# New Methods of

# Machine-Gun Fire

—von Merkatz

# New Methods of Machine-Gun Fire

*By*

Capt. Friedrich v. Merkatz
German Army

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# INTRODUCTION

Captain v. Merkatz was known before the war as one of the most prominent machine-gun experts of the German Army. In the present study, he gives us the benefit of his experience as a commander of a machine-gun unit in the great European war.

Perhaps the principal value of this study lies in the clear analysis which it contains of the various classes of machine-gun fire, their application, and method of employment. We know of no other book which has so completely performed this service in respect to machine-gun fire.

A study of this character will not bear casual reading, but must be made the object of thorough consideration and if possible an application of the principles discussed if the full benefit is to be derived from it.

One of the most interesting features of this translation is the method of regulating the extent of zone (or "deep") fire by the use of a graduated scale on the hand wheel. So far as we are aware, no consideration has ever been given to this question in this country. While zone fire finds little application at the shorter ranges which are the rule in the use of machine guns in trench warfare, the longer ranges at which they will often be used in the war of movements will make necessary some method of compensating for errors in range, deficient observation, variations due to setting up of mount, etc. By the method described, a zone of the depth required in any given case to compensate for these factors can be covered with almost absolute uniformity.

A valuable hint as to the method of training gun pointers is contained on pages 20 and 21 of the text.

Directors of firing exercises will find valuable assistance in the method of appraising the results of machine gun described on page 32-34.

G. A. Lynch, *Captain, Infantry,*
Editor of the Infantry Journal.

# New Methods of Machine-Gun Fire.[1]

By Captain Friedrich v. Merkatz, German Army.

## PART I. KINDS OF FIRE.[2]

### GENERAL.

THE machine-gun sheaf is produced when continuous fire is delivered from a machine gun. Its size depends entirely on the shaking of the sled, the vibration and heating of the barrel, and variations in the ammunition. The machine-gun sheaf has, therefore, constant dimensions even under service conditions. The gun pointer is only able to displace the sheaf but not to enlarge it. In this lies the material difference between the machine-gun sheaf and the infantry sheaf. The sheaf of a poorly trained infantry company is even in peace greater than that of a well-trained one. While under the disintegrating influences of battle, the infantry sheaf is materially enlarged, that of the machine gun will even in action deviate little or not at all from its peace dimensions. The so-called loss of nerve control does not appear here to the same extent, because being protected by the cover of the gun and in some cases by the shield, etc., the gun pointer is not subjected to the same extent to the influences of battle. With 100 or 200 m. deep fire, the new method of firing is so coarse that even any loss of nerve control which results in displacement of the sheaf through aiming errors, but as just stated, not in an enlargement of the sheaf, would be neutralized. The commander has it in his hands to adapt the extent of deep fire to service conditions.

### CHAPTER 1. SERIES FIRE.

Series fire is a string of about 50 shots, fired with fixed deflection and elevation levers.

[1] Translated for the INFANTRY JOURNAL from *Das neue Maschinen-Gewehr Schiess-Verfahren.*

[2] The classification of machine-gun fire according to the form of the sheaf as given in the original text includes: point fire (*Punktfeuer*), deep fire (*Tiefenfeuer*) and broad fire (*Breitenfeuer*). Although these classes of fire roughly correspond to the terms concentrated fire, zone fire, and traversed fire respectively, they are more comprehensive and are used in certain cases where the more usual English term would not apply. They have therefore been retained throughout this translation.—Editor.

Figure 1 presents a diagram of hits thus fired which was described on a large target at a range of 1,000 meters. The distribution of the hits is not the same in every diagram of this kind, but varies with the vibration of the sled, quality of the barrel, etc.

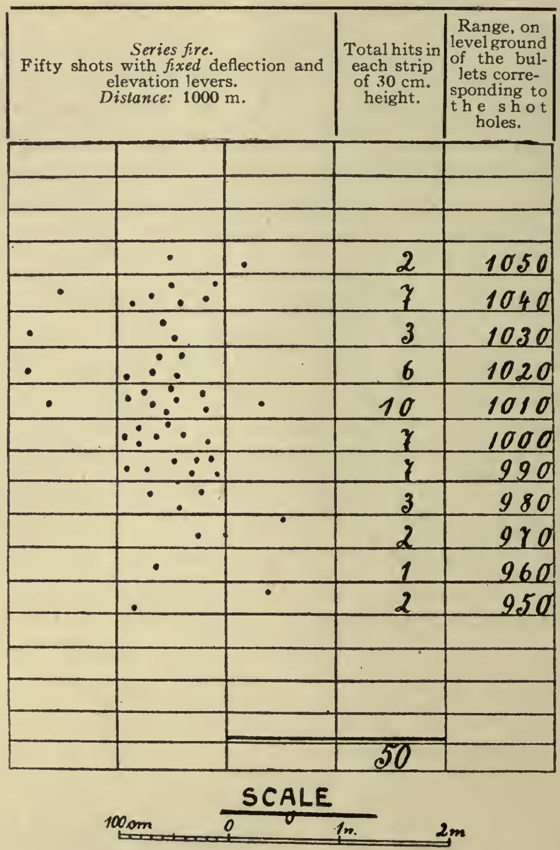


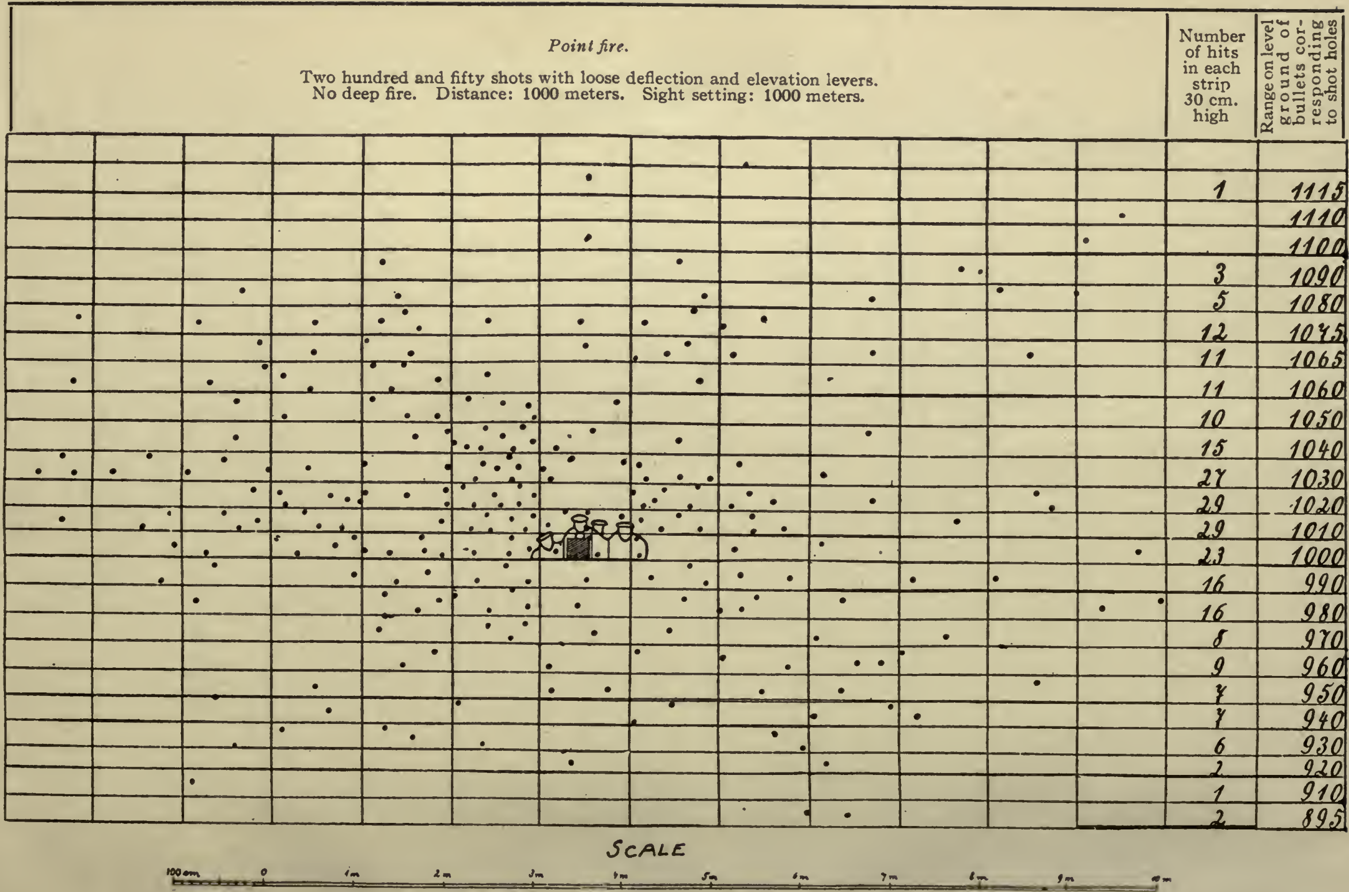

FIGURE 1.

As may be seen from Figure 1, in series fire the machine-gun sheaf is very narrow; leaving out of consideration the isolated hits at the extreme right and left, one can speak here, *e. g.*, of a sheaf 1 meter wide at 1,000 meters. The sheaf is not as narrow as this on all targets, and occasionally the width of the sheaf is greater than the height. These are peculiarities which have their origin in the construction of the sled and the way it is set up. It is not practicable to hit a narrow service target with this sheaf on account of the limited facilities for observation under war conditions; the series-fire sheaf can therefore be used only for adjustment fire. Two machine guns with the same range will seldom have the same center of impact; the location of their sheaves will always be somewhat different vertically as well as laterally. If it is desired to adjust the fire by platoon, *i. e.*, to fire with 2 or 3 machine guns at one and the same point from which the two or three sheaves will practically become one, the point of aim must be accurately announced and then accurate lateral adjustments made. The peculiarities of the different guns must be reckoned with, *e. g.*, a gun which shoots to the left must shift its aiming point, in adjustment fire by platoon, more to the right. Differences in the point of impact, which have their cause in the way the sled is set up, can in some measure be counteracted only by specially careful and uniform setting up of the sled on its four feet. In general, in adjustment fire, one must seek to have the sheaves strike at a lateral interval of 5-10 meters at the target to enable the platoon leader, while observing, to bring at least two or in platoons of three guns, all three sheaves if possible within the field of vision of his glasses. The poorer the conditions for observation, the more accurately must the point of aim be described laterally should it be desired to unite the sheaves of the different machine guns into one.

In firing for adjustment on one point with three or six machine guns, the sheaves will always so overlap that one great sheaf is formed. This sheaf is, however, so deep that it will give only an approximate indication of the range.

The depths of the beaten zone can be found in the table on page 33.

As to the value of these figures, there will be, as always and everywhere, very different views, but I desire to point out that for practical shooting, approximate knowledge of these figures or better still, a consultation of these tables, may save an officer from a false judgment. Who, for example, has not observed in adjustment fire one or the other sheaf extraordinarily deep? And



*Point fire.*
Two hundred and fifty shots with loose deflection and elevation levers.
No deep fire. Distance: 1000 meters. Sight setting: 1000 meters.
Number of hits in each strip 30 cm. high
Range on level ground of bullets corresponding to shot holes
1 1115
1110
1100
3 1090
5 1080
12 1075
11 1065
11 1060
10 1050
15 1040
27 1030
29 1020
29 1010
23 1000
16 990
16 980
8 970
9 960
7 950
7 940
6 930
2 920
1 910
2 895
SCALE
100 cm 0 1m 2m 3m 4m 5m 6m 7m 8m 9m 10m


FIGURE 3

shows a diagram fired with 250 shots under service conditions, and with loose deflection and elevation levers. With poorly trained gun pointers or slightly visible targets, the sheaf is considerably widened. This sheaf can be narrowed only by having the armorer sergeant fit the clamping piece very tightly, or by winding a little asbestos string around the upper trunnion of the jacket before screwing on the upper part of the jacket carrier, so that a lateral movement of the machine gun on the cradle will be impossible. This is, however, an obstacle in broad (traversed) fire, and one must, therefore, be satisfied with a middle course. The sheaf may also be narrowed with clearly visible aiming point and when weather conditions most completely prevent the appearance of powder smoke. Should more smoke or even steam leaking through between barrel and stuffing box appear,[3] unavoidable stops must be made for resighting. A series fire is the result.

Figure 3 is fired without any deep fire with 250 shots, and the machine-gun target is inserted correct to scale. From this it will be seen that at 1000 meters even with very good location of the sheaf, one cannot always count on a particularly high result. Five or six hits out of 250 shots, with best location of the sheaf and without deep fire, may be regarded as a good result; to prove this, the target may be placed in any desired position in the sheaf.

In using deep fire, the sheaf becomes thinner, the resulting hits therefore still fewer. To obtain an equally large number of hits, the amount of ammunition must be materially increased. From this it follows that no blame can be attached to the gun commander or gun pointer should his machine gun using deep fire make only 1 or 2 hits out of 250 shots, especially when at the time of firing the observation was not good. Broad fire against narrow targets, which is an intentional broadening of the already really broad sheaf of point fire, is only justified in very exceptional cases, with total lack of observation, abnormal weather conditions (very strong cross wind), against columns at long range, etc. The result in hits will in consequence be smaller.

*Point Fire as Fire for Effect.*

In war, long lines of skirmishers do not always offer themselves as targets, but often only single heads are visible which

[3] A sign that the asbestos packing is too weak or insufficiently greased.

do not justify a long sustained fire. Nevertheless, these single visible heads must be fought down with machine guns. The machine gun will, to a certain degree, be on the lookout with telescopes, and as soon as a head appears, 5, 10, or even 30 shots point fire must cover the spot so thoroughly that no enemy will venture again to show his head above his cover. These single heads are mostly officers or orderlies and are therefore desirable targets. Point fire is to be used in fire for effect not only against single heads, but also against long lines of skirmishers which are not very visible. All points where an enemy appears will be successively covered with point fire; one point fire after another will be placed alongside each other after short pauses, so that finally a sort of broad fire results. Should the targets be more visible, this series of point fire will become true broad fire. Deep fire will here also almost always be used. For details see later chapters.

## CHAPTER 3. BROAD FIRE.

### (a) *Traversed Once Over the Target Without Deep Fire.*

Broad fire is delivered with loose deflection and elevation levers. It is used in fighting against wide targets.

When changing to fire for effect, it is every gun commander's duty to again adjust his fire and to try again to secure observation in his sector so as to have to use as little deep fire as possible in the ensuing fire for effect. If in this repeated adjustment fire the gun commander attains his object—the sheaf lay exactly on the target—he changes to broad fire. One should suppose in this broad fire the sheaf would now remain in the target, provided that the target is of constant height. Incontrovertible tests have, however, demonstrated that in broad fire, the machine-gun sheaf is subject to variations which are due to the fact that the four legs of the sled are unevenly weighted on account of the lateral displacement of the axis of the gun. Figures 4, 5, and 6 show diagrams of hits, fired at battle ranges with broad fire, in which the elevation aiming apparatus was eliminated. The target was simply covered with broad fire once. In each diagram, sight was taken at a point just below the target at the beginning as well as at the other end. The diagrams show the variations of the sheaf plainly. An idea of the extent of the variations may be readily formed when it is known that each horizontal strip is 30 centimeters high, and the ranges are read off from the column on the extreme right. The distances show where the hits on the target strike level ground. One can easily understand that these variations, as shown in the diagrams, are not the same in all firings. These are characteristic diagrams selected as examples from a great number of firings. They will explain to most machine-gun officers what they have often themselves observed in range firing without knowing the cause of these variations; it will make it clear to them that the gun commander and gun pointer are often undeservedly accused of having fired badly. The conclusion in such cases that the gun pointer depressed or raised the handle is in most cases erroneous; the gun pointer cannot be held responsible for such variations of the sheaf at the target.

As we now know the cause of the variations of the sheaf at the target, we are in a position to counteract these defects of the weapon. These variations are easily detected when firing under excellent observation, and gun commander and gun pointer must be so trained in this respect that they can instantly correct the sheaf and hold it on the target. It is exactly this kind of firing that occurs so often in peace, and it forms an excellent school for the training of efficient gun commanders and gun pointers.

Similar cases also occur under service conditions.

With less favorable observation, it often happens that these variations of the sheaf cannot be detected quickly enough, and the sheaf will often be displaced from the target without being observed by the gun pointer. In such cases, the use of deep fire with broad fire is recommended. Of this, more will be said later.

By closely scrutinizing Figures 4, 5, and 6, a good idea of the machine-gun sheaf in broad fire may be formed; the sheaf is at many points as narrow as a thin band but unfortunately entirely irregular. While the narrow places of the fire-swept zone are often not over 10 or 15 meters deep, the broad parts of the sheaf have often a depth of from 50 to 100 meters.

Firing with a narrow band seems often very attractive, but the position of the sheaf is too variable; such firing cannot, therefore, be considered practicable under service conditions as a habitual procedure. This firing with a narrow band not only requires excellent conditions for observation at the target, but

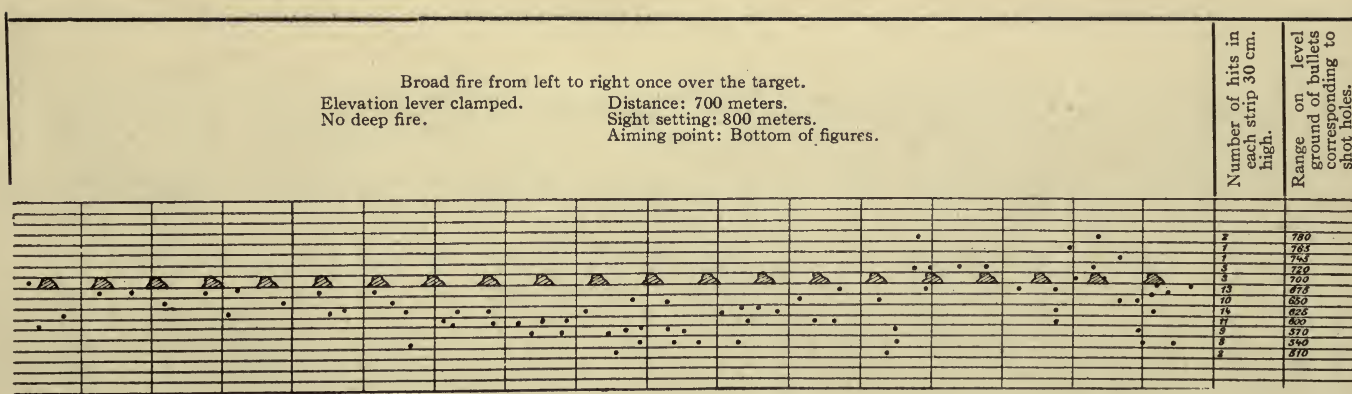



FIGURE 4.

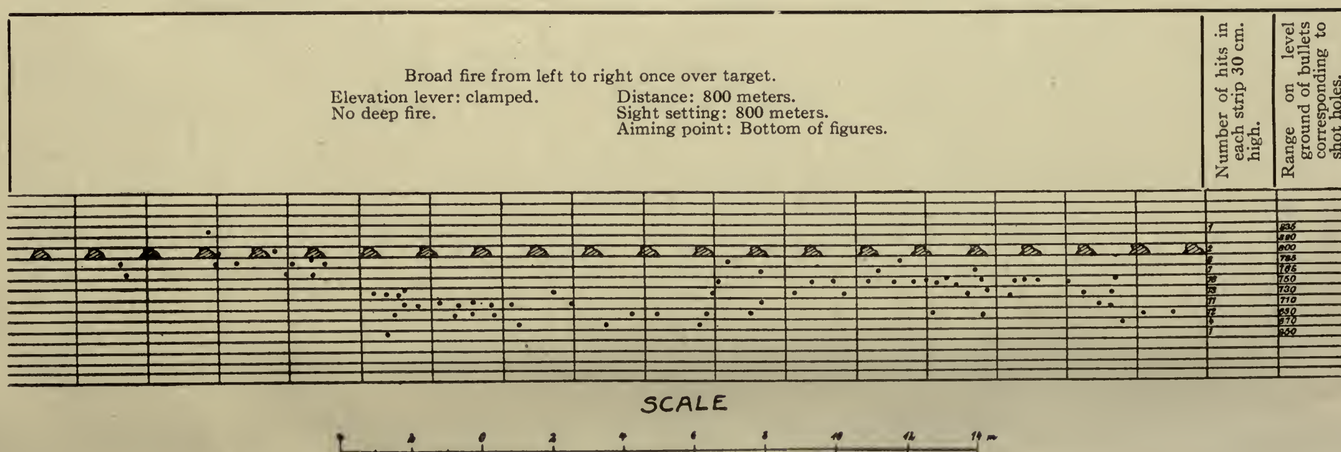



FIGURE 5.

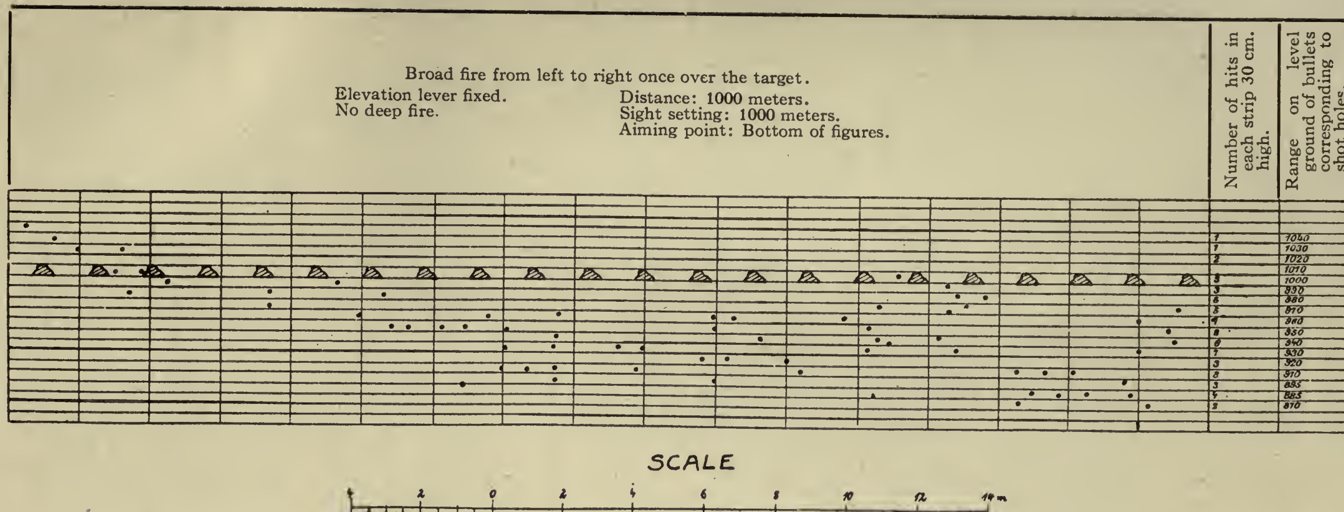

Broad fire from left to right once over the target.
Elevation lever fixed.
No deep fire.
Distance: 1000 meters.
Sight setting: 1000 meters.
Aiming point: Bottom of figures.
Number of hits in each strip 30 cm. high.
Range on level ground of bullets corresponding to shot holes.
1 1040
1 1030
2 1020
1010
3 1000
3 990
6 980
5 970
4 960
8 950
6 940
7 930
3 920
8 910
3 895
4 885
2 870
SCALE
2 0 2 4 6 8 10 12 14 m

FIGURE 6.

also a location of the target on a rising slope, so that one can observe whether the sheaf falls in front of the target or in rear.

The conditions for observation in time of war are identical with those in peace: observation is often excellent, often there is none at all. While before the war, I was of the opinion that the machine-gun sheaf would often disappear in the volume of the infantry sheaf and of striking shrapnel so that it could not be observed, this was not substantiated in the war. The machine-gun sheaves could generally be recognized even in the most intense firing of our own troops. In battle, the difficulty of observation lies not so much in the visibility of the striking projectiles as in the invisibility of the targets. This often forces the machine gun to use extensive deep fire, despite favorable conditions for observation.

The enemy is never in such a position as our targets in peace have up to the present been located; instead, he lies *behind* the rising ground and shows only so much of his head as is absolutely necessary for firing. But firing with the narrow band becomes nearly impossible without observation of the ground in rear of the target.

I would advise all machine gun officers to endeavor to have targets set up under service conditions; although for the training of gun pointers, targets on a rising slope are very instructive.

Exhaustive practice must be had in firing against sections of the terrain—edges of forests, cuts, ridges, etc. Commanders must be trained to detect where the target lies; a solitary head gives often the only indication as to its position. Commanders must know how to direct their machine-gun fire against these sections of the terrain, even under the most severe hostile fire. More detailed information is given at the end of Chapter 6 on "Tables of Fire Effect."

(*b*) *Sustained Fire traversed laterally back and forth without deep fire.*

We have seen in the foregoing chapter that the sheaf in broad fire is very irregular. If the fire is swept continuously back and forth over the target without deep fire, the irregularities will gradually adjust themselves, and uniformly dense sheaves will result. These sheaves, as shown, *e. g.*, in Figure 7, could be used satisfactorily against lines of skirmishers had they not several faults; namely: The gun pointer cannot change his point of aim, even when the sheaf falls in front or in rear of target. Any change in the point of aim causes a considerable enlargement of the sheaf. As may be seen in the tables in Chapter 5, this sheaf is very deep in its total extent; nevertheless, the useful part of this sheaf is so small that a very small error will throw it off of the target. Examine, *e. g.*, the sheaf at 1000 meters. The useful part is only 70 meters deep. Should the target lie well in the useful part, a variation of the sheaf of only 35 meters would suffice to throw it off of the target. For this reason the target could not lie in echelon as a difference in range of only 35 meters would be sufficient to remove it from the useful part.

In spite of all this, some prefer to fire with the last described sheaf, even without observation, as in many cases very high results are thus obtained, needless to say, with one uniformly distant target.

This is unquestionably true, but the effect is then left to chance, and it is certainly wrong for our machine-gun troops to be able to hit the target only by chance. Machine guns must be able to make hits—known hits at that—under service conditions even without any kind of observation. This was, until now, only possible when firing with several ranges and using deep fire. The deep fire used for this purpose was unsystematic, as the amount of turning the handwheel was not uniform.

(*c*) *Firing with several sights without deep fire according to the old firing methods.*

As will be demonstrated in a later chapter, we can not depend, in firing without observation, on the accuracy of the range finder to such an extent as to use only one sight setting. Cases often arise where it becomes necessary to use 2 or 3 sight settings with 100 meters difference in elevation, or 3 or 5 sights, with 50 meters difference. With ranges of 1000, 1100, and 1200 meters for example, we obtain Figure 7, which was fired by the gun-proving board. The amount of the ammunition used is very great, the sheaves are very large and dense; in spite of this, the defect of the old method is at once apparent in the well defined high and low areas of hits. Where the target lies in a high area, it is full of hits, if in a low area the result to be expected is zero. It must also be considered that this diagram was fired with only one gun.

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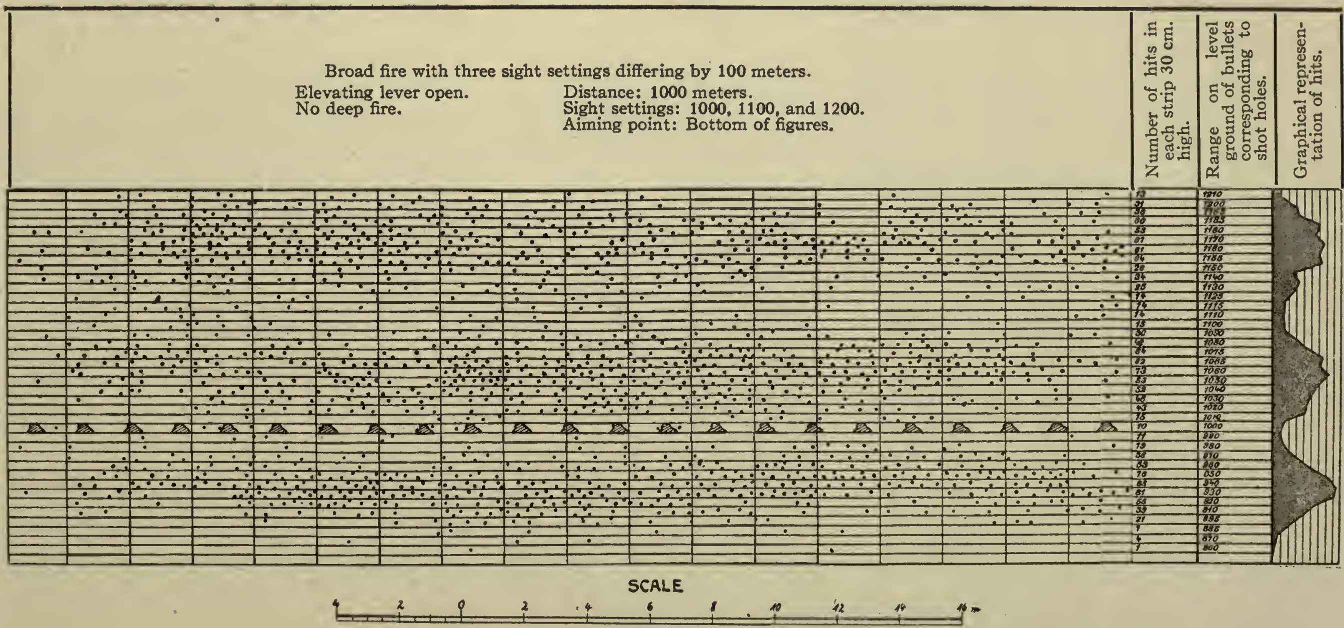

Broad fire with three sight settings differing by 100 meters.
Elevating lever open.
No deep fire.
Distance: 1000 meters.
Sight settings: 1000, 1100, and 1200.
Aiming point: Bottom of figures.
Number of hits in each strip 30 cm. high.
Range on level ground of bullets corresponding to shot holes.
Graphical representation of hits.
SCALE


FIGURE 7.

With 2 or 3 guns, the sheaves would have an entirely different position, as only in rare instances will several machine guns have the same center of impact. Should the gun using a range of 1100 be a "short shooting" gun, the sheaves 1000 and 1100 would coincide, and between 1100 and 1200 a still greater low area of hits than that obtained would result. There would be still less assurance of success.

A systematic distribution of hits could be obtained with machine guns having the same center of impact[5] at all distances, and several sight settings, 50 meters apart, were taken. Regardless of the center of impact, which is never exactly the same, the difficulty of selecting the ranges is added. How should, *e. g.*, three ranges be fired by a section of two guns? Or five ranges by a company at a very wide target, head figures at 1000 meters and the width of the target 300 meters? To all the before mentioned difficulties must be added those of fire direction, since as many machine guns as there are sight-settings to be employed must be concentrated on one sector of the target. Should observation become possible at any point during the firing, a change in sight setting is nearly impossible, as it is not known to which range the observed hits pertain.

By using several sight-settings and the old unsystematic deep fire, an approximately uniform distribution of hits on the target would probably be possible, but the extent of the deep fire would continue to be irregular, the difficulties of range selection would be the same, advantage could not be taken of observation, and low areas of hits could, moreover, result from different centers of impact.

## CHAPTER 4. DEEP FIRE.

### (a) *Deep Fire with graduated scale.*

To avoid the faults and difficulties of the former method, one elevation only was used (here 1,200), instead of several elevations as in the last mentioned example, and the handwheel during sustained fire was turned through an arc equivalent to the difference between the sight settings of 1200 and 1000. The re-

[5] The center of impact is dependent not only on the machine gun, but in great measure on the setting up of the sled. A machine gun which gives a good center of impact, may give an entirely different one if moved 2 meters to right or left.

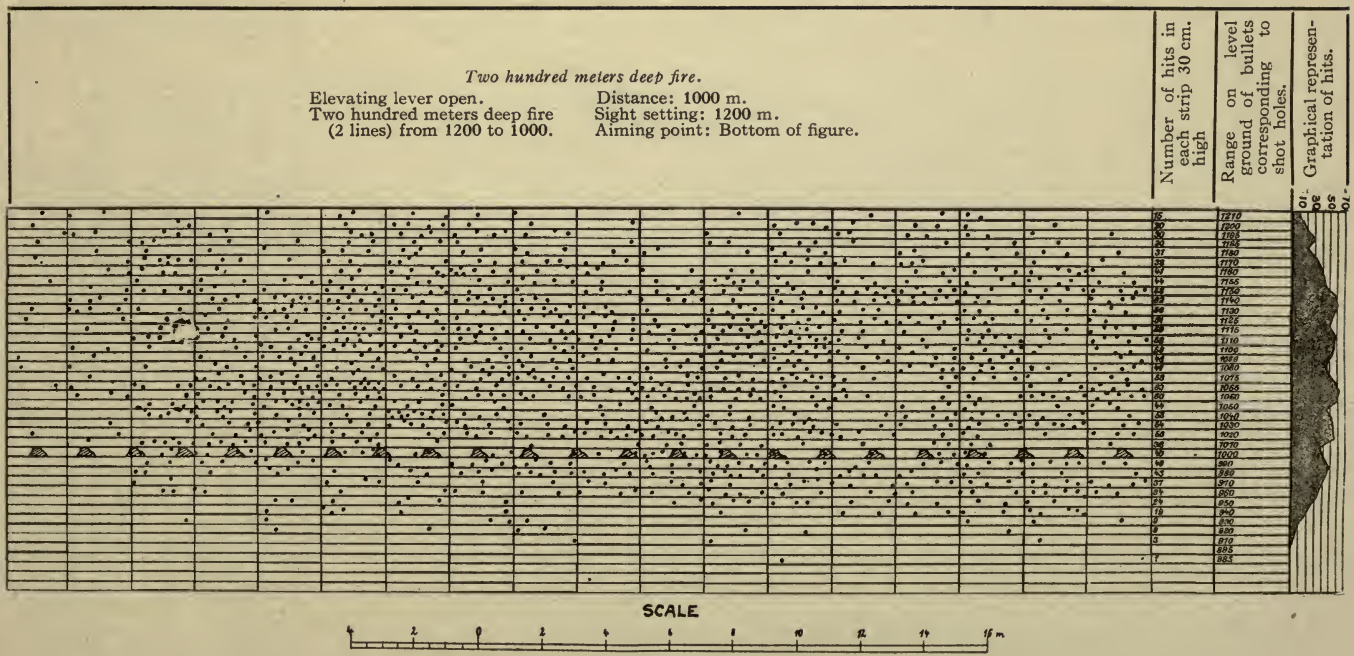
Two hundred meters deep fire.
Elevating lever open.
Two hundred meters deep fire (2 lines) from 1200 to 1000.
Distance: 1000 m.
Sight setting: 1200 m.
Aiming point: Bottom of figure.
Number of hits in each strip 30 cm. high
Range on level ground of bullets corresponding to shot holes.
Graphical representation of hits.
SCALE

FIGURE 8.

sult of this firing is shown in Figure 8. The dimension of the sheaf in depth is the same as in Figure 7, the upper and lower borders are equally uniform, but in contrast with Figure 7, the distribution of the hits over the entire surface of the target is absolutely uniform. The figures on the right of the illustration show the total of hits in each of the 30 cm.-high strips. Neither high nor low areas of hits appear. A target will be equally well hit at all distances of the useful part of the sheaf. To obtain such a result, the handwheel must be turned uniformly, and the required turn must be made sufficiently but not too far. The following error may easily be made: the gun pointer turns by jerks, *i. e.*, he pauses above and below and moves the line of sight quickly over the center part. The result is many hits above and below, and a well defined low area in the center. The turning should also not be too slow, as with a small ammunition supply, the distribution of hits would not be sufficiently uniform.

To give the gun pointer an approximate idea of how far to turn the handwheel at the different ranges in order to displace the sheaves 100 meters on the target, the graduated scale was constructed.

The lines on the scale show the gun pointer how far the handwheel must be turned. The graduation lines correspond each to 100 meters deep fire. At the longer ranges, the lines are longer, since with increasing range the graduations on the sight leaf are also further apart, thus necessitating greater turning of the handwheel.

Example: Range about 1000 m.

The machine gun is sighted with half sight at a target at 950 m. Changing the sight then to 1050, the line of sight is below the target; now turn the handwheel sufficiently to again bring the line of sight on the target, using half sight. The space covered by the handwheel is equal to the line marked with the number 1000 on the graduated scale.

To deliver 200 or 300 m. deep fire, the handwheel must be turned 2 or 3 times the amount indicated by the graduation.

### (*b*) *Instruction in use of Deep Fire.*

It appears at first difficult to keep to the limits indicated on the graduated scale so that the sections of the terrain under fire are really covered as intended. If one takes the trouble to determine the length of a line, it will be found that in every measurement a somewhat different result will be obtained. The cause therefor may be found in insignificant errors in aiming (full sight, half sight, etc.), and in faulty service of the gun at the point of lost motion of the elevating device, which is always in some measure present.

The lost motion has no effect if the machine gun has some over-weight at the rear end. This can best be effected, even with a clamping jacket carrier, if the gun pointer exerts a slight down-ward pressure with the hand on the handle. Should the gun pointer press up on the handle with his hand, the lost motion must first be taken up before the wheel of the elevating mechanism will again respond.

The hand on the handle must be raised by the elevating mechanism; this will not result in an appreciable over-burdening of the hand on the wheel.

The lines on the graduated scale represent averages values. It is, therefore, not necessary to hold accurately to the length of the lines. Should, *e. g.*, it be desired with 1200 meters elevation to cover the zone 200 meters lower, *i. e.*, to 1000 meters, neither the "1200" nor the "1000" line should be taken, but about the middle of both. If it is desired to obtain an accurate measurement, sight should be taken at first with the lower and then with the higher sight setting, and thus the amount of rotation necessary determined.

For instruction in deep fire, the device for aiming control for machine guns constructed by Captain Freiensehner is eminently adapted.

In instruction with this device, a board is placed, as shown in the illustration (Figure 9), in a frame under the muzzle. The pencil holder is inserted with its upper end, the fork, under the stuffing-box, so that the pencil point rests against the board. The pencil has an elastic movement to the front and is held back by the instructor with a string, and is only released to record control points or control lines.

The following can be accomplished with this apparatus:

1. *Exercises in Adjustment Fire.*

In aiming drill, with and without blank ammunition, the machine gun is aimed by the instructor with a certain sight setting at an aiming point. The instructor then marks a control point on the board with the device, and then alters the direction of the gun. The gun pointer will then be required to aim at the same point with the same sight setting, the instructor giving the proper commands as under service conditions. The instructor pulls back the string; as soon as the gun pointer calls "ready," the instructor releases the string, and the error made by the gun pointer can be seen on the board. The device permits of several sights being taken by the gun pointer without compelling the instructor to go behind the gun every time and verify the correctness of the aim.

2. *Excercise in Fire for Effect.*

The instructor aims with a certain sight setting at a target (at first located horizontally), and with the device draws on the board a horizontal line whose length corresponds to the width of the sector of the target pertaining to the gun. He then sights at the same target with 100 (200, 300) m. less elevation and draws, as before, a horizontal line on the board and marks the lateral limits of the sector pertaining to the gun with vertical lines. The gun pointer now executes deep fire with the range given by the instructor. The waving lines now formed on the board should connect the horizontal lines drawn by the instructor, and should not go beyond the vertical lines on the sides. By continuous observation of the lines now formed on the board, the instructor can constantly check the gun pointer and thus instruct him.

With targets which are not horizontal, the instructor must draw on the board the control lines of the two sights settings to be used.

### (*c*) *Use of Deep Fire.*

To prevent possible misunderstanding, I wish to make clear at the beginning of this discussion that the use of deep fire does not always mean the covering of a zone at least 100 or 200 meters deep.

The extent of the deep fire is dependent on:

1. Observation.
2. Target.
3. Range.

The difficulties in firing without any deep fire and the objections to it are described in more detail in Chapter 3. Should there

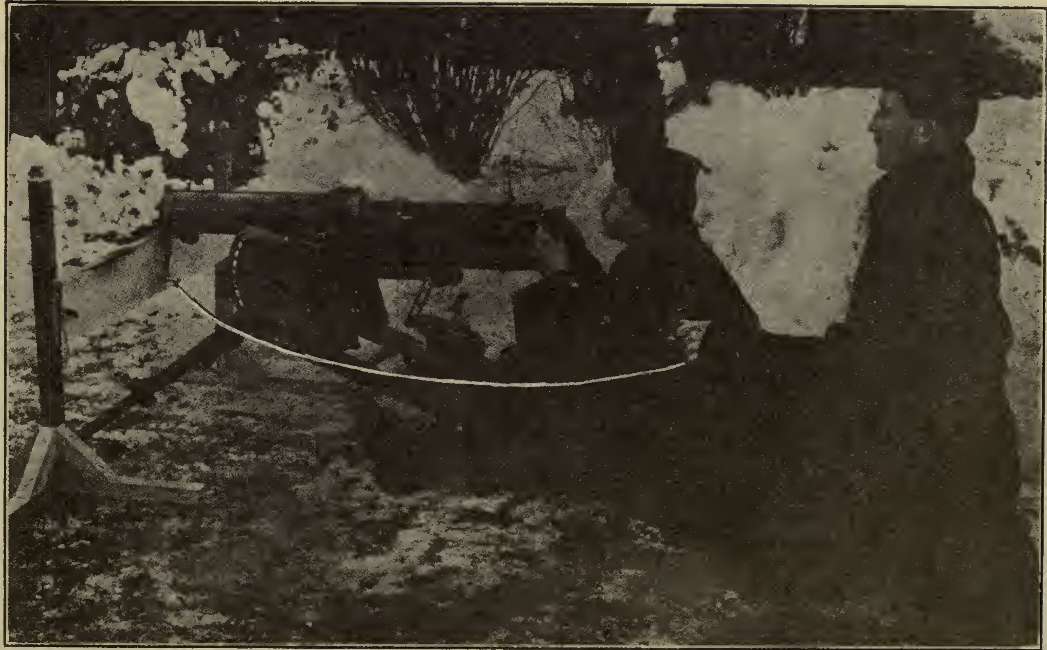

FIGURE 9.

not be such abnormally favorable conditions of observation as are necessary for such firing—which I prefer to designate as "peace firing"—the sheaf on the target must be enlarged.

There are many intermediate stages between "good observation" and "lack of observation" which permit us to get along with very little deep fire—say 50 meters.

To get a clear understanding of how little the line of sight moves with 50 meters deep fire, it is only necessary to lie behind a machine gun and execute this deep fire with 800 or 1000 meters elevation, accurately observing the handwheel and eliminating the lost motion. Deep fire of only 50 meters requires so little turning of the handwheel that the majority of officers will be astonished. An extensive displacement of the sheaf on the target is not involved; the gun commander's corrections of "higher" or "lower" often result in more turning of the wheel than is here the case. We will take as an example the most favorable condition for observation to show how much 50 meters deep fire amounts to at the target. Figure 4, 5 and 6 show the sheaf as it appears on the target. At a range of 800 meters, 50 meters deep fire causes a rise and a fall of only about 45 cm. (centimeters!) each, which can easily be seen from the table of ordinates of the trajectory. (See Appendix.) In firing at a steep slope, the sheaf is actually neither elevated nor lowered beyond the 45 cm., and who can, even with the most powerful field glasses, recognize such a small difference, or will be able to say "too much deep fire"? Transferred to level ground, these 45 cm. at 800 meters distance are changed in consequence of the flatness of the trajectory to 25 meters high or low. But again, who can even with the best field glasses determine differences of 25 meters at a distance of 800 meters on level ground?

Fifty meters deep fire is insufficient to compensate for the variations in the machine-gun sheaf as shown in Figures 4, 5, and 6. To fire with 50 meters deep fire, excellent observation must be possible. Every machine-gun commander must keep his target under constant observation, and must by continuous commands of "higher" or "lower," strive to equalize the variations. The 50 meters deep fire only serves to counteract, to a certain extent, the observer's errors. Such small differences in the lay of the sheaf as 25 meters in depth cannot be continually discerned and corrected with the rapidity required, even with good field glasses.

The effect of fire is materially increased through the 50 meters deep fire. I have demonstrated through much firing that the gun commander often errs in judging the sheaf's position with reference to the target. He often believed himself to be exactly on the target but was actually in front or in rear of it with the narrow band. The 50 meters deep fire permits the gun commander to compensate for many of these errors; he catches the target with the end of the useful part when he would otherwise shoot over it.

I freely admit exceptions in the case of gun pointers who can hold the target for a time without any deep fire, but this only under the most favorable conditions. The majority of all gun commanders and gun pointers will, in firing without deep fire, get on the target only occasionally, crossing the target to a certain extent, though not so frequently as when using 50 meters deep fire. By using 50 meters deep fire, the average gun commander is able to bring his sheaf more frequently in the target, thus obtaining more hits.

A rule as to how much deep fire to use in every case, cannot be laid down; this depends on conditions obtaining at the time.

The conviction comes unconsciously that with use of 100, 200, or even 300 meters deep fire, the useful part of the sheaf will become so thin that no hits can be made. I ask, however, that a trial be made under the following conditions:

Target: head figures at 1000 to 1100 meters.
Observation: poor or none.
Pointers: men perfectly trained in deep fire.

Adjustment fire starts as usual by platoon or with all 6 machine guns on one point.

With no observation, the company will be given a common range and 200 meters deep fire. At the mid ranges, the reading of the range finders will be taken with due allowances for weather conditions.

With poor observation, 100 meters deep fire will be ordered, based on the adjustment fire.

In firing for effect, the gun commander and officers step out of the line after instructing the gun pointers in the distribution of fire. The gun pointers receive strict orders to disregard all observed hits and to find the target solely with the announced elevation and to execute their 200 and 300 meters deep fire uniformly.

The main point to be observed in this firing is the total disregard of all observation.

The result obtained can be almost exactly predicted by use of the Tables of Fire Effect, of which more will be said in a later chapter. The accuracy of the fire is, to say the least, astounding in spite of the fact that the entire procedure is based solely on a systematic, uniform distribution of hits on the target. The accuracy of fire is so extraordinarily great because the corrections of the gun commanders are eliminated, and this brings me to the main point that the gun commanders, through false corrections, often remove the sheaf from the target instead of improving it. I lay here particular stress on the firing under service conditions with poor observation.

This method is particularly adapted for instruction firing, and, as a contrast, I recommend firing with gun and platoon leaders in command, if possible without any deep fire and with poor observation. The result of this last firing will often be poorer than that of the demonstration firing notwithstanding the 100 or 200 meters deep fire of the latter. The few instances in the latter case—let us call it "accuracy fire"—in which the results are materially better than those of deep fire, are so rare that they cannot outweigh the great advantage of the certainty of effect of deep fire.

For the demonstration firing, it is recommended that 2 or 3 lines of targets be set up directly in rear of one another (not echeloned laterally) at 50 meters interval instead of one line of head figures, to show the certainty of the fire effect. In such an arrangement, it must be borne in mind that the lines placed behind one another must, of course, lie in a horizontal plane.

*Deep fire against targets on uneven ground.*

In mountain warfare, where the enemy is more or less equally distant but not on the same level, the use of the deep fire is of the utmost importance.

As already mentioned, at 800 meters distance and 50 meters deep fire, the increase of the vertical diameter of the machine-gun sheaf is only 90 centimeters. Should the target rise or fall to a small extent, a resighting is necessary, as otherwise the target, despite the deep fire, would lie above or below the sheaf. The gun pointer must follow the target with the sight with the utmost care. The deep fire will contribute materially toward causing the machine-gun sheaf to pass through the target more frequently than when the gun pointer fires without deep fire at the gun commander's commands only.

# PART II. FIRE EFFECT.

## A. FIRE EFFECT UNDER NORMAL CONDITIONS.

### CHAPTER 5. DIMENSIONS OF THE MACHINE-GUN SHEAF.

The table in this chapter gives a résumé of dimensions of the beaten zone without deep fire, also with 50, 100, 200, and 300 meters deep fire. The calculations are the results of extensive firing by the gun-proving board. The figures, like all other tables, only represent averages.

The figures in the columns "No deep fire" and "50 meters deep fire" are not interchangeable with Figures 1 and 2, and 4, 5 and 6, respectively. The figures given in the table are the averages of a great number of firings without observation in which the average was based on about 1,000 shots for each firing.

It will be surprising how extraordinarily great are the depths of the 100 per cent sheaf at short ranges, as shown in the columns for 200 and 300 meters deep fire. This is caused by the offshoots in the extremities of the sheaf, which actually occur with

TABLE—THE 100 PER CENT AND USEFUL DEPTHS OF THE BEATEN ZONES IN METERS.

| Distance in meters | No deep fire | | 50 m. deep fire | | 100 m. deep fire | | 200 m. deep fire | | 300 m. deep fire | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 100 per cent sheaf | Useful part | 100 per cent sheaf | Useful part | 100 per cent sheaf | Useful part | 100 per cent sheaf | Useful part | 100 per cent sheaf | Useful part |
| 800 | 250 | 80 | 350 | 140 | 460 | 190 | 570 | 240 | 750 | 300 |
| 900 | 220 | 75 | 290 | 120 | 385 | 170 | 480 | 230 | 670 | 300 |
| 1000 | 200 | 70 | 250 | 110 | 330 | 150 | 420 | 220 | 600 | 300 |
| 1100 | 185 | 70 | 220 | 100 | 290 | 140 | 375 | 210 | 530 | 300 |
| 1200 | 170 | 65 | 200 | 90 | 260 | 130 | 340 | 200 | 480 | 300 |
| 1300 | 155 | 65 | 190 | 85 | 240 | 120 | 310 | 200 | 440 | 300 |
| 1400 | 145 | 60 | 180 | 85 | 225 | 110 | 280 | 200 | 410 | 300 |
| 1500 | 140 | 60 | 180 | 85 | 215 | 105 | 260 | 200 | 380 | 300 |
| 1600 | 140 | 60 | 175 | 85 | 210 | 100 | 250 | 200 | 350 | 300 |

the coarse method of 300 meters deep fire and the additional errors of the gun pointers as a result of the flatness of the trajectory. These are not merely calculated values, but were obtained by actual firing.

### CHAPTER 6. TABLES OF FIRE EFFECT.[6]

Figure 8 shows the even distribution of the hits on a target when the gun pointer executes deep fire correctly. By reason of this even distribution, it is possible to calculate the percentage of direct hits to be expected within the useful part, against targets of any size, with any interval.

Needless to say, ricochets cannot be calculated; but I must discuss in more detail firing without and with only 50 meters deep fire.

In firing without, or with only 50 meters deep fire, an attempt is made to hold the sheaf of Figures 4, 5, and 6 constantly on the target in accordance with the corrections of the gun commander. An exact calculation of the percentage of hits to be expected in this case is impossible. The figures under these two headings are therefore based on the average dimensions of the sheaf from the table on page 175.

While, therefore, the tables showing 100, 200, or 300 meters deep fire actually give the approximate percentage of direct hits expected in round numbers, it is possible to exceed the given values materially with only 50 meters or without any deep fire, as the sheaf may be narrowed through the corrections of the gun commander. If the percentages shown here are not obtained, it can be seen from the table that better results could possibly have been obtained if so many corrections had not been made. From the depths of the useful sheaves at the target as shown in the table, it may be seen that in firing without any deep fire (without corrections during firing), the useful part, *e.g.,* at 1,000 meters, is 70 meters deep. If we succeed in bringing the target within this space, the percentages shown will be obtained, though it must be considered that with such small useful spaces the percentages given are only averages. At the edges, the result will be smaller, and in the center alone will it be greater than

[6]See pages 29 and 30.

shown here. These are, however, such small differences in range that in firing without deep fire, the result is always a matter of chance.

The more deep fire is used, the flatter is the area[7] of hits of the useful space, *i. e.,* the useful space is not so sharply separated from the outer parts of the sheaf, the transition is more gradual, and 20 or even 50 meters difference in range at the target matters little or not at all, while in firing without deep fire, even 10 meters make an enormous difference in the percentages of direct hits expected.

If the result to be expected is exceeded, the useful space has been diminished.

If the result to be expected is not attained, the useful space has been enlarged. Should the corresponding deep fire have, nevertheless, been used, it was incorrectly delivered, or the gun commander did not succeed in bringing the useful space into the target. He would probably have done better in the latter case had he used more deep fire.

The percentages shown below give only averages. The result obtained will, however, always approximate the figures in the table though it should again be emphasized that the more deep fire is used the more closely will the figures agree.

The Tables of Fire Effect are naturally of no value for use in war, as it would be impossible to calculate whether the firing will or will not obtain commensurate results. But in peace, commander and troops can be tested with the tables as to whether or not they know how to use their machine guns correctly.

It seems almost impossible to construct, in peace, targets representing service conditions. Where will lines of heads 300 meters long offer themselves in war? and for from 3 to 5 minutes? These were fallacies! But it is, nevertheless, advisable to fire against such targets in peace if the error is not committed of setting up the targets so that they are plainly visible. On the contrary, but few points of the enemy's lines should be discernible, exactly as the targets show themselves in war. Here and there an incautious head shows itself, or a careless soldier betrays,

[7] *I.e.,* in the graphical representation as shown in the right-hand column of Figures 7 and 8.

## I. Head Targets.

| Distance in m. | No deep fire | | | | | | | | 50 m. deep fire | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth of useful part at target in m. | Clear interval in m. | | | | | | | Depth of useful part at target in m. | Clear interval in m. | | | | | | |
| | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| 800 | 80 | 4.8 | 3.7 | 3.2 | 2.4 | 1.9 | 1.6 | 1.4 | 140 | 2.7 | 2.1 | 1.8 | 1.4 | 1.1 | 0.9 | 0.8 |
| 900 | 75 | 4.0 | 3.0 | 2.6 | 2.0 | 1.6 | 1.3 | 1.1 | 120 | 2.5 | 1.9 | 1.6 | 1.3 | 1.0 | 0.8 | 0.7 |
| 1000 | 70 | 3.3 | 2.5 | 2.2 | 1.6 | 1.3 | 1.1 | 0.9 | 110 | 2.2 | 1.7 | 1.5 | 1.1 | 0.9 | 0.7 | 0.6 |
| 1100 | 70 | 2.7 | 2.0 | 1.7 | 1.3 | 1.0 | 0.9 | 0.8 | 100 | 2.0 | 1.5 | 1.3 | 1.0 | 0.8 | 0.7 | 0.6 |
| 1200 | 65 | 2.2 | 1.7 | 1.4 | 1.1 | 0.8 | 0.7 | 0.7 | 90 | 1.8 | 1.3 | 1.1 | 0.9 | 0.7 | 0.6 | 0.5 |
| 1300 | 65 | 1.8 | 1.4 | 1.1 | 0.9 | 0.7 | 0.6 | 0.5 | 85 | 1.6 | 1.2 | 1.0 | 0.8 | 0.6 | 0.5 | ... |
| 1400 | 60 | 1.5 | 1.1 | 0.9 | 0.8 | 0.6 | 0.5 | ... | 85 | 1.4 | 1.0 | 0.9 | 0.7 | 0.5 | ... | ... |
| 1500 | 60 | 1.2 | 0.9 | 0.8 | 0.6 | 0.5 | ... | ... | 85 | 1.2 | 0.9 | 0.8 | 0.6 | 0.5 | ... | ... |
| 1600 | 60 | 1.0 | 0.7 | 0.6 | 0.5 | ... | ... | ... | 85 | 1.0 | 0.7 | 0.6 | 0.5 | ... | ... | ... |

| Distance in m. | 100 m. deep fire | | | | | | | | 200 m. deep fire | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth of useful part at target in m. | Clear interval in m. | | | | | | | Depth of useful part at target in m. | Clear interval in m. | | | | | | |
| | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| 800 | 190 | 1.8 | 1.4 | 1.1 | 0.9 | 0.7 | 0.6 | 0.5 | 240 | 1.6 | 1.2 | 1.0 | 0.8 | 0.6 | 0.5 | ... |
| 900 | 170 | 1.6 | 1.2 | 1.0 | 0.8 | 0.6 | 0.5 | ... | 230 | 1.4 | 1.0 | 0.9 | 0.7 | 0.5 | ... | ... |
| 1000 | 150 | 1.5 | 1.1 | 0.9 | 0.8 | 0.6 | 0.5 | ... | 220 | 1.2 | 0.9 | 0.8 | 0.6 | 0.5 | ... | ... |
| 1100 | 140 | 1.3 | 1.0 | 0.8 | 0.7 | 0.5 | ... | ... | 210 | 1.0 | 0.8 | 0.7 | 0.5 | ... | ... | ... |
| 1200 | 130 | 1.2 | 0.9 | 0.8 | 0.6 | 0.5 | ... | ... | 200 | 0.8 | 0.6 | 0.6 | 0.5 | ... | ... | ... |
| 1300 | 120 | 1.0 | 0.8 | 0.7 | 0.5 | ... | ... | ... | 200 | 0.7 | 0.5 | 0.5 | ... | ... | ... | ... |
| 1400 | 110 | 0.9 | 0.7 | 0.6 | ... | ... | ... | ... | 200 | 0.6 | 0.5 | ... | ... | ... | ... | ... |
| 1500 | 105 | 0.7 | 0.6 | 0.5 | ... | ... | ... | ... | 200 | 0.5 | ... | ... | ... | ... | ... | ... |
| 1600 | 100 | 0.6 | 0.5 | ... | ... | ... | ... | ... | 200 | ... | ... | ... | ... | ... | ... | ... |

## II. Breast Target (Prone Silhouettes).

| Distance in m. | No deep fire | | | | | | | | 50 m. deep fire | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth of useful part at target in m. | Clear interval in m. | | | | | | | Depth of useful part at target in m. | Clear interval in m. | | | | | | |
| | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| 800 | 80 | 8.8 | 6.6 | 5.7 | 4.3 | 3.4 | 2.9 | 2.4 | 140 | 5.1 | 3.8 | 3.3 | 2.5 | 2.0 | 1.6 | 1.4 |
| 900 | 75 | 7.2 | 5.4 | 4.7 | 3.5 | 2.8 | 2.3 | 2.0 | 120 | 4.5 | 3.4 | 2.9 | 2.2 | 1.8 | 1.4 | 1.3 |
| 1000 | 70 | 5.9 | 4.4 | 3.8 | 2.9 | 2.3 | 1.9 | 1.6 | 110 | 4.0 | 3.0 | 2.6 | 2.0 | 1.6 | 1.3 | 1.1 |
| 1100 | 70 | 4.8 | 3.6 | 3.1 | 2.3 | 1.9 | 1.6 | 1.3 | 100 | 3.6 | 2.7 | 2.3 | 1.7 | 1.4 | 1.1 | 1.0 |
| 1200 | 65 | 3.9 | 2.9 | 2.5 | 1.9 | 1.5 | 1.3 | 1.1 | 90 | 3.2 | 2.4 | 2.0 | 1.5 | 1.2 | 1.0 | 0.9 |
| 1300 | 65 | 3.3 | 2.4 | 2.1 | 1.6 | 1.2 | 1.1 | 0.9 | 85 | 2.8 | 2.1 | 1.8 | 1.3 | 1.0 | 0.9 | 0.8 |
| 1400 | 60 | 2.7 | 2.0 | 1.7 | 1.3 | 1.0 | 0.9 | 0.8 | 85 | 2.4 | 1.8 | 1.6 | 1.1 | 0.9 | 0.8 | 0.7 |
| 1500 | 60 | 2.2 | 1.7 | 1.4 | 1.1 | 0.8 | 0.7 | 0.6 | 85 | 2.1 | 1.6 | 1.4 | 1.0 | 0.8 | 0.7 | 0.6 |
| 1600 | 60 | 1.7 | 1.4 | 1.1 | 0.9 | 0.7 | 0.6 | 0.5 | 85 | 1.7 | 1.4 | 1.2 | 0.9 | 0.7 | 0.6 | 0.5 |

| Distance in m. | 100 m. deep fire | | | | | | | | 200 m. deep fire | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth of useful part at target in m. | Clear interval in m. | | | | | | | Depth of useful part at target in m. | Clear interval in m. | | | | | | |
| | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| 800 | 190 | 3.3 | 2.4 | 2.1 | 1.6 | 1.2 | 1.1 | 0.9 | 240 | 2.7 | 2.0 | 1.7 | 1.3 | 1.0 | 0.9 | 0.7 |
| 900 | 170 | 3.0 | 2.2 | 1.9 | 1.4 | 1.1 | 1.0 | 0.8 | 230 | 2.4 | 1.8 | 1.5 | 1.1 | 0.9 | 0.8 | 0.6 |
| 1000 | 150 | 2.7 | 2.0 | 1.7 | 1.3 | 1.0 | 0.9 | 0.8 | 220 | 2.1 | 1.6 | 1.4 | 1.0 | 0.8 | 0.7 | 0.6 |
| 1100 | 140 | 2.4 | 1.8 | 1.5 | 1.1 | 0.9 | 0.8 | 0.7 | 210 | 1.8 | 1.4 | 1.2 | 0.9 | 0.7 | 0.6 | 0.5 |
| 1200 | 130 | 2.2 | 1.6 | 1.3 | 1.0 | 0.8 | 0.7 | 0.6 | 200 | 1.5 | 1.2 | 1.0 | 0.8 | 0.6 | 0.5 | ... |
| 1300 | 120 | 1.9 | 1.4 | 1.2 | 0.9 | 0.7 | 0.6 | 0.5 | 200 | 1.3 | 1.0 | 0.8 | 0.6 | 0.5 | ... | ... |
| 1400 | 110 | 1.6 | 1.2 | 1.1 | 0.8 | 0.6 | 0.5 | 0.5 | 200 | 1.1 | 0.8 | 0.7 | 0.5 | ... | ... | ... |
| 1500 | 105 | 1.4 | 1.0 | 0.9 | 0.6 | 0.5 | ... | ... | 200 | 0.9 | 0.6 | 0.5 | ... | ... | ... | ... |
| 1600 | 100 | 1.1 | 0.8 | 0.7 | 0.5 | ... | ... | ... | 200 | 0.7 | 0.5 | ... | ... | ... | ... | ... |

## III. Kneeling Targets (Kneeling Silhouettes).

| Distance in m. | 50 m. deep fire | | | | | | | | 100 m. deep fire | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth of useful part at target in m. | Clear interval in m. | | | | | | | Depth of useful part at target in m. | Clear interval in m. | | | | | | |
| | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| 800 | 140 | 8.4 | 6.4 | 5.6 | 4.2 | 3.4 | 2.8 | 2.4 | 190 | 5.4 | 4.2 | 3.6 | 2.7 | 2.2 | 1.8 | 1.5 |
| 900 | 120 | 7.5 | 5.8 | 5.0 | 3.8 | 3.0 | 2.5 | 2.1 | 170 | 4.9 | 3.8 | 3.3 | 2.4 | 2.0 | 1.6 | 1.4 |
| 1000 | 110 | 6.7 | 5.1 | 4.5 | 3.4 | 2.7 | 2.2 | 1.9 | 150 | 4.5 | 3.4 | 3.0 | 2.2 | 1.8 | 1.5 | 1.3 |
| 1100 | 100 | 5.9 | 4.5 | 4.0 | 3.0 | 2.4 | 2.0 | 1.7 | 140 | 4.0 | 3.1 | 2.7 | 2.0 | 1.6 | 1.4 | 1.2 |
| 1200 | 90 | 5.2 | 4.0 | 3.5 | 2.6 | 2.1 | 1.8 | 1.5 | 130 | 3.6 | 2.8 | 2.4 | 1.8 | 1.4 | 1.2 | 1.1 |
| 1300 | 85 | 4.6 | 3.5 | 3.1 | 2.3 | 1.8 | 1.6 | 1.3 | 120 | 3.1 | 2.4 | 2.1 | 1.6 | 1.2 | 1.1 | 0.9 |
| 1400 | 85 | 4.0 | 3.1 | 2.7 | 2.0 | 1.6 | 1.4 | 1.2 | 110 | 2.7 | 2.1 | 1.8 | 1.4 | 1.1 | 0.9 | 0.8 |
| 1500 | 85 | 3.4 | 2.7 | 2.3 | 1.7 | 1.4 | 1.2 | 1.0 | 105 | 2.2 | 1.7 | 1.5 | 1.2 | 0.9 | 0.8 | 0.6 |
| 1600 | 85 | 2.9 | 2.3 | 1.9 | 1.4 | 1.2 | 1.0 | 0.8 | 100 | 1.8 | 1.4 | 1.2 | 0.9 | 0.8 | 0.6 | 0.5 |

| Distance in m. | 200 m. deep fire | | | | | | | | 300 m. deep fire | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth of useful part at target in m. | Clear interval in m. | | | | | | | Depth of useful part at target in m. | Clear interval in m. | | | | | | |
| | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| 800 | 240 | 4.5 | 3.5 | 3.0 | 2.3 | 1.8 | 1.5 | 1.3 | 300 | 3.0 | 2.3 | 2.0 | 1.5 | 1.2 | 1.0 | 0.8 |
| 900 | 230 | 3.9 | 3.0 | 2.7 | 2.0 | 1.6 | 1.3 | 1.1 | 300 | 2.5 | 2.0 | 1.7 | 1.3 | 1.0 | 0.9 | 0.7 |
| 1000 | 200 | 3.4 | 2.6 | 2.4 | 1.7 | 1.4 | 1.1 | 1.0 | 300 | 2.2 | 1.7 | 1.5 | 1.2 | 0.9 | 0.8 | 0.6 |
| 1100 | 210 | 2.9 | 2.3 | 1.9 | 1.4 | 1.2 | 1.0 | 0.8 | 300 | 1.9 | 1.5 | 1.3 | 1.0 | 0.8 | 0.7 | 0.6 |
| 1200 | 200 | 2.5 | 1.9 | 1.6 | 1.2 | 1.0 | 0.8 | 0.7 | 300 | 1.6 | 1.3 | 1.1 | 0.8 | 0.7 | 0.6 | 0.5 |
| 1300 | 200 | 2.1 | 1.6 | 1.4 | 1.1 | 0.9 | 0.7 | 0.6 | 300 | 1.4 | 1.1 | 1.0 | 0.7 | 0.6 | 0.5 | ... |
| 1400 | 200 | 1.7 | 1.3 | 1.2 | 0.9 | 0.7 | 0.6 | 0.5 | 300 | 1.2 | 0.9 | 0.8 | 0.6 | 0.5 | ... | ... |
| 1500 | 200 | 1.4 | 1.1 | 1.0 | 0.7 | 0.6 | 0.5 | ... | 300 | 1.0 | 0.8 | 0.7 | 0.5 | ... | ... | ... |
| 1600 | 200 | 1.1 | 0.9 | 0.8 | 0.6 | 0.5 | ... | ... | 300 | 0.8 | 0.6 | 0.5 | ... | ... | ... | ... |

## IV. Figure Targets (Standing Silhouettes).

| Distance in m. | 50 m. deep fire | | | | | | | | 100 m. deep fire | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth of useful part at target in m. | Clear interval in m. | | | | | | | Depth of useful part at target in m. | Clear interval in m. | | | | | | |
| | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| 800 | 140 | 13.9 | 10.7 | 9.2 | 6.9 | 5.5 | 4.6 | 4.0 | 190 | 8.9 | 6.9 | 5.9 | 4.4 | 3.6 | 3.0 | 2.5 |
| 900 | 120 | 12.4 | 9.6 | 8.3 | 6.2 | 4.9 | 4.2 | 3.6 | 170 | 8.1 | 6.3 | 5.4 | 4.0 | 3.2 | 2.7 | 2.3 |
| 1000 | 110 | 11.1 | 8.5 | 7.4 | 5.5 | 4.4 | 3.7 | 3.2 | 150 | 7.4 | 5.7 | 4.9 | 3.7 | 2.9 | 2.4 | 2.1 |
| 1100 | 100 | 9.9 | 7.6 | 6.6 | 4.9 | 3.9 | 3.3 | 2.8 | 140 | 6.6 | 5.1 | 4.4 | 3.3 | 2.6 | 2.2 | 1.9 |
| 1200 | 90 | 8.7 | 6.7 | 5.8 | 4.3 | 3.5 | 2.9 | 2.5 | 130 | 5.9 | 4.5 | 3.9 | 2.9 | 2.3 | 1.9 | 1.7 |
| 1300 | 85 | 7.6 | 5.9 | 5.1 | 3.8 | 3.1 | 2.5 | 2.2 | 120 | 5.1 | 3.9 | 3.4 | 2.5 | 2.0 | 1.7 | 1.5 |
| 1400 | 85 | 6.6 | 5.1 | 4.4 | 3.3 | 2.7 | 2.2 | 1.9 | 110 | 4.4 | 3.4 | 2.9 | 2.2 | 1.7 | 1.5 | 1.3 |
| 1500 | 85 | 5.7 | 4.4 | 3.8 | 2.8 | 2.3 | 1.9 | 1.6 | 105 | 3.8 | 2.9 | 2.5 | 1.9 | 1.5 | 1.3 | 1.1 |
| 1600 | 85 | 4.8 | 3.7 | 3.2 | 2.4 | 1.9 | 1.6 | 1.4 | 100 | 3.3 | 2.5 | 2.2 | 1.6 | 1.3 | 1.1 | 0.9 |

| Distance in m. | 200 m. deep fire | | | | | | | | 300 m. deep fire | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth of useful part at target in m. | Clear interval in m. | | | | | | | Depth of useful part at target in m. | Clear interval in m. | | | | | | |
| | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | | 0.5 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| 800 | 240 | 7.5 | 5.8 | 5.0 | 3.7 | 3.0 | 2.5 | 2.1 | 300 | 4.9 | 3.8 | 3.3 | 2.5 | 2.0 | 1.7 | 1.5 |
| 900 | 230 | 6.5 | 5.0 | 4.3 | 3.2 | 2.6 | 2.2 | 1.8 | 300 | 4.3 | 3.3 | 2.9 | 2.2 | 1.7 | 1.5 | 1.3 |
| 1000 | 220 | 5.6 | 4.3 | 3.7 | 2.8 | 2.2 | 1.9 | 1.6 | 300 | 3.8 | 2.9 | 2.5 | 1.9 | 1.5 | 1.3 | 1.1 |
| 1100 | 210 | 4.8 | 3.7 | 3.2 | 2.4 | 1.9 | 1.6 | 1.4 | 330 | 3.3 | 2.5 | 2.1 | 1.6 | 1.3 | 1.1 | 0.9 |
| 1200 | 200 | 4.1 | 3.1 | 2.7 | 2.0 | 1.6 | 1.4 | 1.2 | 300 | 2.8 | 2.2 | 1.8 | 1.3 | 1.1 | 1.0 | 0.8 |
| 1300 | 200 | 3.4 | 2.6 | 2.3 | 1.7 | 1.4 | 1.2 | 1.0 | 300 | 2.4 | 1.8 | 1.5 | 1.1 | 1.0 | 0.8 | 0.7 |
| 1400 | 200 | 2.9 | 2.2 | 1.9 | 1.4 | 1.2 | 1.0 | 0.8 | 300 | 2.0 | 1.5 | 1.3 | 1.0 | 0.8 | 0.7 | 0.6 |
| 1500 | 200 | 2.4 | 1.8 | 1.5 | 1.1 | 1.0 | 0.8 | 0.7 | 300 | 1.7 | 1.3 | 1.1 | 0.8 | 0.7 | 0.6 | 0.5 |
| 1600 | 200 | 1.9 | 1.4 | 1.2 | 0.9 | 0.8 | 0.6 | 0.5 | 300 | 1.4 | 1.1 | 0.9 | 0.7 | 0.6 | 0.5 | ... |

through a movement, the location of the enemy's lines—nothing more should be seen. Nevertheless, the enemy's position is densely and almost uniformly occupied, and his fire forces the leader to counter action and therefore to fire against invisible targets, against sections of terrain.

Right here the full value of firing with the graduated scale becomes apparent: the leader is enabled to cover the enemy's position systematically with fire. The skill of the leader and his subordinates shows here to great advantage, as without it, failure will be the only result. But so much the better; leaders of this kind should not be entrusted with machine guns in war.

How can targets be set up to simulate service conditions?

It is not absolutely necessary to place a silhouette at every spot where an enemy skirmisher would lie; it is sufficient if every target can be hit considering the angle of fall.

Should the section of terrain be correctly searched with the machine guns, the target will receive the same percentage of hits 10 meters in front or in rear.

It is of utmost importance to fire against such targets in peace; of course, there are other targets, but they do not pertain to this chapter which discusses only systematic deep fire.

The Tables of Fire Effect give an actual illustration of what the machine gun is capable in similar cases under service conditions, and if we assume the minimum requirement as 0.5 per cent direct hits, it is easy to calculate whether or not in any given case effective results can be obtained. The Tables of Fire Effect also indicate how much ammunition must be expended to obtain sufficient effect at the target.

These are not problems for deliberation during the firing, but they are preparations for firing which the director must work out at home.

Example:

The company commander intends firing against nearly invisible head targets at 1 meter interval, with 200 meters deep fire at 1,100 meters. He wishes to find out if it will pay to use such deep fire, and also how much ammunition he must expend in this case to obtain a satisfactory result.

Table I, Head Targets, shows:

With 200 meters deep fire, range 1,100 meters and 1 meter interval = 0.7 per cent direct hits.

Should the company commander consider about 35 or 40 direct hits a satisfactory result, the amount of the ammunition required would be 5,000 to 6,000 rounds, since—

$$\frac{0.7 \times 5000}{100} = 35 \text{ and } \frac{0.7 \times 6000}{100} = 42 \text{ direct hits.}$$

Adding thereto the ricochets, the company commander will obtain a satisfactory result with 5,000 rounds.

The result will be obtained in about 3 minutes, with absolute certainty.

## CHAPTER 7. CRITIQUE OF THE RESULTS OF MACHINE-GUN FIRE.

Critique of results depends upon the conditions of observation under which the firing was held. The visibility of the target also plays an important part, as is evident from the preceding chapter. A machine-gun company which obtains many hits under favorable observation, is by no means better trained than the one which obtains fewer hits under poor observation. To give a just critique, the amount of deep fire each machine gun used must be recorded during the firing. The results which a well trained company should obtain can then be quickly calculated with the aid of the Tables of Fire Effect. As a machine gun will only in exceptional cases retain the deep fire ordered at the beginning during the entire firing, but will in most cases narrow the sheaf, an impartial observer with each machine gun must note about how many shots were fired with each kind of deep fire.

When this data has been assembled, the calculated results compared with the hits obtained (direct hits) show whether the company fired well or poorly.[8]

Care must be taken not to be deceived by reports of a deeper fire than was really used. The officer in charge can easily determine this by observing the turning of the handwheel from time to time.

It is the director's duty to decide whether the amount of deep fire used was correct, or if more or less deep fire would have been proper.

[8] See examples on pages 33 and 34.

## Critique of the Results of the Machine Gun Fire.

EXAMPLE 1

Target 1. Head Targets at 1000 m. Interval 0.8 m.

| 1. M. G. | | 2. M. G. | | 3. M. G. | | 4. M. G. | | 5. M. G. | | 6. M. G. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of shots | Deep fire | Number of shots | Deep fire | Number of shots | Deep fire | Number of shots | Deep fire | Number of shots | Deep fire | Number of shots | Deep fire |
| 200<br>500<br>100 | 50 m.<br>100 m.<br>200 m. | 500<br>100 | 50 m.<br>None | 300<br>500 | None<br>50 m. | 100<br>500 | 50 m.<br>100 m. | 100<br>600 | 50 m.<br>200 m. | 700<br>300 | 200 m.<br>100 m. |
| 100 shots with 200 m. deep fire = (1 × 0.9) = 0.9 direct hits<br>Total, 60.7 direct hits. | 200 shots with 50 m. deep fire = (2 × 1.7) = 3.4 direct hits.<br>500 shots with 100 m. deep fire = (5 × 1.1) = 5.5 direct hits. | 100 shots, no deep fire = (1 × 2.5) = 2.5 direct hits. | 500 shots with 50 m. deep fire = (5 × 1.7) = 8.5 direct hits. | 500 shots with 50 m. deep fire = (5 × 1.7) = 8.5 direct hits. | 300 shots, no deep fire = (3 × 2.5) = 7.5 direct hits. | 500 shots with 100 m. deep fire = (5 × 1.1) = 5.5 direct hits. | 100 shots with 50 m. deep fire = (1 × 1.7) = 1.7 direct hits. | 600 shots with 200 m. deep fire = (6.0 × 9) = 5.4 direct hits. | 100 shots with 50 m. deep fire = (1 × 1.7) = 1.7 direct hits. | 300 shots with 100 m. deep fire = (3 × 1.1) = 3.3 direct hits. | 700 shots with 200 m. deep fire = (7.0 × 9) = 6.3 direct hits. |

The company should have obtained about sixty direct hits.

EXAMPLE 2

Target 2. The same at 1300 m. (kneeling targets) with 2 m. interval

| 1. M. G. | | 2. M. G. | | 3. M. G. | | 4. M. G. | | 5. M. G. | | 6. M. G. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of shots | Deep fire | Number of shots | Deep fire | Number of shots | Deep fire | Number of shots | Deep fire | Number of shots | Deep fire | Number of shots | Deep fire |
| 200 | 300 m. | 250 | 300 m. | Jams | | 100<br>200 | 300 m.<br>200 m. | 250 | 300 m. | 200<br>100 | 300 m.<br>100 m. |
| 1.2 direct hits. | | 1.5 direct hits. | | | | 1.8 direct hits. | 0.6 direct hits. | 1.5 direct hits. | | 1.2 direct hits. | 1.2 direct hits. |
| 9.0 total direct hits. | | | | | | | | | | | |

The company should have obtained 9 direct hits.

## B. FIRE EFFECT UNDER SPECIAL SERVICE CONDITIONS.

### CHAPTER 8. ERRORS IN RANGE FINDING.

(Using the Hahn Range Finder and Range Finder No. 14.)

Should the distance to a target be measured with a well-adjusted Hahn range finder, the measurement may differ from the correct distance about as follows:

Up to 1000 m., 2-3% of the distance;
Up to 1500 m., 3-3½% of the distance;
Up to 2000 m., 3½-5½% of the distance;

The range finder 14 is much more accurate.

Should, *e.g.*, the correct distance to the target be 1000 meters, the measurement may be between 970 and 1030 meters. Inversely, the target may lie between 970 and 1030 m. when 1000 m. was measured.

These errors in range finding would be of little consequence if for every distance there were a corresponding sight setting. The sight, however, permits only 50 meters change; for the intermediate distances there is but one sight setting available, *e.g.*, the 950 meters sight setting is used for all firing between 900 and 950 meters, and also between 920 and 970 meters. As these distances are first determined with the range finder and are therefore not exact, the errors in range finding become of more importance in this connection, as the following example will show:

A machine gun measured 920 meters as the range to a line of head targets, and fired with sight at 950. The range-finder reading was 3% over the correct distance, which was 893 meters.

A second machine gun, 107 meters in rear, measured 970 meters to the same target, and also sights at 950 meters. The range-finder reading was 3% short, the correct distance being 1000 meters.

Both guns determined the distance with a comparatively small error, which may occur even with new range finders. However, should both guns succeed in bringing the useful part of the sheaf in the target, *i.e.*, with sights at 950 meters to deliver effective fire at 893 as well as at 1000 meters, the sheaf must have a depth of at least 107 meters. The table on page 175 shows, however, that the beaten zone at 950 meters is only about 70 meters deep, the remainder would, therefore, have to be supplemented with deep fire.

In the hands of troops, the range finders will often show greater errors, and consequently greater differences between distance to target and sight setting will occur, on account of which the extent of the supplementary deep fire must also be greater.

It is assumed here that the range measurer does not make any error at all. But even an experienced range measurer obtains materially different results when making several measurements to one and the same target, and the differences become greater with increase of the distance to the target and decrease in its visibility. Even the best range finder cannot eliminate errors in measuring distances, and errors are the rule.

The new range finder 14 is an excellent optical instrument, but from the foregoing it is seen that errors are also made with it, and the deep fire should not be too rapidly narrowed.

Leaving out of consideration the accuracy of range-finding, weather conditions (Chapter 10, p. 186) also influence the range of the bullet materially.

## CHAPTER 9. ERRORS IN ESTIMATING DISTANCE.

The determination of the distance by estimation is much less accurate than with the range finder. Long years of experiment have demonstrated that in general the better half of all estimates at one object lie in a space extending 10% of the distance in front or in rear of the target.

In estimating, *e.g.*, to a target 1200 meters distant, the better half of the estimates will lie between 1080 (= 1200 — 120) and 1320 (= 1200 + 120). The remaining estimates will be distributed over a space four or five times as large, and therefore in the above-mentioned case may lie between 600 and 1800 meters.

Reversing the case and selecting a definite sight setting corresponding to the estimate, the target will be often at a materially different distance. Even when only considering the better half of all estimates in an example, the unreliability of the procedure becomes very apparent.

A machine gun fires at a target with sight set at 950 meters based on an estimate of 920 meters. Even should this be the estimate of the better half, the correct distance could be about 840 meters (to 1020).

A second machine gun, in rear, also fires at the target with sight at 950 meters based on an estimate of 970 meters. The correct range could be about (880 to) 1080 meters.

In sum, with estimates of 920 and 970 meters, both resulting in a sight setting of 950 m., the distance could be between 840 and 1080 m.

To secure fire effect with certainty, the first machine gun would, therefore, be compelled to cover the zone from 840 to 1020, the second the zone from 880 to 1080—both with 950 meters sight setting.

As there is no actual certainty that the estimates were those of the better half, the errors may be considerably greater.

Observation in war has substantiated this fully, as enormous errors have been observed by the author, who had the excellent range finder No. 14 at his disposal, and was, therefore, enabled to check the sight settings of adjacent organizations. To their great discomfiture, I was able at one time, for example, to prove that a target at 1850 meters was fired at with sight at 950 meters; another time a target 2000 meters distant with 1200 meters sight; a third time with the fixed sight at a target at 700 meters!

Could we ourselves have made a better estimate? I doubt it, and he who asserts that he would never make such errors should check himself with range finder 14—after he has estimated—and this in battle, under fire, when he must decide on the range quickly.

It is the universal desire that every platoon commander be provided with an instrument for measuring distance which will protect him at least from excessively great errors; it is to be hoped that our optical industry will soon succeed in giving us such an instrument, handy and light.

## CHAPTER 10. INFLUENCES OF WEATHER.

In its flight from the muzzle to the target, the bullet is subject, in addition to the natural law of gravity, to the varying atmospheric influences. The resistance the bullet encounters in its flight is mainly dependent on the following:

(*a*) Weight of the air (*Luftgewicht*[9]).

(*b*) Motion of the air.

[9]The correct technical equivalent for the word here used in the German text is "density of the air." The literal translation "weight of the air" is here employed, as otherwise the explanation which follows would be meaningless.—Editor.

### (*a*) *Weight of the Air.*

To assist the officer who is not familiar with such details, various points will be more fully explained in the following, which to the expert seem self-evident. The expression "weight of the air" does not mean the air pressure, as read from a barometer, but denotes the density of the air—the mass the bullet must penetrate in its flight. When it is said that the density of the air is 1225, it is meant that 1 cubic meter of air weighs 1225 grams.

TABLE A.

Weight of a cubic meter of air in grams with 50 per cent humidity and various barometer and thermometer readings:

| Temperature in degrees C. | With a barometer reading of | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 710 | 720 | 730 | 740 | 750 | 760 | 770 | 780 |
| +30 | 1080 | 1095 | 1110 | 1126 | 1141 | 1156 | 1172 | 1187 |
| +25 | 1100 | 1115 | 1131 | 1147 | 1162 | 1177 | 1193 | 1209 |
| +20 | 1121 | 1137 | 1152 | 1168 | 1184 | 1200 | 1216 | 1232 |
| +15 | 1142 | 1158 | 1174 | 1190 | 1207 | 1223 | 1239 | 1255 |
| +10 | 1163 | 1179 | 1196 | 1212 | 1229 | 1245 | 1261 | 1278 |
| + 5 | 1185 | 1202 | 1219 | 1235 | 1242 | 1268 | 1285 | 1302 |
| ± 0 | 1207 | 1224 | 1241 | 1258 | 1275 | 1292 | 1309 | 1326 |
| − 5 | 1231 | 1247 | 1265 | 1282 | 1299 | 1317 | 1334 | 1351 |
| −10 | 1254 | 1271 | 1289 | 1307 | 1324 | 1342 | 1360 | 1378 |
| −15 | 1278 | 1296 | 1315 | 1333 | 1351 | 1369 | 1387 | 1405 |
| −20 | 1304 | 1322 | 1341 | 1359 | 1377 | 1396 | 1414 | 1432 |

The greater the weight of the air, the denser it is, and the denser is the mass the bullet has to penetrate, and low shooting is the result. The lighter the weight, the thinner is the air, and the bullet has less resistance to overcome, and high shooting results.

The density of the air is dependent on:

1. The air pressure, indicated by the barometer reading. The higher the barometer reading, the more compressed is the air, and denser it is.

2. The temperature, indicated by the thermometer reading. The higher the temperature, the more expanded and thinner is the air. Here it is to be noted that with the same air pressure, different temperatures may obtain and vice versa, and that for this reason both these influences may enhance or neutralize each other.

3. The humidity of the air, which is so small as to be immaterial in practice.

### Table B.

In the following table the preceding table is converted into a form suitable for practical use; the data are of course only approximate:

At about 1000 m. distance, the sheaf is displaced in meters:

| Temperature in degrees C. | With a barometer reading of | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 710 | 720 | 730 | 740 | 750 | 760 | 770 | 780 |
| +30° | m +70 | m +60 | m +55 | m +50 | m +40 | m +35 | m +30 | m +20 |
| +25° | +60 | +50 | +45 | +40 | +30 | +25 | +15 | +10 |
| +20° | +50 | +40 | +35 | +30 | +20 | +10 | + 5 | ± 0 |
| +15° | +40 | +30 | +25 | +20 | +10 | ± 0 | − 5 | −15 |
| +10° | +30 | +20 | +15 | + 5 | ± 0 | −10 | −20 | −25 |
| + 5° | +20 | +10 | + 5 | −10 | −10 | −20 | −30 | −40 |
| ± 0° | +10 | ± 0 | −10 | −20 | −25 | −30 | −40 | −50 |
| − 5° | ± 0 | −10 | −20 | −30 | −35 | −45 | −55 | −60 |
| −10° | −15 | −20 | −30 | −40 | −50 | −60 | −70 | −75 |
| −15° | −25 | −35 | −45 | −55 | −65 | −70 | −80 | −90 |
| −20° | −40 | −50 | −60 | −65 | −75 | −85 | −95 | −100 |

At a range to the target of about 1500 meters, the sheaf is displaced about twice these amounts.

Our sights are regulated on an air density of 1225 grams. It follows that with an air density of 1225 the bullet strikes where aimed. An air density of 1225 grams, however, is not dependent on either the temperature or the air pressure alone, but the line running diagonally through the table shows when conditions are such that the bullet strikes where aimed, *e.g.,* with —5° C. and a barometer reading of 710 or with +20° C. and a barometer reading 780. There only remains to be ascertained how much the range is increased or decreased. It may be said approximately that a change in the air density of 20 grams changes the range:

at a distance of 1000 m., about 10 m.;
at a distance of 1500 m., about 15-20 m.

(*b*) *Motion of the air.*

The stronger the motion of the air, the more the bullet will be deflected in its flight. Head wind shortens the range, wind obliquely from the rear lengthens the range and also deflects the bullet.

The effect of the wind is more difficult to estimate than the influence of the density of the air, as its direction and force not only change constantly, but also change with the elevation above the ground, and it may assume an entirely different direction and force at a distance from the firer. Gusty winds not only result in displacement of the sheaf, but also in a wider dispersion. As a basis for judging the wind and its influence on the range, the following may be of advantage:

| Force of wind* | Distance | Effect on | |
|---|---|---|---|
| | | Range | Sheaf, laterally |
| 0.5–7 m. sec.<br>Light—moderate | 1000 m.<br>1500 m. | Up to 15 m.<br>Up to 30 m. | Up to 7 m.<br>Up to 15 m. |
| 8–16 m. sec.<br>Brisk—strong | 1000 m.<br>1500 m. | Up to 30 m.<br>Up to 70 m. | Up to 15 m.<br>Up to 40 m. |

* Judging the force of the wind appears difficult, but is very simple if powder smoke and steam from the machine gun is watched, and, at the same time, the period of one second fixed. Light dust or tobacco smoke serve the same purpose.

These figures are merely reference points and mark the approximate limits within which the displacement of the sheaf takes place. It must be considered that wind from the right will have less influence than wind from the left, as the drift of the bullet counteracts its influence. In this connection, it is to be noted that on account of the faulty setting up of the sled and the error caused by its vibration, deflection to the left may result despite the drift to the right and wind from the left, as was incontestably demonstrated by the gun-proving board, even though drift to the right always results in deflection of the bullet to the right.

CHAPTER 11. LOW SHOOTING OF THE MACHINE GUN.

When a well adjusted machine gun fires series fire at a target and then passes to sustained fire, the sheaf of the latter is often shorter than that of the former. The cause for this is not yet satisfactorily explained, but this much has been established that in fire for effect, a range 50 meters higher than was used in series fire is generally required. With some machine guns, the sheaf does not fall at all, but with others as much as 100 meters. The platoon and gun commanders must watch their guns for this tendency during field firing and consider the observations made in selecting the sight setting.

A further falling of the sheaf in sustained fire does not occur if there is sufficient water in the jacket. Should the barrel be not sufficiently covered with water, about 2 centimeters deep, parts of the barrel will be out of the water when it boils. This results, *e.g.*, at a range of 1000 meters, in shortening the range as much as 200 meters. In addition, the sheaf in this low shooting is materially enlarged and becomes so thin that the result obtained is out of all proportion to the amount of ammunition used.

Should jams occur in a machine gun that has previously worked well, the fault lies in most cases in the shortage of water in the jacket. During these jams, the dispersion is also much greater, and at the same time the sheaf falls considerably.

It is useless to shoot while there are jams, as there can be no hits. It is better to take time to refill the water jacket at once and not fire until this is done.

# PART III.

## MACHINE-GUN FIRE IN TACTICAL UNITS.

CHAPTER 12. FIRING WITH MACHINE GUN OVER OUR OWN TROOPS.

Should machine guns be placed in the firing lines of our own troops, they are forced to advance by rushes with the infantry. This is, however, very difficult to execute on account of the bulk of the material (ammunition, water), and particularly on account of the necessity for an assured ammunition supply. Moreover, machine guns especially draw the hostile fire, thus exposing the accompanying infantry to heavy losses. For this reason, machine guns should, if possible, be removed from the firing line, and should be posted so that they can shoot over the heads of our troops. The enemy will thus be compelled to divide his fire between the machine guns and the firing line. Firing through the gaps of our own lines has very seldom been practicable in service; machine guns therefore always seek to shoot over the heads of their own troops.

Our own troops can be fired over with entire safety since the sled with its aiming apparatus permits of the certain control of the machine-gun sheaf. In a flat country, firing over the heads of the firing line is barred on account of the flatness of the trajectory. Theoretically, it would be practicable to fire over the heads of our troops without danger at the longer ranges on account of the height of the trajectory (see Appendix), but the line of sight would always be directed at our own troops or pass very slightly above them, so that such shooting is out of the question.

One requirement is to be able to distinguish friend and enemy from the position of the machine gun in order to prevent mistakes in observing the strike of the bullets. Elevating the line of sight 3 meters over the heads of our own troops is sufficient to exclude the possibility of endangering them.

As shooting over our own troops in a flat country, for reasons stated above, is out of the question, machine guns must try to secure commanding positions. Such positions need not be as high as those for artillery, but only high enough to permit the line of sight to be elevated 3 meters above our own firing line as above stated. For the same reason, machine guns can shoot over our troops when the enemy occupies a commanding position. A commanding position on the part of the enemy is particularly advantageous when the slope in front of his position is very steep. The steeper the slope, the longer can we fire over our own advancing troops without endangering them.

The closer our lines approach the enemy, the more care must our officers take that they do not come within the sheaves of the machine gun. For this reason, an approximate knowledge of the vertical and horizontal diameters of the machine-gun sheaves is necessary. In the following tables, the dimensions of the sheaf with 100 meters deep fire are shown; this is the maximum deep fire permissible in firing over our own troops.

Depth of the 100 per cent machine-gun sheaf with 100 meters deep fire:

| Distance in m. | Depth of the sheaf in m. | Distance in m. | Depth of the sheaf in m. |
|---|---|---|---|
| 800 | 460 | 1200 | 260 |
| 900 | 385 | 1300 | 240 |
| 1000 | 330 | 1400 | 225 |
| 1100 | 290 | 1500 | 215 |

The 100 per cent vertical diameter with 100 meters deep fire:

| At a distance of m. | 100 per cent vertical diameter at a range to the target of | |
|---|---|---|
| | 1000 m. | 1500 m. |
| 100 | 1 | 1.5 |
| 200 | 2 | 2.5 |
| 300 | 3 | 4 |
| 400 | 4 | 5 |
| 500 | 5 | 6.5 |
| 600 | 6 | 8 |
| 700 | 7 | 9 |
| 800 | 8 | 10.5 |
| 900 | 9 | 12 |
| 1000 | 10 | 13 |
| 1100 | .. | 14.5 |
| 1200 | .. | 16 |
| 1300 | .. | 17 |
| 1400 | .. | 18.5 |
| 1500 | .. | 20 |

When firing over our own troops, the machine-gun barrels should not be used above 6,000 rounds.[10] The water jacket must always be full. Should the water in the jacket be cool at the beginning of the firing, 1,000 rounds can be fired without interruption from the same barrel without materially enlarging the sheaf or altering its center of impact. Further firing requires the refilling of the jacket after every 500 rounds. With barrels which have been fired beyond these limits or are insufficiently submerged in water, the beaten zone is at once enlarged by several hundred meters.

[10]If the barrel has been used for firing, and there was too little water in the gun, the barrel can no longer be used for firing over our own troops, and new barrels should be placed in the gun for such firing.

Firing through trees, brush, or even bunches of grass should be absolutely avoided, as the resulting ricochets endanger our troops. In firing over our own troops, the machine gun must be so elevated that it will be impossible for the bullets to graze the vegetation of the foreground.

The probability that in cross fire bullets will strike each other and thus endanger our own troops, is so slight that it cannot affect our firing over them in battle.

Firing over our troops has justified itself to a remarkable degree in service. All prejudices against it, held in time of peace, soon vanished.

The moral effect of firing over our own firing lines, which it was feared would be demoralizing, was on the contrary reassuring and aroused the attacking spirit, as the men know that the enemy will be covered with heavy machine-gun fire during their rushes.

The author has never observed any wounding of our men through firing over them, despite the fact the required 3 meter elevation of the line of sight was on several occasions not available.

Experiences in the field have demonstrated that the division of the hostile fire caused by firing over our own troops was always very marked; the losses were never as great as when the enemy fired on the machine gun and the firing line with the same sheaf.

## CHAPTER 13. FIRING AGAINST AEROPLANES.

This chapter is not based on the report of the gun-proving board, but represents only the author's views on firing against aerial targets.

The experiences of the war in firing against aeroplanes with machine guns and infantry are so far not very encouraging. What is the cause of these poor results, if these apparent failures may be so termed?

In the following discussion, particular mistakes and rules for firing will be discussed.

### (*a*) *The number of machine guns.*

Firing at aeroplanes may best be compared with shooting at partridges in hunting. Even the non-hunter knows that a partridge is not hunted with bullets, but with shot. Why? Because a rifle bullet flies past the mark, but a sheaf is formed of the many trajectories of shot. The denser and the larger the sheaf, the greater the chances of hitting a partridge. A shot gun which compresses its sheaf in a narrow space, is indeed dense but so small and narrow that it is easier to miss with it than with a large, wide sheaf.

I will compare the dimensions of these two sheaves with a machine gun with which 100 and 300 meter deep fire is executed. Here also the 100 meter sheaf is denser, the different trajectories lying closer together. It is therefore better to use 300 meters deep fire, but the sheaf must, nevertheless, be dense, and therefore several machine guns are required. How many? The more, the better, but all guns must form one large, dense sheaf, otherwise dispersion will naturally result.

I hope in this discussion to convert those who so far employed only one or two guns. In my opinion, the simultaneous and unified employment of at least six machine guns is necessary.

### (*b*) *Aiming in front of the target.*

Aim must be taken at a point as many meters in advance of the target as the target travels during the time required for the bullet to reach it. If this amount is exactly known, the required amount of windage can be taken on the sight, aim taken directly at the aeroplane, and the target kept continuously in the machine-gun sheaf. In hunting, such devices are unknown, and the hunter must determine instantly how far he has to aim in front of the target. Each individual case is also different; the target is viewed sometimes from the side, at other times straight from the front, and then again obliquely from the rear.

Differing from the shotgun, the machine-gun sheaf is continuing in point of time; necessary measures must therefore be taken during the firing as soon as the target changes its direction.

The speed of the targets also differs, one flies faster, another slower, but unfortunately this is not known, as the distance is too great to determine it.

I am, therefore, of the opinion, that those who require such an accurately measured amount of aim in front of the target, and follow the target with the sight, are on the wrong track.

From our firing so far, we can utilize to advantage against aeroplanes the many experiments which we have made against targets moving rapidly in a lateral direction. Hundreds of times we have tried to follow the target, but we always reverted to the practice of placing the machine-gun sheaf a distance in front of the target, holding it there and using deep fire until the target has passed through it. The cause of the fact that few hits were made, even with this method, lies principally in the insufficient amount of ammunition, *i.e.*, not enough machine guns were used because, as was said, "the target was not worth it." A second cause of the failure is that during the firing observation becomes possible and the gun commander shifts or narrows the sheaf (which, though thin, is correctly placed) so much that the target just passes it.

In the air, no observation is possible, and we must therefore employ a method of dispersion so great that not only will the amount of holding in front of the target be correctly estimated, but also the dispersion in depth will be so great that the target must absolutely pass through the sheaf.

More will be presently said about aiming in front of the target.

The fastest fliers—and we must reckon with this class—attain a speed of about 150 km. per hour. Such a machine, therefore, covers about 40 meters in one second. It is then necessary to aim as many times 40 meters in front of the target as the bullet requires seconds to reach the target; these factors are:

at 1000 m. about 2 sec. = 2 x 40 = 80 m.
at 1500 m. " 4 " = 4 x 40 = 160 m.
at 2000 m. " 7 " = 7 x 40 = 280 m.

How is the amount now determined? I have used the following very simple method, not only against air targets but also against any other kind:

Extend the right arm and sight with one eye at a target over the thumb; close the eye and sight with the other eye; a point will thus be obtained whose lateral distance from the target is almost exactly 100 meters at a distance of 1000 meters. Any soldier can easily keep this measurement with the eye. Make the trial. I have trained soldiers with flags set up at lateral intervals, and have always found that they discovered the point immediately when I said, *e.g.*: "250 meters to the right of the lone tree!"

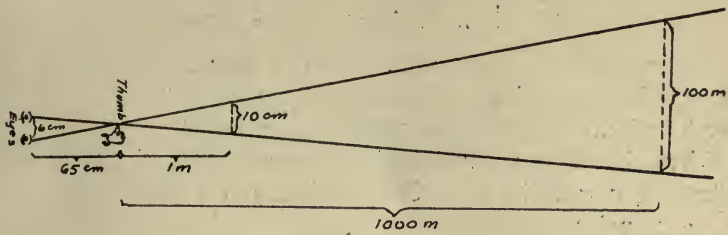


FIGURE 10.

If this is not believed, the following calculations may be convincing:

Interpupillary distance about 6 cm.;
Distance from the eye to thumb about 65 cm.;
We therefore have:

$$65 \text{ cm.} = 6 \text{ cm.}$$

$$1 \text{ cm.} = \frac{6}{65} \text{ cm.}$$

$$100 \text{ cm.} = \frac{6 \times 160}{65} = 9.2 \text{ cm.}$$

$$100 \text{ m.} = 9.2 \text{ m.}$$

$$1000 \text{ m.} = 92 \text{ m.}$$

or about 100 m., sufficiently accurate for practical purposes.

In announcing ranges, this measure of 100 meters is the unit of measure. It is immaterial whether the target is 800, 1000 or 1500 meters distant. The command, "Hold 100 meters in front of the target," means the interpupillary distance projected over the thumb. Of course, to avoid this, the command could as well be: "One width in front of the target," or any other similar command.

With the interpupillary distance as the unit of measure, I always obtain the following results:

| | | |
|---|---|---|
| at 100 m. | about | 10 m. |
| at 1000 m. | " | 100 m. |
| at 1500 m. | " | 150 m. |
| at 2000 m. | " | 200 m. |

Should the flying target, therefore, pass exactly at right angles at a range of 1500 meters, it would be necessary to hold 160 = a little more than one width, or in practice:[11]

"1½ width in front of the target!"

I never had any difficulties with this target designation, but have had many when the command was: "'10' or even '20' lengths of the aeroplane in front of the target."

When the aiming point has been found, there is no difficulty in holding it with the eye. Clouds often give a most satisfactory reference point.

The height of the target can also be easily transferred laterally. The machine gun is then held on the established aiming point with sustained fire and delivers deep fire, described in the next section, until the flier has about reached this point. The process is then repeated as in the case of objects moving rapidly in a lateral direction on the ground.

Wind from the side, on which we are so dependent in the case of targets on the ground, need not be considered as the aerial target will be deflected by it nearly as much as the bullet.

### (*c*) *Deep Fire.*

From section (*a*), we have already seen that it is advantageous to secure a large, wide sheaf. Deep fire from 1500 to 1200 meters, *i.e.,* 3 lines, is recommended. If this is tested with the sight settings, it will be found that it is a very deep fire, but it can be easily executed with the right hand.

This deep fire is always used against aeroplanes, regardless of whether the firing is at 800, 1000 or 1500 meters.

The sheaf is thus of constant dimensions with the following vertical diameters:

at 500 m. = 10.4 m.
at 1000 m. = 20.9 m.
at 1500 m. = 31.2 m.

The machine guns thus cover with their sheaves a space which aeroplanes can hardly pass.

They will be unable to escape such a great sheaf by rising and descending (gliding), because they neither see nor hear it.

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[11] See calculations on page 46.

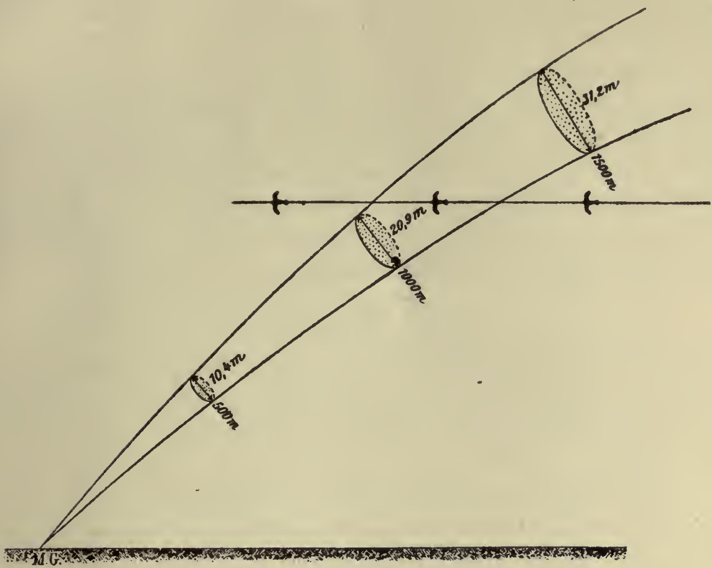


FIGURE 11.

It is therefore only necessary to bring the sheaf in front of the target.

*(d) Distance.*

It has been often asserted that the distance to an aeroplane could be estimated after some practice. I admire such artists, but I doubt their skill, since—

1. Aeroplanes are of different sizes.
2. Aeroplanes do not always present their broad sides; their length is therefore not always shown.
3. No reference points for estimates exist in the air, in contrast to estimating distance on ground.

It is my opinion that the distance to an aeroplane can never be estimated with any degree of accuracy or certainty.

As a basis for firing against aeroplanes, I consider that the range finder must be relied on in addition to the method already described.

The speed of the aeroplane does not in the least alter this. Should the aeroplane be headed directly toward the machine gun, this must be considered in determining the range.

If no range finder is available, or if it is impossible to obtain the range to the aeroplane, it is much better not to shoot at all, as it would be a waste of ammunition to do so.

Are there indeed such great changes in the distance?

In the next section, this question will be more fully discussed, but it may here be said that this is only the case when the aeroplanes fly very low. High-flying targets, even when they are visible at 80°, always present a kind of a laterally moving target at which aim must always be taken as much in front as if the target were flying in a lateral direction.

### (*e*) *Altitude Angles.*

Aeroplanes fly at an altitude of at least 1000 meters while reconnoitering, but this is an exceptionally low limit. We are mostly concerned with targets at an altitude of from 1500 to 2000 meters.

In examining Figure 12, it is seen that angles of 10-30° do not occur at all; they could be considered only as exceptional cases with which we do not have to reckon.

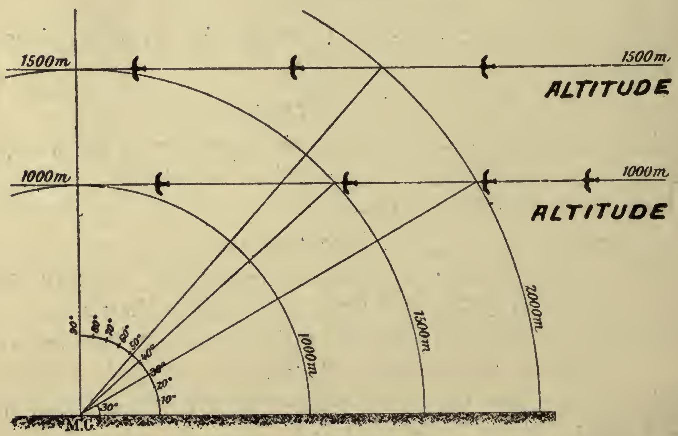


FIGURE 12.

A flying target at an altitude of 1000 meters and a distance of 1500 meters flies at an altitude angle of 40°. A flying target that flies at an altitude of 1500 meters is directly above the machine gun when it is at a distance of 1500 meters. We are therefore concerned with targets which appear, in general, at altitude angles of from 40 to 90°.

Are we able to obtain results against a target flying at such altitudes?

If we take the stand that it is impossible for us to do anything against these aeroplanes, and therefore as a rule do not open fire, they will soon fly lower, and we shall have to reckon more than would otherwise be the case with the well known bombs. We must, therefore, do our best to keep off the aeroplane as far as we can with our ammunition.

I maintain that we can have very good results up to 1500 meters, just as against targets on the ground.

The strong air currents, of which so much is said, exist in general only when there is also a strong wind on the ground. By observing the clouds, it is easily seen whether or not there is a strong wind. In very stormy weather, the clouds generally hang low, and the aeroplanes are compelled to fly lower if they wish to observe anything. It all depends on the ability to bring the target into a systematically laid and very dense sheaf; we have then excellent prospects of hitting the flier, even at distances of 1500 or 1800 meters, regardless of the altitude angle. I would never call such firing waste of ammunition.

*(f) Range Selection—Instruments for measuring angles.*

Everyone knows that in firing with a great angle of elevation, a lower sight setting than the actual range must be used, until finally at an altitude angle of 90° nearly point blank range is used.

Several such tables have been "calculated," but unfortunately none have been actually "fired." It is not so very simple to place a target at a distance of 1500 meters at an altitude angle of 70°. Great elevations and short distances prove nothing.

For the present, we must be satisfied with a calculated range table, *e.g.*, the one calculated by v. Burgsdorff. Should there be errors in the table, the great deep fire will equalize them.

The table alone does not answer the purpose of the machine gun, we must also add the upper half of the deep fire. As, however, we fire with one and the same sheaf at all distances—from 1500 to 1200 meters—and this, therefore, represents a fixed quantity, I have added half of the angle of the coarse deep fire to the table of v. Burgsdorff. The result is the following table:

RANGE TABLE FOR MACHINE GUN FOR USE IN FIRING AGAINST FLYING TARGETS.

| Measured distances* | Range to be announced at† | | | | | 100 per cent vertical diameter‡ |
|---|---|---|---|---|---|---|
| | 40° | 50° | 60° | 70° | 80° | |
| 800 m. | 1000 | 950 | 900 | 850 | 800 | 16.7 m. |
| 900 m. | 1050 | 1000 | 950 | 900 | 800 | 18.8 m. |
| 1000 m. | 1150 | 1100 | 1000 | 950 | 850 | 20.9 m. |
| 1100 m. | 1200 | 1150 | 1050 | 1000 | 850 | 22.9 m. |
| 1200 m. | 1300 | 1200 | 1150 | 1000 | 900 | 25.0 m. |
| 1300 m. | 1350 | 1300 | 1200 | 1050 | 950 | 27.0 m. |
| 1400 m. | 1450 | 1350 | 1250 | 1150 | 950 | 29.1 m. |
| 1500 m. | 1500 | 1450 | 1350 | 1200 | 1000 | 31.2 m. |

* Measured, not estimated.
† Including the coarse deep fire of 1500 to 1200 m.
‡ Of the large sheaf of the deep fire from 1500 to 1200 m.

If, therefore, it is desired, for example, to fire with 50° altitude and 1300 meters measured distance, the command is given: "Range 1300—3 lines," or with 80° altitude and 1400 meters distance: "Range 950—3 lines."[12]

It is now only necessary to determine the angle at which the target is viewed. Until "angle finders" are available, machine-gun troops have to resort to their own devices. A simple piece of board from which a bullet is suspended by a string is sufficient.[13] The table is pasted on the board.

The use of the angle finder is contingent upon the range finder; without the latter the former is valueless.

### (*g*) *Firing Without Deep Fire.*

Deep fire is not appropriate for firing against flying targets which are headed directly towards us and which will, therefore, finally be directly over us; broad fire must here be used in order that the shots may not pass by the target. The extent of the broad fire to be used is dependent on the deflection of the bullets by the wind. To meet all cases, I recommend a broad fire on each side of one-half of the eye and thumb measure, or in total, an entire width. This amount is, of course, very great, but in this way, it is nearly impossible for the flying target to pass by the sides of the sheaf.

I intentionally do not recommend to aim at *one* side against the wind, but on *both* sides, as in firing such great altitude angles,

[12]On the graduated scale.
[13]After the fashion of an improvised clinometer.—Editor.

errors are easily made and the wind conditions are often wrongly estimated. Here again the old principle applies: "The more machine guns, the better."

### (*h*) *Closing Remarks.*

The final objection of those who do not believe in the success of machine guns is the familiar statement that only "chance shots" can hit an aeroplane.

The term, "chance hits," sometimes does a good deal of harm. One may even maintain that every shot, not called as a bull's-eye, is a chance hit. I differ. A hit within a systematically laid sheaf is not a chance hit, but is based on calculation. If we fire with a machine gun against small targets at 1000 meters, with sight set at 1050 meters and 1 line (deep fire), it cannot be called accident if the enemy is hit. By accident, I understand when at 2000 meters, a high, stray bullet hits a man. This is a chance hit.

If we succeed in placing the sheaf correctly on the target, it is good luck when a projectile hits part of the machine, or even the flier himself, in such a manner as to put the machine *hors de combat*. The denser the sheaf, the better the prospect of attaining such a result.

I have no doubt at all that such shooting is possible with machine guns. Of course, well-trained gun pointers are essential, but this can be easily accomplished in a machine-gun company when only one man per gun need be considered, much more thoroughly and easily than in the infantry.

# APPENDIX.

Average Ordinates in Meters of Trajectory Above Horizontal Line of Sight.

| SIGHT SETTING | RANGES 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 | 650 | 700 | 750 | 800 | 850 | 900 | 950 | 1000 | 1050 | 1100 | 1150 | 1200 | 1250 | 1300 | 1350 | 1400 | 1450 | 1500 | 1550 | 1600 | 1650 | 1700 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 400 | 0,15 | 0,25 | 0,35 | 0,35 | 0,35 | 0,30 | 0,20 | 0 | −0,30 | −0,65 | | | | | | | | | | | | | | | | | | | | | | | | |
| 500 | 0,20 | 0,40 | 0,55 | 0,65 | 0,70 | 0,70 | 0,65 | 0,50 | 0,30 | 0 | −0,40 | −0,85 | | | | | | | | | | | | | | | | | | | | | | |
| 600 | 0,30 | 0,50 | 0,75 | 0,90 | 1,05 | 1,10 | 1,15 | 1,10 | 0,95 | 0,70 | 0,40 | 0 | −0,50 | −1,20 | | | | | | | | | | | | | | | | | | | | |
| 700 | 0,35 | 0,70 | 1,00 | 1,25 | 1,45 | 1,65 | 1,75 | 1,75 | 1,70 | 1,55 | 1,35 | 1,00 | 0,55 | 0 | −0,75 | −1,70 | | | | | | | | | | | | | | | | | | |
| 750 | 0,40 | 0,80 | 1,15 | 1,45 | 1,70 | 1,90 | 2,05 | 2,15 | 2,15 | 2,05 | 1,90 | 1,60 | 1,20 | 0,65 | 0 | −0,90 | −1,85 | | | | | | | | | | | | | | | | | |
| 800 | 0,45 | 0,90 | 1,30 | 1,65 | 2,00 | 2,25 | 2,45 | 2,60 | 2,65 | 2,60 | 2,50 | 2,25 | 1,95 | 1,45 | 0,75 | 0 | −1,00 | −2,20 | | | | | | | | | | | | | | | | |
| 850 | 0,50 | 1,00 | 1,45 | 1,90 | 2,25 | 2,60 | 2,85 | 3,05 | 3,15 | 3,15 | 3,10 | 2,95 | 2,65 | 2,25 | 1,65 | 0,90 | 0 | −1,15 | −2,55 | | | | | | | | | | | | | | | |
| 900 | 0,60 | 1,15 | 1,65 | 2,15 | 2,60 | 2,95 | 3,30 | 3,55 | 3,75 | 3,80 | 3,80 | 3,70 | 3,50 | 3,15 | 2,65 | 1,90 | 1,05 | 0 | −1,35 | −2,9 | | | | | | | | | | | | | | |
| 950 | 0,65 | 1,30 | 1,85 | 2,40 | 2,95 | 3,40 | 3,80 | 4,15 | 4,35 | 4,50 | 4,55 | 4,55 | 4,40 | 4,15 | 3,70 | 3,05 | 2,25 | 1,20 | 0 | −1,50 | −3,25 | | | | | | | | | | | | | |
| 1000 | 0,75 | 1,45 | 2,00 | 2,70 | 3,30 | 3,85 | 4,30 | 4,70 | 5,00 | 5,25 | 5,40 | 5,45 | 5,40 | 5,20 | 4,80 | 4,25 | 3,50 | 2,60 | 1,40 | 0 | −1,70 | 3,65 | | | | | | | | | | | | |
| 1050 | 0.8 | 1,6 | 2,3 | 3,1 | 3,7 | 4,3 | 4,9 | 5,4 | 5,8 | 6,1 | 6,3 | 6,4 | 6,4 | 6,3 | 6,0 | 5,5 | 4,9 | 4,0 | 2,9 | 1,6 | 0 | −1,9 | −4,1 | | | | | | | | | | | |
| 1100 | 0,9 | 1,8 | 2,6 | 3,4 | 4,2 | 4,8 | 5,5 | 6,0 | 6.6 | 6,9 | 7,2 | 7,5 | 7,5 | 7,5 | 7,3 | 7.0 | 6,4 | 5,6 | 4,6 | 3,3 | 1,8 | 0 | −2,2 | −4,7 | | | | | | | | | | |
| 1150 | 1,0 | 2,0 | 2,9 | 3.8 | 4,7 | 5,4 | 6,2 | 6,8 | 7,4 | 7,9 | 8,3 | 8,6 | 8,8 | 8,8 | 8,7 | 8,4 | 8,0 | 7,3 | 6,4 | 5,2 | 3,8 | 2,0 | 0 | −2,4 | −5,3 | | | | | | | | | |
| 1200 | 1,1 | 2,2 | 3,3 | 4,2 | 5,2 | 6,0 | 6,8 | 7,6 | 8,3 | 9,0 | 9,5 | 9,8 | 10,1 | 10,2 | 10,2 | 10,1 | 9,7 | 9,1 | 8,3 | 7,2 | 5,9 | 4,3 | 2,3 | 0 | −2,7 | −5,9 | | | | | | | | |
| 1250 | 1,2 | 2,4 | 3,6 | 4.6 | 5,7 | 6,7 | 7,6 | 8,5 | 9,3 | 10,0 | 10,6 | 11,1 | 11,5 | 11.8 | 11,9 | 11,8 | 11,6 | 11,1 | 10,4 | 9,4 | 8,2 | 6,7 | 4,9 | 2,6 | 0 | −3,0 | −6,5 | | | | | | | |
| 1300 | 1,3 | 2,6 | 3,9 | 5.1 | 6,3 | 7,4 | 8,4 | 9,4 | 10,3 | 11,1 | 11,9 | 12,5 | 13,0 | 13,4 | 13,6 | 13,6 | 13,5 | 13,2 | 12,5 | 11,7 | 10,6 | 9,2 | 7,5 | 5,4 | 2,9 | 0 | −3,4 | −7,3 | | | | | | |
| 1350 | 1,5 | 2,9 | 4,3 | 5,6 | 6,9 | 8,1 | 9,3 | 10,4 | 11,4 | 12,4 | 13,3 | 14,0 | 14,7 | 15,2 | 15,5 | 15,6 | 15,6 | 15,4 | 14,9 | 14,2 | 13,3 | 12,0 | 10,5 | 8,5 | 6,1 | 3,3 | 0 | −3,8 | −8,0 | | | | | |
| 1400 | 1,6 | 3,1 | 4,7 | 6,1 | 7.6 | 8,9 | 10,2 | 11,5 | 12,6 | 13,7 | 14,7 | 15,6 | 16,4 | 17,0 | 17,5 | 17,8 | 17,9 | 17,9 | 17,5 | 16,9 | 16,1 | 15,0 | 13,6 | 11,7 | 9,4 | 6,8 | 3,6 | 0 | −4,1 | −8,6 | | | | |
| 1450 | 1,7 | 3.4 | 5,1 | 6,7 | 8,3 | 9,7 | 11,2 | 12,6 | 13,9 | 15.2 | 16,3 | 17,3 | 18,3 | 19,0 | 19,6 | 20,1 | 20,3 | 20,4 | 20,2 | 19,7 | 19.0 | 18,0 | 16,7 | 15,0 | 12,9 | 10,4 | 7,4 | 3,9 | 0 | −4,4 | −9,3 | | | |
| 1500 | 1,8 | 3,7 | 5,5 | 7,3 | 9,0 | 10,6 | 12,2 | 13,7 | 15,2 | 16,6 | 17,9 | 19,1 | 20.2 | 21,1 | 21,8 | 22,4 | 22,8 | 23,0 | 23,0 | 22,6 | 22,1 | 21,2 | 20,0 | 18,5 | 16,6 | 14,2 | 11,3 | 8,0 | 4,2 | 0 | −4,8 | −10,2 | | |
| 1550 | 2.0 | 4,0 | 6,0 | 7,9 | 9,7 | 11,6 | 13,3 | 15,0 | 16,6 | 18,1 | 19,6 | 20,9 | 22,2 | 23,3 | 24,2 | 24,9 | 25,4 | 25,7 | 25,9 | 25,7 | 25,4 | 24,7 | 23,6 | 22,2 | 20,4 | 18,3 | 15,5 | 12,3 | 8,7 | 4,6 | 0 | −5,3 | −11,2 | |
| 1600 | 2,2 | 4,3 | 6,5 | 8,6 | 10,5 | 12,5 | 14,5 | 16,3 | 18,1 | 19,8 | 21,4 | 22,9 | 24,3 | 25,5 | 26,7 | 27,6 | 28,3 | 28,7 | 29,0 | 29,0 | 28,8 | 28,3 | 27,4 | 26,1 | 24,5 | 22,5 | 20,0 | 17,0 | 13,5 | 9,5 | 5,1 | 0 | −5,8 | −12,2 |