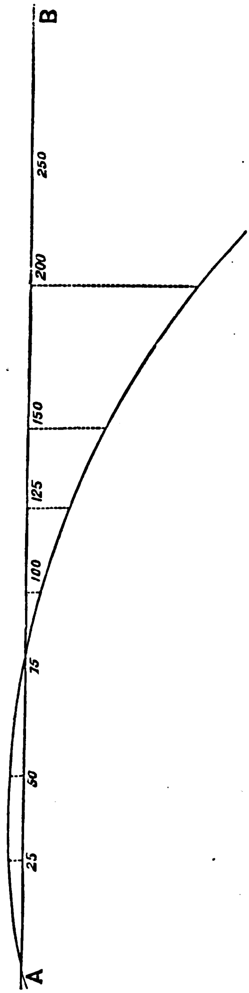
Fig. 18.

get is the middle point of the square, and the points struck by the balls are measured upon the vertical and horizontal lines passing through this point. To measure the distance of the points struck, rule upon a sheet of paper five columns: the first column to the left is for the *number of shots* fired; the following columns bear at their tops the words, *above*, *below*, *right*, *left*. Begin with the balls in the upper left quarter of the square, and with the shot nearest the horizontal through the centre, and proceed to those the more distant. These vertical distances of the points struck, seen by means of numbers marked upon the target, are written in the column *above*. The distances of those points from the vertical through the centre are measured on the horizontal, through the centre of the target, and written in the column *left*. We continue this operation through the superior right quarter of the square, then the inferior left quarter, and finish with the inferior right quarter.

No. of shots.	Above.	Below.	Right.	Left.
1	1 foot.	......	2 feet.	......
2	2 "	......	......	1 foot.
3	......	3 feet.	2 feet.	......
4	......	2 "	1 "	......
5	......	1 "	......	2 feet.
	3 feet.	6 feet.	5 feet.	3 feet.
		3	3	
		3=36 in.	2=24 in.	
		5)36	5)24	
Errors of the mean point of impact.		$7\frac{1}{5}$ in.	$4\frac{4}{5}$ in.	

To calculate and define the mean point of impact.—Let it be supposed, after having operated as indicated above, that for five balls the points struck are such as are marked in the above table; to complete the operation, find the point of the mean trajectory at this distance—that is, the point that occupies a mean position among the points struck by the balls. Now, add the distances comprised in the different columns: it is found that the sum of the *vertical* distances *above* is *three feet*, and that of the *vertical* distances *below*, *six feet:* the difference indicates that the balls have generally carried below the point aimed at; and the quotient of this difference, by the number of balls fired, represents the mean distance, $7\frac{1}{5}$ inches, at which the balls are found below the horizontal which passes through the point aimed at (the centre). This quantity can be considered as the vertical distance of the mean point struck, which is called the point of *mean impact.* In the same manner, by operating on the columns *right* and *left*, we get $4\frac{4}{5}$ inches for the mean distance of the point of impact from the vertical through the centre, and which can be considered as the horizontal distance of the mean point of impact, whose vertical distance has been found to be $7\frac{1}{5}$ inches. These numbers are then the arithmetic means representing the vertical and horizontal distances of the *mean point of impact*, the point about which are grouped, symmetrically, or almost so, the five points struck,—point through which passes the mean trajectory of the five balls fired. Consequently the distance of this point determines the position of the point of the trajectory which corresponds to the distance at which the experiment has been made.

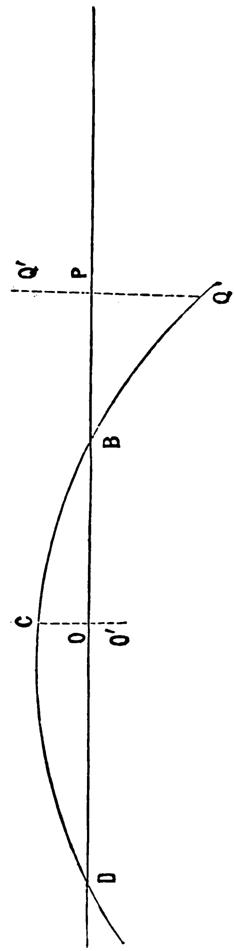
To trace the trajectory.—It results from this, that if a similar operation is made for all points between the muzzle of the musket or rifle and the limit at which it is wished to trace the mean curve, we obtain the distances of all points of this curve, and it can then be easily drawn. But to save the time and trouble necessary for such a labor, we limit ourselves to finding the points corresponding to the principal distances, such as 25 yds., 50 yds., 75 yds., 100 yds., 200 yds., 300 yds., &c., and then use them in the following manner:



Upon the indefinite right line AB (Fig. 19), representing the line of sight, take lengths proportional to the distances, 25 yds., 50 yds., &c., &c., and through each point thus found draw a perpendicular, upon which measure the vertical distance found for the *point of mean impact* corresponding to this distance. Join all the points thus found by a curve continuous and regular: this curve is the same nearly as if we had obtained all the points of mean impact and joined them; or in other words, it is the *mean trajectory* of the arm. This method, simple and expeditious, presents sometimes irregularities; when, for instance, owing to the difference of height of the points of mean impact, the curve presents inflexions that reason and common sense refuse to admit. In this case, rectify in the following manner: by taking into consideration the general form of the curve, and trace it in such manner as to leave as many points above as below, and give it a mean direction between all the points. This is done by increasing the less and diminishing the greater heights in a convenient manner. In every case, before making the rectification, seek to ascertain the causes of these irregularities, and endeavor to remedy them, if possible, by new experiments. Such is the method to be followed to determine, with any thing like accuracy, the trajectory of an arm. It was in this manner that the French determined the trajectory of their musket, firing with a charge of 138 grains, and ball 0.62 of an inch. The precautions taken for this important operation, the skill of the marksmen that fired, the care with which they verified by calculation and corrected by the drawing the data obtained, all induce the belief that the utmost confidence may be given to the results of their labors, and that the trajectory thus determined was as nearly correct as it is possible for it to be.

Rules of fire for the rifle or musket.—In examining with care the curve of the trajectory of the rifle or musket, it is seen, at first, that it cuts the line of fire (Fig. 20) in two points; one situated at a little distance from the muzzle, the other more distant. These points D and B are called *points blank* of the arm. They are the only points where an object placed upon the line of sight can be struck by the ball; for if it be situated between them the trajectory passes above, and if beyond (the second) B, it passes below. It is important, then, to know how to remedy this inconvenience, and strike the object, whatever may be its position on the line of sight. Now, if it is nearer than B, in O for example, the trajectory will pass above it, by a quantity equal to OC; but to hit it, it must pass through

O. As the trajectory and line of sight are invariably bound together, and in the same vertical plane, the plane of fire, it is necessary to make them revolve in this plane, about the point D as a centre, until the line of sight passes through O′ situated below the point O, and at a distance equal to OC. Then, evidently, the trajectory will pass through O, and the object placed there. Then to strike a point within the *point blank* we must sight or aim below. If, on the contrary, the object to be attained is beyond B, at P for example, the trajectory will pass below it a distance equal to PQ; and by means inverse to the preceding, it is seen that to hit it we must sight above, at a distance PQ′=PQ. Now, if it is important to know how to aim, in general, when the object is not at point blank, it is not less important to know the *quantities* by which to aim *above* or *below* the point, according to its distance from the arm. These quantities constitute what are called the *rules of fire*. It is necessary to have two kinds of rules of fire; to wit—those that the soldier can apply upon the drill-ground and in target-practice, and those that he



can use in the presence of the enemy. The first may be more numerous and complicated; but the second, lest they may not be applied, ought to be simple, easy, and as little restricted as possible; for the soldier, carried away by the ardor of combat, aims rapidly, and fires almost horizontally, without regard either to rules of fire or tactical prescriptions.

It is, on this account, considered by the French necessary, and indispensable even, for the point blank of the arm to be confined within the ordinary limits of battle; and it is for this reason that, for the infantry of the line, they have rifle-muskets *without elevating sights.*

CHAPTER VI.

Elevating sights.—Necessity for them.—Manner of graduating them.—Constructing them from the trajectory, and the reverse.—Conditions to be fulfilled by them.

FROM what has already been stated, it appears that when an arm has but one line of sight it is necessary, in general, to prescribe that the soldier shall aim at a point higher or lower than the object to be hit. This practice, which presents inconveniences even at short distances, becomes impossible when the object is at a very great distance: for then it is necessary to raise the line of sight many feet; and in that case not only do we want the point to aim upon, but still we are obliged to complicate the rules of fire, so that the soldier becomes confused, perhaps, and neglects to apply them. In order to avoid these inconveniences, we seek to multiply the number of *points blank* of the arm, and give more lines of sight. It is by means of *elevating sights* that the difficulty is overcome: thus the object of these useful appendages is to give the means of always aiming directly at the object to be hit, without elevating or lowering the arm, at all points not at the point blank.

To explain in what consists the elevating sight, and how it is permitted to aim directly at the object to be struck.—Let GO be the line of sight of an arm, AGK the line of fire, and O the point to strike. As this point is beyond the point blank, it will be necessary, as seen previously, to aim at a point M, situated above the point O, a distance OM equal to ON. The line of sight will then be CGM, and the trajectory will pass through O. If instead of the line of sight CGO we use C′GN, and sight with it directly on the point O, as the angle MGO

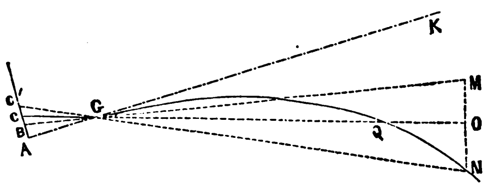


FIG. 21.

is equal to the angle OGN, the line CGO will be upon BGM (Fig. 21); that is to say, precisely in the position that has been given to it in sighting upon the point M, which the rules of fire indicate. Then the result will be the same, and the trajectory will, as previously seen, pass through O. This explained, it is easy to see that the position of C′GM is determined by the line C′A, erected perpendicularly at the point A to the axis of the barrel. It is this line that is called generally the *elevating sight* of the arm. It is composed of two parts; one of which is AC, the distance of the axis of the barrel from the highest point of the upper surface of the same; and the other CC′, the distance that it is necessary to add to AC to determine the line of sight, C′GN. It is this distance CC′ that it is proposed to fix, and to mark, by a little apparatus, to which is given the name of *elevating sight*, and which is soldered upon the upper surface of the barrel. The question, then, is to find the different values of CC′, corresponding to the distances at which we wish to fire, and to mark them on the above designated sight. This is called *graduating* the sight. There are different ways of doing this, the following being one of the most simple.

Manner of graduating the elevating sight of an arm.—After having made dispositions similar to those prescribed for determining the trajectory, take arbitrarily a sight, and one about such length as we wish to determine. Prove, by four or five shots, that with it all the balls can be placed in the target. When it has been so modified that this condition can be fulfilled, commence the operation. Fire, with a rest, thirty or forty shots, having care to aim always at the same point, and then measure the distances of the points struck from the point aimed at. If we have aimed with the line of sight CO (Fig. 22), and find the point of mean impact has a fall ON of three feet, for example, below the point O, mark upon the target a black spot N, very distinct, and situated three feet below the point at which we aimed. Then, with the same sight, direct the piece upon the point O, and, keeping it firmly in this position, move up the slide of the elevating sight until the visual ray which passes its upper surface, and the upper edge of the front sight, falls exactly on the centre of the black spot N. When this is done, the position of the slide indicates the height of the sight for the distance considered; for the line of sight C′N that it determines is the one, according to what has been previously stated, that should be directed upon the point O, in order to strike that point. Mark this point by a line on the sight, and mark the corresponding distance also on the opposite edge of the sight.

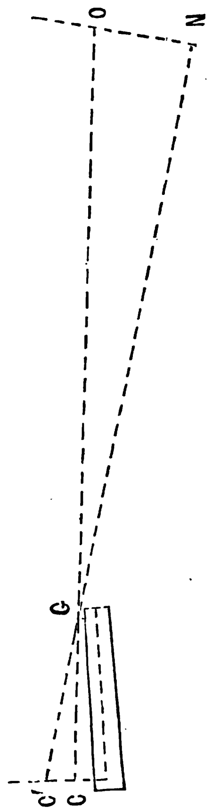
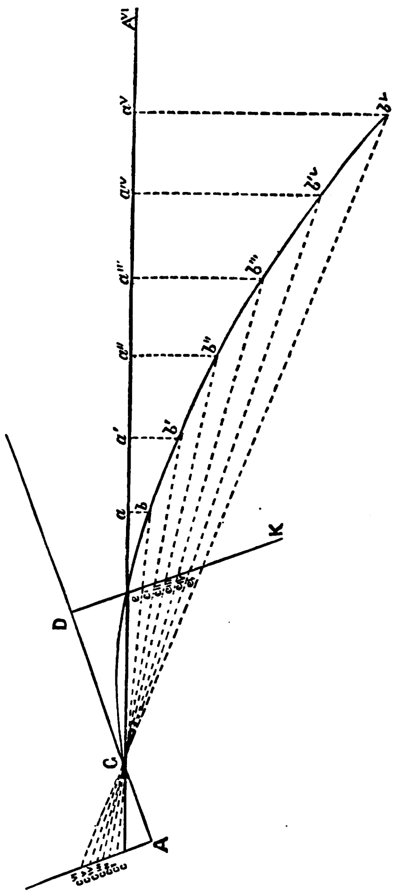


FIG. 22.

To avoid errors, and the difficulties of execution which this second part of the operation presents, suppose that the two triangles C′CG, and OGN, are similar (and they are so without sensible error), then calculate directly CC′ by means of the proportion CC′ : CG :: OG : ON, which the similarity of the triangles gives. From this proportion we have $CC' = \frac{CG \times ON}{OG}$, an expression in which CG, the length of the barrel, ON, the falling of the trajectory, and OG, the distance of the target, are known.

Verification of the elevating sight by means of a *graphic construction which enables us to determine the trajectory from the sight, and, reciprocally, the sight from the trajectory.*—Having determined the sight by one of the two preceding methods, corresponding to the distances at which we have fired, we ought, before marking definitely its graduations, to verify their accuracy, in order to correct any errors that unknown or unseen causes may have occasioned. This verification consists in constructing the trajectory by means of the elevating sight, and in seeing if it be regular; and if not, to rectify it; and to deduce from these rectifications the necessary corrections for the elevating sight. For this purpose let CGA″ (Fig. 23) be the line of natural sight, and AD the position of the line of fire. From G take a distance GA equal to the length of the barrel; between



the rear and front sight, and reduced to the scale of $\frac{1}{m}$. Through the point A erect the perpendicular Ac^{vi}. It will, evidently, be upon this perpendicular that we ought to calculate the elevating sight. Now, to construct the trajectory, mark upon this perpendicular lengths equal to the graduations of the elevating sight, with these various divisions reduced to the scale of $\frac{1}{n}$, and join the points thus found to G. The prolongation of these lines will represent the artificial lines of sight of the arm, and consequently contain each a point of the trajectory. To determine these points, it will be necessary to take upon GA″ points a, a', a'', &c., distant from G quantities corresponding to the graduations of the elevating sight; then the perpendiculars to GA″, drawn through a, a', a'', will contain also the points of the trajectory sought: their intersections with the corresponding lines of sight will give the position of these points b, b', b'', &c., and the trajectory will be the regular curve joining them. Now, it may be remarked that the elevating sights, with their graduations, being in general very small, their lengths reduced to the scale of $\frac{1}{n}$ will be even much less, and that they can scarcely be measured graphically without great chances of error. It would then be important in the preceding construction to substitute for the lines Ac, Ac', Ac'', &c., lengths proportional and similarly situated, but greater and more easily measured with the dividers. Through the point D on AD draw the perpendicular DK parallel to Ac^{vi}; this line will cut the lines of sight in the points e, e', e'', &c., &c., so that the distances De, De', De'', &c., &c., will be proportional to Ac, Ac', Ac'', &c., and can be used for them in the construction of the trajectory. It only remains, then, to determine the position of the point D, so that the lines De, De', De'', &c., may have such lengths as may be desired to give them to facilitate the construction. The similarity of the triangles DGe and cGA permits easily to determine this position. Those triangles give the proportion Ac : AG : : De : GD. Ac is the elevating sight reduced to the scale $\frac{1}{n}$; it is then $\frac{H}{n}$. AG is the length of the barrel reduced to the scale $\frac{1}{m}$; it is then $\frac{l}{m}$. De is the length with which we wish to represent the elevating sight: and suppose it to be the natural length; then De=H. It then results that the preceding proportion becomes $\frac{H}{n} : \frac{l}{m} : : H : GD$; whence $DG=\frac{ln \times H}{m \times H}=l \times \left(\frac{n}{m}\right)$. Thus the point D will be, in this hypothesis, at a distance from G equal to the length of the barrel multiplied by the ratio of the denominators of the scales. If, for example, we suppose that the scale of the elevating sight is $\frac{1}{10}$, and that of the horizontal distance $\frac{1}{100}$, we will have $\frac{n}{m}=\frac{1}{10}$; then for the solution of the problem it is necessary to take GD equal to one tenth of the natural length of the barrel. The distances De, De', De'', &c., will represent, then, the successive graduations in natural lengths; the determination of the points e, e', e'' &c., will not be liable to the same chances of error as the points c, c', c'', &c.; consequently, the results obtained will be less inaccurate. The trajectory having been determined by the latter means with all the accuracy desirable, it must then be examined with care, to see if it does not offer some irregularity incompatible with the form as given. If it be free from all defects, it is to be inferred that the elevating sight has been well determined. If, on the contrary, it presents irregular inflections, they must be corrected, and then the graduations corresponding to this correction be determined in an inverse manner to the one indicated.

Conditions to be fulfilled by elevating sights.—This terminates what has to be said with reference to elevating sights. Nevertheless, before leaving the subject, some of the conditions that they should fulfil will be enumerated. Whatever may be their form, they ought to be at the same time simple and strong, so arranged as not to embarrass the handling of the arm in the exercises, or in marching, &c., &c.; their use should be simple and certain; the soldier should not experience the slightest hesitation in the choice of the height at which the slide should be set; finally, it ought to be arranged so as to give lines of sight at all distances from the muzzle of the piece up to the limit of its range. This last condition has for its object to avoid the use of *rules of fire*; this condition is not well fulfilled in the elevating sight used by the French. (See plate.) For distances less than 335 yards

FIG. 24.

it has three lines of sight fixed, which necessitates rules of fire too complicated. The circular elevating sight proposed by Minié (Fig. 24) is free of these inconveniences, and would probably have been adopted if the first had not been but recently adopted and fixed upon the arms. The elevating sight is only used in the French service by special corps. The infantry of the line at present use rifle-muskets without this sight.

CHAPTER VII.

Causes of irregularity and want of accuracy of fire.—Defective positions of the line of sight.—Recoil.—Powder.—Defects in the barrel.—Wind.—Motion of rotation.—Direction of this motion.—Movement of the musket-ball inside the barrel.—Windage, its object and effects.—Effect of a motion of rotation about an axis parallel to the direction of the trajectory.

Causes of irregularity and want of accuracy of fire.—In the chapter in which the curve of the *mean trajectory* was described, it was stated that many causes, not yet explained, influenced the course of the ball, and caused it to vary at almost every shot. Some of these causes of irregularity it is proposed to investigate, limiting the investigation to those which have the most influence, and indicating what precautions should be taken, and what circumstances avoided, in order to secure as great accuracy of fire as possible.

The causes producing variations in the trajectory are numerous, all of which have an influence more or less marked upon the accuracy of fire. Some are due to exterior causes, independent of the projectile, its form, or particular disposition, or to the arm. Others, upon the contrary, are derived directly from the a m.

We will now examine the first class, and afterwards consider the second. In consequence of their nature, the causes of irregularity of the first kind, which may be called accidental, can be corrected or modified by a good marksman; for they originate, in general, with him, from his manner of holding the piece, the loads, or the manner of loading.

Inclining the piece to the right or left.—The first cause of inaccuracy originating with the soldier is the bad or faulty position that he gives to his piece in the act of firing, by inclining it to the right or left. This fault tends to carry the ball to the side to which the piece is inclined, and to diminish the range (Fig. 25). For example, let AB be the barrel: if it is inclined to the right in firing, the front sight *g* will be inclined to the right, it is true, but to such an extent that it may not be considered; while the rear (elevated) sight A will take a more considerable inclination.

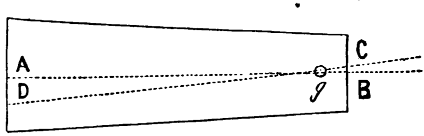


FIG. 25.

The line of sight will then be a straight line CD, making, with the axis of the barrel AB, a certain angle. Now, whatever may be the position of the barrel, the ball moves always in the vertical plane of fire which is determined by the line of fire, and the line through the highest points of the barrel, at the breech and muzzle, this plane having for trace the line AB, which passes to the right of the line of sight

CD, and, consequently, to the right of the point aimed at. From this faulty aiming the projectile goes to the right. It will be seen, in the same manner, that if it inclines to the left, the ball will go to the left; that is, that the ball goes to the side of the inclination of the piece. It is easily seen that the range is also diminished; for if the elevated sight (rear) is inclined to the right or to the left, it will have less height; the total sight will be in this case CD (Fig. 26), which is less than AC, its true height. The range GL′, which

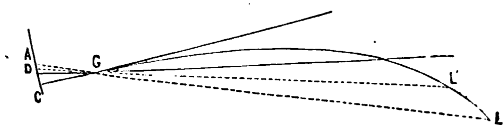


FIG. 26.

corresponds to DC, is shorter than GL, which corresponds to AC: thus, as stated above, the range is shortened.*

Fig. 26′ represents the cross-section of a musket with its rear sight. The rear sight when raised gives the proper degree of elevation, say for 900 yards, when held upright, as at A: incline it to the right, as at B, and it is evident, that although aim is taken with the 900 yards sight, the elevation is lowered by exactly the distance of CD. The ball would therefore not only fly to the right, but would strike low, or fall short, from want of sufficient elevation. The more the sight is inclined, the

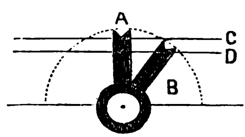


FIG. 26′.—Fig. 26′ represents better than Fig. 26 how the inclination shortens the range.

greater will be the loss of elevation, which a glance at Fig. 26′ will plainly show.

As the length of range increases, more care, if possible, must be taken than at shorter distances to keep the sight upright; for a trifling inclination to either hand, when firing at the longer distances, will throw the ball very wide of the mark.

Aiming with a coarse front sight.—The second cause of inaccuracy arising from the marksman is to aim with a coarse front sight. By this he causes the line of sight to pass to the right or left of the front sight, and as the elevated (rear) sight does not change, this line becomes oblique with reference to its first position. (Fig. 27.)

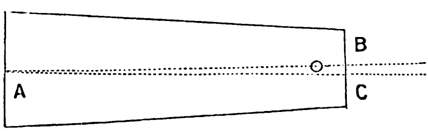


FIG. 27.

Then the ball which follows AB goes to the left (as in figure) or right of the point aimed at. A reverse result is produced when we sight by the left side of the

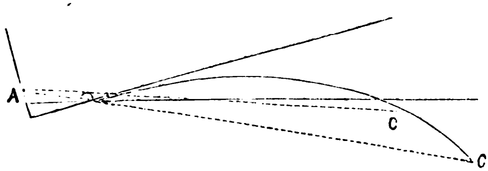


FIG. 28.

front sight. From this we conclude that the ball goes to the opposite side from the one by which we have aimed. Again, the rules of fire having been determined with a fine sight, the range will change when we sight coarsely. The range obtained in the first case being AC (Fig. 28), that with the coarse sight will be AC′ greater than AC; or in other words, with a coarse sight the balls carry higher. Such are the principal causes of inaccuracy originating with the soldier.

Defective position of the line of sight.—Other causes of inaccuracy depend especially on the arm. The *first* a faulty position of the line of sight. This line may be badly directed, in consequence of a false position to the rear or front sight (Fig. 29). If the front sight is to the right of its proper position, the ball goes to the left; if it be to left, the ball goes to the right, and it will be raised (range increased), for the summit of the sight will be lower than if it were in its true position. If, on the contrary, the rear sight is to the right of its true position, the ball goes to the right; if it be to the left, the ball goes to the left, and it will be lowered (range shortened), for the rear sight will have less height in the wrong position.

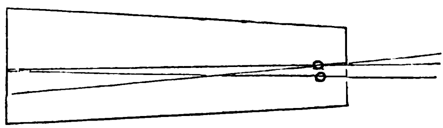


FIG. 29.

False barrels.—The *second cause* of want of accuracy of fire depending on the arm, is a *false* or *defective* barrel. On the interior of the barrel there may be a short ridge or swell, or a short depression or groove. The latter, not destroying the interior lines of the bore, may not have any effect on the fire; but the former, causing an increase of friction, may, by increasing the recoil, have an injurious effect on the fire; or the exterior form of the ball may be affected by it, and thus cause irregularity in its motion. The interior of the barrel may present a long ridge or swell, or a long groove or depression: either of these would change the interior lines of the piece, and would thus give to the ball a false direction, and cause great uncertainty in the fire.

Recoil.—The *third* cause of inaccuracy originating with the arm is the recoil, this tending to make the man turn to the side from which he fires, causes deviation in that direction, and at the same time raising the muzzle in consequence of the bend in the stock, throws the ball upwards. By pressing the piece firmly against the shoulder the recoil is lessened: theoretically, the range increased. Recoil varies with the position of the piece with reference to the horizontal. It is *greater* when the piece is fired *above vertically; less* when fired *down vertically.* When fired horizontally, the resistance to be overcome is the inertia of the projectile, and its friction as it moves through the barrel. When firing at a moving object the recoil is probably less. The bend in the stock diminishes the shock against the shoulder, by decomposing the force of the recoil into two parts—one acting through the stock against the shoulder, the other in the direction of the axis, tending to raise the piece. The vibrations of the barrel tend also to alter slightly the direction of the ball as it leaves the muzzle.

Condition of the powder.—Other causes of irregularity are, the condition of the powder, the manner of loading, and atmospheric causes. *Moisture* in powder diminishes the range; but the influence of powder being only on the velocity of the ball, causes deviation only in the vertical plane. Continued firing of damp powder may augment the recoil in consequence of an increase of friction from fouling, and thus the accuracy be impaired. The manner of ramming (the Austrians and Swiss leave an *interval* between the ball and powder, and do not ram) has also its influence on the fire; if the ball is too much rammed, the powder is pulverized, and thus its inflammation retarded: if it be not rammed sufficiently, the powder occupies too much space and the gas loses its tension. The best results are produced by giving two or three gentle taps with the rammer, just sufficient to cause the powder and ball to adhere well together: at least this is the idea generally entertained.

From what has been stated with reference to the causes of inaccuracy in the fire of the rifle or musket, it is apparent that the first essential is accuracy of construction in the barrel—the gunsmith must first do his duty. It is stated that the best Birmingham manufacturers (England) have never approached nearer to accuracy in the bore of the piece than the 350th of an inch, whereas Whitworth, in his hexagonal rifle, has attained the one 5000th of an inch. There can be no question as to the precision of fire depending upon accuracy of make. Again, the elevating sight requires the greatest possible care in its graduation. If it be inaccurately marked, the fire will be wild. The manner previously indicated for its construction must be complied with for all the various distances. Should the sight be determined for one distance by experiment, and then constructed from the similarity of triangles for other distances, it will be wrong: the trajectory of the ball, as has been seen, being far from symmetrical in its ascending and descending branches.

With the arm properly made, and the elevating sight accurately graduated, with cartridges such as are generally in use, every soldier whose eyesight is not defective, and who is not nervous to excess, can by practice and care become a good marksman. In fact, even those that are more than ordinarily nervous can become good shots, for it is well known that many of the best pistol-shots are of nervous temperaments, and have great unsteadiness of hand. While in the act of firing, the soldier should take the position the most natural and easy, the left side being in general slightly to the front, and the weight of the body mainly thrown upon the left leg: the piece should be well pressed against the shoulder. The sights having been brought to bear upon the target below the point to be aimed at, the piece should be gradually and steadily raised until the centre is covered, then the trigger should be pulled without jerk, using the forefinger. Breathing should be suspended while in the act of firing. The soldier must acquire the habit of pulling the trigger when, in raising his piece, the sights cover the bull's-eye; if he does not then fire he has to lower the piece, or move it to the right or left, and thus contract the awkward habit of *poking* the muzzle about to find the bull's-eye, which causes delay and renders the fire less certain. Where the distance is exactly known and marked upon the elevating sight, the soldier should aim with a *fine sight*, such as is represented in Fig. 30. If the distance is greater than the marked graduation used, the man should aim with a *coarse sight*, such as is Fig. 31.

It may even become necessary, at distances much beyond the graduation used, to fire with a very *coarse sight*, such as Fig. 32.

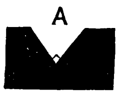


FIG. 30.

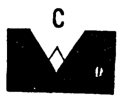


FIG. 31.

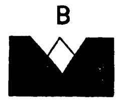


FIG. 32.

The wind.—It is difficult to measure the effect of the atmosphere, and to draw conclusive observations with reference to it: we can give only the general results of experiments. From these it is known that the intensity and direction of the wind have a certain influence upon the fire; that a wind from the left carries the ball to the right, and from the right carries it to the left; a wind from the front lowers the ball and diminishes its range, while from the rear it increases the range and raises the ball. Under the influence of a strong wind from the right or left, perpendicular to the plane of fire, it is said that long hollow balls are thrown to the right or left of that plane. In consequence of the cavity, *these balls* have the centre of gravity near the point, and the wind, acting upon the hollow cylindrical part, drives it in an opposite direction, and thus turning the point towards the wind. The velocity with which the ball moves always tends to drive it along in the direction of its point. The most marked effect of the wind is perhaps on the soldier, in preventing him from holding his piece steadily.

Position of the sun.—It is difficult to determine the effects of the sun upon the accuracy of fire. It is generally admitted that a bright clear day is not so favorable as when the sun is overcast. Such are some of the accidental causes of irregularity of fire. Before undertaking the examination of others, those depending on the projectile, it will be necessary to say something with reference to the *motion of rotation.*

Definition of motion of rotation.—Motion of rotation is such a motion that all the particles of a body having it turn about an axis interior and fixed. Thus a wheel turning on its axle, or a top on its point, are motions of rotation.

Causes which produce this motion.—This motion can originate in various manners, but such ways only will be described as are necessary to understand and properly appreciate what occurs when a musket or rifle is fired. If any round body, a billiard-ball for example (Fig. 33), lying in a state of rest on the table, be struck by a force at the point A on its posterior hemisphere, this shock gives to the ball a motion of translation forward, which all the particles of the body tend to obey with equal velocity. But as the points B, B, &c., which rest on the table, experience a friction, and from this a resist-

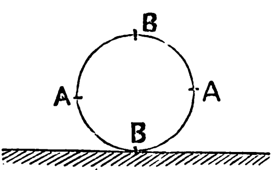


Fig. 33.

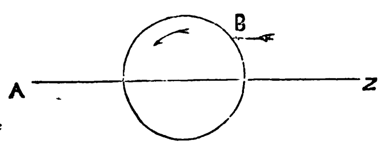


Fig. 34.

ance, they lose a part of their velocity, and move off with less than the points B′, B′, &c., which, not having experienced any friction, move off with all the velocity imparted by the shock; thus the points B′, B′, &c., retarded by the points B, B, &c., do not follow their first motion of translation, but are drawn by their own velocity in the direction B′A′B, and engender a motion of rotation in this direction. The same effect is produced by the same causes. If a ball be moving in vacuo upon the line of translation AZ (Fig. 34), and experiences a resistance from the air or a shock at the point B, it will assume a motion of rotation in the direction of this side or point. As the point B may have any position on the anterior surface of the hemisphere, it follows that the motion of rotation which takes place in the direction of the side experiencing the resistance may have any direction. As the deviation in the flight of projectiles is due in part to their motion of rotation, it becomes important to well understand and consider its direction.

Manner of indicating the direction of this motion.— For this purpose, suppose the observer to be in rear of the ball that moves, and that the direction of the motion be indicated by comparing the movements of points of the posterior hemisphere on the right or left, or on

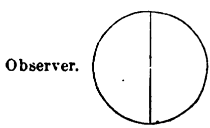


Fig. 35.—Vertical axis.

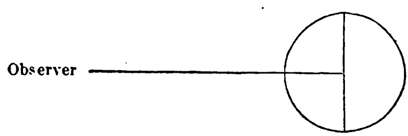


Fig. 36.—Horizontal axis.

the superior or inferior part of the ball, according as it turns on a vertical or horizontal axis. If the motion takes place about a vertical axis (Fig. 35), the points can only move from right to left, or the reverse.

If the ball turns on a horizontal axis (Fig. 36) perpendicular to the direction of the observer, the motion of rotation can only be from above downwards, or from below upwards: in the first case the points of the posterior hemisphere descend, in the second they ascend. When the axis of rotation is parallel to the direction of the motion of translation, the motion is not important to be considered for the present, it will be described afterwards in detail, as it is the motion of the ball fired from a rifle. Finally, when the axis of rotation has a position intermediate to the others (not vertical or horizontal), its motion of rotation is also intermediate to that of the others, and takes a denomination appropriate to its direction. From what has been above stated, it is easy to understand how the motion of rotation is produced, and that it exists at the same time with the motion of translation.

The direction of the deviation produced by the motion of rotation.—Let us now see what takes place when the ball moves at the same time with the two motions of *translation* and *rotation*. If the motion of rotation is from left to right, and the ball experiences a resistance or shock on its anterior surface at the point B (Fig. 35), this shock or resistance takes from the point B and those near it a part of their velocities of rotation, while the opposite points B′, &c., retain all of their original motion of rotation, which tends to drag them and the entire body off to the right. Thus, in case of rotation from left to right, every shock or resistance experienced on the anterior surface produces a deviation to the right. It can be shown, in

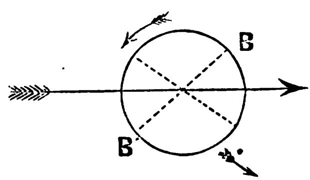


Fig. 37.

the same manner, that if the motion of rotation be from right to left, the deviation is to the left;—that it is above, if the rotation is from below above; and below, if the rotation is from above below. That is, in general, every shock or resistance exercised on the anterior hemisphere of the ball occasions a deviation in the direction of the motion of rotation.

Examination of the motion of the musket-ball inside the barrel.—Let us consider the ball at the moment it receives the action of the powder, and see what takes place from this instant up to the end of its range. If the diameter of the ball was exactly the same as that of the bore of the musket, the friction that the points on the circle of contact experience would be the same; and as the force of the powder would act symmetrically upon all points of the posterior hemisphere, no cause could retard certain points of the hemisphere and thus produce a motion of rotation. The ball would then leave the barrel having only a motion of translation, following the line of fire. If the ball were a perfect sphere, and homogeneous, the resistance of the air would be spread equally over its anterior surface and act symmetrically upon it, and, not tending to drive it from its plane of fire, would have no other effect but to retard its flight, or to shorten its range. If, then, musket-balls were perfect spheres, and homogeneous, and their diameters the same as the bore of the musket, their accuracy would depend alone upon the range, and would hence be at a maximum. But this is far from being the case; a variety of causes—the moulding or transportation, &c., &c.—prevent the balls from being either perfectly round or homogeneous.

Object of windage.—The necessity of loading easily, and of being able to do so when, after a more or less prolonged fire the piece becomes foul, renders it indispensable to leave between the calibre of the ball and that of the piece a certain difference; this is called *windage.*

The effects of windage and want of sphericity and homogeneousness.—The direct consequence of windage is, that the musket (Fig. 36) being in a horizontal position, the ball reposes upon the lower surface of the bore, and leaves between it and the superior surface an interval equal to the difference between the diameters of the ball and bore (windage); so that at the time it receives the action of the moving force (powder), the points in contact with the lower surface experience from friction a loss of velocity, which develops a motion of rotation from below (in rear) upwards, and consequently a deviation upwards. Moreover, the gas, precipitating itself into the interval between the ball and piece, presses the ball against the lower side of the bore. This produces a reaction, which tends to cast the ball upwards: this action, joined to the other, causes the ball, instead of following the lower surface of the bore, to ricochet and strike the upper surface at a point D. This impact sends the ball back against the lower side, where a new shock is produced: this causes a third rebound, &c., &c., so that the ball, instead of following the lower side of the piece, advances by bounds and rebounds until it reaches the muzzle, where it receives its last shock. It is seen from this that the ball, when it reaches the muzzle, has already been seriously deformed by these successive shocks, and that the last shock drives the ball in the opposite direction, and at the same time gives rise to a motion of rotation in the direction of the side struck, both of which causes impair its accuracy. In fine, the effects of *windage* are to alter the sphericity of the ball by the successive shocks against the interior of the barrel, and to impart to it near the muzzle, by deflection, a deviation due to this shock, a motion of rotation, and also loss of force from the escape of gas: each one of which causes it to depart from the line of fire. Now, the defects of homogeneousness, and want of sphericity, arising not only from the moulding and transportation, but from the shocks inside the piece, cause the ball to leave the barrel with its motion of rotation already determined; and from its velocity the air is heaped up in front of it, offering thus a resistance; and in consequence of the defects of the ball, this resistance is not symmetrically spread over its surface, as regards the direction of the motion of translation: this resistance would tend to develop a motion of rotation, if it had not already this motion. But the effect that should rather be investigated, is that which they have upon the rotary motion that the ball has already. The condensed air in front of the ball strikes upon the irregularities of the anterior surface, and thus causes an increased friction, which produces, as has been seen, a deviation in the direction of the rotation. From these causes it happens that a trajectory but rarely resembles the preceding one, or

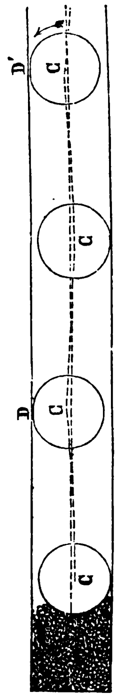


FIG. 88.

the one that follows, and the ball rarely strikes where the preceding one has, though aimed in the same manner.

Effects of motion of rotation about an axis parallel to the trajectory, or on the trajectory.—It may be remarked, that the effects which have been spoken of are produced whatever may be the position of the axis upon which the rotation of the ball takes place, provided it *does not coincide* with the *direction of the motion of translation;* and that it is this kind of rotation that is *never produced* by the shocks inside the piece.

To understand this particular case of rotation, it is sufficient to examine carefully what takes place in this case. First, when the axis of rotation coincides with the direction of translation, it results that the resistance of the air cannot change this motion of rotation; for, if it is exert-

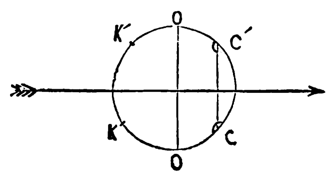


FIG. 39.

ed (Fig. 37) on a point C, tending to alter the rotation in the direction CO, it is at the end of the next instant exerted on its symmetrical point C′: the air then exerts an effort equal to that which it did at C, and this effort will produce upon the motion of rotation an effort which will counterbalance that which it felt at C, for the two are equal and symmetrical. The ball then preserves the same motion of rotation throughout its flight, for the resistance the air offers to the motion of rotation at the points C, O, K, upon one hemisphere, is equal to that which it offers to the opposite symmetrical points: the friction thus produced diminishes equally and symmetrically the velocity of rotation of all the points of the ball, none having an excess which can occasion irregularity or deviation. In this case the deviation of the projectile is *zero*. A projectile having such a motion, then, preserves it throughout its flight, and during all that time cannot depart from the line of fire upon which it was thrown by the motive power (powder). It will then have the accuracy of the *ideal* ball of which we have spoken. Unfortunately, it is too easily seen, as has been before stated, that *never* does the last shock at the muzzle of the musket produce such a motion. To secure such a motion of rotation it is necessary to use an arm different from the one thus far described, viz., the *rifle;* before describing the rifle, we will explain the manner of measuring the accuracy of an arm, and its comparative accuracy with reference to other arms.

PART THIRD.

CHAPTER I.

Different methods of measuring the accuracy of rifles.—The point of mean impact.—The mean horizontal and vertical errors.—The absolute mean error.—The radius of a circle containing a certain fraction of balls.—The per cent.—Transformation of errors with reference to the point aimed at into errors with reference to the point of mean impact.—Curves of accuracy.—Cones of fire.

Manner of measuring the comparative accuracy of two different arms (*rifles*).—When it is proposed to compare the accuracy of two arms, the first idea would seem to be to fire them, the same number of times, and under the same circumstances, at two targets of the same size and at the same distance, always aiming at the same point, and then count the number of balls that have struck. This count will instantly indicate which is the more accurate. With muskets this simple trial would be sufficient, but with rifles it is not; for two rifles may differ very much in their accuracy of fire and yet place the same number of balls, or in fact, all the balls fired, in the target; it is not possible, then, in this way to estimate their relative precision. This precision can, however, be greater for one than for the other, as can be seen at first sight, from the manner in which the balls have hit the target. One of the rifles has, for example, placed all its balls in the target, but scattered over a great surface, while the other has concentrated its balls within a smaller space: the latter rifle has evidently the greater accuracy. It becomes, then, necessary to have a more accurate way of measuring this accuracy than the one just explained. Again, some exterior cause, or some cause inherent in the arm itself, may have carried all the balls to the right or left, above or below the point aimed at, and yet concentrated within a small space, but far from this point. This is not a want of precision, for, by aiming at a point to the right or left, above or below, the desired point can be struck. Now, the manner above explained, not only fails to give accurate results, but it fails to discover the cause of error or irregularity of fire, and does not give the means of improving or correcting it. Thus it is necessary to have other methods, which not only permits to measure in a more exact manner the precision of arms, but also to regulate it, and make it as exact as possible.

The first of these methods is the *point of mean impact*, which has been previously defined and calculated. The remaining methods are,—the *mean horizontal* and *mean vertical error;* the *absolute mean error;* the *radius of a circle containing a certain number or certain fraction of the balls;* and finally, the *per cent.* The *mean horizontal error* is obtained by adding the horizontal distances that the balls have struck the target, measured from the vertical line through the centre, and dividing this sum by the number of balls: this quotient indicates how much the generality of the balls have missed horizontally the point aimed at. The *mean ver-*

tical error is obtained in a similar manner, and indicates how much the generality of the balls have missed vertically the point aimed at.

The absolute mean error.—To get this there are two methods. The *first* is very rapid, short, and simple, and consists in calculating the hypothenuse of a right-angled triangle, in which the other two sides are the *mean horizontal* and *mean vertical errors.* The *second*, which should rather be called the calculation of the *mean* of the *absolute errors*, consists in measuring for each ball its *absolute error* (the absolute error is its distance from the point aimed at), and to take, afterwards, the mean of these absolute errors, by dividing their sum by the number of balls fired. This method is very long, since to have the absolute error of each ball it is necessary to square two numbers, and then extract the square root of their sums: it does not give the same result as the first. The *mean* of the *absolute errors* is greater than the *absolute mean error;* thus should the first method be preferred.

Radius of a circle containing a fraction of the balls.—The radius of a circle containing a fraction of the balls—the third, half, or two-thirds—is a good test of accuracy. Its centre is the point aimed at; its radius is the absolute error of the *third*, *half*, or *two-thirds* of the other absolute errors arranged in order of size. Thus 3, 4, 6, 7, 9, 15, 18, 21, 25, being the order in size of the absolute errors of *nine balls*, 6 will then be the radius of the circle containing the *third* of the best shot; 9 that containing the *best half;* and 18 that containing the *best two-thirds.* If the number of balls fired be even, the circumference of the circle should pass equally distant from the two balls which limit it. For example, if we have *twelve balls*, and wish the circle containing the *best third*, the circumference should pass between the fourth and fifth balls, at equal distances, the fourth within, and the fifth without. If the number of balls be *uneven—nine*, for example—and we want the circle containing the *best half* of them, we pass it through the centre of the fifth ball.

The per cent.—Finally, the *per cent.*, the last test of accuracy, indicates how many of *one hundred balls* fired have hit the target. To get the *per cent.*, count the number of balls A that have hit the target, of the number B that have been fired, and from the proportion B : A : : 100 : x; we have the *per cent.*, $x=\frac{100\times A}{B}$.

Comparison of the five different methods of testing the accuracy of arms.—Which is preferable? The determination of the *mean point of impact* can only be used in comparing the accuracy of two arms that are exactly of the same model, and fired precisely under the same conditions; thus, in general, the *mean point of impact* gives only an imperfect idea of the accuracy of an arm. The *mean horizontal error* indicates only that the greater number of balls have gone too far to the right or left. Moreover, it may occur that two arms have the same *mean horizontal error*, while the *mean vertical error* will be very different. The *mean horizontal* or *mean vertical error* cannot be used, then, to determine the absolute accuracy of two arms.

The *radius of a circle containing a fraction of the balls* gives, also, very imperfect ideas of the accuracy of an arm, unless the balls are placed progressively distant, which cannot reasonably be expected. If, for example, after having fired one hundred balls, we take the circle containing the fifty best shots, this would not indicate if the shots following or preceding these fifty were nearer or more distant from each other, or the point aimed at.

The per cent.—If an arm be fired that has many causes of error, as the musket for example, and we wish to test the skill of the marksmen, or the accuracy of the arms, only to the extent of ascertaining how many balls can be placed in the target; this method is simple, and sufficiently exact. But if the fire be with arms of precision (rifles), it may happen that with each arm all the balls will strike the target: the method of *per cent.* will then be insufficient. The *surface* covered by the balls must be taken into account, for it may occur that with one arm the balls are scattered over the entire target, while with the other they are grouped in a small space: this latter arm would be the more accurate.

It would appear, from what has been said, that the *method of the absolute mean error* should be preferred; for it represents a quantity the ratio of which to the accuracy of the arm the mind can readily see; and this quantity, depending upon the position of each one of the balls, varies when one of them varies, and thus gives a clear and exact idea of the accuracy of an arm.

Transformation of the preceding data, or errors, into data, or errors, referred to the point of mean impact.—It has been seen that the accuracy of an arm does not consist in placing symmetrically all of its balls about the point aimed at, but rather to *concentrate them on as* *small a surface* as possible; for then it becomes easy, by modifying the manner of firing (changing the point aimed at), to cause the point aimed at to coincide with the centre of this surface—that is to say, with the *point of mean impact.* In order, then, to form an idea of what would be the accuracy of an arm from this modification, it would be necessary to have the errors of the balls calculated with reference to the *point of mean impact.* To get these it is necessary to change, or transform, the errors of the balls with reference to the *point aimed at* into errors with reference to the *point of mean impact;* for then it would be easy to make upon the latter the operations that have been indicated, in order to obtain any given data of accuracy. This transformation is very simple, for let V be the *point aimed* at, M the point of *mean impact*, and P the point (ball) whose errors with reference to the point M we wish to find (Fig. 1):

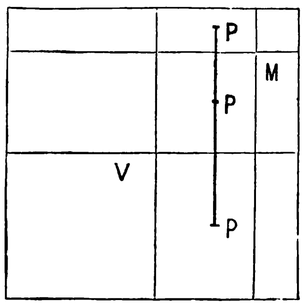
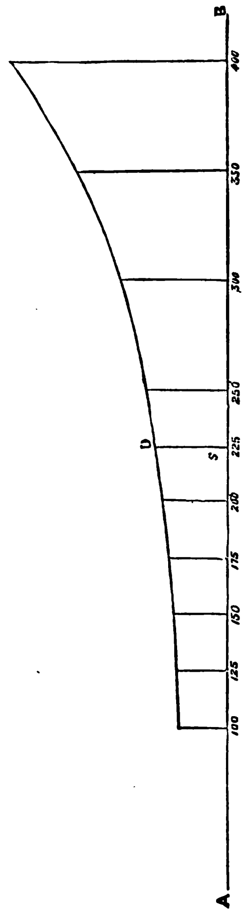


FIG. 1.

if P is above M and V, it will remain above, and we will get its vertical error with reference to M by subtracting the vertical error of M from the vertical error of P. If P is below M and V, it will remain below, and we will get its vertical error with reference to M by adding its vertical error with reference to the point aimed at to the vertical error of M with reference to the same point. Finally, if P is between M and V, and above, with reference to V, it will become inferior with reference to M, and equal to the difference of errors of P and M with reference to the point V. The same thing may be done for the horizontal errors; and thus, with a little practice, we may easily deduce the errors of P with reference to M from those with reference to V. The same operation having been gone through with for all the balls in the target, and the errors having been written down in convenient columns, in a table or register similar to the one mentioned before, it would be easy to prove the correctness of the operation. To do this, it would suffice to remember that the *vertical error* of the *mean point of impact* indicates the distance that the generality of the balls have gone above or below the point aimed at. This distance should be *zero* when the *point of impact* coincides with the *point aimed at.* Then the sum of the errors in the column marked *above* should be equal to the sum of those in the column marked *below;* and for the same reason, the sum of the horizontal errors to the *right* should be equal to the sum of those to the *left.* This verification having proved that there have been no errors in the transformation, these new errors can be used to obtain those with reference to the *point of mean impact*, as we have the others with reference to the *point aimed at*, and deduce from them any given data of accuracy that may be desired. It is by means of these new errors that we can really measure the accuracy of arms, or the skill of the marksmen; for it has been seen that it is the greatest concentration of balls about the *point of mean impact* that indicates both the one and the other, that is, greatest accuracy of the arm, and the highest skill of the marksman.

To trace curves of accuracy.—It is often advantageous to render more intelligible by drawings the data of accuracy obtained by some of the preceding methods. This is done by means of *curves*, that can afterwards be compared at once by a simple glance of the eye. The construction of these curves is very simple: Take one element of the data employed to represent the length of the *abscissa*, and then measure off on the *ordinates* of these abscissas the length equal to the other element of the given data; the curved line drawn through the upper extremities of these ordinates will be the required curve. Thus, for example, the *curve of the absolute mean error* is constructed by measuring off (Fig. 2), on a horizontal line AB, the different distances at which we have fired; and then measure, on perpendiculars at these points, distances equal to the *absolute mean error* at these various distances. By joining the summits of these perpendiculars we have the curve required. The curve of the *absolute mean errors* ought to go on increasing regularly; but owing to variations that have been indicated, it will sometimes occur, in joining the sum-



mits of the perpendiculars, that a broken line is obtained forming entering and re-entering angles. It is necessary, then, in tracing the curve, to be careful to leave as many summits above as below. This curve is at first almost horizontal; it afterwards rises rapidly, assuming the concave form.

To trace the curve of the per cent. of an arm.—Measure off, upon a horizontal line, lengths proportional to the distances at which we have calculated the *per cent.*: at each distance thus determined erect a perpendicular, upon which measure a distance equal to the *per cent.* corresponding to this distance, and then draw the curve through the summits of these lines. If this curve should present irregularities incompatible with good sense and reason, rectify them as in the previous case. This curve is almost the same in its features as the previous one, except that it is inverted with reference to it.

To construct cones of fire.—When it is wished to compare the relative accuracy of many arms, construct one curve of accuracy for each arm, and then make a comparative examination of these curves. These curves give to the practised eye all that is desired, but to persons not familiar with them it would be well to use a graphic representation, which is more easily comprehended: this is what is called a *cone of fire.* This *cone of fire* contains the trajectories of a certain number of balls,—the third, half, or two thirds, for example, of those fired. We can imagine this surface to be generated by the surface which contains those balls at 200 yards, for example, being moved on the line AB (Fig. 3), perpendicularly to it, and parallel to itself, and increasing at each instant by a quantity equal to the divergencies of those trajectories. This cone would then be (as

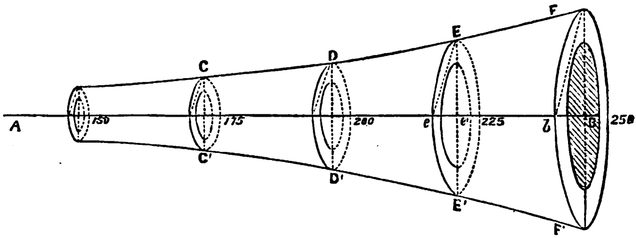


FIG. 8.

it were) a broom formed by those trajectories, and a section through it at any point perpendicular to AB would represent the space that the trajectories cover at this point, and would give an exact idea of the relative accuracy of arms at this distance. Thus this curve would fulfil perfectly the object proposed if it were easy to construct, and nothing is more simple. For, if we cut the cone by a vertical plane passing through the axis, the curves CDEF, C′D′E′F′, cut out by this plane, will be nothing but curves of accuracy of the arm, constructed with the distances as *abscissas*, and the *radii* of circles as ordinates (if the primitive generating surface is the circle which contains a certain fraction of the balls). The *cone of fire* can then be considered as a surface generated by revolving this curve about AB as an axis. Then to trace it, it will be sufficient to trace the generating curve CDEF, after known methods, and then to revolve it about the axis AB. During this revolution it will leave upon the vertical plane a trace C′D′E′F′, equal and symmetrical to CDEF, and the surface will be represented in projection by these two curves. To make still more evident the indications that this cone gives, we will represent on planes parallel, but oblique to AB, circular sections of the cone by vertical planes passed through the points 150, 175, 200 yards. Then the circles will appear under the forms of similar ellipses, giving a very clear idea of the accuracy of the arm. It is easy to construct, in the same manner, and upon the same axis, the *cone of fire* of another arm that is to be compared with the preceding, and obtain, in the same manner, its ellipses. The comparison of these ellipses will give at once the relative accuracy of the arms. It may be remarked that we can give equal inclination to the planes in making the angles *e*E*e'* and *b*FB equal.

CHAPTER II.

Rifles.—When first made.—Their peculiarity.—Methods of forcing the lead into the grooves previous to the system *à tige*.—Delvigne manner of loading.—System *à tige*.—The rifle *à tige* of Minié.—Balls.—Grooves around them, and their effect.—Tamissier's theory of the motion of balls fired from rifles.—Thiroux's theory.—The turn, or twist of grooves.—Instrument to measure it.—Manner of calculating the initial velocity of a ball.

It has been previously stated that the windage of the ball, and its movement of rotation, were the two principle causes of want of accuracy of fire; and, consequently, to improve this accuracy of fire we should suppress the windage, and force the movement of rotation to take place about an axis coinciding with the direction of the motion of translation.

The idea of suppressing the windage is not recent; almost from the invention of fire-arms, the bad effects of the shocks, or bounds and rebounds of the ball within the bore of the piece have been known, and efforts made to remedy this by giving to the ball a calibre equal to that of the piece, and facilitating its introduction into the bore by means of straight grooves, very near each other, thus forming sharp edges around the interior of the bore (Fig. 4). From this it results: *first*, that the fouling (that occurs) takes place at the bottom of these grooves, leaving thus the passage free to the ball. *Second*, that the ball, instead of rubbing against a continued surface, is only in contact with the sharp edges of the grooves, along which it easily glides, there not being much friction, and but a slight pressure of the rammer being required to force it down.

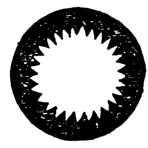


FIG. 4.

About the beginning of the 16th century, Koller, a gunsmith of Nuremburg, was led by accident to use grooves inclined, instead of the straight. It was immediately seen that these new grooves greatly increased the accuracy of the arm, and a number of them were made and given to a company of cavalry called *Carabins*, and from this circumstance they took the name of *carabines*, *carbines* (rifles).

It was in the year 1742 that Robins ascertained that one of the greatest causes of error in the fire of arms was the motion of rotation of the ball; and the manner in which he remedied this was by using the inclined grooves of the carbine; for the ball driven by blows of the rammer into a barrel having many grooves of the same inclination is moulded, as it were, into these groves, like the screw into the nut. From this it occurs, that if the charge of powder is not so great as to give the ball a velocity such as to cause it to pass out in a straight line over the edges of the grooves, that the parts of the ball imbedded in them will be forced to follow them, and the ball will thus follow, having a circular motion of translation through the piece; this circular motion, or motion of rotation, being about the axis of the piece, which is the same as the trajectory at the beginning of the movement, and for reasons previously given, it retains this motion throughout its flight, and fulfils thus the conditions that it should in order not to depart from the plane of fire. Thus the carbine, or rifle, fulfils, theoretically, the condition required for accuracy of fire; and if it is not attained in practice, it is owing to want of nicety of construction in the arm, want of instruction in the marksman, or a faulty manner of introducing the ball into the piece, &c., &c.

Different methods of forcing balls into the grooves of rifles previous to the system à tige.—The *first* consisted in forcing the ball, either naked or covered with a greased patchin, down the muzzle, with blows of a mallet, or with the rammer.

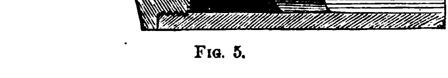


Fig. 5.

This manner of loading deformed completely (Fig. 5) the forepart of the ball, and greatly increased its length, at the same time rendering the process of loading very slow.

The *second method* was loading by the breech. This consisted in giving to the part of the bore at the breech a diameter somewhat greater (Fig. 6) than the other

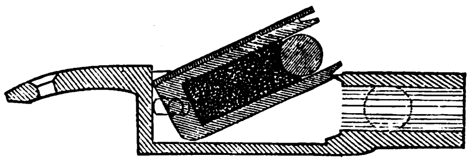


FIG. 6.

part of the barrel, and placing in it a ball larger than the diameter of the barrel, but fitting the breech. This ball, under the action of the powder, was forced into the grooves, and had to follow them, thus getting its motion of rotation. This manner of loading was simple and easy, but the complication of mechanism the breech-loader requires, and the escape of gas at the joint, were inconveniences that prevented it from being generally applicable to arms for troops.

The *third* was to load by the muzzle. It consisted in giving to the ball a circular rim, which, fitting into the

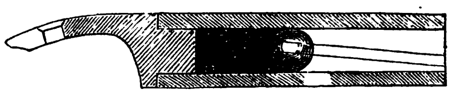


FIG. 7.

grooves (the rifle had but two) followed them, and thus had communicated to it a motion of rotation (Fig. 7). This method did not destroy completely the windage, neither did it give any notable increase of accuracy.

The *fourth* consisted in forcing down the piece a ball smaller than the bore, but surrounded with an envelope or patchin, which, penetrating the grooves, gave to the ball the rotary motion (Fig. 8). This method satisfied but imperfectly the requirements of the rifle.

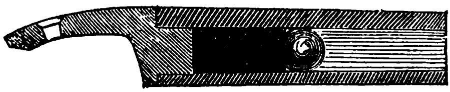


FIG. 8.

Delvigne's manner of loading.—None of the above methods of loading fulfilled the conditions required of an arm for soldiers: the first being too slow; the second offering breech-loading defects; the third not giving any marked superiority over the musket; the fourth, also, being a slow method of loading. The rifle, as an arm for infantry, would probably have fallen into disuse in Europe, and been forgotten there, had not a new method of loading been discovered by M. Delvigne, an infantry (French) officer of the royal guard. His method, after slight modifications suggested by experiment, consisted in screwing into the lower end of the barrel a hol-

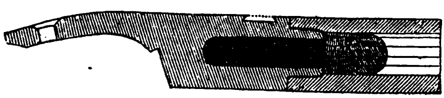


FIG. 9.

low breech, the diameter of which was a little less than the diameter of the barrel, (Fig. 9), forming thus a chamber in the bottom of the piece in which the powder could be deposited, and a projection or shoulder upon which the cartridge could rest. The cartridge was composed of a *sabot* of wood, hollowed out spherically on its upper side, and having about its inferior part a patchin of greased serge. The *sabot*, resting on the shoulders of the chamber, gave to the ball a fixed support, which permitted the person loading to flatten it slightly by means of a few gentle taps of the rammer, thus forcing the lead into the grooves; the shoulders of the chamber prevented the ball from penetrating it, and thus made its expansion into the grooves regular; the patchin served to prevent the inconveniences of fouling; and, finally, the grease, melted by the inflammation of the powder, formed with the residium an unctuous paste which offered no resistance to the descent of the ball in loading, and which was, in part, thrown out by the discharge.

SYSTEM À TIGE.

The system of Delvigne was at this time superior to all others, and was regarded as satisfying very well the conditions of an arm for troops, when a new method was announced, invented by M. Thouvenin and M. Minié, an infantry lieutenant, and claiming a marked superiority. He sought to apply to Delvigne's manner of forcing the lead into the grooves a new method. He replaced the support the ball received from the shoulders of the chamber by (Fig. 10) a rigid *tige* (iron stem) screwed into the breech, about which the powder was placed, and upon which the ball could rest, while receiving the blows of the rammer. At the same time he conceived the idea of trying a *new ball* (Fig. 11), formed of a *cone* reposing upon a *cylinder*, around the cylindrical part of which he made a groove. This groove was to receive a greased woollen thread replacing the patchin of Delvigne. In the preparatory experiments made, Minié discovered that the woollen thread was inconvenient in loading; he determined, then, to suppress, and replace it by greased paper.

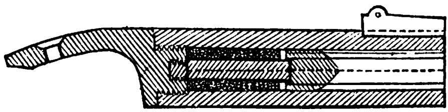


Fig. 10.

He observed, immediately on the suppression of the thread, that the accuracy was considerably increased. Encouraged by his success, and assisted by M. Thouvenin, colonel of artillery, he continued experiments with the view of perfecting his arm; and, after a long series of experiments, finally submitted it to the government for trial and approval. The cylindrical stem screwed into the breech was 1.417 inches in length, 0.34 inches in diameter—the upper end on which the ball reposed was flat; the rifle had four grooves, one turn in 4.664 feet; calibre, 0.689 in.; the ball (Fig. 11) was in weight 1.65 oz., diameter 0.676 in.; charge of powder 64.8 grains; without bayonet, weight of arm 10.15 pounds. The elevating sight graduated up to 1421 yards.

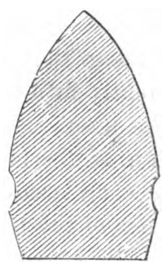


Fig. 11.

This arm was thoroughly tested by the commission appointed for that purpose, with the view to its adoption into service. During the course of experiments with it, the commission compared it with all others then in service, and with many others made for that purpose, varying in length, weight, calibre, number of grooves, width, depth, and inclination of the grooves, &c., &c. This course of detailed and elaborate experiments demonstrated that there existed a certain relation between the length of tige and the charge of powder, which it was necessary to have properly adjusted; for upon the length of tige depends the size of the circular space in which the gas is first developed. If this space be too small the gas acquires too high a degree of tension, and forces the ball out with such velocity that it does not follow the turn of the grooves; and if the space be too great, it has not sufficient tension to produce a good effect; in either case the accuracy is injured. The tige of the rifle under experiment was then slightly modified; its length fixed at 1.496 inches, diameter 0.354 inches; the charge of powder increased to 69.43 grains.

With reference to grooves, the experiments showed that there must be at least *two*, for with one the ball leaves the piece in a false direction; but the number should not *exceed four*. With *three* the accuracy was about the same as with four; but the commission believing that with three the ball was not held sufficiently firm in the barrel, decided that *four* should be the number, and their width should be such that the sum of the lands should be equal to that of the grooves, or each groove should be one eighth of the circumference of the bore.

The commission also ascertained that there existed a certain relation between the twist of the grooves and the charge of powder. With grooves much inclined, and a heavy charge, the ball was driven out with such force that it did not follow the grooves, but was driven across them, and was thus deformed, both of which causes impaired the accuracy; and if the grooves were not sufficiently inclined, the motion of rotation imparted was not adequate to overcome the different causes of deviation.

With grooves much inclined, and small charges, the ball would be driven out following the twist; with slightly inclined grooves the charge should be heavy, in order to insure the requisite rotary motion. It was also ascertained that if the grooves had a twist, or turn, from left to right, the balls carried to the right; and if from right to left, they went to the left of the point aimed at. To this deviation the name of *drift* (*dérivation*) was given: the *drift* was found to be less with a twist of about one turn in *six feet.* The twist of groove adopted by the commission was one turn in six feet, and from left to right, the drift to the right from this twist being counteracted, as they supposed, by the deviation to the left resulting from the natural tendency of the soldier to incline his piece to the left while aiming, especially at long ranges.

We know that the recoil tends to turn the soldier to the side from which he fires, that is to the right; this increases the deviation to the right due to the turn of groove in that direction. If the *twist* were, then, from *right* to *left*, the *drift* and the *error* from *recoil* would tend to *neutralize* each other; the twist of grooves should then be from right to left. It was decided that the turn of grooves should be uniform; for those with an increasing twist did not give a superiority of accuracy compensating for the increased difficulty* of fab-

* There is no increased difficulty when the arms are made and rifled by machinery.

rication. It was remarked that the greased paper surrounding the ball was consumed by the friction against the bore of the piece, thus leaving a windage, giving rise to unsteadiness in the ball injurious to its accuracy; for this reason grooves decreasing in depth from the breech to the muzzle were adopted; for then the interval or space left from the wearing away of the paper would be filled up in proportion to the increased thickness of metal gained by diminishing the depth of the grooves.

The projectiles.—After having determined the different elements of the piece, as above described, they commenced their experiments with reference to the ball, with the view of determining to what were due its superior range and accuracy. Upon examining the target after firing it was seen that the holes made by the balls were circular, and of the same diameters as the balls themselves. This proved that they went point foremost, and turned about their longest axis; but neither explained why they went point foremost, or how it was that they had a superior accuracy. They thought, perhaps, this superior range and accuracy were due alone to two inherent causes in the form of the ball: *first*, its greater weight under an anterior surface, equal to that of the spherical ball; *secondly*, that the form of its anterior surface enabled it to glide through the air with more facility, and to regulate better the resistances of the air. Entertaining these ideas they wished to see what influence the weight and form had. To investigate the effect of the weight of balls they had five (Fig. 12) made, all having the same cone, but with cylinders progressively increasing, so that under the same anterior form and surface they had weights progressively increasing. No. 1, 504.8 grains; No. 2, 631.4 grains; No. 3, 751.9 grains; No. 4, 855.3 grains; No. 5, 1008.2 grains. They fired them under the same conditions, and found that the *first* was without accuracy; that the *third* had a marked superiority over not only the *sec-*

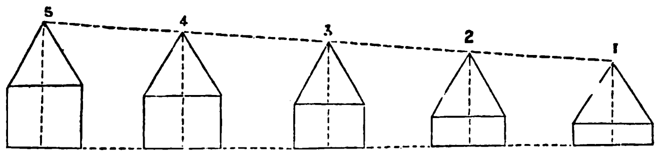


FIG. 12.

ond, which was inferior in weight, but also over the fourth and fifth, which were much heavier than it; but the primitive ball submitted by Minié with the rifle, retained its superiority even over No. 3. The commission was then forced to believe that the weight had, only up to a certain point, a favorable influence upon its accuracy, and that beyond this it became injurious. The elevating sight required for the new balls was greater than with the primitive ball. This showed, that notwithstanding their superior weight, they had less range. They then experimented with balls having differently shaped points, points more or less sharp, but with the same weight. From these experiments they found that it was not the longest, or sharpest cone, that gave the best results; and that there was no very perceptible difference with cones of different heights. From this they concluded that if the anterior form of the projectile had influence upon the range and accuracy of the ball, it was too feeble to serve for the solution of the question. The commission then combined, in every possible manner, the cone and cylinder, and found that they only approached the accuracy of the primitive ball (Minié's) as they approached its shape, and, especially, as they adopted a *groove* around the cylinder like that of the primitive ball. This fact, then, of an accuracy which seemed to depend almost entirely upon the groove, suggested to the reporter of the commission, Captain Tamisier, the following explanation.

Resistant directrices—Object of grooves.—The groove on the cylindrical part of the ball (Fig. 13) offers no

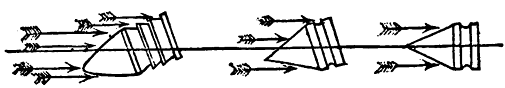


FIG. 13.

resistance to the air when its point is in the direction of the motion of translation; but so soon as the point leaves this direction, the resistance of the air, which acts in the opposite direction, continues during a short, but appreciable length of time, to act in this opposite direction. Consequently the groove is exposed to the action of the air, and experiences a resistance which causes it to turn the ball about its centre, and tends to lead the point back in an opposite direction to the one in which it was deviating; and this tendency is stronger and more instantaneous as the groove is farther to the rear. Then, every groove upon the rear of the cylindrical part of the projectile causes resistance, which tends to correct the deviations of the ball, by bringing its point back upon the primitive direction, and for this reason they (grooves) are called *resistant* *directrices;* and hence the idea originated to increase their number.

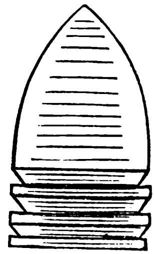


Fig. 14.

Experiments were then made with balls having more than one groove, and the truth of the above theory confirmed. The commission finished their labors by adopting this ball (Fig. 14), thus terminating their investigation of two years with reference to the arm. Having finally determined the arm and projectile, they wished again to compare it with the original arm proposed and with the smooth-bored musket. This comparison showed a marked superiority over both of the others as regards accuracy, range, and penetration.

The causes of its immense superiority are explained in the preceding discussion: we will recapitulate them. The increase of accuracy is due: 1st. To a complete suppression of the windage; 2d. To a rapid motion of rotation which takes place in the direction of the motion of translation; 3d. To the grooves around the cylinder, which tend to retain the point of the ball in its primitive direction. The increase of range is due: 1st. To the fact that the initial velocity is less; 2d. That the ball, under the same anterior surface, has more weight than the round ball; 3d. The anterior form from its shape experiences less resistance from the air. It results from these three causes, that the loss of velocity due to the resistance of the air is infinitely less than in the case of the round ball; consequently the initial velocity is retained longer and the range augmented. Finally, the penetration is increased by the pointed shape of the ball, and its greater mass and velocity. This arm, then, which was the one presented by Minié, slightly modified in consequence of the experiments of the commission upon it, was adopted into the French service, and is known as the carbin à tige (rifle) model, 1846.

Theory of motion of the cylindro-conic ball, as given by Captain Tamissier, French artillery.—In order that the cylindro-conic ball may have the best possible effect, it is necessary that the point should keep in front, and that its axis of rotation should follow the inflection of the trajectory. Should this axis remain parallel to its original or primitive direction, the resistance of the air would tend to turn the projectile about an axis perpendicular to the direction of the trajectory, and passing through its centre of gravity.

For example, let ABC (Fig. 15) be the trajectory described by the centre of gravity of the ball, p, p', p'',

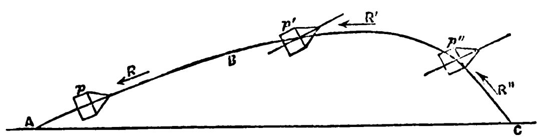


Fig. 15.

three positions of the ball on the curve, and supposing the axis remains parallel to the direction it had when it quit the piece, R, R′, R″, the directions of the resistance of the air, which acts always in the opposite direction to that of the ball's motion. It is seen from the figure, that in the position p of the ball, the resistance R has only the effect to retard the motion; but that in the positions p', p'', the forces R′, R″, acting upon a greater surface than R to retard the motion, tend at the same time to force the axis of the ball more and more from the trajectory, and to make it turn in a direction opposite to that of its flight.

Captain Tamissier, in experiments to determine the length of the conical and cylindrical parts of the ball, ascertained that the cones should be shorter as the cylinders increased in length, and that there was a limit to the length of the cone.

To examine the action of the air upon a cylindro-conic ball, whose axis is not in the direction of the motion of translation or flight of the ball.—Suppose DD (Fig. 16) to be the direction of this motion, AA the axis of the ball, S*bc* the cone, *bcef* the cylinder, G the centre of gravity of the ball situated on the axis, between the centre of gravity of the cone and that of the cylinder; R the direction of the air's resistance.

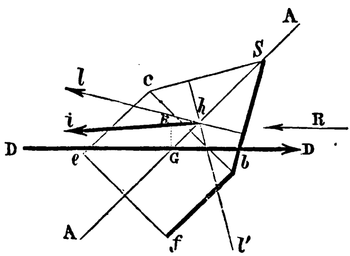


FIG. 16.

Action of the air upon the cone.—If the axis AA is in the direction of the motion DD, the air's resistance will be spread symmetrically over the triangular elements of the cone, giving resultants (*hl*, *hl'*) equal and perpendicular, and passing at one third the length of the triangular elements (or generatrices) from their base. (S*c*, S*b* are supposed to be the projections of two of the triangular elements of the cone.) These resultants can be united into a single one in the direction of the axis of the cone, having no other effect but to retard the motion of the ball. But when the axis AA makes an angle with DD, the part S*b* is more directly exposed to the action of the air than its symmetrical posterior part S*c*, so that the resultant of the resistances on these two parts, instead of being in the direction of the axis will be in a direction *hi*, approaching the direction of the stronger component. From the centre of gravity G let fall the perpendicular G*k* upon *hi*, this line G*k* will be the arm of the lever of the force *hi*, which tends to make the projectile turn about its centre of gravity, and to force the axis more and more from the direction of the motion of translation.

If the angle at the vertex of the cone is very obtuse (Fig. 17), the resultant *h′i′* of the strongest resistance will pass below the centre of gravity G′ of the projectile (since the perpendiculars to the elements drawn at one third of their height from the base will pass below the centre of gravity G′), and act with an arm of lever G′*k*′, which will tend to draw the axis of the projectile in the direction of the motion of translation. The resisfance of the air upon the cone with the obtuse point is greater than it is upon the first cone, as it is easy to see in comparing the two figures. It is seen, also, that as the cylinder is increased in length, the centre of gravity G, G′ is more and more distant from the base of the cone; and in order that the resistance of the air upon the cone may serve to correct the position of the ball, and keep its axis in the

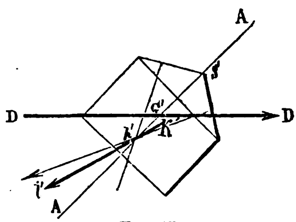


FIG. 17.

direction of the motion of translation, the height of the cone must be diminished as that of cylinder is increased.

If the general resultant *hi* of the air's resistance upon the cone passes through the centre of gravity, it has no effect upon the direction of the projectile. It may also be remarked, that the height of the cone may be increased without altering the accuracy of fire of the ball, provided grooves be made around the cylindrical part; both theory and experiment prove this.

Action of the air upon the cylindrical part of the ball.—When the axis AA is in the direction of the flight or motion of translation DD, the air glides symmetrically over the cylindrical surface and causes no deviation in the ball. When the axis AA (Fig. 18) is inclined with reference to DD, the air's resistance on the anterior part will have a resultant R passing through the centre of gravity *g* of the cylinder, below the centre of gravity G of the entire ball, and having for arm of lever G*l*; the resistance of the air will tend then to lead the axis of the ball in the direction of its line of flight. The resistance of the air upon the cylindrical part will correct more and more the deviation of the ball, as this part offers more surface to the action of the air.

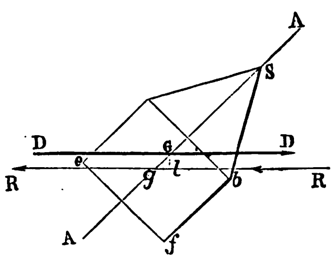


Fig. 18.

It has already been stated, that a groove around the cylindrical part had given greater accuracy than with no groove. Tamissier believed if the number of grooves were increased, that as they would offer more surface to the action of the air they would tend to correct the position of the axis of the ball, and increase its range and accuracy; he accordingly had balls made with various numbers of grooves, and of variable depth; experiment proved his theory to be correct.

It is seen from an inspection of the figure (19): 1st. That if the axis AA of the ball be in the direction of its line of flight DD, the air's resistance would be exercised symmetrically upon the conical part, and would give no deviation. 2d. But if the axis deviates in any direction to the right, left, above, or below, the resistance of the air, acting almost perpendicularly upon the opposing sides of the grooves, will tend powerfully to bring back the axis in the direction of its line of flight; the number of grooves (three) have been fixed by experiment.

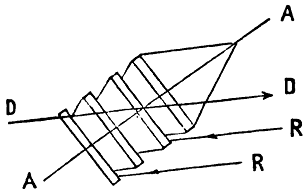


FIG. 19.

The grooves enable us to use longer cones.—The resistance which the air offers to these grooves aids the motion of rotation in maintaining the axis of the ball in the right direction. Without the grooves, the axis of the ball would remain parallel to its primitive direction, and then the difference of pressures of the air upon the anterior and posterior parts of the ball would engender a deviation which is called (*dérivation*) *drift.*

Drift.—It had been remarked, that in firing rifles with grooves of strong twist, one turn in less than four feet, and with balls of smooth surface (no grooves), that, notwithstanding the care and accuracy of aiming, the balls would go to the right or left of the target, according as the grooves had a turn from left to right, or from right to left.

Explanation given.—The projectile, during its flight through the air, tends, in virtue of its normal rotation and inertia, to keep its axis parallel to its primitive direction; so that, after a certain space is passed over, the point of the ball is found above the trajectory described by its centre of gravity; from that instant the air acts more strongly upon the anterior lower part than upon the posterior superior part: the effect of this difference of pressure will be seen.

Suppose the ball turns about its axis from left to right (on the upper side), the air will oppose this motion of rotation, but its resistance will be greater for the anterior longitudinal half than for the posterior longitudinal half, when the axis is inclined with reference to the trajectory; this anterior half (below) turning then from right to left experiences a resistance directed from left to right, while the posterior half (above) turns from left to right, and experiences a resistance directed from right to left; and as the first resistance is stronger than the second, the ball goes to the right. Similar reasoning would show that the ball would go to the left if its rotation was from right to left.

The *mean drift* of cylindro-conic balls without grooves, fired from rifles with grooves of one twist in 6 feet 3 inches, was 10 feet in 872 yards; but with grooves this drift was inappreciable at the same distance.

Cylindro-conic balls of increased length.—Tamissier having demonstrated the fact, that the grooves around the cylindrical part of the ball had an effect analogous to the feather upon the arrow, had balls of seven calibres in length made, for experiment With these balls he obtained great accuracy at 1100 yards. His experiments showed, that as the length of the ball increased it became necessary to increase the twist of the grooves, in order to give a rapid motion of rotation, which was required to keep the point of the ball to the front. The balls used in these experiments had 9 grooves (Fig. 20) around the cylinder. The increased length of ball requires greater twist to the grooves, which occasions greater friction and recoil.

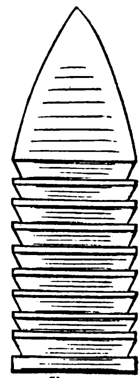


FIG. 20.

Thiroux's theory of motion of projectiles.—The following is the substance of his theory as regards deviation and drift:

A spherical ball moving through the air and revolving at the same time about a vertical axis, in such manner that the points of the ball to the left of the plane of fire turn from left to right, deviates to the right. This is explained by the fact, that the motion of translation of the particles of the ball to the left of the plane of fire is increased by the motion of rotation of these same particles; while the motion of translation of the particles of the ball to the right of the plane of fire is diminished by the motion of rotation of these same particles. It results from this, then, that as the resistance of the air is proportional to the square of the velocity, that the particles of the ball to the left of the plane of fire meet with a greater resistance than the corresponding particles to the right of the plane of fire, and consequently the ball deviates or is driven to the side of less resistance. With motion of rotation in the opposite direction, the deviation would be in an opposite direction.

If the motion of rotation were about a horizontal axis perpendicular to the direction of the trajectory, and in such manner that the particles of the ball on its upper surface revolved forward, and those on the lower side to the rear, the motion of translation of the upper particles would be increased by this forward motion of rotation, and the motion of translation of the lower particles diminished by their motion of rotation to the rear; the resistance of the air being proportional to the square of the velocity, the upper half would meet with greater resistance, the ball would deviate to the side of less resistance, and be driven down; if the motion of rotation were in the opposite direction, the ball would deviate upwards for the same reason.

Spherical balls fired from rifles have drift; for the axis of rotation of the ball does not always, as has been supposed, coincide with the tangent to the trajectory; but this axis of rotation in the ascending branch of the trajectory is above, and in the descending branch below the tangent. When the axis of rotation is above the tangent, the front particles of the ball on the right of the plane of fire, in turning from left to right, add to the motion of translation, and consequently increase the resistance of the air; while the corresponding points on the left of the plane of fire diminish the motion of translation, cause less resistance, and thus the ball drifts to the left in the ascending branch; in the descending branch, where the axis of rotation is below the tangent, the reverse takes place, and the ball drifts to the right. Thus, in the ascending branch, the ball drifts to the left, and in the descending branch, to the right; but in the ascending branch, for some distance after the ball quits the piece, the axis of rotation and the tangent coincide (or nearly so); then the axis becomes above the curve, until it reaches the culminating point, where it again coincides with the tangent; passing the culminating point, the axis falls below the tangent, and continues to do so, more and more, even to the overturning of the ball. In the ascending branch the tangent and axis coincide part of the time; and that half of the trajectory being traversed by the ball in much less time, the drift to the left is much less than the drift to the right (which occurs in the descending branch), and thus the prevailing drift is to the right when the ball or the grooves turn from left to right. In the descending branch the motion of translation is diminished rapidly, while that of rotation is lessened but little: thus, in this branch, the velocity, added by the motion of rotation is very apparent in its effects.

In elongated projectiles drift occurs in the same manner and for the same reasons, being greater in like manner in the descending than in the ascending branch, and becomes greater as the diameter of the ball and the angle of fire increase, the velocity of translation becomes less, that of rotation greater, and as the range increases.

Grooves, their turn or twist.—The most important feature to be considered with reference to grooves is their inclination; the curved line resulting from this inclination is called a *helix*.

To form an idea of this curved line or *helix*, take a right cylinder ABCD (Fig. 21), and develop, or roll it out on the rectangle BEMC; then divide the lines BC, EM (the height of the cylinder) into equal parts, and draw the transversals BG, RH, QK, PL, OM. Now roll or wrap this rectangle around the cylinder, these transversals will describe a continuous curve, called a *helix*. Each one of them forms a spiral from B to R, from R to Q, &c. The parts of any given element of the cylinder, as BR, RQ, &c., &c., comprised between two consecutive spirals are equal, and this constant interval is called the *turn* or *twist* of the *helix* or *groove*.

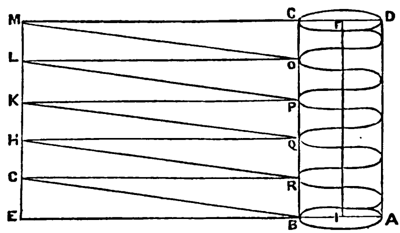


FIG. 21

Thiroux, of the French artillery, gives the following formula for determining the proper twist of grooves for firing elongated balls, viz., H=56.8 D; in which H is the twist of grooves and D the diameter of the piece, expressed in *millimètres*.

General Timmerhaus, Belgian artillery, proposes the following hypothetical law, viz.: "The ratio of the living initial force of rotation to that of the living initial force of translation, should be the same for different calibres." An hypothesis that Major Coquilhat, of the Belgian artillery, renders thus: "That the turn of grooves are to each other as the calibres, provided the projectiles are similar." This law establishes between the twist of grooves and the calibre the same ratio as the formula of Thiroux.

The object of grooves is to impart to the ball a motion of rotation about its axis, parallel to the line of flight, or trajectory. This rotation tends to keep the ball in the plane of fire, by making the various causes of irregularity of flight, such as want of homogeneous resistance of the air, want of coincidence of centres of gravity and figure, &c., neutralize each other. This motion of rotation should be more rapid as the form of the ball is more complicated, and as the centres of gravity and figure are more distant from each other. It should then be greater for the elongated, or cylindro-conic, than for the spherical ball. In the cylindro-conic ball, the velocity of rotation of the surface of the cylinder is in direct proportion to its calibre, the velocity of translation, and in inverse proportion to the turn or twist of the grooves.

Let u be the velocity of rotation of the ball on leaving the muzzle of the piece,

V the initial velocity of translation,
D the calibre,
h the twist or turn of the grooves.

We will then have $\frac{V}{h}$ = the number of revolutions per second of the ball on leaving the muzzle of the piece;

$u=\frac{V}{h}\times\pi D=$ the initial velocity of rotation of the surface of the cylinder, which may be considered alone, to the exclusion of that of the point, or cone.

The velocity of rotation in the interior of the piece increases progressively as that of translation, and causes the ball to pass over, in equal portions of time, lengths of grooves greater and greater in proportion as it approaches the muzzle. At this point it has its maximum velocity.

As soon as the ball leaves the piece, the velocities of rotation and translation are constantly diminished by the action of the air, but in very different degrees. The resistance of the air being in proportion to the square of the velocity (or in proportion to the power $\frac{5}{2}$ for great velocities), the velocity of translation diminishes much more rapidly than that of rotation.

Suppose, for example, that $V=1200$ feet,

$u=120$ feet.

We will find that the diminution of the velocity of translation will be to that of rotation as $(1200)^2 : (120)^2$, or as $100 : 1$.

Experiment proves that the velocity of rotation is but slightly retarded at the end of the flight of the ball, while that of translation is constantly and rapidly diminished.

This property of the velocity of rotation explains the latitude that experience gives to the turn, or twist, of grooves, and induces the belief that in artillery it is possible to fire ricochet and breeching charges from the same rifle-cannon.

Twist of grooves.—The hypothetical law previously indicated for the determination of the twist of grooves, gives for different calibres the same turn of grooves. To demonstrate this let us develop the cylinder of the bore and the grooves or helices (Fig. 22).

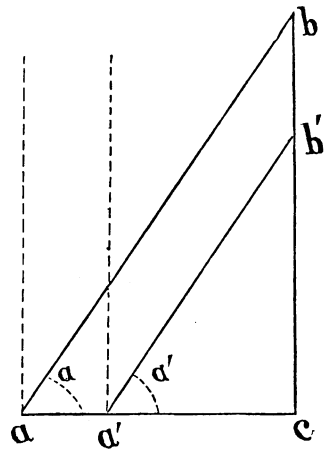


Fig. 22.

Let D, *d*, be the calibres of two pieces;
H, *h*, the twist of the grooves (cb, cb');
a, *a*, the angles of inclination of the grooves ab, $a'b'$, upon the developed surfaces ac, $a'c$ of the bores of the pieces.

If $a = a'$ we have tan. $a =$ tan. a', or $\frac{H}{\pi D} = \frac{h}{\pi d}$, and consequently H : *h* : : D : *d*. That is, the twist of grooves of different calibres are to each other as the calibres.

This law, not taking into consideration two important circumstances in the fire, has not that degree of accuracy desired. 1st. The difficulty projectiles experience in following grooves increase in proportion as the calibres augment, because they have at the same time with equal initial velocities an increase of living forces of translation and rotation. 2d. That the living forces of rotation are preserved or retained in proportion to the size of calibre, since the resistances of the air act in direct proportion to the surfaces, and in inverse proportion to the volume of the projectiles.

These two circumstances cause us to admit, for the determination of the twist of grooves, the two following propositions, viz.: 1st. That the velocities of rotation of two projectiles, similar but of different calibres, are to each other inversely as their calibres. 2d. That the inclinations a a' of the grooves will be proportional to the preservation of the velocities of rotation.

These two hypotheses being more in harmony with ballistic principles than the first, may be expressed by the following proportion or formula, $H : h :: D^2 : d^2$; that is, the twist of grooves are to each other as the squares of the calibres. This is easy to demonstrate:

Let us retain the previous notations, and call V the initial velocity of translation, which we suppose to be the same for the different calibres: we will have $\frac{V}{H}$, $\frac{V}{h}$, for the number of revolutions per second described by the balls whose calibres are D and d.

$\pi D \frac{V}{H}$, and $\pi d \frac{V}{h}$, for the velocities of rotation of the surfaces of the cylinders.

First proposition, $\pi D \frac{V}{H} : \pi d \frac{V}{h} :: \frac{1}{D} : \frac{1}{d}$; whence $H : h :: D^2 : d^2$.

Second proposition, tan. a : tan. a' :: D : d; or rather $\frac{H}{\pi D} : \frac{h}{\pi d} :: D : d$. Whence $H : h :: D^2 : d^2$.

This seems to be more exact than the hypothetical law previously indicated.

Instrument to measure the twist of the grooves of rifles.

—To measure the turn or twist of the grooves on the interior of the barrel, we use an instrument (Fig. 23) composed in part of a square iron rod of sufficient length to

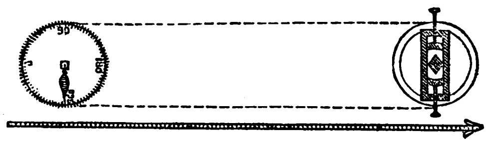


Fig. 23.

reach the bottom of the barrel, and divided off into feet and inches. This rod at the lower end has two claws, or projections, which enter the grooves at the muzzle, and descend to the bottom following them. The rod passes through the centre of a graduated disk, which is fixed firmly upon the muzzle of the rifle. In the centre of this disk is a needle, or hand, through which the rod also passes, and, as it descends, turning with the grooves, this needle also turns, and measures the arc, which enables us to read the *turn*, or *twist* of the grooves.

To calculate the initial velocity of a projectile.—The

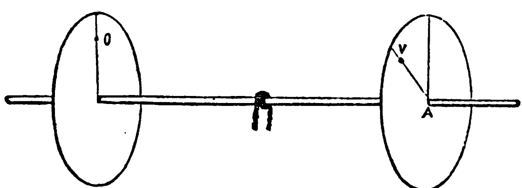


Fig. 24.

initial velocity of a ball is the velocity with which it leaves the muzzle of the piece: this velocity can be calculated by means of a revolving machine.

Two vertical disks (Fig. 24), through which a horizontal axis is passed, are separated by an interval of nine feet. A motion of rotation is imparted by means of an endless rope. This motion becomes uniform after a few revolutions, a dozen, for example. Fire the arm horizontally in the vertical plane of the axis of the machine, and as near as possible to the first disk. The ball pierces the first disk, and takes a certain time to reach the second. The point where the ball pierces the second disk is at a greater distance from the vertical as the motion of rotation is the more rapid.

To find the velocity the ball had in passing through the space separating the two disks.—Suppose that the machine makes *eight* revolutions in *one second*, and that the distance between the disks is *nine feet*, the time of one revolution would be $\frac{1''}{8}=0.125''$. Suppose the ball to have struck the first disk at O, and the second at V, the angle at the centre A, for example, 30°; it would appear that the second disk had revolved through a circular space of 30°, while the ball was passing from the first to the second disk. It is evident that if this circular space had been 360°, the time taken by the ball to pass from the first to the second disk would be 0.125''; but the circular space being only 30°, the time that the ball takes to pass over the interval of nine feet will be found in the following manner:

If the circular space be

360°, the time is		0.125''.
1°	"	$\frac{0.125''}{360}$.
30°	"	$\frac{0.125''\times 30}{360}=0.0104''$.

Knowing that the ball passes over 9 feet in 0.0104″, the space passed over in 1″ is found thus:

If in 0.0104″, or $\frac{104''}{10000}$, the ball passes over 9 feet,

In $\frac{1}{10000}$, it will pass over $\frac{9}{104''}$ feet.

And in $\frac{1000''}{1000}$, or 1″, it will pass over $\frac{9 \times 1000}{104} = 865$ feet.

865 represents, then, the number of feet that the ball passes over in the first second of its flight; or, in other words, its *initial velocity.*

CHAPTER III.

Ball with wedge (*á culot*).—Expansion of ball by means of the wedge.—Experiments with wedge balls.—Expansion of the ball without the aid of a wedge.—Accidents to which such balls are liable.—Comparison of the two kinds of balls.—Two new balls: the ball of the Guard, and Nesler's ball.

Ball (*à culot*) *with wedge.*—In the rifle with tige it has been seen that the ball was forced into the grooves by means of the rammer; and as no two soldiers would probably employ the same number of blows with the rammer, or the same force, various degrees of expansion would take place: in some very little, while in others, from the strong blows of the rammer, great expansion, and perhaps, a deforming of the ball. This produced irregularity in the fire, and it was soon sought to supersede this manner of expanding the ball by another that should be independent of the action of the soldier. It was with this view that Minié invented a hollow ball, the wedge ball (*á culot*), which was designed to expand by the action of the powder alone. Minié's idea was to have a ball that could be fired with the same rifle as the oblong ball, that is, with the rifle à tige, or with rifles without the tige. He endeavored then to make this ball resemble in exterior shape and dimensions the oblong ball. The new Minié ball was hollow, the shape of the cavity being that of the frustum of a cone; in this cavity was placed a piece of iron to act as a wedge. The breech of the rifle was plain; the ball to go down easily, and resting upon the powder; the inflammation of which drives the wedge into the cavity of the ball, thus expanding the ball, and forcing it into the grooves. Such was the ball presented by Minié in the beginning of the year 1849. Before speaking of the experiments to which it was subjected, we will describe, in a few words, how it is acted upon by the gas, and driven into the grooves of the rifle.

Expansion of the wedge ball.—This ball was designed to be fired from a rifle without tige, of 0.7 inch bore, and with a charge of 77 grains of powder: the loading to be the same as with the round ball, by simply pouring in the powder, and then introducing the ball, the wedge downwards, and adjusting it by two or three gentle taps of the rammer, in order that it may adhere slightly to the powder. Let it be supposed, then, that the ball is in its place at the bottom of the piece (Fig. 25), it will be seen what takes place at the moment of the inflammation of the powder.

Of the first gas evolved, some is precipitated into the space between the ball and the sides of the barrel; another part acts upon the lower edge of the ball. The culot, or wedge, receives the greatest part of the gas,

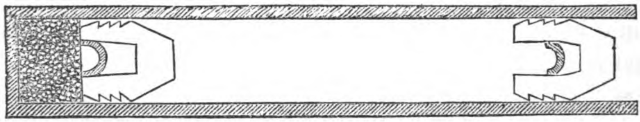


FIG. 25.

and having a density and volume less than the ball, ought, evidently, to be put in motion first, and to be driven into the cavity, thus expanding the ball into the grooves. The resistance to this expansion arises from the cohesion of the lead, and from the gas that has penetrated between the ball and the sides of the barrel. This resistance causes the first motion impressed upon the wedge to be communicated to the ball, and moves it forward before the wedge has been driven entirely to the bottom of the cavity. Nevertheless, after a short interval, and one scarcely sufficient for the ball to have passed over the first quarter of the barrel, the wedge has caused the lower rim of the ball to expand into the grooves, and in proportion as it penetrates the hollow it expands successively the different rims of the ball, and the air compressed by the wedge into the upper part of the hollow expands the upper or forward rims, so that when the wedge has reached the bottom of the cavity all the cylindrical part of the ball has been expanded, and the filling of the grooves is complete. The pressure the gas exerts, then, against the interior side (hollow), prevents the compression, or shrinking in of the lead that might be produced by the friction against the outer surface of the ball, and by the pressure of the gas that is between the ball and the sides of the barrel, and maintains, increases even, the expansion of the ball in proportion as the wearing away, or consuming of the paper patchin of the cartridge would render it necessary.

It arrives, then, at the muzzle with an expansion into the grooves as perfect as it had immediately after the driving in of the wedge. It results from this: 1st. That grooves *progressively increasing* in depth are *useless*, and *even injurious*, because they increase considerably the friction of the ball, and tend thus to tear or strip the cylindrical part. 2d. The expansion is moderated by the gas which penetrates between the ball and the sides of the bore, and is consequently less rapid and violent as the windage is greater. 3d. That with a short barrel the windage should be small, in order that the ball may be entirely expanded before it leaves the piece. 4th. With a long barrel the windage ought to be greater, in order that the expansion may be retarded, and the friction resulting from it may not be such as to tear the ball.

Experiments with wedge balls.—It was for the reasons above stated that Minié gave the form to his hollow ball that has been indicated. The first experiments with it showed that it was at least as accurate as the oblong (primitive) ball. These experiments were made simultaneously in the four schools of instruction for musketry—Vincennes, Grenoble, Saint Omer, and Toulouse. The object of these experiments being to compare its accuracy and penetration with that of the oblong ball; to ascertain if it was held or retained securely in the piece; and what would be the influence upon its fire of rain or humidity. As regards accuracy, it had a marked superiority over the oblong ball: and had a much greater range, for it required a less elevated sight. As regards penetration there was no perceptible difference. Thus upon the three principal points of *accuracy*, *range*, and *penetration*, the new ball was superior, or equal to the primitive or oblong ball; this ball seemed to leave nothing to be desired. Finally, soldiers were required to load their rifles with the new ball, and then to go through the various manœuvres of drill, violent gymnastic exercises, &c., &c., in order to see if the balls would be retained, or if they would fall out of the pieces. They were found to be held firmly in their places, and the grease of the cartridge served to protect the powder from the effects of moisture.

Expansion of balls without the aid of the wedge.—At the termination of the above experiments, 1849, M. Faucompré, captain of artillery (French), presented a hollow ball (Fig. 26), which he claimed could be expanded under the action of the gas, *without* the aid of the *wedge*. Experiments with this ball proved that the expansion was good, but that its accuracy was much inferior to that of the wedge ball. These experiments led to the important discovery that Minié's new ball could be fired without the wedge, and with an accuracy almost as great as with it. When it is fired without the wedge the gas is thrown at once into the cavity, and acts violently upon all of its interior surface, and expands, almost instantly, the cylindrical part. From this it

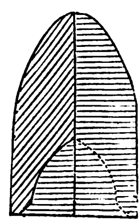


FIG. 26.

seems that we secure an expansion as perfect, and an accuracy almost as great, as with the wedge ball. But, sometimes, the gas which penetrates between the ball and the sides of the piece, resists the action of the gas in the hollow of the ball, and causes thus a deficient expansion. At other times the gas enters the fissures that are occasionally found at the bottom of the cavity (especially when the balls have been moulded), and, stretching or tearing them, finishes by making an opening in the conical portion of the ball. At other times the rapid expansion of the lead, and the violence of the friction resulting from it, causes a tearing of the cylindrical part at the grooves, or at the junction of the cone and cylinder. It is easy to be seen that when any one of these three accidents occurs the ball will miss the mark; and hence its inferiority as compared with the wedge ball, the wedge always insuring a perfect expansion, and moderating it in such manner as to prevent tearings at the cylindrical part,—and by preventing the gas from entering the fissures occasioned by imperfect moulding, no apertures are made through the cone. The latter accident would occur less frequently if the balls were pressed.

Accidents that occur with the hollow ball.—Balls fired with the wedge are liable to be torn by the action of the gas, if it be too violent; or if the ball be defective from its fabrication, as often occurs with moulded balls. The tearing of hollow balls are designated under the following heads, to wit: 1st. *Lunettes* (Fig. 27). In this case the cylindrical part of the ball remains behind in the piece, the conical part being torn off by the action of the gas, and driven out without range or accuracy. In case of accidents of this kind the arm is temporarily unfit for use, and has to be unbreeched to extract the *lunette:* sometimes by forcing a second ball down point forward, and ramming it hard against the lunette, they may both be fired out. 2d. *Anneaux* (Fig. 28), composed of a circular part of the hollow portion of the ball, comprising one or more of the

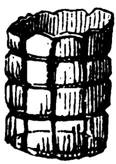


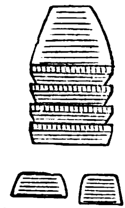
Fig. 27.

Fig. 28.

Fig. 29.

grooves; these accidents arise entirely from a defective fabrication. 3d. *Affouillements* (Fig. 29). In this case the gas penetrates through the fissures, or openings in the ball, from defective moulding, and pierces, without separating, the front part of the ball, thus driving the ball out with but little force or accuracy.

The general conclusion, after all these experiments, was, that the ball with wedge was superior in all respects to the oblong (primitive) ball; and that it was well to retain the wedge to regulate the expansion, and thus increase the accuracy, but that the fear of wanting these appendages in active service should not be a bar to the adoption of the ball. It was accordingly issued to four regiments, and after undergoing the or-deal of service, it was slightly modified, by terminating the cavity with the surface of a sphere (Fig. 30); reducing the diameter of the ball slightly, the diameter of the entrance to the cavity, as also that of the base of the wedge; the reduction of the diameter of the ball at the last rim (or lower edge of the base), which Minié thought facilitated its introduction into the piece, was suppressed as useless. In service it was found that the wedges were driven from the cavity of the ball by the air compressed in front of them, as soon as this compressed air was not counterbalanced by the gas of the powder in rear; and this expulsion of the wedges might occasion accidents, and injure the accuracy. This was remedied by increasing the length of the wedge, and diminishing the thickness of its sides, in order that it might yield to the pressure of the gas, and thus offer a passage or escape to it. These slight changes prevented the wedge from being expelled, and increased the accuracy.



Primitive. Modified.
FIG. 30.

Again in 1853 and 1854 this ball, after the modifications above mentioned were made, was issued to three regiments of infantry, for further experiments. These regiments made comparative experiments with it and the rifle-musket, the oblong ball and the rifle à tige, and the smooth-bored musket with spherical ball. These experiments proved that the rifle without the tige, with the wedge ball, was superior to the rifle à tige and oblong ball, and that each of these was vastly superior to the smooth-bored musket and round ball.

Although this ball with the rifle without the tige was proved to be superior to all others, yet the following defects were admitted: 1st, The wedge. 2d. The facility with which the ball could be deformed when transported in large quantities without the wedge. 3d. The necessity of using with it an elevating sight of too great height.

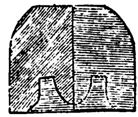


FIG. 31.

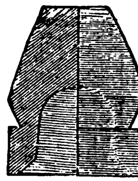


FIG. 32.

The desire to overcome these inconveniencies gave rise to the consideration of *two new balls—the Nesler ball* (Fig. 31), so called from Lieut. Nesler, by whom it was invented, and the *ball of the Guard* (Fig. 32). Each one of these balls was temporarily adopted into the French service.

CHAPTER IV.

Experiments with hollow balls.—The Nesler ball.—Ball of the Guard.—Its form and size.—Experiments for a ball for the French infantry.—Triangular cavities found to have advantages.—The form and size of the ball adopted in consequence of these experiments, and now issued to the infantry.—Manner in which the trajectory of the ball was determined.

Experiments with hollow balls—The Nesler ball.—While experiments were being made in France with the wedge ball, various inventors sought to profit by the discoveries thus far made, and labored to devise a ball that would take its motion of rotation in the direction of the motion of translation without the aid of grooves, and thus avoid the necessity and expense of rifling the arms then in service, which the systems à tige and with wedge required. One experiment with this view was crowned with partial success: it was the ball proposed by Lieut. Nesler. This ball weighs 463 grains, and is fired with a charge of 92 grains of powder: it moves under the action of the gas of the powder in the following manner (Fig. 33).

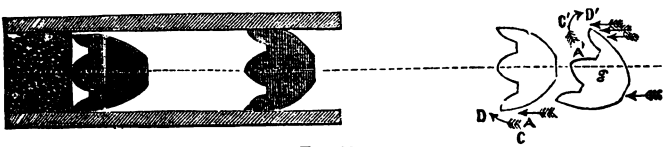


FIG. 33.

The first gas evolved penetrates the hollow, and causes the posterior, or lower part of the cylinder, to expand, and forces it against the sides of the barrel, so that the windage is suppressed at this part of the ball, and there can be no shocks, or bounds and rebounds; neither can there be any motion of rotation in the interior of the piece. However, as the front part of the ball is not expanded, there would be shocks, or unsteadiness injurious to the accuracy, but for the conical projection left in the centre of the cavity. This projection offers a large surface upon which the gas acts symmetrically in all directions, when the ball is in its normal position. These symmetrical pressures of the gas keep the ball in this position, and prevent bounds and rebounds, shocks or unsteadiness, somewhat like the hand upon the handle of an open *umbrella*, that may be moved horizontally, the position and direction of the motion of the umbrella being maintained and governed or directed by the hand on the handle. The ball leaves, then, the piece following its axis, and without any motion of rotation.

It is easy to see, that, during its passage through the air there can only be produced a motion of rotation in the direction of the axis of translation; for, if the resistance of the air upon the point A, tends to produce a motion of rotation in the direction ACD, the upper cylindrical part offers then to the resistance of the air a considerable surface, upon which it acts with more intensity. The effort which is there exerted, causes the ball to turn about its centre of gravity, situated near the point O, and checks the motion of rotation that is produced in the direction of A′C′D′; this motion, then, is annulled or transformed into a motion of rotation about the direction of translation, the only one that does not experience on the part of the air the effect that has been previously described. Moreover, this ball being of greater width than height, as is seen from the figure, is almost in the same condition as the round ball, after it has been flattened by being expanded according to the Delvigne system. This circumstance tends to cause it to retain its rotary motion in the direction of translation, for all moving bodies tend to turn about their shortest axis. Thus the ball is in a condition similar to one driven into the grooves of a rifle, and has, like it, an accuracy superior to that of the spherical ball; but its little volume and its flattened anterior surface prevents its having a long range, and its accuracy and penetration are inconsiderable at 550 yards. Its trajectory is more flattened than that of the wedge ball.

The Nesler ball, at 270 yards, has *twice* the accuracy of the round ball; at 440 yards it has the same accuracy as the round ball at 270; at 550 it has *one half* the accuracy of the round ball at 270 yards.

This ball having a greater accuracy and range than the spherical ball, and being fired from a smooth bore, caused it to be temporarily adopted and issued to troops serving in the Crimea; but its range and accuracy was not such as to cause experiments with reference to the wedge ball to be renounced; they were accordingly continued, and gave rise to the adoption of another ball—the ball of *the Guard*—which became the type and point of departure for further researches.

Ball of the Guard.—It has been seen, while speaking of the wedge ball, that it could be fired without the wedge, and had an accuracy but little inferior to what it had with the wedge, and that its want of accuracy was due to the tearing or splitting occasioned by friction and the action of the gas. This gave rise to experiments after a ball that could be used without a wedge, and which would not be liable to the accidents of splitting, &c., &c., mentioned above; and one that would be less heavy than the wedge ball, have a more flattened trajectory, and an accuracy almost as great. Minié produced a ball that he believed would fulfil the required conditions.

Form and size of the ball of the Guard.—This ball had a total height of 0.9055 in.; calibre, 0.6693 in.; was composed of a cylindrical part, 0.4331 in. long, and of a conical part, 0.4724 in.; point flat, 0.3150 in. wide. In order to overcome the tendency to tear at the junction of the conical and cylindrical parts, the lead here was made thicker, and the number of grooves around the cylindrical part reduced to one. The cavity was almost cylindro-spherique, and the orifice widened in order to render the expansion easy and progressive. The weight of the ball, 555 grains; charge, 62 grains. This ball, made especially for the Imperial Guard, took its name from this fact, and was experimented with in comparison with the wedge ball; the result of the experiment was, a little inferiority in accuracy, but infinitely less accidents from tears, &c., &c., and that up to 660 yards its trajectory was more flattened; it required consequently a shorter elevating sight.

Experiments to establish the form and shape of a ball for the French infantry of the line.—The above remarkable facts, with reference to the *Nesler* and *Guard* balls, gave a new direction and impulse to researches with reference to a definitive determination of a ball destined to replace in the French service the oblong and round balls. In September, 1856, an order, issued by the Minister of War, prescribed the conditions that this new ball must fulfil. It should, in the first place, be of one piece, having neither wedge nor any other appendage; it was to be applicable to all small-arms in their service; its weight not to exceed 556 grains; its range and accuracy not to be less than that of the oblong ball; its penetration should, if possible, be equal to that; the loading with it to be easy and simple; finally, the stripping and tearing, if possible, to be obviated; and there should be no leading.

A special commission was charged with the solution of this difficult problem; and their labors, with the view of simplifying them were, divided into two parts; one destined to the investigation of the exterior form, the other to that of the hollow.

Exterior form.—After a great number of trials, and without confining themselves too exclusively to the condition of weight prescribed by the Minister of War, and which it was impossible to satisfy, at first, without injury to range and accuracy; the commission directed their researches particularly upon three balls, Nos. 1, 2, and 3 (Fig. 34). Each of these balls weighed about

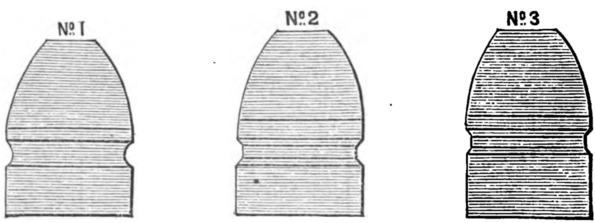


FIG. 34.

617 grains, and had a cavity sphero-tron-conic, similar to that of the ball of the Guard. These balls were compared with each other and with the oblong ball, and were found to be inferior in accuracy to the oblong ball, but with reference to each other there was no very marked difference; No. 1 had, however, a little superiority, which gave it a momentary preference.

This series of experiments proved that hollow balls *without grooves* could be fired. The explanation of this fact, which offers advantages that will be spoken of subsequently, is extremely simple. For, in consequence of the hollow made in the rear part of the ball, the centre of gravity is thrown forward near the base of the cone at C, for example (Fig. 35). It occurs then, that if the point of the ball deviates, or turns up, the lower conical and cylindrical parts experience each a greater resistance from the air than the corresponding superior parts, and these resistances unite to exercise on the inferior part of the ball an effort to make it turn about its centre of gravity C, and to bring back its point on the trajectory. And this action is greater as the hollow is more deep. It is seen, then, that the cavity alone suffices to redress the ball, and that we may dispense with the grooves. This property of the hollow redressing the ball's position presents two great advantages: 1st. The ball being no more subjected to great friction and resistance resulting from the grooves, loses less velocity and takes a more flattened trajectory; 2d. What is called the *drift* of the ball, that is, its tendency to go in the direction of the twist of the grooves, is diminished, for the grooves tend in part to produce this *drift*. These deductions, drawn theoretically, have been proved experimentally, and demonstrate that balls without grooves require less elevating sight, have less drift, and are more accurate than the same balls with grooves.

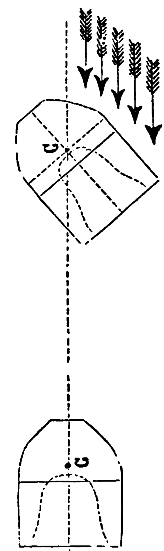


FIG. 35.

Interior form of the ball.—After the first series of experiments, the commission commenced investigations as to the interior or hollow of the ball. With this view, they made in the three balls above described, and in others of the same form but of variable lengths, cavities of all sizes and shapes; some sphero-tron-cônic, others pyramidal, having pentagonal, square, and triangular bases. They discovered by these experiments: 1st. That the depth of the cavity ought to vary with the length of the ball; 2d. That it ought to be less than half the length; 3d. That the elevating sight should be increased as the depth of the cavity diminishes; but yet they could not determine satisfactorily the choice of the form of the cavity.

Triangular cavities found to have advantages.—The commission had advanced thus far, when they were required to ascertain if balls of larger calibre had the accuracy that the calibre .66 in. gave. It was found, that balls with sphero-tron-conic cavities had much less accuracy as the calibres were increased, while the pentagonal and quadrangular cavities gave greater accuracy by increasing the diameter of the balls. The commission believed this difference attributable to a want of expansion in balls of the first-named cavities; to satisfy themselves that this was the case, they conceived the idea of placing in the moulds small thin pieces of iron, the width of the diameter of the ball and half its height. They secured by this means, in the sides of the balls, clefts or thin lines, that disposed the ball to open easily under the action of the gas. Experiments with balls thus made were most satisfactory; they found the same accuracy with all calibres that they had attained with the ball of .66 in. calibre. Having thus fixed the point upon which their investigations should be directed, the commission sought at once the means of rendering balls more expansible without impairing their solidity. They determined, *first*, that with hollow balls it sufficed to give to the grooves an *uniform depth* of two *decimilimètres;* then in seeking to use the idea of balls with the clefts or thin lines, they, after a series of trials, determined to give to the ball a cavity of the form of a triangular pyramid with *pans-coupés*, with which they obtained, for all calibres, an accuracy as great as that with the balls with clefts or thin lines, as above described.

Complete form of the best ball as determined by the above experiments.—At the conclusion of these experiments, the commission studied all the previous discoveries in the making of a single ball, and then finally adopted the following (Fig. 36), as fulfilling in the best manner the conditions prescribed by the minister of war. The exterior shape of the ball is similar to that of No. 2 previously spoken of, differing from it only in the following dimensions: total. height, 0.8465 in., of which 0.4724 in. for the conical part; 0.3740 in. for the cylindrical part; the point flat; 0.2362 in. width; the groove around the ball begins at 0.0787 in. from the base of the cone, and terminates 0.1575 in. from the base of the cylinder; it is, consequently, 0.1181 in. in width, its depth one third of the width.

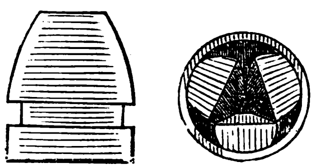


FIG. 36.

The cavity is in form a triangular pyramid, resting on a *chanfrein* 0.1968 in. high, to which the faces of the pyramid are joined by *pans-coupés;* the depth of the cavity is greater than that adopted up to this time; it is 0.5512 in. This difference in the depth of the cavity arises from the necessity of having an expansion of the lead throughout the entire cylindrical part of the ball. The interior form of the ball, or its cavity, will be represented to the eye in the following manner: In a circumference of 0.6653 in. diameter, representing the diameter of the cylinder of the ball, inscribe two concentric circles, one 0.5905 in. diameter, the other 0.4724 in.; then inscribe an equilateral triangle in the second circle, the parts of this triangle cut by the third circle are the bases of the faces of the pyramid, and the beginning of the *pans-coupés* of the *chanfrein.* The salient angles of the pyramid are eased off thus by the *pans-coupés* which have for bases the little portions of the third circle, intercepted by the sides of the triangle. This projectile has at the base of the pyramid a thickness of 0.1968 in. opposite the middle of the faces, and a thickness of only 0.0787 in. opposite the salients cut off. We see from this, that it has at this point sufficient solidity to resist long transportation without being too much deformed; but it is not so at the beginning, or orifice of the cavity, for here the thickness of the metal is only 0.0394 in.; a simple pressure of the fingers will deform it, showing that it cannot be transported save with the greatest care without being injured. If to this defect we add, that the accuracy of these balls, although very good, is, however, inferior to that of the wedge ball, we see that the only advantage that the new ball has over the other is, that it weighs only 500.20 grains.

A change contemplated in the arms for the French in-

fantry.—No elevating sight to be used.—Experiments had reached this point when the commission received in April, 1857, from the minister of war an order, in which it was announced that, 1st. All arms of the infantry were to be reduced to the length of those of the Voltigeurs; 2d, That they were to have four grooves, of 0.02758 in. width, and 0.00788 in. depth, and the same twist (one turn in six feet) as the arms then in use; 3d, That they should have a fixed rear-sight, the height of which was to be determined so as to have a convenient *point blank;* 4th, That as the fire of infantry ought not to exceed 660 yards, it would suffice for the ball to have penetration and accuracy up to this distance; 5th, That this ball should have no wedge, its weight not to exceed 494 grains, and its trajectory should be as flattened as possible.

The last ball devised by the commission, and described above, fulfilled very nearly these conditions; it was deficient only in solidity. But, previous to seeking a remedy for this, they proceeded to the determination of a new rear-sight to be given to the arm. With this view they found the mean trajectory from 55 up to 330 yards, by firing upon screens placed 27 yards apart, and ascertained at each of these distances the number of inches the trajectory fell below the original line of sight of the arm, and obtained in this manner, after corrections, the following results:

The elevation and lowering of the trajectory with reference to the original line of sight.

At the distances,..	54½ yds.	82 yds.	109 yds.	131 yds.	164 yds.	191 yds.	218½ yds.	245 yds.	273 yds.	300 yds.	328 yds.
Above............	5.5 in.	6.7 in.	5.9 in.	1.9 in.							
Below............					8.7 in.	15.7 in.	29.5 in.	47. in.	68.8 in.	94.8 in.	133.4 in.

It was by means of these numbers that they calculated the height to be given to the fixed rear-sight, in order that the point blank might be at a convenient distance. The rifle-musket of the Guard seemed to the commission to fulfil in the best manner the conditions of an arm for infantry; and they adopted for its fixed rear-sight the height of 0.97 in. above the barrel, while that of the rifle-musket of the infantry of the line was only 0.78 in.; and then they determined, by transformations simple and easy, the position of the trajectory with reference to the new line of sight. They found the following Table:

At the distances,..	54½ yds.	82 yds.	109 yds.	131 yds.	164 yds.	191 yds.	218½ yds.	245 yds.	273 yds.	300 yds	328 yds.
Above	13.7 in.	18.9 in.	22.8 in.	22.4 in.	20. in.	13.3 in.	3.5 in.				
Below............								10.6 in.	27.5 in.	48. in.	83.7 in.

From an inspection of this table, it is seen that the greatest elevation of the trajectory above the line of sight is 22.8 in.; that the point blank is about 225 yards, and that it is only at 280 yards that the trajectory falls a distance greater than that of a man's waist above his feet; so that it is permitted to aim directly at the waist at 275 yards, and it is only beyond this that it becomes necessary to have recourse to the rules of fire, or to use the *thumb* across the barrel as an elevating sight.

The sight having been determined, the commission occupied themselves with comparing the ball with others in service, with the view of improving it as regards solidity. This ball had a marked superiority, both in range and accuracy, over the spherical and *Nesler balls:* but the second part of their labors has not as yet been published. The ball above described is used by the infantry of the line; the heads of the rammers are flat, not hollow.

The experiments of the French have been given in detail for the reason that the results of their various experiments having been published in a more regular and connected manner than any other, illustrate, for this reason, more clearly the changes and improvements that have been brought about of late years in arms for infantry. Other nations have made many and similar experiments to those of the French, which have led, as in their case, to the general adoption of the rifle as the arm for infantry. It will be seen that the French differ from other European governments in rejecting elevating sights for the great mass of their infantry, retaining them only for special corps—Chasseurs, Zouaves, &c.

CHAPTER V.

Infantry firing.—Definition of efficacy of fire.—Of rapidity of fire.—Difference in the time observed during the fire by company and that of file, or as skirmishers.—Comparative efficacy of the smooth-bore and round ball, and the rifle and wedge ball in the different kinds of firing—company, file, and as skirmishers.

Thus far the rifle in the hands of a single person has been considered; but this should not limit the investigation, for it is of higher importance to know what effects are produced when it is employed by a number of men united in one body, as a company for example, obeying the commands of an officer, and executing the various fires prescribed in tactics. To attain this object, and to compare, at the same time, the rifle with the smooth-bored musket, suppose two equal numbers of men, alike skilled in the use of arms, one portion firing the smooth-bore and round balls, the other the rifle with wedge or hollow ball. Then compare the results, and deduce from this comparison which is the superior arm, and which of the three species of fire—*company*, *file*, or *skirmishers*—is the most effective, and which is to be preferred in any given contingency. It will be seen at once that this is an interesting study of the rifle and musket; as tactical questions of the highest importance attach to it, the solution of which depending upon the efficacy of the arms used, will probably undergo some change now that rifles have attained the accuracy that they have, and at such great distances.

General definition of efficacy of fire.—The object proposed by the fire by volley is to disable a certain number of the enemy in a given time: in this consists the *efficacy of fire*. This efficacy of fire being an excellent term of comparison in estimating relatively the different kinds of arms and fires, we will explain how it can be used, and expressed in numbers susceptible of being introduced into the calculation of the accuracy of an arm.

It is evident, after the above definition, that the *efficacy of fire* depends upon the *accuracy*, *range*, *penetration*, and also very much upon the *rapidity of fire*. Imagine two arms of unequal accuracy firing at the same distance upon a given target. Out of an equal number of shots the more accurate arm will place the greater number of balls in the target; but if by chance this arm should require more time to be charged and fired than the arm of less accuracy, the latter arm, in the same length of time, would fire more shots, and might compensate, in this manner, for its want of accuracy, and strike the target a greater number of times. Leaving out of consideration the greater consumption of ammunition, the arm of less accuracy, in this case, would really have an equal or greater *efficacy*.

Thus, as has been stated, the *efficacy* depends directly upon the *accuracy*, *range*, *penetration*, and *rapidity of fire*. Now, the *accuracy* depends upon the *distance* and the *dimensions of the target;* these two latter terms are then to be considered also in the determination of the *efficacy of fire*. Let us explain how these various quantities may be represented and used in the determination of the above-named element, *efficacy of fire.*

The *accuracy* is ordinarily represented in one of the ways explained in Part third, Chapter first, generally by the *per cent.*

The *range* is the *maximum* number of yards that the ball can pass over. This quantity, always greater than the distance at which the projectile loses its *accuracy*, is involved in the *efficacy* only up to the latter distance, consequently it is useless to take it into consideration beyond this distance.

Penetration: it is the same as regards penetration. For it is only against live beings, men or horses, that these small projectiles produce the destruction desired.

This important object is not really to kill the men or horses, but to wound them, thus placing them *hors de combat.* It is sufficient, then, that the ball may have at the distances that it can strike the object *penetration* enough not to be arrested by the clothing or equipments of the man, or by the harness of the horse. Experiments made with the round and wedge balls give results which show, that in estimating the comparative efficacy of the two balls it is useless to take the *penetration* into the calculation.

Definition and expression for rapidity of fire.—It is important to know how to define and represent this quantity. By *rapidity of fire, we understand the number of balls that one man can fire in one minute.* This number is, in general, a fraction; to get it, observe, with a well-regulated watch, the length of time the fire has continued. If it is a fire by *company*, estimate the time from the command *load*, until the command *cease firing;* if it is a fire by *file* or as *skirmishers*, begin to estimate the time from the command *commence firing*, and continue until the command *cease firing*. Count carefully the number of balls that have been fired during the time of observation, and from this deduce by the rule of three the number of balls $X=\frac{C}{HT}$ fired by *one man* in *one minute*. H is the number of men, C is the number of balls fired, and T the time observed.

$$\begin{array}{l} H : 1 :: C : X' \\ T : 1' :: X' : X \\ \hline HT : 1 :: C : X \end{array}$$

This number X serves to compare the *rapidity of fire* of an arm, or of a *species of fire*, with that of another arm or species of fire; but when it is wished to calculate only the *efficacy of fire*, it is unnecessary to make for the time observed the transformation above indicated. Its value, taken upon the ground, suffices for that purpose.

The two last quantities, upon which the *efficacy of fire* depends, are the *distance* and the *size of the target.* They each give a particular value to this element.

A more exact definition of efficacy of fire—expression for it.—The *efficacy of fire* ought to be calculated for each particular *distance*, and *target of given dimensions;* in these cases, it depends only upon the *accuracy* and *rapidity of fire;* and it is easy to have for it one expression and an exact definition. For, if we designate by *efficacy of fire*, *the fractional number of balls that one man can place in a target of given dimensions, firing at a given distance, during one minute*, it will suffice to multiply this quantity by the number of men present during the fire, and by the duration of this fire, to have the *efficacy*, such as it has been before, defined; besides, this quantity, depending upon the *accuracy* and *rapidity of fire* (as the first), it is then the true expression for *efficacy of fire.* To obtain its numerical value, count the number B of balls placed in the target during the time of fire T, and from the rule of three, we have $X=\frac{B}{HT}$. The unknown quantity X indicates the number of balls placed in the target in 1′ by one man, then it is nothing but the *efficacy of fire*, and its value $\frac{B}{HT}$ is the expression for this efficacy.

H	:	1	: :	B	:	X′
T	:	1′	: :	X′	:	X
HT	:	1′	: :	B	:	X

It is calculated, ordinarily, up to three decimals, in order to be able to apply without calculation the results found for one man in 1′, to a company of 100 men firing for 10′. Thus 0B.895 being the efficacy of an arm, 895B would be the efficacy of a fire of 10′ by 100 men, that is to say, the number of balls placed in the target by 100 men is 10′. It is seen, by means of this expression, that we can compare the *efficacy* of different kinds of fires, or of different arms in the same fire, at a given distance and target. For this, it will suffice to count with care in each fire, the number of men firing, the number of balls that have struck, the duration of the fire, and to note, at the same time, the distance and dimensions of the target.

Difference in the time observed in the fire by company and that by file, or of skirmishing—means of correcting this difference.—The results obtained by the above operations are very exact when we wish to compare different arms only, or the differences of *their fire*, in the same kind of fire. But when it is wished to compare one species of fire with another, they are no longer exact. For, in the fire by company, the time is estimated from the command *load*, up to that of *cease firing*, given immediately after a discharge. We see from this, that the duration of this fire, as calculated, is too great by the time required to go through with the first loading. In the fire by file, or as skirmishers, the time is reckoned from the command *commence firing* up to that of *cease firing*, the *first loading* has already been accomplished, and is not included in the time observed; but, at the command *cease firing*, there are a certain number of arms loaded, that have been so loaded during the time observed, and which increases this time by the time required to load them. Experiment shows, that in general one half of the arms are found to be in this condition; then the duration of the fires by file and skirmishers, is increased by the time necessary to load one half the arms, or by one half the time required to load. Thus the time observed in the fire by company is too great by the time required to load; that in the fire by file, and as skirmishers, too great by half of that time; then the time observed in the fire by company is greater than in the other two fires only by the half of the time to load, we will have its true value then by subtracting from it this quantity, which is easily done. For, if T is the time observed, and n the number of fires executed, $\frac{T}{n}$ will be the mean time of a fire, or almost the same thing, that of the time to load, $\frac{T}{2n}$ will be the (half duration) time to be subtracted from T, so that the time that enters into the calculations will be; $T=T'-\frac{T'}{2n}$, T' being the time observed. In order to make this correction, it suffices to count the number of fires delivered during the time observed.

Comparative efficacy of the smooth-bored musket with round ball, and the rifle with the wedge ball.—Experiments were made in 1851 at Vincennes, to test the efficacy of the different fires of *company*, *file*, and *skirmishers*, and also the relative efficacy of the musket and rifle at various distances, the musket firing the round ball, the rifle the cylindro-conic or wedge ball. These experiments proved that the fire of skirmishers was more effective than that of file, and that the latter was more so than that of company: which seems to be attributable to the fact that the skirmisher is not annoyed by the smoke, his comrades, or the commands of his officer; while in the fire by file, the smoke and the file on either side derange constantly his aim and position; and in the fire by company the necessity of obeying the command of the officer does not permit a deliberate aiming, and forces the soldier to pull the trigger suddenly and with a jerk. Commencing with the fire by company and finishing with that of skirmishers, the mean efficacies are to each other nearly as 2 : 3 : 4. Which show, that to produce the same effect in the different fires, it is necessary to use numbers of men inversely proportional to the preceding figures, or, in other words, *two* men as skirmishers will produce the same effect as *three* men by file, or *four* men by company. The conclusions from these experiments may be summed up as follows: 1st. In the fire by company, the rifle with the wedge or hollow ball has little or no superiority over the smooth-bored musket with round ball at 164 yards. 2d. At 218 yards the rifle has one and a half times the efficacy, and at 437 yards the rifle has *six times* the efficacy. 3d. Beyond 437 yards the musket had neither *accuracy* nor *penetration*, but the rifle had still very considerable efficacy; and the relative efficacies of the different kinds of fires were, as above stated, in the proportion of 2 : 3 : 4, or, in other words, 50 skirmishers would produce the same effect as 75 men firing by file, or, as 100 firing by company.

Table showing the comparative efficacy of the smooth-bored musket with round ball, and the rifle-musket with wedge ball, in the fire by company, file, and skirmishers; experiments made at Vincennes, in 1851.

	SIZE OF TARGET.	DISTANCES.	FIRE BY COMPANY.		FIRE BY FILE.		FIRE OF SKIRMISHERS.		MEANS.	
			Smooth bore, round ball.	Rifle-musket wedge ball.	Smooth bore, round ball.	Rifle-musket wedge ball.	Smooth bore, round ball.	Rifle-musket, wedge ball.	Smooth bore, round ball.	Rifle-musket, wedge ball.
EFFICACY OF FIRE.	Feet.	Yds.	B.	B.	B.	B.	B.	B.	B.	B.
	6½×13	164	0.848	0.760	0.949	1.100	1.199	1.506	0.999	1.122
	6½×13	218	0.529	0.622	0.658	0.956	0.799	1.314	0.662	0.964
	6½×18	437	0.105	0.387	0.112	0.468	0.120	0.876	0.112	0.677
	6½×26	656	.....	0.277	.....	0.442	.....	0.450	.....	0.390
	6½×32	874	.....	0.184	.....	0.259	.....	0.179	.....	0.207
	6½×38	1098	.....	0.115	.....	0.171	.....	.....	.....	0.143
MEANS.			0.494	0.391	0.573	0.566	0.706	0.721	0.591	0.566
VELOCITY OF FIRE.	Feet.	Yds.	B.	B.	B.	B.	B.	B.		
	6½×13	164	1.301	1.044	1.642	1.652	2.280	1.750		
	6½×13	218	1.333	1.045	1.613	1.848	2.213	1.662		
	6½×18	437	1.291	0.951	1.806	1.278	1.933	1.688		
	6½×26	656	.....	1.041	.....	1.394	.....	1.698		
	6½×32	874	.....	1.030	.....	1.385	.....	1.672		
	6½×38	1093	.....	1.014	.....	1.402	.....	1.640		

PART FOURTH.

CHAPTER I.

Rifles with which the infantry of the different European powers and the United States are at present armed.—France.—England.—(Experiments at Hythe).—Austria.—Prussia.—Russia.—Sardinia.—Switzerland.—Sweden and Norway.—Belgium.—Spain.—Hanover.—Baden.—Bavaria.—Wurtemburg.—Brunswick.—Dessau.—Hesse-Electoral.—Grand Duchy of Hesse.—Mecklenburg.—Naples.—Nassau.—Oldenburg.—Holland.—Portugal.—The United States.—Old rifles in the Artillery Museum of Paris.—Recapitulation of the arms described.—Table.

France.

In France the Chasseurs and Zouaves are armed with the carbine with tige, model, 1846. The latter were armed with rifle-musket with tige until 1858, when it was superseded by the carbine with tige. The different elements of this arm have already been given: its ball, as has been seen, is solid, cylindro-conic, with three grooves around the cylindrical part; the weight 733.4 grains; charge of powder 69.4 grains.

Sabre bayonet, of the form of the Turkish yatagan, its length 22½ inches, the total length of the carbine with bayonet is 3½ inches less than than the rifle-musket of the infantry of the line; the weight, length, and form of this bayonet renders it a formidable weapon in hand-to-hand contests. The handling of the carbine in the bayonet exercise is superior to that of the rifle-musket, owing to its less length; with bayonet off, the length is only 49½ inches, which renders it highly favorable for light troops.

The following Table gives the result of experiments to test its accuracy, &c., &c.

Distances in yards	164	246	328	437	546	656	765	885	984	1093
Height of elevating sight in inches	.39	.56	.70	.95	1.23	1.55	1.92	2.36	2.83	3.38
Time of flight expressed in seconds	.50	.78	1.06	1.44	1.86	2.37	2.97	3.67	4.35	5.07
Width of target, 2.19 yards										
Height of target at the various distances in yards	.54	.54	1.09	1.63	2.19	2.73	3.28	4.37	5.47	6.56
Per cent. of balls struck, first-class marksmen firing	54.50	40.30	46.50	46.60	29.70	26.50	18.80	19.70	23.90	17.40
Radius of circles, in inches, containing half of the balls	7.08	9.42	13.17	18.89	24.41	30.70	43.30	57.87	76.37	90.78

The infantry of the line have a rifle-musket, model of 1854, nearly the same as that of the Voltigeurs; it has four grooves decreasing in depth; uniform twist of 6 feet 6 in.; calibre, .68 in.; length, without bayonet, 4 feet 8 in.; with bayonet, 6 feet 2 in.; total weight with bayonet 10 lbs. 2 oz.; weight of ball 494 grains; charge of powder 77 grains. This ball is hollow, the shape of which is that of a triangular pyramid, as has been previously explained. The rifle-musket has no *elevating sight;* the rear sight is fixed. To aim at 200 yards, or under, the rear sight is used; but beyond that the soldier places his thumb across the barrel, and sights over the nail, or, to give a greater elevation, aims over the joint of the thumb. The motive for rejecting the elevating sight seems to be in part the fear of a waste of ammunition, this sight inducing the soldier, under excitement, to begin firing beyond the range of his piece.

It would seem difficult to justify this action of the French government; but as it knows well the advantages and defects of the elevating sight, and from practical knowledge in battle have had opportunities of judging of its usefulness, and whether or not the soldier, under the excitement of battle, avails himself of it or not, it would be well to study the matter thoroughly before venturing to disapprove.

Experiments in France, showing that the round ball fired from the Delvigne rifle with an initial velocity of 1408 feet per second, and the cylindro-conic ball fired from the tige rifle with $1023\frac{3}{5}$ feet initial velocity have the following comparative velocities during their flight through the air. *Carbine Delvigne* not fired beyond 546 yards.

Distances in yds.......	164.04	218.72	328.08	437.44	546.80	656.16
Time of flight of round ball of 516.88 grs.....	0.42″	0.74″	1.29″	1.75″	2.61″	
Time of flight of cylindro-conic ball, same calibre, of 725.68 grs..	0.50″	0.69″	1.18″	1″.44	1.86″	2.37″
Distances in yds	765.52	874.88	984.24	1093.60	1202.96	1312.32
Time of flight of cylindro-conic ball, same calibre, of 725.68 grs..	2.97″	3.67″	4.55″	5.07″	5.81″	5.71″

England.

It was not until 1851 that the English government began seriously to take into consideration the improvement of arms for their infantry. This year rifle-muskets were made (called Minié muskets), and with them the cylindro-conic ball with wedge was used. From this time they began to make elaborate experiments similar to those of the French, both with reference to the arm and ball. These experiments led to the adoption, in 1854, of the Enfield rifle, made in 1853, and subjected to repeated experiments by boards of officers, and by the school of instruction in musketry at Hythe, established in this year (1853). The rifle has three grooves (Fig. 1) of uniform depth and twist, the twist being one turn in 6 feet 6 inches; total length 6 feet 1 in.; without bayonet, 4 feet 7 in.; length of barrel, 3 feet 3 in.; total weight, with bayonet, 9 lb. 3 oz.; the diameter of ball (Fig. 2), 0.568 in.; its length 0.960 in.; diameter of bore 0.577 in.; weight of ball 520 grains; charge of powder 68 grains. The ball is cylindro-conic, without grooves, hollow, and has a wooden wedge, with the view rather of preserving the shape of the ball during transportation than to increase its accuracy of fire. This rifle is lighter than the French rifle, and of smaller calibre; is quite as strong, and better balanced.

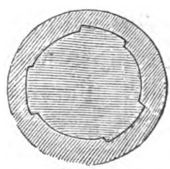


Fig. 1.

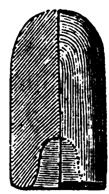


Fig. 2.

Experiments with it gave at 500 yards 47 per cent., and at 900 yards 11 per cent., in targets 8 and 16 feet wide by 6 feet high.

In June, 1855, an interesting experiment was made at Hythe, to ascertain the effect of a platoon of skirmishers firing upon a battalion of infantry in column.

For this purpose two targets (see Plate No. 1) were placed, one in rear of the other, at a distance apart of 50 yards, representing the front and rear companies of the column, which was supposed to be 700 strong. The front target was of iron, in order that balls striking it might not pass through to the second. The skirmishers were marched out in front of the target, one half ordered to fire *ten* cartridges from a halt, at a distance, unknown to them, of 820 yards; then advance firing, until they had fired *ten;* then to halt and fire *ten* more: this last distance being 550 yards, and unknown to the men. The second half were ordered to fire from this last distance *ten* cartridges; then to retreat, firing until they should have fired ten; then to halt and fire ten: these distances being the same as in the first case, and unknown to the men.

The number of cartridges consumed was 1050; of this number 379 struck the first, and 238 the second target; or 58 per cent of the whole number struck the two targets, representing the head and rear of the column. For the Enfield rifle-musket at 600 yards the *dangerous space* is 60 yards; at 800, 40 yards. This experiment was interesting in showing what would be the effect upon a column in which the rear could be struck by balls passing over the head of the column. In firing upon a column, in consequence of its depth the ball may take effect even if the soldier should commit an error in estimating the distance of 60 yards in 600 yards, or of 40 yards in 800 yards.

In May, 1856, a second experiment was made at Hythe, with the view of ascertaining the effect of the fire of a company of skirmishers upon a field-piece of artillery. (See Plate No. 2.)

The company numbered 60 men, only 23 of whom had been well instructed in target practice. The target consisted of a group representing the piece of artillery going into battery—six horses in harness, and one for the chief of piece, three drivers, eight cannoneers, one chief of piece—in all twelve men and seven horses: the figures representing the men and horses were the size of life. The caisson was represented by an iron target, upon which were traced the outlines of six horses; but the drivers and cannoneers were not represented.

The company deployed as skirmishers at a distance of 610 yards, unknown to them, and began to fire at the signal "commence firing," and continued *two minutes*, when the signal "cease firing" was given.

Two cartridges per man had been fired.

Piece and limber.	Number of horses struck	6,	balls struck	22.
	Number of men "	7,	"	7.
Caisson 50 yards in rear.	Number of horses "	4,	"	8.
	No men represented with the caisson.			
	Total number of balls struck . . .			37.

A second fire was delivered at 810 yards in the same manner, except that it continued for *three minutes*. The men of the front rank fired three cartridges, those of the rear two.

Piece and limber.	Number of horses struck	5,	balls struck	16.
	Number of men	"	6,	"	8.
Caisson 50 yards in rear.	Number of horses	"	5,	"	10.
	No men represented with the caisson.				
	Total number of balls struck, . . .				34.

In the first experiment, 11 balls struck that could not be represented in the sketch, being masked; many struck the piece itself, and some the caisson.

In the second experiment, 4 balls struck that could not be represented in the sketch; many also struck the piece and caisson.

In a range of 300 yards the highest point (at 175 yards) of the trajectory is 43 inches, with a charge of 60 grains.

Initial velocity, 1115 feet per second, as determined in 1853 at the camp of Beverlo, in Belgium.

Austria.

After a series of experiments, Austria finally, in 1855, adopted, without restriction, rifles for all the infantry. The chasseurs have carbines, and the infantry of the line rifle-muskets: they have the same cartridge for these two arms. Some of the Austrian carbines have the tige, others have not. The first are given to the non-commissioned officers, men of the third rank (who by their tactics are the skirmishers), and to the best marksmen of battalions: they have elevating sights graduated up to 1000 yards. The second (without tige) have elevating sights graduated up to 770 yards. These two carbines differ only in the tige and elevating sight.

The tige in the Austrian carbine is used simply to to *support* the ball, thus preserving an interval between it and the powder; it is not intended to assist the taps of the rammer in expanding the ball into the grooves. The rammer of the carbine, like that of the Bavarian carbine, is carried separate from the piece.

The *range* and *accuracy* of the Austrian carbines with tige are both very remarkable: firing at 820 yards, 95 per cent. of the balls struck the target; at 984 yards, 65 per cent.; at 1230 yards, 49 per cent.—the target being 6 by 55 feet. At 246 yards, out of 100 balls the entire number struck within a circle of 6 inches diameter; at 1640 yards, the ball pierced three deal boards, each 1.02 in. thick, placed a foot apart, one in rear of the other.

The rifle-musket adopted in 1855, differs from the carbine in length of barrel, twist of grooves; having no tige, and having the ordinary bayonet. It has a graduated sight up to 245 yards; those of the men of the third rank are graduated up to 820 yards. The rifle-musket is for the infantry of the line, and the frontier regiments (Greuzers). The carbine with tige has four grooves (Fig. 3), uniform depth; sum of grooves equal to that of the lands; one turn in 5 feet 2 in.; calibre, .54 in. The bayonet of the carbine is 23 inches long; broad and flat; for several inches near the point both edges are sharp, after that but one is sharp. Length with bayonet, 66.5 in.; length without bayonet, 43.5 in.; total weight with bayonet, 11 lbs. 1 oz.; without

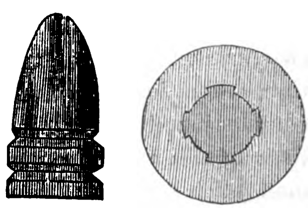


FIG. 3.

bayonet, 8 lbs. 6 oz.; charge, 61 grains; weight of ball (Fig. 3), 450 grains. The barrel of the rifle-musket is longer, and the grooves have less twist than the carbine (rifle) with tige.

Table showing the relative penetration of the round and cylindro-conic balls.

437 yards.	Target 6 ft. 6 in.	NUMBER OF PLANK.							
		1	2	3	4	5	6	7	8
Musket, round ball, 120 fired..................	Struck........ Penetrated....	4 2	2 1	....	....	....	....	....	....
437.44 yards	Target 6 ft. 6 in.								
Tige rifle, cylindro-conic ball, 120 fired.........	Struck........ Penetrated....	63 63	63 55	55 52	51 43	43 32	27 14	10 3	1 1
656.16 yards.	Target 13 feet.								
Tige rifle, cylindro-conic ball, 120 fired.........	Struck........ Penetrated....	20 20	20 16	16 9	9 7	7 2	2 2	....	....
874.88 yards.	Target 19 feet.								
Tige rifle, cylindro-conic ball, 120 fired.........	Struck........ Penetrated....	13 11	11 7	7 7	7 1	 1	....	....	....

Poplar plank 1.02 inch thick, placed 18 inches in rear of each other; charge of powder for round ball, 123.5 grains; cylindro-conic, 69.5 grains.

PRUSSIA.

In 1847, Prussia adopted for the chasseurs a carbine with tige and tron-conic chamber, the ball (Fig. 4) is cylindro-conic, with two grooves; weight, 490 grs.; charge of powder, 50 grs. The elevating sight is graduated up to 700 yards, being composed of two (*lamettes*) leaves or cramps. The cartridge contains only the powder, the ball being separate, and *greased* about the cylindrical part. It has eight grooves of uniform twist, one turn in 3 feet 1 inch.

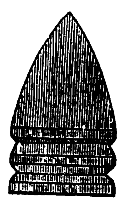


FIG. 4.

In 1848, a breech-loading rifle, with four grooves of uniform depth and twist, of one turn in 42 inches (called *Zundnadelgewehn*), was issued to the Guards, the elevating sight of this graduated to 490 yards; up to this distance its fire is very accurate, but beyond this it decreases rapidly; weight of ball (Fig. 5), 451 grains; charge, 65 grains; total weight with bayonet, 11 lbs. 4 oz.; initial velocity, 1027 feet with 62 grains. In 1855, the infantry regiments not provided with the breech-loading *needle rifle*, were armed with rifle-muskets having an elevating sight (see Plate), which is in part fixed and in part movable; it is lowered in its position on the barrel *either to the front or to the rear.* The fixed part of the sight gives lines of sight for 150 and 300 yards; the movable part has a slide. To fire at 400 yards, erect the sight, the slide being lowered, and aim through the notch in its centre; to fire at 600 yards, aim through the notch on its upper edge; at 800 yards, aim through the notch on the upper edge of the movable arm of the sight; and finally, to fire at 850, 900, 950, and 1000 yards, aim through the notch on the upper edge of the slide, moving the slide so that its inferior edge shall be on a line with the figures indicating these distances. The rifle-musket has five grooves of uniform depth and twist, of one turn in $4\frac{1}{2}$ feet; a tron-conic chamber; wedge ball (see Fig. 6 for ball and section of bore); its weight, 705 grains;

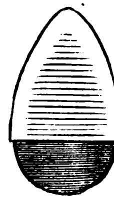


FIG. 5.

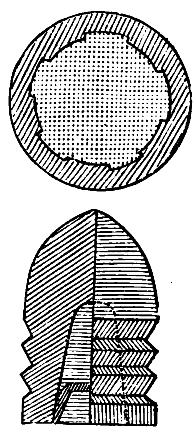


FIG. 6.

charge of powder, 79 grains; total weight with bayonet, 10 lbs.

Recently they have given to the riflemen of the regiments of the Guard, and to two battalions of chasseurs of the Guard, a breech-loading needle rifle, similar to the one already in service, the ball (Fig. 7), however, is different, belonging to the Lorens or Austrian system, the hollow in its base being intended merely to lodge the fulminating composition, the elevating sight can be lowered either by *pushing it forward* or *pulling it back.*

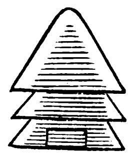


FIG. 7.

RUSSIA.

The Russians have had in their service, for a long time, a carbine with two grooves; the battalions of chasseurs are armed with it. (See Fig. 8 for ball and section of bore.) The cylindro-conic ball, 772 grains, charge, 71 grains, has been adopted into general service, having two projections on the cylindrical portion to fit

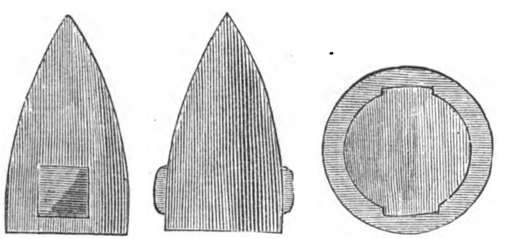


FIG. 8.

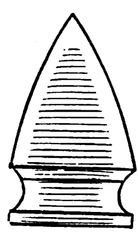


FIG. 9.

the grooves of the rifle. A carbine with tige has been lately introduced into their service; of its particular elements nothing is stated: the calibre is 0.70 inches;

projectile, cylindro-conic (Fig. 9), with one groove; weight, 705 grains.

The infantry of the line are now armed with the rifle-musket and cylindro-conic hollow ball, without wedge. The two-grooved carbine weighs 11.2 lbs.

Sardinia.

The carbine of the Bersaglieri, has eight grooves, of uniform depth and twist, one turn in 17 inches; a chamber of 0.44 inch diameter, cylindrical and joined to the bore, which is 0.65 inch, by a curved shoulder, on which the ball, cylindro-conic and solid (Fig. 10), rests. The ball weighs 530 grains; charge, 54 grains; total length with bayonet, 6 feet 1 inch.; length of bayonet, 23½ inches; total weight, with bayonet, 11 lbs. 6 oz. The elevating sight is (*lamette*) of the leaf system.

In 1854, a rifle-musket with tige was adopted; total weight with bayonet, 10.4 lbs.; total length, 6 feet 1 inch; calibre, 0.68 inch. It has four grooves (Fig. 11)

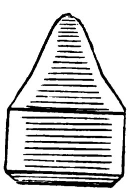


Fig. 10

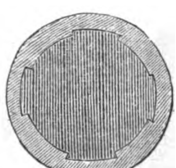


Fig. 11.


Fig. 12.

of uniform twist, one turn in five feet, and decreasing in depth from the breech to the muzzle; an elevating sight similar to that of the French, and graduated up to 800 yards; the ball (Fig. 12) is cylindro-conic and solid, with three grooves; weight, 700 grains; charge, 63 grains.

SWITZERLAND.

The Swiss have been surpassed by no people in Europe in the number and variety, as well as success of their experiments with small arms. In 1847 a commission was appointed to determine the relative merits of the oblong and spherical balls, and to produce a rifle that should be superior to any then in their service. This commission experimented with many varieties of rifles, and decided at once in favor of the oblong ball; but they were not satisfied as to the relative merits of the tige and chambered rifles: they accordingly directed two rifles to be made, one with tige, the other chambered.

In 1848, experiments were again made with a great variety of rifles, including the two suggested by the previous commission, and with a new one made during this course of experiments. This commission rejected tige and chambered rifles, and adopted the rifle that had been made by their order, having neither tige nor chamber. This rifle being issued to a few troops for experiment, and conflicting reports having been made with reference to it, the commission was again assembled for further experiments; and a rifle and ball (Fig. 13) proposed by Colonel Wurstemberger, Federal artillery, submitted among others for trial. The range and accuracy of this new rifle were

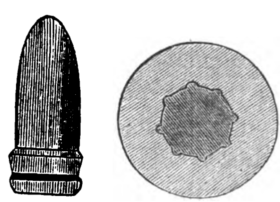


FIG. 13.

both so extraordinary that the commission recommended unanimously its adoption for riflemen. The rifle has eight grooves of uniform depth and inclination, the sum of the grooves being equal to that of the lands, the twist is one turn in 3 feet; the calibre, 0.41 inch; length of ball, 1.0039 inch; weight, 257 grains; charge, 62 grains.

At 818 yards this rifle placed 66 per cent. of its balls in a target 4 by 6 feet, and the *entire hundred* balls at the same distance, in a target 13 by 10 feet. The commission, by experiment, ascertained that in rifles of very small calibres, the accuracy diminishes rapidly at extreme ranges.

This rifle, adopted for the carbineers, is called the *federal rifle*, model, 1851. The elevating sight (see Plate) is graduated up to 1000 yards. It is attached to the barrel in a peculiar manner, being fastened by the side, in a groove made in the metal of the barrel, and retained in its place by a small screw, pressing from above down. It is graduated from 200 up to 1000 yards; this graduation can easily be continued up to any distance. The rammer is so made that it presses the ball down, but not upon the powder (thus leaving *an interval*) being arrested at the muzzle by a projection on the rammer, for that purpose, at 2.9 inches from the head. The federal rifle was slightly modified (Fig. 14) for the chasseurs, to whom it was issued in 1856. These changes were, reducing the number of grooves to four,

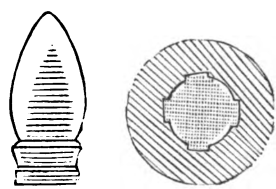


FIG. 14.

with one twist in 27 inches, increasing the length of barrel by three inches, the ball little reduced in height, but of the same weight; the elevating sight the same as that of the federal rifle, but graduated up to 660 yards. The federal rifle is slightly superior in accuracy and range to the chasseur rifle.

In 1855 experiments were made with these two rifles, the Baden rifle, Belgian, Prussian, and Enfield rifle-musket. The result of these experiments was a marked superiority in favor of the two Swiss rifles.

At 654 yards the Enfield rifle-musket placed 40 per cent. in a target 9 × 12 feet; at 818 yards the *federal rifle* placed 96 per cent. in a target 8 × 8 feet, and the *entire hundred* balls in a target 10 × 13 feet; the Belgian rifle at 818 yards put 20 per cent. in a target 13 × 20 feet; the Baden rifle 61 per cent. in a target 9 × 30 feet; at 990 yards, in a target 10 × 19 feet, the federal rifle put 85 per cent. of its balls; at 1308 yards the federal rifle put 47 per cent. in a target 10 × 19 feet; the chasseur (Swiss) rifle 30 per cent. in the same target. These experiments proved that the two Swiss rifles were greatly superior to the others tried, both in range and accuracy. Total weight of federal rifle with bayonet, 10.7 lbs.; chasseur rifle-musket with bayonet, 9.9 lbs.; length of federal rifle with bayonet, 69.1 inches; length of bayonet, 20 inches; chasseur rifle-musket is 71.9 inches long; the recoil of the two Swiss rifles is less than that of any European rifle.

Saxony.

In Saxony, the chasseurs have a rifle with tige, four grooves of uniform depth and twist, the twist being one turn in 20 inches. These rifles are issued also to two non-commissioned officers and 16 men in each company of infantry of the line, these men being skirmishers. The ball weighs 358 grs. (Fig. 15); charge, 78 grs.

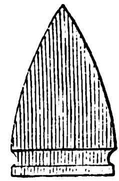


Fig. 15.

Sweden.

The Swedes have a carbine with tige and chamber, eight grooves of uniform depth and twist, of one turn in 40 inches; the ball (Fig. 16) is the primitive French ball; the elevating sight is of the leaf pattern (*lamettes*), and graduated up to 460 yards. This arm is given to eight men per company in the infantry of the line; and in chasseur battalions to 12 men per company.

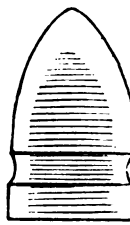


Fig. 16.

The Norwegians have a carbine similar to the one above described. The Swedes have two breech-loading rifles; one (the Norwegian) has been in service for many years; with it is used a ball like the primitive French ball (Fig. 16), weight 772 grains. The other (Swedish), adopted in 1851, has six grooves of uniform depth and twist, of one turn in six feet six inches; the ball (Fig. 17) weighs 402 grains; charge, 77 grains. Rifle-muskets are issued to the infantry of the line; the hollow Belgian (Peeters) ball is used with them.

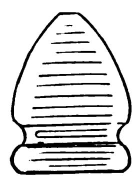


Fig. 17.

Belgium.

The Belgians adopted the French tige carbine of

1846 for the chasseurs, their infantry of the line being armed with the rifle-musket. The chasseur rifle has a cylindro-conic ball (Fig. 18), solid, with three grooves around the cylindrical part; diameter of the cylinder at the base of the cone, 0.66 inch, it is slightly less at its base; total length of the ball, 1.14 inch, of the conical part, .74 inch; weight, 756.5 grains; charge of powder, 62 grains. The ball of the rifle-musket is the Peeter's ball, cylindro-conic and hollow (Fig. 19); the cylindrical part has three grooves around it; in the hollow is a conical projection, extending from the bottom (which extends slightly into the conical part) of the cavity to half its length, this (*noyau*) projection is concentric with the ball, and serves to prevent the rupturing of the sides of the ball, by moderating and directing conveniently the action of the gas of the powder; it also serves to place the centre of gravity of the ball in the axis, by receiving or attracting the flaws, which are sometimes formed by the moulding. Total length of this ball, 1.19 inch; of the cone, .74 inch; the diameter of the cylinder at its base, .66 inch, somewhat larger than it is at the base of the cone, which is .65 inch; diameter of the entrance to the cavity, .45 inch; at the bottom of cavity, .29 inch; total weight of ball, 725.5 grains; charge of powder, 85 grains.

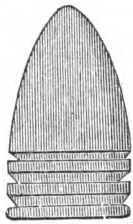


Fig. 18.

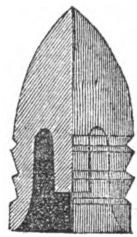


Fig. 19.

Elevating sight for the chasseur carbine, the same as that of the French for that arm; that of the rifle-musket is composed of an upright piece working on a hinge or joint; this upright, with its joints, gives three lines of sight,—the first passing through the notch of the short arm of the upright, this being down in its place on the barrel; the sight being erect, the second line passes through the notch in an opening in the upright; the third passes through the notch of the upper end of the sight,—the sight is graduated up to 650 yards.

Experiments at the camp of Beverlo, in Belgium, in 1851, with the rifle-musket and the tige carbine, with angles of elevation for the first of 1° 12′, and for the second, 1° 2′, gave a total *dangerous space* of 124 yards for the first, and 105 yards for the second, the firing being at 328 yards against a target 6 × 18 feet; the per cent. of balls that struck was 51 for the first, and 49 for the second arm. At 492 yards, same target, angles of elevation for the first 1° 50′, and for the second 1° 51′, dangerous spaces were 44 for the first and 42 yards for the second; per cent. for first, 37, and 25 for second. At 658 yards, same target, angles of elevation for former 2° 41′, and for latter 2° 48′, total dangerous space for the two arms 32 yards; per cent. 21 musket, 31 carbine,—the carbine being superior at this distance. At 820 yards, same target, angles of elevation 3° 30′, and 4° 5′, the per cent. of balls that struck was 13 and 7. In these experiments the rifle-musket proved superior. In subsequent experiments the carbine proved the better. In reality, as regards efficacy, they may be regarded as equal.

At 656 yards the rifle-musket penetrated pine plank 2.9 inches; the carbine, 3 inches. In comparative experiments with animals and pine wood, it has been proved that balls penetrating .62 inch in the wood, will inflict dangerous wounds upon animals. In the above experiments, with targets of 12 × 18 feet, at distances of 820 and 656 yards, angles of elevation the same as above stated for those distances, the per cent. was 20 and 12, 41 and 46 respectively.

In this experiment the size of a man was represented on the target, and the men directed to aim at it. At 328 yards this was struck by the rifle-musket 16, and by carbine 14 times; at 492 yards, 6 and 2 times; at 658 yards, 2 and 3 times; at 750 yards, by rifle-musket, once.

At Beverlo, in October, 1853, comparative experiments were made with the Enfield rifle and the Belgian rifle-musket, each firing its regulation-cartridge. At 750 yards, target 9 × 18 feet, angles of elevation for the first 2° 54′, for the second 3° 8′, out of 50 balls fired, 10 of the former, and 42 of the latter, struck; at 600 yards, angles of elevation for first 2° 7′, and for second 2° 21′, of 30 balls fired, 20 and 28 struck; at 500 yards, angles of elevation for first 1° 42′, and for the second 1° 50′, of 30 balls fired, 24 and 29 struck; at 400 yards, angles of elevation for first 1° 21′, and for second 1° 27′, out of 30 balls fired, 26 and 29 struck; at 300 yards, angles of elevation for first 1° 6′, and for second 1° 8′, of 20 balls fired, all struck; this experiment proved the Belgian rifle-musket to be superior, and being a marked improvement over the experiment at the same place in 1851. At 600 yards, the *dangerous spaces* for cavalry and infantry, for the two arms were, respectively, 32 and 36 yards (cavalry), 21 and 26 yards (infantry); penetration in beech plank, 4 inches for the Enfield; Belgian, slightly greater.

Initial velocity of the Enfield 1113 feet, Belgian 1022 feet, per second. The Belgian chasseur carbine gives an initial velocity of 1007 feet per second.

Spain.

In October, 1858, Spain adopted the rifle-musket with the Peeters (Belgian) ball (Fig. 20) for the infantry of the line. In 1852 rifle-muskets with wedge balls were issued to the chasseurs; grooves four, and progressive in depth, one turn in 58 inches; weight of ball, 447 grains; charge, 69 grains.

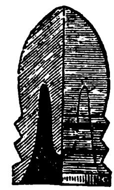


Fig. 20.

Hanover.

The Hanover infantry have two kinds of rifles. The non-commissioned officers of the line, and the non-commissioned officers and soldiers of the rifle-men have a tige rifle, with seven grooves of uniform depth and twist, one turn in 43 inches; ball (Fig. 21) cylindro-conic; weight, 448 grains; charge of powder, 74 grains. In the light infantry the men have a rifle-musket; the non-commissioned officers, a tige rifle. They have also a tige carbine with eight grooves, progressive in depth, twist the same as the tige rifle.

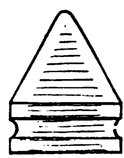


Fig. 21.

Baden.

In 1841, Wild, a Swiss officer, proposed to the federal government a carbine of his invention. Experiments with this arm gave it a certain notoriety, and caused it to be adopted in some of the German States, especially in Baden: in this country it was given to ten men per company—the skirmishers. Wild's system consisted in employing a number of grooves, varying from 10 to 16, with but little depth, and an inclination less than is ordinarily given. The ball being spherical, and surrounded by a patchin not greased, the windage is great, thus making it easy to load. After each discharge water is poured into the barrel from a copper vial, in drops. By this means 100 rounds can be fired without rendering it necessary to clean the arm. The accuracy of this rifle was equal to that of the arms of that time. The ball and patchin were united with the cartridge. In order that the ball might not be in contact with the powder when loaded, the rammer had a small projection that caught at the muzzle when the ball was at its proper place, that is, near, but not in contact with the powder. This arm was retained in Baden until 1853.

The infantry of the line in Baden were furnished in 1853 with rifle-muskets and wedge balls, cylindro-conic, having three grooves around the cylindrical part; the cavity of the ball deep. At 820 yards these rifle-muskets placed 39 per cent. of balls in a target of 6 × 25 feet. They have five grooves of uniform depth and twist, which is one turn in 52 inches; elevating sight graduated up to 820 yards. The chasseurs have a rifle differing from the rifle-musket in the grooves only, which are progressive in depth. The ball has no cavity; elevating sight the same as the rifle-musket; weight of ball (Fig. 22) for rifle-musket, 590 grains; charge, 69.5 grains. The elevating sight for the rifle-musket is like that of the French chasseurs. For the chasseur rifle the sight is like that of the Swiss. The two sights are regulated up to the same distance.

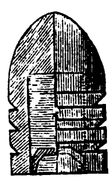


Fig. 22.

Bavaria.

In 1854 tige carbines were issued to six battalions of chasseurs, having four grooves of uniform depth and twist, of one turn in sixty inches. The elevating sight (Fig. 24) is peculiar, being arranged so as to correct the *drift* of the ball; the slide being made to enter a slit on the left upright part of the sight. The slide, in following this slit, changes the line of sight more and more to the left as it is elevated. The rammer has one end hollowed, in order to fit the ball; on the other end is a wooden ball for the hand to rest upon in ramming the ball down;

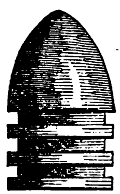


Fig. 23.

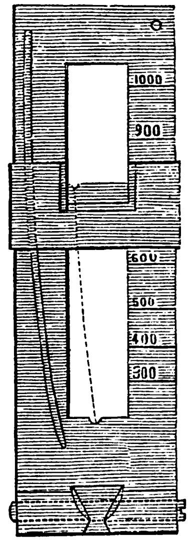


Fig. 24.

this rammer is not carried attached to the piece, but as the Austrian chasseurs carry theirs. At 1000 yards, 15 per cent. of balls were placed in a target 9 × 18 feet. The ball (Fig. 23) is made by pressure, and weighs 675 grains; charge, 66 grains.

Wurtemberg.

In the army of Wurtemberg 10 men per company are armed with a carbine of the system Wild, with 12 grooves of uniform depth and twist, of one turn in 34 inches; ball sphero-conic (Fig. 25), with a

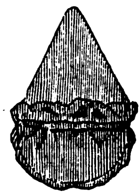


Fig. 25.

patch of fustian, and tied to the cartridge; charge, 92 grains.

BRUNSWICK.

The Berner, or two-groove system, is used in Brunswick, being, however, slightly modified. The rifle has two grooves which diminish in depth up to a certain distance in the barrel, where they are eased off smooth with the bore, thus leaving it elliptical. There are three kinds of balls—one oval, the other two spherical. The oval and one of the spherical are fired with a patch; the other spherical ball is fired without patchin, and is called a ball *roulante:* latterly they have used but two balls, both spherical; one with patchin, the other naked; the charge of powder for the two is different, being greater for the ball without patch; elevating sight, the leaf pattern.

DESSAU.

In 1855 the Duchy of Anhalt Dessau adopted a rifle-musket of the same pattern and calibre as the Austrian. The projectile (Fig. 26) is also Austrian, of the system Lorens, with one deep groove; weight of ball, 463 grains; charge, 77 grains. This rifle gives great accuracy and range.

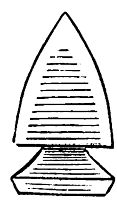


FIG. 26.

HESSE-ELECTORATE.

In 1855 the two brigades of the Electoral army received rifle-muskets with chambers; ball (Fig. 27) of the system Peeters, the lower portion being slightly bevelled, so as to fit snugly on the cham-

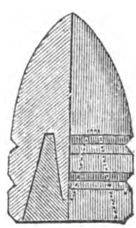


FIG. 27.

ber; grooves, four, and of uniform depth and twist, of one turn in 74 inches; weight of ball, 608 grains.

Grand Duchy of Hesse.

In 1855 the army of the Grand Duchy was provided with two rifles: one for the infantry of the line, the other for the riflemen. Grooves, five; sum of the lands equal to that of the grooves; depth, uniform; weight of ball, 625 grains; charge, 69.5 grains: the one for the riflemen being shorter; the elevating sights in the two arms are regulated up to 650 yards; the one for the riflemen is of the Swiss model; the ball has a wedge (Fig. 28).

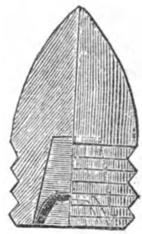


Fig. 28.

Mecklenburg.

In 1851 the Mecklenburg infantry were armed with a rifle with both chamber (Fig. 29) and tige: the cham-

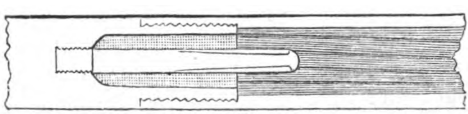


Fig. 29.

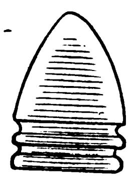


Fig 30.

ber is tron-conic in shape; the tige is for half of its length cylindrical, then square, with a rounded point; the ball (Fig. 30) is cylindro-conic; weight, 442 grains; charge, 56 grains.

NAPLES.

In Naples they use rifles modelled after the Swiss, with hollow balls.

NASSAU.

In 1848 tige rifles were issued to the riflemen. Five grooves decreasing in depth, with a twist of one turn in 52 inches; weight of ball (Fig. 31), 722 grains; charge, 69 grains. In 1853 the arm was changed for a rifle-musket without tige, firing the French cylindro-conic ball with wedge; this rifle was the same as the first, save the tige.


FIG. 31.

OLDENBURG.

The Berner system was adopted in 1832; the spherical ball latterly has been replaced by a ball (Fig. 32), cylindro-conic, with three grooves; the bottom of the hollow of the ball is protected by paper, to check the perforation of the gas. In 1847 the rifle with tige (Fig. 33) and conical chamber was adopted: the tige cylindrical, and pointed at the top; the barrel slightly thin-

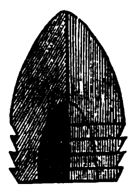


FIG. 32.

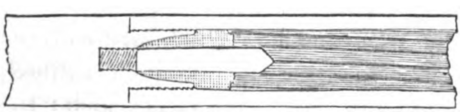


FIG. 33.

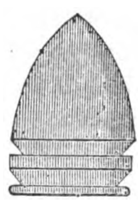


FIG. 34.

ner near the breech; grooves, four; depth, uniform;

twist one turn in 80 inches; weight of ball (Fig. 34), 421 grains; charge, 47 grains.

HOLLAND.

In Holland, for many years the chasseurs have had the tige carbine, eight grooves of uniform depth, one turn in 38 inches; the ball cylindro-conic (Fig. 35), with one deep groove, around which a greased thread is tied; the elevating sight is of the leaf (*lamette*) system; the ball weighs 494 grains; charge, 61 grains. In 1855 the rifle-musket was adopted for the infantry.

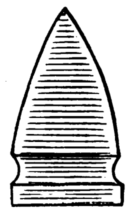


FIG. 35.

PORTUGAL.

No positive information with reference to its armament

UNITED STATES.

The United States, like the various governments of Europe, have been much occupied of late years with improvements in small arms; and after many experiments, conducted under the direction of officers of the ordnance corps, well informed theoretically and practically on the subject, have adopted rifles and rifle-muskets for the entire infantry. The rifle-muskets and rifles at present in use in the army are as follows:—the rifle-muskets, model 1822 and 1842, .69 inch calibre; the new rifle-musket, model 1855, .58 inch calibre; the rifle, model 1841 (altered), calibre .58 inch; the new rifle, model 1855, .58 inch calibre. All of these arms have the same number of grooves, to wit, three;

the same twist, one turn in six feet, and decreasing in depth from the breech to the muzzle. The ball is the same for all—cylindro-conic, with three grooves around the cylinder, hollow, and no wedge (Fig. 36)—weight of ball for the rifle-muskets, model 1822 and 1842, 730 grains; charge of powder, 70 grains. Weight of ball for the other arm, 500 grains; charge, 60 grains.

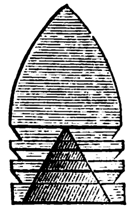


FIG. 36.

Barrel of the new rifle-musket has a length of 40 inches, that of the new rifle, 33 inches; total length of new rifle-musket with bayonet, 73.85 inches; of new rifle with bayonet, 71.8 inches; weight of barrel of new rifle-musket, 4.28 lbs.; of new rifle, 4.8 lbs.; total weight of new rifle-musket with bayonet, 9.90 lbs.; of new rifle with bayonet, 12.98 lbs.

The new rifle-musket, fired from a fixed rest at 1000 yards, gave out of 120 shots a mean vertical deviation of 55.9 inches, and a mean horizontal deviation of 25.5 inches. The rifle, 1841 (altered), at the same distance, and fired under similar circumstances, the same number of shots gave a mean vertical deviation 58 inches, and a mean horizontal deviation of 25.2 inches, ball and charge of powder the same in the two cases.

The altered musket of 1822 and 1842 model, fired at the same distance, and under similar circumstances, gave out of 50 shots a mean vertical deviation of 61.2 inches, and a mean horizontal deviation of 26.4 inches; ball, 730 grains; charge, 70.

From the above experiments it appears that at 1000 yards the new rifle-musket is the more accurate arm. Firing at 200 yards with new rifle-musket, 60 grains charge, the highest point of the trajectory is 19.6 inches; at the same distance with altered musket of 1822 and 1842, 70 grains powder, the highest point of the trajectory is 20.9 inches; at 500 yards with the Harper's Ferry rifle, 50 grains powder, ball 400 grains, the highest point of the trajectory is 150 inches.

Firing at 300 yards with new rifle-musket, the highest point of the trajectory is 40 inches.

At 1000 yards the angle of elevation for the new rifle-musket is 4°15′; the Harper's Ferry rifle, 4°30′; altered musket of 1822 and 1841, 4°50′. At 500 yards, angles of elevation, 1° 30′, 1° 45′, and 1° 50′; the ball and charge being of regulation size and weight: each of the above angles being the mean of 50 shots.

Initial velocity of the new rifle-musket, 963 feet per second; of the altered Harper's Ferry rifle, 914 feet per second.

Initial velocities of the round balls under the old system are as follows: musket with 110 grains powder, 1500 feet per second; rifle with 70 grains powder, 1750 feet per second.

Recoil of the new rifle-musket expressed in feet, 7.08 feet; of the altered Harper's Ferry rifle, 6.88 feet.

The rifles and rifle-muskets of the United States compare favorably with those of European powers, resembling in appearance very much those of the English, although no target-practice is reported giving such range and accuracy as the Swiss or Austrian rifles. Nevertheless, in material, manufacture, and appearance, the United States arms are inferior to none.* With the United

* All that is said with reference to the United States arms, is taken from "Small Arms," published by the Ordnance Department, 1856.

States rifles the ball is fired without patchin ; it would seem that the arm being loaded, the powder is more apt to become wet in case of rain than if the ball were patched. The U. S. rifles are too hard upon trigger.

Old rifles in the Artillery Museum in Paris.—The Artillery Museum in Paris contains an interesting collection of old rifles. Of these, 311 have a .68 inch calibre and under ; 32 have a calibre greater than .68 inch ; 32 have barrels 19½ inches and under in length ; 267 between 19½ and 39 ; 36 above 39 inches. 19 have straight grooves ; 321 have inclined grooves ; 131 grooves uniformly inclined ; 81 have grooves of increasing twist near the breech ; 29 increasing twist towards the muzzle, and 83 with increasing twist near the middle of the barrel.

Sixty-seven have grooves making a half turn and under in the length of barrel ; 219 make from a half to a whole turn ; 55 have from one to two entire turns ; 226 have an even number of grooves ; 117 an odd number ; 79 have from two to six grooves ; 232 have from seven to twelve grooves.

Two hundred and seventy-five have grooves with rounded edges ; 33 have triangular grooves ; 9 have rectangular grooves, and 26 have grooves not defined.

Two hundred and ninety-six have grooves .11 inch and under in width ; 47 have grooves wider than .11 inch ; 153 have grooves .0197 inch and under wide ; 179 from .0197 inch to .0394 inch wide, and 14 have grooves wider than .0394 inch.

The above is interesting as showing what varieties of grooves have been experimented with many years since. None have grooves decreasing in depth : these are a new species of groove first practised by Tamissier in 1846. The elliptical-bored rifle is also a late idea, originating with Lancaster, an English gunsmith.

Recapitulation.—From the preceding brief statement as regards the infantry arms of Europe and the United States it is seen that the smooth-bored musket and round ball have been entirely superseded by the rifle and the elongated or cylindro-conic ball. This change did not occur until the most elaborate experiments, conducted under the direction of skilful officers, had proved its necessity. It is seen, also, that notwithstanding the long time that has elapsed since the discovery of the rifle, that its principle is not yet so well understood as to have led to the general adoption of any particular form of this arm as the best.

We see, from the synopsis of the arms as given, that there exists much variety as regards calibre. The Swiss rifle, for example, and the smallest, being .41 inch; while that of the Swedes, the largest, is .74 inch. In the number of grooves there is also much variety: in Brunswick, Oldenburg, and Russia, the two-grooved rifle is yet in use; in Wurtemberg we find a twelve-grooved rifle. These numbers 2 and 12 are the extreme limits; but few rifles with either of these number of grooves are now in service. The number most generally adopted is *four;* rifles with *eight* are the next most numerous. There is as regards the shape or form of grooves a want of uniformity: some have sharp edges, in others the edges are rounded off, and the bottom of the groove is concave. They differ much in the turn or twist: in Oldenburg they have a twist of 6 feet 8 inches, which is the longest; in Sardinia we find the shortest twist, that of 17 inches for the rifle of the Bersaglieri. In France, Belgium, and the United States the grooves are all progressive in depth; in Hanover, Nassau, and Spain, one of the rifles of the infantry have progressive grooves, the other uniform.

In some countries rifles have neither *tige* or *chamber*, as in England, the United States, and Switzerland; in others both the tige and chamber, as in Prussia and Sardinia; in some the tige and the plain breech, for example, Austria, Belgium, and France.

The longest rifle is the Prussian needle breech-loader, having a total length with bayonet of 6.4 feet; the shortest are the Bavarian and Austrian tige rifles of 5.57 feet total.

The Swedish rifle with tige is the heaviest, weighing without bayonet 13.7 lbs.; the Bavarian tige rifle is the lightest: its total weight with bayonet is 9.1 lbs.

With reference to the projectiles the same uncertainty exists as to the best form to be given: among the balls now in service there is much variety in form and weight. They may be divided into two general classes, to wit: the *solid* and *hollow*. Of the solid there are several varieties: some with three shallow grooves around the cylindrical part, as for example, the French and Belgians; in others two deep grooves, as in Austria; in others one deep groove, as in Holland. Of the hollow balls there are several varieties: but one of them is without grooves around the cylindrical part, viz., that of the English. In the United States, and other countries, we find a hollow ball with three grooves around the cylinder. In some countries wedges are used with the hollow ball, as in England, Baden, the Duchy of

Hesse; in others no wedge, as in the United States, France, Prussia. The Belgian, or Peeters hollow ball is peculiar, having a conical projection in the cavity; that of the French is also peculiar, having a triangular cavity, as has been explained, with one groove around the cylinder; its point is flat.

In England, the United States, Austria, and Switzerland *but one* ball is used,—hollow for the first, and solid for the other two; in Sardinia two solid balls; in France, Belgium, Prussia, and Russia both hollow and solid balls are used. In general, solid balls are used with tige and chambered rifles; hollow balls, with or without wedge, with rifle-muskets, no tige or chamber.

The heaviest charge of powder is 92 grains, used in Wurtemberg with a sphero-conic ball patched. The lightest is 47 grains, used in Oldenburg. The solid balls in France and Belgium are fired with less powder than the hollow balls in the same countries. In general, stronger charges are used with hollow balls.

The Swedish .74 inch rifle has probably the heaviest ball. The heaviest given is the Russian solid ball, 772 grains; charge 71 grains. The lightest is the Swiss, 257 grains; charge 62 grains.

The Swiss have the heaviest charge of powder in proportion to the weight of ball; the ball is patched; is not pressed down upon the powder, but has a *space* preserved between it and the powder: this gives the greatest accuracy and range, and less recoil.

The following table contains the various kinds of balls, with their weights, charges of powder, and the number of grooves, with their twist, of the rifles from which they are fired.

	BALLS.			POWDER CH'GE.	NO. OF GROOVES.	TWIST OF GR'VES.		SPECIES OF RIFLES.
	SOLID.	HOLLOW.						
		No wedge.	Wedge.					
	GRAINS	GRAINS	GRAINS	GRAINS		FT.	IN.	
Austria	Lorens. 450	......	......	61	4	5	2	Tige carbine and rifle-musket.
Baden	......	......	590	69	5	4	4	Rifle-musket.
Bavaria........	675	......	......	66	4	5		Tige carbine.
Belgium	756.5	......	......	62	4	6	6	Tige carbine.
"	......	Peeters 725.5	......	85	4	6	6	Rifle-musket.
Dessau	Lorens. 463	......	......	77	4	5		Same as Austria.
England.......	......	......	520	68	3	6	6	Enfield rifle.
France........	733.4	......	......	69	4	6	6	Tige carbine.
"	......	494	......	77	4	6	6	Rifle-musket.
Hanover	448	......	......	74	7	3	7	Tige carbine.
Hesse Duchy..	......	......	625	69	5	6	2	Rifle-musket.
Hesse Electoral	......	Peeters 608	......	......	4	6	2	Rifle-musket with chamber.
Holland	494	......	......	61	8	3	2	Tige carbine, rifle-musket adopted 1853.
Mecklenburg ..	442	......	......	56	......	......		Tige carbine.
Nassau........	722	......	......	69	5	4	4	Tige carbine.
"	......	Ball hollow.	......	......	......	......		Carbine without tige, and hollow ball since 1853.
Norway.......	772	......	......	......	......	......		Carbine with tige and chamber.
Oldenburg	421	Ball hollow.	......	47	2 } 4 }	6	8	Tige carbine and the two-grooved rifle.
Prussia	490	......	......	50	8	3	1	Tige carbine with tron-conic chamber.
"	451	......	......	65	4	3	6	Needle breech-loader.
"	......	705	......	79	5	4	6	Rifle-musket.
Russia	772	......	......	71	2	......		Two-grooved rifle.
"	705	......	......	......	......	......		Tige carbine.
"	......	Ball hollow.	......	......	......	......		Rifle-musket.
Sardinia.......	530	......	......	54	8	1	5	Chambered rifle, Bersaglieri.
"	700	......	......	63	4	5		Rifle-musket with tige.
Sweden	402	......	......	77	6 } 8 }	3	4	Tige carbine with chamber.
"	......	Peeters Ball hollow.	......	......	6	6	6	Rifle-musket.
Switzerland....	257	......	......	62	{ 8	3		Federal rifle.
					{ 4	2	3	Chasseur rifle.
Spain	......	Peeters 447	......	69	4	4	10	Rifle-musket.
United States..	......	500	......	60	3	6		Rifle-musket and rifle.
Wurtemberg ..	......	......	......	92	12	2	10	Carbine system Wild.

CHAPTER II.

Rifles that are or have been the subject of experiments, but not as yet issued to troops.—Jacobs' double-barrelled rifle.—Whitworth's.—Lancaster's.—Breech-loading rifles.—Thiroux's balls with sabots.—Balls of Delorme-Duquesnoy.

HAVING described the rifles and rifle-muskets, such as are actually in service in Europe and the United States, a brief description will be given of three rifles that have been experimented with in England, though not adopted into the service to any very great extent, viz., *Jacobs'*, *Whitworth's*, and *Lancaster's*.

The *Jacobs rifle*, so called from its maker, General Jacobs, of the East India service, is double-barrelled, with four deep grooves, of breadth equal to that of the lands; length of barrel, 24 inches, weight of barrel, six pounds; the grooves of uniform depth and twist, making four-fifths of a turn in the length of the barrel; diameter of bore, .529 inches. The ball (Fig. 37) has four projections or ridges to fit the four grooves of the barrel; these projections have the same inclination as the grooves of the rifle, extending throughout the length of the cylindrical part of the ball: which is used with a thin greased patchin; diameter, .524 inches; it has no hollow, the base being flat and smooth; length, 2½ diameters; weight, 754 grains; charge, 68 grains.

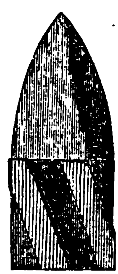


FIG. 37.

General Jacobs reports excellent practice with this rifle at 2000 yards, both with the solid ball and the shell, which is of the same exterior form as the ball. At 1000 yards, he says that a soldier tolerably instructed, can strike a target the size of a man *once* out of *three* times. Firing at 1200 yards, with his shells, they penetrate a brick wall several inches, and bursting, tear out large fragments. In the rammer to this rifle the head is hollow, in order that in pressing down the shell no accident may occur. A copper tube, containing the powder, and having the fulminating composition at its upper extremity, is inserted in the shell, as seen in Fig. 29, plate of cartridges. The ball and shell have the same shape, both flat at the base. This rifle, although highly recommended by General Jacobs, as well as by those that have seen it used in the East Indies, has not been adopted into the English service.

General Jacobs has invented a very simple method for diminishing the recoil of heavy rifles. This is attained by simply fixing in the stock a powerful spring under the heel plate, which works longitudinally upon two steel bars. If, in addition to this spring-bolt, about twice the usual quantity of metal in the breech be interposed between the chamber and the false breech, the recoil of the most ponderous rifle will not exceed that of an ordinary fowling-piece.

The following table, the result of experiments, shows the average duration of the flight of some of the shells, size of 24 guage, 2½ diameters long, weighing 615 grains, and of the form represented in Fig. 29, plate of cartridges, charge of powder 2½ drams:

TIME IN SECONDS AND THOUSANDTHS OF A SECOND.

Yards.	Seconds.	Yards.	Seconds.
100	.325	1,100	4.030
200	.650	1,200	4.500
300	.975	1,300	5.000
400	1.300	1,400	5.500
500	1.625	1,500	6.000
600	1.975	1,600	6.500
700	2.350	1,700	7.200
800	2.750	1,800	7.950
900	3.160	1,900	8.670
1,000	3.600	2,000	9.400

With a four-grooved single rifle, No. 8 gauge, weighing 14 lbs. 8 oz., and with shells of the same form, but weighing 3 oz. 8 drs., and with a charge of 4 drs. of powder, the time of flight was as follows:

Yards.	Seconds.	Yards.	Seconds.
700	2.380	1,400	5.610
800	2.785	1,500	6.140
900	3.203	1,600	5.710
1,000	3.620	1,700	7.300
1,100	4.900	1,800	7.900
1,200	4.570	1,900	9.510
1,300	5.600	2,000	9.120

Angle of elevation at 2000 yards, 12° 30′.

Double barrels, converging and parallel.—Experiments with double-barrelled rifles show that barrels converging have a greater accuracy than those that are parallel. An experiment in Belgium, with converging and parallel barrels, with a ball of 448 grains, and charge of powder 139 grains, gave, at 82 yards, a point of mean impact of nearly one half the error for the converging that it did for the parallel barrels; as the distance increased, the relative accuracy of the converging barrels increased. At 220 yards, the error of the mean point of impact for the converging barrels was much less than half that of the parallel barrels. The superior accuracy of the converging barrels is due to the effect of the recoil.

The *Whitworth rifle*, so called from its maker, the celebrated Manchester machinist. In 1854 the English government appropriated $60,000 to enable Whitworth to experiment with small arms. His experiments led to the making of a rifle different from any then known in Europe.

The bore of his rifle was not cylindrical, but *polygonal*, a *hexagon;* length of barrel, 39 inches; the sides of the hexagon having a twist of one turn in 20 inches, so that the ball makes nearly *two* turns before it leaves the piece; diameter of hexagon, from side to side, 0.438 inch; from angle to angle, .49 inch. The ball (Fig. 38) is a hexagon, its sides having the same twist as the bore of the rifle; for about the length of half a diameter from the foremost end the ball is conical; length of ball, 1.45 inch (or 2½ diameters). This rifle was made with a degree of accuracy never before attained; the best Birmingham gunsmiths never having reached a higher standard than the 350th of an inch, whereas Whitworth attains the 5000th of an inch. Whitworth proves the possibility of measuring sizes mechanically up to the millionth of an inch, and says that up to his time no steps have been taken to test, by means of different gauges, the accuracy of the interior of gun-barrels, upon which the correctness of the fire so much depends. By applying his delicate tests to the most highly finished barrels hitherto produced, he shows that they are very

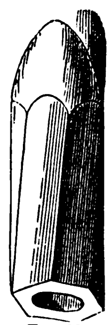
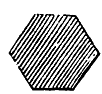


Fig. 38.



false, and contain inequalities that cannot but detract greatly from their precision of fire. In some the bore was found to be conical in one direction, cylindrical in the opposite, and all were more or less irregular.

In April, 1857, Whitworth's rifle, as above described, was experimented with at the school of musketry at Hythe, and compared with the Enfield rifle. From this experiment the efficacy of the Whitworth, as compared with the Enfield, was as 20 to 1. At 1880 yards (at 900 yards the English targets are 16 feet wide and 2 feet high, at 1800, 32 feet wide and 2 feet high) the Whitworth drove its balls into the target, while at 1440 yards the Enfield made no hits. As regards accuracy, the Whitworth, at 1100 yards, was nearly on a par with the Enfield at 500 yards; and when both were fired at 500 yards, the Whitworth was in the proportion of 3 to 1. With the regulation charge of powder the Enfield drove its balls through 12 half-inch plank; the Whitworth penetrated 33, and was only stopped by a solid block of oak.

The Whitworth ball is not lead, but pewter, or a harder metal. This rifle has only been an affair of experiment, it has not been issued to troops (even as an experiment). Its defects seem to be its great recoil and tendency to foul rapidly. Although giving such fine results when carefully fired at a target, it might be found in service to be less effective than the Enfield, now in the hands of the English infantry. Whitworth has adapted to his rifle an ingenious contrivance to counteract the recoil.

The *Lancaster rifle*, so called from its maker, a London gunsmith. In this rifle we have the simplest modification of the principle of rifling; and the question of reducing the windage, without too great an increase of friction, seems to have been satisfactorily met. This rifle is not polygonal, like Whitworth's; neither is it cylindrical, with grooves, like ordinary rifles; but elliptical: so slightly, however, as to be almost imperceptible to the eye, and can only be measured with the gauge. The twist of this barrel is one turn in 32 inches; diameter of bore, .498 inch; length of barrel, 32 inches. The eccentricity of .01 inch in a half-inch bore is found to be sufficient to cause the ball to have the rotary motion to the end of its flight. It is not material whether the ball be made hollow or solid. The length of the ball is $2\frac{1}{4}$ diameters; windage, sufficient to enable it to be used with a thin, greased-

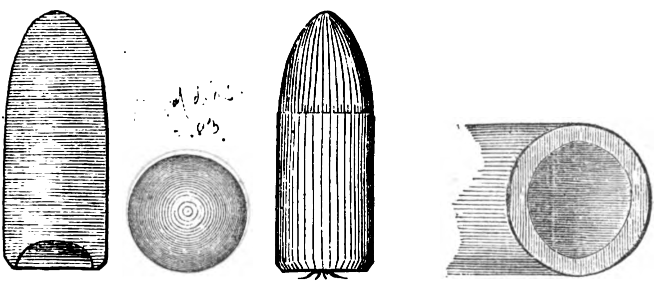


FIG. 89.

paper patchin. This rifle is said to be equal in accuracy and range to Jacobs'. It has been issued to a few companies of infantry in the English army for experiment, and has proved thus far more accurate than the Enfield, and does not lead or foul so readily. At Woolwich, an experiment made with the Lancaster rifle, shows that—

At	500 yards	2	out of	4	balls hit the	bull's-eye,	24	in.	diam.
"	400 "	2	"	3	"	"			"
"	200 "	6	"	6	"	"	8		"

On the same day, experiments with the Minié rifle gave the following:

At	500 yards	1	out of	4	balls hit the	bull's-eye,	24	in.	diam.
"	400 "	1	"	3	"	"			"
"	200 "	6	"	6	"	"	8		"

These experiments giving a superiority in favor of the Lancaster rifle. Experiments made at the camp of Aldershott, in 1858, showed that the Lancaster was superior to the Enfield. Experiments at the island of Malta have shown the same results. This rifle is also said to have the advantage of shooting shot as well as the ordinary smooth-bored musket.

The above description of these three rifles is taken from the *Rifleman's Manual* of Hans Busk, M. A., and Lieutenant of the Victoria Guards, England.

Fig. 39 shows the muzzle of the piece on the right; the figure on the left a section of the ball; the next figure the hollow of the ball; the next, the ball with paper patchin.

BREECH-LOADING RIFLES.

From what has been said with reference to the infantry rifles of Europe, it is seen that breech-loading arms have been introduced but to a very limited extent. In Prussia, part of the infantry is armed with the needle breech-loading rifle; in Sweden and Norway the breech-loader is partially introduced; and in France the Cent Guards are so armed. With the above exceptions, no breech-loading rifles are in the hands of European troops.

The facility of breech-loading gives great rapidity of fire, and consequently would strengthen the weak, by enabling them to deliver a greater quantity of fire upon a too powerful adversary. It cannot be denied, that in many instances breech-loading would be preferable to ordinary rifles; the cannoneers of field-artillery, if armed with breech-loaders, would be more capable of defending their batteries from the attacks of infantry and cavalry; engineer troops, in trenches and in mining, as well as their guards, would make a better defence with breech-loading arms in cases of surprise; escorts to supply trains could use them to advantage in cases of sudden attack or ambuscade, &c., &c.

It cannot be denied that the breech-loading arm inspires more confidence in the individual, and gives him a superiority over his adversary, if not similarly armed. In the defence of forts, block-houses, trenches, breaches, bridges, defiles, and in fact, *in all cases* where rapidity of fire should compensate for paucity of numbers, the breech-loader would be preferable. With the many advantages thus offered, it is perhaps strange that breech-loading arms have not been more generally introduced into service. The influence of a fire of a few regiments of infantry armed with breech-loaders, at critical periods of an action, could not fail to be decisive; and the army that has such corps with it must be more efficient. The objections to, or defects of breech-loading arms, are, that they are complicated in their mechanism, are liable to get out of order from fouling, or escape of gas at the joints, want of strength; and, as the facility of loading gives great rapidity of fire, it is asserted that in battle, under the influence of excitement, the soldier would load and fire without reflection, or without the orders of his officer, and when the decisive moment should arrive, he would have exhausted his ammunition. The facility of fire, which is the greatest advantage of the system, is thus made to appear to be its greatest inconvenience. The future will determine whether or not the breech-loading arm is to be more generally introduced into service, or to be abandoned.

Henry II., of France, was the inventor of breech-loading arms, in 1540.

It would require too much time and space to describe the various breech-loading arms that have been, with more or less success, experimented with. It has only been proposed in this work to describe such rifles as are at present actually in the hands of the infantry of Europe and of the United States. A bare enumeration, however, of such breech-loaders as have been tested by artillery commissioners of foreign countries will be given, to wit:—the *Fusils of Marshal Saxe*, *Tourette of Saint-Etienne*, *Pauly*, *Robert*, *Le Roy*, *Lefaucheux*, *Charroi*, *Jh. Montigny*, *Pierre Montigny*, *Norwegian*, *Swedish*, used in the Marine; the *Prussian needle-rifle*, *Clerville*, *Treuille*, *Thomas*, *Riera*, *Prince's*, &c.; *Musketoon-Lepage*, *Gilbys*, *Gillet of Liege*, *Potet*, &c., &c.

The United States have, in like manner, many varieties of breech-loading arms; among them we may particularize *Sharp's*, *Burnside's*, *Merrill's*, *Joslyn's*, *Maynard's*, and *Colt's*.

Prince.—Of the European breech-loaders above mentioned, *Prince's* appears to be regarded with more favor as an arm for military purposes. It loads with ease and rapidity, fires with precision and force, and with but little recoil. In experiments at Hythe it was fired 120 rounds in 18 minutes; it has five deep grooves, making three fourths of a turn in three feet. This rifle was also experimented with at Brussels, in November, 1856, and was highly indorsed by the commission for its simplicity of construction, and the rapidity, range, and accuracy of its fire: its recoil in this experiment was found to be less than that of the tige rifles, or rifle-muskets, in service among most of the European powers: charge, 70 grains; weight of ball, 470 grains; length of ball, 1.18 inch; length of the cone, double that of the cylinder; diameter, 0.59 inch. The ball has a paper patchin, either of ordinary paper, or that of the inventor; the latter burns rapidly without residue, and is not affected by moisture. The inventor states that the range is from 1640 to 1986 yards, and at this distance the wounds are dangerous, and often mortal.

A Board composed of army officers was convened at West Point, in the autumn of 1857, to experiment with breech-loading rifles, and to report the one in their opinion best adapted to military purposes. In this experiment many varieties were examined and subjected to the test of target firing. The Board, although not recommending the adoption of any one, gave the opinion that of those presented, Burnside's was the one best adapted to the use of the soldier. During the experiment Sharp's rifle was fired by an expert marksman 18 times in 50 seconds.

A second Board convened at the same place in 1858, and, as in the former case, reported in favor of Burn-

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side's as the best presented, though not recommending its adoption into the service.

At present a few breech-loading rifles have been issued to troops in our service as a matter of experiment, to wit: Sharp's, Burnside's, Merrill's, and Colt's.

Colt.—Of the various breech-loading arms of American manufacture none seem to be so well known and appreciated, both at home and abroad, as those of Col. Colt. His revolving pistol has been extensively used of late years, especially in the Crimea and British India. His rifle, made after the same principle as the pistol, is highly praised in England: like the pistol it has seven grooves of uniform depth and *increasing* twist.

Lieut. Busk, of the Victoria Rifles (English service), reports, on the 25th of April, this year, that with Colt's regulation rifle, at a distance of 400 yards, firing at a target 6 × 2 feet, bull's eye 8 inches, that of 48 shots *all* struck the target, 17 within the bull's eye, and *all* within a square of *two feet;* 24 of the shots with a rest, 24 without rest. The above target-practice, given as reported to Col. Colt by Lieut. Busk.

Thiroux's balls with sabots.—Thiroux (French artillery) has proposed, in the *Journal des Arms Spéciales*, a ball for smooth-bored musket, the idea of which seems to have been inspired by the arrow of the ancients.

The projectile proposed is composed of a point of lead or iron fixed upon a sabot of hard wood. The sabot has towards its base three circular grooves, to act as directrices to the point. If the point be of iron it should be made round, and terminate by a tige, by means of which it is attached to the sabot (Fig. 40).

If the point be of lead, the ball has a hole following the axis of the cylinder, and is attached to the sabot by means of a screw with a rounded head (Fig. 41).

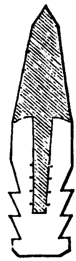

Fig. 40.

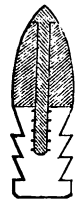

Fig. 41.

The weight of the iron ball is 370 grains; that of the lead is 386 grains. According to Thiroux, these balls fired with a charge of 123 or 138 grains, would probably have an initial velocity of 1640 feet per second, and give flattened trajectories, because the points are very sharp, and the sabot being large and of wood, encounters a great quantity of air which tends to sustain it.

In experiments made by Thiroux these balls have always struck the target point foremost, and have penetrated sufficiently.

Numerous experiments could alone indicate their real merit. It is probable, however, that they would be inferior to balls used with the tige rifle, or those used with rifle-muskets, since they have less weight, and do not receive their motion of rotation inside the barrel of the piece.

The sabots might be so arranged as to cause them to follow the grooves of the rifle, and communicate thus a motion of rotation, and check the shocks that otherwise occur. It would suffice for this purpose to have on the sabots projections corresponding to the grooves of the rifles; these would cause the ball to follow the grooves both in descending and in leaving the piece. A thread of greased woollen tied around the first groove would facilitate its introduction, and at the same time clean the arm at each fire. Projectiles of this kind might be applicable to rifle cannon.

Balls having a rotary motion imparted by the action of the air, or by the action of the powder.—The chief of squadron, Delorme-Duquesney, proposed in his book upon the fire of the muskets two models of balls revolving by action of the powder, or of the air, which he believed would be equal to balls fired from tige rifles, and which could be fired from the smooth-bored musket without the necessity of expansion in the barrel.

His *first ball* was cylindro-conic, terminating in rear by a spherical cap. Six spiral grooves were made on the cylindrical part, and prolonged upon the spherical cap terminating at its summit: the depth of these grooves at the spherical cap were 0.07 inch, and diminished forward to the base of the cone, where they were only 0.01 inch; the edges of these grooves towards the side that they were to turn were perpendicular or sharp, on the opposite joined to the cylinder by a curve. This ball, according to Delorme-Duquesney, was destined to revolve about its axis by means of the action of the gas of the powder.

This ball was experimented with at the school of Vincennes, and fulfilled, in no manner, the expectation of its inventor. Three of them, fired with a charge of 92 grains, at 164 yards against a target 12 feet long, gave bad results: but two of the three struck the target, and they sideways. They were much deformed; their length sensibly increased, and a part of the grooves filled up by the edges of the lead being mashed in. It was not considered necessary to continue the experiment.

The *second ball* was in form cylindro-conic; but the grooves ran from the vertex of the cone down to about half the length of the cylinder. It was expected that this ball would be made to revolve by the resistance of the air.

Experiments with this ball at Vincennes gave the following results: at 164 yards three balls fired struck the target point foremost, the errors not exceeding 20 inches. At 218 yards five balls were fired; three struck point foremost, with an error of 4 feet; the two others carried high, and missed the point aimed at by 13 feet. At 328 yards the charge of powder was increased to 123 grains; of five balls fired two only struck the target, and one of them sideways. This experiment proved that balls of this kind were no better than the round ball. Balls of the same form, but without grooves, would invariably strike the target sideways; which proved that the grooves on the ball had a certain influence upon its direction. From this experiment it may be inferred, that to fire with accuracy, the ball should receive its motion of rotation inside the barrel; and should not be liable to bounds and rebounds in the barrel, which tend to vary the angle of departure. The rotation produced by the action of the air is not sufficient to correct the initial deviation of the ball. It may also be remarked, that when the balls are not expanded in the barrel, the impulsive force varies very much from one fire to another, and becomes thus a cause of irregularity in the range.

CHAPTER III.

The different systems of expanding balls into the grooves of rifles, as now practised in the armies of Europe, their relative advantages and inconveniences.—Delvigne's system.—Berner's system.—System Delvigne-Minié-Thouvenin.—System Delvigne-Greener-Minié.—Systems Wild and Wild-Wurstemberger.—System Wilkinson-Lorens.—System Scheele and Feilitzen.—System Dreyse.

The different European systems of expanding balls.— After having described briefly the arms in the services of the different powers of Europe, in order that a correct estimate may be made of their relative excellence, a synopsis and classification of them, as regards the expansion of the lead into the grooves of the rifle, will be made. This will be superficial, giving only the arms of each system, and indicating the principal advantages and inconveniences regarded as inherent to each. It is to be presumed that each power considers its armament superior to that of its neighbors.

1st. The *System Delvigne*, that is to say, the flattening of the ball upon the shoulders of the chamber, by means of the rammer.

2d. The *System Berner*, expansion, or rather rotation impressed upon the ball by means of a projecting rim or wings fitting the grooves of the rifle.

3d. The *System Delvigne-Minié-Thouvenin*, expansion by flattening the ball upon a tige, by blows with the rammer.

4th. The *System Delvigne-Greener-Minié*, expansion of the ball by the action of the gas upon a cavity in the base of the ball, the action of the gas being regulated by a wooden or metal wedge placed in the cavity.

5th. *Systems Wild* and *Wild-Wurstemberger*, a space left between the ball and powder, the form of the ball being preserved, so as to be the same after as before the fire.

6th. *System Wilkinson-Lorens*, expansion by driving the lead in upon itself, thus shortening the length of the ball by means of the gas alone.

7th. *Systems Scheele* and *Feilitzen*, with movable breech, the calibre of the breech, which is smooth, being greater than that of the barrel, which is rifled.

8th. *System Dreyse*, or with needle, breech-loading, inflammation of the front part of the charge of powder, *empty space* in rear of the cartridge.

1st. *System Delvigne, or with chamber.*—The arms of this kind are the carbines and rampart pieces of the French, made in 1840 and 1842, the old carbine of the Austrian chasseurs, the old carbine of the Belgian riflemen, and the Sardinian carbine of the Bersaglieri. This system has been explained sufficiently. It led to the change in the infantry armament of Europe. In this system the ball enters freely the barrel, and resting upon the shoulders of the chamber, two or three taps of the rammer flattens it sufficiently to force it into the grooves. The *empty space* left between it and the powder favors the complete combustion of the latter. The *advantages* of this method are: 1st. The loading is as easy as with the old smooth-bored musket, thus removing the chief obstacle to the introduction of the rifle into general use. 2d. Increased accuracy, giving a per cent. at 650 yards *double* the smooth-bored musket at 325 yards. The principal *inconveniences* are: 1st. Rapid fouling. 2d. Complication of cartridge by the use of a *sabot*, and the frequent breaking of the *sabot.*

2d. *System Berner, or elliptical bore.*—The arms of this system are the old English carbine, the ball having a projecting rim, the Brunswick rifle-musket, the old rifle-musket of Oldenburg, the Russian carbine with ball with projections.

The pure Berner system consists in having two grooves, which, from the breech to the muzzle, ease or round off, so that the section near the muzzle is an ellipse, the axes of which will be smaller than those at the breech; the balls have either elliptical sections, or are spherical, and called balls *roulantes.* Different modifications of this system led to the adoption of two grooves with uniform width, depth, and twist, and balls with rim or projections. The most marked *advantages* of this system are: 1st. A more rapid loading than with a mallet or by blows of the rammer, thus permitting a more general introduction of the rifle. 2d. An accuracy very superior to that of the smooth bore at distances of from 450 to 550 yards. The *defects* are: 1st. A difficulty in loading rapidly, to adjust properly the ball with its rim or projection. 2d. Rapid fouling. 3d. Complication in the use of different kinds of cartridges for the same arm.

3d. *System Delvigne-Minié-Thouvenin, or with tige.*—The arms of this kind are the carbines of the French, Belgian, Hanoverian, Holland, Prussian, and Russian chasseurs; the rifle-muskets of Hanover, Mecklenburg, Nassau, Oldenburg, Sardinia and Saxony.

In the *Delvigne-Minié-Thouvenin* system, the expansion of the ball is obtained by flattening it *on the tige* instead of the shoulders of the chamber. In this system *a space* is preserved between the ball and the powder.

The principal *advantages* of this system are: 1st. A great range. 2d. Great accuracy. 3d. Considerable force of penetration. 4th. The impossibility of displacing the cartridge when the piece is charged, either in marching or in the exercises. 5th. A perfect protection against moisture or rain.

The *defects* are: 1st. A difficulty of regular expansion. 2d. Difficulty of preservation of the arm about the tige. 3d. Complication and weight of the accessories of the arm.

4th. *System of Delvigne-Greener-Minié, or hollow balls.*—The arms of this class are: the rifle-musket of the French infantry, the Enfield rifle-musket of 1853, rifle-muskets of Baden, Belgium, Spain, Hesse-Darmstadt, Hesse-Electoral, Nassau, Prussia, and the rifles and rifle-muskets of the United States.

In this system the loading is effected by simply pressing the ball down upon the powder; the expansion of the ball being produced by the action of the gas directly upon the cavity of the ball, or by driving a wedge into the cavity, thus forcing the lead into the grooves.

The principal *advantages* are: 1st. A range and penetration but little inferior to that of arms with the tige. 2d. Great accuracy. 3d. Facility in loading. 4th. Regularity in the expansion of the balls.

The *inconveniences* are: 1st. Tearing of the balls, and leaving thus, sometimes, in the piece, fragments that render it unfit momentarily for service; this occurs when the balls are moulded—not so apt to occur with pressed balls. 2d. Complication of the cartridge if the ball has a wedge. 3d. Deforming of the ball during transportation if it has no wedge. 4th. If the pieces are loaded, a rapid deterioration of the charge in case of rain.

5th. *Systems Wild and Wild-Wurstemberger.*—The arms of this kind are, of the Wild system proper, the old carbine of the Baden chasseurs, and the carbine of the Wurtemberg chasseurs. Of the system Wild-Wurstemberger: the Swiss federal carbine, and that of the chasseurs.

In this system the expansion consists in forcing the envelope or patchin of the ball into the grooves. Wild did not wish to deform the shape of his ball, but to preserve it purely spherical. In Wurtemberg they have departed slightly from Wild's system. In Switzerland they have departed from it in adopting the Wurstemberger ball, which is very long. They preserve an *interval* between the ball and powder, but renounce the use of water in loading; they have also reduced considerably the calibre.

The *advantages* of this last system are: 1st. Very great accuracy. 2d. A very flattened trajectory; the Swiss federal rifle has a lower or more flattened trajectory than any of the other European rifles; the Bavarian carbine is second to it. With the Swiss federal rifle at 655 yards the dangerous space is 98 yards; at 820 yards, the dangerous space 73 yards; at 983 yards, dangerous space is 57 yards; at 1308 yards, dangerous space 28 yards. 4th. Considerable power of penetration. 5th. Reduction of weight of ammunition, which permits an increase of rounds to the man. The Swiss carbine, with its 60 cartridges, weighs 13.4 lbs.; the

French carbine, with 60 rounds, weighs 18.5 lbs. 6th. A feeble recoil, being less than that of the Enfield rifle-musket by a fifth, and less than that of the French tige carbine by one third; the recoil of the carbine for the Swiss chasseurs is slightly greater than that of the federal carbine. Recoil of federal rifle, from 33.64 lbs. to 34.74 lbs.; chasseur rifle, 35.29 lbs.; Enfield rifle-musket, 39.70 lbs.; French tige carbine, 44.11 lbs. to 46.32 lbs.

The *inconveniences* of this system are: 1st. A little slowness in loading with the patchin. 2d. A want of solidity in the cartridge of the chasseur carbine.

6th. *System Wilkinson-Lorens.*—The arms of this system are: the new Austrian carbine, the Austrian and Dessau rifle-musket. In this system the expansion takes place by shortening the length of the ball, or by driving in the lead upon itself by the action of the gas; this driving in of the lead is facilitated by making the grooves around the cylindrical part of the ball *deep*.

The *advantages* of this system are: 1st. Great accuracy of fire. 2d. Great range. 3d. Considerable force of penetration. 4th. A flattened trajectory. 5th. Diminution of weight of ammunition in consequence of reduction of calibre. 6th. A loading simple and rapid.

The *inconveniences* are: 1st. The possibility of bending the balls in transportation, they being long, and the depth of the grooves being great a flexion in the ball would render its expansion defective or irregular. 2d. The inconvenience inherent to all systems in which the expansion is by the action of the gas, that is to say, the powder is not sufficiently protected from moisture, or from rain.

7th. *Systems of Scheele and Feilitzen—Breech-loading.* —The arms of this group, in which we have only considered the systems of Scheele and Feilitzen, those only in use in the infantry (marine), are: the Norwegian and Swedish rifle-muskets with movable breech. In these two arms when the powder is inflamed the ball is forced from the breech into the barrel, and driven into the grooves in consequence of the barrel being of smaller calibre than the chamber or breech.

The *advantages* of this system are: 1st. Easy loading in all positions. 2d. Great rapidity in loading. 3d. Great accuracy (at least) with the Feilitzen rifle. 4th. Great facility in cleaning the arm.

The *inconveniences* are: 1st. An escape of gas. 2d. Possibility of the cap falling off when in the act of firing, the nipple being inverted. 3d. Liability to waste ammunition in consequence of the rapidity of loading.

8th. *System Dreyse, or with needle.*—The arms of this class are: the needle breech-loading rifle of the Prussian infantry; the carbine (needle) of the Prussian chasseurs and tirailleurs of the Royal Guard.

The loading is at the breech; the expansion of the ball into the grooves takes place when the ball passes through the barrel, it having a less calibre than the breech.

The *advantages* of this system are: 1st. Rapidity of fire. 2d. Convenience in loading under all circumstances. 3d. Much accuracy at short distances.

The *inconveniences* are: 1st. Difficulty in adjusting and preserving the different parts. 2d. The needle bending or corroding at its extremity. 3d. Failing to make fire, which involves a removal of the cartridge and the substitution of another. 4th. Danger in transporting cartridges in which the fulminating composition is united with the cartridge. 5th. Impossibility of using the arm if its particular cartridge should fail.

CHAPTER IV.

Infantry cartridges.—Different methods of making them.—Balls explosive and incendiary.—Infantry fire.—Its inaccuracy.—Various estimates as to its efficacy.

Infantry cartridges.—There are but few arms in the hands of infantry with which cartridges are not used; and even in these cases the powder is usually contained in a cartridge, the ball being separate, and carried in the pocket. Examples of this sort are: 1st. The tige carbine of Holland, the ball of which has a greased thread tied around the groove. 2d. The Prussian tige car. bine, the ball of which is plastered with tallow. 3d. The Russian carbine with two grooves. 4th. The Sardinian carbine of the Bersaglieri: these balls are sometimes enveloped with a thin patchin, around which is tied a greased thread. 5th. Swiss federal carbine (Fig. 42), and that of the Wurtemberg carbine, in which, as in the Bersaglieri, the ball is patched and tied with a string.

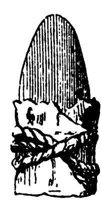

FIG. 42.

As to ball-cartridges, they are all composed of an envelope of paper, containing in the same case both the ball and powder, the percussion caps not forming a part of the cartridge, but carried separate. Many efforts have been made to supersede the use of paper by other material, as leather (kid-skin) for example; but this material, when used, has not been sanctioned by experience: it has, in experiments, generally increased the fouling of the piece. The efforts to combine the cap, or igniting composition, with the cartridge has had no better success, the fear of accidental explosions being a bar to this. The igniting, or fulminating composition is contained, in all cases, in a copper cell or small cup. The English have, for a year or two, made many experiments with gutta-percha capsules, or caps made by Eley, well known for his cartridges of long range, for hunting or sporting purposes. These caps were at first rejected, but afterwards tried at the school of musketry at Hythe: the advantages claimed for them is, that they protect the powder from moisture coming through the nipple; but thus far it has not been shown, experimentally, that it does so more effectually than the copper cap well made.

The paper envelope of the cartridge is made everywhere by rolling with the hand the paper around a cylindrical mould, generally of wood; the only differences to be observed are in the manner of closing, or tying the cartridge, or in the use of a second case placed inside of the first, to separate completely the ball and powder, and to give more strength and solidity to the cartridge.

Cartridges may then be divided into *two* classes: the *first* in which the ball is in contact with the powder, the cartridge being closed by means of a string tied around or above the ball. Such are the cartridges of the Belgian tige carbine, the paper being rolled about the ball, and tied with a string around the last groove, the paper cut at this height, the powder introduced into the case, which is closed by a simple twisting of the paper. (See Fig. 1, Plate 3.)

The Hanover cartridge is the same, except that the closing of the cartridge is by a double fold, pressed down squarely (Fig. 2).

The cartridges of the tige rifle-musket of Mecklenburg and Oldenburg are made after the same principle, but a little different in manner: the paper case is rolled around a tron-conic mould, or form; the smaller end is then closed with glue; the powder poured in, and the ball inserted and tied as in the Figures 3 and 4; to load, the cartridge is inserted entire, and is broken by being pressed on the tige by the rammer. The Saxon cartridge is tied above the cone (Fig. 5).

The cartridges for the Norwegian and Swedish breech-loaders are tied around the grooves (Figs. 6 and 7). In these different cases the cartridges are greased about the ball.

In the *second* class of cartridges the ball and powder are *separated;* this separation is effected in various ways, the most complicated being that of the Prussian breech-loading rifle (Fig. 8). In this cartridge there is another peculiarity: *it contains the igniting or fulminating composition;* the powder is separated from the ball by a rolled and compressed paper cylinder which is hollowed at the end next to the ball so as to fit the base of the ball; it also has a cavity in which is lodged the fulminating composition to be exploded by the needle being driven into it; the cartridge is greased about the ball.

The most simple method is that used for the Bavarian cartridges (Figs. 9, 10). It consists in tying the cases above the balls, which isolates them completely. The same method is used for the cartridge of the chambered (with the lock Console-Augustin) Austrian carbine (Fig. 11). This cartridge has its cap tied to it, and suspended by a string.

The *third* means of separation, and that most in use for the hollow ball, was first adopted in France. This consists in rolling upon the mould, besides the paper, a little rectangle of pasteboard, and bending under and pressing into the hollow of the mould the paper projecting beyond it. In this manner is formed a case, in which to receive the powder. The ball is then placed against the mould; the point of the cone in the hollow, and the paper, in shape a trapezoid, is rolled around it, and the cartridge terminated like the ordinary cartridge. Figs. 12 and 13 are the French cartridges for the tige carbine and the rifle-musket. These cartridges are greased about the cylindrical part of the ball. Similar methods are followed—

In England, for the cartridge of the Enfield rifle-musket (Fig. 14).

In Austria, for the cartridge of the new arms (Fig. 15).

In Baden, for the cartridge of the rifle-musket (Fig. 16).

In Belgium, for the rifle-musket (Fig. 17).

In Dessau, for the rifle-musket (Fig. 18).

In Nassau, for the rifle-musket (Fig 19).

In Russia, for the tige carbine (Fig. 20). The pasteboard in this is only used to increase the solidity; the system of ligatures above the cone and around the groove is maintained.

The cartridges of the new Sardinian carbine (Fig 21), and of the Swiss chasseurs (Fig. 22), are made after the French method. In the latter, however, the pasteboard is not used.

Besides the methods above described, Prussia has adopted a cartridge for the rifle-musket with hollow balls, which is made in part by machinery. This cartridge has, as a means of separation of the ball and powder, a *sabot* of *papier mâché;* it is compressed by the aid of machinery so as to be fitted to the grooves of the ball. Another little machine pricks the paper around the base of the cone of the ball in AB; this pricking (like that of the English postage stamps) being with the view of facilitating and making regular the tearing when the ball is introduced into the barrel (Fig. 23).

The English have invented a manner of making cartridges by machinery. These cartridges are called *bag-cartridges.* The machinery operates on the paper when it is in the condition of paste, and forms of it little cases, closed at one extremity. These cases are of two different sizes. The one serving to contain the powder is the smaller, and placed in the other, at the bottom of which is the ball, the twisting of the paper at the open end sufficing to close it. This cartridge is adopted in principle, but it is not certain if the machinery is in operation (Fig. 24).

The Danes are the only people in Europe that have a cartridge with two balls. This cartridge was highly recommended by Marshal Bugeaud in certain cases, and was experimented with by Panot, at the School of Musketry at Saint-Omer (Fig. 25).

The United States rifle and rifle-musket cartridge is represented in the plate of cartridges (Fig. 31). The United States formerly had cartridges composed of a ball and three buck-shot, also buck-cartridges of from 9 to 12 shot.

Differences in the elements composing the cartridges.—Having noticed the different methods of preparing cartridges with the nations of Europe, a few remarks will be made with reference to the different elements of the cartridge.

The following table serves to show, at a glance, the different powders in use in the armies of Europe:

Proportions used among the European Nations.

NATIONS.	CANNON-POWDER.			RIFLE-POWDER.		
	Saltpetre.	Charcoal	Sulphur.	Saltpetre.	Charcoal.	Sulphur.
Austria	70.00 76.00	17.00 13.00	16.00 11.00	75.50	13.20	11.30
Bavaria	75.00	12.50	12.50	75.50	13.20	11.30
England	75.00 75.00 76.00	15.00 17.00 14.50	10.00 8.00 9.50	76.50 78.00 78.00	14.50 12.75 13.50	9.00 9.00 9.00
France	75.00	12.50	12.50	75.50	13.20	11.30
Hanover	71.20	18.00	10.80	"	"	"
Hesse-electorate	73.40	13.30	13.30	"	"	"
Hesse (Grand Duchy)	74.40	15.00	10.60	73.70	15.60	10.70
Holland	70.00	16.00	14.00	"	"	"
Portugal	75.70	13.00	10.70	"	"	"
Prussia	75.00	13.50	11.50	"	"	"
Russia	71.00 75.00	17.50 15.00	11.50 10.00	80.00	11.30	8.70
Saxony	75.50	16.30	8.20	76.50	13.00	10.50
Spain	76.50	12.70	10.80	75.50	13.20	11.30
Sweden	75.00	16.00	9.00	76.50	13.00	10.50
Switzerland	76.00	14.00	10.00	76.50	13.00	10.50
Wurtemberg	75.00	13.00	12.00	74.50	14.80	10.70

The *powder* presents great variety in the relative proportions of its ingredients. The manner of making it is familiar to all nations.

There are two methods of making balls, viz., *moulding*, and by *pressure*. Balls were made by pressure in England in 1838, and have since been made in that manner by every people but the French. The method of moulding is slower, and gives a less homogeneous ball; that by pressure requiring machinery, might not be practicable with an army in the field, but it gives a better ball. The method of making caps is familiar to all. In France, Belgium, England, Prussia, and the United States, they are made by machinery, men being required only to watch and feed the machine.

Explosive and hollow balls.—Before terminating the subject of infantry munitions, a few words will be said with reference to explosive balls, so little employed, notwithstanding the great service they may render under particular circumstances. It would be difficult to say who was the first to use them; but Captain Norton in England, and Delvigne in France, were the first whose experiments attracted the notice of the public.

Delvigne's method consisted in using a cylindro-conic ball containing the powder (Fig. 26); a tube screwed into the orifice of the cavity of the ball receives upon its head a cap, which explodes the moment the ball strikes the object. The inventor obtained the same result in placing in the axis of the ball a needle, upon which rested the capsule, over which was pressed the upper edges of the orifice, which retained it in place (Fig. 27). The use of the tube gave the great advantage of transportation without danger, the cap being fitted only when the ball was to be fired. It is this system that is applied to the ball with grooves, ordinarily experimented with by Minié, at Vincennes (Fig. 28).

General Jacobs, of the East India army, has experimented largely with explosive balls. These balls are of the same form as those used in the ordinary practice with his rifle. They inclose a tube of copper containing the fulminating mercury or ordinary powder, and having on its front point the cap, which explodes by the shock against the target (Fig. 29). In 1857, experiments were made at Enfield with them. General Jacobs, at 2,000 and 2,400 yards, blew up caissons with them with great success; and in shooting against brick walls at that distance, found the wall to be much torn by their explosion. In Baden and Wurtemberg they have adopted little (*fusées*) rockets, to be fired from small arms. They are inclosed in copper tubes to increase their weight, and thus the range (Fig. 30).

Inaccuracy of infantry fire.—The want of accuracy of fire has ever been a reproach to infantry. During the wars of the French revolution and the empire, according to Gassendi, a French general of artillery, the infantry fired 3,000 cartridges for every enemy killed or wounded; Piobert admits the same thing. Decker, a Prussian general, and one of the best military writers of Germany, estimates that not less than 10,000 cartridges are burned for every enemy killed or wounded.

At the battle of Vittoria, the English are supposed to have killed or wounded one of the enemy for every 800 balls fired.

An English officer states that at the battle of Churubusco (Mexico) the Mexicans killed or wounded one American for every 800 balls fired, and that the Americans killed or wounded a Mexican for every 125 balls fired.

These various estimates are more or less inaccurate; but, nevertheless, prove that the fire of infantry is far more inaccurate than is generally supposed. The previous estimates were made for the smooth-bored musket and round ball.

Many causes conspire to render the fire of infantry in battle ineffective, the rapidity of fire, the excitement incident to the strife, difficulty of aiming properly in consequence of the dust or smoke, necessity of firing by command, unsteadiness resulting from the pressure of files to the right or left, or in front or rear, and in general, one of the opposing forces being protected by fortifications, field or permanent. A more general cause of want of accuracy has been, doubtless, the firing beyond the effective range of the musket. In view of the improved rifle, it may confidently be asserted that battles will be more destructive than formerly, a greater number of balls will take effect; it will be difficult for the soldier to find himself in presence of the enemy, and yet beyond the range of his rifle, at least he would scarcely commence to fire beyond the range of his present piece. He will be inspired with more confidence, knowing the range and accuracy of his arm. At great distances he will no longer fire by hazard, but will use his elevating sight; at short distances, knowing the power of his rifle, he will fire with the utmost coolness, and with a certainty that the smooth-bore and round ball never could inspire. It may be that the infantry soldier, occupied with the care of aiming or adjusting his sight, will have his mind diverted from thoughts of danger, and be in the moral condition attributed to cannoneers, whose proverbial *sang froid* in the presence of the enemy is said to be due to the occupation that the pointing or aiming of the piece gives.

The increased range and accuracy of the rifle, and the confidence with which it must inspire the soldier, will cause the fire of infantry to be far more destructive than formerly, and every enemy killed or wounded will no longer cost his weight in lead (or ten times his weight in iron, when killed by artillery).

CHAPTER V.

Schools of instruction for rifle-practice, theoretical and practical.

A RIFLE, whatever may be its range and accuracy, in the hands of a soldier unskilled in its use, loses much of its value; hence the necessity of giving the most detailed and thorough practical instruction as to the means of preserving the piece, and of attaining the greatest possible precision of fire; hence the necessity of creating schools specially for the purpose of teaching the soldier the art of firing, &c., &c.

Such schools are now general in Europe, and are designed chiefly to form of officers and non-commissioned officers instructors capable of teaching the men of their various companies and regiments every thing necessary to be known, both in theory and practice, as regards the use of the rifle.

The most ancient, as well as the most celebrated of these schools, is that at Vincennes (France). When the French army was increased by the addition of chasseur battalions armed with rifles, this school was organized with the view of forming instructors competent to teach the men how to use the rifle, hitherto not well appreciated by this people. Officers and detachments were sent from all the infantry corps to be instructed at this school, and soon subsidiary, or branch schools, were established at Grenoble, Saint Omer, and Toulouse. These detachments were composed at first of officers, non-commissioned officers, and soldiers. The best results were speedily realized; and to these schools is principally due the great improvement that has been made of late years in the range and accuracy of the rifle. Latterly the school at Vincennes receives only officers, and the supplemental schools at Grenoble, Saint Omer, and Toulouse have been discontinued. The programme of the course at Vincennes is much more extended than at similar schools in other countries: it comprehends every thing relating to the theory of motion of projectiles, fabrication of arms and munitions, caps, balls, cartridges, &c., &c.; the method of estimating distances by means of instruments, and more particularly that by the eye alone, &c., &c.

The course at this school is taught by a captain of artillery, assisted by a second officer of artillery. The The term of instruction is *four* months. One officer from each infantry regiment, and a certain number from the marines are sent there annually.

The staff of the school is composed of a brigadier-general, as commandant superior; a colonel, or lieutenant-colonel of infantry, commandant of the school; a chief of battalion (infantry), instructor of firing; a captain of infantry, sub-instructor; a captain of artillery, professor, and a captain of the same arm, adjunct-professor.

In England a school of instruction for musketry was established at Hythe in 1853; the course at this school is not so extensive, theoretically, as the one at Vincennes; but the course of practical instruction to the men in the matter of estimating distances by the eye is much more insisted upon. The term at this school is *two and a half* months. Many detachments succeed each other during the year; they are composed of *one-twentieth* of the officers of the different regiments, each officer being accompanied by a non-commissioned officer and eight men from his regiment.

The staff of the school is composed of a colonel of infantry, commandant; a lieutenant-colonel, instructor of firing, and two captains, sub-instructors. Like the school at Vincennes, and other similar schools of Europe, the *staff of this school forms a permanent committee to examine all improvements and inventions with reference to small arms, cartridges, projectiles, &c., &c.*

In Spain, in 1855, a school for musketry instruction was established at Pardo, near Madrid, under the direction of a colonel of infantry. It resembles in its organization, the school at Vincennes.

In Holland a similar school is established at Haye.

During the year 1857 a school was created in Russia, near St. Petersburg, similar in its organization to the French school.

In 1855 a similar school was organized in Sweden, near Stockholm, under a general of artillery, assisted by a major and three officer-instructors. The term at this school is *two* months; an officer from each battalion of infantry, and eight from the marines are sent to it annually; the course is as extended as that of Vincennes.

In all of these schools much time and labor is devoted to teaching the men to estimate distances, for with the rifle of long range it is not possible to use it with effect if the distance at which it is fired be not known.

All instruments for this purpose are thus far unsatisfactory, either from giving an inexact approximation, being too complicated, or requiring too much time to use them. An approximation such as the practised eye can give is most to be desired, but it is rare that a man is found who can measure accurately distances with his eye; but labor and care will enable most men to attain it within the limits that would enable them to strike an object the size of a battalion of infantry in column, at a distance of 1200 or 1500 yards, with the best rifles of the present time.

CHAPTER VI.

The improved rifle with reference to tactics.—Infantry.—Artillery.—Cavalry.—With reference to field fortifications.

A CHANGE in the arms for infantry, or even marked improvements in them, have always had a preponderating influence upon their formation for battle.

The Grecian phalanx; the different orders of battle among the Romans, from the earliest times down to the reign of Trajan; the orders of battle during the middle ages; in the wars in Spain and Italy; the tactics of the Swiss, Spaniards, and Germans; and finally, those of the thirty, and of the seven years' war, all give proof of the truth of this assertion.

The art of war keeps pace with the development of the human mind; and from the condition of this art in a nation we may judge of its civilization and intellectual progress.

Without entering into a detailed enumeration of the changes that the improved rifle will produce in tactics, a brief statement will be made as to its probable effect.

Fields of battle will be more extended than formerly; there will be more difficulty in estimating the variety and number of the adversary; more difficulty in properly placing troops on the field, and directing their movements. Keeping them together, holding them well in hand so as mutually to protect and sustain each other, will, in future, require the greatest care. As fields of battle will cover more ground than formerly, new tactical means to obviate the disadvantages resulting from this will be required; that continuity of lines required by tactics will no longer be necessary.

The commencement of a battle will require the greatest care and circumspection on the part of the general, lest he may lose control of his men and their movements; and to prevent the fire of skirmishers from degenerating into a mere waste of ammunition. Formerly the position of the enemy could be approached to within 300 yards without experiencing much loss from the fire of his infantry. Now this fire is destructive at 1000 or 1200 yards, and well directed at 600 yards, becomes irresistible. The range of the rifle permitting battles to commence at considerable distances, without great care on the part of the general, his whole lines may become exposed at once to a destructive fire; the position assigned to troops not immediately engaged will require as much attention as those that are so engaged. The distances between lines in battle are fixed by tactics, and much importance seems to be attached to this feature: this will probably give way to a different order. In the Crimea, the Russians admit that their reserves were seriously compromised by the French chasseurs: so it is difficult to prescribe clearly the means of obviating such difficulties. To shelter troops from the enemy's fire as long as possible without being too far distant, and to hold them well in hand, will probably be the best rule to observe.

With the improved rifle, the infantry fire is fourfold more destructive than formerly; hence the necessity, in order to secure the full effect of the arm, to have a thorough system of instruction in target practice; every infantry soldier should be so instructed before he enters his battalion.

The system of tactics that admits of the greatest as well as the most rapid development of this fire will be preferable. The two-rank should therefore be the fundamental formation in line; and small columns, susceptible of great mobility, easily deploying into line, and yet with sufficient strength to resist the shock of cavalry by forming square, should replace on the field, deep, heavy, and unwieldy columns.

Fields of battle having a greater extent in future, more instruction, quickness, and accuracy of observation, will be required on the part of the battalion commanders, and greater latitude should be given them by tactics, with the view of enabling them to take advantage of all the exigencies of the field. The great desire to prescribe by rule, and with mathematical precision, different tactical formations for battle will probably cease; for every field there are tactical manœuvres peculiar and well suited to it, which the talent of the general, from his knowledge of its configuration, the physical and moral condition of his own and the opposing force, will know how to apply.

The experiment at Hythe, in June, 1855, shows the effect of the Enfield rifle upon a battalion of infantry in column; it shows how destructive to infantry columns this fire has become. This experiment being made at 550 and 820 yards, the column five division deep. The Swiss rifle would have produced even a greater effect upon the same column at 1312 yards. *The fire of grape-shot at its most effective distance is not so destructive to infantry columns as the fire of the present rifles.*

The tactical organization best adapted to infantry under existing circumstances, is probably that of battalions of *six* companies, 100 men each; the front of this number of men in line in two ranks would not be too great to enable the commander to overlook it well, and to be heard when giving commands. Columns formed by battalions of this strength should be on fields of battle habitually by division in mass; this column would not from its size offer much surface exposed to fire, and with only three divisions, line of battle would be readily formed. A square formed from three divisions would be capable of delivering more fire upon the side threatened than a square formed from a greater number of divisions, the number of men being the same. The square formed from a column of three divisions has *one third* of its rifles in the 1st, and *one third* in the 4th front, the other two fronts having a *sixth* each; the 1st front is the one most usually attacked; with *four* divisions the fire is equal upon all fronts; with *five* divisions *one fifth* of the rifles is in each of the 1st and 4th fronts, the remaining *three fifths* in the other two fronts.

Columns of three divisions seem to be preferable to those of greater depth for habitual formations, but should there be necessity for greater depth it can be had by placing one battalion in rear of another. The distance between these columns at the beginning of a battle might be such as to admit of deployment; this to be lessened in the presence of a strong force of cavalry, or if the adversary by accumulating large masses of troops upon particular points, shows an intention of attacking with heavy forces.

There should be *four battalions* to the regiment; every company should be thoroughly instructed at target practice and the skirmish drill; but as some men will excel others in the use of the rifle, and have greater aptitude for the duties of light troops, the fourth battalion of each regiment should be formed of such soldiers. These battalions, although excelling at target practice, are not to be employed exclusively as skirmishers, but to be organized at times into special corps, to be launched at critical periods of battle in mass, moving with the *accelerated pace* against the almost victorious adversary: it was in this manner that the brigade of chasseurs, under Bosquet, was used at Inkermann; and at Traktir the Zouaves were employed in a similar manner, and contributed powerfully to the defeat and destruction of the Russian columns under General Read.

The improved rifle against cavalry.—Formerly cavalry could take up its position in columns of squadrons in full view of the infantry to be charged, at a distance of 400 yards, and could approach within 300 yards without experiencing much loss. At this distance it moved against infantry, first at a trot, then gallop, and finally at full speed, and in general without success. Even with the smooth-bored musket, the cavalry charge against infantry, to be made with a probability of success, had to be in general preceded by the fire of artillery; or the infantry must have been already exhausted or demoralized from its contests with other arms. Under the existing condition of the infantry armament, cavalry will be within its sphere of action at 1200 or more yards, and as it approaches nearer the fire will become more and more destructive.

The chances of success with cavalry are much lessened in presence of the new arms; nevertheless, infantry has its critical moments when a charge of cavalry can be made with great chances of success, when, for example, there is embarrassment, indecision, or wavering in its ranks, or being unskilfully commanded. Cavalry, in the hands of a skilful general, must ever be a formidable arm; but at present it becomes more difficult to manœuvre it properly on fields of battle; its charges against infantry will be made with more danger and loss to itself, and with less probabilities of success; in minor operations of campaigns its dangers and difficulties have increased.

Improved rifle against artillery.—Formerly artillery began battles; it could take its position at pleasure in front of infantry and deliver its fire without incurring danger or loss from the fire in return of the infantry. Now that the range of the rifle is equal, if not superior, to that of field-pieces, the influence of light artillery in battles will be lessened. In the experiment at Hythe, in 1856, the effect of the fire of the Enfield rifle upon a piece of artillery with its men and horses was shown to be such, that it would be impossible for a field-battery to remain in front of infantry at a distance of 810 yards for ten minutes; *three minutes* alone sufficed at that distance for 30 files to wound the men and horses to such an extent as to disable the piece. With the more accurate Swiss rifle at that distance the destruction would have been more rapid and complete; and at a distance of 1312 yards it would have inflicted the same, or even greater, damage than the Enfield rifle at 810 yards. It is clear that field artillery, with its present range, cannot with any chances of success remain in action in front of infantry; its comparative efficacy is lessened, and even by extending the range by increase of calibre, or by a successful application of the principle of rifling, cannot restore it to its former comparative condition. The infantry rifle has now a range equal, or greater, than the limit of distinct vision, and greater even than the extent offered by fields of battle in general, and should a range of several miles be given to artillery it would still fail to restore it to its former comparative state.

In times past, artillery assisted cavalry in its attacks against infantry; now infantry may render cavalry great service by directing its fire against artillery, thus preparing the way for the cavalry charge.

The new rifle clearly gives to infantry, in all secondary operations of war, and in the defence of positions, an element of force that it did not possess formerly. Artillery in minor operations, in attacks of posts and positions, has its offensive element much altered and lessened; *but in its legitimate sphere of action in removing obstacles, in the attack and defence of forts and fortresses, artillery remains intact, as well as in the grand tactics of battles.*

The new rifle considered with reference to field fortifications.—The most elementary species of fortifications are those in right lines, as for example, the straight wall, stockade, or ditch with parapet. It was with works of this class that the art of fortification began. Right-lined works were defended by a fire direct to the front: in process of time the engineer found that the defence of works of this class could be strengthened by means of a fire crossing in front of them. This cross-fire was secured by constructing upon the right lines, from distance to distance, small *redans;* a work of this kind is called a *line of redans and curtains.* Redans being resorted to with the view of the cross-fire in front of the *curtains*, it became necessary to regulate the distance between the redans in a manner permitting this cross-fire. With the smooth-bore musket, the distance from one salient to another was at the maximum about 330 yards.

A work of this kind is not strong, and is difficult to defend, presenting as it does a number of points of attack, salients of the redans, and these points cannot be diminished, for the reason that the interval from one to the other, that is, the length of the curtain, is determined by the range of the arm employed. These salients, moreover, have not sufficient space to organize a good and efficient defence, for their angles, 60° at a minimum, and 72° at a maximum, cannot be increased, because a too great obliquity of the faces would weaken or diminish the effect of the fire of those faces. The space in front is badly defended; certain points are only swept by oblique fires, or direct fires at a distance too great to be effective.

With the improved rifle, the *principle of the works will not be changed*, but the inconveniences may be diminished; for since the range of the rifle has been so much increased the length of the *curtain* can be augmented, and thus the number of points of attack lessened; the space to be defended will be better seen, and infinitely better defended; and should the assailants wish to establish a ricochet battery, say at 650 yards from the work, to enfilade one of the faces of the redan, or to destroy its defence, it will be exposed there at a distance of 600 yards to the fire of one of the curtains, a dangerous proximity, which ought to retard if not check its establishment.

Crémaillère lines are very imperfect works, offering but an indifferent defence when occupied by troops armed with the smooth-bored musket. Their long faces are parallel, consequently they do not mutually protect each other by their fire; they are much exposed to ricochet fires, and have as many sectors without fire as there are salients; their smaller faces are so short, that the enemy, after having attacked the salient, can leap into the ditch and soon place himself under shelter in reaching the dead angles, through the ditch of the short faces.

With the present rifle these inconveniences disappear; in the first place the lengths of the greater faces can be increased, and the number of salients proportionally diminished, and consequently, points of attack. The attack of this work can only be against one of the two faces of the system. If the enemy wishes to attack the greater face, and establishes his batteries at 650 yards on its prolongation, he will find at this distance that the batteries are only about 200 yards from the line of defence, and that they cannot be maintained under the fire of the rifles and artillery of the defence. If the enemy attack a smaller face it will be necessary to establish the batteries at 600 yards, and at this distance it will be difficult, if not impossible.

But, finally, should the attack succeed, and the face be no longer tenable, it only results that the flanking of one of the great faces is lost, nothing more; the defence would not be for an instant compromised.

Bastion fronts.—With these there are many salients with sectors without fire; and the number of these cannot be diminished, since the distance from one to the other is determined by the range of the musket. The bastion is too narrow to offer a good defence; its flanks are too short, thus giving a weak fire in front of the great faces, and a cross-fire in front of the curtains little to be feared, and but few balls would be sent from it against the enemies' battery established against the salient of the opposite bastion. It is easy to increase the width of the bastion, its amplitude, by diminishing the length of the perpendicular—that can be made more or less short in establishing the front. But another inconvenience, and it is a grave one: the angle of the salient, and the amplitude of the bastion, increase as the perpendicular diminishes. But it is the contrary with the length of the flanks, which diminish as the perpendicular diminishes, and it is not admissable to lose or lessen the fire of the flanks, already so weak. With the smooth-bore musket there exists, then, a remedy perhaps worse than the evil; but it is not so with the long-ranged rifle. The distance between the salients is no longer limited to 220 or 330 yards, but may be doubled, increased to 650 or more yards, which permits a reduction in the number of bastions, and, consequently, fronts of attack, critical, or weak points; gives more space to the bastion, and augments the length so precious of the flanks.

Lines with intervals.—The first two lines are composed of *lunettes;* the third of simple *redans*, destined to be armed with artillery for the purpose of flanking the advanced salients. The angle of the salients of the *lunettes* of the first line is 78°, and cannot be increased. The length of the front at its maximum is about 330 yards. The length of the perpendicular which determines the position of the works of the second line is 130 yards, and can be no greater, owing to the range of the smooth-bore musket. The angle of the salients of the second line is 102°. With works of this kind it is difficult for the enemy to insult the second or third line. The space in front of them is well seen, and thoroughly swept; but the enemy can attack, with great chances of success, the first line, where there are numerous salients with small angles, thus giving but little space in the interior of the works for the defence; little or no cross-fire; in fine, a weak defence, and nothing more.

With the new rifle these inconveniences disappear; their balls carry much further, and the enemy is forced to be more distant in his attacks.

The most important of the advantages offered by the improved rifle is the possibility of increasing the front from 330 to 660 yards without changing the length of the perpendicular which fixes the salients of the second line, and without augmenting the depth of the work, and leaving to the flanking its full force. Thus is secured: 1st. A less number of salients upon the space occupied. 2d. 120° to the angles of the first lines, that is to say, a great obliquity of faces, which would cause an enfilade battery, established at 655 yards from one of the salients to be at 330 yards from the line of fronts, and in a position scarcely tenable. 3d. The salients of the second line could have 136°.

From what precedes it is evident that the precision and range of the new rifle permits a reduction by one half of the number of salients; renders the attack of those salients extremely difficult, and quadruples the space reserved between the works for the quartering and manœuvering of troops, a great gain for the defence.

With reference to *permanent works* much might be said, but it will suffice in this place to state that the new rifle will impose upon the engineer new calculations, and will aid him in his art, by permitting him, according to the necessities of the case, to increase his fronts, which obliges the enemy to move more slowly, and with more circumspection, and renders the taking of position in front of the works more difficult and dangerous.

APPENDIX.

The following description of the lunette or telescope of Messrs. Lerebours and Secretan,* and the telescope or teleometer of M. Porro, an officer of the Piedmontese engineers, is taken from the Appendix of Thackery's "Manual of Rifle-firing."

The lunette of Messrs. Lerebours and Secretan has micrometric wires stretched over the field of the telescope, as shown in Fig. 1, at various distances marked with the letters *a*, *b*, *c*, *d*, and *e*.

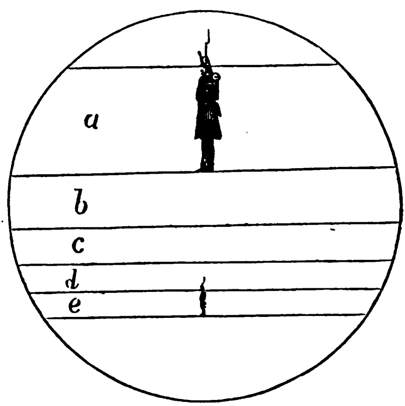

Fig. 1.

The space *a* corresponds to a distance of 100 French metres, or about 110 yards.

The space	*b*	to about	220	yards.
"	*c*	"	330	"
"	*d*	"	440	"
"	*e*	"	550	"

When a soldier is included between the lines of the space *a*, he is at a dis-

* The eminent opticians of the French Imperial Observatory and Marine, 18 Place du Pont Neuf, Paris.

tance of about 110 yards. When between the lines of the space *b*, about 220 yards, and so on.

If the soldier should not fill more than half of one of these spaces, he is at double the distance indicated by such space. If the half of the height only of the soldier should be included between the lines of any space, he will be at half the distance indicated by such space.

The height of a soldier is here measured from the soles of his feet to the line of his eyes.

The prismatic micrometric telescope or teleometer of Porro derives its name of teleometer from two Greek words signifying "a measurer of distances." By a happy adaptation of prisms, as reflectors, its length is reduced from the ordinary dimension to about the measure of the breadth of the hand (Fig. 2), so as to be easily portable, and it is set for any eye in a moment by a small screw moved by the thumb.

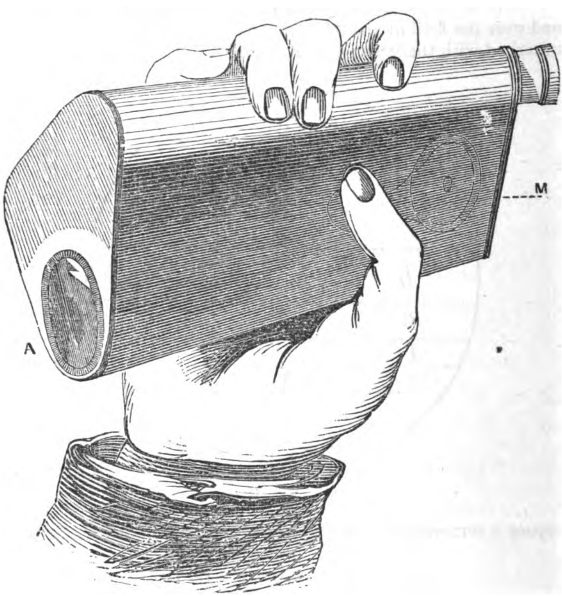

FIG. 2.

Our limits will not allow us to describe particularly the optical arrangements of the instrument, which would lead us away from our present subject into too lengthened and too scientific details on the principles and effects of reflection; we must content ourselves by stating, that it may be used either as an ordinary telescope, or as a means of measuring the distance from the eye, of any object whose actual height is known. It is in this latter applicatlon that we shall now particularly consider the teleometer of M. Porro.

An apparatus is adapted to a small tube which contains the focal glass, or that glass which is applied to the eye, consisting of wires stretched across this tube at various spaces, such as that shown in Figs. 3, 4, 5, and 6.

These wires have three separate spaces, viz., AB, including the space occupied by three wires, or in other words between the upper and lower wire; CD, the space between the two wires—the intermediate and lower wire; and EF, the space between two other wires, not so distant from each other as CD.

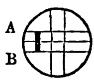

Fig. 3.

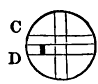

Fig. 4.

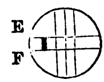

Fig. 5.

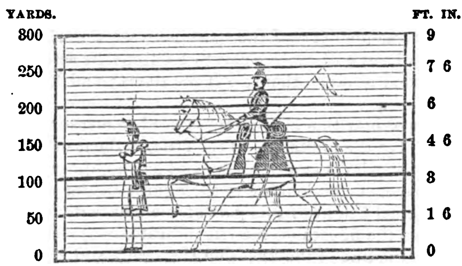

Fig. 6.

THE PRISMATIC TELEOMETER, OR MICROMETRIC TELESCOPE.

By the subdivisions of the scale at the side, the whole, or a part only, of the object, whose total height is known, may be taken as a term of comparison in the estimation of distances. The object, or part of the object selected, must correspond exactly with one of the spaces, or in other words be intercepted by two of the wires of the teleometer.

The micrometer is an apparatus applied to the focal glass of the telescope: it consists of five wires placed across the disk of the telescope, as shown in Figs. 3, 4, 5, in which AB shows one space; CD a second; and EF a third space. AB shows the distance to be equal to 100 times the height of the object; CD 200 times; and EF 500 times.

1st Example.—If the lower wire of the space AB cuts or crosses the knees of a body of infantry, the other line the points of the bayonets, the scale on the left hand gives 200 yards distance.

2d Example.—If one of the wires of the space CD touches the feet, the other the waistband of an infantry soldier, the scale would give 110 double yards, or 220 yards distance.

3d Example.—If one of the wires of the space EF cuts or crosses the horse's hoofs, the other the epaulets of the cavalry soldier, the scale will give 250 times 5 yards, or 1250 yards.

Now these spaces, AB, CD, and EF, represent three distinct distances from the eye: the first, or AB, 100 times as great; the second, or CD, 200 times as great; and the third, or EF, 500 times as great as the actual height of an object looked at through the teleometer.

On the diagram, or plan (Fig. 6), a scale will be found applied to the actual heights of an infantry and a cavalry soldier. On the right hand are the figures 0, 1 ft. 6 in., 3 ft., 4 ft. 6 in., or scale of heights up to 9 ft. or three yards. Between these figures are lines running from the left to the right, or horizontally, dividing each yard into tenth parts, for the facility of calculation; by examining these figures and lines the height of an infantry soldier is found to be given as about 6 feet or two yards, and that of a cavalry soldier and his horse as about 8 feet.

On the left or opposite side of the scale are figures ranging from 0 to 300. These figures denote the distance of the object as measured by AB. The intervals between the figures on the scale are again subdivided into fifths, by the horizontal lines running from left to right.

Now it will be remembered that the space between the wires AB (Fig. 3) shows an object to be at a distance equal to 100 times its actual height, when the object is included between them; CD 200 times; and EF 500 times the actual height.

We will now show how this instrument is used to measure distances.

First example: Let the lower line of the space AB cut or cross the knees of an infantry soldier who is at a distance, and let the upper line cut or cross the point of his bayonet; on looking to the figures on the right of the scale we find that the actual height of this part of the man with his bayonet is 2 yards. Now, since the figures on the left indicate the distance, we find the space between 50 (the line of the knees on the scale), and 250 (the line of the bayonet), to be 200; and as the quantity is taken in yards we find, therefore, the scale to indicate that the soldier is at 200 yards distance.

This scale, therefore, corresponds with the indications of AB, taken in another point of view. We have seen that the space AB has shown the height by the scale to be 2 yards, and as this space shows an object at 100 times the distance from the eye, we multiply 2 yards by 100, which gives us 200 yards, the actual distance of the object.

Again, as another example: Let us take the space EF (Fig. 5) and apply it to a cavalry soldier. We find that from the feet of the horse to the head of the rider is included within EF. Now on the right hand of the scale we find that the actual height of him and his horse to this point is 2½ yards: we therefore multiply 2½ yards by 500, and we find 1250 yards to be the distance from the object.

This result is not shown in figures on the left hand of the scale, which, to avoid confusion, is confined to the distances shown by AB, but it could be easy to add them for CD and EF, and they may be ascertained by multiplying the distances on the scale by 2 and 5 respectively.

MUSKETRY INSTRUCTION.*

PART I.

Duties of the Instructors of Musketry in Battalions.

1. *Officer-instructor of musketry.*—In every battalion the instruction in *firing*, placed, like all other exercises, under the responsibility of the commanding officer, will be especially confided to the direction of a captain, who, having been reported by the commandant of the school of musketry qualified to exercise the functions of *officer-instructor of musketry*, will be charged with the entire training in musketry of the young *officers* and *recruits*, and with the theoretical and preliminary instruction, annually, of the other officers and soldiers of the battalion.

2. The target practice of the soldiers, when practising by companies, will take place under the command of their captains; the officer-instructor, however, will be present to assist the captains by his superior knowledge in this particular branch, and in order that the instruction and practice may be conducted with uniformity throughout the battalion.

3. The commanding officer will assemble the officers of the battalion at least once in each half-year, and will cause the non-commissioned officers and men to be assembled occasionally by squads or companies, when the officer-instructor, having previously explained the theoretical principles contained in this book, 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 first invention of gunpowder, and the successive steps by which the rifled musket 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.

* * * * *

6. The officer-instructor and his assistants will inspect all the practice registers, diagrams, and returns, and see that they are correct and strictly according to form; he will also make out, for the commanding officer's information and signature, the battalion returns which are to be transmitted at the prescribed periods to the school of musketry, and submit for his

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* Extract from the English System, approved 1856.

approval the names of men eligible for the battalion and company rewards, or prizes for target and judging-distance practice.

7. The officer-instructor will be exempted from all regimental duty, and from such garrison duty as may interfere with his duties as an instructor of musketry.

8. *Assistant officer-instructor.*—A subaltern in each battalion will be chosen to act as assistant instructor; he will be exempted from such garrison and regimental duties as may interfere with his duties as assistant instructor. This officer must have qualified himself for the appointment at the school of musketry.

* * * * *

10. *Non-commissioned officer-instructor.*—If a diagram has been kept, the non-commissioned officer-instructor will compare it, first, with the target, and then with the register, and ascertain their correctness. He will receive, at the conclusion of each practice, the column "*duplicate total points*," of the registers; these he will make use of to check, at the conclusion of each period of target and judging-distance practice, the companies' returns, which, if found correct, he will take to the officer-instructor, who, after careful inspection, will countersign them, and make out the battalion return from them. He will be exempted from all garrison and regimental duty.

11. *The company-instructor.*—The senior sergeant of each company will be charged with the instruction of the men in *target practice*, *judging distance*, and *cleaning arms*, under the orders of his captain and of the officer and non-commissioned officer instructors of the battalion. He will keep the registers for his company on the practice ground, and at the conclusion of each practice will read over to the men the number of points obtained by each, after which he will compare his register, first with the target, and afterwards with the diagram in the marker's butt, should one have been kept; both register and diagram will then be signed by two sergeants, viz., the company-instructor and the sergeant who has marked in the butt; the company-instructor will then take them to the officer-instructor, who will countersign them.

12. The column "*duplicate total points*" of the register, after receiving the initials of the officer-instructor, will be immediately torn off and handed over to the non-commissioned officer-instructor of the battalion. The same form will be attended to in the practice of judging distance.

13. The company-instructor will attend with his company when it is ordered for target drill or judging-distance drill, and assist the officer and non-commissioned officer instructors in the performance of their duties.

Summary of Instruction.

14. The instruction of musketry is divided into two principal parts, the THEORETICAL and the PRACTICAL.

15. The theoretical branch is confided especially to the officer-instructor, who will explain the principles thereof.

16. The practical branch is divided into two principal parts, DRILL and PRACTICE. In the former are comprised *cleaning arms*, *target drill*, *judging-distance drill*, and the *manufacture of cartridges;* the latter is divided into *target practice* and *judging-distance practice.*

* * * * *

19. *Target drill.*—Is divided into *aiming* and *position drills;* in the first, the soldier will acquire a knowledge of the use of the sights, and his progress in this branch will be tested by making him aim at different distances by means of a rest; in the second, the soldier will be put through all the motions of firing, standing and kneeling, with the same accuracy as if actually firing ball, attention being paid to each movement. This exercise is to habituate the soldier to the correct position, and to the natural connection that should exist between the hand and the eye; and is intended to make up in some measure for the small amount of target practice of which the yearly allowance of ball-ammunition admits.

20. *Judging-distance drill.*—In this drill the soldier will be accustomed to take note of the size and appearance of men and objects at different distances.

21. *Manufacture of cartridges.*—In each company from ten to twelve men will be instructed in the manufacture of cartridges by the company-instructor.

22. *Target practice.*—Target practice is the *proof* of the attention that has been paid to the preliminary drills; it is divided into three parts, namely: firing *singly*, *file-firing and volleys*, and firing in *extended order* as skirmishers, in which the practice of judging distance is combined with that of target practice.

23. *Judging-distance practice.*—This practice has for its object, to test the proficiency of each company in judging distance, and, when possible, will be carried on, during target practice, by the sections that are not occupied in firing.

Recapitulation of the Number of Drills or Practices in the Instruction of Musketry, to be gone through by every Non-commissioned Officer and Soldier of the Battalion annually, and by the Recruits before they join in the Practice of the Battalion.

Preliminary Drills.	N. C. Officers and Soldiers.		Recruits.		Remarks.
	No. of Drills or Practices.	No. of Rounds.	No. of Drills or Practices.	No. of Rounds.	
Theoretical principles	6	..	According to the discretion of the Officer-Instructor	..	By the Officer-Instructor.
Cleaning arms	6	..		..	By the N. C. Officer-Instructor.
Target drill: Aiming drill	6	..		..	By the Officer-Instructor.
Target drill: Position dr'l	6	..		..	Ditto.
			No. of Percussion Caps.	Blank cartridges.	
Snapping caps, and blank cartridges	..	..	20	20	Ditto.
Judging-distance drill	12	..	According to the discretion of the Officer-Instructor	..	Ditto.
Practices.				Ball cartridge.	
Preliminary firing, one round to be fired from a rest at the several distances to 300 yds.	..	..	5	20	By the Officer-Instructor. N. B. These 20 rounds are to be recorded in a register, but not in the company's practice return.
Individual firing: 1st Period	5	20	5	20	In the company under the captain of companies, and recruits by the Officer-Instructor.
Individual firing: 2d Period, 2d class	6	20	6	20	By the Officer-Instructor.
Individual firing: 2d Period, 3d class	5		5		
Individual firing: 3d Period, 1st class, 2d class	6	20	6	20	Ditto.
Individual firing: 3d Period, 3d class	5		5		
File-firing & volleys	1	10	1	10	In the companies by their captains, recruits by the Officer-Instructor.
Skirmishing practice	2	20	2	20	Ditto.
Judging distance practice: 1st Period	4	..	..	..	By the Officer-Instructor.
Judging distance practice: 2d Period	4	..	..	..	Ditto.
Judging distance practice: 3d Period	4	..	..	..	Ditto.
Total....	..	90	..	110	

PART II.

Theoretical Principles,

Such as have been explained in the foregoing pages.

*   *   *   *   *

34. *Too strong a pull required to move the trigger.*—If the trigger pulls too hard it will cause the soldier to alter the direction of the arm while firing. This is easily rectified, when necessary, by the armorer.

35. *Fore sight.*—The soldier should pay attention, in cleaning his arms, never to rub the fore sight against any hard substance which would injure it, either forcing it to one side, or blunting it so much that he would be unable to take a proper aim. In leaning his firelock against a wall he should be careful not to make it rest on the point of the fore sight.

*   *   *   *   *

42. *Inexact measurement.*—If, in loading, the soldier observes that there is not sufficient powder in the cartridge, he should, in firing, aim a little high, as a small charge will not send so far as the regulation charge.

*   *   *   *   *

49. *Necessity of constant practice in judging distance by the eye.*—In conclusion, the instructor should not fail to impress upon his men the great importance of training themselves to judge distance, without which all the firing at a target is so much waste of time. It has already been shown how necessary it is that the back sight of the firelock should be adjusted to the correct distance; but the soldier cannot do this if he is not thoroughly trained to judge distance by the eye. It is of no use his being a good shot at a fixed mark if he cannot hit the enemy in the field; this is the object of all training.

50. It has been ascertained, by experiment, that if the rifled musket, pattern 1853, be fired with the elevation due to 600 yards at an object 570 yards off, the bullet will strike 2.30 feet above the mark; if the musket be fired with the same elevation at the distance of 630 yards, the bullet will strike 2.54 feet below the mark, showing that any error of 30 yards in the appreciation of distance would, at this range, cause the soldier to strike the figure of a man either in the head or feet, according as the error of appreciation was under or over the correct distance. When firing with the 300 yards sight, the bullet will take as much as 70 yards to fall half the height of a man, owing to the trajectory of 300 yards being less incurvated than that of 600 yards. At 800 and 900 yards, the curve being greater than at either of the above-mentioned distances, the same fall would take place in passing over a much shorter distance, consequently the *greater the distance the greater the necessity of knowing it accurately.* It is for this reason that none but well-trained soldiers should ever be allowed to fire at such distances as 800, 900, and 1000 yards, and then only at columns of infantry whose depth would make up, in some degree, for the mal-appreciation of distance. Thus, in firing at a column whose depth is 100 yards, if the soldier overestimates the

distance of the front rank by 100 yards, although such an error would cause him to miss the front rank, he would, if the ground is level, strike the column in its rear. As the soldier, however well trained, cannot always be certain of his distance, it is preferable, when in the field, to give the first shot an elevation rather under than over the correct one; the shot will then strike the ground before reaching the object, and may possibly hit in its bound, or *ricochet*, as it is called. He should be taught to watch the effect of his shot, which may generally be ascertained by observing the dust thrown up when the bullet strikes the ground; he can then adjust his sliding-bar by raising it higher or lower, according as his first shot strikes before or beyond the object.

PART III.

Preliminary Instruction in Firing.

Target Drill.—Aiming with a Rest.

* * * * *

6. Having explained the foregoing rules, the instructor will cause each soldier to take aim at an object of the same size as the bull's eye used in practice, at every distance of fifty yards from 100 to 900 yards, viz.:—

From 100 to 300 yards.—	Bull's eye,	8 inches	in diameter.
" 350 to 600	"	"	2 feet	"
" 650 to 900	"	"	4 feet	"

7. After each man aims he will step aside, in order that the instructor may examine and see if the aim is correctly taken; should he observe any error, he will cause the next man to advance and point out the defect; the error, however, is always to be corrected by the man who has aimed.

8. To vary the practice, the squad should occasionally be exercised at intermediate distances (as 425 yards for example), as also be made to aim at a soldier placed in front of the target, or at a group of several men together.

Position Drill.

* * * * *

Judging-Distance Drill.

13. *Instruction for recruits and others in the company.*—In order to apply the rules of firing laid down for the musket, it is necessary to know the distance which separates a man from the object he is firing at.

14. In firing for instruction the target is generally placed at known and measured distances, but before the enemy the distance is unknown; it is necessary, therefore, to judge the distance quickly and exactly, in order to regulate the elevation of the piece accordingly.

15. In order to teach the soldier to estimate distances by the eye, he will be instructed according to the following rules in the first instance, before he passes on to the method contained in the "*Judging-Distance Practice.*"

16. The instructor will cause a line of 300 yards to be measured accurately; this line will be divided into equal parts of 50 yards each, by perpendicular lines.

17. At the extremity of each of these perpendicular lines the instructor will place a soldier standing at ease, and facing the squad he is about to instruct.

18. It will be observed that each of these soldiers is placed at a greater distance from the line of 300 yards, in proportion as he is distant from the point where the squad will commence their instruction, in order that each soldier may serve in turn as a point of distance for the squad to make observations on.

19. The instructor will point out successively to the men the different parts of the figure, arms, accoutrements, and dress, which they can still perceive distinctly on the soldier placed at 50 yards distant, and also those parts that they can no longer perceive clearly at this distance; he will question the men one after the other in the observations they make on what they see, but he must not expect that the answers should be the same from every man, since the eye-sight is not the same in all. Every soldier will try to impress upon his mind the appearance of the man placed at 50 yards.

* * * * *

27. The instructor will then call each man separately to the front and question him, noting down his answer,—which must be given in a low tone of voice, in order that those following him may not be influenced by his opinion.

28. Every man will adjust the sight of his firelock to the distance he judged.

* * * * *

33. The number of drills to be devoted to this exercise will be arranged as follows:

Four drills, at fixed points to 300 yards.
Three " at unknown distances up to 300 yards, each drill to consist of four answers.
Two " at fixed points from 300 to 600 yards.
Three " at unknown distances from 300 to 600 yards, each drill to consist of four answers.

Manufacture of Cartridges.

34. Articles for the instruction of soldiers in the manufacture of cartridges will be supplied to each barrack by the war department.

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Target Practice.

38. The targets for this practice will be six feet in height, by two in breadth; they will be constructed of cast-iron, three-quarters of an inch thick, and squares of six inches cut on the face, to facilitate the marking off of the hits in the diagrams provided for the purpose; in the centre is a bull's eye, eight inches in diameter; and from the same centre, with a radius of one foot, a black circle is described, dividing the target into two parts, centre and outer. Circular rings will also be cut on the face of the target, to serve as guides in painting it.

* * * * *

43. Each man will expend, as his annual allowance of ammunition, 90 rounds in the following manner, viz., 60 in firing individually; 10 in file firing and volleys; and 20 in firing in extended order.

44. The targets will be arranged as follows for the different distances :—

Up to 200 yards			the practice	will be	at	1 single target.	
At 250	and	300	"	"	"	2	targets.
" 350	"	400	"	"	"	3	"
" 450	"	500	"	"	"	4	"
" 550	"	600	"	"	"	5	"
" 650	"	700	"	"	"	6	"
" 750	"	800	"	"	"	7	"
" 850	"	900	"	"	"	8	"

45. The troops will fire at every distance of 50 yards from 100 to 900 yards. These distances are divided into three parts, viz., up to 300 yards included will be for the practice of the 3d class; as far as 600 yards included for the 2d class; and the 1st class only will continue the practice to 900 yards.

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Individual Firing.

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49. Ricochets, or shots which strike the ground first before they strike the target, are to receive no signal, and are to be counted as misses in individual firing.

50. The signals for the different distances, and the value attached to each shot, will be as follows :—

	SHOTS.	FLAGS.	VALUE.
In the practice of the 3d class.	Outer	White	1
	Centre	Dark blue	2
	Bull's eye	Red and white	3
	Miss		0
Practice of the 1st and 2d classes.	Outer	White	1
	Centre	Dark blue	2
	Miss		0

51. The danger, or cease-firing signal, will in all cases be a red flag. This will be hoisted whenever it is necessary to "cease firing," in order to run out to wash the target, or for any other purpose; it will invariably be answered from the firing point by sounding the "cease fire," and will always be kept up as long as the markers are out of the butt. Whenever the "cease fire" is sounded from the firing point, it will be answered by raising the danger flag from the marker's butt, and in like manner the "commence firing" will be answered by lowering it.

52. Whenever a shot strikes the target to the right, the flag denoting the value of the shot will be inclined to the right, *vice versâ;* when the shot strikes high, the flag will be raised as high as possible; and when low it will only be raised high enough to be easily distinguishable above the butt.

* * * * *

54. The non-commissioned officer-instructor of the class or company will keep a register; on this he will note, under the number of the shot fired, the value or number of points obtained by it, whether 1, 2, 3, or 0. At the conclusion of the practice he will add up the total number of points obtained by each man during the practice: the addition of the column of total points will give the total of the squad or section, and this divided by the number of men will give the average, should it be required.

55. All entries are to be invariably made *in ink* on the ground; and should any erasures be necessary, a fine line will be drawn through the figure thus—the correction made, and the officer's initials immediately attached to it.

~~2~~	1	*A. L. F.*

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57. The marker in the butt is invariably to be a non-commissioned officer of a different company from that engaged in firing; he will be responsible for the correct signals being given to the several shots which strike the target; and will, if convenient, keep a diagram of the practice as it proceeds. Should it not be considered necessary to keep a diagram (which will be entirely left to the judgment of the instructor) the marker will keep a memorandum of each shot as it strikes, under the head of bull's eye, centre, and outer. This will prevent delay and insure each man's shot receiving the correct signal.

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60. The non-commissioned officers of each section will fire at the head of their sections according to seniority, and the company-instructor should fire at the head of his company or class.

* * * * *

65. At the conclusion of each practice the bugler will sound the assembly, when the company-instructor will proceed to compare the register with the target, as also the diagram (if one has been kept); both register and diagram will then be completed and signed by the *company-instructor*, and *marker*, and countersigned by the *officer-instructor*, after which the "*duplicate total points*" initialled by the officer-instructor, to verify its agreement with the column "*total points*," will be torn off and immediately handed over to the

non-commissioned officer-instructor of the battalion, who on the practice-ground is especially responsible that this order is rigidly attended to in all cases.

66. The company-instructor will, immediately on his return to barracks after every practice, transcribe the column "total points" of the registers to the company target-practice return F.

* * * * *

69. The practice of individual firing is divided into three "periods," in each of which the soldier will fire twenty rounds.

FIRST PERIOD.

70. *Practice of the company in the third class.*—The battalion will commence the "*first period*" yearly with the practice of the 3d class, which will be carried on by companies under the command of their captains, superintended by the officer-instructor. All shots which hit the bull's eye will be marked with No. 3 in the register; those that strike the centre with No. 2; those that strike the outer with No. 1; and the misses with 0. Each man will fire four rounds at 100, 150, 200, 250, and 300 yards. At 100 and 150 yards the practice will be conducted standing and with fixed bayonets, and at the other distances with unfixed bayonets, the men being allowed to stand or kneel at pleasure.

71. When the whole of the company has executed the practice up to 300 yards in the 3d class, the total points obtained individually at each distance in the "first period" will be added together, to show the practice of each man in the 3d class in the company practice return marked F. From this column the company will be divided into two classes; all men who have obtained in this practice 13 points will pass into the 2d class; the remainder will recommence the practice of the 3d class at 100 yards. This "period" of the return will be signed by the captain of the company, as a proof of its correctness, and by the officer-instructor after he has carefully examined and compared it with the "duplicate total points" in his possession.

72. The names of the men who have passed into the 2d class will be read to the companies on parade by their captain.

SECOND PERIOD.

73. *Practice of the second and third classes.*—After the men of the company have been divided into classes the practice will no longer continue as a company, but be carried on by classes under the superintendence of the officer-instructor of the battalion. Each class, if the number will admit of it, will be divided into sections, and their names will be placed in the registers of each company in the order in which they stand in the practice return.

74. The company-instructor will attend when possible with every class.

75. Whenever there is a choice of time for practice the senior class will always have the advantage.

76. The 3d class will repeat the practice from 100 to 300 yards, firing as before directed.

77. The 2d class will fire three rounds per man at the distances of 350, 400, 450, 500, and 550 yards, and five rounds at 600 yards.

78. In the practice of the 2d class all shots which strike the centre will be marked No. 2 in the register; those which strike the outer with No. 1; and the misses 0. The bull's eye in this practice will only count as centre, the whole of which is to be painted black.

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80. At the conclusion of the practice of the "second period," the company-instructor will total the points obtained at each distance by the men of the 2d and 3d classes recorded in the practice returns, which the captain of the company will then sign and send to the officer-instructor of the battalion, who, having found that it is correct, will also attach his signature and return it to the company.

81. A second classification will now be made, when all those men who, in the practice of the 2d class, have obtained ten points will pass into the 1st class; the remainder will repeat the practice of the 2d class.

82. The qualification for passing from the 3d to the 2d class will be the same as in the first period.

THIRD PERIOD.

83. *Practice of the first, second, and third classes.*—The three classes will be told off into sections as before; the 2d class will now be composed partly of men who repeat the practice of the 2d class, and partly of men who have passed out of the 3d class in the second period.

84. The practice will be conducted on the same principles, and the hits will have the same value, as in the second period, except that the centre in the practice of the 1st class will have a diameter of four feet instead of two feet, all of which to be painted black.

85. The 1st class will fire three rounds per man at the distances of 650, 700, 750, 800, and 850 yards, and five rounds at 900 yards.

86. At the conclusion of this period the columns of the "third period" in the company's practice return will be totalled, and from which a final classification for the year will be made. From this the company-instructor will make out a list, in which each man will be placed according to his performance, with the number of points obtained in the third period attached to his name, viz., those who obtain most points in their class first, and so on; which list will be posted up in the barracks.

87. The men of the 1st class will be exempt throughout the following year from target drill.

88. That man who obtains the greatest number of points in the practice of the 1st class will receive the prize as the best shot of his battalion.

89. Should two or more men obtain the same number of points in the practice of the 1st class, the prize will be awarded to that man who has obtained the greatest number of points throughout the whole practice of individual firing.

File and Volley Firing.

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Skirmishing.

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103. The average points obtained in these practices, added to the average obtained in the "*practice of the company in the 3d class*," and that of "*file-firing*," and "*volleys*," will denote the merit of the company; and that company which has the highest figure will be the best shooting company in the battalion. No man is to fire either in the "file and volley" or "skirmishing" practice who has not fired up to 300 yards.

* * * * *

Judging-Distance Practice.

110. The following course of judging-distance practice will be gone through annually by every soldier of the battalion, and, when possible, will be carried on by the sections not occupied in firing, when at target practice.

111. A cord or chain of the length required for the practice (divided into parts of five yards each, with the distances of each division from the end so marked as to be distinguishable only on close inspection), to be stretched in any direction that may be found convenient for the practice, care being taken to vary the ground as much as possible for the several practices.

112. One or more men, when judging at 300 yards only, but beyond that distance a section of not less than eight or ten file, will be stationed at the end, or at any other part of the chain that may be directed, to serve as objects to estimate from.

113. The answers of each man to be recorded in a register of the form marked C, which will invariably be kept by a non-commissioned officer of a different company to that under exercise.

* * * * *

117. When all the answers of each section or party have been noted down they will be read over to the men, and any error which may be discovered will at once be corrected; after which the commander will refer to the chain or cord, and state aloud to the men the correct distance, which will at once be noted at the top of the column, the number of points obtained by each individual being at the same time registered and made known.

* * * * *

119. At the conclusion of each practice the number of points obtained by each man will be read over to the men; and the register when completed by filling up the column "total points" and "duplicate total points" (which is always to be done on the practice-ground), will be signed by the non-commissioned officer who has kept it, and by a non-commissioned officer of the company exercising, and countersigned by the officer-instructor, who will also place his initials to the "duplicate total points," which are then to be torn off and given over to the non-commissioned officer-instructor of the

battalion; the company-instructor retaining the register, the total points of which he will invariably transcribe into the company's judging-distance practice return immediately on his return to the barracks.

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123. The practice of judging distance, like the target practice, will be divided into three periods, each period consisting of four practices. The 3d class will practice as far as 300 yards; the 2d, 600 yards; and the 1st, as far as 900 yards.

124. The value of the men's answers by points in the several classes in judging-distance will be registered as follows:—

3d class, or when judging distance between 100 and 300 yards.	Within 5 yards,	3 points.
	" 10 "	2 "
	" 15 "	1 "
2d class, or when judging distance between 300 and 600 yards.	Within 20 yards,	2 points.
	" 30 "	1 "
1st class, or when judging distance between 600 and 900 yards.	Within 30 yards,	2 points.
	" 40 "	1 "

125. It is to be observed that should the 1st or 2d class be brought to judge within the distance of an inferior class, which, in order to test the proficiency of the men, ought frequently to be done, the points should then only be counted agreeably to the conditions laid down for these classes.

FIRST PERIOD.

126. *Practice of the company in the third class.*—Every man will commence the yearly course of practice in the 3d class, and be exercised therein at sixteen different distances in four practices.

127. At the conclusion of these practices the columns in the company judging-distance practice return will be totalled up, and receive the signature of the captain of the company to verify its correctness, as also of the officer-instructor, who will previously compare it carefully with the "duplicate total points" in his possession.

128. All those men who obtain sixteen points will pass into the 2d class, the remainder will recommence the practice of the 3d class.

SECOND PERIOD.

129. *Practice of the second and third classes.*—Each company will now be told off into two classes and into sections, and the practices continue in that order. Each class will be exercised at sixteen different distances in four practices.

130. At the conclusion of the practice in the second period the columns of this period in the company judging-distance practice return will be totalled up, and signed by the captain and officer-instructor as before.

131. All those men who in the practice of the 2d class obtain sixteen points will pass into the 1st class, the remainder will repeat the practice of the 2d class. The test for passing from the 3d to the 2d class will be the same as in the practice of the first period.

THIRD PERIOD.

132. *Practice of the first, second, and third classes.*—The company will now be told off into three classes, and into sections as before, and each class exercised at sixteen different distances in four practices.

133. The 2d class will be composed partly of men who repeat the practice of the 2d class, and partly of men who have passed out of the 3d class in the second period.

134. At the conclusion of the practices in the third period, the columns of this period in the company's judging-distance practice return will be totalled up and signed as directed for the first and second periods. A final classification will then be made, and the man who, in the practice of the first class, obtains the greatest number of points will obtain the battalion prize as the best judge of distance. Should two or more men obtain the same number of points, the prize will be awarded to that man who has obtained the greatest number of points throughout the whole practice.

INSTRUCTION OF RECRUITS.

135. Every recruit, before he is allowed to join the practice of the battalion, will be put through the foregoing course, with the exception of the *judging-distance practice*, under the close superintendence of the officer-instructor and his assistants.

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139. After all these exercises have been gone through, the soldier will be competent to join the practice of his battalion; but any man who concludes his practice as a recruit after the target practice of his battalion has commenced, will not fire with his battalion until the ensuing year.

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RETURNS, &c.

142. *Company returns.*—The following forms will be made use of in the different branches of the instruction, viz.:

Form A.—A company index return of preliminary drills, in which the men's names are to be entered by sections or squads, the non-commissioned officers heading each section. This return is to be filled in by the company-instructor after each drill or parade, for which the captain is responsible.

Form B.—A register of target practice, for each squad or section, to record the practice as it proceeds, the men's names to be entered in the order in which they stand in the company's index and practice returns.

Form C.—A register of judging-distance practice, for each squad or section, to record the practice as it proceeds, the men's names to be entered in the order they stand in the company's index and practice returns.

Forms D and E.—Diagrams to record the file and volley firing, and skirmishing practice of each section.

Form F.—A company target-practice return, to be filled in as the several practices occur by the company-instructor, the men's names to be inserted therein by sections, the non-commissioned officers heading each section. As this return is a record showing the progress of the company in its practice, as well as its efficiency in the use of the rifle, the captain is to be held responsible that it is kept with great care and correctness.

GENERAL ORDER.

HORSE GUARDS, S. W., March 10, 1858.

The General Commanding-in-Chief, with a view to stimulate individual exertion, and to reward the proficiency of soldiers in the use and management of the rifle-musket, has been pleased to institute a system of "Prizes for good Shooting;" and the accompanying regulations for the award of the same having received the concurrence of the Secretary of State for War, His Royal Highness desires that they be strictly observed throughout the infantry and embodied militia.

By command of His Royal Highness
THE DUKE OF CAMBRIDGE,
General Commanding-in-Chief,
G. A. WETHERALL, A. G.

REGULATIONS

To govern the Issue of Prizes for Good Shooting in the several Battalions of Infantry.

HORSE GUARDS, S. W., February, 1858.

1. The regimental prizes for good shooting will be three, viz.:

1st Prize.—To the best shot of the battalion, a badge of *Cross Muskets and Crown* worked in gold, and entitling the wearer to extra pay at the rate of 2*d.* per day.

2d Prize.—To the best shot of each company, a badge of *Cross Muskets* worked in gold, and carrying with it extra pay at the rate of 1*d.* per day.

3d Prize.—To certain of the first-class shots, to be styled "*Marksmen,*" and not to exceed 100 per battalion, a badge of *Cross Muskets* worked in worsted, with 1*d.* per day additional pay to each wearer.

2. The badges are to be worked on cloth the color of the facings of the regiment, and to be worn on the left arm, immediately above the slashed flap of the sleeve.

3. In order to insure, on the one hand, a high standard of efficiency, and

on the other to guard against the public being called upon to pay for a lower standard of merit than is necessary, as well as to secure the utmost impartiality in the distribution of the rewards, it is intended that the registers and annual practice returns shall be the data upon which the proficiency of the men shall be estimated.

4. Accordingly, the best shot of the battalion will be that soldier who, in the practice of the 1st class, firing between 600 and 900 yards, obtains the greatest number of points over seven.

5. The best shot of the company will be he who, in the practice of the 1st class of his company, firing between 600 and 900 yards, obtains the greatest number of points over seven.

6. To qualify a soldier for the position of a *marksman*, and the rewards attaching thereto, he must, in the yearly course of practice, have obtained at least seven points, in the 1st class, firing between 600 and 900 yards, and possess competent knowledge of the laws affecting the flight of the bullet, and the rules to be attended to in maintaining the efficiency of the rifle under all circumstances and conditions, and display the requisite skill in judging distances, being at least in the 1st class at the final classification of the judging-distance practice.

7. Should it happen that more than 100 men in the battalion (includi.. the best battalion-shot and the best shot of each company) come under the conditions specified in the foregoing paragraph, then those men who have obtained the greatest number of points are to be first selected for the reward and distinction. Should two or more men have obtained the same number of points (not less than seven) in the 1st class, and be otherwise eligible for the reward, reference is to be made to their respective performances in the first and second periods of individual shooting, and those are to be selected who have obtained the greatest number of points therein. Should there still be a tie, reference is then to be made to their performances in the judging-distance practice, and the preference given to those who are the best judges of distance.

8. Should the number of paid marksmen in a battalion be reduced by casualties during the year, the number may be completed from those men eligible for the reward (if there are any) under the conditions prescribed in paragraph 6.

9. As a further inducement to all ranks to vie with each other in this essential part of the soldier's instruction, and in order that every man may feel that though he may not himself succeed in obtaining a prize, he can assist in obtaining one for his company. His Royal Highness the General Commanding-in-Chief has further approved of a *supplementary prize of Cross Muskets and Crown* worked in gold, but unaccompanied by any pecuniary allowance, being worn on the *right* arm, by the *sergeants of the best shooting company* of every battalion.

10. Should a sergeant of the best shooting company be either the best shot of the battalion, the best shot of his company, or a marksman, he will wear the distinguishing badge of that position, in addition to the badge sanctioned in the foregoing paragraph.

11. With a view to insure strict impartiality it is essential that the several companies of a battalion should be kept as much intact as possible; they should, therefore, be equalized before the annual course of drill and practice commences, and no transfers be made, except such as are indispensable, until the period for commencing the practice in the following year.

12. Although the *best shooting company* can be established wherever a range of 300 yards can be obtained, and the *company badge* may be issued accordingly, it is to be clearly understood that no rewards will be granted to *battalions* unless they have been practised in the three periods of individual firing, as detailed in paragraphs 70, 77, and 85 of the "Book of Instruction,"—that under no circumstances will the limit of one best shot per battalion, one for each company, and 100 marksmen, including the two former, ever be allowed to be exceeded;—that, as an invariable rule, both the badge and its attendant allowance will have to be surrendered by all who cease, in the next annual course, to fulfil the conditions, and maintain the superiority, by which these rewards were earned;—and that, should the shooting of any battalion fall below the average, the prizes will be wholly withdrawn, and the issue of the additional pay suspended.

13. Should it be ascertained, either through the reports received from the District Inspector of Musketry, or through any other source, that any undue advantage has been taken by a battalion in the execution of the several exercises in target and judging-distance practices—such, for instance, as counting ricochets; placing marks to aim at, to denote the allowance to be made for wind, &c., whereby the *practical* skill of the soldier in the use of his rifle would be defeated; firing at distances shorter than those enjoined by the regulations, and at a greater number of targets than are prescribed for the several distances; departing, in any way, from the rules clearly defined for conducting the platoon and skirmishing practices, or otherwise deviating from the spirit of the Musketry Regulations, published to insure a uniformity of procedure in this particular throughout the army,—by which alone a fair comparative merit can be arrived at,—such battalion will not be eligible for the rewards granted by these Regulations.

14. As it is of the utmost importance—in order to insure a faithful record of the soldier's performances, and to protect the public from paying for merit undeserved—that the registers and company practice returns should be correctly kept, and that the said documents should be always forthcoming until authority has been received to dispose of them,—if any irregularity should come under the notice of the Inspecting Musketry Officer whereby the integrity of the returns may be questioned,—such as erasures; corrections not initialled by the officer-instructor, or his assistant; absence of the signature either of the marker, or company-instructor, or serjeant acting in his stead; or loss of documents—the battalion will be subject to forfeit the rewards herein prescribed.

15. The best shot of the battalion, and the best shot of the company, will be allowed, in addition to the reward as such, the extra pay as "Marksman;" but no soldier will be eligible for a reward for shooting who is not in the 1st class in the final classification of the judging-distance practice.

16. Each portion of a regiment will be allowed its proper proportion of company prizes, and 100 prize-holding marksmen are to be distributed between service and depot companies in the following manner, viz.:—

10 service companies,....................................	90	100
2 depot companies,....................................	10	

17. In colonial corps, or battalions composed of less than ten companies, prizes will be sanctioned as follows:—

1 best shot of battalion or corps.
1 best shot of each company.
10 marksmen per company, but not to exceed 100.

18. The extra pay is to be drawn, and the distinguishing badges are to be worn for one year, commencing on the first day of the quarter succeeding that in which the annual report of practice is required to be made up, or as soon as the necessary authority is received.

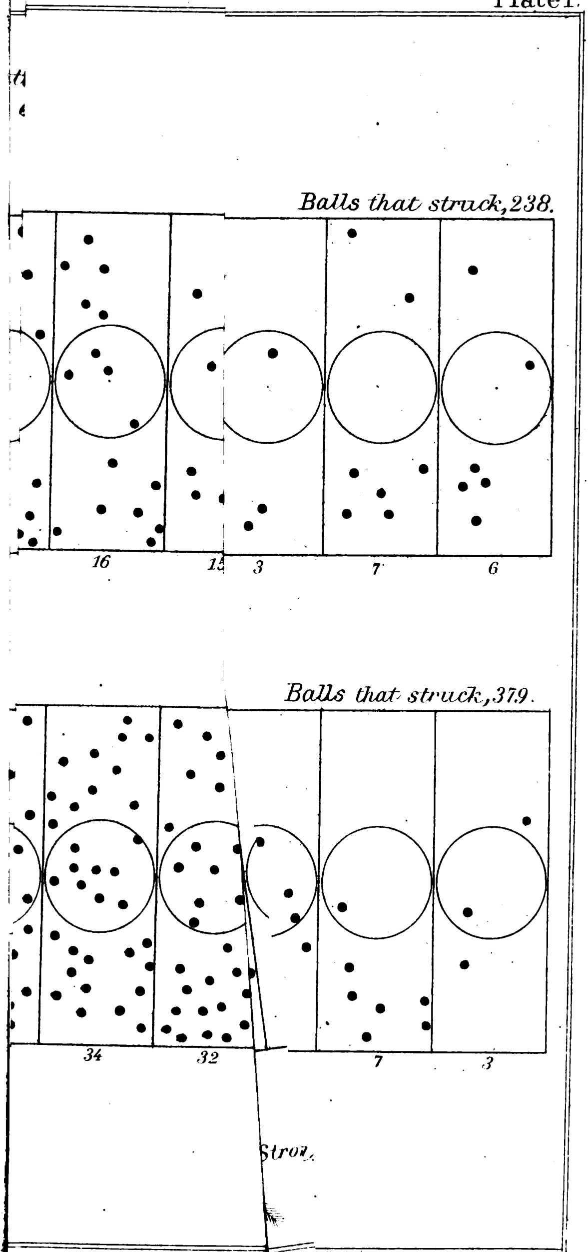
19. When a battalion is on active service in the field, or at a station where from want of range the prescribed annual course of rifle-practice cannot be proceeded with, the rewards will be continued to those men in possession of them until an opportunity occurs of their being challenged by another annual course of instruction, which is to be gone through at the earliest possible time. A certificate from the commanding officer, verified by the general officer under whose command the battalion is serving, to the effect that under the circumstances above detailed (for under no other is the allowance to be continued beyond one year), the battalion has been prevented undergoing the prescribed annual course of rifle-instruction for the year 18—, is to be forwarded to the Inspector-General of Instruction, for transmission to the Adjutant-General to the Forces, for the information of the General Commanding-in-Chief.

20. All recommendations for prizes are to be prepared on the form of return annexed (a supply of which will be furnished on application to the War Office), and forwarded in duplicate, with the annual practice returns, to the Inspector-General of Musketry at Hythe, by whom, after due examination, one copy will be transmitted, with his recommendation, to the Adjutant-General to the Forces, for the approval of the General Commanding-in-Chief.

21. Badges of distinction will be supplied, on application in the usual annual requisition for clothing, and are to be retained in the Quartermaster's store, for issue under the provisions of these regulations.

By Command,
G. A. Wetherall,
Adjutant-General.

Plate 1.



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