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THE UTILIZATION OF RIFLE FIRE IN THE FIELD.

By Major C. K. BROOKE, 1st Batt. East Yorkshire Regt.

UNFORTUNATELY the study of the science of "Fire Tactics" has been so neglected in this country, and so little data has been collected, that it is necessary to appeal chiefly to the results of experiments carried out abroad for the facts on which to base a theory of how best to utilize the power of the rifle in the field.

This paper will therefore be based upon, and make free use of, the tables, deductions, and criticisms contained in a "Commentary on the German Musketry Instructions" which appeared in 1882 in the "*Revue Militaire de l'Étranger*."

The result of the experimental firing conducted near Dungeness in 1879-80 will also be made use of as far as practicable.

Firing in the field may be divided into two categories: Individual, and Collective; the former being the fire of individual men when left to their own initiative, the latter the fire of several men acting together under the orders of a superior.

The discussion of the subject divides itself naturally into two parts; and it is proposed in the first to deal with individual fire, and in the second with collective fire.

PART I.

INDIVIDUAL FIRE.

The questions which mainly concern the individual firing of men are:—

"a." The relation which exists at each distance between the size of the object aimed at, and the dimensions of the grouping of a series of shots at the same distance.

"b." The point to aim at.

"c." The employment of fixed sights.

"d." The limit of effective individual fire.

"a." *The Relation between the Objective and Shot Groups.*

The influences which act on rifle firing are so diverse that even when the same man with the same rifle fires a series of about 50 shots without committing the least error, and aiming steadily at the same spot, the bullets

striking a vertical target cover a surface more or less large; this surface represents the vertical grouping of the shots of the series at this distance, and may be called a vertical shot group.

The combined trajectories of all these shots constitute their "gerbe," and this may be likened to a curved horizontal cone, having its apex at the muzzle of the rifle, and its base at the object aimed at.

Plate XXV, Fig. 1, extracted from the "German Musketry Regulations," represents this gerbe or sheaf of shots; and $a_3 O_4 b_4$ its terminal vertical shot group.

The horizontal grouping of the shots of a series is obtained from the vertical shot group by calculating the distance each shot would travel before reaching the ground. Since the drop of a bullet which strikes the top of a six foot high target is known for every distance, the calculation of the drop of all other shots can be practically determined by simple proportion. For example, the drop of a bullet at 500 yards when fired from the Henry-Martini rifle is, from the Dungeness experiments, 64 feet in 6 feet; consequently, if a shot struck the target 4 feet from the ground, its horizontal projection behind the target would be $\frac{4}{6} = \frac{64}{7}$, or the bullet would reach the ground $42\frac{1}{2}$ feet in rear of the target. Plate XXV, Fig. 2 (Ger. Mus. Regn.) graphically represents the horizontal grouping of a series of shots. It has been found by experiment that in these groups, the shots tend to form a sort of nucleus in the centre, and to be more scattered at the margin.

The vertical grouping of the shots from the Mauser rifle takes the form of a circle as far as 150 m. inclusive, and thence the shot groups assume an oval shape of which the longer axis is vertical. The axes of these ovals go on increasing as the distance becomes greater, and their dimensions also vary more or less in accordance with the accuracy of the shooting of each rifle.

The dimensions of the vertical shot groups of the Mauser rifle are shown in Table 1; in which will be seen the percentage of abnormal hits which are subtracted at each distance in Germany. The centre of the shot group is determined by the position of a point which has an equal number of shots above and below it; and an equal number to the right and left of it. Plate XXV, Fig. 3 (G. M. I.) illustrates this. In France, it is not thought that this central point is determined by such a rudimentary method.

Before proceeding further it will be necessary to assume some dimensions for the objects which are most frequently fired at in the field: the following will be the data made use of in this paper; and are, except the height of a standing man, the dimensions adopted in Germany:—

	m.	ft.	in.
Man standing	1'60	or 5	4
„ kneeling	1'10	„ 3	8
„ lying down, but not under cover.....	0'45	„ 1	6
„ lying down, and under cover	0'35	„ 1	2
Breadth of a man (the vulnerable part).....	0'40	„ 1	4
„ „ group of two men	0'80	„ 2	8
„ „ „ three men.....	1'20	„ 4	0
A cavalry soldier, riding at a rapid rate.....	2'00	„ 6	8

The relation between the above dimensions and the areas shown in Table 1 must always be borne in mind; for allowing that the sighting of a series of shots is correct, and that no mistake is made in aiming, still these shots will only strike the mark so long as their grouping and the objective have the same extent of surface. When a distance is reached at which a shot group has a larger surface than that of the objective, then many of the bullets, though well directed, will miss their mark; the number of misses increasing in proportion as the area of the shot group exceeds that of the objective.

For example, with correct sighting and accurate firing, it is necessary that the objective at 300 m. should be 48 cms. wide, and 58 cms. high, in order that 95 per cent. of the shots should strike it; if the object fired at had a less width or height, then a proportionably smaller number of hits would be made.

Passing on, the several trajectories which together define the shape of the "gerbe" must be glanced at. The mean trajectory of a rifle for any distance can be graphically traced by connecting the centres of a series of intermediate vertical shot groups, and is represented in Plate XXV, Fig. 1, by the line $a, O, \dots o_s$. The upper trajectory is traced by joining together the upper parts of these same shot groups; and the lower trajectory by joining all the lower parts of the groups: the line $a, a_1, \dots, a_6$ shows the former, and the line $a, b, \dots, b_6$ the latter.

The ordinates of the mean trajectory are the distances of the centre of the shot groups above the line of sight; the ordinates of the upper and the lower trajectories are obtained by adding to, or subtracting from the ordinates of the mean trajectory, half the vertical axes of the shot groups at the several distances.

For example, to find the ordinate of the upper trajectory of the 400 m. gerbe, at say 300 m.; add 29 cms., half the vertical axis of the shot group at 300 m., to 1.44 m., the ordinate of the 400 m. trajectory at the same distance, and their sum 1.73 m. is the ordinate required. Table 2 (G1, Ger. Mus. Inst.) shows the ordinates of the trajectories with the fixed sight of 270 m., the flap sight of 350 m., and the sight of 400 m.

If a gerbe be pictured mentally as a solid curved cone, lengthened by the elevation given to it, and having its terminal vertical area rapidly increased as it is directed on more and more distant objects; then the meaning of the term "shot groups" at various distances will become apparent, and they will be seen to be merely a series of vertical sections taken through the imaginary solid cone at the different distances. Looking thus at a gerbe, the conclusion arrived at from the foregoing investigation may be defined under the statement, that, in individual firing, the relation between an objective and a shot group is the relation that exists between their respective areas at the distance fired at.

"b." *The Point to aim at.*

The shot groups in individual firing have hitherto only been considered with reference to the object aimed at, when this has been at the same distance as that of the sight made use of: they must now, however, be considered with reference to an object which is at a less distance than that of the sight employed: there are two cases to examine.

(1.) When the aim is directed at the object.

(2.) When the aim is directed at an object whose distance from the firer corresponds with the sight made use of.

(1.) For example, in the first case let the aim be directed with the 350 m. sight, at the foot of an object 300 m. from the firer; then if reference be made to Table 2 it will be seen that the centre of the shot group at this distance is 70 cms. (the ordinate of the 350 m. trajectory at 300 m.) above the line of sight, and as this is directed at the foot of the target, the centre of the shot group may be taken as 70 cms. above the ground.

But if under the same conditions the aim had been directed at the centre of the target (90 cms. above the ground) then the centre of the shot group would be $90 + 70$ cms. or 1 m. 60 cms. above the ground; and as the semi-diameter of the vertical axis of the shot group at 300 m., Table 1, is 29 cms., then the upper trajectory of the gerbe would pass 1 m. 60 cms. + 29 cms., or 9 cms. above the top of the target, and in consequence many shots would fail to hit:

whereas, if the aim had been directed at the foot of the target the whole of the shot group would have struck it.

The movement of the shot group is well shown in Table 3, in which the upper and lower trajectories of 350 m. gerbe are recorded as the aim is directed either at the foot or the centre of the targets placed at intervals of 50 m. from the firer. The trajectories are obtained as said before by adding to or subtracting from the ordinates of the mean trajectory the semi-diameters of the vertical axes contained in Table 1.

(2.) In the second case the position of the firer has to be taken into account, as the aim is directed at a mark beyond the object fired at. The heights of the different firing positions are in Germany laid down as under :—

Standing	....	....	....	1 m. 50 cms.
Kneeling	....	....	....	90 "
Lying down	....	....	....	30 "

It is evident, since the trajectory follows the line of sight, that if the latter be raised the ordinates of the former will be increased at all distances between the firing point and the object aimed at. Take for example the line of sight proceeding from a man standing to the centre of a target 1.80 m. high, and the line of sight directed by a man kneeling to the same place on the target : the former is a line falling from 1.50 m. to 90 cms., the latter is a horizontal line 90 cms. above the ground ; the firing position of a man kneeling and the centre of the target coinciding in height. Table 4 shows the height of the ordinates of these several lines of sight at different distances, under the conditions that the aim is either directed at the foot of the target, or at its centre.

To obtain the ordinates of the mean trajectory of 350 m. gerbe, it is only necessary to add to the ordinates of the line of sight in Table 4, the ordinates of the 350 m. trajectory as given in Table 2 ; the result is shown in Table 5. In order to further define the movements of the shot groups at intermediate distances, Tables 6 and 7 have been added ; they have been obtained respectively by adding to or subtracting from Table 4, the semi-diameters of the vertical axes contained in Table 1.

Using the above data, the position of the shot group on a target at 300 m. can be examined, when aim is taken with the 350 m. sight at another target at 350 m.

Let aim be first taken at the foot of the 350 m. target by a standing man ; then by Table 6, the upper trajectory of the shot group at 300 m. will be only 1.20 m. from the ground ; whereas, if the firer aimed at the centre of the target it would be 1.97 m. to 17 cms. off the target : again, if the firer kneels, and aims at the bottom of the target, the upper edge of the shot group will be 1.11 m. above the ground ; but if he aims at the centre of the target it will then be 1.89 m. from the ground, that is 9 cms. off the target.

Thus when firing either standing or kneeling, and aiming at the centre of the distant target, the upper part of the 350 m. gerbe passes above the 1.80 m. intermediate target, placed at 300 m. And the deduction may be made that when an object is 50 m. short of the mark aimed at, aim should be taken at the foot of this mark, both when firing standing or kneeling.

Before proceeding to consider generally how the 350 m. gerbe acts at all distances intermediate between the firer and 350 m., a glance at a battle-field must be taken. In a battle which is intended to be brought to an issue, one side must act on the offensive, the other on the defensive ; the rôles may be interchanged, but at any given moment the opposing front lines of the adversaries must be either advancing to the attack, or staying still to defend the position attacked ; therefore the distance between the two sides tends to diminish, and it becomes most important that the intervening space between the adversaries should be swept by a storm of bullets. The ideal of rifle fire

on the field is reached, when no bullet in the intervening space between the opponents passes over the head of a standing man: that is, does not rise higher than 1.60 m., or 5 feet 4 inches above the ground.

Other kinds of actions there are: demonstrative, and retreating; in the former a delaying fire is made use of, and time is given to work out distances; in the latter, the victors being safe, have to raise their sights as the enemy flies before them. But before the action is decided, when the strain is most intense and time most limited, then fingers must hold firmly the rifle which may at any moment be required for use in the way our forefathers handled it; they cannot be loosened to fiddle with a sight, or to adjust it to distances of 50 yards, nor can the eyes be lowered for the purpose, or taken off the enemy, when he is advancing on us, or we on him.

In discussing this question of rifle fire in the intervening space between closely opposing forces, tables based on the employment of the 350 m. sight will alone be made use of; for if they serve to prove that it is advantageous under the above circumstances to aim at a certain portion of the objective, then analogous tables based on the use of other sights are not needed as they would only tend to confirm the same fact.

If Table 5 be examined it will be seen, that when firing standing and aiming at the bottom of the target, the centre of the shot group will pass over the heads of standing men for 150 m., viz., from 50 m. to 200 m.: if aim is taken at the centre of the target, the centre of the shot group will clear a man for 250 m., viz., from 50 m. to 300 m. Again, Table 7 shows that when the firer is standing, and aim is taken at the bottom of the target, the lowest part of the gerbe passes over a standing man from 50 m. to 200 m., and if aim is taken at the centre of the target from 50 m. to 250 m. Table 6 shows that the upper part of the gerbe under similar conditions passes respectively over a man's head from 50 m. to 250 m., and from 50 m. to 300 m. Further, if a man is firing lying down and aim is taken at the middle of the target, the whole of the shot groups for 100 m., viz., from 150 m. to 250 m., pass over a man's head; whereas if aim is taken at the bottom of the target, the whole of all the shot groups strike a standing man.

From all these facts the deduction may be: that when aim is taken at the bottom of an object the intervening space swept by the gerbe is lengthened.

Another point in the question must be considered, viz., the effect of taking a fine or full sight. At 300 m., if the former is made use of, the mean trajectory is depressed 15 cms., and if the latter, it is raised a similar amount. Looking at Table 5, it will be seen that at 300 m. the use of the full sight will raise the centre of the 350 m. gerbe above the head of a standing man, when aim from the kneeling or lying down position has been directed at the centre of the target; whereas under similar conditions, if aim had been taken at the foot of the target the full sight would not have caused any shots to pass over a man's head. Hence the deduction may be made, that aiming at the foot of an object diminishes the evil resulting from the use of a full sight.

When a fine sight is employed in conjunction with aiming at the bottom of the target more ricochets are caused, and this brings into prominence an objection that might be raised to aim being always directed at the foot of an object, namely, that when the correct sighting is used only one-half of the shot group will directly strike the mark. The action of ricochets can be studied by the light thrown on them by the Dungeness experimental firing; in the report it is stated that "the bulk of ricochet hits is effective," and that the mean rise of a bullet is twice that of its drop. Having this data, the objection raised can be met, and the following example may serve as an illustration. Let aim be taken with the 350 m. sight at the foot of a target at 350 m., then by Table 7 the lower trajectory will theoretically pass 34 cms.

below the target, but the bullets will really strike the ground in front of the target. This distance may be obtained proportionally from Table 1, which shows that a bullet fired under the circumstances above stated falls 39 cms. in the last 25 m., consequently the bullets in question will strike the ground 18 m. from the target; since the rise is twice the drop, the bullets in ricocheting will strike the target 2×34 cms., or 68 cms. from the ground. It may be noticed that the height at which the shots of the lower trajectory ricochet into the target, always coincides with the vertical axis of the shot group at the distance fired at.

As the lower trajectory represents the path of the bottom bullet of a gerbe, it follows that in the case discussed all the bullets strike the target.

From Table 1 it will be seen that up to 600 m. the longer axis of a shot group does not exceed a man's height; consequently the deduction may be made that if aim is taken at the foot of a standing man he is liable to be struck by all the ricochets proceeding from the lower trajectories of the several gerbes up to 600 m.

Tactical reasons have been adduced in support of the principle of aiming at the foot of the object, and they have been stated as follows: "If the smoke hides the objective it is impossible to aim at its centre, while on the contrary it is very easy to distinguish and aim at a mark taken on the line of separation which exists between the cloud of smoke and the ground, this line being clearly defined in the field. On the other hand, if the adversary, while advancing, disappears behind some artificial shelter, or is lost to sight in a depression in the ground, aim can still be taken at the entrenchment, or at the mark on the ground previously selected, the bullets thus fired will have a good chance of being well directed. Besides, is not the soldier in the heat of action always tempted to take too full a sight? in making him aim at the bottom of the object a compensating influence is brought to bear on this fault, which is so common amongst men in the field." Further by thus aiming at the bottom of the objective the gerbe is lowered, and the enemy as he advances, plunges himself more deeply into the rain of bullets, instead of getting out of it, as he would, if aim had been taken in the centre of the object fired at.

To sum up, aim in individual firing should always be directed at the foot of the object for the following reasons:—

"a." That the intervening space swept by the gerbe is lengthened.

"b." That the evil arising from the use of a full sight is mitigated.

"c." That the ricochets of the lower half of all gerbes up to 600 m. are better utilized.

"d." That tactically it is advantageous.

"c." *The Employment of Fixed Sights.*

It has been shown that for tactical reasons soldiers cannot adjust their sights at the critical moment of the combat, either when they are advancing rapidly on the enemy or he on them. The maximum distance which separates the opposing sides at the commencement of this stage of an action, may be assumed to be about 400 yards (360 m.), therefore a fixed sight or fixed sights are required to sweep this space. The number of sights employed must be limited, one would be best, but two are the most that would fulfil the required conditions. In Germany two are made use of, viz., a 270 m. fixed sight, and a 350 m. easily raised flap sight. An examination of the action of these two sights will be sufficient to prove if the principle of the use of fixed sights is advantageous or not. Unfortunately the question cannot be discussed with reference to our own Martini-Henry rifle, as no accurate data is published, and it is very doubtful if the necessary long-continued experimental firing has ever been carried out.

To aid in the investigation, Tables 8-11 have been calculated in a similar

manner to Tables 4-7; and, in addition, the action of ricochets has been added to Tables 5-7, and embodied in Tables 9-11.

First with regard to the action of the 270 m. sight: if Tables 9-11 be examined it will be seen that the whole of the gerbe proceeding from men firing in the standing position, and aiming at the bottom of a target, will strike a standing man (5' 4" or 1.60 m.) throughout its course up to 270 m.; with the solitary exception that the bullets in its upper trajectory pass 2 inches above a man's breast at 190 m. If the action of ricochets is included, the same tables show that the ground swept by the gerbe may be extended to 300 m.; thus, practically, men firing standing and aiming at the foot of their objective, cover with their fire any standing man up to 300 m. Again, if the ordinates of the gerbe of men firing in the kneeling or lying down position be looked at, it will be seen how much closer the gerbe sweeps to the earth; and as few men in action would be firing otherwise when the enemy was within 300 m. of them, the efficiency of the gerbe is largely increased.

Another point must be taken into account, that is, when aim is taken at any object at a less distance than 270 m., the line of sight is proportionably depressed, and the gerbe in consequence passes closer to the ground.

From all the above it may safely be concluded that the use of the fixed 270 m. sight, combined with aiming low, enables all the ground in front of the firer to be swept up to 300 m.

To cover the remaining space, viz., up to 360 m. or 400 yards, the 350 m. sight will suffice; looking at Tables 5 to 7 it will be seen that with a standing man aiming at the foot of a target the upper trajectory of the 350 m. gerbe at 300 m. is only 1.20 m. above the ground; and that at 360 m., including the action of ricochets, no shots rise higher than 1.06 m.; again, the mean trajectory at 300 m. will strike a kneeling man, and at 360 m. its ricochets only rise 0.06 m. above a man lying down; hence with flap sight of 350 m. all the ground between 300 m., the limit of the action of the 270 m. sight, and 400 yards, is thoroughly swept; and the conclusion is arrived at that two sights, combined with aiming at the foot of the mark, are sufficient to keep all the ground up to 400 yards well under fire.

Incidentally it may be observed that the analysis of the action of these two sights affords a strong argument in favour of reducing the trajectory of the rifle, for if this were flattened one fixed sight would cover all the ground up to 400 yards.

"d." *The Limit of Effective Individual Fire.*

Individual fire has previously been defined as "the fire of individual men when left to their own initiative;" that is to say, it is the fire of skirmishers freed from all directions, therefore free to choose their object, their sight, and to regulate their own consumption of ammunition. Accepting this definition, it becomes necessary to fix some limits within which this fire may be employed, otherwise a serious waste of ammunition would take place. These limits may be theoretical or practical; the first case postulates a very good shot making no mistakes, and knowing the exact distance; the second assumes that two factors, at least, will always militate in the field against attaining the theoretical result, viz., errors in aiming, and errors in estimating distance.

First, with regard to the theoretical limit: if infantry fire against infantry the largest objective is a standing man, 1.60 m. or 5 feet 4 inches high; turning to Table 1, it will be seen that the height of the shot group at 600 m. is 1.58 m., and its width 1.26 m.; this may be taken to represent a group of three men standing side by side; hence a perfect shot, knowing the exact distance, may have a chance of putting 91 per cent. of his shots into these

three men. But if this same man, under similar conditions, were to fire at a standing man at 700 m. nearly a fourth of his shots must pass over the man's head; for the height of the shot group at 700 m. is 2.12 m., whereas the height of a standing man is only 1.60 m. Consequently with regard to firing at infantry the theoretical limit of individual fire may be fixed at 600 m.; provided, that the aim is absolutely correctly taken, that the exact distance is known, and that the objective is not less in size than three men standing side by side. The mere statement of this conclusion is enough to show its eminent unpracticability, and that to let the mass of men fire individually at this distance would lead to an enormous loss of ammunition.

What then is the practical limit for the employment of individual fire in the field? As said before, two factors govern it: errors, in aiming, and in judging distance. Errors in aiming cause either an increase or decrease of angular elevation, and a consequent rise or fall of a bullet on a vertical target, and it has been stated that these errors range from 3 to 6 and up to 12 millimetres in the first metre measured from the muzzle of the rifle: this is equal to angular errors of about 10, 20, 30 minutes, and gives rise to a vertical displacement of:—

0.30 m.	....	0.60 m.	....	1.20 m.	at	100 metres.
1.20 "	....	2.40 "	....	4.80 "	"	400 "
1.50 "	....	3.00 "	....	6.00 "	"	500 "
1.80 "	....	3.60 "	....	7.20 "	"	600 "

But though the vertical displacement increases with the distance, the horizontal decreases; for example, at 200 m. an error of 1 minute gives rise to a horizontal displacement of about 8 m., whereas at 500 m. this is reduced 5 m., and at 1,000 m. to 3 m.

Assuming that under the circumstances of firing at an enemy, the majority of men fire high with the minimum error of 10 minutes, their shots at 400 m. will be raised 1.2 m. above the ground; if to this be added half the height of the shot group at this distance, 0.42 m., the centre of the gerbe will be 1.62 m. high; that is, the mean trajectory will just clear the heads of standing men. Again at 500 m. the mean trajectory will be 2.09 m. above the ground, 0.49 m. above the head of a standing man. Hence on account of inaccuracies in aiming, and the tendency men have to fire high in action, the limit of individual fire from this point of view should be fixed at 400 m.

With regard to errors in estimating distance, taking into account the difficulty of judging distance in action, it is fair to assume that errors of a tenth of the distance up to 300 m., a seventh up to 600 m., and a sixth up to 1,200 m., will be committed. In Table 12, the probable errors in judging distance from 400 m. to 600 m. are compared with the extent of ground swept by the entire gerbe at each distance, assuming that the objective is a standing man, 1.60 m. high. From this table it will be seen that at 400 m., errors in judging distance can cause but few shots to miss, as the zone swept by the entire gerbe is 106 m. in extent, while the probable miscalculation of distance is only 57 m. At 450 m. these spaces are practically equal, and most of the shots will hit the objective; but at 500 m. an error of 21 m. will prevent any shots striking the object; hence from this standpoint the limit of individual fire must be fixed at 450 m.

Taking both the above factors into consideration, the limit of effective individual fire at standing men may be placed at 400 m. or 450 yards for the great majority of men, but a good shot, knowing the exact distance, may be permitted to fire up to 600 m. or 650 yards. The limit of individual fire at kneeling men may from similar calculations be placed at 400 m. or 450 yards for good shots, and at 250 m. or 275 yards for ordinary men; lastly, the limit for individual fire at men lying down may be fixed at 200 yards.

PART II.

COLLECTIVE FIRE.

Before proceeding to an examination of the action of collective fire, it is well again to point out, that the limits for individual fire laid down in the first part of this paper apply solely to the Mauser rifle: a rifle with a lower trajectory would have a flattened gerbe, with diminished transverse section, and hence the limit for its employment in individual firing would extend beyond that fixed for the Mauser; still, at the same time, the principles on which these limits are fixed remain the same in both cases. Similarly, in the following discussion, the action of the Mauser rifle will alone be under review, but the principles which underlie its usefulness in collective firing will apply to any other rifle; hence the study becomes useful as a clue to the study of the action of all rifles.

Collective fire, as said before, is "the fire of several men acting together under the orders of a superior," and since at 400 m., the limit of individual fire from the Mauser rifle is reached, the action of collective fire must be studied from 450 m. onwards.

Method of Obtaining a Record of the Result of Collective Fire.

The plan adopted in Germany to obtain a record of the flight of bullets is approximately the same as that in France, Italy, Austria, and England; but, since fuller details of the method of conducting these researches are published in the first-named country, the German plan will be described as a type of how such investigations are generally carried out.

The effects of collective fire have been determined in Germany by means of experiments on a large scale carried out at the Musketry School at Spandau. The experiments extended over a considerable length of time, and were executed by firing a great number of rounds in order to reduce to a minimum all abnormal influences. The men firing were relieved from time to time, and were sent to Spandau from their regiments only a few days before taking part in the experiments; they were second and third class shots, that is, men respectively in their second or first year's service; they were in marching order, and had to make a march of some hours before arriving on the practice ground. The fire was conducted by means of volleys fired by men lying down using rests, and at targets 1·80 m. (6 feet) high and 20 m. (22 yards) wide. The number of men firing varied from 10 to 50, as a rule 25 were employed; the number, experiments have shown, has hardly any influence on the results, provided there are at least 10 men firing. The men were extended over 20 m., a space equal to the extent of the target, and were ordered to aim straight to their front and at the bottom of the first target of the series.

Care was taken to choose a flat surface parallel to the line of sight, on which to place the targets, thus the tops of all the targets of the series were practically level. The targets were made of some slight material covered with paper, and stretched on easily movable frames. They were arranged in column, and were separated by distances deduced from the total theoretical length of the dangerous zone, in such a manner that a bullet which grazed the top of one target struck the bottom of the target next behind it; under these conditions, each bullet theoretically left but one mark on the entire series of targets. The intervals between the targets are shown in Table 13, which is a copy of Appendix L of the German Musketry Instructions of 15th November, 1877. In order that all the shots should be registered, the targets had a depth of 150 to 200 m. when a single sight was used, and a depth of 300 to 400 m. when two sights, with a difference of 100 m. between them were employed. For example, with the line of sight of 600 m., the

targets were placed at 535, 586, 629, 669, and 700 m., thus having a depth of 165 m.

When the firing was concluded the number of hits were counted to verify that each bullet had left but one mark of its passage; then the position of the hits on each target were taken off, and from this vertical record the horizontal representation of the graze of each bullet was calculated.

General Results of Collective Fire.

Such is the method by which the data for the examination of the action of collective fire was obtained in Germany. The results, broadly speaking, are that the hits spread remarkably evenly over a space lengthened in the direction of the line of fire and depending for breadth on the extension of front given to the fire. A nucleus shown by a slightly denser grouping of the hits, appears towards the centre of the surface struck; the hits outwards to the periphery becoming more and more scattered. The regularity with which the hits are distributed is due to the reciprocal action of the different influences which tend to make the bullets spread, and it is to this reciprocal action that the great value and great certainty of collective fire is due. The longitudinal dispersion remains nearly constant at all distances, and up to 1,400 m. it has even a tendency to diminish; this is due as said before to the fact, that the same angular error in elevation has a diminished influence on the range of the bullet in proportion as the distance is increased.

Construction of Tables to show the Result of Collective Fire.

In order to arrive at the value of the experimental firing, the results obtained on a series of targets placed as before described are decomposed, under the supposition that targets 1.80 m. high, and equal in width to the gerbe, are placed at intervals of 10 m. along the entire path of the bullets; then the number of hits which would have struck each of the targets is calculated, and thus the terms of the series required are obtained. For example, in order to find the number of hits in a target at 400 m., it is only necessary to count the number of grazes that lie between its position and that of a parallel target 75 m. in its rear, since the bullets making the grazes must have passed within 6 feet of the ground at 400 m.; the dangerous zone or "margin" of the 400 m. trajectory with reference to a 6 feet target having a depth of 7.5 m.

The target which receives the largest number of hits is called the nucleus of the series.

Table 14 "A" (K_1 No. 1, G.M.I.) gives the destructive effect of a collective fire with a single sight against a series of targets 1.80 m. high and 20 m. wide; that is, against fifty men standing side by side. And also the effect of the same fire on a company column, the men standing; this is obtained by adding the depth of the column to the extent of the dangerous zone and counting the number of grazes which lie in this space.

Table 14 "B" (K_1 No. 2, G.M.I.) gives the destructive effect of a collective fire with a single sight against a series of targets 45 cms. high and 20 m. wide; that is, against fifty men lying down side by side, not under cover; and also the effect of the same fire on a company column lying down, this is obtained in the same way as described above.

Table 15 "A" (No. 3, K_2 , G.M.I.) gives the effect of a collective fire with two sights against a target 1.80 m. high and 20 m. wide, i.e., against fifty men standing side by side.

Table 15 "B" (No. 4, K_2 , G.M.I.) gives the number of men's breadths (0.40 m.) struck by a collective fire with two sights; this is obtained by dividing, in the direction of the line of fire, the horizontal representation of the grazes into bands 0.40 m. wide, and then at each distance counting the

number of bands which in a length equal to the dangerous zone at the distance have one or more grazes on them. For example, at 500 m., when the 500 m. and 600 m. sights are combined thirty-four men's breadths are hit; that is, on each of these men's breadths extending 65 m. (equal to dangerous zone at 500 m.) behind the target, there has been counted one or more grazes, with the same fire at 600 m. forty-one men's breadths are hit.

Observations on the Series obtained from the Use of One Sight.

"a." The length of a series from the first term to the last represents the depth of what is called the "dangerous ground." See Plate XXV, Fig. 4.

"b." In the tables, the sum of any series does not represent the number of bullets that have struck the targets, as the same bullet may traverse several successive screens; for example, the bullet which grazes the top of the screen at 400 m. will pass through the next seven screens, since the margin of the 400 m. trajectory is 75 m., and the screens are arranged at intervals of 10 m. apart.

"c." The position of the nucleus of the shots of a series has been found to be about half the length of the "margin" in front of the target up to 700 m.; this is caused by the aim being taken at the foot of the first target of the series. After 700 m. the position of the nucleus corresponds practically with that of the object fired at; this is due to the shading off of all objects at a distance, and the consequent unconscious tendency of the firer to aim more at the centre of his mark.

The "margins," or dangerous zones of the Mauser rifle, depending on a target 1·80 m. high are as follows:—

75 metres at 400 metres.			17 metres at 1100 metres.		
65	"	500	15	"	1200
48	"	600	13	"	1300
38	"	700	12	"	1400
32	"	800	10	"	1500
25	"	900	9	"	1600
20	"	1000			

The position of the nuclei in front of the target as taken from the tables are:—

35 metres for 400 metres sight.		
30	"	500
21	"	600
18	"	700

By doubling the above numbers and comparing them with the extent of the dangerous zones at the same distances, it will be seen that the position of the nuclei in front of the object aimed at is practically one half of the extent of the dangerous zone.

Distances.	Position of nuclei.	Extent of dangerous zone.
400 metres.	35 metres $\times 2 = 70$ metres.	75 metres.
500 "	30 " $\times 2 = 60$ "	65 "
600 "	21 " $\times 2 = 42$ "	48 "
700 "	18 " $\times 2 = 36$ "	38 "

"d." The terms of the series in the several tables were obtained, as said before, by means of a large number of experiments; consequently the firing of 100 rounds will not give exactly the same results; but the approximation will become closer as the number of rounds fired is increased. At the same time the length of the series will not vary considerably whether the number of rounds fired be either increased or diminished, provided the number is not

reduced below fifty, which is the minimum number required to show clearly the grouping of the hits.

"c." The term "the effective dangerous ground," see Plate XXV, Fig. 4, has been applied to the space contained between the first imaginary screen of a series which has received ten hits, and the last which has received the same number. With the sight of 400 m. when firing at the 180×20 m. target, this ground commences 140 m. in front of the nucleus and ends 70 m. behind it, and hence has an extent of 210 m. In the same manner, with the sights of 500 m. and 600 m. its length is 200 m. and 170 m. respectively. With the 800 m. and the 1,000 m. sight the effective dangerous ground is 110 m. in extent. In the effective dangerous grounds from 400 to 900 m. at least one-tenth of the rounds fired are effective.

The following table extracted from the German Musketry Instruction of 28th September, 1875, is interesting from this point of view.

Table 16.

Sight.	Number of rounds fired.	Depth of effective dangerous ground.	Approximate number of hits	
			At the limits of the effective dangerous ground.	At the nucleus.
Metres.				
400 to 600	100	150	15	50 to 70
700 to 800	100	100	10	30
900 to 1200	200	100	10	30 to 50
1300 to 1600	300	100	10	undetermined.

"f." Errors in judging the distance must not exceed half of the extent of the effective dangerous ground, otherwise only a few scattered shots would hit the mark; thus at 500 m. an error of 100 m. would throw almost all the shots off the object; and as here the probable error in judging the distance would be about 70 m. it would not be advisable to use only one sight unless the distance were approximately known; for this reason the German Instructions state that "beyond 400 m. the employment of a single sight does not promise good results unless the mark is stationary, and there is the time and the means to regulate the fire, and finally unless the configuration of the ground in front is not likely to diminish the effectiveness of the fire." "In all other cases, and especially against moving objects which advance or retire, it is necessary to make use of two or more sights having a difference between them of 100 m."

Observations on the Series obtained from the Use of Two Sights.

"a." The series representing the effect of a collective fire with two sights having a difference of 100 m. between them, have not been determined directly by experiment. Thus to find the terms of the combined series with the 600 m. and 700 m. sights, it is necessary to add to the terms of the series with the 600 m. sight, the terms of the series with the 700 m. sight. Table 17 shows how this is effected.

"b." The effective dangerous ground when two sights are employed has a greater depth than when only one sight is used, and this with an equal consumption of ammunition. For example, if reference be made to Table 17 it will be seen that with one sight, and an expenditure of 200 rounds, this ground

extends from 510 m. with twenty-two hits to 690 m. with ten hits ; that is to say, it has a total depth of 180 m. ; but if 200 rounds are fired with the combination of the 600 and 700 m. sights, then the depth of the effective dangerous ground is extended to 260 m.

The mingling of these two series is graphically shown in Plate XXV, Fig. 4.

In firing with two sights up to 700 m., and with three sights up to 1,200 m., the extent of the ground swept by the bullets is such, that the effects of errors in judging distance, of atmospheric influences, and of those due to the bullets falling on sloping ground, are eliminated ; and thus the shots can be grouped around the objective. Table 18 shows the grouping of shots when the 1,100, 1,200, and 1,300 m. sights are employed together, the effective dangerous ground will be seen to extend uninterruptedly from 1,090 m. to 1,220 m., and thence with three gaps to 1,300 m. The total effective depth may be taken as 130 m., but the probable error in judging distance at 1,200 m. amounts to 180 m. Therefore, since the effective dangerous ground at any range should at least be double the amount of the probable error in judging distance at that range, the firing of 300 rounds under the above conditions would be ineffective so long as the distance from the objective was not accurately known. If twice 300 rounds were fired Table 18 shows that the effective dangerous ground would have a depth of 300 m., extending from 1,040 to 1,340 m., hence under these conditions, if a rough approximation of the distance could be obtained the fire would be effective, but if not known, it would be only partially effective. This reasoning applies, of course, to the Mauser rifle, but given a rifle with a flatter trajectory, causing consequently a greater dispersion of bullets at long ranges, then a combination of three sights would be effective at a considerable distance beyond 1,200 m. The above shows that in long-range firing the amount of ammunition required to produce the required effect must be carefully determined for each case as it arises ; hence the decision as to the employment of this kind of fire must be retained in the hands of the senior Officers of the battalions.

Returning to the discussion of the use of two sights, it has been found that, as a rule, when firing 100 rounds, the number of hits on the screens does vary very much from the number made when only one sight is employed. Table 19 gives the percentage of hits when the 600 and 700 m. sights are used together, and when only the 600 m. sight is employed.

Before proceeding further it is advisable to obtain some idea, by means of experimental data, supplemented by theoretical deductions, of the vertical grouping of the hits, and of the shape of the gerbe in collective firing, in the same manner as the different trajectories were analyzed in individual firing. It will be useful to compare the depth of the ground struck as calculated from the above theoretical conditions, with its actual extent as derived from experimental firing, and thus to bring out the several reciprocal influences which determine the dispersion of the bullets.

The Dimensions of the Shot Groups in Collective Firing.

The factors which govern the size of the shot groups in collective firing are, "a." Differences in the rifles. "b." Errors in aiming.

"a." *Differences in the Rifles.*—If a certain man fire 100 rounds, and make use of ten different Mauser rifles, it has been found that the hits on the target have a greater vertical extension than the major axes of the shot groups as shown in Table 1, which are derived from the firing of the same man with the same rifle. This increase in vertical dispersion is due to differences in the construction of the rifles, and to differences in the treatment it has received while in the soldier's possession. In fact, in spite of the progress made in modern industry, it is impossible to obtain products perfectly identical to each other, and even if this were attainable, the

different usages rifles are subjected to would, after a year or two, create differences which would influence the grouping of the shots on a target. Experience has shown that after the Mauser rifles have been in use two years, an angular error in elevation of 0.333 m. in 100 m. has supervened; therefore in collective firing this addition has to be made to the major axes shown in Table 1. For example, at 300 m. the major axis would be $3 \times .333 + 0.58$ m. (the major axis in individual firing at 300 m.) or 1.58 m.

"b." *Errors in Aiming.*—If several men fire with different rifles it is found that the vertical axis is greater than the one calculated as above, this is due to each man making use of a different amount of foresight; the difference between a full and a fine sight in the Mauser rifle has been found to cause an angular error in elevation of about twenty minutes. But experience has shown that men firing, even when making use of a rest in the lying down position, commit errors in aiming, of thirty minutes, this amount, therefore, must be added to that caused by differences in the rifle. In consequence, in order to obtain the vertical axis of the short group at 400 m., it is necessary to add to the dimensions given in Table 1, viz., 0.84 m., the maximum amount of error due to differences in the rifles, viz., $4 \times .333 = 1.333$ m.; the total 2.17 m. gives the vertical dispersion due to the arm: to this must be added the proximate amount of personal errors in aiming, viz., $4 \times .873 = 3.49$ m. (0.873 m. being the value of the natural tangent of 30 minutes at 100 m.), the grand total $2.17 + 3.49 = 5.66$ is therefore the vertical axis of the shot group in collective fire at 400 m. These calculations are made in Table 20.

There is no need to calculate the breadth of these shot groups, as it is assumed that the front under fire depends on the extension given to the troops firing.

In Table 20 is also given the mean trajectory of the 1,600 m. sight extracted from Table G., G.M.I., and from this is calculated the upper and lower trajectory of the 1,600 m. gerbe by means of the addition to, or subtraction from it, of half the height of the shot groups at the several distances as shown in column 5 of the same table. In a similar manner the trajectories of the gerbes of all the lines of sight from 400 m. to 1,500 m. can be calculated.

The Depth of the Ground struck and of the Dangerous Ground as obtained by Calculation, compared with the Results derived from Experimental Firing.

The distinction between the terms dangerous zone and dangerous ground will be more clearly understood if reference is made to Diagram 5; in which the track of a gerbe, from its lower edge first touching a 6-foot target to its upper trajectory meeting the ground, is clearly indicated. This diagram, with regard to the "zone swept by the entire gerbe," applies chiefly to individual fire as beyond 600 m., the height of the shot groups exceeds that of the target.

Looking at Plate XXV, Fig. 5, and imagining that the line T_1G_1 is a straight line, then the angle T_1G_1T represents the angle of the drop of the bullet; and since T_1T equals half the depth of the gerbe at the extreme range of the sight used, and TG_1 equals half the extent of the ground struck: then the extent of the ground struck is equal to the vertical height of the shot group, corresponding to the distance of the sight employed, divided by the tangent of the angle of the drop at the same distance. For example, with the 900-m. gerbe the vertical height of the shot group at this distance is from Table 20, 14.63 m.; the angle of drop is $4^\circ 20'$, and its tangent is .07578, consequently the extent of ground struck is $\frac{14.63}{.07578}$, or 193 m.

In Table 21 these calculations are made for all distances between 400 and 1,400 m.

If to the length of the ground struck is added the depth of the dangerous

zone, the extent of the dangerous ground is obtained. The depths of these "dangerous grounds" thus calculated are inserted in column 6 of Table 21, and by their side, in column 7, are placed the extent of the several dangerous grounds extracted from Table 14, "A," and obtained from direct experiment. The small differences which exist between the results obtained by either method, prove the correctness of the considerations which have formed the basis of the calculations. The mean depth of the dangerous ground as obtained by calculation is 226.8 m., and 228 m. as obtained from experimental firing, the average difference between these amounts being only 1.40 m.

The Reciprocal Action of the Causes which produce the Dispersion of the Shots.

If Table 20 be examined it will be seen that up to 1,000 m. the vertical dispersion due to errors in aiming exceeds the vertical dispersion due to the Mauser rifle, and that from 1,000 m. to 1,600 m. the reverse takes place. This shows that in estimating the value of different rifles it is not only necessary to compare the flatness of their trajectories and the accuracy of their shooting, but it is also necessary to compare the extent of the spread of the bullets when a dozen or more different rifles of the same pattern are made use of in collective fire. The pattern of rifle which, under these circumstances, gives rise to a denser and a more regular grouping of hits will be the best, and have the most destructive effect in the field. There is no method more searching for testing the value of different patterns of rifles than the rigid comparison of the series of terms obtained from long-continued collective firing.

Modification in the Series when the Conditions of the Firing are changed.

If the men, though still firing from a rest, are less skilful, and make errors in elevation in excess of 30', the series will be lengthened, and the shots in the nucleus and in the adjoining screens will be less dense, and, further, the series will be less regular in character. By employing men still less skilful in firing all these irregularities will be accentuated, and it may happen that gaps will appear in the series in the neighbourhood of the distance corresponding to the sight in use.

When the firing takes place without rests the series is much lengthened and becomes irregular; the destructive effect of the gerbe ceasing in some places. These gaps are more numerous and nearer the distance corresponding to the sight in use in proportion as the inaccuracy of the firing increases. This proves the incorrectness of the statement, that collective fire is the negation of all musketry instruction. On the contrary, representative series show, by the modifications they undergo when deduced from the firing of bad shots, that the drilling and careful instruction of the soldier carries as much weight and has as much influence on collective fire as it has on individual fire. The skill of the firers is so much the greater as the record of their shooting gives a more regular, more continuous, and denser series. From this it follows that the collective fire of several men at a single target at distances over 400 m. is not the true gauge of their efficiency. It is necessary that they fire at a series of screens, which will register all the hits; then from their density an estimate of the value of their shooting can be obtained. The position of the nucleus offers no clue, as it does not depend on the efforts of the men, but on factors beyond their control.

Atmospheric conditions have their influence on firing; thus, temperature lower than 3° C. (the sight of the Mauser rifle is adjusted to 2.5° C.) would cause the series to be less dense than the normal one, while the series would become denser if the temperature rose above 3°; not taking into account, of course, the hygrometric state of the air. An atmosphere more or less warm has the effect of advancing or retreating a whole series with reference to its normal position. Between -3° and +3° a fall of one degree displaces the

series towards the firing point; about 4 m. at 100 m., 8 m. between 200 and 300 m., and 12 m. between 400 and 1,200 m. On the other hand, each rise of one degree between 3° and 16° removes the series further back: 2 m. between 0 and 300 m., and 4 m. between 400 and 1,200 m.

The deviations in the range of the bullets, due to the influence of temperature, are similar to the deviations due to errors in aiming, nearly constant, and diminish instead of increasing at distances beyond 1,200 m. The hygrometric state of the air sometimes counterbalances this increase of range, as it has been found that, when the ground is much heated by the sun, the most densely saturated layer of air is at a certain distance above the ground; and, consequently, acts as a retarding force more powerfully on the high trajectories than on the lower ones. With a temperature of 15° C. (58.5° F.) the shot groups of the Mauser rifle will be displaced 48 m. away from the firing point, if the firing is at 400 yards. But as at this distance aiming at the foot of the target has the effect of bringing the nucleus 35 m. towards the firing point, the deviation in range caused by an elevation in temperature, approximating to the mean temperature of Central Europe, is compensated up to 700 m. by the practice of aiming at the foot of an object.

Modifications caused in the Series by the Ground on which the Objective rests, rising or falling with reference to the Line of Sight.

The next point to consider is, how the dispersion of the bullets is affected by the slope of the ground on which they fall. Mathematical proof need not be given to show that when ground rises with reference to the line of sight, the extent of the ground struck is diminished, and that the contrary takes place when the ground falls; nor to prove the corollary that the density of the hits is increased in the first case and diminished in the second.

Still the length of the dangerous ground under all circumstances requires to be known, and therefore the following calculations must be made:—Let G represent the vertical axis of the shot group in collective firing at any selected distance, α the angle of the normal drop of the bullet at this same distance, and α' the angle of the actual drop of the bullet on a surface inclined with reference to the line of sight; let x equal the interval which must exist between the terms of the new series—bearing in mind that the intervals in the normal series are 10 metres—and n represent the number of terms in each series; then, since the extent of the dangerous ground is equal to the depth of the ground struck, added to the depth of the dangerous zone, the following equations are arrived at:—

$$10n = \frac{G}{\tan \alpha} + \frac{1.8^{\circ}}{\tan \alpha} = \frac{G + 1.8^{\circ}}{\tan \alpha}$$

$$nx = \frac{G}{\tan \alpha'} + \frac{1.8^{\circ}}{\tan \alpha'} = \frac{G + 1.8^{\circ}}{\tan \alpha'}$$

for $\frac{G}{\tan \alpha}$ and $\frac{G}{\tan \alpha'}$ represent the ground struck

and $\frac{1.8^{\circ}}{\tan \alpha}$ and $\frac{1.8^{\circ}}{\tan \alpha'}$, the extent of the dangerous zone.

$$\text{then } \frac{x}{10} = \frac{\tan \alpha}{\tan \alpha'} \text{ and } x = \frac{10 \tan \alpha}{\tan \alpha'}$$

Substituting the value of x for the 10 m. in the normal series and multiplying by the number of terms in the same series, the extent of the dangerous

ground can be obtained for all slopes and at all distances. The preceding calculations must not be thought to be applicable on the field of battle where tactical considerations are dominant, but still they serve their purpose by pointing out how the slopes of ground affect the destructive action of collective fire, and from this information serviceable tactical rules can be deduced.

In Table 22 the reduction in length of the normal 10 m. intervals are shown for distances between 400 and 1,600 m., and when the ground rises respectively 3°, 5°, or 10°. The following examples will show how the calculations have been made.

Example.—Find the length of the interval which separates the different terms of the 400 m. line of sight when firing at an object on an ascending slope of 3°.

In Appendix G, G.M.I. of 1877, the normal angle of the drop of a bullet at 400 m. is stated to be 1° 8' 16"; for all practical purposes 1° 10' is sufficiently near. The actual angle of the drop of a bullet when the ground on which the bullet falls rises with reference to the line of sight is equal to the normal angle of drop added to the angle which the slope of the ground makes with the line of sight; and when the ground falls, to the normal angle of drop diminished by the angle formed by the slope of the ground and the line of sight. Applying the above data and calling x the reduced interval required, we have from the preceding equation—

$$\frac{x}{10} = \frac{\tan 1^{\circ} 10'}{\tan 4^{\circ} 10'} = \frac{.02037}{.07286}$$

$$\text{and } x = \frac{.2037}{.07286} = 3 \text{ m.}$$

If Table 22 be examined, it will be seen that when firing at an object on an ascending slope, the normal extent of the dangerous ground, and in consequence the extent of the ground struck by all the bullets in the gerbe, is diminished by one-half; at 800 m., when the slope is 5°, at 1,000 m. when the slope is 5°, and at 1,500 m. when it is 10°.

Depth of the Effective Dangerous Ground when the Surface on which the Bullets fall is not parallel to the Line of Sight.

It has been said before that when the value of the interval of a series derived from collective fire at an object on a slope has been obtained, it is easy to calculate the corresponding extent of the effective dangerous ground, but an example may make this clearer.

Example.—Find the length of the dangerous ground at 600 m. when the ground which receives the bullets makes an ascending angle of 5° with the line of sight. Referring to Table 14, "A," it will be seen that the extent of the normal effective dangerous ground with the 600 m. sight is 170 m., and that it contains seventeen terms. Looking at Table 22, the length of each term of the series with the 600 m. sight, when employed against a slope of 5°, will be found to be 3 m.; consequently the effective dangerous ground is 17 × 3 or 51 m.; thus the effect of firing against a slope of 5° is at 700 m. to reduce the effective dangerous ground from 170 m. to 51 m.

Table 23 contrasts the extent of the effective dangerous ground when fire is directed on an ascending slope with its extent when the fire takes place on a plane. It may be observed that the mean length of the effective dangerous ground at distances between 400 m. and 1,400 m. is 134 m., and that for the slopes of 3°, 5°, 10°, its mean length is reduced respectively to 70, 54, and 30 m.; in other words, when fire is directed at ascending slopes forming angles of 3°, 5°, or 10° with the line of sight, the effective dangerous ground is approximately one-half, one-third, or one-fourth the length of the effective dangerous

ground under normal circumstances ; and, similarly, when the bullets fall on descending slopes, making angles of 3° , 5° , or 10° with the line of sight, the extent of the effective dangerous ground is approximately double, treble, or quadruple the length of the normal effective dangerous ground.

Tactical Considerations.

Before concluding it may be pointed out how the foregoing study may be utilized with reference to tactical questions ; for instance, the length of the dangerous ground in the different series serves to determine the distances which should separate the different *échelons* during an attack or when on the defensive. It is clear that the placing two lines under the influence of same *gerbe* is to be avoided whenever it is possible ; but since the extent of the dangerous ground increases the nearer the enemy is approached, the paradox is arrived at, that the nearer the front line is to the enemy the further the supports should be from it. This difficulty is met by placing as many rifles as possible in the front line of the attack from its very commencement, and by keeping the supports about 500 yards in rear, and thus clear of the fire directed at the front line. Under these circumstances, the strong front line would be able to push rapidly and energetically forward until checked by some serious opposition. During this halt, and while preparing for a further advance by trying to dominate the enemy's fire, the front line would be strong enough, if a counter-attack were made, to hold it in check sufficiently long to give time for the supports to come up. The supports, if not thus required, would remain outside the influence of the fire aimed at the front line until the losses in it necessitated its being reinforced.

Again, a study of the series helps to show the relative amount of losses due to different formations at different periods of an action. Thus in the German Musketry Instructions it is stated, that a standing company column up to 700 m. suffers little more loss than a line, but beyond this distance, and up to 1,600 m., its losses are more than double those of a line ; while a company column lying down must expect losses double or treble those of a line lying down.

A consideration of the data connected with the influence of slopes on the dispersion of bullets, leads to the conclusion, that when the ground on which the objective rests, makes an ascending angle of over 3° with the line of sight, it is advisable to make use of a combination of two sights, and to employ three sights, if the slopes be steeper still. Whereas, if the ground slopes away from the line of sight, one sight only should be made use of.

The study of the blending of *gerbes* when two or more sights are made use of leads to the impression that a single line of men cannot give full effect to the deadly power of long-ranging rifle-fire ; hence arises the idea of double tier fire, or the firing of one line of men over the heads of another line at the same object : possibly to be realized on the defensive on some prominent spur commanding and flanking the enemy's line of approach ; possibly, if time admits, in a skilful arrangement of shelter trenches, and, lastly, to be carried out in earthworks intended to act as supports in a position, or as an outer line of defence around some important village or town.

Before quitting this part of the subject a few words must be said as to the method of employing collective fire in the field. Looking at its mode of action, viz., the simultaneous discharge of many rifles at the same object, its effect may be likened to that of a blow ; hence, like a blow, it must be delivered with rapidity ; the number of rounds allotted to it must be discharged at the same time ; a pause would then take place, the smoke would be allowed to clear off, the men's nerves would become steadied, and then, if required, another blow could be struck ; or, a certain number of blows might be given rapidly, one after the other. The suddenness with which such fire

would be delivered, and its intermittent nature, would have a moral effect on the enemy ; it would create a feeling of suspense, and prevent the nerves of the men getting accustomed to the ping of the bullets. Further, as collective fire should not be carried out by a less number of men than 100, its employment, as a rule, should be directed by a battalion commander ; and in his hands it is probable that no waste of ammunition would be permitted, as the objective would be well selected, its distance fairly estimated, and the result of the fire carefully studied.

Conclusion.

Having travelled over many paths, branching one from the other, it may be well, in conclusion, briefly to summarize what are the salient features connected with the combination of two or more sights in collective fire. The advantages claimed for this system of firing at all distances beyond the limits of individual fire, fixed at 400 m. for the Mauser rifle, are—that it counterbalances the loss of effect in rifle-fire due to moving objectives, errors in judging distances, deviations caused by atmospheric influences, and the shortening of the dangerous ground resulting from the surface on which the bullets fall not being parallel to the line of sight. The mere statement of these facts brings at once to mind the number of situations in war where the employment of this kind of fire would have a marked influence on the fortunes of the day ; and no more important tactical problem awaits the test of practical experience than that of how best to utilize collective fire on the field. The plan must be thought out in peace-time, and practised in war ; not to make use of the full power of the infantry rifle is like asking a man to defend himself with one hand tied behind his back. Whatever power is latent in rifle-fire must be drawn out, and no impediment should be placed in the way of obtaining the necessary data on which to formulate a decision.

And now, at the conclusion of this paper, as at its commencement, my indebtedness to the articles in the "*Revue Militaire de l'Etranger*," on the German Musketry Instructions, must again be acknowledged ; tables have been bodily extracted from them, entire paragraphs have been copiously used, and arguments and deductions freely borrowed. Thus my paper lays no claim to originality, but is merely a critical collection and arrangement of data connected with rifle-fire ; useful perchance at this time, when all Officers are studying the theory as well as the practice of musketry.

Table 1.

Dimensions of the shot groups of the Mauser rifle.

Distances.	Major-axis.	Minor-axis.	Per cent. of abnormal hits deducted from those taken off.	Remarks,
m.	m.	m.	per cent.	
100	0·16	0·16	1	
150	0·24	0·24	2	The size of a man's head.
200	0·34	0·32	3	
250	0·44	0·40	4	The breadth of a man.
300	0·58	0·48	5	A little broader than a man.
350	0·68	0·58	6	
400	0·84	0·68	7	
500	1·18	0·96	8	A little broader than a group of two men.
600	1·58	1·26	9	The height of a 5 ft. 3 in. standing man.
700	2·12	1·68	10	
800	2·80	2·12	11	
900	3·78	2·64	12	More than twice the height and six times the breadth of a standing man.
1000	4·74	3·24	13	
1100	6·06	3·88	14	
1200	7·60	4·60	15	
1300	9·64	5·34	16	
1400	12·12	6·12	17	
1500	15·12	6·96	18	It is necessary to place eight targets 1·8 m. high and 6·9 m. wide at 10 m. from each other in order to intercept 82 per cent. of the hits.
1600	18·72	78·6	19	It is necessary to place ten targets 1·80 m. high and 7·86 m. wide at 9 m. apart in order to intercept 81 per cent. of the hits.

Ordinates in metres of the mean trajectory of the Mauser rifle, pattern 1871, above or below the horizontal line of sight, and at distances in metres of—

Sights.	Ordinates in metres of the mean trajectory of the Mauser rifle, pattern 1871, above or below the horizontal line of sight, and at distances in metres of—																
	25	50	75	100	125	150	175	200	225	250	270	300	325	350	375	400	425
Fixed 270 m. }	+0·21	+0·39	+0·53	+0·62	+0·68	+0·69	+0·65	+0·55	+0·40	+0·19	±0	-0·42	-0·83	-1·30	—	—	—
Flap 350 m. }	+0·30	+0·57	+0·80	+1·00	+1·14	+1·25	+1·29	+1·29	+1·24	+1·12	+0·94	+0·70	+0·39	±0	-0·16	-0·99	—
400 m. ..	+0·37	+0·70	+0·99	+1·24	+1·46	+1·62	+1·73	+1·79	+1·80	+1·74	+1·63	+1·44	+1·19	+0·87	+0·47	±0	-0·55

Table 3.

Ordinates of the upper and lower trajectories of the 350 m. gerbe above a horizontal plane, or one sensibly parallel to the line of sight, according as the firer is standing, kneeling, or lying down, and aim taken at the foot or centre of the target at the several distances named below.

Distances.	Upper trajectory.		Lower trajectory.	
	Foot of the target.	Centre of the target.	Foot of the target.	Centre of the target.
Metres.	m. c.	m. c.	m. c.	m. c.
50.....	0 61	1 51	0 53	1 43
100.....	1 08	1 93	0 92	1 82
150.....	1 37	2 20	1 13	2 03
200.....	1 46	2 36	1 12	2 02
250.....	1 34	2 24	0 90	1 80
300.....	0 99	1 89	0 41	1 31
350.....	0 34	1 24	0 34	0 56

Table 4.

Ordinates, at intervals of 50 m. above a horizontal plane, of the 350 m. line of sight, according as the firer is standing, kneeling, or lying down, and aim taken at the foot or centre of the target.

Distances corresponding to the ordinates.	Aim directed at the foot of target at 350 m.			Aim directed at the centre of a target at 350 m.		
	Firing.			Firing.		
	Standing.	Kneeling.	Lying down.	Standing.	Kneeling.	Lying down.
Metres. ..	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.
50.....	1 50	0 90	0 30	1 50	0 90	0 30
100.....	1 23	0 77	0 25	1 40	0 90	0 38
150.....	1 07	0 64	0 21	1 32	0 90	0 47
200.....	0 85	0 51	0 17	1 24	0 90	0 55
250.....	0 64	0 38	0 12	1 14	0 90	0 64
300.....	0 42	0 25	0 08	1 06	0 90	0 73
350.....	0 21	0 12	0 04	0 98	0 90	0 81
350.....	..	..	..	0 90	0 90	0 90

Table 5.

Ordinates, at intervals of 50 m. above a horizontal plane, of the mean trajectory of the 350 m. gerbe, according as the firer is standing, kneeling, or lying down, and aim taken at the foot or centre of target.					
Distances corresponding to the ordinates.	Aim directed at the foot of a target at 350 m.			Aim directed at the centre of a target at 350 m.	
	Firing.			Firing.	
	Standing.	Kneeling.	Lying down.	Standing.	Kneeling.
Mètres.	m. c.	m. c.	m. c.	m. c.	m. c.
..	1 50	0 90	0 30	1 50	0 90
50	1 85	1 34	0 82	1 97	1 47
100	2 07	1 64	1 21	2 32	1 90
150	2 10	1 76	1 42	2 49	2 15
200	1 93	1 67	1 41	2 43	2 19
250	1 54	1 37	1 20	2 20	2 02
300	0 91	0 82	0 74	1 68	1 60
350	..	..	..	0 90	0 90
360	..	..	..	..	..
380	..	..	..	..	..
400	..	..	..	..	..

Table 6.

Distances corresponding to the ordinates.	Ordinates, at intervals of 50 m. and above a horizontal plane, of the upper trajectory of the 350 m. gerbe, according as the firer is standing, kneeling, or lying down, and aim taken at the foot or centre of the target.						Ordinates of ricochets proceeding from the upper trajectory of the 350 m. gerbe.					
	Aim directed at the foot of a target at 350 m.			Aim directed at the centre of a target at 350 m.			Aim directed at the foot of a target at 350 m.			Aim directed at the foot of a target at 350 m.		
	Firing.			Firing.			Firing.			Firing.		
	Standing.	Kneeling.	Lying down.	Standing.	Kneeling.	Lying down.	Standing.	Kneeling.	Lying down.	Standing.	Kneeling.	Lying down.
Metres.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.
..	1 50	0 90	0 30	1 50	0 90	0 30	1 50	0 90	0 30			
50	1 89	1 38	0 86	2 01	1 51	0 99	2 01	1 51	0 99			
100	2 15	1 72	1 29	2 40	1 98	1 55	2 40	1 98	1 55			
150	2 22	1 88	1 54	2 61	2 27	1 92	2 61	2 27	1 92			
200	2 10	1 84	1 58	2 60	2 36	2 10	2 60	2 36	2 10			
250	1 76	1 59	1 42	2 42	2 24	2 07	2 42	2 24	2 07			
300	1 20	1 11	1 03	1 97	1 89	1 80	1 97	1 89	1 80			
350	0 34	0 34	0 34	1 24	1 24	1 24	1 24	1 24	1 24			
360	0 17	0 18	0 18	..	..	..	..	..	..			
380	..	..	..	..	..	..	..	..	..	0 34	0 24	0 16
400	..	..	..	..	..	..	..	..	..	1 02	0 86	0 36

Table 7.

THE UTILIZATION OF RIFLE FIRE IN THE FIELD.

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Distances corresponding to the ordinates.	Ordinates, at intervals of 50 m. and above a horizontal plane, of the lower trajectory of the 350 m. gerbo, according as the firer is standing, kneeling, or lying down, and aim taken at the foot or centre of the target.						Ordinates of ricochets proceeding from the lower trajectory of the 350 m. gerbo.		
	Aim directed at the foot of a target at 350 m.			Aim directed at the centre of a target at 350 m.			Aim directed at the foot of a target at 350 m.		
	Firing.			Firing.			Firing.		
	Standing.	Kneeling.	Lying down.	Standing.	Kneeling.	Lying down.	Standing.	Kneeling.	Lying down.
Metres.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.
50	1 81	1 30	0 78	1 93	1 43	0 91			
100	1 99	1 56	1 13	2 24	1 82	1 39			
150	1 98	1 54	1 30	2 37	2 03	1 68			
200	1 76	1 50	1 24	2 26	2 02	1 76			
250	1 32	1 15	0 98	1 98	1 80	1 63			
300	0 62	0 53	0 45	1 39	1 31	1 22			
350	-0 34	-0 34	-0 34	0 56	0 56	0 56	0 68	0 68	0 68
360	..	..	..	..	..	..	1 06	1 02	0 99
380	..	..	..	..	..	..	1 81	1 70	1 61
400	..	..	..	..	..	..	2 57	2 38	2 22

Table 8.

Ordinates, at intervals of 50 m. and above a horizontal plane, of the 270 m. line of sight, according as the firer is standing, kneeling, or lying down, and aim taken at the foot or centre of the target.

Distances corresponding to the ordinates.	Aim directed at the foot of a target at 270 m.			Aim directed at the centre of a target at 270 m.		
	Firing.			Firing.		
	Standing.	Kneeling.	Lying down.	Standing.	Kneeling.	Lying down.
Metres.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.
..	1 50	0 90	0 30	1 50	0 90	0 30
50	1 22	0 73	0 24	1 39	0 90	0 42
100	0 95	0 57	0 19	1 28	0 90	0 53
150	0 67	0 40	0 13	1 17	0 90	0 64
200	0 39	0 23	0 08	1 06	0 90	0 75
250	0 11	0 07	0 02	0 94	0 90	0 87
270	..	..	..	0 90	0 90	0 90

Table 9.

Distances corresponding to the ordinates.	Ordinates, at intervals of 50 m. and above a horizontal plane, of the mean trajectory of 270 m. gerbo, according as the firer is standing, kneeling, or lying down, and aim taken at the foot or centre of the target.						Ordinates of ricochets proceeding from the mean trajectory of the 270 m. gerbo.					
	Aim directed at the foot of a target at 270 m.			Aim directed at the centre of a target at 270 m.			Aim directed at the foot of a target at 270 m.					
	Firing.			Firing.			Firing.					
	Standing.	Kneeling.	Lying down.	Standing.	Kneeling.	Lying down.	Standing.	Kneeling.	Lying down.	Standing.	Kneeling.	Lying down.
Metres.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.
50	1 51	1 12	0 63	1 78	1 29	0 81	1 50	0 90	0 30			
100	1 57	1 19	0 81	1 90	1 52	1 15	1 50	0 90	0 30			
150	1 36	1 09	0 82	1 86	1 59	1 33	1 50	0 90	0 30			
200	0 94	0 78	0 63	1 61	1 45	1 30	1 50	0 90	0 30			
250	0 30	0 26	0 21	1 13	1 09	1 06	1 50	0 90	0 30			
270	..	..	..	0 90	0 90	0 90	1 50	0 90	0 30	0 90	0 78	0 63
300	..	..	..	..	..	..	1 50	0 90	0 30	1 80	1 56	1 26
330	..	..	..	..	..	..	1 50	0 90	0 30	1 80	1 56	1 26

Table 10.

Distances corresponding to the ordinates.	Ordinates, at intervals of 50 m. and above a horizontal plane, of the upper trajectory of the 270 m. gerbe, according as the firer is standing, kneeling, or lying down, and aim taken at the foot or centre of the target.						Ordinates of ricochets proceeding from the upper trajectory of the 270 m. gerbe.					
	Aim directed at the foot of a target at 270 m.			Aim directed at the centre of a target at 270 m.			Aim directed at the foot of a target at 270 m.					
	Firing.			Firing.			Firing.					
	Standing.	Kneeling.	Lying down.	Standing.	Kneeling.	Lying down.	Standing.	Kneeling.	Lying down.	Standing.	Kneeling.	Lying down.
Metres.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.
50	1 50	0 90	0 30	1 50	0 90	0 30	1 82	1 33	0 85			
100	1 55	1 16	0 67	1 82	1 33	0 85	1 98	1 60	1 23			
150	1 65	1 27	0 89	1 98	1 60	1 23	1 98	1 71	1 45			
200	1 48	1 21	0 94	1 98	1 60	1 23	1 78	1 62	1 47			
250	1 11	0 95	0 80	1 78	1 62	1 47	1 35	1 31	1 28			
270	0 52	0 48	0 43	1 35	1 31	1 28	1 15	1 15	1 15			
300	0 23	0 25	0 25	1 15	1 15	1 15	..	..	..	0 32	0 18	0 04
330	..	..	..	..	..	..	..	..	..	1 15	0 87	0 57

Table 11.

Distances corresponding to the ordinates.	Ordinates, at intervals of 50 m. and above a horizontal plane, of the lower trajectory of the 270 m. gerbo, according as the firer is standing, kneeling, or lying down, and aim taken at the foot or centre of the target.									
	Aim directed at the foot of a target at 270 m.					Aim directed at the centre of a target at 270 m.				
	Firing.					Firing.				
	Standing.	Kneeling.	Lying down.	Standing.	Lying down.	Standing.	Kneeling.	Lying down.	Standing.	Lying down.
Metres.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.	m. c.
50	1 50	0 90	0 30	1 50	0 90	1 74	1 25	0 30	0 50	0 50
100	1 47	1 08	0 59	1 82	1 44	1 74	1 28	0 84	1 50	1 29
150	1 49	1 11	0 73	1 82	1 44	1 74	1 28	0 84	2 50	2 08
200	1 24	0 97	0 70	1 74	1 47	1 44	0 87	0 65	2 50	2 08
250	0 77	0 61	0 46	1 44	1 13	0 91	0 65	0 65	2 50	2 08
300	0 08	0 04	-0 01	0 91	0 84	0 65	0 65	0 65	2 50	2 08
330	-0 25	-0 25	-0 25	0 65	0 65	0 65	0 65	0 65	2 50	2 08
	..	..	..	..	..	..	..	..	2 50	2 08
	..	..	..	..	..	..	..	..	2 50	2 08

Table 12.

An approximate comparison between the zone swept by the entire gerbe and the probable errors made in judging distance in the field.

Distances.	Zone swept by entire gerbe.	Probable error in judging distance.
Metres.	Metres.	Metres.
400.....	106	57
450.....	62	64
500.....	21	71
600.....	5	85

Table 13.

Intervals between the experimental targets deduced from the theoretical dangerous zones or "margins."

Number of the target.	Distance from the firing-point.	Number of the target.	Distance from the firing-point.	Number of the target.	Distance from the firing-point.	Number of the target.	Distance from the firing-point.
1	Metres. 300	20	Metres. 1015·4	39	Metres. 1313·3	58	Metres. 1526·4
2	400	21	1034·4	40	1362·2	59	1536·3
3	475	22	1052·9	41	1338·9	60	1546·1
4	535	23	1070·9	42	1351·4	61	1555·8
5	555·8	24	1088·4	43	1363·7	62	1565·5
6	629·1	25	1105·9	44	1375·7	63	1575·2
7	669·1	26	1122·9	45	1387·5	64	1584·8
8	706·1	27	1139·5	46	1399·2	65	1594·3
9	742·1	28	1155·7	47	1410·7	66	1603·8
10	775·6	29	1171·5	48	1422	67	1613·3
11	806·1	30	1186·9	49	1433·1	68	1622·7
12	834·5	31	1201·9	50	1444·2	69	1632
13	860·3	32	1216·7	51	1455	70	1641·3
14	884·5	33	1231·2	52	1465·6	71	1650·6
15	908·7	34	1245·5	53	1476·1	72	1659·8
16	931·8	35	1259·5	54	1486·4	73	1668·9
17	953·9	36	1273·3	55	1496·6	74	1677·9
18	975	37	1286·9	56	1506·6	75	1686·8
19	996	38	1300·2	57	1516·5		

Table 17.

Series with a combination of two sights.							Remarks.
Distances.	Series in the German Musketry Instructions.			Series carried 20 m. towards firing point. ¹			
	600 m. sight.	700 m. sight.	Combined 600 and 700 m. sights.	600 m. sight.	700 m. sight.	Combined 600 and 700 m. sights.	
Metres.	100 rds.	100 rds.	200 rds.	100 rds.	100 rds.	200 rds.	The parts of the series printed in large figures represent the effective dangerous zones, in which 10 or more hits are counted on each screen. ¹ True position of the series, see remarks in para. "C" in "Observations on the series obtained from the use of one sight."
440	..	..	..	..	..	..	
450	..	..	..	1	..	1	
460	..	..	..	4	..	4	
470	1	..	1	4	..	4	
480	4	..	4	4	..	4	
490	4	..	4	11	..	11	
500	4	..	4	17	..	17	
510	11	..	11	21	..	21	
520	17	..	17	23	..	23	
530	21	..	21	25	..	25	
540	23	..	23	35	..	35	
550	25	..	25	49	..	49	
560	35	..	35	48	..	48	
570	49	..	49	49	..	49	
580	48	..	48	52	3	55	
590	49	..	49	51	4	55	
600	52	3	55	47	6	53	
610	51	4	55	34	7	41	
620	47	6	53	31	14	45	
630	34	7	41	24	15	39	
640	31	14	45	24	19	43	
650	24	15	39	16	26	42	
660	24	19	43	11	26	37	
670	16	26	42	5	29	34	
680	11	26	37	3	35	38	
690	5	29	34	..	28	28	
700	3	35	38	1	33	34	
710	..	28	28	2	32	34	
720	1	33	34	2	26	28	
730	2	32	34	2	29	31	
740	2	26	28	1	17	18	
750	2	29	31	..	13	13	
760	1	17	18	..	6	6	
770	..	13	13	..	3	3	
780	..	6	6	..	4	4	
790	..	3	3	..	5	5	
800	..	4	4	..	4	4	
810	..	5	5	..	4	4	
820	..	4	4	..	3	3	
830	..	4	4	..	2	2	
840	..	3	3	..	2	2	
850	..	2	2	..	..	..	
860	..	2	2	..	..	..	
870	..	..	..	..	..	..	

Table 18.

Series with a combination of three sights.

Distances.	1100 m. sight.	1200 m. sight.	1300 m. sight.	Combined 1100, 1200, 1300 m. sights.	Combined 1100, 1200, 1300 m. sights.	Remarks.
Metres.	100 rounds.	100 rounds.	100 rounds.	300 rounds.	600 rounds.	
990	..	..	..	..	..	Each screen receiving 10 or more hits has its record printed in large figures.
1000	1	..	..	1	2	
1010	3	..	..	3	6	
1020	4	..	..	4	8	
1030	4	..	..	4	8	
1040	6	..	..	6	12	
1050	11	..	..	11	22	
1060	13	..	..	13	26	
1070	9	..	..	9	18	
1080	7	..	..	7	14	
1090	17	..	..	17	34	
1100	18	2	..	20	40	
1110	17	3	..	20	40	
1120	14	..	..	14	28	
1130	12	1	..	13	26	
1140	15	2	..	17	34	
1150	11	2	..	13	26	
1160	5	6	..	11	22	
1170	2	12	..	14	28	
1180	..	13	..	13	26	
1190	2	15	..	17	34	
1200	1	22	3	25	50	
1210	..	14	2	16	32	
1220	..	10	2	12	24	
1230	..	6	1	7	14	
1240	..	7	5	12	24	
1250	..	2	4	6	12	
1260	..	..	6	6	12	
1270	..	1	10	11	22	
1280	..	2	8	10	20	
1290	..	2	8	10	20	
1300	..	1	14	15	30	
1310	..	1	7	8	16	
1320	..	..	10	10	20	
1330	..	..	8	8	16	
1340	..	..	6	6	12	
1350	..	..	3	3	6	
1360	..	..	2	2	4	
1370	..	..	..	..	..	
1380	..	..	1	1	2	
1390	..	..	1	1	2	
1400	..	..	..	..	..	

Table 19.

Percentage of hits with one sight and with two; the distance unknown, and the series not displaced by atmospheric influence.

Real distances. Metres.	Percentage with the--		Remarks.
	600 m. sight.	Combined 600 and 700 m. sights. ¹	
570	49	24.5	It is assumed that the distance has been judged to be 650 m.: the mean error in judging being $\frac{1}{4}$ of the real distance, this may vary between $\frac{650 \times 7}{6}$ and $\frac{650 \times 7}{8}$, that is between 760 and 570 m.
580	52	27.5	
590	51	27.5	
600	47	26.5	
610	34	20.5	
620	31	22.5	It must not be forgotten that the depth of the effective dangerous ground, resulting from the fire of 200 rounds with the combined sights of 600 and 700 m., is 280 m.; while it is only 160 m. with the single 600-m. sight and the same consumption of ammunition.
630	24	19.5	
640	24	21.5	
650	16	21	
660	11	18.5	
670	5	17	
680	3	19	
690	..	14	
700	2	17	
710	1	17	
720	2	14	
730	2	15.5	
740	1	9	
750	..	6.5	
760	..	3	
Total....	355	361.5	
Mean per cent.	17.75	18.07	

¹ The terms of the series have been taken from Table 17; the terms depending on the combination of two sights have been divided by two, to bring them into correspondence with an expenditure of 100 rounds with the single sight.

Table 20.

The vertical axes and the ordinates of the 1600 m. gerbe in collective firing.

Distances.	Extreme vertical dispersion due to differences in 10 samples of the Mauser rifle of recent manufacture.	Vertical axes of the shot groups in individual fire.	Total vertical dispersion due to the rifle.	Vertical dispersion resulting from errors in aiming of 30 minutes.	Vertical axes of the shot groups of the Mauser rifle in collective fire.	Ordinates of the mean trajectory of the 1600 m. sight.	Ordinates in collective fire of the	
							Upper trajectory of the 1600 m. gerbe.	Lower trajectory of the 1600 m. gerbe.
Metres.	Metres.	Metres.	Metres.	Metres.	Metres.	Metres.	Metres.	Metres.
400	1.33	0.84	2.17	3.49	5.66	43.57	46.40	40.74
500	1.66	1.18	2.84	4.36	7.20	51.74	55.34	48.14
600	2.00	1.58	3.58	5.23	8.81	58.43	62.84	54.02
700	2.33	2.12	4.45	6.11	10.56	63.44	68.72	58.16
800	2.66	2.80	5.40	6.98	12.44	66.57	72.79	60.35
900	3.00	3.78	6.78	7.85	14.63	67.62	74.93	60.31
1000	3.33	4.74	8.07	8.73	16.80	66.39	74.79	57.99
1100	3.66	6.06	9.72	9.60	19.32	62.68	72.34	53.02
1200	4.00	7.60	11.60	10.47	22.07	56.29	67.32	45.26
1300	4.33	9.64	13.97	11.34	25.31	47.03	59.68	34.98
1400	4.66	12.12	16.78	12.22	29.00	34.69	49.19	20.19
1500	5.00	15.12	20.12	13.09	33.21	19.08	35.68	2.48
1600	5.33	18.72	24.05	13.96	38.01	..	19.00	-19.00

Table 21.

Comparison between the depth of the dangerous ground as obtained by calculation and from experimental firing.

Distances.	Vertical axis of the shot groups of the Mauser rifle in collective fire.	Tangents of angles of drop.	Depth of the ground struck by all the bullets in the gorge. ¹	Theoretical dangerous zone in individual firing.	Depth of the dangerous ground as obtained	
					From calculation.	From experimental firing, <i>vide</i> Table 14.
Metres.	Metres.	Metres.	Metres.	Metres.	Metres.	Metres.
500	7.20	.02910	240	65	305	300
600	8.21	.03783	232	48	280	290
700	10.56	.04949	213	38	251	260
800	12.44	.06116	203	32	235	230
900	14.63	.07578	193	25	218	220
1000	16.80	.09042	185	20	205	200
1100	19.32	.10510	183	17	200	200
1200	22.07	.12278	179	15	194	210
1300	25.31	.14351	177	13	190	190
1400	29.00	.16435	176	13	188	180
				Totals	2266	2280
				Means	226.6	228

$$^1 \text{ Ground struck} = \frac{\text{Height of shot group}}{\text{Tangent of angle of drop}}$$

Table 22.

Reduction in the normal interval of 10 m. between the screens, due to the ground on which the bullets fall not being parallel to the line of sight.

Sights.	Normal angle of drop.	Tangent of the normal angle of drop.	Tangent of the actual angle of drop when the ground on which the bullets fall, rises with reference to the prolongation of the line of sight.			Reduction in length of the normal 10-m. interval between the screens, when the ground on which the bullets fall, rises with reference to the prolongation of the line of sight		
			3°	5°	10°	3°	5°	10°
Metres.	° ' "					Metres.	Metres.	Metres.
400	1 10	·02037	·07286	·10805	·19740	3·0	2·0	1·1
500	1 40	·02010	·08163	·11688	·20648	3·5	2·4	1·4
600	2 10	·03783	·09042	·12574	·21560	4·0	3·0	1·7
700	2 50	·04949	·10216	·13758	·22781	4·8	3·5	2·1
800	3 30	·06116	·11394	·14945	·24008	5·0	4·1	2·5
900	4 20	·07378	·12869	·16435	·25552	5·8	4·6	2·9
1000	5 10	·09042	·14351	·17633	·27107	6·3	5·1	3·6
1100	6 00	·10510	·15838	·19436	·28675	6·6	5·4	3·7
1200	7 00	·12278	·17635	·21256	·30573	6·9	5·7	4·0
1300	8 10	·14351	·19740	·23393	·32814	7·2	6·1	4·3
1400	9 20	·16435	·21864	·25552	·35085	7·5	6·4	4·6
1500	10 30	·18534	·24008	·27732	·37280	7·8	6·5	4·9
1600	11 50	·20352	·26483	·28360	·41040	8·0	7·3	5·2

Table 23.

Comparison between the extent of the effective dangerous ground when the bullets fall on a surface parallel to the line of sight, or on one inclined to it.

Sights.	Number of rounds.	Depth of the effective dangerous ground			
		When the bullets fall on a surface parallel to the line of sight.	When the bullets fall on a surface which makes with the line of sight an angle of—		
			+ 3°	+ 5°	+ 10°
Metres.	Metres.	Metres.	Metres.	Metres.	Metres.
400	100	210	63	42	23·1
500	100	200	75·5	50·4	29·4
600	100	170	63	51	28·9
700	100	130	62·4	43·5	27·3
800	100	110	55	45·1	27·5
900	200	140	81·2	61·4	40·6
1000	200	110	69·3	56·1	39·6
1100	200	120	79·2	61·8	44·4
1200	200	80	55·2	45·6	32
1300	300	100	72	61	43
1400	300	110	82·5	70·4	50
	Totals ..	1480	761·3	594·3	386·4
	Means ..	134	70	54	35