MANUAL

FOR THE

BATTERY COMMANDER

FIELD ARTILLERY

*

75-mm. GUN

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BATTERY COMMANDER

FIELD ARTILLERY

75-MM. GUN

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The following pamphlet, Manual for the Battery Commander, Field Artillery, is published for the information of all concerned.

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BY ORDER OF THE SECRETARY OF WAR.

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PREFACE.

The object of the Manual of the Battery Commander is to place in the hands of the officers of the 75-mm. batteries a summary of all necessary information on the occupation of positions, adjustment of fire, and the execution of fire for effect.

All the notes herewith are regulations or are contained in the notes of the G. H. Q.

We have taken up, in a special manner, the study of dispersion, the use of battle maps, firing-data books, correction of the moment, corrections due to atmospheric conditions or variations of weight, fire by single piece directed from an observation station at any given point, barrage fire, and the choice of observation stations, none of these subjects being mentioned in the regulations for the 75-mm. gun.

Everything in the Instruction on Foot Artillery Fire which can be applied to the 75 mm. has been made use of. It is indispensable, whatever matériel be used, that the method be the same. This is true in all that concerns dispersion, adjustment by piece, and fire with lateral or bilateral observation.

Finally, we have developed matter relative to the effects of projectiles according to their type and the manner in which they are fused, to fire with aerial observation, and to the very important question of liaison between the different units of artillery and with the infantry—questions which are becoming more important every day.

MANUAL FOR THE BATTERY COMMANDER, FIELD ARTILLERY.

CHAPTER I.

GENERAL REMARKS.

ARTICLE 1.

DIFFERENT UNITS OF ANGLES.

1. *Degree, grade, mils.*—The different units of angles used in artillery are:

First. The degree, which is the three-hundred-and-sixtieth part of the circumference. One degree equals 60 minutes; one minute equals 60 seconds.

Second. The grade, which is the four-hundredth part of the circumference. One grade equals 10 decigrades.

Third. The mil, which is the six-thousand-four-hundredth part of the circumference. (The mil of certain matériel (155 mm. R. F. How.) is the 6,000th part of the circumference.)

The grade has the advantage over the degree of belonging to the decimal system. The mil has the advantage over the other two in giving a simple formula for the solution of those problems which constantly confront the artilleryman.

2. *Angular deviation, parallax.*—The angular deviation between two points is the angle formed by two vertical planes passing through the observer's eye and each of the points.

The parallax of a point with relation to a line (or a front) is the angle at which the line (or front) is seen by an observer placed at that point.

3. *Relation between a front F and the parallax m* at which the front is seen at a distance D. The front F (AB) is supposed perpendicular to OA (D). Assume the circumference of a circle with a radius equal to 1, with center O, which cuts OA and OB at M and N. Let MP be perpendicular to OM.

In the two similar triangles, OAB and OMP, we have:

(1) $$\frac{F}{MP}=\frac{D}{l}$$

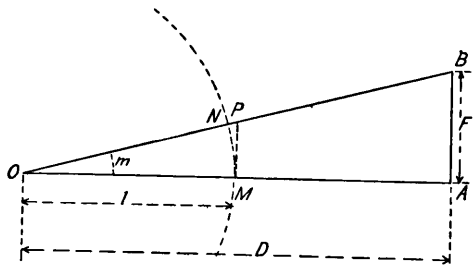


Fig. 1.

The angles m, which we are considering, are sufficiently small in practice, so that we may assume, with sufficient approximation, that the length MP is equal to the length of the arc MN, and the equation (1) becomes:

(2) $$\frac{F}{\text{Arc MN}}=\frac{D}{l}$$

or, expressing m:

In degrees, $$\frac{\text{Arc MN}}{2\pi}=\frac{m}{360}$$

In grades, $$\frac{\text{Arc MN}}{2\pi}=\frac{m}{400}$$

In mils, $$\frac{\text{Arc MN}}{2\pi}=\frac{m}{6400}$$

and the formula (2) gives:

(3) In degrees, $F=Dm\left(\frac{2\pi}{360}\right)$

(4) In grades, $F=Dm\left(\frac{2\pi}{400}\right)$

(5) In mils, $F=Dm\left(\frac{1}{1000}\right)$

(because, $\frac{2\pi}{6400}=\frac{2\,(3.141)}{6400}=\frac{1}{1000}$ approximately).

Formula (5) is more simple than the other two. When we express F in meters and the distance OA in kilometers ($D=1000\,d$), formula (5) is simplified, and becomes:

(6) $$F=d'm.$$

Note 1.—In formula (6), when F=1 and d=1, we find that m=1. The mil is also, therefore, the angle at which one meter is seen at 1000m.

Note 2.—16 mils are equal to 9×6 (=54) minutes, or 10 decigrades.

4. *Use of different units.*—In the 75-mm. gun, the aiming and laying apparatus are graduated in mils. In numerous guns the sights for aiming in direction are graduated in decigrades. The levels, model of 1888–1900, for laying in elevation, are graduated in degrees and minutes.

ARTICLE 2.

IDEAS ON BALLISTICS.

A. THE TARGET IS AT THE SAME ALTITUDE AS THE CENTER OF MUZZLE OF THE GUN.

5. *Definitions.*—The *range* is the distance from gun to the target on which it is firing.

The *line of fire* is the indefinite prolongation of the axis of the gun when the gun is laid.

The *plane of fire* is the vertical plane passing through the line of fire.

The *elevation* is the angle which the line of fire makes with the line gun—target.

The *line of departure* is the line obtained by prolonging indefinitely the original direction of the projectile when it leaves the bore of the gun.[1]

The *jump* is the angle made by the line of fire with the line of departure. For a given gun, this angle is assumed to remain constant, whatever may be the angle of elevation, so long as the charge does not vary. The value of this angle is always very small; for the 75 mm. it is 7 minutes for shrapnel and 1 minute for shell.

6. *Trajectory.*—This is the curved line which the center of gravity of the projectile follows during its course in the air. At its origin—i. e., at the muzzle of the gun—it coincides with the line of departure; later it is deflected more and more by the action of gravity and the resistance of the air.

Due to the resistance of the air, and to their own rotating movement, the oblong projectiles of rifled guns leave the plane of fire and deviate farther and farther from it. We say that they drift, and the distance which they deviate from the plane of fire is called

[1] At the instant the projectile passes the face of the muzzle, it does not follow exactly the line of fire; it generally travels a little above it, but for certain guns (100 R. F., for example) it travels below it.

the *drift*. The drift is in the direction of the rotating motion of the upper part of the projectile—i. e., to the right for the 75 mm.—which is rifled to the right.[1]

Remark: In the following, we will ignore the drift and consider the projection of the trajectory on the plane of fire.

7. *Definitions pertaining to the trajectory.*—

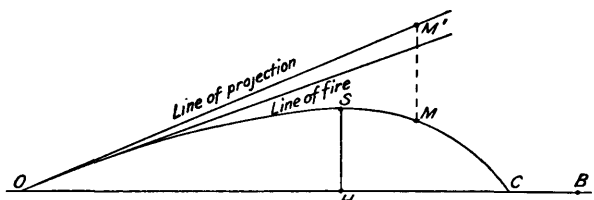


Fig. 2.

Origin, the initial point of the movement in the air (center of muzzle of gun).

Summit, the highest point (S).

Maximum ordinate, the elevation SH of this summit above the horizontal plane of the gun.

Ascending branch, the curve OS included between the origin and the summit.

Descending branch, the curve SC included between the summit and the point of fall.

Point of fall, the point where the trajectory meets the line gun—target.[2]

Base, the right line OC joining the origin with the point of fall.

Range, the distance from the origin O to the point of fall, measured along the base.

Angle of fall, the angle which the trajectory makes at the point of fall with the line gun—target. (It is greater than the elevation.)

Initial velocity, the velocity of the projectile at the muzzle.[3] For a given projectile and gun, the initial velocity depends only on the charge. The new 75-mm. projectiles are marked on the case with the value of their initial velocity (V_o=550).

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[1] All the guns actually in service are rifled to the right, except the 95 mm., which is rifled to the left. The naval guns are rifled some to the right, some to the left.

[2] In practice, we have to extend this definition and call the point of fall the point where the trajectory meets the ground, whether or not this point is on the line gun—target.

[3] The measure of velocity of a moving object is given by the number of meters covered by it in a second if, during that time, the velocity does not vary.

Terminal velocity, the velocity at which the projectile is moving when it reaches the point of fall; it is less than the initial velocity.

Drop in the trajectory at the point M, the distance MM′ from the point M to the point M′ where the vertical line meets the line of departure.

8. *Form of the trajectory.*—The general form of the trajectory depends essentially on the interior and exterior make-up of the projectile, on its initial velocity, on the direction and rapidity of its rotation, and on atmospheric conditions.

These being considered constant,[1] the form of the trajectory varies with the elevation; the other elements result from the latter, and vice versa. There exists between these elements a necessary correlation which can not be changed. For example, if we fix in advance either the range or the angle of fall, the other elements are determined by that, either by calculations based on ballistic formula, or by means of the range tables, where the results of calculation are tabulated.

When the elevation increases from zero, the summit of the trajectory rises and the maximum ordinate and angle of fall increase; the range increases to a maximum, corresponding to an elevation a little less than 45°, then it diminishes to zero for an elevation of about 90°. A given range can thus be obtained by two values of the elevation, one inferior and the other superior to the angle corresponding to the maximum range.

In practice, the 75-mm. guns are fired at angles less than 32° (except in the case of aerial targets, for which a special matériel is constructed). Therefore only the elevation corresponds to a given range, and this angle is given in the range table opposite the given range.

B. THE TARGET IS NOT AT THE SAME ALTITUDE AS THE CENTER OF THE MUZZLE OF THE GUN.

9. The preceding explanations assume that the point of fall is located on the horizontal plane passing through the origin of the trajectory. Range tables, based on this assumption, give a numerical explanation of the relations existing between the different elements of trajectories.

10. *Angle of site.*—In practice, the target B is often higher or lower than the gun. The *angle of site* is the angle S which the line gun—target makes with the horizontal plane. It is called positive

[1] With the 75 mm., the initial velocity of a given projectile is constant, since the charge is constant.

when the target is higher than the gun (fig. 3) and negative when lower (fig. 4). By means of range tables, the elements of the desired trajectory OSB can also be determined.

11. *The hypothesis of the rigidity of the trajectory.*—If we consider a point C located on the horizontal plane of the muzzle at the same distance from the gun as the target B, the trajectory OTC, passing

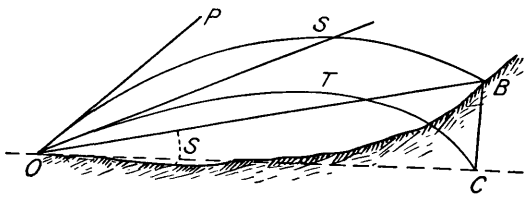


Fig. 3.

through C, is that whose elements are given in the range tables for the range OC=OB. The hypothesis of the rigidity of the trajectory is that which assumes that the desired trajectory OSB is the same as the trajectory OTC revolved around the point O, as if it were a rigid curve, through an angle equal to the angle of site COB, in such a manner as to bring the point C on target B. It follows, from

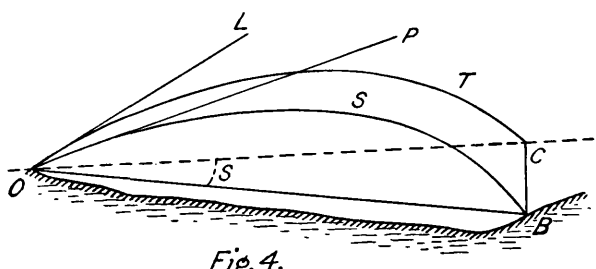


Fig. 4.

this hypothesis, that the elements of the trajectory OSB referring to an inclined base OB, are the same as those of the trajectory OTC referred to on the horizontal base OC and given by the range tables. To deduce the first from the second it is only necessary to consider the inclination of the base OB in relation to the horizontal plane.

12. *Quadrant elevation of the gun.*—This is the angle which the line of fire of the gun, when laid to fire on B, makes with the horizontal plane. It follows that it is equal to the algebraic sum of the elevation corresponding to the range to target B and the angle of site of B (angle of site plus elevation, if the target is higher than the gun, elevation minus angle of site if the target is lower than the gun).

13. The hypothesis of the rigidity of the trajectory is sufficiently verified by experience in field firing.

C. LAYING THE 75-MM. GUN FOR ELEVATION.

14. In the 75-mm. gun, the angle of site is given to the rocker by means of the elevating handwheel, and the elevation is given to the gun in relation to the rocker by means of the independent quadrant. The latter is graduated in ranges instead of angles. By construction, when a certain range is laid off on the quadrant, the gun forms an angle with the rocker equal to the elevation corresponding to the range under consideration. (This relation only exists for the ammunition for which the quadrant has been graduated: shrapnel, I. V.=535.) In addition to the graduation of the quadrant, the elevation is given by means of the level, model 1888–1900, placed on the seat of the gunner's quadrant, or else the means discussed in paragraph 23 may be used.

D. PERCUSSION FIRE—TIME FIRE.

15. The fire is called percussion when the projectile bursts on contact with the ground or an obstacle. It is said to be time fire when the projectile bursts in the air at any point of the trajectory.

ARTICLE 3.

STUDY OF THE TRAJECTORY.

16. Every battery officer should always carry with him the range tables for his matériel. The tables in degrees and in mils are reproduced at the end of this book for the different projectiles fired by the 75-mm. gun.

A. CALCULATION OF THE ELEMENTS OF THE TRAJECTORY.

I. Formulas.

17. The trajectory being supposed rigid, any point M is defined by the angle T_k between OM and OT, or by the distance OM=K.

By definition T_k is the elevation corresponding to the range K. In all practical applications we will assume that T_k bears a fixed relation to K. If the trajectory of shrapnel (I. V.=535) is considered, the following remarks will permit the solution of the different problems which arise.

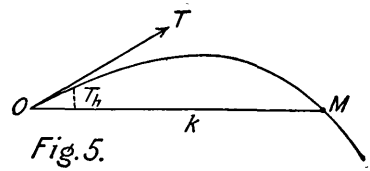


Fig. 5.

First we have, with sufficient approximation:

$$T_k=4K(K+4).$$

T_k being the elevation in mils and K the range in kilometers.

Second, the angle of fall w_k is given approximately by:

$$w_k=\frac{3}{2}\times T_k.$$

Third, the variation of the elevation corresponding to a variation of range of 100 m. from the range K, expressed in kilometers, is equal to

$$K+1.$$

Fourth, the summit of the trajectory is approximately on the bisector of the quadrant elevation.

18. *Table of corrections.*—The elevations of the tables correspond to a fire executed at the normal initial velocity, with projectiles of normal weight, and under atmospherical conditions such that the weight of 1 liter of air is 1.208 grs. and there is no wind. When these conditions are not realized, the following corrections must be applied to the range when firing shell:

Variations in range for:

An increase of dV_0=10 m. of initial velocity.

An increase of dp=100 gr. in weight of projectile.

An increase of dw=0.1 gr. in weight w=1.208 grs. of a liter of air.

A longitudinal component in the direction of fire of dW_x=10 m. of the velocity of the wind.

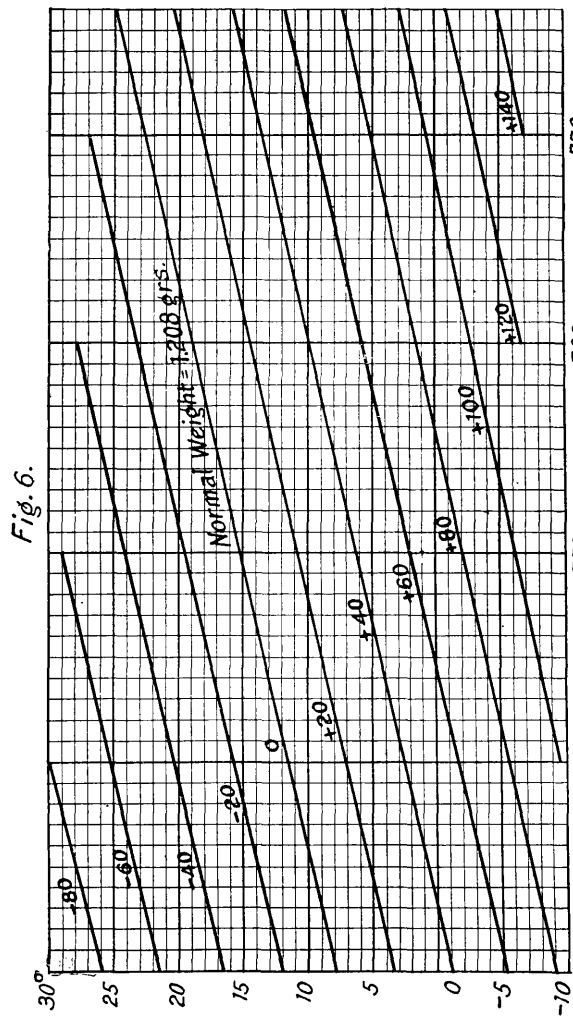

Normal Weight = 1,200 grs.
-80
-60
-40
-20
0
+20
+40
+60
+80
+100
+120
+140
30°
25
20
15
10
5
0
-5
-10
730
740
750
760
770

Fig. 6.

Range		1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000
Shells; delayed action or instantaneous fuses; weight, 5.4 kg.	dV_0=10 M.	31	50	60	67	71	74	77	80
	dp=100 gr.	− 8	− 7	− 2	4	11	19	29	39
	dw=0.1 gr.	−14	−48	−85	−122	−161	−202	−248	−294
	dW_x=10 M.	5	24	58	100	149	203	266	329
Shells; supersensitive fuse; weight, 5.4 k.	dV=10 M.	30	49	59	65	67	67	65	.....
	dp=100 gr.	− 8	− 7	− 2	4	12	22	36	.....
	dw=0.1 gr.	−17	−48	−86	−122	−163	−211	−267	.....
	dW_x=10 M.	4	24	60	104	157	221	311	.....

The initial velocity varies with the temperature; the variations of dV_0, as a function of the variations of temperature dt can be roughly obtained by the aid of the formula,

$$dV_0=0.0011\ V_0\ dt^1,$$

dt being the variation of temperature. For the initial correction, let $dt=t-15°$. The variation in milligrams of the weight of a liter of air (average hygrometrical degree $\frac{1}{2}$) is given by the diagram (fig. 6). Example: $t=-7$, $p=765$, $dw=+130$; at 4,000 m., the correction to be applied to the range is −158.6 m.

In the case of shrapnel fire, a double entry table (temperature and pressure) determines a coefficient which enables us to take into account the variation in range resulting from the variations of temperature and of pressure. A table gives the corrections to be made for the wind. Variations in weight of projectiles are ignored. (Instruction of February 2, 1916.)

II. Applications (shrapnel).

19. (*a*) What is the elevation at 3,300? We know by heart the elevations for each 1,000 m., or we calculate them by the formula $T_k=4K(K+4)$ and interpolate for the expression K+1.

$$T_{3300}=T_{3000}+3(K+1)=84+3(3+1)=96.$$

(*b*) To what range does the elevation 96 correspond?

Never try to solve $96=4K(K+4)$, but use the method shown by the example (*a*):

$$T_{3000}=84$$
$$K+1=4$$
$$\frac{96-84}{4}=3 \text{ hectometers.}$$

The range is 3,000+300=3,300 m.

[1] A formula very nearly accurate, the temperature being that of the powder, i.e., of the shelter. It is a correction for seasons rather than for days.

(*c*) Plotting the trajectory by points. Methods (*a*) or (*b*) enable us to plot the trajectory by points.

(*d*) On the trajectory of 3,000, calculate the height of a point situated 2,500 m. from the origin. (The difference between O*m* and OM is disregarded.)

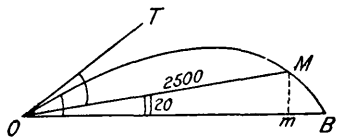


Fig. 7.

$$TOB = T_{3000} = 84$$
$$TOM = T_{2500} = 64$$
$$MOm \qquad\qquad 20$$

therefore $mM = 2.5 \times 20 = 50$ meters.

(*e*) Particular case, problem of the maximum ordinate.

To determine, on the trajectory of 3,000, the position of the summit.

$$SOs = \frac{TOB}{2} = 42.$$

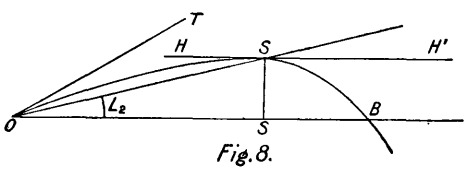


Fig. 8.

We have, therefore, TO*s*=42, O*s*=1,800 m.

And *s*S=1.8×42=76 meters.

(*f*) Fire with:

Site: +5.

Quadrant range: 2,000, on a glacis of a slope of 20 mm.

At what angle of incidence does the projectile strike the ground?

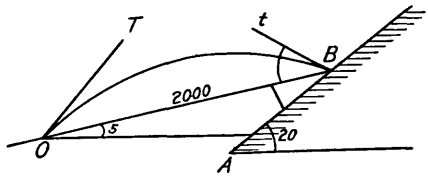


Fig. 9.

tBA=tBO+OBA
but tBO=3/2 TOB=3/2×48=72
and OBA=20−5=15
and tBA=87 m/m.

B. HANDLING OF THE TRAJECTORY IN THE PLANE OF FIRE.

20. *Position of the point of burst.*—The position of the trajectory in the plane of fire depends on the angle of site and the elevation. Equal variations in the angle of site and the elevation produce exactly the same effect on the trajectory—rotation of the whole around the origin. In the case of time-fuse fire, the position of the point of burst E depends on three elements—angle of site, quadrant range, and corrector.

To define the position of a point of burst, B being the target and C the point of fall, we consider (fig. 10):

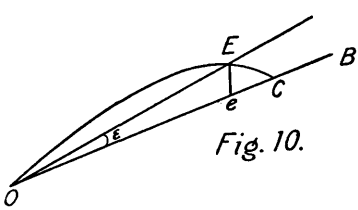


Fig. 10.

The height of burst, ϵ, is the angle between OE and OB, the line of site to the target (by hypothesis, the angle of site laid off on the gun is equal to the angle of site of the target).

The burst range Oe=OE (approximately).

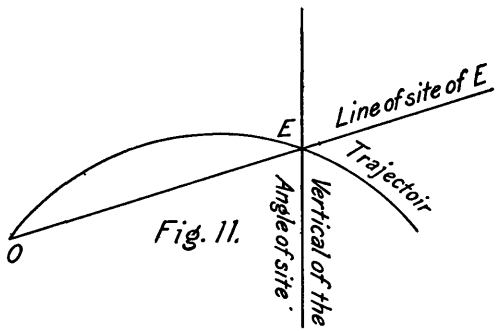


Fig. 11.

The burst interval is eC.

Thus the burst range, plus the burst interval, equals the range—$Oe+eC$=OC.

21. *Displacement of E*, when only one of the elements—angle of site, elevation, or corrector—varies and the others remain constant.

(*a*) *The angle of site alone varies.*—No change is made on the fuse setter. The burst range is therefore constant, but the trajectory has been revolved around O. Hence, E is moved on a circumference with center O, which can be regarded as the vertical to the point E.

(*b*) *The elevation alone varies.*—The corrector being stationary, by construction of the fuse setter, the burst is moved along the line of site OE.

(*c*) *The corrector alone varies.*—The gun is not moved, and the trajectory therefore remains the same and the point E is moved along the trajectory.

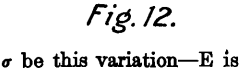


Fig. 12.

22. *Calculation of variations of E.*—We disregard the burst interval, which is deduced from the range and the burst range.

(*a*) *Variation of the angle of site.*—Let σ be this variation—E is moved along the vertical and comes to E′. The range: The trajectory has revolved by σ around O. Hence the range has varied by an amount corresponding to an increase in angle of site of σ. The height of burst: For the same reason, the height of burst has varied by σ. The burst range does not vary (the time of flight has not been changed).

(*b*) *Variation of quadrant range.*—Let *h* be this variation. E shifts along the line of site. The range varies by *h* (by construction of the quadrant). The height of burst does not vary (by construction of the fuse setter). The burst range varies by approximately *h* when *h* is small, and by a quantity which differs sensibly from *h* when *h* is large.

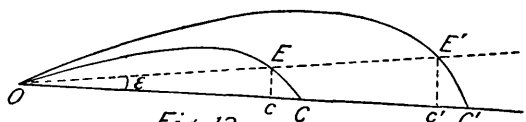


Fig. 13.

Example: OC=2000
h=CC′=1000
E=3 mils

we have $OE' = 3000 - \frac{3 \times 100}{3+1} = 2925$

$OE = 2000 - \frac{3 \times 100}{3+1} = 1900$

$EE' = 1025.$

(*c*) *Variation of corrector.*—Let *c* be the variation. E moves along the trajectory. The range does not vary. The height of burst, by construction of the fuse setter, varies by *c* mils.

The maximum of ϵ is T_k, a value which is reached for a burst theoretically at O, at the muzzle of the gun.

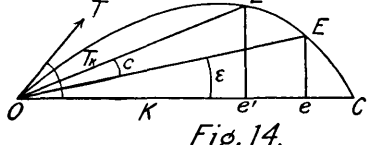


Fig. 14.

Remark: With corrector 17 we have, theoretically, a burst at zero height.

Suppose K=1,200, T_k=23.

If we take C=17+23=40, we have a burst at zero.

For ranges less than 1,200, the fuse can be set at the maximum corrector: $17+T_k$ (theoretically, disregarding the jump.)

Burst range:

$$T_{oe}' - T_{oe} = -c$$
$$ee' = OE' - OE = -c\left(\frac{100}{K+1}\right).$$

Recapitulation table.

Variation of—	Range.	Height of burst.	Burst range.
Site: σ	$\sigma\left(\frac{100}{K+1}\right)$	σ	o
Elevation: h	h	o	h
Corrector: c	o	c	$-c\left(\frac{100}{K+1}\right)$

23. *Applications.*—(*a*) If one of the elements of fire is erroneous the error can only be corrected by the simultaneous alteration of the other two elements. The quadrant range found in an adjustment thus corresponds to the true range to the target only if the angle of site is correct.

(*b*) If we want to use the data of an adjusted fire furnished by a neighboring battery, we must receive, at the same time, the three elements. If we know only, for example, the elevation and the corrector, the burst range obtained with these elements will be good, and we should regulate the height of burst by means of the angle of site.

(*c*) If the first salvo of a time-fuse adjustment gives, with a normal corrector, a height of burst not too erroneous, there is an advantage in changing the angle of site because the error observed is an indication of an incorrect angle of site.

(*d*) In the course of an adjustment undertaken with an incorrect angle of site, the latter may be modified when it is impossible to adjust the corrector. In this case, a calculation will enable us to take advantage of bracketing previously obtained:

Example: With $s=-20$ and $c=40$, we get the bracket 3,000 short, 3,400 over, but all the rounds burst on impact. By modifying the angle of site and the elevation by the same amount, with contrary signs, we will have, with $s=o$ and $c=20$, the bracket 2,500 short, 2,900 over.

But all calculations of this kind should be forbidden in the course of an adjustment. For greater certainty, recommence the adjustment.

(*e*) The range disk is only graduated up to 5,500. To fire beyond that—

First. Increase the angle of site by 70 mils (variation of elevation between 5,500 and 6,000).

Second. Lay off on the quadrant the required range, diminished by 1,000 meters, and on the fuse setter the required range. (The fuse setter is graduated up to 6,800).

Third. As soon as the desired mean height of burst is obtained, with a certain quadrant range and corrector, modify the corrector by n graduations for each jump in range of n hectometers, the two jumps being in the same sense.

Let E_1 be a burst obtained with corrector 20, fuse setter range 6,400, site 70, and quadrant range 5,400 (trajectory T_1).

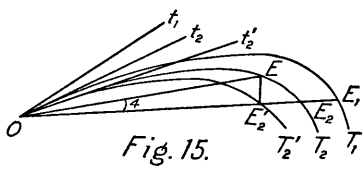


Fig. 15.

The captain wants to obtain, with a quadrant range of 6,000, a burst E_2 at the same height, i. e., on OE_2 (trajectory T_2). The two trajectories T_1 and T_2 form an angle: $t'_2Ot_1=4(5+1)=24$ mils (difference between T_{5400} and T_{5000}). If the corrector c is maintained on the fuse setter, with the range at 6,000, we obtain the burst E'_2, at the same height as E_1, on the trajectory T'_2 characterized by $t'_2Ot_1=4(6+1)=28$ mils (difference between T_{26400} and T_{26000}). But, in reality, we are firing on the trajectory T_2, and from then on the correction c would give the burst $E(EOE'_2=4$ mils). To bring E to E_2, the corrector must be lowered by 4.

(*f*) An enemy who reaches the dead space in front of a battery can not be hit by ordinary means. But a certain effect can be obtained on him by making the projectiles burst on the trajectory which corresponds to the minimum elevation. Raising the corrector progressively up to 40 is sufficient. If this play of the corrector is not sufficient, raise the angle of site by 10, for example, which will permit a decrease in the quadrant range of 300 m. without changing the trajectory. Start again from $c=30$ (which bursts where the last burst was obtained with $c=40$) and the corrector can again be raised to 40.

This type of fire is capable of only small results, especially if the quadrant range is greater than 1,300 m. and if the slope of the terrain beyond the mask or cover is accentuated we can not expect anything more than a moral effect on the enemy.

(*g*) A dispersed target on a slope descending toward the battery can be effectively covered by a time fuse fire on its whole extent only if the points of burst are moved parallel to the terrain, by varying simultaneously the quadrant range and the corrector. In particular, a deep target situated on such a slope can not be covered by a progressive fire. On the other hand, a progressive fire is effective against a narrow target so situated if the height of burst is regulated with regard to the target itself.

(*h*) Against a target hidden by a crest we always fire in the same manner as against a deep target. In time-fuse fire, in order to take into account the slope of the terrain behind the crest, increases in quadrant range are combined with decreases in corrector. The steeper the slope the less we change the quadrant range and the more we change the corrector. For example, at 3,000 m., on a slope of 60 mils, a displacement of 100 m. in the point of burst will be obtained by an increase of the quadrant range of 50 m. and a decrease of the corrector of 2. The angle of fall at 3,000 is 120 mils. Therefore the triangle CC_1C' is isocoles.

$$CC_1=C_1C^1=\frac{CC^1}{2}=50 \text{ m.}$$

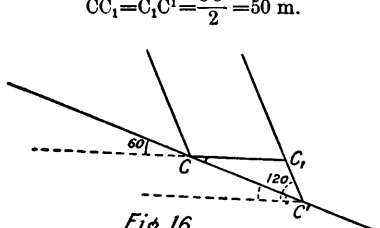


Fig. 16.

In order that the point of burst, which would be at C_1 if we did not touch the corrector, may move to C^1, it is necessary to lower it by 2, since 4 mils changes the burst range by 100 m. at 3,000 m.

At long ranges, since the angle of fall increases, the terrain is more easily covered.

In the case of percussion fire, it is necessary, at short ranges, that we use shell with delayed action fuse and nose disk.[1] In fire without

[1] The nose disk is a metal disk placed on the ogive of the shell and held in place by the fuse. It increases the resistance to the air and hence the angle of fall.

nose disks the slope may be equal to the angle of fall, and, the trajectory being parallel to the ground, the terrain will not be covered (terrain with a slope of 70 mils, range 2,000). With the nose disk p, the angle of fall is about 120 mils, and, by making jumps of 25 m., the terrain will be uniformly covered, thanks to the dispersion.

(*i*) At a range of K, what are the variations of quadrant range and of corrector which will move the point of burst of 100 meters parallel to an ascending or descending slope of n mils?

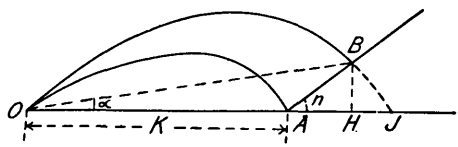


Fig. 17.

Let c be the variation of corrector and h the variation of quadrant range, which will bring the burst from A to B (AB=100 m.).

First: In the figures 17 and 18.

$$c=\alpha=\frac{BH}{K}=\frac{n}{10\,K}$$

$$BH=n\left(\frac{AB}{1{,}000}\right)=\frac{n}{10}$$

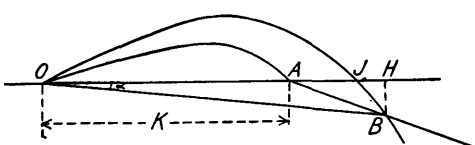


Fig. 18.

In the first case, c, it is positive; in the second, negative.

Second: $h=AJ=AH\pm HJ=100\pm HJ$.

Now, HJ is the difference of ranges of the two trajectories whose elevations differ by α:

$$HJ=\alpha\left(\frac{100}{K+1}\right)=\frac{10\,n}{K(K+1)}.$$

In giving to n the plus sign when the slope ascends and the minus sign when it descends away from the battery, we will have:

$$c=\frac{n}{10K} \qquad h=100+\left(\frac{10\,n}{K(K+1)}\right).$$

Example: At 3,000 m., for $n=60$ mil slope, descending:

$$c=-2,\ h=100-\frac{10\times 60}{3\times 4}=50.$$

It is therefore necessary to make jumps of 50 m. in lowering the corrector by 2.

(*j*) In firing on a target, the elements of which are on different planes, the angles of site of the guns are echeloned.

ARTICLE 4.

PHENOMENONA OF DISPERSION.

24. Experience shows that when we fire a certain number of rounds with the same gun, under conditions as identical as possible (same elevation and of deflection, and the same gunner, temperature, pressure, direction and velocity of wind, and lot of projectiles and of powder), the projectiles, nevertheless, do not fall on the same point, but are distributed in a manner more or less irregular about a point M, called "center of impact," the range of which is the average range of the different points of fall, and the direction is the average of the directions.

A. RANGE DISPERSION.

25. By drawing perpendiculars to MP, which limit the zones of shorts and overs in regard to M, and subdividing each of these two zones into four equal zones, we find that each of the eight zones comprises the number of rounds indicated in the following diagram, called the dispersion ladder.

The depth of each of these eight zones is called the "*probable error in range*" and the dispersion of fire in range can be measured thereby. Consequently we say that the probable error of a gun, at a given range, is E*p*, i. e., if, under conditions as nearly identical as possible, we fire one round after another, half the rounds will fall within the area 2E*p*, and the other half will fall outside this area.

For a given range the dispersion in range is the same in vertical and in plunging fire. Example: Probable error in range of the long 155-mm. howitzer shell of initial velocity of 250 m., at 4,500 m. range, in plunging fire is 16.55 m., and in vertical fire 17.22 m.

The more the rounds converge on the center of impact the greater the precision. Now, a consideration of the dispersion ladder shows that the rounds converge the more closely on the center of impact as the probable error becomes smaller. A gun is therefore the more accurate as its probable error is reduced.

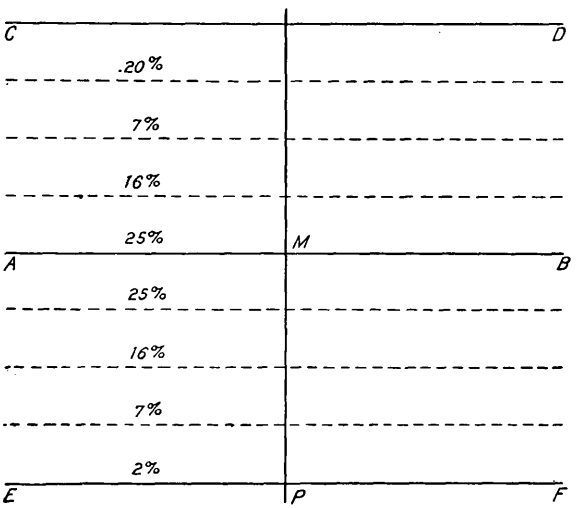


Fig. 19.

The dispersion on a vertical plane can also be plotted. The phenomenon is identical to the dispersion in range. A probable error in height E*h* is thus brought out. Between the probable error in height E*h* and probable error in range E*p*, there is this relation:

$$Eh = Ep \tan. \omega \text{ } (\omega \text{ being the angle of fall}).$$

On an ascending terrain the dispersion in range is reduced, while it is increased on descending slopes. Thus, when the slope of the terrain in the neighborhood of the point of fall and on the plane of fire has the value α, the probable error E*i* on the inclined ground bears the following relation to the error E*p* of the tables:

$$\frac{Ei}{Ep} = \frac{\text{Sin } \omega}{\text{Sin } (\omega - \alpha)}, \text{ or approximately } \frac{Ei}{Ep} = \frac{\omega}{\omega - \alpha}.$$

Example: The probable error of the long 155-mm. gun shell, O charge, at 5,000 m. is 22.2 m. on horizontal ground; on terrain with a slope of 10 per cent it would be

$$22.2\left(\frac{27}{27-10}\right)=22.2\left(\frac{27}{17}\right)=35.26 \text{ m.}$$

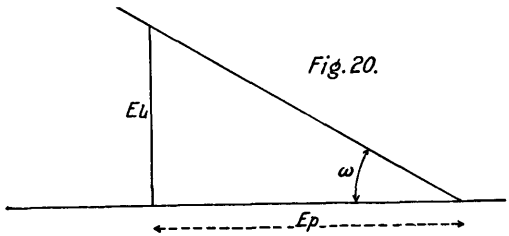


Fig. 20.

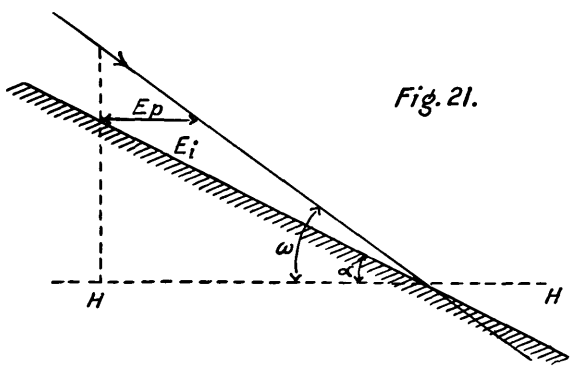


Fig. 21.

B. DISPERSION IN TWO DIRECTIONS.

26. All the rounds are included in range in a zone of indefinite width, having for center a mean point and having a total depth of eight probable errors in range. Each of these zones AA_1, A_1A_2, A_2A_3, A_3A_4, will receive 25, 16, 7, and 2 per cent, respectively, of the number of rounds fired.

Similarly, in direction, all the rounds will fall in a zone of indefinite depth, having for center a mean point and having a total width of eight probable errors in deflection. Each of these zones BB_1,

B_1B_2, B_2B_3, B_3B_4 will receive 25, 16, 7, and 2 per cent, respectively, of the total number of rounds.

It is at once seen that all the rounds fall within a rectangle having the mean point as its center, a depth of eight probable errors in range, and a width of eight probable errors in deflection.

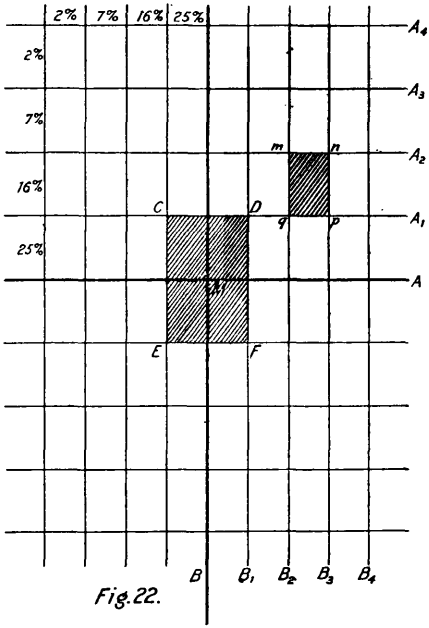


Fig. 22.

How many rounds will fall in the rectangle *mnpq*? The zone A_1A_2 only receives 16 per cent of the number of rounds contained in the zone B_2B_3. The zone B_2B_3 receives in all 7 per cent of the rounds. Therefore in the rectangle *mnpq* there will only be:

$\left(\frac{16}{100}\right)\times\left(\frac{7}{100}\right)=\frac{112}{10,000}$ rounds, or 1.12 per cent. (See discussion of composite events in any treatise on probability.)

We calculate, in the same way, the number of rounds falling on any given surface by dividing it into rectangles.

The rectangle having the mean point as its center and total dimensions of two probable errors in range and two probable errors in deflection will contain the best grouped fourth of the rounds.

The following table gives the proportionate per cent of rounds falling in the different rectangles:

0.02	0.10	0.24	0.37	0.37	0.24	0.10	0.02
0.10	0.49	1.12	1.75	1.75	1.12	0.49	0.10
0.24	1.12	2.56	4	4	2.56	1.12	0.24
0.37	1.75	4	6.25	6.25	4	1.75	0.37
0.37	1.75	4	6.25	6.25	4	1.75	0.37
0.24	1.12	2.56	4	4	2.56	1.12	0.24
0.10	0.49	1.12	1.75	1.75	1.12	0.49	0.10
0.02	0.10	0.24	0.37	0.37	0.24	0.10	0.02

C. DISPERSION IN TIME-FUSE FIRE.

27. When projectiles of the same type, with fuses of the same kind, are fired under the same conditions, the bursts will take place around a mean point, in the neighborhood of which they will be more dense than elsewhere. (The principal causes of irregularities in the operation of fuses are differences in construction and setting.)

28. *Probable errors in time-fuse fire.*—If the positions of the bursts on the vertical plane of the line of fire are noted, the same laws are observed as those that govern fire on horizontal ground. If, through the point M, we draw the vertical MZ and the horizontal My, we can note the height of burst for each round in reference to My and the interval of burst in reference to Mz. Thus the probable errors in height of burst and in range of time-fuse fire are defined.

29. *Probable errors of the fuse.*—The errors in range and height of burst, shown above, are the result of errors observed in percussion fire and errors due to the fuse which would be obtained in an imaginary fire all the trajectories of which were identical.

If e_1 is the probable error in percussion fire, and e_2 that of the fuse, we have the relation (E being the resulting error),

$$E=\sqrt{e_1^2+e_2^2}$$ (See Theory of Probability).

The range tables give the values of the probable errors in range and in height of burst of the fuze. We also have the relations:

$$e_2h=e_2p \tan \omega, \text{ and } Eh=Ep \tan \omega.$$

30. *Practical probable errors.*—In experimental fire the utmost precautions are taken, and the probable deviations obtained are called theoretical errors. In actual service fire practical probable

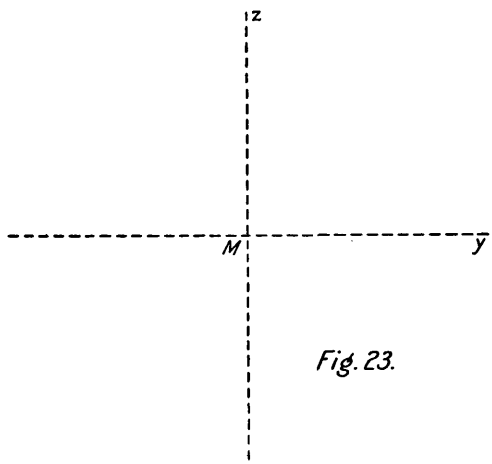


Fig. 23.

errors are obtained. It is assumed that the practical error$=\frac{3}{2}$ the theoretical error.[1]

The "fourchette" is equal to six probable theoretical errors or four probable practical errors. The total zone of dispersion is therefore, in practice, two fourchettes.

The probable range errors are much greater than the probable errors in direction, whence the great advantage of enfilading fire. For example, for the 155-mm. gun, fired with an I. V. of 458 m., at 6,000 m., we have Ep=25.3 m. Ed=2.8 m.

[1] If the matériel is poorly served, the ammunition not taken from the same lot, the projectiles improperly fused, the surfaces and the bands of the projectiles in bad condition, the aiming not well done, etc., the dispersion will be greater.

I. Application of the preceding principles to the adjustment of fire.

31. *Relative positions of the target and the center of impact.*—Problem 1: Given the position of the center of impact, with relation to the target, we deduce the proportion of overs (or shorts) which must be expected.

(*a*) Knowing that the target B is at 2 probable errors beyond the center of impact M, to determine the proportion of overs. Let

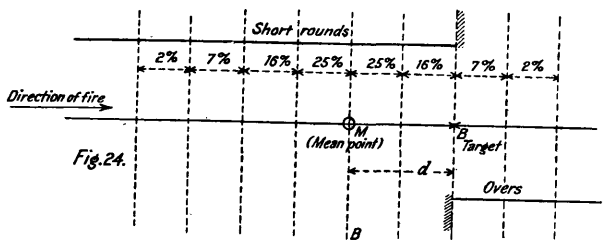


Fig. 24.

M be the center of impact. Construct the dispersion ladder having its center on this point. It is immediately seen that the proportion of overs, with respect to B, is 7+2 per cent=9 per cent.

(*b*) Knowing that the probable error in range at the range considered is 12 meters, and that target B is 20 meters beyond the center of impact M, to determine the proportion of overs. The probable error E_p being 12 meters, 1 meter equals $\frac{1}{12} E_p$ and 20 meters equal

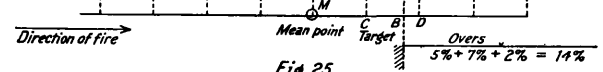


Fig. 25.

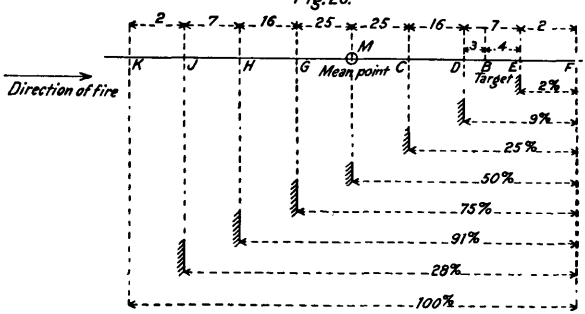
$\frac{20}{12} E_p = \frac{5}{3} E_p$. The distance MB is therefore 5/3 of the probable error. Let us locate the point B on the dispersion ladder. We see that it is in the zone CD containing 16 per cent of the rounds and at 2/3 of the width of this zone from the point C. We may assume, with sufficient accuracy, that the rounds which fall in the zone CD are uniformly distributed. Under this assumption 11 per cent of the rounds

will fall between C and B and 5 per cent between B and D. The proportion of overs will therefore be 5+7+2=14 per cent, i. e., about 1/7.

Problem 2: Given the ratio of overs (or shorts), to deduce the most probable position of the center of impact with relation to the target.

Let 94 per cent be the proportion of shorts. The overs will be 6 per cent. The center is evidently between D and E, because the

Fig. 26.



proportion of 6 per cent of overs is intermediate between those of 2 per cent and those of 9 per cent, which give the positions D and E. As there are already 2 per cent of the rounds in the zone EF, the position of B in the zone DE must be such that there will be 4 per cent of the rounds between B and E, and therefore 3 per cent between

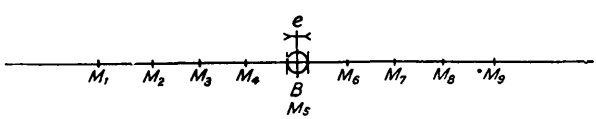


Fig. 27.

B and D. If it is again assumed that the rounds are uniformly distributed in the zone DE, we must have $DB=\frac{3}{7}DE=\frac{3}{7}E_p=0.4\ E_p$. The target is, therefore, at a distance MB from the center of impact such that $MB=MD+DB=2.4\ E_p$. If the probable error of fire is 12 meters, it may be concluded that the fire is probably long by $2.4\times12=29$ meters.

II. Accuracy to be sought in adjustment of fire.

32. Assume a target to have a vulnerable depth equal to one-fifth of the probable error (say, 5 meters, if E_p is 25 m.), and that we execute a series of fire of which the centers of impact are M_1 ..... M_5 ..... M_9, echelonned by distances each equal to one probable error. The application of the preceding principles show us that the target will receive [1]—

$1/5\left(\frac{2\%}{2}\right)$ $=0.2\%$ if the center of impact is at M_1

$1/5\left(\frac{2\%+7\%}{2}\right)$ $=0.9\%$ if the center of impact is at M_2

$1/5\left(\frac{7\%+16\%}{2}\right)$ $=2.3\%$ if the center of impact is at M_3

$1/5\left(\frac{16\%+25\%}{2}\right)$ $=4.1\%$ if the center of impact is at M_4

$1/5\left(\frac{25\%+25\%}{2}\right)$ $=5\%$ if the center of impact is at M_5

$1/5\left(\frac{25\%+16\%}{2}\right)$ $=4.1\%$ if the center of impact is at M_6

Therefore, when the center of impact moves from M_4 to M_6 the ratio of rounds on the target varies but little. It follows that we gain little

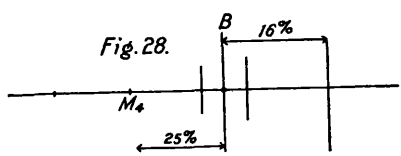


Fig. 28.

by bringing the center of impact nearer than our probable error to the target, and it will therefore not be necessary to vary the quadrant range by quantities less than one probable error.

III. Verification of the sensing for range.

33. An examination of the dispersion ladder shows that, if the center of impact is less than 4 probable errors from the target, we may obtain shorts from a range which is long, and inversely. Observation of one or even several shorts at a given range does not, there-

[1] When the center of impact is at M_4, for example, the target lies on the dividing line between the zones which contain 25 per cent and 16 per cent of the rounds. We therefore assume that it receives the mean number of rounds which would hit it if it were placed entirely in one or the other of the zones, that is:

$1/5\left(\frac{25+16}{2}\right)$ per cent$=4.1$ per cent.

fore, give an absolutely certain assurance that this range is effectively short. In other words, we can not be certain that, if the fire is continued indefinitely under the same conditions, the majority of rounds will not be long.

But if, at a given range, we observe two short rounds, it is very probable that that range is short, or else that it is long by less than two probable errors.

Let M be the center of impact. Consider a series of points, B_1, B_2 ..... B_9 distributed along the line of fire at distances

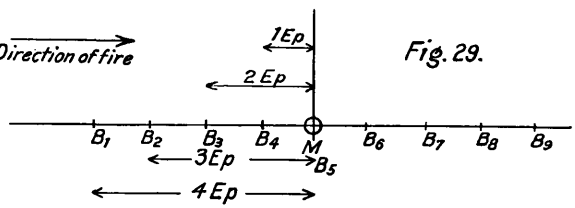


Fig. 29.

equal to one probable error, the point B_5 coinciding with the center of impact so that:

$B_1M=4Ep$	$MB_7=2Ep$
$B_2M=3Ep$	$MB_8=3Ep$
$B_4M=Ep$	$MB_9=4Ep$.
$MB_6=Ep$	

If the target is at B_1, or on this side of B_1, the probability, with a range which gives a center of impact at M_1, of getting a short with respect to B_1 is nil. If the target is at B_2, the probability of getting a short is 0.02. The probability of getting 2 shorts (composite event) is $0.02\times0.02=0.0004$. The probability of getting one over is 0.98, and of two overs $0.98\times0.98=0.96$.

By going through the same reasoning for the different positions of target, B_1, B_2, B_3 ..... B_9, we obtain the results shown in the table below:

Position of target.	Probabilities of getting—		
	One over.	Two overs.	Three overs.
This side of B_1	1.	1.	1.
B_2	0.98	0.96	0.94
B_3	0.91	0.83	0.75
B_4	0.75	0.56	0.42
B_5	0.50	0.25	0.125
B_6	0.25	0.0625	0.015
B_7	0.09	0.0081	0.00729
B_8	0.02	0.0004	0.00008
Other side of B_8	0.00	0.0000	0.00000

Examination of this table shows that, if we have observed two overs at the same range, there is a probability greater than 99 per cent that the target is either on this side of the point of impact or else less than two probable errors beyond it, i. e., between M_1 and B_7.

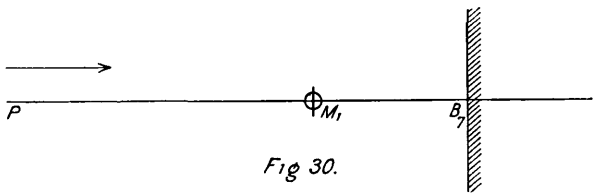


Fig 30.

Inversely, if we have observed two shorts with a certain range M_2, there is a probability greater than 99 per cent that the target is either on the other side of M_2 or else less than two probable errors this side of M_2, i. e., between B_3 and M_2.

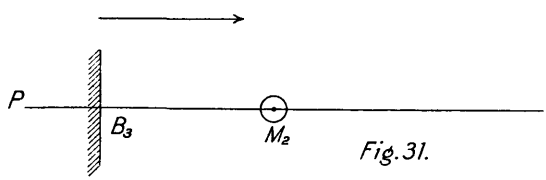


Fig. 31.

Therefore, if we obtain successively two shorts with the range M_2 and two overs with the range M_1, there is a probability of 99 per cent that the target is on the other side of B_3 and a probability of 99 per cent that it is on this side of B_7. There is thus a probability greater than $99\% \times 99\% = 98\%$ that it is between B_3 and B_7, for example.

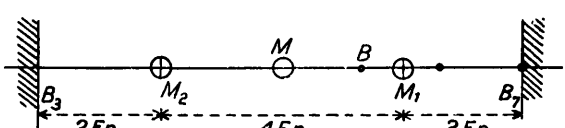
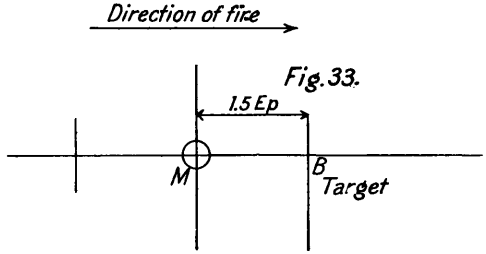


Fig. 32.

If the difference between ranges M_1 and M_3, otherwise known as the value of the bracket, has been taken equal to four probable errors, the distance from B_3 to B_7, between which the target is probably situated, will be equal to eight probable errors. There-

fore, if we fire with the mean range M, of the preceding bracket, there will be a probability greater than 98 per cent that the distance between the point M and target B is less than four probable errors. The target B will therefore probably be in the zone of dispersion of the point M, and we may, in the course of the fire executed at this range, obtain shorts and overs, the proportion between which will enable us to determine the relative position of the point of impact and the target, and thus correct the range.

Suppose, for example, that six rounds fired with the mean range of the bracket (verifying fire) give five shorts. The application of the foregoing principles shows that the most favorable position of the target is at $1\frac{1}{2}Ep$ on the far side of the center of impact. To correct the range we must, therefore, increase it by the corresponding amount.



The instructions on fire prescribe a variation in range of one-sixth of the fourchette as often as necessary to change the sensing of the rounds in order to obtain an equality of shorts and overs. This rule is in accordance with the preceding theory, since the fourchette is of four probable (practical) errors, the increase of range is, in the case under consideration, $\frac{2}{6}\times 4Ep=\frac{8}{6}Ep=1\frac{1}{3}Ep$, and this differs from that given by the theory only by the quantity $(\frac{1}{2}-\frac{1}{3})Ep=\frac{Ep}{6}$.

It would evidently be useless to seek a greater precision in the corrections.

IV. *Fire at echelonned ranges (searching fire). Uniform distribution of rounds over the terrain.*

34. Suppose we fire 100 rounds at each of the ranges P_1, P_2, P_3, P_4, echelonned at intervals of four probable errors. The distribution of the points of fall will be, for each fire, according to the known rule, so that, if the terrain is divided into zones of size equal to these

probable errors, each zone will receive rounds from the two ranges between which it lies. If we add the rounds which fall in each of the zones lying between P_1 and P_4, we get alternately the numbers 27, 23, 23, 27, 27 . . . The distribution is therefore approximately uniform.

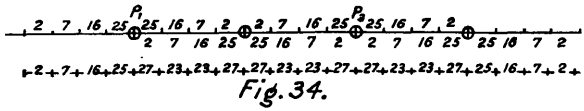


Fig. 34.

If we want to cover a terrain in this manner with a gun whose probable error is 25 m., we must proceed with jumps of 100 meters. There is no reason to modify the extent of this echelonnement in depth if the ground is sloping, but since the probable error will be greater, the density of the points of fall on a given area of ground will be diminished, and it will be necessary to increase the number of rounds at each range.

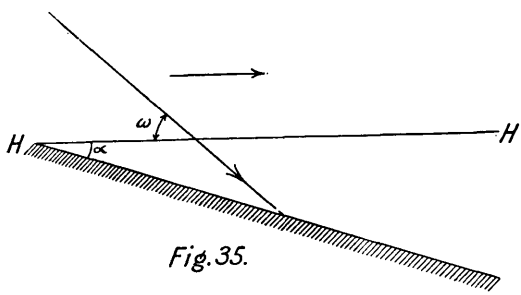


Fig. 35.

ARTICLE 5.

PROJECTILE AND FUSES OF THE 75-MM. GUN.

35. The 75-mm. gun fires shrapnel and shell (model 1900). It also fires, on occasion, a shell, type A. L., of cast iron, a tracer shell (against balloons), a shell loaded with special products (gas), and an incendiary shell.

A. SHRAPNEL.

I. *Description.*

36. The cylindrical steel body contains 12-gr. balls (hardened lead) and a charge of powder. The screwed ogive also contains balls. There are two principal types of shrapnel, which act in exactly the same way.

(*a*) *The shrapnel, model 1897* (*Robin*), with mixed charge, painted white, and containing 290 balls. Weight, 7.240 kg. Bursting charge, 440 gr. F_3. Bursting velocity given to the balls, 85 m. This shrapnel, hard to manufacture, is only found in small quantities in the magazines; those that existed before the war have all been fired.

(*b*) *Base charge shrapnel,* painted red, containing 261 balls. Weight, about 7.250 kg. Bursting charge, 110 gr. F_3. Bursting velocity given to the balls, 100 m. Maximum range, 8,500 m.

Charge marks.—The marks placed on the body of the shrapnel show the factory, the month, and the year of loading and the initial velocity—535 m. These marks are made with black paint on the shrapnel of 1897 model (for those, the letter M is added to the charge marks), and with white paint on the base-charge shrapnel.

Ex: ECP (Central School of Pyrotechny).

5-97 (5th month of the year 1897).

Fuses.—Both types of shrapnel are primed with the 22/31 fuse, model 1897, graduated from 0 to 24 seconds. This combination fuse is equipped with: (*a*) A time system which operates if the fuse has been set, and bursts the projectile after a certain length of time (if it has not yet struck an obstacle). (*b*) A percussion system which bursts the projectile when it undergoes a sudden decrease of speed (by meeting an obstacle or the ground).

They may also be primed with the 22/31 time fuse, model 1916, graduated from 0 to 24 seconds, to fire against aircraft (aero cartridge).

The 30/55 fuse, whose duration of combustion is much greater (49 seconds) than that of the 22/31 fuse, by reason of the length of its fuse train, is used with the 1897–1911 shrapnel (used principally in antiaircraft fire), and it differs from the others only in the shape of its ogive.

II. *Method of action of shrapnel.*

37. (*a*) *Time-fuse shrapnel.*—When a time-fuse projectile is burst in air the balls are projected in a cone-shaped sheaf in which they are uniformly distributed under the influence of—

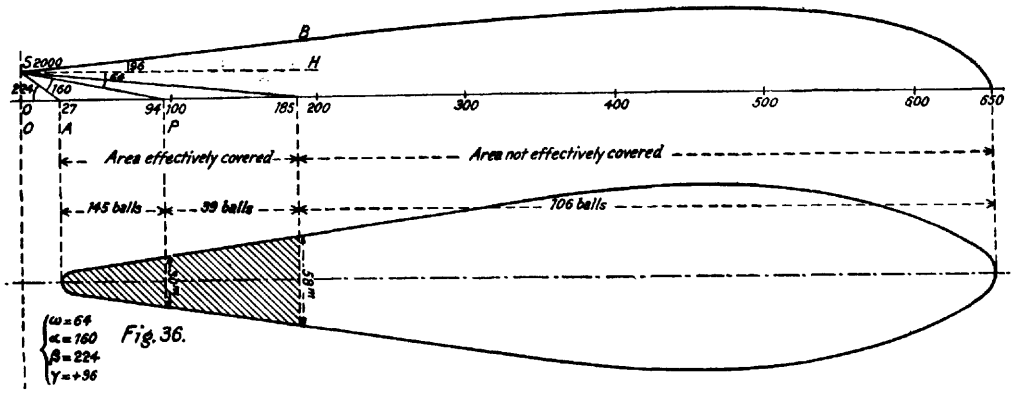


Fig. 36.

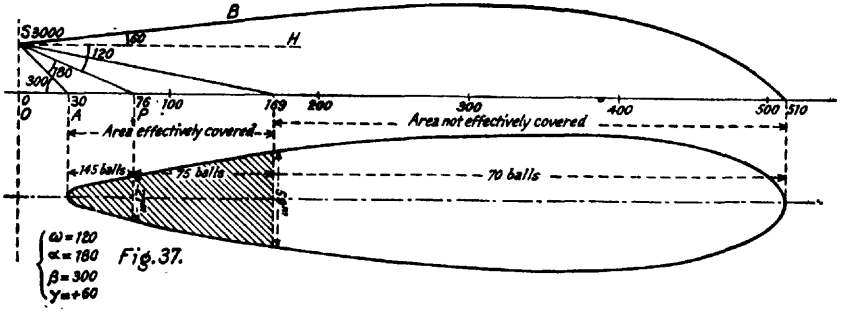


Fig. 37.

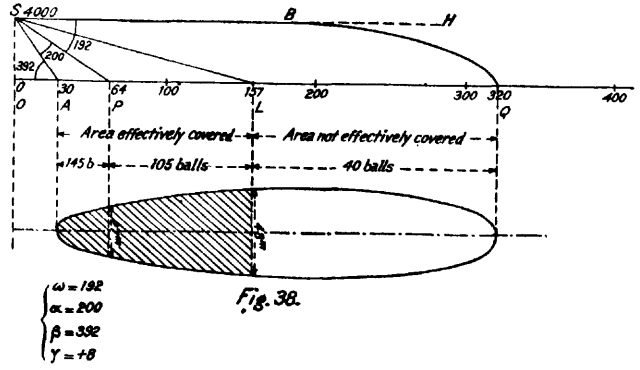


Fig. 38.

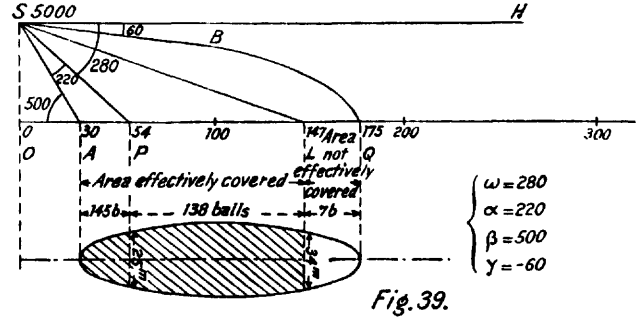


Fig. 39.

S. Point of burst at height of 3 mils.

S. P. Tangent to trajectory at point of burst.

P. Point of fall.

S. B. Upper generatrix of the sheaf.

S. A. Lower generatrix of the sheaf.

A. Point of fall of the shortest ball.

L. Point of fall of the effective ball traveling the greatest distance.

Q. Point of fall of the ball in the sheaf traveling greatest distance.

ω. Angle of fall of projectile.

α. Half opening of the sheaf.

β. Angle of fall of the shortest ball.

γ. Angle between the horizontal and the upper generatrix.

First. The terminal velocity of the projectile, at the time of burst, in a direction tangent to the trajectory.

Second. The centrifugal force (rotation of projectile) in a direction perpendicular to the axis of the projectile at the time of burst.

Third. The additional velocity due to the explosion of the bursting charge.

The body of the projectile is not burst.

The zone covered is the pattern of the sheaf on the ground.

The zone effectively covered is that portion of the zone covered which is reached by balls in sufficient density and with sufficient velocity (greater then 180 m.) to be deadly. Because of their spherical form, the balls lose their velocity rapidly. The distance they can travel in the air without losing their effectiveness increases as the range diminishes, but seldom exceeds 180 m.

Opening of the sheaf.—The angle at the apex of the cone of balls is called the opening of the sheaf. It increases with the range. The half-opening α is given in the range tables.

Normal height of burst.—For a time-fuse shrapnel to be efficient, the balls which reach the target must have sufficient penetrating force, and their number per unit of surface must not fall below a certain figure. The surface of the zone covered is increased by increasing the height of burst, but the number of balls per unit of surface is reduced. The distance which they travel in the air is also increased and they lose, on account of air resistance, a part of their velocity and their force of penetration.

The figures show sheaths of shrapnel bursting at a height of 3 mils at 2,000, 3,000, 4,000, and 5,000 m. range. The scale of elevation is tripled, and the angles are therefore false. The angles are expressed in mils.

Experience has fixed the most effective height of burst. This height is called "normal height of burst." For the 75-mm. gun it is 3 mils at all ranges (in reality, it increases slightly with the range).

Pattern of the sheaf on horizontal ground.—The trajectory of a ball will deviate more or less from a straight line, according to the original direction of the ball and the length of its course; but it may be assumed that all effective balls have a straight-line trajectory. The pattern of the sheaf results, therefore, from the intersection of the cone of burst with a horizontal plane, at least in the effective zone. Its boundary is evidently a closed curve. Figures 36, 37, 38, and 39 give the patterns of the sheaf at 2,000, 3,000, 4,000, and 5,000 meters for a burst taking place at 3 mils.

The table below and figures 36 to 39 (vertical projection) give the position, relative to the horizontal, of the upper generatrix of the sheaf.

Range.	Angles of fall.	$\alpha=120+20$ K.	Superior generatrix.
	Mils.	*Mils.*	
1,000	24	140	$\alpha>\omega$ (above the horizontal).
2,000	64	160	
3,000	120	180	
4,000	192	200	$\alpha=\omega$ (approximately horizontal).
5,000	280	220	$\alpha<\omega$ (below the horizontal).

En résumé, the figures of the sheaf show that, as the range increases:

First. The depth and width of the pattern of the sheaf diminish rapidly.

Second. The depth and width of the effective zone diminish also, but much more slowly.

Third. The number of effective balls increases. (On the other hand, as their trajectory become more curved, their dangerous zones will diminish).

Fourth. The zone AP, corresponding to the lower half of the sheaf, continues to contain half of the balls.

In practice, it must be remembered that, at average ranges, shrapnel bursting at 3 mils is effective on a front of 20 m. and a depth of about 150 m. If two rounds are fired under the same conditions, the zone effectively covered is 25 m. (because the balls of the second round, which fall on each side of the 20 m. of the first round, have a sufficient density over an area of 2.5 m. in width on either side).

Rapid calculation of certain elements of the sheaf.—The distance OP is the burst interval corresponding to a height of burst of 3 mils.

$$OP=3\left(\frac{1\,CO}{K+1}\right).$$

The angle of incidence of the most plunging ball is $\beta=\alpha+\omega$.

But $\alpha=120+20K$ and $\omega=\frac{3}{2}T_k=\frac{3}{2}4K(K+4)$.

Therefore OA or AP can be calculated, noting that $OA\times\beta=OP\times\omega$.

38. *Percussion shrapnel.*—If the angle of incidence on the ground is sufficiently small (less than 15°) the shrapnel bursts only after

raising again (ricochet). The sheaf obtained sweeps the ground well so long as the angle of ricochet remains small. This angle increases with the angle of incidence. Therefore a time comes when the whole sheaf will pass above the target.

Up to 1,500 m., and on terrain favorable for ricochet, the effectiveness of percussion fire can be compared to that of time-fuse fire against uncovered personnel. The area efficaciously covered extends, on an average, up to 200 m. from the center of impact.

Percussion fire does away with the adjustment of the height of burst, and its probable error is less than that of time-fuse fire.

If the projectile "fougasses," the effect is nil.

(c) *Incendiary effects.*—Shrapnel (especially mixed charge shrapnel) can produce incendiary effects.

B. SHELL.

I. Description.

39. *The 1900 model shell* (N, FN or GN) is of steel, of one piece, galvanized or polished inside. It is charged with compressed explosive (0.695K), and carries, in the upper and central part of the charge, a little charge of pulverized melinite to communicate the explosion of the detonator.



Fig. 40.

These projectiles are fired with variable charges of powder BSP or US_3, which give to the projectiles, primed with the percussion detonator fuse 24/31, model 1899 or model 1899–1908, or the 1914 model fuse I an initial velocity of 550 m., which is inscribed on the cartridge. The maximum range is 8,000 m. If the projectile is primed with the I. A. fuse, this initial velocity is reduced to 542 m. and the maximum range to 7,800 m.

The weights of the shells are the following:

DELAYED FUSE, OR FUSE I (INSTANTANEOUS).

[Normal weight, 5.315 K.]

Shells marked.	Weight.		*dp*, average.
	From—	To—	
	K.	*K.*	
L	5.000	5.150	−240
+	5.151	5.300	− 90
+ +	5.301	5.450	+ 60
+ + +	5.451	5.600	+210
+ + + +	5.601	5.750	+360

SUPERSENSITIVE I. A. FUSE.

[Normal weight, 5.55 K.]

L	5.235	5.385	−240
+	5.386	5.535	− 90
+ +	5.536	5.685	+ 60
+ + +	5.686	5.835	+210
+ + + +	5.836	5.985	+360

Detonating fuses.—The shell fired percussion is furnished with a detonating fuse of 24/31, which is introduced at the moment of fusing into the relayed fuse container, and screwed down.

The principal models are:

1899–1908 model, delayed-action fuse.

1899 model, nondelayed-action fuse.

1914 model, I } instantaneous fuse. The duration of func-
1915 model, I. A. } tioning is less than 1/100 of a second.

The shell intended for time-fuse fire is primed with a combination detonating fuse 24/31, model 1916. This fuse, which is delayed action, operates either as time fuse or percussion. In the latter case, it acts as an ordinary fuse of 24/31, 1899–1908 model. The fuse is set before being placed on the projectile.

Observations concerning the use of detonating fuses.—(*a*) The priming is not done until the moment of fire (for security).

(*b*) Fuses other than the I. A. fuse, model 1915, should always be protected by regulation felt washers when in the boxes and cases used for shipment. Even when they are screwed down in the fuse container of the projectile they should be protected by their washers, and it is essential that they should be screwed as far as they will go.

(*c*) Concerning the I. A. fuse, model 1915.—First. Because of its special shape, it modifies slightly the trajectory of the 75-mm. shell, and slightly diminishes its range. The range table is calculated for fire with this fuse only beyond 4,000 m. Its use must therefore be limited to ranges greater than 4,000 m. The angle of fall is then sufficient to permit the fuse to operate with certainty.

Second. It is protected by a tin cover, which should be taken off only after the fuse has been screwed by hand into the fuse container.

Third. After the cover has been taken off, none of the organs uncovered should be touched, especially the brass spirals.

Fourth. If, at the end of the fire, a projectile primed with an uncovered fuse has not been fired, the fuse should be unscrewed and sent back to the park. It is forbidden to use such a fuse to prime another projectile.

Fifth. To avoid striking the head of a fuse, when withdrawing a projectile from a gun, a wooden sleeve, whose length is 30 cm. and whose exterior and interior diameters are those of the head of the rammer, is interposed between the projectile and the rammer.

Sixth. After decapping a fuse see that the spiral is well in place and that it has not been pushed up by the decapping operation. (A fuse without a spiral should never be used; it should either be destroyed or be put aside to be returned to the park.)

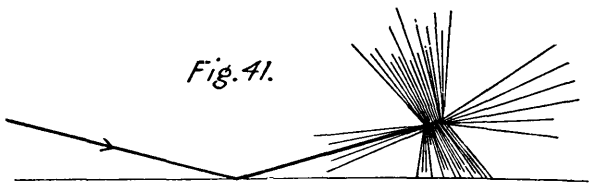
Seventh. Verify that the tightening band which fastens the cartridge case to the body of the fuse is perfectly tight. Also see that the cartridge case can not turn on the body of the fuse. Every fuse in which the tightening band or the cartridge case can be taken off by hand should be returned to the park.

II. *Manner of action of the shell.*

40. (*a*) *Shell fired with delayed-action fuse.*—The delay is $\frac{5}{100}$ of a second. This is called the normal delay and is the only one which is suitable for ricochet fire. A shell striking the ground at an angle less than 15° ricochets. The ricochet deflects the projectile outside of the plane of fire, and, all things being equal, the projectile deviates toward the right on account of its movement of rotation.

It bursts between 5 and 10 m. from the point of fall and between 2 and 10 m. above the ground. It gives an ogive sheaf (50°) of few fragments and of little effectiveness. It also gives a very narrow rear sheaf, the fragments of which are rather large but very small in number These fragments strike the ground in the neighborhood of the point of impact. They may be effective up to 50 m. to the rear, and sometimes even farther. Finally, the burst gives a lateral

sheaf, very open (200°), but very hollow, containing about 1,000 fragments, of which the central part traces on the ground a "hatchet blow" of about 0.70 m. in width. The barbed fragments are very dangerous, for they have great velocity. Their radius of action does not exceed about 20 m.



If the angle of incidence is greater than 15°, the projectile does not ricochet, but makes a "fougasse."

With an angle of incidence of 25°, and a terminal velocity of 220 m., the projectile buries itself 1 m. underneath the surface of the ground, with an average horizontal course in the ground of 1.50 m.

(*b*) *Shell fired with I. or I. A. fuse.*—With these two fuses, favorable exterior effects are obtained in action against personnel and matériel. Those obtained with the I. A. fuses are, in general, greater than those obtained with the I. fuses.

With the I. fuse the burst takes place very close to the ground, and a sphere of compression of 30 to 35 cm. in depth is formed on the ground, whose crater makes a sharp indentation into the surface of the ground.

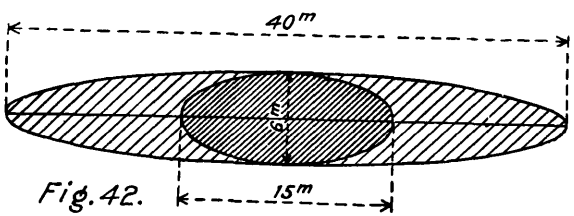


Fig. 42.

With the I. A. fuse, if the angle of incidence is sufficient (greater than 15°), the projectile bursts slightly above the ground and forms a very slight sphere of compression of only 10 to 15 cm. in depth, whose crater indents the surface only to a slight degree.

(*c*) *Shell fired with combination fuse.*—When the burst takes place at a height of between 3 and 16 meters, the pattern of the sheaf on the ground varies but little, and is as shown in figure 42.

(*d*) *Malandrin nose disks.*—The Malandrin nose disks, interposed between the fuse and the body of the shell, modify the manner in which the resistance of air is exerted on the projectile in motion. The retarding action is more considerable, and it results in a modification in the shape of the trajectory, reducing the range and increasing the angle of fall at a given range. The use of nose disks thus enables us to reach targets which, by their defilade, escape the fire of projectiles without nose disks. But it is important to notice that the use of nose disks increases notably the probable error in range and direction, and also that the ricochet of the delayed-action shell equipped with a nose disk can not be counted on when the angle of incidence exceeds 10°. Therefore nose disks are only suitable for zone fire and not for accurate fire, and they must be prohibited for fire executed on a target too near our own troops.

If the angle of incidence of a projectile fired with a nose disk exceeds 10° (or if, in practice, we see that ricochet is not reasonably certain), we substitute nondelayed action fuses for delayed fuses.

Use of nose disks (fuses other than the I. A.)

(I. V.=550.)

Nose disk.	Range.	Angle of fall.	Probable error at maximum range.
		° ′	*M.*
L	4,000	17 7	27
P	4,000	28 59	46

With the I. A. fuse, the use of the nose disk does not sensibly modify the trajectory.

(*e*) *Use of high explosive reduced charge ammunition.*—This ammunition permits curved fire. The charge is 250 grains of B. C. powder. The case is marked V_0=334, the initial velocity when primed with short fuse (I. V.=338.5 for I. A. fuse). Below the ordinary marks the case has a ring of black paint. The base is marked, in addition, with a black cross.

In addition to the advantage of being able to reach targets defiladed from flat trajectory shells, this ammunition can be used on all targets at close range, and the wear on the matériel is not so great.

The short fuses give the most accurate fire because the dispersion is smaller. The elongated fuses, however, are more effective, since all the fragments are distributed above the ground.

For fire at high angles, the platform is prepared as for fire against aircraft, except that it does not have to be so firm, the I. V. being less.

Range table.

Range.	Elevation.	Fourchette.	Angle of fall.	Terminal velocity.
	° ′	° ′	° ′	
Short fuses (initial velocity=344 m.):				
1,000	2 42	10	3 05	305
1,500	4 16	10	4 55	.....
2,000	5 57	15	7 10	.....
2,500	7 42	.....	9 50	.....
3,000	9 42	20	13 20	.....
3,500	12 10	30	17 10	.....
4,000	14 40	.....	21 30	.....
4,500	17 30	40	26	.....
5,000	21 3	.....	31 35	.....
5,500	25 9	1 30	37 50	.....
6,000	30 45	2	45 40	205
Elongated fuses (initial velocity=338.5 m.):				
1,000	3	10	3 25	295
2,000	6 21	15	7 45	.....
3,000	10 44	20	14 40	.....
4,000	16 15	40	24	.....
5,000	23 35	1 30	35 30	.....
6,000	35 20	2	51 30	210

CHAPTER II.

PREPARATION FOR FIRE.

41. The battery commander receives information on the tactical situation, his mission, and his orders as to the position to occupy. The preparation for fire then consists in putting his battery in a condition to open fire rapidly, by simple commands, on all targets showing themselves in the zone covered by the battery.

The preparation for fire includes:

First. Reconnaissance of the captain, during which he—

(*a*) looks for an observation station;

(*b*) determines the battery position;

(*c*) determines the liaisons to be established between the battery and observation station.

Second. Occupation of the position, effected under the command of the lieutenant.

Third. Placing the battery in observation—

(*a*) Establishment of the direction of the directing gun, by the captain;

(*b*) Formation of the sheaf, by the lieutenant;

(*c*) Recording of the data.

Fourth. Making a panorama sketch (the captain), summing up the study which he has made of the zone of action assigned to his battery.

Fifth. Establishment of the liaisons (signal and telephone).

ARTICLE 1.

RECONNAISSANCE BY THE CAPTAIN.

A. CHOICE OF OBSERVATION STATION.

Every observation station should enable the observator to see well, and without much strain, because he may be called on to pass long hours there, if not entire days. It is also essential to see without being seen. This necessitates numerous precautions in the installation and a certain astuteness in the choice of position.

Observation stations may be classified in several different categories, according to their respective distances from the batteries and the targets. Some are near the batteries; other near the targets;

while others are in intermediate positions. They all have their respective advantages and disadvantages, and it is very seldom in war that a single station is sufficient for all purposes. In most cases it is necessary to have an observation station close to the batteries and also one near the targets.

43. Observation stations near the batteries have the advantage of a much greater field of view than those near the targets. Commanding positions are also, in general, easier to find for them. Furthermore, it often happens that they alone permit observation of the second lines of the enemy and everything which is in rear of the first line—which is very rarely possible in the case of observation stations close to the targets. Another advantage lies in the fact that they afford their observers a relative quietness and much easier communications. Finally, the officers are nearer their own troops and are never completely separated from them in case of severance of telephone connections (unfortunately a frequent occurrence), but may continue to command their men and may intervene with all their moral energy when necessary.

On the other hand, the targets being distant, it is indispensable to have good field glasses in order to see well and do the necessary work. Also, it is very difficult, if not impossible, to adjust on the enemy infantry in contact with our troops and on the special points of support of the line which are barely visible from a distance.

44. *Observation stations near the targets* have the disadvantage of a limited field of observation. Their lack of commanding position rarely permits observation of the enemy's second line, which is always very important in all attacks. It is also difficult, if not impossible, to adjust the heights of burst of time-fuse fire from these stations, and, with shell, the ricochet of which raises the burst sometimes 10 meters in the air (2 meters to 10 meters), it is not easy to adjust for range unless the points of impact of the projectiles on the ground can be observed.

Nevertheless, observation stations near the targets have great advantages. They alone enable us to adjust accurately on the different sinuosities, flanking defenses, listening posts, machine guns, emplacements, etc., of the first line, whatever may be the distance separating the hostile lines. They also facilitate the study of this enemy line, and their positions permit an intimate liaison with the infantry—a liaison of the subordinates, which is one of the most important factors in the cooperation in action that must exist between the two arms. Furthermore, this artillery intervention, with observation close to the targets, gives a very appreciable moral

support to the infantry, besides obliging the artilleryman to take precautions in his adjustment which he might either ignore or neglect if he were always personally far away from the points of fall of his projectiles. By neglecting these precautions, the friendly infantry are often hit by short salvos, and this has a most injurious effect on the morale, causing the infantry to lose not only its enthusiasm but even its confidence in the artillery—all this counting against the desired end, a close liaison between the two arms. At all cost, everything must be done to avoid this.

Observation stations close to the first lines have quite a few material disadvantages which should be remedied, in a certain measure, whenever possible. In the first place, owing to their limited field of action, it is indispensable to multiply their number sufficiently to carry out their given mission in its entirety. Also, if they desire to work with little inconvenience and without fear of being constantly bombarded, it is necessary that they should not be seen. The same is true for the telephone lines which run to them. Nor must these telephone lines be so arranged that they can be interrupted by the infantry moving through the connection trenches. It is therefore advisable to fix the wires against the trench walls by hooks, or else to bury them in the neighborhood of the observation stations, or else to use special artillery trenches for this service and to close them to troops of other arms.

But, unhappily, in spite of all precautions, it is often impossible for an observer close to the targets to see anything during the attack itself, either because the infantry completely hide all the terrain in front, or because the hail of enemy shells hinders the observers. Furthermore, the telephone wires are nearly always cut, in spite of all precautions, either by the movement of the infantry or by the enemy artillery fire. All these inconveniences, which must be expected in an attack, do not occur or are reduced in importance during the work of preparation before the attack.

45. To overcome them, in part, during an attack, it is advantageous to choose a command post from which there is a good view of the terrain of the attack, which enables us to keep the telephone wires intact as long as possible, which facilitates visual communication with the batteries and which is relatively little hampered by the enemy artillery fire.

These command posts should be located from 500 to 1,000 meters from the first infantry lines. They should be prepared in advance, during the preparation for the attack. They should be occupied only at the moment of attack.

46. It follows from the preceding discussion that, if we visualize the different successive phases of the occupation of a position of a battalion, (the normal unit of battle in field artillery), for example we are led to consider:

First. A phase preliminary to the entrance into action, during which the battalion commander makes his reconnaissance, prepares the installation of his batteries on the terrain, and chooses an observation station in the neighborhood, from which he can divide his mission between his different batteries. From this station he informs his unit commanders as to the situation of the enemy, the position of friendly troops in front or on the flanks, the general mission of the battalion, and the special mission of each battery. He gives his batteries orders on the liaisons to be established, and defines the manner in which they are to go into action. This generally results in an order to the battery commanders to post their guns in a given zone.

Second. The second phase follows, in which the guns are posted in accordance with their future missions. This preparation will be considered complete when, from an observation station near the targets, it is possible to make a thorough study of the latter. But before this is done it is necessary that, from an observation station near the batteries, the battalion fire sector be divided between the batteries. In this way we may be certain of avoiding gaps in the line of artillery fire, not only between the batteries of the battalion, but also between the neighboring battalions. Thus no corner of the battlefield will be overlooked, and we may be sure that, from a near-by observation station, an artillery unit can be found capable of covering any given target. This initial division of the front between the different batteries can not be well made from an observation station close to the targets, on account of the limited field of vision. Furthermore, it takes time to locate an observation station near the targets, occupy it, and connect it by telephone with its unit. With the above procedure, on the contrary, the artillery can be posted more quickly, and we can open fire on the enemy as soon as the firing data has been calculated.

Third. During this phase of reconnaissance of an observation station near the targets (a phase which may take rather a long time), the artillery in position must be able to fire in case of need. How can this be done? From the observation station near the batteries the deflections are verified and the batteries seek to establish, by firing a few rounds, the firing data necessary for a barrage fire on the whole front. This fire will be directed on or near the first enemy

line (approaching that line from the rear), according to facilities at the observation station for getting the firing data.

Fourth. This phase, in which the artillery contents itself with laying down a barrage, in case of need, ends as soon as the advanced observation station is found and prepared, and it becomes possible to adjust on targets in the first line. These adjustments are made successively over the whole artillery front of the battery, taking care to make them in order of their importance.

47. *Lateral observation stations.*—When an observation station is outside of the plane of fire of a gun or battery it is called lateral. These stations, like the others, may have the advantages of large fields of observation and good views of the targets. But they entail a little more difficulty in adjustment for deflection, and consequently for range. This difficulty increases as the line of observation (observer-target) becomes more oblique to the line of fire (gun-target). Although very small in the case of observation stations close to the batteries, this difficulty is, on the other hand, very large in the case of those which are distant from the line of fire.

In spite of their faults, lateral observation stations must often be chosen, at least temporarily, because the masks behind which the batteries are generally placed often hamper the observation of the details of the terrain around the targets, and even of the targets themselves. Important objects are often discovered by lateral observation which would never be suspected by direct observation, whether close or distant.

In seeking a lateral observation station it may be necessary to leave our sector of action, and we should do this without hesitation, reporting it later to the staff.

48. These auxiliary observation stations (generally in the very front line) can not be used as the habitual post of the battery commander, because of their limited field of view, in width and depth, and their precarious communications with the battery. The normal post of the captain is at the advanced station, while that of the lieutenant is the station near the battery. At the auxiliary observation station are posted intelligent target scouts, connected by telephone or by other means to the advanced station. The captain goes to these auxiliary stations when necessary. These three types of stations are not required for every battery position. All depends on the terrain. The advanced observation station is, of the three, the most important, and very often there is no other. Above all, we must be able to see.

B. LOCATING THE BATTERY POSITION.

49. *Definitions.*—A battery placed behind a cover or a mask is defiladed with respect to a given point when an observer at that point can not see the battery.

The words "*covering mass*" (abbreviated to "*cover*") are generally applied to terrain formations, the highest part (or crest) of which is easily accessible. The word "*mask*" is applied to hedges, walls, embankments, lines of trees, etc, the summits of which are usually inaccessible.

The *plane of defilade* is the plane passing through the highest part of the cover (or mask) and the point defiladed.

The *dead space* is that part of the terrain between the top of the cover, or the foot of the mask, and the point of fall corresponding to the trajectory passing just over the summit of the cover or mask.

50. The commander of an isolated battery has absolute independence in the choice of the battery position within the area indicated by the commander. In a battalion or a larger command, the choice is limited by the presence of neighboring batteries, and, in this case, certain limitations are laid down by the battalion commander.

51. The positions of field batteries in the present war are determined primarily by their rôle in barrage fire. There should be no hesitation, in order to get a barrage in front of the enemy trenches, in changing the position of batteries and even in moving them to neighboring sectors to obtain enfilade fire. The batteries are echelonned in depth in order to assure the best continuity of the barrage, under all conditions. They will be posted in such a manner that all, or part of them, can cover the terrain between our first and second positions, in case the enemy penetrates our lines.

All the batteries should also be able to participate in the concencration of fire. To do this they must have an extended field of fire. The necessary arrangements to this effect must be made in the casemating of the pieces.

Each battery must have, whenever possible, several positions, prepared in advance, provided with firing data books and connected by telephone with the observation stations.

All definitely abandoned battery positions should be organized as false batteries, with false flashes.

52. Whether chosen by the battalion commander or by the battery commander, the positions of the guns must have certain general qualifications, the exigencies of which may be contradictory.

First. The battery must always be able to fulfill its *tactical mission*, i. e., it must be able to fire on a given point, defined by its range and its site, in the minimum time.

Second. The battery must be *exposed as little as possible*. An initial security is obtained by concealing the guns from view. This security will be increased if the battery increases its defilade, and above all, if it causes the enemy uncertainty as to its location by getting well back from the crest or mask. When a natural mask or cover is lacking, we must make an artificial one in front of the battery, more or less distant from the guns, according to circumstances. We must seek to conceal the batteries from terrestrial and aerial observation. They must be carefully camouflaged. We must avoid the bottoms of valleys where gases accumulate.

Third. The battery commander must secure the necessary *rapidity of fire* corresponding to the targets and tactical situation with which he is dealing.

53. The greatest facility of command exists when the captain is within speaking distance of his battery. But the advantage obtained in defilading the flashes (placing the guns 4 m. below the plane of defilade) and in posting the guns at such a distance from the cover or the mask that there is small chance of the enemy reaching them by a systematic fire of many rounds, generally leads to the battery commander being posted at a distance from his battery.

When the captain arrives in reconnaissance, he finds a zone assigned by the battalion commander in which he must choose his battery position in depth, without leaving the terrain assigned to him.

With the projectiles actually in service it is well to note that if we can fire on a point with shrapnel, we can also fire on it with shell, regardless of the fuse. The problem will, therefore, always be treated by considering the elevations for shrapnel.

54. *Case of the covering mass.*—On a terrain of approximately uniform slope and sufficient depth, there are two series of positions which may be occupied, generally separated by a zone which is not tenable. The first series, near the crest, comprises the positions called "crest"; the second series, farther away, comprises the positions called "well defiladed."

I. Crest positions.

55. Since this series of positions is always near the crest, we may assume, without appreciable error, that the minimum range will be the distance D from the crest to the target and that the angle of site

of the target will be that which is measured from C. We may also assume that, between the guns and C, the trajectory is rectilinear and lies along the axis of the gun.

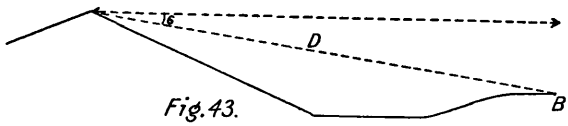


Fig. 43.

Under these conditions an elevation T_D will correspond to the range D, and the quadrant elevation of the gun to fire on B will be:

$$i = T_D + \sigma \text{ (σ being taken with its sign).}$$

In order to be able to fire on B from the selected position it is only necessary that the angle i be greater, or at least equal to the angle at which a man at the height of the trunnions (for 75 mm., a man kneeling) sees the summit of the crest (angle of site of the crest). If P is the position for which the angle i is equal to the angle of site of the crest, every position between P and C will be tenable, but any position immediately in rear of P will not be.

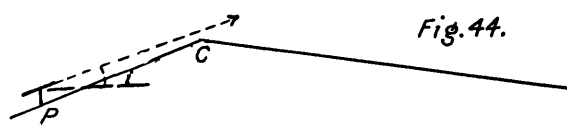


Fig. 44.

Method of operation—With the sitogoniometer.—Measure or estimate the distance D from the crest to the target; deduce the corresponding angle T_D. Measure the angle of site of the target, s, and add algebraically $T_D + s = i$. Take a position in rear of crest such that, when kneeling, the crest is seen at an angle equal to i. The position thus found determines the extreme limit of "crest" positions.

In the preceding, we have taken for the range the distance from the crest to the target, which is slightly less than the range from the battery to the target. Furthermore, we have measured the angle of site of the target, not from the position of the guns, but from the summit of the crest, and the value thus found is always smaller than the real value. For these two reasons, the calculated minimum angle i is less than the real quadrant elevation laid off on the gun to fire on the target. A margin of safety is therefore always advantageous.

Example:

$$D=1500 \text{ m.} \qquad s=+5$$
$$p=40 \text{ mils, whence } i=32+5=37,$$
$$\text{and } d=\frac{1}{40-37}=\frac{1\text{km}}{3}=300 \text{ m.}$$

In reality, the minimum range will be 1,800 m. (1,500+300), and the actual angle of site will be +10 mils. This will give for the real minimum quadrant elevation 40+10=50 mils, whereas the gun, from the position chosen, can fire at a quadrant elevation of 37 mils. There will therefore be a margin of 13 mils, or 400 m. in range.

II. *"Well defiladed" positions.*

In the preceding, we have neglected the distance d from the battery to the crest and the drop of the projectile on its trajectory. If we now seek positions far from the crest, we can not neglect this drop because, if we lay the axis of the gun from P on C, the drop in the trajectory will cause the projectile to hit the crest. The limiting position P will be such that the drop in the trajectory for the distance d will still allow the projectile to pass just above the crest.

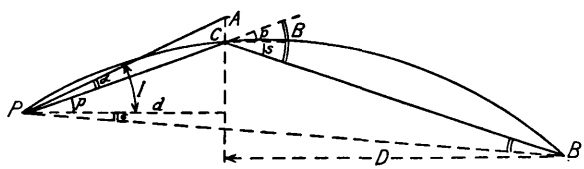


Fig. 45.

This drop AC is seen from P at an angle α which, on account of the rigidity of the trajectory, is equal to the elevation for the range d;

$$\alpha=T_d.$$

To fire on B from P, the gun must have a quadrant elevation I such that $I=T_{D+d}+s$, s being the exact angle of site of the target calculated from P. Now, according to the figure, in order that the projectile may clear the crest, we must have:

$$I \text{ greater than or equal to } p+\alpha$$

or

$$T_{D+d}+s \text{ greater than or equal to } T_D+p$$

The limiting position will be given by the equation:

$$T_{D+d}-T_D=p-s$$

Practically, we may assume that the trajectory is an arc of a circle. Under these conditions the figure shows that, in the triangle CPB, $\beta=(p+s)+\gamma$, but $\gamma=\alpha$ and $\beta=p-s$ (s being taken with its sign).

Therefore $\beta=p+s+\alpha=\text{APB}=T_D+d$

or

$$T_{D+d}=p-s.$$

Whence the rule: "From the summit of the crest C measure the slope of the terrain p toward the battery, and the angle of site s to the target. Take the algebraic sum of these two angles, β, and calculate the corresponding range." Call this range $\triangle$, and call D the minimum distance from the crest to the target. The guns can be posted at a distance $d=\triangle-D$ behind the crest. (This supposes ground of uniform slope p.)

The distance d, given by the formula, fixes the nearest point to the crest for positions of great defilade. The tenable positions are behind this point.

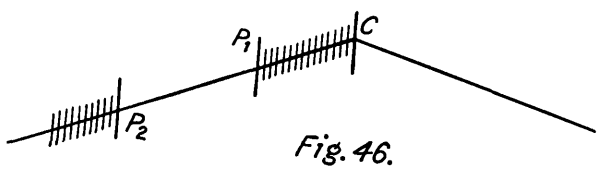


Fig. 46.

Consequently, on all slopes of sufficient length, we find two distinct series of positions:

First. The crest positions, between the summit C of the crest and the point P_1 for which the angle of site of the crest is equal to the minimum quadrant angle of elevation of the gun.

Second. The well-defiladed positions, between the point P_2, determined as above, and the bottom of the slope. Between P_1 and P_2 a battery can not be posted.

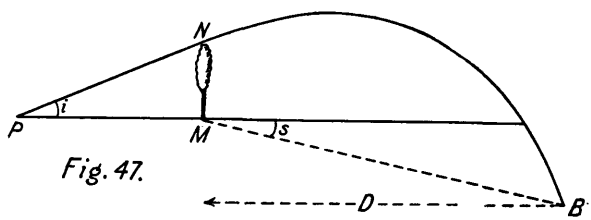


Fig. 47.

57. *Problem of the mask.—(a) The bottom of the mask is accessible, and we can see the target.*

From M measure the angle of site D of the target and add the elevation T_D corresponding to the range MB=D. Choose a point

P in rear of the mask so as to see, when kneeling, the top N of the mask at the angle i, such that $i=T_D+s$. This point P fixes the nearest limit to the mask for the guns.

(*b*) *The bottom of the mask is inaccessible, and rather far from the position sought.*—The preceding example supposes that PN is rectilinear, i. e., that PN does not exceed 200 to 250 ms. If it does exceed that amount, the drop in the trajectory for the distance to the mask must be taken into account.

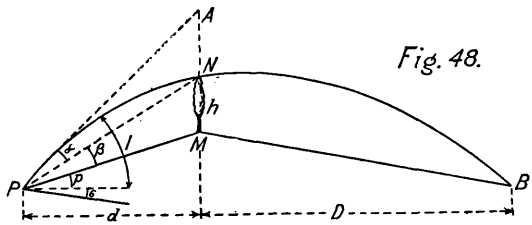


Fig. 48.

P is given by

$I=T_{D+d}+s=\alpha+\beta+p$, in which

s=the exact angle of site of the target,

$\alpha=T_d$, the drop in the trajectory.

$\beta=\frac{h}{d}$, the apparent height of the mask,

p=slope of the ground behind the mask.

Hence, $T_{D+d}-T_d=p+\frac{h}{d}-s$.

In flat country this formula becomes:

$$T_{D+d}-T_d=\frac{h}{d}.$$

Example: At what distance from a 10 m. mask is it possible to put a gun on a slope 4%, to fire on a target at 2,000 m. and an angle of site of −5 mils?

Try 500 m. $T_{2500}=67$, $T_{500}=7$, $T_{D+d}-T_d=60$

$$\frac{h}{d}=\frac{10}{0.5}=20,\quad p+\frac{h}{d}-s=40+20+5=65 \text{ mils.}$$

Hence, $T_{D+d}-T_d<p+\frac{h}{d}-s$, and 500 m. is too small.

Try 600 m. $T_{2600}=70$ and $T_{600}=9$, hence $T_{D+d}-T_d=61$.

Now $\frac{h}{d}=\frac{10}{.6}=16$, hence $p+\frac{h}{d}-s=40+16+5=61$, and the battery can be placed 600 m. and beyond, from the mask.

For positions on the reverse slope, the crest in front is to be considered as a mask and not as a cover.

58. *Minimum quadrant range.*—The minimum quadrant range with which a gun placed behind a cover may fire without striking the crest is the sum of the minimum quadrant range determined by the chief of section and the elevation corresponding to the distance gun—crest.

When the four guns have not the same mimimum quadrant range the largest is adopted for the fire of the whole battery.

We must not forget that a minimum quadrant range is only correct for the angle of site with which it has been determined. If the angle of site varies, the quadrant range varies in the contrary sense. There is only one constant element: *the minimum quadrant elevation.*

When the battery is posted, the measured minimum quadrant elevation only is considered, and it, with the angle of site, is written on the shields.

ARTICLE 2.

OCCUPATION OF THE POSITION.

59. This is under the command of the lieutenant. (See Art. VI, Drill Regulations.)

ARTICLE 3.

BATTERY IN OBSERVATION.

60. *Definition.*—A battery is in "observation" on a registration point R (R being a point in the zone of possible targets) when the plane of fire of the right gun passes through R, when the trajectories of the other guns form a certain sheaf (known to the captain), and when the deflections are recorded.

The guns must be laid, and in the middle of their traverses. The minimum range and corresponding angle of site must be recorded on the shield.

61. *Advantages of the system of observation.*—The battery being in observation, to open fire on any target appearing suddenly in its zone, the captain has only to give elementary commands, corresponding to simple operations of the entire battery—shifting of the sheaf and, if necessary, opening or closing it. A fire having been executed, the captain can bring his battery back to the original data by the command "in observation." At this command, the gunners again lay the guns on the recorded data.

This method is advantageous under all conditions, and indispensable when the battery is not acting as a unit.

62. *The sheaf of fire and the "faisceau."*—The sheaf of fire of a battery in observation on a point R may be characterized by the angle under which the bursts of the flank pieces are seen from the battery when it fires on the point R. The sheaf is regular when the intervals between any two neighboring bursts are the same. The sheaf of 60 mils is generally adopted for a battery in observation. The angle between the planes of fire of two neighboring guns is called the "faisceau." (Equal to our deflection difference when the parallelism of the aiming point is zero.—Translator.)

Assume 4 pieces posted at regular intervals and parallel. With a faisceau of n mils, we get a sheaf of:

$$3n+\frac{F}{D}\begin{cases}F \text{ being the front of the battery in meters.}\\ D \text{ being the range from the battery to the target in kilometers.}\end{cases}$$

Example: When $F=50^m$, $D=2000^m$ and $n=15$ mils.

The sheaf $=45+25=70$ mils.

In practice we assume that the sheaf of fire obtained from parallelism by opening by 15 is always 60.

63. *Posting the battery in observation.*—This consists of:

(1) The laying of the first piece on R.

(2) The formation on the first piece of a faisceau corresponding to a sheaf of 60 mils.

(3) The recording of the data.

Of these operations, the formation of a regular faisceau is essential, because, if regularity is not secured before the fire, it can only be obtained by individual corrections, which are difficult and which make the adjustment much slower. The other operations, though useful, are not so important, because:

(1) If the first salvo, or even the first round, shows an erroneous deflection of the entire sheaf, a single general command corrects the error.

(2) If the opening of the sheaf is not correct, it is rectified by a single command.

(3) Finally, the record of the data corresponding to a given deflection and sheaf serves only as a basis for subsequent fire, and is not absolutely necessary.

It is not obligatory that the first piece be laid in direction, but the piece for which the operation is the most simple. The plane of fire of this piece must, however, not pass through R but through a point $(p-1)$ 20 mils to the left of R (p being the number of the gun), so that, when the sheaf is formed, the trajectory of the first piece will pass through R.

The two operations of laying the directing gun and forming the sheaf are independent, and may be executed in any order. The sheaf may be formed before it is laid in direction. When these operations are executed successively, the captain lays the directive gun in direction and the lieutenant forms the sheaf. When they are executed simultaneously the captain gives the commands.

A. LAYING THE DIRECTING GUN.

64. The captain selects his registration point about in the center of the zone of the targets. The best processes of laying in direction is that which avoids any kind of movement of dismounted men above the defilade line, which is the most rapid and which eliminates all calculations.

(1) *The battery is near the crest.*—The captain walks from the piece directly toward R and stops at the point Q of the crest on the line of dismounted defilade. The gun is then laid on him with deflection $O \pm \alpha$ (α being the angle between R and Q).

(2) *The battery is behind a mask.*—The captain places himself on a flank of the mask at a point from which he sees R and the directing gun. An assistant at this point sights on the directing gun with glasses. The captain measures the angle α between the plane of the face of the glasses and R. The gunner lays on the glasses with deflection 1600 (or 4800) $\pm \alpha$. The parallax correction is made, if necessary. These operations may be done before the battery arrives on the position. The position of the gun and the aiming point must then be marked, and the direction must be staked out with two stakes.

(3) *Aiming by compass or sun.*—The captain measures the bearing of the registration point from the magnetic north (determined by compass) or the sun. As in the preceding case, this angle is corrected for the parallax at R. The resulting bearing is sent to the lieutenant, and gives him the bearing of the plane of fire from the sun or from a point shown by the compass as being in the magnetic meridian. In case the aim is made on the sun, the aiming operation should follow as closely as possible the measure of the bearing R–sun, because of the apparent movement of the sun. This aiming can also be made equally well on the moon or any easily recognizable star.

(4) *Aiming by the map.*—Given the gun P, the registration point R and the aiming point Q, all of which can be plotted on the map, we measure the angle RPQ with a protractor graduated in mils. This

gives us the deflection which must be laid off on Q in order that the plane of fire of P should pass through R. In short, the map permits us to measure the angular deflection between Q and R. If the compass is used for aiming based on a deflection measured on the map, we must be careful not to confuse the magnetic north and the geographic north.

(5) *Aiming by estimation.*—Lay the piece in direction by estimation. Open fire with the directing gun, firing a time-fuse projectile high in the air, and correct the deflection of the whole sheaf by the angle between the burst obtained and the registration point (or target).

B. FORMATION OF THE SHEAF.

65. Being given two guns P_1 and P_2, numbered from right to left, and the deflections D_1 and D_2 such that when the guns are laid on the point Q their planes of fire will converge on R, we have $D_2=D_1+Q-R$ (Q and R being the parallaxes at the points Q and R of the front of the two guns). We may consider Q as positive when the point Q is in front of the line of guns, and negative in the contrary case.

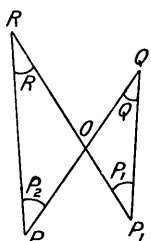


Fig. 49.

Demonstration: $D_1=100+p_1$ (azimuth micrometer), $D_2=100+p_2$ (azimuth micrometer), or $D_2=D_1+p_2-p_1$. In the triangles ORP_2 and OP_1Q, $p_2+R=p_1+Q$. Hence (1) $D_2=D_1+Q-R$. The same demonstration applies to any case. If Q is behind the line of guns, (2) $D_2=D_1-Q-R$, which is the same as equation (1) except for the sign of Q.

66. *Method of forming the sheaf.*—Assume that the four guns of a battery are posted at regular intervals on the terrain (and therefore that the parallaxes at Q and R of the front of any two adjoining guns are constant if Q and R are sufficiently distant). To form a sheaf of 60 mils, a sheaf for parallel fire is calculated and then opened by 15. At 3,000 m. parallel fire gives a 15-mil sheaf if the battery front is assumed to be 45 m.

Parallel fire is obtained by adding to the deflection difference for converging fire the parallax at Q if Q is in front of the line of guns, and by subtracting this parallax if Q is in rear of the line of guns. When Q is on the prolongation of the front, no calculation is needed to open parallel fire. This condition is therefore always to be desired But we must avoid choosing a point Q too near the battery, for the

possible error in estimating the distance for the calculation of the parallax may be serious, as shown by the following table:

Parallax of Q at 250 m.= $\frac{15}{.25}=60$

Parallax of Q at 500 m.= $\frac{15}{.5}=30$

Parallax of Q at 3000 m.= $\frac{15}{3}=5$

Parallax of Q at 3250 m.= $\frac{15}{3.25}=4.6$

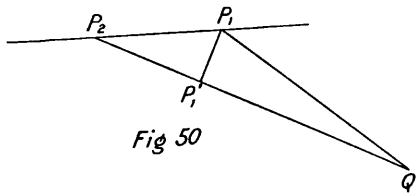


Fig 50

An error of 250 m. in estimating the distance to Q doubles the correction in one case and is negligible in the second.

When Q is off the line of guns of the battery front, the value of the parallax is obtained by estimating by the eye the length $P_1 P_1'$ of the perpendicul to QP_2.

Reciprocal aiming.—When there is no aiming point corresponding to the above conditions, reciprocal aim can always be executed. Its only disadvantage is slowness.

The sheaf may be formed in reference to any gun chosen by the captain as the directing gun. This is to be avoided, however, and, if adopted, the lieutenant must be careful not to alter the direction of this gun while forming the sheaf. If the lieutenant forms the sheaf before the captain has laid the directing gun, the lieutenant shifts the whole sheaf by the error in deflection of the directing gun announced by the captain. If, for example, the third gun is laid with a deflection of main scale 8, azimuth micrometer 50 after the sheaf is formed, and if it should have a deflection of main scale 8, azimuth micrometer 120 after the captain has announced the correct deflection, the lieutenant announces "Add 70." [1]

C. RECORDING THE DEFLECTIONS.

67. When the sheaf is formed and laid in deflection, the lieutenant commands "Record the deflections."

[1] The sights of the 75-mm. gun are so constructed that each division of the main scale (numbered 2, 4, 6, 8 ..... 16 in each quadrant) is equal to 200 divisions of the azimuth micrometer. There is a mechanical connection between them.

ARTICLE 4.

STUDY OF TERRAIN—PANORAMIC SKETCH.

(Omitted. Published in Manual for Artillery Orientation Officer.)

ARTICLE 5.

ESTABLISHING LIAISONS.

73. The telephone system is the most important means of communication. The other means are used in case the telephone is lacking or has been destroyed. The actual allowances vary, but it may be assumed that a battalion has at least 20 km. of wire and 12 telephones of different models.

The artillery system is established by the battalion telephone personnel. This system is laid with light or field wire (overhead or underground), with the exception of lines connecting the batteries and the observation stations. The latter may be wire inclosed in lead.

These liaisons must be established as soon as the position is occupied. The battalion commander's and the captain's reconnaissance details include mounted telephonists, who study the route of the lines and commence to unroll the wire. Since most of the telephones are carried on wagons, they can not ordinarily be placed in position until the arrival of the batteries or the telephone wagon. The latter may sometimes be pushed on ahead.

Signals should be used to supplement the most exposed portions of the telephone system, and to prolong it until such time as the system itself can be pushed out to the most advanced elements. We therefore have to establish signal communication for infantry, artillery liaisons and for communication between the observation stations and the batteries.

74. Besides the signal lanterns and searchlights, Bengal lights, Ruggiere flares, rockets, and Lamane torches (whose flashes are visible at a good distance), are used also by the infantry. The rockets are particularly recommended, provided they are very visible and that their use is reduced to a few simple signals which are known to all. In position warfare, to avoid being deceived by the enemy, the rockets should be fired from places designated in advance. Arm signals are made with or without flag (double faced, half red, half white). Panels are used to communicate with aircraft. Sound signals operate very well at a distance of 1 or 2 kilometers, according to the atmospheric conditions, permit of a complete defilade, and

assure transmission across all obstacles. In certain cases wireless telegraph and even wireless telephones are used.

Liaison is not complete unless the receiving station is able to acknowledge and to reply.

Near the first lines, visual communication to the front must be reduced, as otherwise the enemy may intercept the communications or destroy the station. From the rear, a simple signal should be used for "acknowledge" or "go ahead with your message." A receiving station in rear can not repeat the message.

The preparation of liaisons presents special difficulty in offensive action. All possible means must be used to preserve the liaison between infantry and its supporting batteries. Artillery observers accompany the commanders of the infantry, and must be in communication with the batteries by wire. Visual signals, flags, conventional signals, rockets, Bengal lights—all of which must be thoroughly known to all concerned—must be used. All of the telephone personnel of the battalion, as well as the officers, liaison agents, and scouts, must know the Morse code and the conventional signals.

74½. The liaisons established must enable the commander to keep constantly in touch with the state of the units under his command, and to be able to send them his orders. They must also assure all the communications necessary to obtain concentration of efforts, particularly the close cooperation of the infantry and the artillery, between all units of the command, between neighboring units, and between the different arms.

The liaison is maintained by (*a*) means of information (liaison agents, terrestrial and aerial observations, etc.), (*b*) means of transmission—telephone system, wireless, earth conduction telegraphy, visual signaling, signals (panels, flares, arms), runners, and carrier pigeons.

Liaison of artillery with the infantry.—This close liaison is indispensable. It is maintained by constant contact between the commanders, and by liaison agents detailed from the artillery to the infantry. To carry out an offensive action, each artillery unit charged with supporting an infantry unit attaches a chief liaison officer to the latter unit commander. The chief liaison officer has a liaison and observation detachment under his orders, made up of noncommissioned observers, liaison agents, telephone operators, and signalers. The object is always the same: To secure for the infantry effective artillery support when necessary.

(*a*) *Telephone system.*—Each battalion has two telephone working squads (1 noncommissioned officer and 5 men to a working party), 6 telephones, 2 four-way switchboards, and 8 kilometers of light wire. Each battery has, in addition, 1 working squad, 3 telephones, 1 switchboard, and 4 kilometers of light wire.

The system installed by the artillery consists of the liaison between the artillery commander, the battalions, the batteries, and the observation stations, and also between the infantry and the artillery units charged with supporting it. This last system is double, as the infantry also establishes a line.

The routes should be carefully studied. The lines are grouped, laid in order on appropriate supports, and labeled. The greatest precautions must be taken to avoid the enemy intercepting the communications. All liaisons must be established with double wire to within at least 2,000 m. of the first line, and thoroughly insulated. The discipline of conversations must be rigidly enforced.

(*b*) *Visual signaling.*—This should be prepared, under all circumstances, to supplement the important telephone lines or to extend the telephone system while waiting for it to reach the first line. Each battalion has six portable searchlights of 24 cm. and each battery has three portable searchlights of 14 cm. The telephone operators, scouts, and liaison agents handle this material. Signal lanterns still in service will be withdrawn by degrees.

Range of apparatus.

Apparatus.	By day.	By night.
	Km.	*Km.*
24 cm. searchlight	1.5 to 6	3 to 10
14 cm. searchlight	1.0 to 3	2 to 6
Signal lantern	0.5 to 1	1 to 3

Visual signaling should operate in the interior liaison of the artillery right up to the observation stations, and also in the infantry-artillery liaisons. The signals must be sent from front to rear. The communications toward the front must be reduced to simple signals, to announce reception of a message or to ask for repetition.

(*c*) *Signaling by flares.*—This permits the infantry to make a few conventional signals or to mark their position. The signal code has not been fixed once for all. There are in use the flare signals (signal rocket, signal cartridge, and Bengal light) and the illuminating flares (illumination rocket, illuminating cartridge, and grenade).

Preparation for transmissions in case of offensive.—This preparation presents great difficulties on account of the increased circulation of the troops and greater artillery activity. These difficulties must be overcome by—

(*a*) Establishing the original telephone system with especial care.

(*b*) Pushing out the branch lines to be established on conquered terrain as far as possible.

(*c*) Above all, providing all means that can possibly be used to maintain the liaison of the infantry with its supporting batteries (artillery observers accompanying the infantry commanders, in liaison with the batteries by wire, visual signals, flags, rockets, Bengal lights, etc., all of which must be thoroughly known by all concerned).

CHAPTER III.

EXECUTION OF FIRE.

75. If a target appears in the area under observation of the battery, the captain must immediately determine the type of projectile to use, the type of fire for effect to be used, and the number of guns to employ. It is possible that the action of the battery on the target will include several successive phases, for which different types of projectiles and methods may be appropriate. (See Chap. IV.—Fire Against Visible Artillery.) The captain should fire one or more series for adjustment to determine the data of the fire for effect. The fire for adjustment is therefore a function of the succeeding fire for effect, and the two will be studied in the order—fire for effect, then fire for adjustment.

ARTICLE 1.

FIRE FOR EFFECT.

A. TYPE OF PROJECTILE TO USE.

76. It results from considerations as to the method of action of the different projectiles that—

1. *The delayed-action shell* is used against all animate targets (cavalry particularly), moving or stationary, unsheltered or sheltered behind artillery shields, embankments, or walls, or in an open trench, as well as against houses and woods. The shells which burst while passing through the front walls of houses, or after passing through them, give out injurious gases. The explosion has the effect of rupturing the blood vessels. The shell is not incendiary.

2. *The nondelayed-action shell* is used when a destructive effect on matériel is to be produced at the point of impact. With the nondelayed shell we get the combined effect of the striking force of the projectile and of its explosion. It is used when we desire the destruction of artillery matériel, walls, stockades, breastworks, wire entanglements, shelters, observation stations, machine-gun shelters, woods, and houses, as well as when a delayed-action shell will not ricochet, and will therefore have no effect on personnel. The angle of incidence must be below 15° in fire without nose disks and 10° in fire with nose disks to assure a proper ricochet. On horizontal ground, a 15° angle of fall, or less, is obtained with a shell without nose disk up to a range of 4,350 m.

3. *The time-fuse shell* is used when ricochet fire is not applicable, particularly—

(*a*) Against masked targets in rear of crests, at short and medium range.

(*b*) Against unmasked targets at very long range—in this case, fire with instantaneous or supersensitive percussion fuses also gives satisfactory results.

There is no effect on matériel. On personnel and in zone fire, the effect is 50 per cent when 80 rounds per hectare are fired at medium range (or 110 rounds at long range). But it is always inferior to ricochet fire for an equal amount of ammunition expended.

4. *Time-fuse shrapnel* is used against animate targets, moving or stationary, and against aerial targets. It is less effective than delayed action shell against prone or sheltered personnel or cavalry, but more effective against exposed personnel, standing or kneeling (and its use requires a smaller expenditure of ammunitions), on condition that the height of burst can be regulated by adjusting on the target itself. For enfilade fire (village streets, uncovered communication trenches, or trenches), it is much better than shell.

Shrapnel, especially the mixed charge shrapnel called "Robin" (painted white), is incendiary.

5. *Percussion shrapnel* is used, when shell is lacking, to demolish obstacles and matériel. In certain cases, it is used against personnel—for example, in case of surprise, when there is no time to adjust the corrector, and, in firing over troops, when they are near the target. (Up to 1,500 m. percussion shrapnel is as effective as time-fuse shrapnel against an upright or kneeling target in the open.)

B. METHODS OF FIRE FOR EFFECT.

77. Fire for effect is executed either at successive or single ranges. Each of these methods permits single or double sweeps.

Progressive fire (with or without single or double sweeps) is a fixed method of fire at successive ranges, only applicable to time-fuse shrapnel.

In certain cases the fire may be ordered by the chiefs of section.

Before opening fire for effect, each gun is laid on the right of its sector of the target if sweeping is to be employed; otherwise on the center of its sector.

I. Fire at successive ranges.

78. This method consists in firing a certain number of rounds at a range surely over and a range surely short, as well as at intermediate ranges, taking care to distribute the rounds in deflection over the

front of the entire target. This method can not be used to destroy targets of narrow front except at a prohibitive cost in ammunition. It is executed at the longest range first, unless otherwise ordered. Fire at the longest range first allows us to observe the effect produced by successive volleys, and hence to change the firing data of succeeding volleys when necessary. But we must reverse this order of fire when a target is advancing on the battery and we desire to halt it.

(*a*) *Fire with percussion shell (with or without delayed action).*—The successive changes of range are by 25 m., and if the front to be covered by each gun is n mils, we must make as many single sweeps of a front of $\frac{n}{5}$ as there are kilometers in the range, taking care to join up the sweeps one to another. If the observation of fire for effect shows that one of the intermediate ranges is short, we do not fire at any shorter range.

When a target is discovered masked behind a crest, we use shell with nose disk at (topographical) ranges below 3,500 m. (nose disks P from O to 2,500 m., nose disks L from 2,500 to 3,500 m.). The nose disks are used to increase the angle of fall, in order to cover a number of cases in which the slope of the terrain in rear of the crest would render it immune to fire without nose disks. It is therefore never necessary, in this type of fire, to use nondelayed action shells, nor to worry about the ricochet of the delayed action shell, since we are trying to increase an insufficient angle of fall and since the nose disks are so constructed that the ricochet is assured even on slight slopes. This is the reason that there are two types of nose disks. On the other hand, when nose disks are used to reach a target which is visible but which is on terrain unattainable without nose disks, it will be necessary to use nondelayed action shells if it is feared that the use of the nose disks will give an angle of incidence too great for ricochet.

(*b*) *Time-fuse shell fire—Fire behind crests.*—We bracket on the crest by time-fuse fire with low bursts. We then fire at the long limit, or at the long limit increased by 100 m., after having adjusted the height of burst to 3 mils. We then proceed by simultaneous jumps in range and corrector, increasing the range by 50 m. and lowering the corrector by 1 mil. We distribute 40 projectiles over each 100 meters of front, in order to get a 50 per cent effectiveness. We determine the number of jumps according to the depth to be covered. Example: Range 3,000, slope of terrain in rear of crest 6 per cent. There is a corresponding increase in burst range of 100 m.

for each increase in quadrant range of 50 m. The points of burst lie along a line forming an angle of 40 mils with the horizontal, and these bursts follow the form of the terrain the more closely as the slope approaches 4 per cent. If fired with a corrector raised by 3, the bursts will be approximately above the same points of the terrain, but higher.

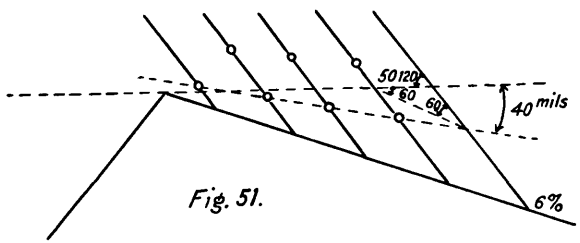


Fig. 51.

Fire on uncovered targets at long range.—Proceed by jumps of 50 m. to get a 50 per cent effectiveness, or by 100 m. to get 35 per cent. Adjust the height of burst to 3 or 4 mils. Distribute 60 projectiles per 100 meters of front at each range. When firing beyond 5,500 m. with 70 mils angle of site, and when the fuses are set for ranges 1,000 m. greater than that indicated by the quadrant, it is necessary to systematically increase the corrector by 1 mil for each 50 m. increase in the range.

In the two cases (1) and (2), the fire is conducted along the lines of shrapnel fire, with the following precautions: In the neighborhood of 5,000 m. the ranges are 100 m. to 150 m. greater than those of projectiles with percussion fuse. The same graduation is used for the range and for the fuse setter. The corrector to be used for the profectiles of I. V. 550, to obtain a zero height of burst, is generally 16 (according to tests made by the Experimental Commission at Calais).

(c) *Time-fuse shrapnel fire.*—The successive ranges are 100 m. apart, and if the front to be covered by each gun is n mils, the sweep will be a double one of a front of $\frac{n}{10}$ between 0 and 2,000 meters range, and a single one of a front of $\frac{n}{5}$ beyond 2,000.

If the target is not deep, the height of burst, once adjusted in reference to the target, remains constant during the fire. If the target

is deep, the height of burst is adapted, in the successive ranges, to the form of the terrain. If the target is in rear of a crest, the corrector can not be adapted to the form of the terrain unless the slope in rear of crest is known. Since this slope is generally unknown, a fire 200 m. beyond the crest is risky from the point of view of effect on the target under consideration.

If the target is such that only the most vertical balls in the shrapnel sheaf may be expected to reach it (personnel prone or sheltered), it is necessary to increase the successive ranges by 50 m., and we must not fire at the short limit of the bracket obtained by adjustment. If the zone to be covered has an appreciable slope, it may be necessary to modify the jumps between the successive ranges.

(*d*) *Shrapnel percussion fire.*—The successive ranges are separated by 25 m. or 50 m., according to the shape of the terrain. The sweep is carried out under the same conditions as in time-fuse fire. This type of fire is used only in the very rare case of surprise, when time is lacking for adjustment of the corrector and we have to fire over our troops close to the target.

79. *Remarks.*—(*a*) It is always advisable, in order to economize ammunition, and especially when time and the nature of the target permit, to narrow the fire for effect bracket as much as possible.

(*b*) In the case of fire by the four guns, the minimum bracket which can be obtained on a shallow target is 50 m., and then only when the target is not oblique to the line of fire.

(*c*) When the target is invisible, the over and short ranges limiting the fire for effect bracket will be those sensed without doubt as over or short by means of their positions with reference to visible objects or forms of the ground. In certain cases, only the short limit of the bracket can be determined. The width of the bracket to be established when we have to refer to auxiliary points of adjustment varies according to circumstances, but it should never fall below 100 meters.

In the case of an invisible target, we may get aerial observation which will give us the long and short limits of the fire for effect bracket. If this invisible target can be located on the map or on the battle map, the initial firing data required can be determined according to the map, and fire for effect can be opened on a rectangle inclosing the target, which will be wider and deeper in proportion to the inaccuracy in the location of the target.

If possible, we limit this rectangle by an adjustment on an auxiliary target, and then transfer the fire to the real target.

In these two cases, we fire for effect, as a general rule, with shell. The adjustment of the height of burst by aerial observation is long and very difficult. In map firing it is impossible to determine the proper corrector with sufficient accuracy.

(*d*) If, under the conditions of combat or observation, only one limit of the bracket can be determined, this limit is taken as the basis of fire for effect. The depth of this fire is limited by determining beforehand the depth of the suspected area and, whenever possible, by observing either the sense of the successive volleys or the effect of the fire on the target.

(*e*) Application of the rules given above (for successive ranges and sweeps) give the following results: In fire with shell, about 80 shells, uniformly distributed, will fall per hectare on a horizontal terrain. This follows from the fact that the patterns can not be grouped side by side, as in shrapnel fire, because of their small dimensions and because their axes may lie in any direction in respect to the line of fire (delayed action shell). The rounds are spaced 25 m. in depth and 5 m. in width. The density is greater in the case of a slope ascending away from battery and less in the contrary case. In the latter case, however, the difference between density 80 and the actual density is reduced if nose disks are used. Density 80 gives a 50 per cent effect on personnel lying prone, sheltered behind shields, sheltered behind embankments, or in an open trench.

In shrapnel fire, the terrain is covered with approximate uniformity. The patterns on the ground of the sheafs of the different projectiles lie perceptibly side by side in direction and overlap in depth at average combat range. At long ranges the terrain is also well covered.

The number of projectiles to be fired depends essentially on the supply, the target, and the certainty (in the case of invisible targets) with which we can effectively bracket the target. The rules for fire for effect are modified accordingly. For example, in the case of shrapnel, we may order a single sweep, even at short ranges, in order to increase the density of fire, or we may order double sweep at long ranges, if we are contented to spray the terrain lightly. In the same way, in firing shell we may order only a single sweep, or even a double sweep and jump by 50 m. Particularly in the case when the width of the target does not permit of sweeping, fire is carried out by volleys of 1, 2, or 3 rounds at the different ranges, according to circumstances and the amount of ammunition available.

EXAMPLES.

I. Shell fire.

80. (1) A line of enemy artillery, several elements of which are seen, is about 3,000 m. away, and its front is 60 mils. Delayed-action shell fire is used to reach the personnel of this artillery. In the adjustment, it is possible, thanks to the several visible elements of the battery, to obtain the bracket 2,900–3,000. The guns having been previously placed on the right of their respective sectors, we fire—

3 rounds, sweeping, 3,000, 2,975, 2,950, 2,925 (short).
Battery relay—left one turn.
Battery 3 rounds, sweeping, 3,000.....2,925.
Relay—left two turns.
Battery 3 rounds, sweeping, 3,000.....2,925.
Relay.

(2) Same target at about 5,500 m. Nondelayed-action shells are used, as those with delay action would form fougasses. Moreover, the difficulties of observation only permit a 200-m. bracket (5,400–5,200) to be obtained.

Battery, three rounds, sweeping, 5,400, 5,375.....5,250 short, etc.

(3) Information states that enemy artillery is in action in rear of a crest situated about 3,000 m. away and on this side of a road which is parallel to the crest and at about 300 m. from the crest. Certain indications give us the direction of the target, and we suppose its front to be 80 mils. We fire with nose disks L, and adjustment of fire on the crest gives the bracket 3,300–3,400. The guns having been previously laid on the right of their respective sectors, we fire—

Battery 4 rounds, sweeping, 3,700, 3,650, 3,625.....3,350 (short), or better, on account of the great zone to be covered:

3,700–3,600.....3,300 (short).
3,650–3,550.....3,350 (short).
3,675–3,575.....3,375.
3,625–3,525.....3,425.

This latter method has the advantage of covering more rapidly the whole of the suspected area.

The first sweep has expended 240 rounds. The captain launches his second sweep, or else he waits for other information to carry on his fire, according to his supplies and the degree of certainty concerning the bracketing of the target by his fire. Even if he is sure of having bracketed the target, it is generally best to wait a certain time before reopening fire, for the enemy battery will not stand a

fire of 25 rounds per hectare with impunity, and the personnel will probably be sheltered from the volleys. (See Chap. IV on the subject of the opportune moment to fire.) This example shows the amount of ammunition which must be expended by fire on even a restricted area and for uncertain results. Hence the necessity for aerial observation, which permits us to define the area to be covered and to fire for effect only under favorable conditions.

(4) Fire with time-fuse shell. Troops masked by a crest which has been bracketed between 2,900 and 3,000 m. The front is 120 meters. The front being 40 mils, we must fire 43 projectiles at each range.

Corrector 26. Battery 2 rounds, 3,000.
Left 1 turn, 3,000.
Same.
Same.
Same.
Same.
Corrector 25. Battery 2 rounds, 3,050.
Right 1 turn, 3,050.
Same.
Same.
Same.
Same.

If we begin at the long limit increased by 100, the commands will be—

Corrector 29. Battery 2 rounds, 3,100.
Left 1 turn, 3,100.
Same.
Same, etc.

Another example: Infantry are advancing on a front of 160 m. at 5,000 m. range. The front being 32 mils, 96 projectiles must be fired at each range.

Corrector 29. Battery 6 rounds, 5,000.
Left 1 turn, 5,000.
Same.
Same.
Right 1 turn, 5,050.
Same.
Same.

The effect is 50 per cent.

Same target, front of 150 m., range 6,000 m. The front being 25 mils 90 projectiles must be fired at each range. Angle of site =+70.

Corrector 29. Battery 6 rounds, 6,000.

Left 1 turn, 6,000.

Same.

Same.

Corrector 31. Battery 6 rounds, 6,100.

Same.

Same.

In this case the effect is only 35 per cent.

II. Shrapnel fire.

81. (1) Enemy infantry is surprised in the act of maneuvering at 3,000 m. With a sheaf of fire of 60 mils, roughly covering the target, we obtain by adjustment the bracket 3,000–3,400 and the corrector 20.

On first piece close 5.

Corrector 22. Battery 4 rounds, sweeping, 3,400.

Same, 3300.

Same 3200.

Same 3100 (3,100 short).

The range 3100 raises a cloud of dust distinctly short of the infantry detachments, who disperse and thin out. Fire is continued on the detachments still visible or sheltered behind depression of the terrain, hedges, etc., according to the circumstances.

(2) Fire on a target dispersed over a glacis. The adjustment gives the bracket corrector 22, range 2,400 and corrector 16, range 2,100.

Fire for effect—

Corrector 24, 2,400.

Corrector 22, 2,300.

Corrector 20, 2,200.

Corrector 18, 2,100.

(3) The battery is in observation. The guns are set on their wheel spades. The terrain has been registered (result of previous fire or systematic adjustment). The angle of site is known. An enemy machine gun reveals itself 10 mils to the left of the observation line of the second piece. For second piece—"Left 5 turns: Corrector 24, 2 rounds, 2,400." This first verification fire, preceding the fire for effect, is to verify the data and correct it if necessary. Two rounds are fired to increase the chances of observation and to get a clear idea of the value of the corrector. This fire is sensed—"Deflection correct. Height of burst 2 mils. Over." "Corrector 25, 3 rounds,

2,400, 2,300, 2,200 (2,200 short)." The fire is continued with shell to demolish the matériel.

(4) Infantry units endeavor to cross a crest at about 3,000 m. range and on a front of 60 mils. The visible units suggest that others may be behind them.

An adjustment on the crest gives a bracket of 3,000–3,100 and a corrector of 18. The slope beyond the crest is assumed to be steep.

"Corrector 14, 3 rounds, sweeping, 3,200.
Corrector 16, 3,150.
Corrector 18, 3,100.
Corrector 20, 3,050."

This solution is theoretically exact for 60-mil slope. It is not necessary to fire at 3,000.

In these two latter cases the terrain has been covered to a depth of 200 m. beyond the crest. If we desire to cover a greater depth, shells with nose disks must be used, because it is impossible to adapt the corrector to unknown forms of terrain.

III. Progressive fire.

82. This type of fire, which is only applicable to time-fuse shrapnel, is the most rapid, also the most rigid, variety of fire at successive ranges. It is very prodigal in its expenditure of ammunition, and does not allow the captain to vary the rapidity of fire at will, nor to adjust the jump and the corrector to the form of the terrain, nor to observe each volley so as to narrow the limits of fire or to change the data, if need be. It has the advantage, however, of giving the captain greater liberty once the fire is opened.

It is only suitable when the importance of obtaining a certain effect as soon as possible is very great, either because the target is important and fugitive or because it must be hit before it goes into action.

Fire is opened at the short limit of a 400 m. bracket, or simply at a short range when the conditions of combat do not permit us to obtain a bracket by observation.

Example.—An important reconnoitering party appears on the crest. The sheaf of fire of the four guns is shifted in such a way as to cover the target.

"Corrector 20, 3,000." The second piece is 15 mils to the right. The height of burst is 1 mil and the salvo is short. Nos. 1, 3, and 4 cease firing. No. 2, left 5 turns, corrector 22, progressive fire, sweeping, 3,000."

IV. Fire at a single range.

83. When time and the nature of the target enable us to carry out a sufficiently exact adjustment, fire for effect is executed at a single range. This method, which is economical in ammunition, is capable of great effectiveness. By it alone the destruction of obstacles or shelters and matériel may be effected.

(*a*) *Fire with shell (against personnel or for demolition) and percussion shrapnel fire for demolition.*—Fire is executed at a range giving two or three overs in a series of four observed rounds. After each series of four observed rounds the range is changed by 25 m., in the proper sense, if necessary. If the first three rounds of a series of four are short the fourth need not be fired. The first range to be tried is the mean range of a 50 m. bracket, or the long limit of a 25 m. bracket (when the elevation is given by the quadrant, case of the 90 mm. by level). Fire is always executed by independent pieces, because of the necessarily different systems of the pieces.

The rules given for sweeping fire at successive ranges and with shell apply to fire on a single range against personnel. This method of fire is only suitable to a shallow target, which is almost normal to the line of fire. The obliquity of the target to this line is more apt to be revealed in the case of large targets. It reveals itself, during fire for effect, by the fact that the rounds fired to the right or left of the line of fire on which the adjustment was made are systematically over or short. In this case it is necessary to cover the target in successive sectors, with different ranges, or to discard fire at a single range and fire at successive ranges between the long and short limits of the whole target. The latter method is more rapid, but also more wasteful of ammunition.

In fire for demolition, the fire is continued until the result is obtained, and, if necessary (in the case of a wall, for example), the target is covered by successive sectors. This type of fire is impossible at long ranges because of the extent of the dispersion.

(*b*) *Time-fuse shrapnel fire.*—The fire is executed either at the short or at the long limit of a 50 m. bracket. The short limit is used if the target is standing or kneeling in the open. The long limit is used if the target is lying prone or is sheltered.

The following figures show (see study of trajectory)—

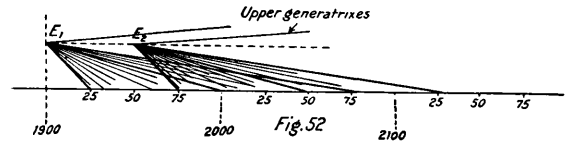


Fig. 52

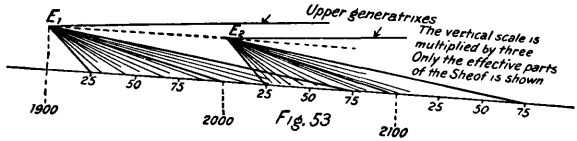


Fig. 53

(1) That the target bracketed between 2,000 and 2,050 is contained either in the short part of the sheaf, at the long limit, bursting 3 mils high (E_2), or in the best of the long part of the sheaf at the short limit, bursting 3 mils high (E_1). Hence, an unsheltered standing or kneeling target is more effectively covered by the grazing balls of E_1, while a prone or sheltered target is more effectively covered by the plunging balls of E_2.

(2) It is unnecessary to fire at a range whose point of fall is nearer the target.

(3) On the other hand, a 100 m. bracket is insufficient. Neither of the two sheafs cover all the zone 2,000–2,100.

It is not possible to obtain the 50 m. bracket necessary in this method of fire unless the target is sufficiently shallow. In addition, in the case of fire with four pieces the target must be almost normal to the line of fire. The obliquity of the target to this line of fire is more apt to be revealed when the target is large. It reveals itself by the fact that, in seeking to reduce the bracket below a certain value, we systematically obtain shorts with certain pieces and overs with the others. In this case, and according to circumstances, fire at a single range must be discarded and the target must be covered by the fire of the four pieces at successive ranges between the long and short limits of the whole target (rapid, but wasteful of ammunition), or the fire must be executed at different single ranges for the different pieces after each piece has obtained a 50 m. bracket on its particular sector (slower but more economical in ammunition.) If the sector of each piece is fairly wide, the question of obliquity may come up in firing at a single range. The rules given

for sweeping fire at successive ranges with time-fuse shrapnel apply to fire at a single range.

(c) *Percussion shrapnel fire.*—Fire against personnel is executed at the mean range of a 50 m. bracket, but this is very rare.

Remark.—An exact adjustment is required, not only in the case of shallow targets, in view of the execution of fire at a single range (which gives greater efficiency with only a slightly increased expenditure of ammunition), but also, sometimes, in the case of deep targets. If narrow brackets can be obtained on the extreme right and left edges of the zone to be covered, the extent of the zone will be limited and ammunition will be economized. The search for a narrow bracket is also indispensable in the fire on the most advanced enemy units when the two opposing lines of infantry are in immediate contact (for reasons of safety). Moreover, the exact firing data thus obtained will serve as a basis for fire for effect in depth, preparing for, or supporting the attack which is carried on under the protection of the fire.

V. Fire commanded by the chiefs of section.

84. In certain cases, the captain, after having adjusted the fire, may find it advisable to turn over to the chiefs of section the details of the fire. For example, in cases where, for some reason, the adjustment has to be made independently by piece and leads to different firing data for each piece, in the case of neutralizing fire on certain parts of the front of the target, etc.

The captain gives all his attention to observing the target and varies the firing data of the different pieces according to the changes observed in the shape and vulnerability of the target. Certain pieces may not fire.

The necessary adjustment may have immediately preceded the fire, or have been carried out some time before. In the first case, the fire is executed by commands, such as the following: "No. ———, on ——— front (expressed in mils or in turns of the hand wheel), shell with ——— fuses (or ——— correctors, or percussion fire), ——— rounds, or at ——— second intervals, ——— range (or between ——— ranges)." The chief of section immediately determines the different elevations and deflections with which he must fire to cover uniformly the terrain assigned him. He executes the fire at the given cadence. If the cadence ordered is slow, he changes the deflection between rounds in any order and at irregular intervals of time, limiting himself to obtaining the mean

density of fire expected of him. A diagram of the type indicated below will be useful to him.

In the second case, the firing data for all the targets on which the piece has been adjusted is recorded in the chief of section's data book, in the form of the series of commands to be used (and with the proper sketches, if necessary). The fire is executed according to the data in the data book on simple designation of the target and indication of the corrections of the moment (deflection, corrector, range), which the chief of section takes into account when giving his commands.

85. *Examples.*—(1) Take example 1 of paragraph 80. After having executed the fire indicated in paragraph 80, the captain decides to demolish an enemy gun that he has located approximately in the direction of the fire of the second piece. His object is to prevent the other enemy guns from entering into action during this time. He commands: "Nos. 1, 3 and 4, under the command of the chiefs of section, Nos. 1 and 4 on a 15-mils front to left of present position, No. 3 on a front 15 mils to right and 15 mils to left of present position. Delayed-action shell. One round every two minutes (2 for No. 3). Between 3,000 and 2,925." For No. 2, he commands: "Nondelayed-action shell, 2,950, etc."

The chief of section of the third piece makes the following sketch:

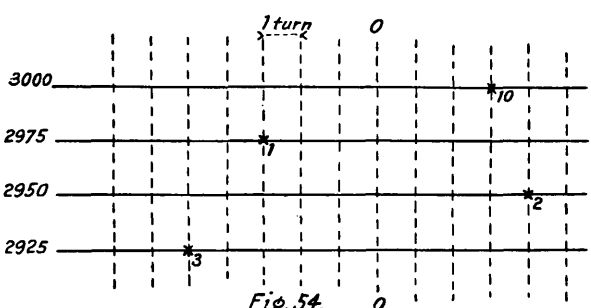


Fig. 54.

And commands, for example:

"Left 3 turns, 2,975." He plots 1. Then "Right 7 turns, 2,950." He plots 2. Then "Left 9 turns, 2,925." He plots 3, etc., up to 10.

At this moment activity is renewed toward the center in the enemy battery, and the captain commands: "No. 3, rapid fire, sweeping." The chief of section commands: "Right 4 turns, 6 rounds, sweeping, 3,000, 2,975, 2,950, 2,925."

(2) The captain commands: "No. 1, target Y, corrections for the moment, right 5, 50 meters more." In his data book, under target Y, the chief of section reads: "Left 35, delayed-action shell, 5 rounds, sweeping, 3,000, 2,975, 2,950."

The chief of section gives the written commands, except that he gives only 30 left and increases his range by 50 meters.

(c) NUMBER OF PIECES TO USE.

86. The number of pieces depends essentially on the front to be covered, on the density of fire to be realized, and, above all, on the situation. Strict rules can not be given. It is a matter of judgment and skill on the captain's part.

ARTICLE 2.

FIRE FOR ADJUSTMENT.

87. The object of fire for adjustment is to determine the data for fire for effect: Deflection, range, and corrector (if necessary). It is based on observation of rounds, observation of errors in deflection, and corrector, and observation as to the sense only in range adjustment.

A. NUMBER OF PIECES TO BE EMPLOYED.

88. As a rule, adjustment is made with all the guns before commencing fire for effect. We gain time in this way, and may also expect a certain effect on the front covered. But if economy of ammunition is more important than the factor of time, the adjustment can be carried on with a restricted number of pieces (even a single one) after the direction of the pieces has been assured.

When observation is made from a point considerably to one side of the line of fire, and particularly when it is near the targets, the difficulties of adjusting lead, as a rule, to adjusting by single piece. (See "Lateral and Bilateral Observation.")

B. TYPE OF PROJECTILE TO USE.

89. Fire for adjustment is carried out with the same type of projectile to be used in fire for effect, and it is employed in the same way (nondelayed-action H. E. shell, delayed-action H. E. shell, time-fuse shell, time-fuse shrapnel, percussion shrapnel). To facilitate observation and make it independent of the formation of the terrain, however, adjustment of fire may be simplified by the use of time-fuse shrapnel.

If observation with delayed-action shell is difficult (for example, when the observation station is near the targets, when the smoke of burst is too high to be observed and the fall of the vertical fragments

is not seen), adjustment is made with nondelayed-action shells. But we do not use the supersensitive (I. A.) fuse because it gives a different trajectory from those obtained with other detonating fuses. When passing to fire for effect, we must remember that the burst of a delayed-action shell is between 5 and 15 meters beyond the point of fall of a nondelayed-action shell.

If observation with time-fuse shrapnel is difficult (for example, when a target has a slight relief, or when the observation station is near the target), we adjust the range by using percussion shrapnel and then the height of burst by using the time-fuse shrapnel.

C. PRINCIPLES OF OBSERVATION.

I. Observation for deflection.

90. The sense and value of the angle MPO must be deduced from the observation of a round M (O being the point which we wish to hit and P the piece firing). The angle MPO is that by which the deflection must be changed in order to bring the round to the direction of O.

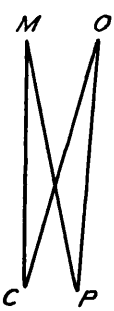


Fig. 55.

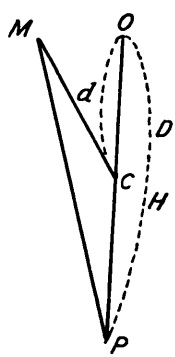


Fig. 56.

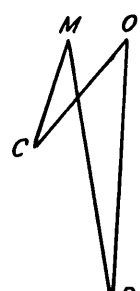


Fig. 57.

(*a*) Observer C is in the vicinity of the piece P. The angle MCO has the same sense and value as the angle MPO when M is in proximity to O.

(*b*) Observer C is on the line of fire, but at a distance *d* from O, different from D, the range from P to O. The angle MCO has the same sense as MPO, and we have, approximately—

$$\text{MPO}=\text{MCO}\div\frac{\text{D}}{d}$$

when M is in the vicinity of O. The proportion between the range to O and the distance of the observer from O must therefore be obtained. In practice this proportion is taken in round numbers, or at least in simple fractions (3/2, 4/3, 5/2, 5/3, 5/4). The angle by which the deflection must be changed is equal to that measured by the observer divided by the above proportion.

(*c*) Observer C is outside the line of fire and at a distance from P. (See "Lateral observation.")

II. Observation of errors in range.

91. An over (or short) round is one whose trajectory reaches the ground beyond (or on this side of) the target. The sense of the round is, consequently, the sense of the observed burst when the round bursts on impact. (In delayed-action shell fire the burst is produced only a few meters beyond the point of impact.)

In time-fuse fire, an over burst in air always corresponds to a long range; a short burst in air does not correspond to a short range except when the burst interval (and, consequently, the height of burst), is zero or very small. If, for example, the burst interval HC has an

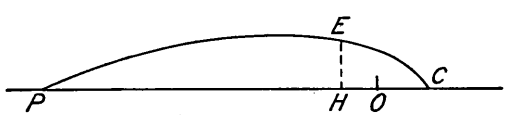


Fig. 58.

appreciable value, it is possible that the target O is in this interval, in which case the short burst E corresponds to a long range C. In practice we can not conclude that a time-fuse round which has been observed as short is actually short except when the height of burst is less than half the normal height. It is therefore necessary, in adjustment with time-fuse fire, to obtain an average height of burst of 1 mil.

If the smoke hides the target, the point of burst is short; if the target is silhoutted against the smoke, the point of burst is over.

To be able to sense time-fuse bursts, their height must be in proportion to the relief of the target—that is, as a rule, between 0 and 1 mil. The dust and débris raised by the balls from time-fuse fire may also furnish useful indications on the sensing of the round or on the burst. Short balls indicate short bursts; but we can not sense the rounds as such. A round which gives a pattern entirely on the other side of the target may, however, be sensed as long.

If the terrain on which the target is located slopes down toward the battery, the round may be sensed as short or over, according as the point of impact is seen below or above the target.

In all cases it is advisable to take into consideration the effect of a round on the target, whenever this effect can be observed with certainty.

The officer who is observing should confine himself, in sensing a round (or a salvo), to one of the announcements—"short," "over," "doubtful," or "bracketing." He must always allow the smoke time to form. When rounds are suspected of having fallen in woods, in holes, or behind a crest, they must be observed for several seconds, at the end of which time the smoke of the burst may appear. Sometimes the sensing of the rounds for range may thus be determined, but not the deflection, since the wind may have blown the smoke to one side of the point of burst.

The sensing must be made very promptly when shells are used, for their smoke ball (black or plum), on which the observations are generally made, is very fugitive.

III. Observation of error in elevation.

92. The heights of burst are measured from the foot of the target, if the latter is not sheltered in intrenchments or behind a crest, in which case they are measured from the top of the covering mass.

If the observer is at the distance d from the target, and the range at the gun is D, the height of burst H, seen from the gun, is deduced from the height h seen by observer by the formula—

$$H = h \div \frac{D}{d}$$

Therefore we estimate the same proportion of distances D/d which we used in the observation of errors in deflection. The height of burst seen from the gun is equal to that seen by the observer divided by this proportion of distances.

A burst below the plane of site should be considered as a graze burst.

The height of a series of air bursts fired with the same corrector is taken to be the mean height of the bursts.

D. PRINCIPLES OF ADJUSTMENT.

93. The adjustments in deflection, in range, and in height of bursts (if necessary) are usually carried on simultaneously.

I. Adjustment in deflection.

94. *Distribution of fire in deflection.*—As a rule, fire is distributed in deflection over the whole front to be covered immediately on the opening of fire. This method gives, even in fire for adjustment, a certain effect on the entire target. The final object of adjustment in deflection is a suitable distribution for fire for effect. But this distribution may be changed after firing the first salvo for effect.

95. *Distribution in firing the first salvo.—Targets of a front of less than 140 mils* are covered by a normal sheaf of fire of 60 mils, whose axis is laid on the center of the target. In case the target has a front greater than 60 mils, the sheaf of fire may be opened before firing, but this method prevents regrouping the fire of the four pieces on any front of 20 mils contained within the front of the entire target unless the wheel spades are disengaged.

Targets of a front greater than 140 mils.—Each gun is laid on the center of its sector, the sheaf of fire having been opened accordingly. Each gun can thus cover, by its traverse movement on its axle, a minimum of 40 mils on either side of the center of its sector.

96. *Distribution of fire for the following salvos in adjustment—Registration points (or marks).*—The first consideration in fire for adjustment is to bring the rounds into the directions of the registration points of the target (called registration points), in relation to which sensing for range is particularly easy and sure. These points can even be chosen outside the target, if their location is accurately and certainly known in relation to the target. (This proceeding, generalized and extended, is what is known as "transfer of fire.")

It will be seen later that it is necessary, at certain ranges (the limits of the brackets), to observe at least two rounds. It is therefore advantageous, in the case of fire executed with several pieces, to have at least two registration points on which the rounds of two of the pieces can be adjusted. If the target only presents one registration point, we either concentrate the fire of two pieces on it (lengthening the cadence, if necessary), or we fire in this direction with a single piece, either by two rounds (lengthening the cadence, if necessary) or by one round, but it will then be necessary to repeat the ranges at which we must observe at least two rounds.

In the case of fire with more than two pieces, it is advantageous to choose registration points which will give as regular a sheaf as possible when the adjustment in deflection on these points is completed, in order to be able to change the distribution of fire by one command applicable to all the guns.

97. *Distribution in fire for effect.*—Before opening fire for effect, each piece is laid on the right of the sector that it is to cover if sweeping is to be used, or on the center of the sector if sweeping is not to be used.

Remarks.—All things being equal, the most simple procedure, in fire for adjustment, consists in laying the right piece on the right of the target, the left piece on the left of the target, and distributing the rounds of the second and third pieces equally in the interval. Before opening fire for effect, the deflection difference is reduced by one-twelfth of the front when sweeping is used. If sweeping is not used, the fire is shifted by one-eighth of the front toward the left, and the deflection difference is reduced by one-twelfth of the front.

98. *Execution of adjustment in deflection.*—Starting from the distribution observed in the fire of the first salvo, adjustment in deflection consists in obtaining successively the distributions shown below in sections 2 and 3. To accomplish this the captain commands additions (or subtractions) to be applied to the whole sheaf, and deflection differences or individual corrections.

In firing with the four guns, the captain, after the first salvo, prescribes only the changes necessary to bring the first and fourth pieces into direction, using such commands as "Add (or subtract) ———," or "On No. ———, open (or close) ———." This operation may, if necessary, be divided into two phases. (1) After the first salvo, shift the line of fire of the first gun to the registration point by adding (or subtracting) so much. (2) After the second salvo, shift the line of fire of the fourth gun to its registration point by opening (or closing) so much on the first piece.

Individual corrections are not applied to the second or third pieces in the first salvo unless their rounds are outside those of the first and fourth pieces. After the second or third salvo the captain applies the individual corrections necessary to assure the exact distribution of the four rounds.

After making a certain correction, if the captain desires to make the same correction, but in the inverse sense, he reduces it by half.

If the captain has doubts about the deflection of his sheaf before opening fire, he fires a test round with the first piece without setting it on his wheel spades, corrects the deflection by the error observed, and then sets his guns on their wheel spades before continuing the fire.

When the captain can not see the bursts, he increases the height of burst, raising the angle of sight rather than the corrector.

When he gets into difficulty in adjustment of deflection, he fires by piece.

When the direction is adjusted, he may fire either by salvos or by one-round volleys, provided the width of the sheaf is distinctly smaller than the field of view of his field glass.

II. Adjustment in range.

99. It follows from article 2 (Fire for effect), that the execution of fire for effect assumes, as a general rule, that a long and short range has been obtained in respect to the target. These two ranges constitute the bracket, and the difference in range between them is called the value of the bracket (for example, the 2,000-2,100 bracket is a 100 m. bracket).

The value of the bracket to be obtained depends on the type of fire for effect contemplated. Fifty-meter brackets are called narrow brackets, while brackets of 100 m. and above are called wide brackets.

100. *Initial range in fire for adjustment.*—The range to the target is obtained by a telemeter, or measured on a map or battle map, or estimated by sight, or taken from the results of previous fire on the same target, or on adjoining targets whose positions in relation to the present target can be accurately stated.

The initial range used, as a rule, is that which one of the above methods gives us as the real range. It is taken in even hundreds of meters. (This rule is not absolute, but is convenient.) The range quadrant range is equal to the determined range if the cartridge fired is that for which the altitude micrometer head of the independent quadrant has been graduated (shrapnel of initial velocity of 535).

If the target is close to friendly troops, however, we open fire at a range which is surely long. Such a range, moreover, may render observation easier in certain cases—for example, if the target, or the registration point on which the adjustment is made, does not stand out clearly in the sheaf of fire, or if the wind is such that the smoke from the bursts hampers observation.

101. *Successive ranges in fire for adjustment.*—The first range having been sensed, we proceed by successive jumps of the same lengths until we obtain two ranges which bracket the target. The length of the jump, and consequently of the first bracket, is as a rule, 400 m. It may be reduced to 200 m. in certain cases, when observation is easy and sure, or when we base our data on information furnished by a previous fire or by that of another battery, or on measurements made with a telemeter.

But consideration for the safety of friendly troops comes before all others. Fire at a range which may be dangerous to our troops must be absolutely and always avoided. Therefore a jump in the sense of decreasing the range should always be distinctly less than the distance separating the target from our most advanced units, because it is impossible, as a rule, to know by how much the preceding rounds were in front of them, and because of the dispersion. It is, therefore, necessary to have previous information, as accurate as possible, on the position of our most advanced units.

The first bracket having been established, we narrow its limits until the desired bracket is obtained.

102. *Sensing for range—(I) Case of fire with one piece only.*—(1) A single round observed as short (over) enables us to sense the range as short (over).

(2) A range is not taken as the limit of the bracket unless at least two rounds have been similarly sensed at this range. In fire with one piece only it is best, from the point of view of time, to fire two round volleys, increasing the cadence if necessary. If the target is in motion, or is capable of changing its position, the bracket is not considered effective unless the last range fired is that of the limit of the bracket toward which the target is moving, or, when definite information is lacking on the direction of its movement, unless the last range fired is the short limit of the bracket.

(3) When a short and a long round are obtained at the same range, the range is considered doubtful. To remove this doubt, we fire two more rounds at the same range. If the two new rounds are of the same sensing, we sense the range accordingly. If the two new rounds again give opposite sensings the range is said to be the "bracketing" one. A bracketing range sensed with graze bursts is considered as the most probable range to the target. A bracketing range sensed with air bursts at 1 mil height of burst is considered long, but close to the target, and the length of the next jump can always be reduced to 100 m.

(4) One round on the target is considered as equivalent to both a short and an over at the same time, that is, as doubtful. A second round on the target enables us to sense the range as bracketing.

(5) When several rounds (2, 3, or 4) fired at the same range are observed, the range is sensed on the basis of all of them or the majority of them. It is sensed as doubtful if only two rounds are fired and one is short and the other over (sec. 3). It is sensed as bracketing if there are two shorts and two overs.

In percussion fire, after sensing four rounds fired at the same range as 3 short and 1 over, the following jump in range may be reduced to 50 m. If the round (or rounds) observed at the new range gives the same sensing as the majority of the rounds at the preceding range, we conclude that the round of the opposite sensing is abnormal, and the adjustment is continued without taking them into further account.

103. (*II*) *Case of fire with several pieces.*—The rules given above apply to the fire of several pieces (distributed or not in deflection).

It is always necessary, however, to remark that, in the case of fire with a single piece, when all the rounds observed at the same range are not sensed in the same way, we may attribute this result to dispersion alone, and conclude that the range considered is close to that of the target. But, in the case of fire with several pieces, this contrary sensing may result from the pieces not being exactly similar. Two pieces are similar, in point of view of range, if they give the same range when laid with the same data. This results from similarity of aiming apparatus, and also from similarity of rifle barrels. The verification of the sights and quadrants (No. 117 of Appendix 1, Chapter IV of the Drill Regulations) enables us to remedy dissimilarity between them. Well-preserved barrels that have been fired but little are considered similar by reason of construction. Two barrels are considered dissimilar when, the aiming apparatus of the two pieces being similar, one of them systematically gives longer rounds than the other. There is no way of adjusting this dissimilarity. It is advisable, therefore, to group the pieces in batteries of four guns whose barrels are approximately similar.

Contrary sensing of rounds from different guns may also result from actual differences in the ranges of the different registration points from their corresponding pieces.

From the above, it follows—

(*a*) In firing with several pieces, the minimum bracket that can be obtained on a shallow target is generally 100 m. When a 50 m. bracket is desired, it is almost always necessary to fire by independent pieces.

(*b*) In firing with several pieces, after a salvo has given 2 or 3 rounds in one sense and one round in another, we may continue the adjustment normally, without taking into consideration the round in the sense contrary to that of the majority.

(*c*) In firing with two pieces, a range can not be definitely considered as the bracketing range until each piece has given a short and an over. If, on the other hand, one piece has given two shorts

and the other two overs, it is more to the point to conclude that the target is oblique to the line of fire.

(*d*) In firing with four pieces it is necessary to assume the obliquity of the target in reference to the line of fire if, in a salvo giving two overs and two shorts, the two shorts are from the same platoon. If necessary a new salvo at the same range will remove any doubt.

104. *Remarks.*—(*a*) In case shell fire is preceded by an adjustment with time-fuse shrapnel, the latter is continued (for ranges below 3,000 m.) until the 200 m. bracket is obtained, and then the adjustment is completed with shell, starting at the long limit of the bracket obtained and proceeding by 200 m. jumps. Beyond 3,000 m. it is inadvisable to cut down the shrapnel bracket below 400 m. In fire with nose disks P or L, the initial range when passing to the adjustment with shell is the long limit increased by 400 or 800 meters, and it proceeds by 400 m. jumps.

The following concordance table shows the variation in range when we pass from shrapnel to shell fire (delayed action, instantaneous, or supersensitive fuse).

Measured range.	Shrapnel quadrant range.	Shell quadrant range.	
		Delayed action (A. R.) or instantaneous (I.).	Supersensitive (I. A.).
1,500	1,500	1,500	
2,000	2,000	2,050	
3,000	3,000	3,200	
4,000	4,000	4,325	4,575.
5,000	5,000	5,500	Site+70, 4,600.
6,000	6,000	Use the level.	
7,000	7,000		

(*b*) In case percussion shrapnel fire is preceded by an adjustment with time-fuse shrapnel, the latter can be continued until a 50 m. bracket is obtained, but it is necessary to verify the short limit of the bracket obtained before continuing the fire.

III. Adjustment in height of burst.

105. The adjustment in height of burst, in the case of time-fuse fire, is effected in order to determine the proper corrector to obtain the normal height of burst (3 mils) in fire for effect.

As a rule, in order to gain time and to make independent observations of the shape of the terrain, the adjustment is made with time-fuse fire. In the course of this fire we must obtain bursts at 1 mil height. Consequently, during fire for adjustment, the corrector to give bursts at 1 mil is determined, and it will then be sufficient, when passing to fire for effect, to increase the adjustment corrector by 2 mils. When fire has been adjusted on a crest, however, it may be advantageous not to raise the corrector 2 mils.

If, on the other hand, the adjustment in range is effected with percussion rounds, we must then proceed to adjust the height of burst. Under these conditions either the corrector giving the normal height of burst is determined directly or else we pass through the intermediary of the corrector which gives 1 mil bursts.

106. *One-mil adjustment.*—We must get a series of at least two observed rounds fired with the same corrector. The mean height of this series being estimated in mils, the corrector is changed by the number of mils necessary to give the required height of burst.

The corrector corresponding to a mean height of burst of 1 mil is characterized by the fact that it gives, as a rule, one burst on graze (or air burst below the target) in every 4 rounds observed (3 out of 8 at ranges greater than 5,000). This enables us to adjust the height of burst to 1 mil, even from a station at a distance from the target which is very different from the range from the battery to the target. When an equality of graze and air bursts is obtained, we have the corrector giving a mean height of burst of 0, a height which is too low by 1 mil.

When a corrector gives a series of at least two graze bursts, and no air burst has yet been obtained, the corrector is increased by four.

When, on account of the form of the terrain, a corrector gives graze bursts above the target, no change is made in the corrector because of these graze bursts, because we do not know, as a matter of fact, how the rounds will act in the plane of site until they reach it.

When an initial series of at least two rounds shows that a decided correction is needed, it had best be made in the angle of site and not in the corrector.

When a corrector gives both air and graze bursts in the plane of site, it is considered as the corrector for the zero height of burst.

If, after a change has been made in the corrector, we are led to make a correction in the contrary sense to the preceding, and equal to or greater than it in absolute value, we adopt an intermediate corrector.

Rounds of abnormal height are not taken into account. The abnormal rounds are due to faults in fuse setting or laying, or to errors in setting off the angle of site or range. If the captain fears an erroneous angle of site on one or more pieces, he repeats the command for the angle of site.

107. *Adjustment to 3-mil height of burst.*—We proceed as has been shown above. Before concluding that the corrector is adjusted for a mean height of burst of 3 mils, a series of at least four rounds must be observed whose mean height is 3 mils.

108. *Adjustment to 1-mil height of burst with shell.*—The difficulty of this adjustment arises from the possible confusion between rounds bursting after having ricocheted and low air bursts. The following may be used in default of definite instructions.

When adjustment is made on a crest, we first adjust the range, and then the corrector, by firing at long ranges.

It is always advisable to fire a verifying salvo after raising the corrector by 3, in order to note whether the fuses really give air bursts. If they do, the bursts will respond to the play of the corrector and burst higher. If they do not, the height of burst will not vary. Moreover, it is always well to measure the exact site of the target and to make a note of this, as well as of the information on the corrector of the day, so that we may fire, with a determined corrector, as exactly as possible.

109. *Adjustment to 3-mil height of burst with shell.*—The range is adjusted first. The corrector is considered adjusted when, in a series of four observed rounds, the mean height is 3 mils.

110. *Remarks.*—(1) The preceding rules can be applied either to a series of rounds fired by a single piece or to salvos fired by different pieces. In fire with a single piece, because of the necessity of observing at least two rounds before reaching a decision, it is advisable to fire by two-round volleys, lengthening the cadence if necessary, or to fire by single or double sweeps of two rounds, if observation in range is possible in the second direction of the sweep.

(2) We must not forget that, in raising the corrector without altering the range, we diminish the burst range. Therefore, if the target is near our advanced units, we must never order a raise in the corrector which might, whether combined or not with a decrease in range, give bursts dangerous to our troops. Similarly, when for any reason a round is to be fired way up in the air, it must be done by the angle of site and not by the corrector. This method has also the advantage of giving a wider margin and of not changing the burst range.

(3) It frequently happens that of two correctors, differing only by 1 mil, one gives a mean height of burst which is too low and the other one which is too high. In this case, one of the two correctors may be taken as the adjustment corrector, for the effectiveness of the fire varies little when the height of burst is maintained between 2 and 4 mils.

IV. Verifying salvo.

111. A verifying salvo is one fired, after the adjustment is made, with all the pieces which are to take part in the fire for effect. The object is to verify the data for fire for effect. It is carried out with the deflections which are to be used for fire for effect (right of the sector of each piece, if sweeping is used; center of the sector, if sweeping is not used). It is fired at a range which will permit of sensing the rounds—all things being equal, at the short limit of the fire for effect bracket. The adjustment corrector is used, if possible, so that sensing of the rounds may be secured.

112. For example, in the case of time-fuse fire at a single range on skirmishers sheltered in a trench, the verifying salvo is fired at the long limit of the 50 m. bracket. But if the trench is situated on the slope of a glacis, the salvo is fired at the short limit of the 50 m. bracket—this allows the value of the corrector to be taken into account; while, if we fire at the long limit, grazes will be obtained above the target from which nothing can be concluded in reference to the value of the corrector.

The verifying salvo can be repeated if it has entailed important changes in the firing data.

The captain decides whether or not it is necessary to fire a verifying salvo.

E. USE OF THE BATTLE MAP—CORRECTIONS OF THE MOMENT, CORRECTIONS IN ADJUSTMENT, REPETITION OF FIRE, FIRING DATA BOOKS.

113. Since the present war is conducted on the lines of siege warfare, the methods of the latter have had to be adopted. In matters relating particularly to the artillery, the use of range triangulation control of fire has been extended even to the field batteries, to the extend noted below.

The nature of the battle maps and cross-section maps that are distributed in each army has been discussed in the "Preparation of a Battle Map." Emphasis is particularly laid on the facilities that are afforded by their use to the liaisons between the infantry and the artillery.

The use of these maps permits the field artillery to execute fire on targets that are invisible from all terrestrial observation under conditions given later. It facilitates the transfer of fire to targets, even visible ones, on which surprise fire is to be opened. In the present method of warfare, to give warning of the opening of fire for effect by an adjustment, no matter how rapid, usually enables the enemy to reach his bombproof shelters, and no good results can be obtained. In the remainder of these Instructions, the examples refer entirely to the 75-mm. gun, model 1897, but all the developments are applicable to other fieldpieces, and even to the heavy artillery.

I. Material in use.

114. Each battalion and battery commander of the 75-mm. guns is issued, in addition to the battle map, a protractor graduated in mils; a plane table with declinator and leveling alidade, or a clinometer with sighting rod, suitable for simple topographical operations; and a firing data book (for registering different fires).

The exact positions of the directing piece and its aiming point are carefully located on the battle map or cross-section map.

It often happens that the coordinates of the right piece are furnished to the battery commander by the topographical service. He has then only to plot the point on the battle map. The same often applies to the battery observation stations. Finally, an outstanding point shown on the battle map can often be used as an aiming point.

If the coordinates of the directing piece are unknown, its exact position on the battle map must be determined by using the oriented plane table and leveling alidade, as described in the Instruction on the Use of Topographical Material for Field Batteries (Appendix to "Instruction of Nov. 10, 1914"—also refer to "Instruction on Topography," "Preparation of Battle Map," and "Description and Use of Battery Topographical Instruments").

II. Preparation for fire of battery of 75 mm.

115. (1) *To read the deflection.*—The fire is prepared for the directing piece. The sheaf is formed according to known rules.

Let P be the directing piece, B the target, and R the aiming point of the battery, on a battle map or a cross-sectioned map of 1/50,000^e. Draw the straight lines PB and PR, and measure, by means of the mil protractor, the angle RPB. This angle must be measured from PR (or its prolongation, so as to get an angle less than 1,600 mils). The angle is given the plus sign if the line PB lies in a counter-

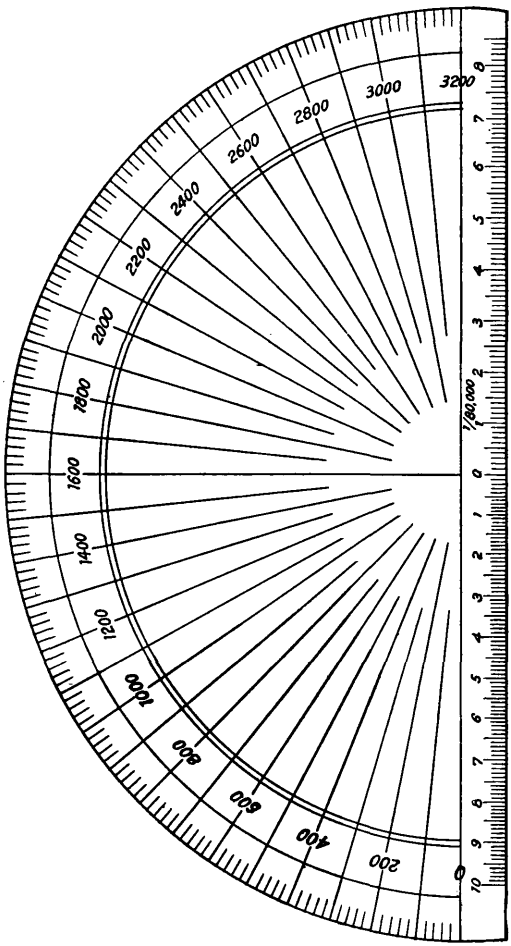

0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
1/80,000
Graduation in mils
Protractor in mils

Fig. 59.

clockwise direction with respect to the line PR, and the minus sign in the contrary case. If, for example, this angle is + 1,420 mils, the deflection given to the piece P is:— main scale 0, azimuth micrometer 100+1,420=main scale 14, azimuth micrometer 120, to which the drift must be added.

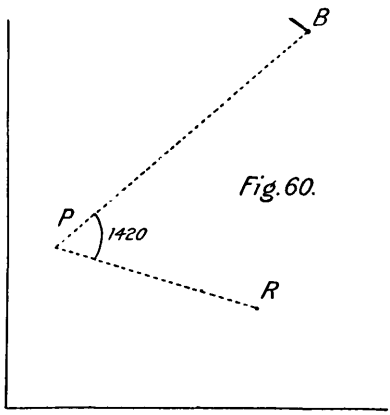


Fig. 60.

(2) *Determination of the range and angle of site.*—The range is obtained by measuring the length PB on the scale of the map (1/20,000 or 1/50,000), using the base of the protractor or a double decimeter ruler. (The method of obtaining a quadrant range corresponding to the determined map range is discussed later.) The angle of site is deduced from the difference between the altitudes of the target and the battery, according to the known rule:

$$\text{Site} = \frac{\text{difference of altitude in meters}}{\text{range in kilometers.}}$$

The difference between the altitudes can be read on the battle map, if it is contoured, or on the hachured 1/50,000 map.

Importance of accuracy in preceding methods.—The use of the 1/50,000^e map and (to an even greater degree) the battle map, enables us to obtain the firing data with sufficient accuracy for the immediate opening of a zone fire (200 m. this side and 200 m. beyond the target, and 15 mils to the right and left of it) or for the opening of fire for adjustment with aircraft observation. In the latter case, although the object of the adjustment is the rectification of the inaccuracies

of fire, we must, nevertheless, make our preparations with care in order that the first salvo, falling near the target, may surely be observed. This is a very important condition for the rapidity and success of the adjustment. In the two cases of fire considered, the data taken from the battle map or the 1/50,000 map must be corrected as is shown later. To obtain the desired accuracy, the position of the directing piece should be marked by a very fine small cross. (It is more visible if a line is drawn around it.) The aiming point is marked in the same way. The straight lines PB and PR must be carefully drawn in fine lines.

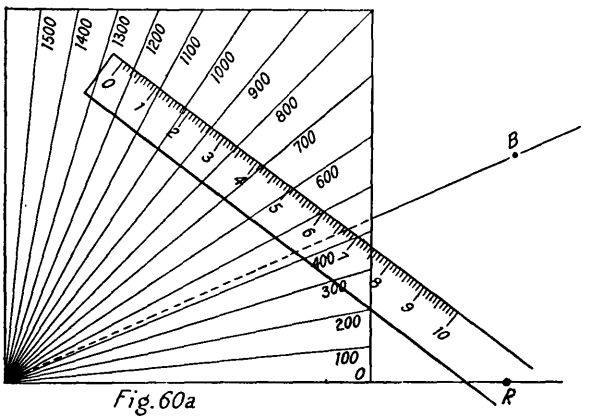


Fig. 60a

The range PB may be easily read to within 25 m. (25 m. being represented by 1.25 mm. on the 1/20,000 scale and by 0.5 mm. on the 1/50,000 scale).

(The decimeter rule is assumed to be transparent in order to make the figure clearer.)

The angle RPB should be measured to within 10 mils. It is easy to estimate 10 mils with the Geographic Service protractor. If the only protractor at hand is a more primitive one, the device shown on the preceding figure may be used in the following way: Place a double decimeter ruler on the protractor, orienting it so that one centimeter (centimeter 6–7 in the figure) lies between the two lines of the protractor which inclose the direction PB. On the figure, 430 mils is read for the angle RPB. Always take great care to place the origin of the protractor exactly on P and the zero edge exactly along

the line PR. It is well to place on the paper the face of the protractor on which the graduations are cut.

The firing data obtained by the above measurements serves as a basis for a shrapnel or shell fire, the range measured on the battle map being corrected, if necessary, for atmospheric conditions.

116. *Importance of accuracy in the angle of site.*—A simple examination of the range table shows errors of range in meters resulting from given errors in the elevation. In particular, it is established that an error of 5 mils in the angle of site gives for shrapnel (I. V.=535^{m}) a displacement of the point of fall of—

200 mils for range of 1,000 meters.
154 mils for range of 2,000 meters.
125 mils for range of 3,000 meters.
100 mils for range of 4,000 meters.
85 mils for range of 5,000 meters.

It is thus seen that preparation for fire based on the battle map may be greatly at fault if an important error is made in the angle of site. It is often impossible to avoid such an error, either because of the inaccuracy of the battle map or measurements on the terrain, or because of the system of graduating the site-micrometer head. It is therefore necessary to get a more accurate determination.

If accurate measurement of the angle of site is impossible, we take as close an approximation as possible, estimating it either from the map or by comparison with known angles of site of points in the vicinity of the target. The error committed consequently gives an adjustment range more or less different from that which would be obtained with the accurate angle of site. In the course of fire on the target we may use this range, which corrects the error in the angle of site. But the true range of the target can not be deduced from it so long as the error in the angle of site remains unknown. Furthermore, as will be seen later, the correction of the moment, with reference to the exact data for normal atmosphere, can not be deduced from the results of an adjustment made with an inaccurate angle of site.

Error in range resulting from the altitude of target.—The ranges measured on the battle map are horizontal ranges. In the average rolling country the error made by taking horizontal ranges is slight.

III. Consideration of momentary atmospheric conditions.

117. The deflection and elevation data deduced directly from the battle map, must be corrected by the momentary atmospheric conditions (see the study of the trajectory). These conditions will

generally be different from those on which the range table is based—temperature 15° and zero wind. The data must also be corrected for the lot of ammunition used.

The corrections to be made can be deduced from the tables and graphic charts which are given in the recent range tables for all calibers. These atmospheric corrections, and the corrections for the curve and rotation of the earth, the latitude, etc., are made with the greatest care for the preparation of fire of the pieces of heavy caliber (in which the rifling must be spared and the ammunition economized), so as to reduce to the minimum the number of rounds devoted to the adjustment. They can also be used advantageously for pieces of average and of small caliber.

But as a certain number of disturbing causes escape the calculation of the correction, the firing data thus corrected, while closer to the real value than the data first determined, should be verified by observation, or else it can only be used for zone fire.

Under these conditions, for small and average caliber pieces, it is often preferable to transfer the fire. This gives good results, but requires a greater expenditure of ammunition.

IV. Transfer of fire—Repetition of fire.

118. When the observation of a fire is impossible, or when it can not be continued on a target whose position is exactly known on the map, or when we wish to surprise a target, the procedure is as follows:

The battery commander directs his fire on a target visible from his observation station, called the "auxiliary target for adjustment." Knowing the direction, the range, and the altitude of this auxiliary target from the map, the adjustment enables us to obtain the adjustment corrections by which the different elements of the data must be effected in order to allow for the atmospheric conditions of the moment.

The corrections thus found, the battery commander transfers his fire to the real target, taking for firing data on this new target that which results from its deflection and range as determined on the map, corrected by the adjustment corrections obtained.

As regards the deflection and the fuse, the adjustment corrections obtained in the fire on the auxiliary target are used to correct the elements calculated for the real target.

As to range, the "Instructions on Fire" considers the adjustment ranges of the two targets as proportional to their actual ranges. The rule is as follows: If R_A is the range obtained in adjustment on the

auxiliary target, whose real range is A, the range R_B to be adopted for the real target, whose real range is B, is given by—

$$R_B = B\frac{R_A}{A}\left(\frac{R_A}{A} = \text{the coefficient of adjustment}\right).$$

To increase the chances of hitting the real target in this way the "Instructions for Siege Fire" states that the fire for effect must be executed on an area covering in width and depth the entire portion of the position known to contain the target.

119. *Application of the preceding rule to 75-mm. gun.*—Let us assume that the adjustment ranges of the two targets (auxiliary and real) are proportional to their actual ranges—that is, that the adjustment corrections in range (differences between the adjustment ranges and actual ranges for each of the two targets) are themselves proportional to the ranges. Then the equation $\frac{A}{B}=\frac{R_A}{R_B}$ may also be written $\frac{A}{B}=\frac{R_A-A}{R_B-B}=\frac{C_A}{C_B}$ ($C_A=R_A-A$ and $C_B=R_B-B$ being the corrections in range).

If the rule given in the "Instructions on Fire" is to be applied to most matériel, particularly to the Heavy Artillery, under the same form given by these instructions $\left(R_B=R_A\frac{A}{B}\right)$, it is simpler, in the special case of the 75-mm. guns, to apply this same rule under the form: $R_B=B+C_B$, with $C_B=C_A\frac{B}{A}$. Actually, for the 75-mm. gun, the adjustment correction in range should be given in multiples of 25 m. We therefore get simple fractions, and hence an easier calculation.

In fire with 75-mm. guns the errors due to the atmospheric conditions are less important than in fire with howitzers and mortars, and they are negligible when the range is short. But in firing at a range greater than 1,500 m. very considerable errors sometimes result from atmospheric variations.[1] These errors must absolutely be avoided, because a previously well-adjusted fire can thus become not only entirely ineffective, but even dangerous to friendly troops.

[1] A strong head wind may decrease the range by 100 to 200 m. in 4,000 m. If it is accompanied by a sharp drop in the temperature, the adjustment of fire may be thrown out by double the preceding figures. In a general way, the adjustment correction in range is less than one-fortieth of the range in 50 per cent of the cases. It may reach one-tenth of this range in the most unfavorable circumstances.

These considerations have led to a frequent check of the firing data of field batteries in the present phase of the war. This check, intended to show by experiment the corrections due to the momentary atmospheric conditions, is attained by firing on an object which plays the rôle of an auxiliary target.

120. *Choice of auxiliary target.*—As in siege fire, the auxiliary target can well be one of the targets of the battery considered, or even one assigned to another battery of the battalion.

Its position should be carefully plotted on the battle map, and its angle of site should be known. It is advisable that it be chosen so that its range will approximate that of the majority of the real targets. (As a rule, transfer of fire is not possible unless the proportion between the ranges of the two targets lies between 3/4 and 4/3.) Moreover, transfer of fire is not possible unless the difference in deflection between the two targets (auxiliary and real) is less than 300 mils. (Within this limit we may assume that the value of the longitudinal and lateral components of the wind are the same for the two targets.) But the principal condition which the auxiliary target must fulfill is that it will enable us to make an accurate adjustment with shrapnel or with shell. It must afford accurate sensing, for all subsequent fire depends on the results of this observation. Lastly, we should be able to make continuous use of the auxiliary target, and therefore a permanent object should be chosen (ends of trenches, farm, woods, etc.).

Of course an auxiliary target is not always necessary. The adjustment corrections may have been determined during a previous fire on a well-observed target.

In any case, if the fire for effect is to be of long duration, the "Instructions" prescribe that the atmospheric variations must be noted during the course of the fire, by means of a few rounds fired on an auxiliary adjustment target or on a target which performs that rôle.

121. *Determination and transfer of the corrections of the moment.*—The modifications to be made in data obtained from the map, from the telemeter, or from a preceding adjustment, in order to fire on a given target, differ according to the projectiles used.

We will examine successively:

(A) The case of shrapnel fire (I. V.=535), in which the range graduation is, by construction, the same as the range. This is the simplest case.

(B) The case of shell fire (I. V.=550), in which the quadrant range and the real range are not the same.

(A) THE CASE IN WHICH THE QUADRANT RANGE IS THE SAME AS THE REAL RANGE.

Let A be the auxiliary target. Fire having been prepared, as shown in paragraph 2, the adjustment is made on the auxiliary target.

The difference between the deflection of the directing piece, after adjustment, and the deflection obtained on the same aiming point in the preparation for fire, gives the correction of the moment in deflection. The difference between the mean range of the 50 m. bracket obtained by adjustment and the range calculated for the preparation for fire, gives the correction of the moment in range (assuming that the angle of site has been correctly obtained). These corrections must be given their proper signs. We must remember that they are determined by comparison with those which would have been found if the atmospheric conditions had been normal.

The corrector for fire for effect obtained is the corrector of the moment.

122. *Use of the corrections of the moment.*—To use the corrections of the moment found in fire on an auxiliary target A for fire on another target, assuming that the angle of site of the latter is accurate, the following rules are applied:

The correction in deflection is transferred as it stands, or, sometimes, under the rule for the transfer of the correction in range.

The correction in range is corrected before being transferred, by the proportion which exists between the ranges. The corrector of the moment is transferred as it stands.

The use of the corrections of the moment enable us to execute a fire prepared by means of the battle map, to repeat a fire previously adjusted, and to plot a new target on the battle map according to the results of an adjustment.

EXAMPLES.

123. (1) *Determination of the corrections of the moment.*—Let A be a visible object chosen as auxiliary target. Let P and R be the positions of the directing piece and the aiming point on the battle map. Assume that RPA=1,620 mils. We deduce that the deflection of the directing piece is main scale 0, azimuth micrometer 80+the drift (4)=main scale 0, azimuth micrometer 84.[1] We measure PA, and we find PA=4,025 m. Assume that the difference of altitude between A and P=+20 m. We deduce that the angle of site

$$=+\frac{20}{4}=+5.^{2}$$

[1] The French zero line is main scale 0, azimuth micrometer 100. Each of the 4 quadrants is graduated in the same way.

[2] The French datum point for the angle of site is zero, not 300.

Fire having been opened with this data on A, let us suppose that the adjustment gives—

Deflection of directing gun=main scale O, azimuth micrometer 99.

Bracket=4,200–4,250. Corrector for fire for effect=21.

The corrections are—Correction in deflection: C_d=99−84=+15. Correction in range: C_p=4,225–4,025=+200 m.

124. (2) *Transfer of fire.*—These corrections having been obtained on target A, we must transfer them to the real target B.

Since target B is plotted on the battle map and its angle of site is given accurately, we may assume that the preparation of fire gives directing piece—

Main scale O, azimuth micrometer 120 (including the drift).

Range 4,575 m.

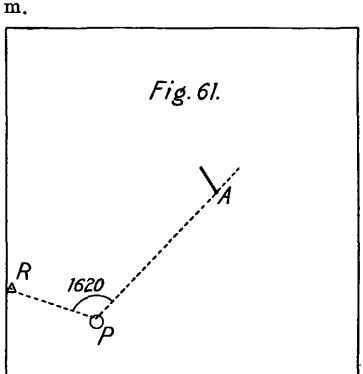


Fig. 61.

Applying the correction in deflection, we get, as deflection of the directing piece—

Main scale O, azimuth micrometer 120+15=M. S. O, A. M. 135.

The correction x to be applied to the range is given by:

$$\frac{x}{4{,}575}=\frac{+200}{4{,}025},\text{ or } x=+225 \text{ m.}$$

The range to be adopted on B is therefore 4,575+225=4,800 m.

If fire so prepared can be adjusted (by aircraft, for example), the first salvo is fired with the above data and the corrector determined by the adjustment on A. If fire for effect is to be executed immediately on target B, the sheaf is opened out 15 mils to the right and left with respect to the given deflection, and fire is executed with the corrector 21 at ranges comprised between 4,600 and 5,000 m.

But, of course, if fire is to be executed on a target very near friendly trenches, the range obtained is not decreased. It may even be increased a little if there is any doubt as to the accuracy of the data.

The determination thus made of the correction in range and of the corrector of the moment, as well as their use in the transfer of fire, assumes that the angles of site of the auxiliary target A and the actual target B are accurately known. It has been shown above that, if this is not the case, the range must be modified by a quantity which will correct the error. The difference between the adjustment range obtained on the auxiliary target and its real range does not, therefore, represent the absolute correction in range, but this correction modified by the quantity by which the range is false. Errors, more or less serious, may therefore be expected in transferring the corrections of the moment. Moreover, the corrector itself being falsified by the error in the angle of site, can not be adopted for other targets unless they also have the same error in the angle of site.

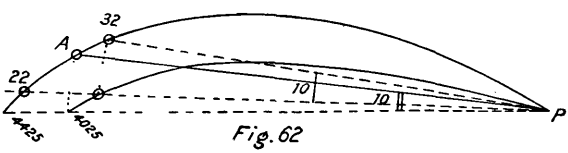


Fig. 62

Example.—Let us assume that the auxiliary target A, at a range of 4,025 m., has an error in the angle of site of −10 mils. It has been shown above that this error leads to the adoption in the fire for adjustment of a quadrant range 200 m. greater than the range. If, moreover, the atmospheric conditions at the moment of fire produce another 200 m. increase in the quadrant range, we will get a mean quadrant range for A equal to 4,025+200+200=4,425 m. Calculating roughly the difference between this quadrant range and the range 4,025 m., the correction of the moment appears to be +400 m., while actually the atmospheric conditions only require a correction of 200 m. in the range. We thus see how false may be the results obtained by transferring this correction to other targets.

As for the corrector, if 22, for example, is the proper corrector for the real angle of site, under the conditions of the moment, the error of 10 mils in the angle of site causes the corrector to be raised by 10, and we thus get the corrector 32, or an increase of 12 above the normal corrector, while in reality the difference is only 2.

In the same way, if a transfer of fire is effected on a target B, it is necessary that the angle of site of the latter be accurately

shown, for, unless this is the case, the quadrant range and the corrector used will be false by a quantity corresponding to the error in site, no matter what care may have been taken in transferring the correction of the moment.

125. (3) *Registering the results of adjustment on a target—Record in the data book.*—Let C be a target on which adjustment gives the following results:

Deflection of the directing piece from R: Main scale 14, azimuth micrometer 35.

Bracket: 4,825–4,875.

Let us assume that the corrections of the moment, on the auxiliary target at 4,025 m. range, are $C_d=+15$ and $C_p=+200$.

To eliminate the correction of the moment from the adjustment deflection on R, the correction in deflection, with changed sign, must be added to the adjustment deflection on R, which gives M. S. 14, A. M. 35−15=M. S. 14, A. M. 20.

But this deflection takes into account the drift increment, whose value at 4,850 meters, with shrapnel, is 5 mils. The adjustment deflection, with the drift eliminated, is therefore M. S. 14, A. M. 20−5=M. S. 14, A. M. 15.

To correct in the same way the mean quadrant range of 4,850 obtained, we must deduct the correction $\alpha=+200(4{,}850-4{,}225)=230$, which gives us 4,850−230=4,620, or 4,625 m.

These results must be recorded in the data book, so that the fire on C can be repeated later, applying each time the corrections of the moment to this data.

As we have seen, if the angle of site taken for C is in error, the quadrant range 4,625 m. does not represent the true range to the target. This does not affect subsequent fire on the same target, if the correction of the moment is applied to this quadrant range.

If, for example, under other atmospheric conditions, verifying fire on A gives: $C_d=+5$ and $C_p=-150$, we take, as average data for fire on C, with the same angle of site as above, directing piece M. S. 14, A. M. 15+C_d+the drift (shrapnel)=M. S. 14. A. M. 25; and we take, for the quadrant range: $4{,}625-150\left(\frac{4{,}625}{4{,}025}\right)=4{,}625-175=4{,}450$.

If the angle of site of C is accurately known, the quadrant range 4,625 will represent the real range to the target, and it will be possible to deduce the position of the latter on the battle map. Since the deflection M. S. 14, A. M. 15 enables us to draw the direction of the target through the position of the directing piece, we lay off on this line a length of 4,625 m. to the scale of the battle map. The point

thus obtained is the target C. (The front can be deduced from the opening of the sheaf.) The coordinates of the target thus plotted on the battle map are sent to the artillery commander.

126. *Comparison with the results of previous fire—Reference target.*—It frequently occurs that the corrections of the moment are determined, not by comparison with the elements found when the atmospheric conditions are normal, but by comparison with the results of previous fire. In this case, there is no need for the battle map. This method has some advantages in all cases, and it is the only possible one when there are neither maps nor battle maps at hand.

The method of transferring corrections in the case of repetition of fire remains exactly the same. The rule given in the "Instructions on fire" is written:

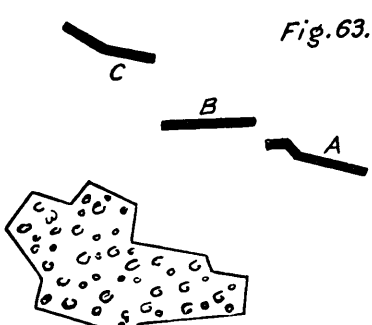
$$\frac{A}{B}=\frac{R_A}{R_B}=\frac{R_A'}{R_B'}.$$

When A and B are the actual ranges of two targets, R_A and R_B the adjustment ranges at a given moment, and R'_A and R'_B the adjustment ranges at another given moment. The formula may also be written:

$$\frac{R_A}{R_B}=\frac{R'_A-R_A}{R'_B-R_B}=\frac{A}{B}.$$

$C_A=R'_A-R_A$ and $C_B=R'_B-R_B$ are the corrections in range for the second fire to be given to the elements determined by the first adjustment.

Fig. 63.



Example.—A battery is given the trenches A, B, and C for a target. Only the trench A is distinctly visible from the battery observation station, the targets B and C being masked by a wood. A serves as a reference target. The captain carries out careful

adjustments on these three targets (fire on B and C being observed from friendly trenches, for example). With the same atmospheric conditions, he finds—

On A 2,400—2,450, corrector 14.
On B 2,450—2,500, corrector 13.
On C 3,500—3,550, corrector 15.

These results are recorded in the data book with the corresponding deflections, corrected for drift. The value of the drift is also recorded. Later, before firing on the same targets, the captain first fires on A, which is visible from his observation station. He thus finds, for example, that the elements recorded for fire on A should be modified in the following manner: Rights 5, corrector 12, bracket 2,550–2,600. For fire on targets B and C, he takes into account the modifications he must make in the elements previously obtained, in the following manner:

Deflection, right 3 turns.[1]
Corrector, down 2.

For B, open fire with the corrector 11, bracket 2,600–2,650.

For C, the correction found in the range, which was 150 m., becomes $150 \times \frac{3,500}{2,400} = 225$ m. Therefore open fire with the corrector 14, bracket 3,725–3,775. (He should not, of course, limit himself to covering the target with a 50 m. bracket. It is advisable, particularly if the fire can not be observed, to cover a depth of at least 100 m. on B and C.)

127. *Remark 1.*—Every time the captain wishes to fire on B or C, he begins by firing on A, in order to determine the corrections of the moment, as shown above. This verifying fire can be executed with a single piece, if necessary, and only requires a small expenditure of ammunition.

Note that the angles of site of the targets may be in error without effecting the fire.

The advantages offered by this method of fire, which is often applicable, are sufficiently great to merit attention. (The same advantages are found when the corrections of the moment are obtained by reference to the theoretical elements in normal atmosphere, when it is possible to determine these latter—targets exactly marked on a map or battle map, exact angle of site known.) The advantages are—

(1) An increase in the rapidity with which fire is opened on designated targets, even in case the fire on A leads to new corrections.

[1] Three turns of the traversing handwheel changes the deflection by 5 mils.

Verifying fire observed from the battery observation station is much more rapid than a new adjustment on B or C made with the aid of an auxiliary observer, even supposing the latter to be placed at an advantageous point beforehand.

(2) An effect of surprise is produced on the targets B and C when fire for effect on these targets is not preceded by any warning adjustment.

(3) Accuracy of fire: More confidence can be placed in the elements obtained by applying the corrections of the moment determined on A to the data of the first adjustment (of which we are sure) than to the results of hasty adjustments on B and C under conditions which are often unfavorable.

(4) Lastly, we obtain an increase in the fire power of the battery. After a single verifying fire, the captain is able to open an immediate and effective fire on the different targets without requiring the aid of observers, who may be usefully employed on other adjustments.

Remark 2.—Each time that the captain is required to fire on a new target, D, he must be careful to execute a fire on A immediately before or after the fire on D, and to record the data for D and A in the same page of his data book. This permits him to repeat the fire on D by determining the corrections of the moment. He determines these corrections by comparing the results obtained at this moment on A with those obtained on A at the time of his first adjustment on D. This point is very important.

Remark 3.—The corrections obtained by comparing the results of previous fires can hardly be used by other batteries. The captain of the battery under consideration can only furnish information of the following type: "I find, at this moment, that such a range, which I used on such a day, should be corrected by so much."

On the other hand, the use of corrections with reference to the elements in normal atmosphere, in case the angle of site is accurately known within a very close approximation, enables us to transmit useful information on any target.

(B) CASE IN WHICH THE QUADRANT RANGE IS NOT THE SAME AS THE REAL RANGE.

128. This is the case of the 75-mm. gun firing shell. Although we use a quadrant graduated in meters for normal ranges, it is only a means of giving an elevation to the gun, and we must not confuse the number of meters of the range with the number of meters set off on the quadrant (which simply perform the functions of a number of degrees and minutes of a quadrant graduated in angles). We are therefore obliged, in order to obtain the accurate fire necessary in

the present phase of the war, to consult the range table, which gives us the corresponding quadrant range for the actual range to be obtained. For the same range measured on the map or by telemeter, the table shows two different quadrant ranges, according to whether the fire is executed with shell primed with nonelongated fuses or shell primed with elongated fuses. If the adjustment is commenced by adopting the range measured as the quadrant range, there is a possibility of dangerously short rounds.

In the case previously studied, where the quadrant range was the same as the range, all the operations relative to the corrections of the moment could be carried out on the quadrant. In the present case we endeavor to find, as in siege fire, the ranges corresponding to the quadrant ranges, and to apply the corrections of the moment to the ranges and not to the quadrant ranges.

The problems already studied, given in the examples, may be solved as below. (That which has already been stated in reference to corrections in deflection is not repeated. We need only remember that it is necessary to take the drift increment into account, particularly in long ranges.)

129. (1) *Determination of the corrections of the moment.*—We assume, in fire with shell, model 1900, nonelongated fuses (I. V =550), that the range to the auxiliary target is 3,825 m. The quadrant range to be given, as shown by the range table, is 4,125 m. We also assume that the adjustment gives the bracket 3,900–3,950. The mean quadrant range of the bracket, 3,925, corresponds to the adjustment range 3,650 m., according to the table. The correction in range is equal, in value and sign, to the difference between the adjustment range and the true range. Hence C_p=3,650 m.−3,825 m.=−175 m.

130. (2) *Application of the corrections of the moment to the preparation for fire.*—We assume, always with the same type of shell, that the target B is at 4,700 m. The correction χ to be made to this range is given by—

$$\chi = -175\,\text{m}.\frac{4,700}{3,825} = -225\ \text{m}.$$

The mean range to adopt for B is therefore 4,475 m., and the corresponding quadrant range is 4,900, according to the table.

Remark.—The verifying fire on A should be executed with shells of the same type as those used on target B, for, at the same range, the correction of the moment is not necessarily the same with shrapnel and shell. However, no great error is committed if, before firing on B with shell, we correct the corrected range obtained on B by

the result of a verifying fire on A with shrapnel. But this procedure is not recommended. In a still more general way, fire on the auxiliary and real targets should be executed, not only with projectiles of the same type, but also of the same lot, if all disagreeable surprises are to be avoided. Apropos of this, information on the range differences between the different types of shells can be found in the chapter on "Projectiles and fuses."

Example of a case in which the limits of range quadrant graduations are exceeded.—The method given above applies to all ranges, even when we are obliged to have recourse to an increase in the angle of site or to use the model 1888 level graduated in degrees and minutes.

For example—assume a fire with shell, nonelongated fuse, range to auxiliary target A=5,500 m. Verifying fire on A, with the corresponding quadrant range of 5,000 given by the table (angle of site +70), gives us a mean quadrant range of 5,225 (angle of site +70). The adjustment range is therefore 5,650 m., according to the table.

Since the range read was 5,500 m., C_p=150 m., suppose we desire to fire on a target B, at 6,000 m. The corrected range will be:

$$6{,}000+150\,\frac{6{,}000}{5{,}500}=+6{,}175\text{ m.}$$

The range table gives the elevation 17° 59′ for this range. This is the quadrant elevation to be given to the piece if the angle of site of B is zero. If the angle of site is not zero, its value in degrees and minutes must be added (with its proper sign) to the angle 17° 59′. To facilitate this, a table of the values of the angles of site in degrees and minutes is given later. Assume for this case an angle of site of +10 mils=34′. We open fire with a quadrant elevation of 17° 59′+34′=18° 33′.

131. (3) *Registering the results of adjustment on the target—Recording them in the data book.*—Assume that a fire for adjustment with shell, model 1900, nonelongated fuse, on a target C gives a bracket of 4,075–4,125, which corresponds in the range tables to a mean range of 3,800 m. Also assume that a verifying fire with shell, model 1900, on an auxiliary target at 3,000 m. gives a mean quadrant range of 3,300, which corresponds to an adjustment range of 3,100 m. We deduce that the correction of the moment for range is 3,100−3,000=+100 m. This data is used to eliminate from the results on C the correction of the moment. For the range 3,800 m. the correction of the moment will be $+100\,\frac{3{,}800}{3{,}100}=+125$ m., and the range C, with the correction of the moment eliminated, will therefore

be 3,800 m. − 125 m. = 3,675 m. This range is not the true range of the target C unless the angles of site are accurately known. If they are in error, this conclusion can not be drawn. In any case, the range 3,675 m. is the one recorded in the data book, with the angle of site used, for it is to this range that we apply the correction of the moment whenever fire is repeated on C.

132. *Comparison with results of previous fires—Reference target.*— The method shown above is applicable to shell, on condition that we reason in ranges and not in quadrant ranges. Attention is again called to the ease of this method and the great advantages offered by it.

Example.—Shell, I. V. =550, nonelongated fuse. Result of an initial adjustment on October 10 at 3 o'clock—

On A—M. S. 8, A. M. 90. 3,950−4,000 $s=-5$.

On B—M. S. 6, A. M. 180. 5,200−5,250 $s=0$.

133. (1) *Record in the data book.*—For the deflection, eliminate from the deflections laid off on the aiming apparatus the drift increment corresponding to the range, that is, for A, 5; for B, 8.

For the range, write the ranges corresponding to the quadrant ranges obtained, both under the same atmospheric conditions, that is, according to the range table, for A, 3,675; for B, 4,750. The record in the data book will therefore be as follows:

Date.	Target.	Deflections.	Site.	Range.	Observations.
Oct. 10—3 p. m.	A	M. S., 8, A. M. 85. Drift+5.	−5	3,675, quadrant range=3,9.5.	Nonelongated fuses, shells, I. V. =550.
Do...	B	M. S. 6, A. M.. 172. Drift+8.	0	4,750, quadrant range=5,225.	Same.

134. (2) Later, for example on the 12th of October, before reopening fire on B (invisible from his observation station), the captain fires first on A, which serves as a reference target. He finds, with site −5, M. S. 8, A. M. 90, bracket 4,150−4,200. The range 3,850 and the drift increment 5 correspond in the range table to the mean quadrant range 4,175. He therefore deduces the following corrections, with respect to the firing data of October 10th: Deflection (M. S. 8, A. M. 90)−(M. S. 8, A. M. 85)=+5. Range, 3,850−3,675=+175. The opening range for the new fire on B will therefore be—

$$4{,}750+175\left(\frac{4{,}750}{3{,}675}\right)=4{,}975,$$

a range for which the range table gives drift 9, quadrant range 5,475. The initial data therefore is:—M. S. 6, A. M. 172+drift 9+ C_m5=M. S. 8, A. M. 186. Quadrant range, 5,475.

135. *Simplifications in certain cases.*—The Instruction on Fire for Foot Artillery gives a simplified method for the transfer of fire which is applicable in many cases: "When the auxiliary target and the real target are relatively close together, or if previous fire has shown that the coefficient of the adjustment in range is approximately 1,[1] we may correct the elevation calculated for the real target by the adjustment correction found for that angle in fire on the auxiliary target." The adjustment correction in the angle is the difference between the elevation obtained by the adjustment and the elevation calculated for the range to the target. By analogy, with the 75-mm. gun, we may, without great error—

(1) Transfer as it stands a correction in quadrant range when the difference in range between the two targets is less than 500 m.

(2) Transfer integrally, over the entire extent for which transfer of fire is admissible, a correction in quadrant range less than or equal to 50 m.

As to the deflection, we may neglect the drift in the case of shells at ranges below 3,000 m. and in the case of shrapnel at ranges below 4,000 m.

136. The preceding study shows the great importance of knowing the correction of the moment, and gives simple methods for fire based on it.

No rule can be given on the subject of how often fire on the auxiliary target should be verified. Whenever it is supposed that the atmospheric conditions have changed, particularly when the wind has veered or increased and when there has been a considerable variation in the temperature, a few verifying rounds should be fired on the auxiliary target, and the adjustment should be recomputed on them if they show that the preceding bracket can not be used. This verification is indispensable when we have to reopen a fire, previously adjusted, on a target near friendly trenches. Cases frequently occur in which a difference in range of 50 m. may make the fire not only ineffective on the enemy, but even dangerous to our own trenches. A violent wind or a 15° drop in the temperature is sufficient to decrease by 50 m. a range of even 1,500 m., not to

[1] For differences of range less than 500 m. the coefficient of adjustment lies between 0.98 and 1.02. This rule is also applicable for a difference of 1,000 m. and a coefficient of 0.95 or 1.05, when fire is to be opened rapidly, or if fire is to be carried out on a zone equal to or greater than 200 m.

mention the probable error, which may run up to 30 m. in the same sense. In this case it is not wise to require the artillery to repeat instantly a fire for effect executed even a short while before. It should be given time to fire a few verifying rounds, which will assure the required effects of the fire. (It has already been stated that this verifying fire should be executed, not on the target itself, but on an advantageous auxiliary target.) The importance of a fire on trenches is never so great as to suppress verifying fire. If fire must be opened within a few seconds of the warning, only fire on a zone or barrage fire can be executed, and even in these types of fire precautions have to be taken so that the accidental variations of range will not be dangerous. This is the case particularly in night fire, when it is impossible to obtain any check on atmospheric variations. The best use of artillery at night consequently consists in bombarding villages, farms, distant roads, etc. (firing on areas of sufficient extent to be certain of covering the target in spite of the variations due to the atmosphere), and in executing barrage fire under conditions shown above.

V. Establishment and use of firing notebooks.

137. Every battery commander, whether of Heavy or Field Artillery, in the present phase of the war, should keep an exact list of all the targets on which he has fired, as well as the results of the fire, so arranged as to allow the results to be given as a whole either to another officer of his battery or to the commander of a relieving battery.

He must distinguish between the firing data book, in which the fire is recorded, and the firing bulletin, which serves for a transfer of fire or to determine firing data. It may even be unnecessary to to preserve the bulletin.

Refer to the Foot Artillery Drill Regulations (Provisional Instructions on Fire, Table III and following), for the form of the bulletin with reference to the transfer of fire. Examples are given at end of this book.

For the form of the firing data book, see the instruction given by the Army. If a regulation model is lacking, the book should be made out in the most convenient form, but there is certain fundamental data which the data book must furnish. First of all the position of the battery should be given (coordinates and complimentary information) as well as the position of the aiming point (coordinates and complimentary information); no doubt must exist as to the location of the latter on the terrain, as all the deflections recorded in

the data book are based on it. It is therefore advisable to make one or more sketches. A double page should be devoted to each target. On the left-hand page a sketch of the target is made, and also an enlargement of the battle map for the area considered. On the right-hand page a certain number of columns are drawn in which the indispensable data is written. The coordinates of the target are placed at the top of the page.

We must distinguish between the three kinds of information:

(1) Preparation for fire—that is, the initial data, deduced from the battle map or map, and the fire for effect to be executed. (If the fire is on a target not marked on the battle map, and impossible to locate, this data can not be entered from the map.)

(2) The corrected firing data. It may happen that we fire on a target that is inaccurately shown on the battle map, and that the adjustment gives data other than that of the preparation of fire. In this case the new data must be recorded, after being reduced to normal temperature, pressure, etc.; that is to say, so that it will be unaffected by the corrections of the moment.

(3) Record of all fire executed. This page of the data book may be drawn up as shown below.

TARGET—92-86.

Dates.	Wind.	Temperature.	Pressure.	Deflection.	Site.	Range.	For fire effect.				Lot of powder.	Projectile employed.	Remarks.
							Shrapnel.		Shell.				
							Corrector.	Quadrant range.	Corrector.	Quadrant range.			
				Firing data before correction.				*Three rounds, sweeping.*					
				In observation. +30 + drift..... Shr..... +4 Shell..... +7 Shell IA..... +8 Open 15.....	+5	4,350	20	{4,300 4,400}	P. F.	{4,725 4,750 4,775}	Normal.	Normal.	
								Three rounds, sweeping.					
				Firing data after correction.									
				In observation. +34 + drift..... Shr..... +4 Shell..... +7 Shell IA..... +8 Open 15.....	+5	4,300	22	{4,300 4,400}	P. F.	{4,675 4,700 4,725}	Normal.	Normal.	
				Firing records.									
1/11	F.... ↗	10°	758	In observation. +36 + 4	+5	4,250	18	{4,200 4,300}	.....	.....	.....	.....	Direct adjust.
5/11	F.... ↖	15°	765	In observation. +32 +7	+5	4,325	.....	.....	.....	{4,700 4,725 4,750}	.....	+ +	By transfer of fire Aux. target No. 635
8/11	F.... ↑	12°	761	In observation. +28 +7	+5	4,275	.....	.....	.....	{4,650 4,675 4,700}	.....	+	Adjustment by aircraft.

We have already discussed the nature of the data to be recorded, according to whether the corrections of the moment are determined by comparison with the normal atmospheric data or by comparison with the results of previous fire. Let us now discuss the different methods of using the data book.

(1) Knowing the firing data on any target under normal conditions of temperature and pressure and with zero wind, we can calculate the data under the atmospheric conditions of the day, and then adjust and open a zone fire for effect.

(2) In the case of transfer of fire to a target entered in the data book, we can deduce from an adjustment on an auxiliary target the corrections of the moment, and then apply them to the real target.

(3) In the case of repetition of fire without previous adjustment on an auxiliary target, if we know the temperature, the pressure, and the wind of the moment, we can, if necessary, take the data recorded for a previous fire under similar atmospheric conditions, on the target itself, or we can take a fire executed on another target, under similar atmospheric conditions, consider the data of this previous fire as if it had been obtained on the same day on an auxiliary target, deduce the correction of the moment, and then transfer the fire in the usual way.

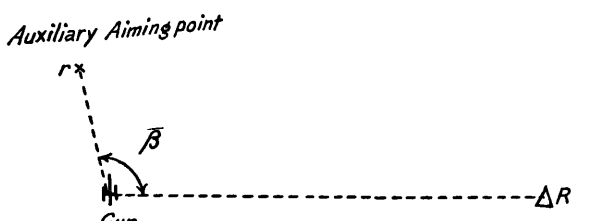


Fig. 64.

We have said that the deflections recorded in the data book should be those that refer to an aiming point which is clearly shown on the battle map (or on the 1/50,000 map). These are the deflections used in the preparation or transfer of fire by means of the battle map. But usually the gunners are obliged to use auxiliary aiming points or stakes during the fire. It is even advantageous, from the point of view of rapidity, that the gunners should use these latter for laying on their different targets. The battery should, therefore, have a list of deflections in terms of these auxiliary aiming points. This data is

indispensable in case the pieces are to be laid at night, by means of a lantern, on the auxiliary aiming stake. Note that, if the terrain is good and we do not move the gun, the angle β, formed by the lines given, aiming point—gun and auxiliary aiming point—gun, remains approximately constant, so that it is easy to change from one deflection to another, the difference between the deflection based on the aiming point and that based on the auxiliary aiming point being constant for the same piece.

VI. Organization and rôle of observation stations.

138. The combined organization of the artillery in a sector, based on the principle of preparation for siege fire, enables us to utilize the available observation stations to greater advantage than if a battery or battalion of 75-mm. guns was left to its normal resources. This subject can not be enlarged on at present, and we must limit ourselves to showing the advantages of preparing the artillery observation stations as well as possible.

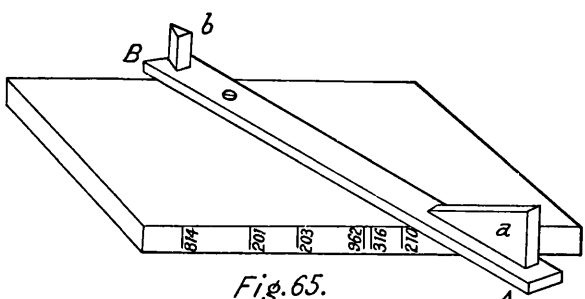


Fig. 65.

An observation station must have a sighting instrument. If there is not even a sighting triangle, it is at least easy to make a primitive instrument of the type shown in figure 65 from a board and a few pieces of wood. This instrument carries a sort of movable alidade, AB, on a board that is firmly fixed. In sighting along the side of the piece *a* and on an edge of the piece *b*, a plane of sight is determined that can be used at night by means of lateral lighting—with an electric pocket torch, for example. The base can be graduated as in the sighting triangle, or at least the positions of the alidade, when sited on the different targets, may be marked by numbered lines. This instrument can be used at night to recognize which enemy battery is firing by the direction of its flashes or to determine the direction of new flashes.

139. The values of the angles of site in degrees and minutes to be used (with proper sign) for the elevation in laying with the level are given below—

Table of comparison of degrees and mils.

Mils.	Degrees.	Mils.	Degrees.
	° ′		° ′
5	17	55	3 6
10	34	60	3 23
15	57	65	3 39
20	1 8	70	3 56
25	1 25	75	4 13
30	1 42	80	4 30
35	1 58	85	4 47
40	2 15	90	5 4
45	2 32	95	5 21
50	2 49	100	5 37

140. *Table of range increments, dP, for the 1900 model shell.*

Type of shell. / Range.	dP.				
	L	+	++	+++	++++
500	+11	+ 4	− 3	−10	− 17
1,000	+16	+ 6	− 4	−14	− 23
1,500	+17	+ 6	− 4	−15	− 25
2,000	+14	+ 5	− 3	−12	− 21
2,500	+ 8	+ 3	− 2	− 7	− 12
3,000	+ 1	+ 1	0	− 1	− 2
3,500	− 6	− 2	+ 2	+ 5	+ 9
4,000	−14	− 5	+ 4	+12	+ 21
4,500	−24	− 9	+ 6	+20	+ 35
5,000	−34	−13	+ 8	+29	+ 50
5,500	−44	−17	+11	+39	+ 66
6,000	−55	−21	+14	+49	+ 83
6,500	−67	−25	+17	+59	+100
7,000	−79	−29	+20	+69	+117
7,500	−91	−34	+23	+79	+135

Method of using this table.—Assume a fire to be adjusted with shell marked + + + (nonelongated fuse) at a mean quadrant range of 5,000 m., with angle of site increased by 70 mils. The adjustment range, according to the range table, is 5,500 m. Let us assume that it is necessary to continue the fire with L shells. The + + + shells have a range 39 m. greater than the model 1900 shells, and the latter, in their turn, have a range 44 m. greater than the L shells at 5,500 m., according to the table of range increment. Consequently the + + + shells have a range 83 m. greater than the L shells. If, therefore, in changing from the + + + shells to the L shells, we keep the same quadrant range, the range will be reduced 83 m. To get back to the previous range, the quadrant range must

be increased by an amount corresponding to an increase of range of 83 m. We must, therefore, take the quadrant range 5,125 (always with site increased by 70 mils) shown on the range table opposite the range 5,583 (between 5,575 and 5,600).

FIRST EXAMPLE.

141. Transfer of fire on a target whose angle of site is accurately known, and the organization of a consecutive fire for effect.

Shrapnel. I. V.=535 m.

Auxiliary Target A.		Target B.	
Data given by the battle map.		Data given by the battle map.	
Exact site	+10	Exact site	−5
Range (or quadrant range) A.	3,425 m.	Range B	4,100 m.
Deflection	M. S. 14, A. M. 120	Deflection measured on map)	M. S. 14, A. M. 60
Drift increment	+3	Deflection increment	+4
Deflection prescribed	M. S. 14, A. M. 123		M. S. 14, A. M. 64
Corrector (adjustment)	18	Corrector (adjustment)	18
Results of fire for adjustment.		Firing data after fire for adjustment on A	
Range (or quadrant range).	3,350	Range	4. 100 m.
Deflection	M. S. 14, A. M. 133	$+C_m = -75 \times \frac{4100}{3425} = -100$	
Drift increment	−3		
	M. S. 14, A. M. 130	Range (or quadrant range) to prescribe.	4. 000
Corrector (adjustment)	21		
		Deflection	M. S. 14, A. M. 60
		+Drift increment	+ 4
		$+C_m$	+10
		Deflection to prescribe	M. S. 14, A. M. 74
		Corrector for effect	20
		$+C_m$	3
		Corrector to prescribe	23
Calculation of correction of the moment.		Fire for effect.	
Adjustment range	3,350	Subtract—	Open by—
−Range A	−3,425	..... rounds.	Sweeping.
C_m (range)	−75	Corrector 23—	
Adjustment deflection.	M. S. 14, A. M. 130	Quadrant ranges	3,800
Initial deflection	M. S. 14, A. M. 120		3,900
			4,000
C_m (deflection)	+10		4,100
Adjustment corrector in range.	21		4,200
Theoretical corrector	−18		
C_m (corrector)	+ 3		

SECOND

Transfer of fire on a
Record of firing data
Shell. I. V.=550 m.

Auxiliary Target A.		Target B.	
Data given by the battle map.		**Approximate data.**	
Exact site	−15	Site	0
Range A	4,450	Range B	3,800
Quadrant range to prescribe (according to table)	4,875	Deflection	M. S. 8, A. M. 120
Deflection	M. S. 8, A. M. 160	**Initial data.**	
+Drift increment	+7	Site	0
Deflection to prescribe.	M. S. 8, A. M. 167	Range	3,800
Results of fire for adjustment.		$+C_m=+100\,\frac{3,800}{4,450}$	+75
Deflection	M. S. 8, A. M. 155	Corrected range	3,875
−Drift increment	−7	Quadrant range according to table	4,200
	M. S. 8, A. M. 148	Deflection	M. S. 8, A. M. 120
Mean quadrant range.	5,000	+Deflection increment	+ 6
Corresponding range..	4,550	$+C_m$	−12
Calculation of corrections of the moment.		Deflection to prescribe.	M. S. 8, A. M. 114
Range:		**Result of observation of preceding fire.**	
Adjustment range.	4,550	Mean quadrant range.	4,250
−Range A	4,450	Corresponding range..	3,925
C_m (in range)	+100	Deflection	M. S. 8, A. M. 125
In deflection:		(−Drift increment)...	−6
Adjustment deflection	M. S. 8, A. M. 148	**Corrected elements (recorded in firing note-book).**	
− Initial deflection	M. S. 8, A. M. 160	Range obtained	3,925
C_m (deflection)	−12	−Correction of the moment	−75
		Range to record	3,850
		Deflection obtained...	M. S. 8, A. M. 125
		−Drift	− 6
		−Correction of the moment	+12
		Deflection to record...	M. S. 8, A. M. 131
		Site to record	0

EXAMPLE.

target not accurately located.
after adjustment.
(nonelongated fuse).

I. PREPARATION FOR FIRE.

Date.	Wind.	Temperature.	Pressure.	Deflection.	Site.	Range.	Fire for effect.				Lot of powder.	Type of shell.	Observation.
							Shrapnel.		Shell.				
							Corrector.	Quadrant range.	Corrector.	Quadrant range.			
.....	.....	.....	.....	M.S.8, A M.120 +drift 5	0	3,800	...	...	Three rounds sweeping.	4,075 4,100 4,125	Normal.	Normal.	Target not located accurately on the battle map.

II. CORRECTED DATA.

.....	.....	.....	.....	M.S.8, A M.131 +drift 6	0	3,850	...	...	Three rounds sweeping.	4,150 4,175 4,200	Normal.	Normal.	According to fire of 15/11.

III. REGISTRATION DATA.

15/11	f	10°	763	M.S.8, A M.119 +drift 6	0	3,925	...	...	Three rounds sweeping.	4,225 4,250 4,275	Normal.	Normal.	Direct adjustment (observation station 4), according to transfer fire (A is the aux. target).

Since target B is not accurately located on the battle map, the data furnished by this latter is necessarily only approximate. The initial data (data furnished by the battle map plus corrections of the moment furnished by A) are also only approximate, hence the necessity of adjustment. Corrected data is deduced from this adjustment, which enables us to locate target B on the battle map, if the site was accurate.

In the data book we record—

(*a*) The preparation of fire, as furnished by the battle map;

(*b*) The result of the fire for adjustment on the 15/11;

(*c*) Lastly, having fired on A immediately before this adjustment, we get the corrections of the moment, correct these corrections by the data furnished by the adjustment on B, and then calculate and record the corrected data.

THIRD

Adjustment by aircraft. Re

Repetition of fire—Shell,

TARGET A.

I. *Preparation for fire.*

[Extract from data book.]

Date.	Deflection.	Site.	Range.	Quadrant range.	Observations.
1	M. S. 6, A. M. 173 + drift 4 M. S. 6, A. M. 177	0	3,075	3,275	According to battle map.

II. *Recorded data.*

4/11	M. S. 6, A. M. 165 + drift 4	0	3,150	3,350	Direct observation.
17/11	M. S. 6, A. M. 180 + drift 3	0	2,950	3,150	

Since the target B is not located on the battle map, the latter can not be used for preparation for fire on B. Hence the corrected data must be deduced from an adjustment.

On the 14/11 fire is observed on B, and the results recorded in the data book (see table opposite in reference to B). Immediately afterwards fire is executed on A, and the data obtained is recorded, from which the corrections of the moment are made—

Corrections of moment, 14/11.

In direction	M.S. 6, A.M. 165 M.S. 6, A.M. 173	In range	3,150 −3,075
	−8		+75

We deduct these corrections of the moment from the results of the fire on B, and thus obtain the corrected data for B.

EXAMPLE.

corded firing data for a new target.

I. V.=550 m, nonelongated fuse.

TARGET B.

I. *Corrected data.*

[Extract from data book.]

Date.	Deflection.	Site.	Range.	Quadrant range (shell).	Observations.
	M. S. 6, A. M. 160 + drift.	−5	3,525	3,775	Following the fire on the 14/11 auxiliary target A.

II. *Recorded data.*

14/11.....	M. S. 6, A. M. 152 + drift.	−5	3,625	3,900	Observation with aircraft.
17/11.....	M. S. 6, A. M. 167 + drift.	−5	3,375	3,625	Repetition of fire. A is the aux. tar.

Direction $-C_m$. M.S. 6, A.M. 152 +8

M.S. 6, A.M. 160

Range 3,625

$-C_m = -75\left(\frac{3625}{3150}\right) = -100$

3525

On the 17/11 we wish to reopen a surprise fire on B. A previous adjustment on A gives the corrections of the moment—in deflection—

M.S. 6, A.M. 180 2950
M.S. 6, A.M. 173 3075
+7, and in range 125

Then the elements of fire on B are calculated—

M.S. 6 A.M. 160,
+drift +4
$+C_m$. +7

M.S. 6. A.M. 171

Range.....3525

$+C_m = -125\left(\frac{3525}{3075}\right) = -150$

3375

Quadrant range (according to table) 3625.

FOURTH

Case in which there is Record in data book. Repetition of fire by Shell, I. V. =550 m.

TARGET A.

[Extract from data book, page n.]

Date.	Deflection.	Site.	Range.	Quadrant range—shell.	Observation.
14/11.....	M. S. 10, A. M. 120 + drift 6.	—5	4,025	4,350	Adjustment from observation station No. 1.
16/11.....	M. S. 10, A. M. 110 + drift 6.	—5	4,125	4,500	Adjustment from observation station No. 1.

On the 14/11 the battery commander adjusts on B from observation station No. 3 (difficult of access), and immediately afterwards on A from observation station No. 1. The result of the two adjustments are recorded, the deflections being cleared of the drift, and the range being taken from the table, from the corresponding quadrant ranges obtained. On the 16/11 he receives an order to fire on B. He adjusts on A from observation station No. 1, and calculates the corrections with reference to the data of the 14/11.

In deflection:	In range:
M. S. 10, A. M. 110	4125
—M. S. 10, A. M. 120	—4025
—10	+100

EXAMPLE.

no battle map.

comparison with results of previous fire.
(nonelongated fuse).

TARGET B.

[Extract from data book, page p.]

Date.	Deflection.	Site.	Range.	Quadrant range—shell.	Observation.
14/11	M. S. 10, A. M. 30 + drift 5.	0	3450	3,700	Adjustment from observation station No. 3.
					Reference target A. (Shell.) See page n. — M. S. 10, A. M. 120. +drift inc. 6. Site—5. Range 4025. Quadrant range 4350.
16/11	M. S. 10, A. M. 20 + drift 5.	0	3525	3,775	Repetition of fire, using reference target A.

The firing data of the 16/11 is obtained by applying the corrections to the data obtained on the 14/11 on target B.

In deflection:

M. S. 10	A. M. 30
+drift increment	+ 5
$+C_m$	−10
M. S. 10	A. M. 25

In range: 3450

$$+C_m = +100\left(\frac{3450}{4025}\right) = +75$$

3525

Quadrant range (according to the table) 3775.

FIFTH EXAMPLE.

Transfer of fire (quadrant range exceeding 5,500). Shell, with supersensitive fuse (I. A.) (I. V.=542 m.).

Target A.		Target B.	
Data given by battle map.		Data given by battle map.	
Site (exact)	0	Site (exact)	−5
Range A	4,500	Range B	5,050
Quadrant range to prescribe	5,150	Deflection (measured on map)	M. S. 0, A. M. 180
Deflection	M. S. 2, A. M. 30	+Drift.	+11
+Drift	+8		
Deflection to be prescribed	M. S. 2, A. M. 38	Firing data according to adjustment on A.	
Results of fire for adjustment.		*I. Quadrant range.*	
Quadrant range	5,350	Range	5,050
Range (according to table)	4,650	$+C_m+150\times\left(\frac{5050}{4500}\right)$	+175
Deflection	M. S. 2, A. M. 30	Corrected range	5,225
−Deflection	−9	Corresponding quadrant range greater than 5,500.	
	M. S. 2, A. M. 21	1st method:	
Calculations of the corrections of the moment.		Site (+70−5)	65
		Quadrant range with a. of s. equal to +70	4,900
In range:		2nd method:	
Adjustment range	4,650	Elevation by level (corresponding to 5,225)	14° 9
−Range A	−4,500	+Site	−17
	+150	Quadrant elevation prescribed	13° 52
In deflection:		*II. Deflection.*	
Adjustment deflection	M. S. 2, A. M. 21	Deflection	M. S. 0, A. M. 180
−Initial deflection	M. S. 2, A. M. 30	+Drift	+12
	−9	$+C_m$	− 9
		Deflection to prescribe	M. S. 0, A. M. 183

F. FIRE WITH UNILATERAL OBSERVATION.

146. The range of a round can not be sensed unless it bursts on the line of observation (line observation station—target), or at leas in the zone of observation (zone limited by the two straight lines running from the observation station to the two extremities of the target).

When the captain is on the axial line of gun—target, it suffices, at any range, to place one round on the line of observation if we desire all the following rounds to fall on the same line without change in the deflection.

If, on the other hand, the captain is posted laterally in reference to this axial line, and if the first round bursts on the line of observation at a certain range, he must then make corresponding changes in deflection to his changes in range in order to maintain the rounds on this line. This is especially so when the captain occupies an observation station at a distance from the battery and near the targets. The difficulties in adjustment in this case often lead to independent adjustment by piece. As the observation of time-fuse rounds involves other difficulties, the adjustment is generally made by percussion rounds, leaving the adjustment for height of burst to be made later.

When a round does not burst on the line of observation and we desire to place the following round on this line, we can either change the deflection without changing the range or the range without changing the deflection. But we must not alter both at the same time. If the angle between the line of observation and the line gun—target is small, it is better to change the deflection. But if this angle is large (>45°), it is better to change the range.

I. The angle between the line of observation and the line gun—target is small.

147. The first problem to be solved consists in shifting the plane of fire passing through the point S to the direction PB. No difficulty is experienced if a battle map is at hand. If we are on the ground it is relatively easy to imagine the plane of fire PS and to pick out on the terrain a point S′ whose distance from P is equal to the range PB. (In case of doubt, it is advisable to fire a round at a very different range from that of S, so that the line SP will be marked by 2 points.) We then measure the angle BOS′, and calculate the angle BPS′ from it. This procedure avoids the great error which we would certainly make if we simply measured the angle BOS, and

the process gives, in practice, sufficiently accurate results. Opening at a range as accurate as possible, the fire is conducted in the following manner:

(1) *To shift the point of impact to the line OB.*—Let 1 be the first round observed. The next round must be shifted to the left by an

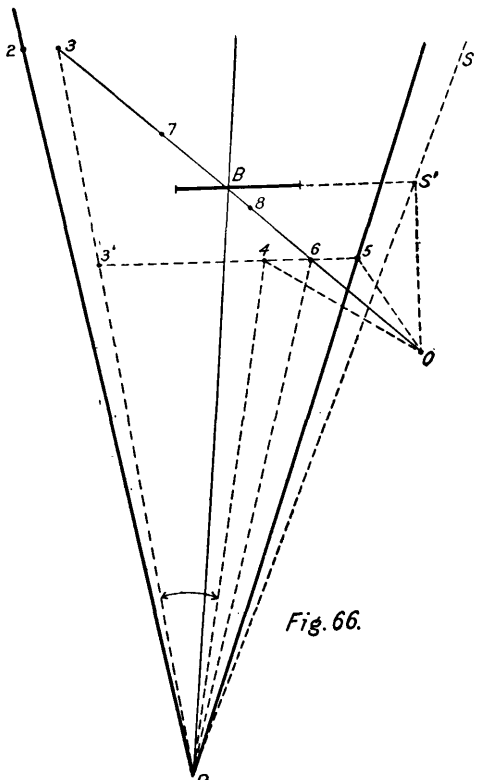


Fig. 66.

approximate correction smaller than the angle 1OB. The scale of reduction varies materially with each succeeding round according to the relative position of point 1 in reference to the points P and O. We then obtain the burst 2. From 1 and 2 we get the value of the correction in deflection which shifts the gun by the observed angle

102, between the two points of impact 1 and 2, and from this we deduce the value of the correction to be given in order to shift the next round to 3, on the line OB.

(2) *To make a jump of 400 or 200 meters, and to again bring the point of impact on OB.*—Starting at 3, the range is reduced by 400 or 200 m., as the case may be. Since this change in range will shift the point of burst to the left of the line OB, we must diminish the deflection at the same time. We only know, a priori, the direction in which this change in deflection must be made. The amount of the change can only be obtained from the fire. We shift the rounds to 4, then to 5, and then to 6, on the line OB, by the process indicated above. From the correction 3P6 (the result of the corrections made at the gun) we then get the value of the lateral observation bracket F corresponding, at the target B, to a jump of 400 m.

(3) *To continue the fire until the desired bracket is obtained.*—From this point on, since we have determined F, we know the value and the direction of the shift in deflection corresponding to each jump in range. The fire is therefore conducted more rapidly.

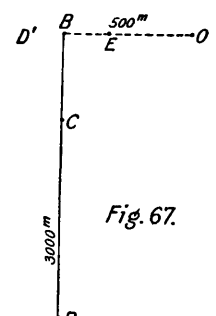


Fig. 67.

148. *Remarks:*

I. The great difficulty in this type of fire control arises from the dispersion in range. To realize its importance, we must imagine an observer who goes from the gun to an observation station on the line of the target (range 3,000 m.) and 500 m. on one side of the plane of fire PB. The greatest possible error in deflection, as seen from P, between any rounds fired with the same data at the mean point B is DPE when DE=8 probable errors in deflection; that is to say, 8 m., or DPE=8/3, or less than 3 mils. But at O the greatest error in deflection which may be observed between any rounds fired under the same conditions is AOC, when AC=8 probable errors in range, that is to say, 80 m., or $AOC=\frac{80}{.5}=160$ mils.

In the course of the preceding fire, rounds 1, 2, and 3 do not fall at the same distance from P. The observer at O, therefore, receives the impression that corrections made in deflections do not give accurate results. Hence a difficulty in the adjustment. The only way to obtain certain and rapid results is to recall that, in the phenomena of dispersion, we must base our observation on all the observed

rounds, and that the greater their number the more accurate will be the corrections based on them. In particular, the bracket F, obtained from the two rounds 3 and 6 on the line OB, will be changed and permanently verified as a result, during the course of the adjustment, of other rounds, 7, 8, etc., on the line OB.

II. If the fire is well conducted, the changes in deflection will be such that no round falls outside of the angle 2P5, 2 being the left-hand round obtained at the longest range fired, and 5 the right-hand round obtained at the shortest range fired.

III. The target is thus bracketed in deflection by the rounds 5, 6, 7, 8, in the same way that it is bracketed in range, in proportion as the jumps are reduced. When the adjustment is finished and we begin to verify the limits of the bracket, we must observe two rounds at each limit. These rounds will be fired with different deflections (differing by the value of F corresponding to the size of the bracket desired). When we pass to fire for effect we open with the mean deflection. It is certain that, on account of the dispersion in range, the rounds which appear to be in the right direction, as seen by the observer at O, will be the exception. The fire is considered adjusted in direction and in range when all the overs are to the right and all the shorts to the left, and when we have an equality, or a majority, of overs. If the overs are to the left, the plane of fire lies to the left, and we must change the deflection and reopen the fire for effect.

IV. If, during the fire, we get a round on the target, we assume that the gun is laid in direction. We make no further changes in the deflection, but continue the fire by sensing as overs or shorts those rounds which are to the right or left, respectively, of the line OB.

V. It is evident, because of the dispersion in range, that it is difficult to place a round on the line OB. Adjustment on a target which appears as a point from the observation station will therefore be excessively long. The rapidity of the adjustment will be proportional to the dimensions of the target as seen from the observation station. But this must not prevent us from choosing a point B on a wide target, so that the line OB may be materialized. This line OB, on which we try to place the rounds, will enable us to sense for range the maximum number of rounds when B is chosen in the center of the target.

VI. We may dispense with the round No. 3, in order to economize ammunition, if the target is of a certain width and if we can sense for range the round No. 2, for example. We simply add the corrections to be made for the shift from 2 to 3 to those for the shift from 3 to 4,

and send to the gun only a single correction in deflection with the new range.

VII. If, at the beginning, the rounds fall a very long way from the target, which can often be seen from an advanced observation station, it is advisable to change the range without altering the deflection. It is evident that, if an attempt is made to shift to OB rounds that are very far from B, great changes must be made in the deflection. It will be impossible to fix the gun on its wheel spades. The trail must be lifted out after each round, and the adjustment becomes very slow. But, if the range is changed at the beginning of fire, care must be taken not to change the deflection at the same time. The apparent gain in time only results in confusion.

II. The angle between the line of observation and the line gun—target is great.

149. If the observation station is in the vicinity of the perpendicular to the plane of fire passing through the target, the preceding adjustment will be very long and practically impossible. The most rapid procedure will then consist in laying the gun in the general direction of the fire of the battery, or on a point O near the line gun—target, and adjusting the range by considering the rounds as overs or shorts, according as they fall on one side or the other of the line OB.

If the target is fairly large, the adjustment in direction is made by firing at the most probable range to the target, sensing the rounds in reference to the target, and bracketing the latter by jumps in deflection. The number of rounds which can be sensed will be in proportion to the width of the target.

The more the angle OPB is increased beyond 45° the more it is advisable to shift the first round onto OB by variations in range rather than by variation in deflection. Later a jump in deflection can be made, and we can then recommence the process of bringing the bursts to the desired deflection by variations in range. We will then have a first value of F corresponding to a variation in range of n meters. From this we deduce the value of F for the 200 m. jump, and continue the adjustment as before. It is evident that this procedure enables us to conduct fire from an observation station closer to the target.

Combined observation—It results from what has been said above that many rounds must be expended in firing on a given point (demolition fire). The practical solution consists in having an auxiliary

observer placed on the line gun—target. The auxiliary observer observes for deflection while the observer at O observes for range. As soon as the deflection is adjusted, we come back to the case above. The auxiliary observer on the line gun—target only needs to know the direction of the target, without being obliged to see it well. This is the so-called combined observation method. It is equally applicable when the line of observation is slightly inclined on the line gun—target. It is only a special case of the bilateral observation studied below.

G. FIRE WITH BILATERAL OBSERVATION.

150. *Principle of the method.*—Bilateral observation can be employed when means of direct observation are lacking or when we

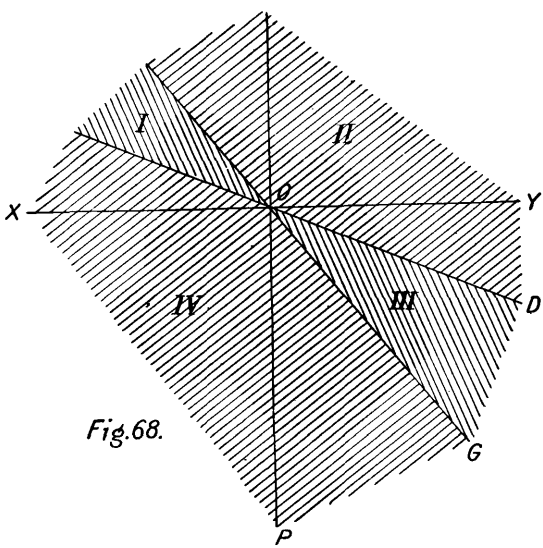


Fig.68.

can not sense the errors in range except by repeating the rounds too often. The method is particularly applicable to fire on targets of insufficient relief which have one point visible (luminous objects, for example), and on targets whose direction can be exactly determined from two different stations. It is of practical value only when the target shows a definite point that is easy to describe

to the two observers. It is with reference to this point that the apparent errors in deflection are observed or measured, as stated below. The method is applicable to either percussion or time-fuse fire.

As a rule, the adjustment is made independently by single piece. The method consists essentially in observations made by two lateral observers on the apparent errors in deflection of a burst (percussion or time fuse) in respect to a reference point on the target. From these observations are deduced the sensing of the errors in range and in deflection. The observers may or may not be on opposite sides of the line gun—target, and they may be at any distance from the target.

151. *First method—Observation of the sense of the errors.*—We assume that the two observers are not beyond the line which is perpendicular to the line of fire at the target. Let P be the gun, O the target, D the observer on the right, and G the observer on the left. The observers announce the sensing of the apparent errors in deflection in respect to O and the sensing for range when they can observe it. Four cases are possible:

	D announces.	G announces.	The round is in the segment.	In range, the round is therefore—
First case	Right	Left	I	Over.
Second case	do	Right	II	Doubtful.
Third case	Left	do	III	Short.
Fourth case	do	Left	IV	Doubtful.

We can therefore sense the round if it is in the segment I or III. It is doubtful if it is in II or IV, but we know that it is to the right or left of I or III. In this way we can bring the burst into these segments by suitably changing the deflection. Adjustment in range is therefore possible. Moreover, we bring the deflection to O automatically when we accomplish our adjustment in range.

152. *Second method—Observation on the size of the errors.*—This second method is more rapid, more accurate, and more economical in ammunition than the preceding. The result of each observation is expressed by an algebraical quantity whose absolute value is the size of the angular error between the point of burst and the reference point and whose sign is plus if the right (left) hand observer (regardless of the line OP) announces the error as right (left), and minus if the right (left) hand observer announces the error as left (right).

Index of a round.—The algebraical sum of the two quantities expressing the results of two observations relative to the same round is called the index of the round.

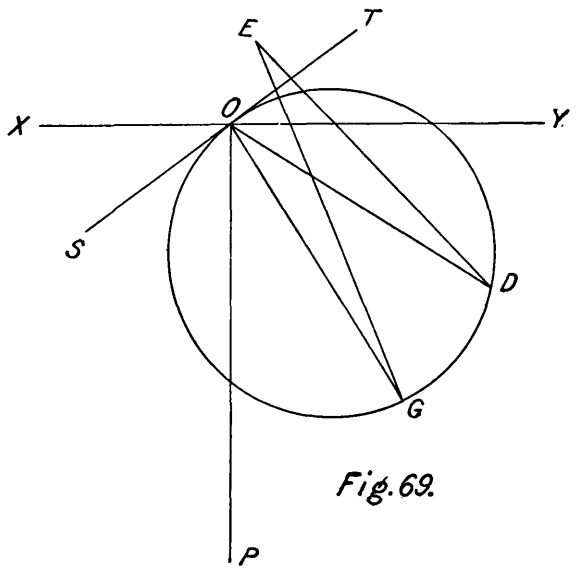


Fig. 69.

Adjustment in range.—The round is over if the index is >O, short if the index is <O, and on the level of the target if the index equals O. Draw the circumference OGD. Take a point E (point of fall or horizontal projection of an air burst). The index of E is >O if E is outside of the circle, =O if E is on the circumference, <O if E is inside the circle. But, as the measured angular errors are small, we may confuse, in the neighborhood of O, the circumference with the tangent ST at O. The rules given above on the subject of the index will be accurate if the tangent ST coincides with the perpendicular XY to the line gun—target. In practice, therefore, we must so arrange matters that the center of the circumference passing through the target and the two observers G and D will lie approximately on the axial line (line of fire). This condition is realized when the base of observation GD is perpendicular to the axial line of fire and the two stations are at equal distances on either side of the line.

By considering the index of a round, therefore, we are able to sense the round, and hence to adjust for range. It is well to note that—

(1) The sense of the round in direction as seen by an observer is given by the sign of observation made at the other station.

(2) If the angular errors are measured to within α mils, a round must be considered as doubtful and approximately on the level of the target when its sign has an absolute value less than or equal to 2α mils, for the index comprises the sum of the errors made at each observation station.

(3) A round whose direction is announced by only one station is doubtful.

(4) Whenever the observer can sense the round by the obscuring of the target by the smoke, or inversely, he should announce it. This information permits the round to be sensed even when the value of the index is too slight to permit a conclusion to be drawn from it (see No. 2, above). Direct sensing is, nevertheless, always more certain than that calculated by an index.

(5) If this direct observation of the sensing of rounds with slight index is impossible, fire for effect is executed on a zone lying between the range giving rounds with distinctly positive indices and the range giving rounds with distinctly negative indices.

Adjustment for deflection.—After each round a correction is made in deflection equal in amount and in sign to the algebraic half-difference of the errors taken with their signs (the error to right less the error to the left) when the two observation stations are approximately on the line of the battery. The effect of these corrections is to shift the points of impact into the interior angles of the lines of observation—a condition favorable to adjustment in range and from which the adjustment in deflection automatically results.

When the two stations are near the target and at about the same distances from the target, the correction after each round is equal to the half-difference defined above divided by $\frac{D}{d}$, D being the range gun—target and d the distance from the observation station to the target.

In the particular case in which the base of observation GD is perpendicular to the axial line of fire and the two observation stations are at equal distances on either side of this line, the effect of the corrections shown is to shift the points of fall onto the axial line, and once there they stay there.

In all cases, whatever may be the distance from the observation stations to the targets, it is well to have the two stations symmetrical in relation to the axial line and the base of observation perpendicular to this line.

H. USE OF AERIAL OBSERVATION IN LIAISON WITH THE ARTILLERY.

I. Conditions of use.

153. *A. Aeroplane.*—Under good atmospheric conditions the aeroplane permits rapid and accurate observation, and a vertical one if necessary. It also enables the salvos to be sensed, and often their error in reference to the target to be exactly valuated. It communicates with the ground by wireless, searchlights, weighted messages, or rockets. The receiving station communicates with the aeroplane by panels, and sometimes by searchlight. Each artillery command is furnished with a receiving station from which the antennæ officer communicates by voice or telephone with the battery, and with an identification panel, which is particularly useful in case the batteries change their positions.

B. Balloon.—The balloon can not ascend above 1,500 m., and is obliged to keep at least 7 kilometers away from the enemy lines. Portions of the terrain are therefore hidden from the observer at a given ascension point. In comparison with the aeroplane it is therefore only an auxiliary in the adjustment of artillery fire, and generally carries out missions of surveillance.

II. Artillery missions.

154. *Information missions.*—The aeroplane, with the aid of photographs, is the surest method of investigating the enemy lines. The activity on the front, in particular, can not be ascertained except by an observer in an aeroplane.

Missions of surveillance.—Since this type of mission is very tiring, it is undertaken by means of balloons.

Firing missions.—Their object is the observation of fire for adjustment or verification, of accurate fire, of fire at a single range, and of systematic fire. An aeroplane's flight is limited to three hours at most, and, as it may end abruptly, the unit commanders should conduct their fire as rapidly as the matériel permits.

III. Duties of the personnel.

155. There should be a close understanding between the observer, the antennæ officer, and the battery officers. This understanding can not be had except by frequent interchange of visits, and it must therefore be obtained during periods of calm or rest.

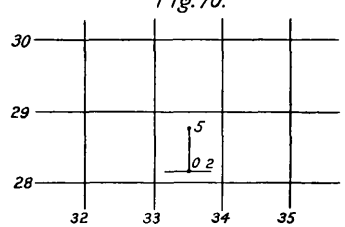
IV. Conduct of fire.

156. When the aeroplane starts out, the air squadron notifies the antennæ officer, who warns the battery according to orders received. The latter forms and verifies the sheaf. The range of the moment is not verified on an auxiliary target, except in the heavy batteries. Fire is executed by battery salvos, parallel fire, the pieces firing simultaneously and with the same lot of ammunition to be used in fire for effect. At the opening of an adjustment, fire should be executed with time fuse (75-mm. guns), to permit adjustment in deflection. The salvo should be fired when the aeroplane signals "Fire." The battery changes its firing data if the observer repeats several times the signal "Not seen." If the aeroplane signals "I was not in position to see," the data is not changed. The errors of the salvos are estimated for range with reference to the center of burst of the salvo and for direction with reference to the round on the right in its relation to the right of the target. When the bracket is obtained, the observer only signals the sensing of the rounds, commencing with the deflection.

Example: 055 mils to the right, 202 meters short; which is equal to 50 meters to the right, 200 meters short. The quantities signaled are always of three figures, and although the errors are estimated in multiples of 10 meters, the zero which should terminate the quantity is replaced by the first significant figure. If the observer does not know the battery position, he may signal 101 mils east, 055 mils north.

The observer is the representative of the battalion commander in matters concerning the reconnaissance and designation of targets. He signals the targets by using the conventional signals and the battle map. A battery of artillery at O, for instance, is signaled 3583 BTO (BTO=battery target observed). On the other hand, he is the collaborator of the battery commander, and must leave to the latter the responsibility for the conduct of his fire. Nevertheless, the battery commander should give the observer everything he asks for to facilitate his observation. The different types of fire for effect with aeroplane observation are:

Fig. 70.



Fire at a single range.—Battery volley of 2 to 4 rounds per piece, fired on the aeroplane's demand for each volley.

Accurate fire by piece.—The piece fires a series of 4 rounds as rapidly as possible, consistent with the greatest accuracy, when the aeroplane signals "Fire." This only applies to the 75-mm. gun, which is the only gun that fires with sufficient rapidity.

Zone fire.—Comprising time-fuse controlled fire (following fire for adjustment) and systematic fire executed according to the data of a preceding adjustment and without new verification.

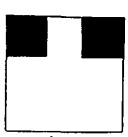
As a rule, aeroplanes should only be used for very accurate fire.

V. Signal Code.

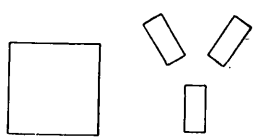
157. (*a*) *Aeroplane to ground.*—The signals used in aerial wireless are—

1. Conventional signals for adjustment.
2. Groups of two letters forming signals (reconnaissance signals).
3. Groups of 2, 3, 4, or 5 letters, or numbers, serving as complementary signals.

Conversations in plain language are avoided as much as possible. The signal code applies equally to the searchlights.



A C
Corps Artillery
Fig. 71.



An enemy aero is in sight
Fig. 72.

(*b*) *From ground to aeroplanes.*—Panels or searchlights are used. The first are more convenient for the aeroplanes, but are more visible to the enemy. The reverse is true of searchlights. In each artillery command an identification panel (white square showing special unit mark) is placed near the antennae during the periods of work with the aeroplane. In addition, 3 signal panels (4 m. by 1 m.) enable us to send a certain number of signals. They should be placed near the receiving station, on a dark background and in the sun, leaving an interval of at least 4 m. between two adjoining signals. The necessity of concealing them from the enemy's view is only secondary. As a rule, the searchlights only signal in answer to an aeroplane's question.

CHAPTER IV.

CONDUCT OF FIRE.

158. Good shooting does not lie only in the knowledge and observation of the technical rules. It also lies in an appropriate and delicate application of these rules, so as to obtain the greatest useful effect for the battery with regard to its situation and its targets.

The most tangible and least questionable result is effective fire, but it is not the only one. Different targets do not possess the same degree of vulnerability, and are not dangerous in the same way. They should therefore be fired on by different methods. The following observations on the useful effect and, in particular, on effective fire and the nature of targets, are intended to guide the battery commanders in the conduct of their fire.

ARTICLE 1.

EFFECTIVE FIRE.

159. The artillery's essential object in war is the destruction of the enemy. If this destruction can not be obtained, the effects produced during the course of the fire will at least neutralize the enemy by imposing a momentary and more or less complete cessation to his activities. The guns give a moral support to the friendly troops, and divert the enemy's attention and fire from them. Neutralization, moral support, and diversion result from the known effectiveness of the artillery. They are not less distinct even if they are produced by a fire whose real effect is small or even nil. They must be taken into consideration in questions affecting the hastening or the delaying of the opening of fire, increasing or reducing the intensity of the fire, and suspending or reopening the fire. The result sought is always more surely obtained when it is supported by as great an effect as possible. The effect of a projectile fired against a given target, with firing data corresponding to the position of the target, is known. But service fire does not consist only of projectiles fired under these conditions. The firing data is determined within more or less wide limits, and the vulnerability of the target changes—it may change even during the fire. The determination of the firing data, within narrow limits, is only possible under sufficiently favorable conditions of

observation. It takes time. Moreover, narrow limits are more subject to error than wide limits. But it is more effective, and involves less expenditure of ammunition, when we fire on a target whose vulnerability does not change. The battery commander must seek the effect which he deems necessary, according to the urgency of obtaining the result, the duration of the opportunity, and the conditions of observation. He must do this either by a greater expenditure of ammunition, fired more rapidly on an extended area, or by a less expenditure, taking more time, on a more limited area.

160. *Relative influence of the elements of adjustment:*

(*a*) *In range.*—An error in one of the limits of range may lead to an absolutely ineffective fire.

(*b*) *In height of burst* (time-fuse fire).—When the height of burst is maintained between 2 and 4 mils, the effect varies little. Outside these limits, the effect decreases rapidly. A constant error in height of burst of 3 mils on the part of a battery commander firing 1,200 rounds is equivalent, from the point of view of effect, to the loss to his battery of about 3 caissons. A comparative table of effect obtained at 2,500 m. range, with height of burst differing by 3 mils, follows:

Nature of targets.	Heights of burst.	
	3 mils.	6 mils.
	Per cent.	*Per cent.*
Infantry standing, in one rank	42	30
Infantry prone, in one rank	17	9
Personnel of a shielded battery in action	16	14

(*c*) *In deflection.*—In fire for demolition of matériel, all projectiles are lost that are not absolutely accurate in deflection. In fire against personnel, accurate adjustment in deflection is not so necessary. For a particular piece, it is necessary to take the width of the sheaf of burst into account. For an entire battery, if the target is very vulnerable, an exact distribution increases the effect, but the time taken to obtain this may be profitably used by the enemy to reduce his vulnerability. If, on the contrary, the target is only slightly vulnerable (personnel sheltered behind gun shields or in trenches, prone infantry, etc.) the increase in effect resulting from an exact distribution will be slight, and it also may be annulled in part by the delay and the causes for errors introduced into the operation of the battery by the necessary commands to modify the

direction of one or more pieces. On the other hand, an exact distribution not only has the advantage of increasing the probable effect, in variable proportions, but it is also a manifestation of the good fire discipline that prevails in the battery, and it facilitates the captain's observation. This consideration must not be overlooked and, on the whole, an exact adjustment in deflection must be considered a question of measurement and opportunity.

161. The variation (actual or potential) in the vulnerability of the target during the fire is one of the essential factors of the effect of the fire, not only in the opening of fire but also in the launching of salvos or successive volleys. Sometimes a target vulnerable for a short time may furnish a fugitive occasion for fire. At other times the vulnerability, while not disappearing entirely, definitely becomes less—for example, artillery when going into battery and after this operation has been completed. Still, again, the target may preserve the same general vulnerability, but this vulnerability may change irregularly and constantly—infantry manning a trench and firing irregularly, or artillery with gun shields. (In the latter case the personnel is only slightly vulnerable from shrapnel when the artillery is not firing, since it is behind shields, but it becomes slightly more vulnerable when the artillery is firing.) Eventually the vulnerability may disappear entirely when the personnel (infantry or artillery) is hidden in bombproof shelters.

It is evident that neither the same methods nor the same conduct of fire can be applied in all these cases. If, for example, we wish to obtain a certain effect on infantry occupying a trench, it is necessary, once the fire is adjusted, to fire by volleys of one or two rounds, irregularly spaced, all the pieces firing simultaneously (order for simultaneous fire given by whistle). If the fire is further prolonged, there is not much chance of reaching the enemy, who intrenches or shelters himself from the time of the first volley, and we can only prevent him from reopening fire. In the same way, the personnel of an enemy battery on which we adjust have a tendency, if it is not absolutely necessary for them to continue their fire, to shelter themselves as soon as our volleys come close to them. In this case it is evidently better that fire for effect should not immediately follow fire for adjustment. It is better to wait until the enemy personnel have resumed their combat posts. But it is difficult to choose this moment, and definite rules can not be given; it is a matter of judgment on the part of the captain. (If he allows an appreciable time to elapse between the conclusion of the adjustment and the execution of fire for effect, he must not forget, when opening the latter fire, to take the corrections of the moment into consideration.)

On the other hand, fire for effect should immediately follow fire for adjustment on targets which are immediately dangerous, such as enemy's artillery whose pieces can be seen. Even if the personnel shelters itself, the matériel can always be destroyed.

The opportunity for fire and the instantaneousness necessary for effect are often one and the same thing. Unless the firing data is known, adjustment can not be dispensed with, under penalty of rendering our fire ineffective by reason of shorts, overs, or bursts too high. But the search for accurate bracketing has the disadvantage of warning the enemy, of removing the effect of surprise, and of delaying the moment when the fire reaches its highest rapidity. We must, therefore, use all means of simplifying the adjustment operations and reducing their length. The range measurements taken by telemeter or from the map, the estimation of sites, the location of certain variations in the terrain by means of projectiles fired, the determination of the relative ranges of two points, one of which has already been adjusted on (transfer of fire), etc., sometimes enables us to reduce our fire for adjustment to a verifying salvo. All batteries that have to deal with fleeting targets, against which a methodical adjustment is impossible, must be in a position to strike the enemy by making use of similar methods.

ARTICLE 2.

THE DIFFERENT TARGETS ON THE BATTLE FIELD—MEANS OF ATTACKING THEM.

162. Nearly all the targets on a battle field come under one of the following heads:

(*a*) Field fortifications and auxiliary defenses to be destroyed.
(*b*) Localities.
(*c*) Woods.
(*d*) Reconnaissance parties or staffs.
(*e*) Observers, signalers, telephone operators.
(*f*) Aerial targets.
(*g*) Cavalry.
(*h*) Artillery.
(*i*) Infantry.

163. *Field fortifications.*—Light fortifications can be destroyed by the field artillery, at the price of a more or less great expenditure of ammunition. They are fired on with nondelayed-action shell, or, lacking this, with percussion shrapnel. In the case of loopholed

walls, the defenders in rear are best reached by using delayed-action shell. The 75-mm. shell can not destroy earthworks. The bombardment of earthworks is only intended to effect the defenders who are sheltered there. Fire is executed with delayed-action shell or with time-fuse shrapnel, according to circumstances. Time-fuse shrapnel fire on trench defenders only gives a minimum effect when the enemy is sheltered behind the parapet, but it forces the enemy to get into the ground and prevents his firing—and this with a relatively small expenditure of ammunition. (The fire is conducted at the long range of a 50-m. bracket, or at the long range and the intermediate ranges in 50-m. jumps of a wider bracket.) On the other hand, fire with delayed-action shell is capable of considerable effect against the defenders of an uncovered trench. (If haste is necessary, the trench is searched with a maximum bracket of 50 m. with an intermediate jump of 25 m. If the factor of economy in ammunition is more important than the factor of time, fire is executed at the single range which gives two or three overs in every four rounds observed.)

164. *Auxiliary defenses.*—Wire entanglements form the best auxiliary defenses. There are generally two or three entanglements, each 6 m. to 10 m. wide, the interval between them being ordinarily 10 m. But as their total width is never known definitely, it is always best to fire at successive ranges between the short range of the near edge and the long range of the far edge. Experience has shown that the action of the 75-mm. guns, added to that of the trench guns, is, as a rule, sufficient to make breaches in wire entanglements. Nevertheless, a certain number of 120-mm. Schneider guns or 155-mm. howitzers are generally needed to complete the action against entanglements on a counter slope. Nondelayed-action shells are used.

The fire of about 150 rounds at a single deflection and range opens a gap of from 5 m. to 10 m. in width in entanglements 20 m. deep. (The range used is that which gives a mean point of burst in the center of the entanglement—in practice, the range which gives two or three overs, with respect to the near edge of the entanglement, out of four rounds observed.) If the entanglement is deeper, we fire 150 rounds at each 25-m. jump in range, beginning with the long range with respect to the far edge of the entanglement and ending with the range which gives two or three overs out of every four rounds observed, with respect to the near edge of the entanglement, without altering the deflection.

Often only the near edge of the auxiliary defenses of the works can be seen. We must then fire systematically, as indicated above, on the terrian comprised between this near edge and the supposed position of the trench that covers it.

Good firing ranges to make a breach are those between 1,400 and 3,000 meters. At less than 1,400 meters the angle of fall is too small and the least variation in the slope of the terrain protects a portion of the entanglement from the effects of the fire. Beyond 3,000 meters the dispersion is too great, and a greater amount of ammunition must be fired to obtain a result—the expenditure is doubled at 6,000 meters.

Breaches are made by batteries, not by platoons or sections. To make a breach by battery, the 4 pieces are adjusted in deflection, so that the planes of fire are spaced from 5 to 6 meters apart at the entanglement. The battery will thus make a breach of about 25 meters.

To make a breach by battery in an entanglement 2,000 to 4,000 meters away on horizontal terrain, we must fire—

Width of entanglement.	Number of rounds.
10 to 15 meters	500
15 to 25 meters	600
25 to 50 meters	900
50 to 75 meters	1,200

Beyond 4,000 meters the expenditure will increase with the range, and we must allow 1,000 rounds at 5,000 meters and 1,200 rounds at 7,000 meters.

These roughly calculated figures apply only to an accurate fire. They can be reduced if the terrain slopes up toward the enemy and must be increased if the terrain slopes down. It is better to fire at long ranges, rather than at short ranges, to increase the angle of fall. Nose disks are only used as a last resort, for they reduce the accuracy of fire and may be dangerous to our own troops. If the slope is too great the fire must be oblique, or we must use trench or heavy artillery. Shell is used. Shrapnel is effective only at short ranges ($<$2,500) and on light entanglements, but it may be used in small quantities, in combination with shell, to clean the breaches. The choice of fuse depends on the terrain and range. The instantaneous, nonrichochet fuses give the best results on ordinary terrain. The ricochet fuses, whose height of bursts do not exceed 1½ meters, are more effective than the others on clayey ground, heavy and soaked by the rain. At ranges $>$4,000, the supersensitive fuses are best.

Accurate fire is essential. The accuracy should be obtained by using the 88 model clinometer.

A battery can not fire more than 400 rounds an hour, hence a minimum of 1½ hours for an ordinary breach. We must allow three hours to complete a breach, taking into consideration the necessary delay for accurate adjustment.

165. *Localities.*—Localities are fired on with a view to inflict losses on the troops supposed to be assembled there, or to make them untenable by destroying the buildings. Incendiary fire may occasionally be used with the latter end in view.

The efficiency of field-gun shells enables us to obtain the desired result within certain limits. But heavy artillery shells, containing more explosives, cause greater destruction to important localities—tall houses close together, for example. The incendiary shells of the 75-mm. gun are useful for the bombardment of villages and cantonments.

166. *Woods.*—If the edges are occupied, they are covered by time-fuse fire or shells of any priming. The interior of the woods, where concealed troops may be reached, is covered by shell, with or without delayed action.

167. *Reconnaissance parties—Staffs.*—These are important and very vulnerable, but they afford only a fugitive occasion for fire. Time-fuse fire is executed on a wide front, over wide limits and with the maximum rapidity.

168. *Observers, signalers, telephone operators.*—These offer important targets, of variable vulnerability but of a certain fixity. Fire is executed over a narrow front, and is more and more confined in range. If the observer is in an observation station, time-fuse fire will be followed by percussion fire with shell.

169. *Aerial targets.*—This type of fire forms the subject of special instructions.

170. *Cavalry.*—Cavalry, while very vulnerable when halted and in close formation, protects itself from artillery fire by mobility and by scattering. When the cohesion of the enemy cavalry is destroyed its dispersion is itself an important result and advantageous to the friendly cavalry. To the effect of dispersion may often be added some material losses and the fear of crossing certain areas, which will be the greater as the more material effect is produced at the same time on men and horses. This combination of results is, as a rule, the maximum to be hoped for by the artillery. All necessary arrangements are made to increase the mobility of fire in order to accomplish the end. If the battery is so placed that it can not use

direct fire, we must open the sheaf of fire and cause each piece to fire in depth when the cavalry enters its zone. If the battery can use direct fire, the target should be followed in direction by all the guns. We must choose wide limits in range and open fire with all the guns at the same time on the short or long limit, according to whether the target is approaching or withdrawing. As the target is fugitive, the fire will be of short duration. It must therefore be executed at maximum rapidity, either time fuse or percussion, or, best of all, with shell. When the cavalry charges a battery, the latter will operate to the best advantage by forming a percussion or shell barrage in front of the enemy line.

171. *Artillery.*—The artillery presents targets of extremely variable vulnerability. The greatest vulnerability exists from the beginning of the reconnaissance up to the moment when the guns are ready to fire. Effective fire on the reconnaissance parties may cause important delays in the posting of the battery, and may even deprive the artillery of its commanders. Effective fire at the moment of going into battery may produce losses and disorder from which it will be difficult to recover. The withdrawal from a position is also a critical moment if the withdrawal is carried out by a movement of the whole unit.

The 75-millimeter gun destroys exposed artillery. Against casemated artillery the 75-millimeter can undertake embrasure hits that are effective up to 5,000 meters. In both cases the number of rounds which must be fired to get 2 hits is 100 at 3,000 meters, 200 at 5,000 meters, or an average of 150 rounds per enemy gun, or 600 rounds per battery.

The 75-millimeter neutralizes the enemy artillery. The object of neutralization is to cause losses to the personnel of the enemy batteries and to force them to withdraw, so as to silence them for a period more or less long. Vigorous action is essential at the opening of fire, followed by slow fire to keep the personnel in their shelters. Vigorous action is resumed if the battery reopens fire. The rapidity of fire is more important than the caliber, hence the advantage of the 75-millimeter.

If pieces of a battery in position are visible from a point not too far away, a great expenditure of ammunition is not required in order to destroy the matériel. The number of rounds necessary in order to hit one of the two carriages of a section (gun or caisson body) varies with the range and the observation conditions. It averages 15 at 2,500 meters and 25 at 3,500 meters. Fire for the demolition of the matériel is, of course, effective against the personnel.

If the pieces are not visible, or if they are too far away, or if we know only the direction from the flashes or the dust, fire for demolition can only be executed by aid of aerial observation. But there are always staff personnel, agents of communication, observers, etc., in advance, in rear, or in the intervals of the batteries who are incompletely sheltered, especially during artillery activity. Moreover, the gun shields do not afford complete protection to all who take shelter behind them. Even time-fuse fire secures certain effects, which are greater in proportion to the obliquity of the fire, while shells can reach the cannoneers no matter what their position may be. Only a sufficient distance from the covering crest or the mask can render a target absolutely immune, since there are no means of firing on terrain of indefinite depth. An opinion must be formed, from all the indications observed, as to the depth of the zone that can be reasonably considered as suspect. There is a certainty in some cases and probability in others. The cost in ammunition for a useful and probable effect, as well as the urgency for producing the effect, must be considered. From these considerations we must make our decision.

In combat against enemy artillery aerial observation is an indispensable auxiliary (see special instruction).

The above considerations dictate the principles to be followed in the conduct of fire against an artillery target.

If we get into position before the enemy, we must observe, with care, all signs of enemy reconnaissance and of his going into position. We must seize these moments for fire (time-fuse fire, wide limits, wide front, maximum rapidity). If necessary, we must repeat the fire, reducing the limits. If the enemy gets into position before us, or if we lose the occasion for fire on his reconnaissance or his battery going into position, we must proceed as follows:

First case—Artillery whose pieces are visible.—(1) Reach the exposed personnel and produce a first disorganizing effect by time-fuse fire (wide limits, wide front). (2) Extend this effect by reaching even the sheltered personnel. Use delayed-action shell for this fire, reducing the limits of the range as much as possible, without losing too much time, and restricting the front fired on to the exact front of the target. (3) Destroy the personnel at the same time as the matériel. This should be done with nondelayed-action shells (or, if they are lacking, with percussion shrapnel). This fire must be as accurate as possible on all the pieces seen. It must be continued until the result is obtained, unless another task is required of the

battery, unless a lack of ammunition forces economy, or unless the range is so great as to make demolition impossible. In these different cases, one element of the battery (piece or section) must be designated to hold itself always ready to fire when the target manifests activity anew, while the other elements of the battery remain available.

The three phases shown above should follow one another without a noticeable interval.

Second case—Pieces not visible.—The presence of artillery is then known by its flashes, by the dust raised by its fire, or by any other information, or else the fire is adjusted by aerial observation. There is no reason for time-fuse fire intended to reach the personnel, as in the preceding case, since it is impossible (or else takes too long, in case of aerial observation), to adjust the height of burst with respect to the target, and therefore time-fuze fire would probably be only slightly effective. The second phase is executed as in the preceding case, except that, when aerial observation is lacking, the long limit must be arbitrarily determined (the short limit being the crest), or else the two limits of fire for effect must be arbitrarily determined from the map. This fire having been carried out, we must observe with the greatest care so as to profit by any new opportunity. We must seek out the enemy observation stations or command posts, and destroy them when discovered if possible. Fire for demolition can not be executed without aerial observation.

171. *Infantry.*—The infantry, like the artillery, offers a target of variable vulnerability. But, while the enemy artillery, once in position, forms a definite target whose only important variations lie in more or less exposing or sheltering the personnel when passing from action to inaction, the infantry target changes from one instant to another—its form, dimension, density, and sometimes its position. An artillery target can sometimes be destroyed, but an infantry unit, whose elements can shift for themselves and withstand fire almost without loss, can not, in practice, be destroyed. In short, we can say that the artillery is limited in quantity and that, because of the effectiveness of fire of even a single piece, all guns seen are worth firing on; while the infantry exists in almost indefinite quantities pretty much everywhere, but in detachments of slight importance which, by reason of their weakness, do not provoke our fire, or which, by reason of their numbers, require a dispersed fire. Moreover, fire on infantry rarely produces grest losses. But other results can be accomplished.

On the defensive.—From the moment the enemy first appears until our infantry, by halting it, changes it into a fixed target sufficiently dense and vulnerable, we must force the assailant to deploy at a distance, to scatter his units, to seek defiladed approaches, to hesitate in crossing fire-swept areas (or else to make him pay a penalty for crossing), and finally to prevent him from crossing such or such a line by barrage fire.

On the offensive.—We must keep the defender in his shelters, prevent him from firing when he wishes, deprive him of the use of certain supporting points, and hamper the work of his reserves. These results are usually obtained by fire of great density when occasion offers, taking into consideration the supplies, the rapidity of progress of the general attack, and the approach of the assault. In the thick of the fight, and when the climax is imminent, a greater and greater number of batteries will fire against the infantry. But so long as the situation is not fully developed, in order to avoid uselessly disclosing all our artillery and to keep batteries ready to ward off the unforseen, it is advisable to engage only the necessary number of guns against the infantry (as against the artillery)—a number that is increasing as the need of making a more complete preparation for the infantry increases. The importance of the matériel preparation by guns can no longer be given in figures.

To sum up.—Rules can not be given for the conduct of fire against infantry, because of the great variety of special cases, even though the rules be as broad as those given above in reference to fire against artillery. The best guarantee of a well-conducted fire lies in the faculties of the captain—his power of grasping a situation, his calmness, his well developed tactical sense, his thorough knowledge of the resources of his matériel, and his long habit of command.

173. *Barrage fire.*—The object of the barrage is: (1) To halt the enemy attack at the moment of its appearance, and (2) to prevent the arrival of reenforcements and reserves intended to supply it. A barrage should have the greatest possible density—all the field artillery, without exception, must take part in it. Each battery must have its zone, and batteries may even be superimposed on the same zone. When it is possible the front action of an infantry unit and the zone of barrage of an artillery unit should correspond exactly (for example, an artillery battalion to an infantry battalion).

Targets.—The barrage should form a continuous curtain, and should be laid down as near to our lines as is consistent with the safety of our infantry.

The minimum range at which our shells should burst beyond our lines is as follows:

	A. Frontal fire barrage—			B. Enfilade fire barrage (at all ranges).
	2,000 meters.	3,000 meters.	4,000 meters.	
Shell	90	100	150	50
Shrapnel, percussion	60	90	100	30
Shrapnel, time fuse	150	150	150	60

Because of the variations in range, due to the atmospheric conditions, these figures can not be used unless the range is verified morning and night, and all the corrections are made for temperature, pressure, wind, weight, etc., as the conditions change. The range of the moment (which may be determined with a single piece) will be found whenever necessary. If its accurate determination is impossible, we must remember that, above all, fire on our own troops must be avoided, and that, in extreme cases, two ranges referring to the same target may differ by 20 per cent from one day to the next.

The barrage, to be effective, must be laid down in front of or on the enemy first-line trenches. In certain cases, considerations of safety require that the barrage be laid down only in rear of the enemy trenches. It then loses its value. The sector commanders must seek by every means to lay their barrages on the first-line enemy trenches, by bringing up batteries, by the use of batteries or pieces firing in enfilade, by the use of percussion shrapnel fire, etc.

Laying down the barrage.—The barrage should be laid down with all possible rapidity, consequently it should be laid down automatically on data determined beforehand. It is laid down either at the infantry's request (by telephone, rocket, etc.), or originated by the battery commanders, on information from the observation station, or when the situation seems to call for this type of fire (sharp fusillade, gas attack, etc.). Everything should be so prepared that the barrage can be laid down instantly. The guns not firing are laid, the ranges and the type of fire to be used are known by all (officers, chiefs of section, gunners, Nos. 1 and Nos. 3). The batteries are provided with an electric lighting system designed to light the battery instantaneously.

Conduct of fire and its requirements.—Fire should have the greatest rapidity possible when the barrage is first laid down. Later the rate of fire is modified according to information received from the in-

fantry, or according to circumstances. A 75-millimeter gun can fire about 6 rounds rapid fire per minute for five minutes. Rapid fire can not be continued for long, owing to the heating of the gun. To avoid having the matériel put out of action by premature wear and tear, the rapidity of fire of the 75-millimeter should not exceed 100 rounds per hour per piece. Two cadences must therefore be used for the barrage—rapid fire and slow fire. Once the barrage is laid down at rapid fire, slow fire is automatically reverted to until the infantry requests a repetition of the rapid barrage. Slow fire is not obtained by firing all the pieces slowly, but rather by firing one piece, or one section, while the other pieces or sections are cooled, inspected and cleaned.

The barrage should be laid down 100 m. or 200 m. in advance of our trenches, according to the range and the formation of the terrain (glacis or counterslope). If the barrage is laid down in front of the first-line enemy trenches, it is moved forward to those trenches, on which it rests.

If the enemy penetrates our lines, all or part of the barrage should be laid down at the infantry's request on that part of our trenches occupied by the enemy. The disposition of the batteries on the terrain should be such that this need can be met in all cases. The barrage is taken off at the request of the commander of the unit before which it lies, or, if communications are cut, at the moment the commander of the artillery of the sector considers the attack to have been halted.

APPENDICES.

APPENDIX NO. 1.

CHOICE OF AMMUNITION AND PRIMING, ACCORDING TO THE TARGETS.

Keep shrapnel for moving targets. Shells are used on all targets. Gas shells are used for neutralization fire.

Targets.	Ammunition and priming.
Exposed personnel	1. Time-fuse shrapnel (9 times more effective than shell). 2. Delayed-action shell, quadrant elevation 10°—shell, I or I. A. (instantaneous or supersensitive), quadrant elevation 10°.
Personnel sheltered in trenches taken in enfilade.	1. Shrapnel (time-fuse, height of burst 4 or 5 mils—jumps of 25 m. or 50 m. according to slope of terrain.) 2. Delayed-action shell. 3. Nondelayed-action shell.
Personnel sheltered in trenches not taken in enfilade, or behind gun-shields.	1. Delayed-action shell. 2. Nondelayed-action shell. 3. Shell, I. or I. A. fuse.
Personnel behind walls	1. Nondelayed-action shell, generally bursting after penetrating wall. 2. Shell, instantaneous fuse. 3. Shrapnel (percussion).
Personnel sheltered in houses	1. Delayed-action shell. 2. Incendiary shells.
Artillery matériel exposed, or reachable by fire through the embrasures.	1. Shell, supersensitive fuse (I. A.). 2. Shell, instantaneous fuse (I.). 3. Nondelayed-action shell.
Artillery matériel behind a parapet or under a light casemate.	1. Delayed-action shell. 2. Nondelayed-action shell.
Overthrow of trenches and parapets	1. Nondelayed-action shell. 2. Shell, instantaneous fuse. 3. Delayed-action shell.
Wire entanglements	1. Delayed-action shell. 2. Shell, instantaneous or supersensitive fuse. On ordinary terrain, instantaneous and nondelayed action. In clay, heavy or soaked by rain, delayed action, whose height of burst does not exceed 1.5 meters under these conditions, though it is generally greater than 1.5 metres under other conditions. 3. Nondelayed-action shell. 4. Shrapnel, low bursts in combination with shell, to clean the breaches.
Chevaux de frise	1. Nondelayed-action shell. 2. Shell, instantaneous fuse.
Woods	1. Shell, all types of fuses. 2. Incendiary shell.
Localities	1. Shell, all types of fuses. 2. Shrapnel, time fuse. 3. Incendiary shell.
Communications and depots of the enemy.	1. Shrapnel, time fuse 2. Shell, I. or I. A. fuse } Short volleys.

In the choice of shells and priming, the battery commander must consider, not only the nature of the target, but also the range, the form of the terrain, and the nature of the ground. Thus, delayed-action shell will not ricochet, even at short ranges, if fired on a glacis descending toward the battery when the ground is very wet. Again, the nondelayed-action shell will give grazing effect on hard terrain while, on the other hand, the instantaneous shell will hardly give it on muddy or soaked terrain, etc.

The following simplified rules show the corrections to be made in range by reason of the variation in wind and temperature:

Wind	light, V. <5	1/100 of the range.
	average, V. >5 and <10	2/100 of the range.
	strong, V. >10	3/100 of the range.
Temperature (Centigrade)	10° or 20°	0. 5/100 of the range.
	5° or 25°	1/100 of the range.
	0°	1. 5/100 of the range.
	—5°	2/100 of the range.

The range is reduced for temperatures $<15°$, and increased for temperatures $>15°$, the range table being based on 15° temperature.

APPENDIX NO. 2.

Precautions to be Taken in the Choice of Position and in the Construction of Batteries.

A battery should be concealed and well protected from fire. Good concealment is preferable to great protection.

The indications by which batteries may be located on aerial photographs are the excavations due to construction and the paths near the batteries. Positions should therefore be sought on the edge of a road or a sufficiently wide path; in woods (preferably small woods, to avoid having to cut down trees); in old infantry positions; in ruined settlements; in quarries and in the orchards of villages. Concealment is completed by the judicious distribution of the paths of communication (cul-de-sacs must be avoided), by the camouflage of working parties and emplacements and by the preparation of false batteries.

APPENDIX NO. 3.

TELEPHONE, TOPOGRAPHIC AND OPTIC MATÉRIEL ASSIGNED TO A BATTERY OF 75-MM. GUNS.

3 telephone apparatus.
1 4-terminal switchboard.
4 km. of light wire.
1 reel, 2 poles, with forks, 2 tool bags, 3 ground rods.
3 flash lights, 14 cm. diameter.
1 prismatic scissor telescope.
4 prismatic field glasses, with micronometer.
2 periscopes.
1 plane table, with orienting compass.
1 leveling alidade.
1 celluloid protractor.
1 ruler and 1 square.
1 Peigné compass (prismatic).
1 directing compass.
1 battery goniometer compass (aiming circle).

APPENDIX No. 4.

RANGE TABLES FOR 75-MM GUN, MODEL 1897.

Shrapnel, I. V.=535 (range table of Sept. 8, 1904).
Shell, I. V.=550 (provisional range tables of Aug. 12, 1916).

Range.	Shrapnel, I. V.=535.				Shell, model 1900, nonelongated fuse, I. V.=550.			
	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.
	Degrees and minutes.	Mils.			Degrees and minutes.	Mils.		
	° ′				° ′			
100	− 1		0					
200	+ 5	1	0					
300	+12	3	0		13	3	0	
								300
400	19	5	0		19	5	0	
								400
500	26	7	0		26	7	0	
								500
600	33	9	0		34	9	0	
								600
700	41	11	0		41	11	0	
								700
800	49	13	0		49	13	0	
								800

The quadrant ranges correspond to the actual ranges.

RANGE TABLES FOR 75-MM GUN, MODEL 1897—Continued.

Range.	Shrapnel, I. V.=535.				Shell, model 1900, nonelongated fuse, I. V.=550.			
	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.
	Degrees and minutes.	Mils.			Degrees and minutes.	Mils.		
	° ′				° ′			
900	57	16	0		57	16	0	
								900
1,000	1 6	19	0		1 6	19	1	
								1,000
1,100	1 14	22	0		1 15	22	1	1,100
1,200	1 23	25	0		1 24	25	1	1,200
1,300	1 32	28	0		1 34	28	1	1,300
1,400	1 41	31	1		1 44	32	1	1,400
1,500	1 51	34	1		1 54	35	1	1,500
1,600	2 1	37	1		2 5	38	1	1,600
								1,700
1,700	2 11	39	1		2 16	41	1	

The quadrant ranges correspond to the actual ranges.

RANGE TABLES FOR 75-MM GUN, MODEL 1897—Continued.

Range.	Shrapnel, I. V.=535.				Shell, model 1900, nonelongated fuse, I. V.=550.			
	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.
	Degrees and minutes.	Mils.			Degrees and minutes.	Mils.		
	° ′				° ′			1,800
1,800	2 21	41	1		2 27	44	1	
								1,900
1,900	2 32	44	1		2 39	47	2	
								2,000
2,000	2 43	47	1		2 51	50	2	
								2,100
2,100	2 54	50	1		3 4	54	2	
								2,200
2,200	3 5	54	1		3 17	58	2	
								2,300
2,300	3 17	58	1		3 30	62	2	2,400

The quadrant ranges correspond to the actual ranges.

RANGE TABLES FOR 75-MM.

Shrapnel I. V.=535. (Range
Shell I. V.=550. (Provisional

Range.	Shrapnel, I. V.=538.			
	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.
	Degrees and minutes.	Mils.		
	° ′			
2,300	3 17	58	1	
2,400	3 29	61	1	
2,500	3 41	64	2	
2,600	3 53	68	2	
2,700	4 6	72	2	
2,800	4 19	76	2	
2,900	4 32	80	2	
3,000	4 46	84	2	

The quadrant range corresponds to the actual range.

GUN, MODEL 1897.

table of Sept. 8, 1904.)
range tables of Aug. 12, 1916.)

Shell, model 1900, nonelongated fuse, I. V.=550.				Shell, model 1900, supersensitive fuse (I. A.) 1915. I. V.=550 (real I. V.=542).			
Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.	Angle of elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.
Degrees and minutes.	Mils.			Degrees and minutes.	Mils.		
° ′				° ′			
3 30	62	2	2,400				
3 44	65	2	2,500				
3 58	69	3	2,600				
			2,700				
4 12	73	3					
			2,800				
4 27	77	3					
			2,900				
4 42	82	3					
			3,000				
4 59	87	3					
			3,100				
5 16	92	3	3,200				

RANGE TABLES FOR 75-MM.

Range.	Shrapnel, I. V.=538.			
	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.
	Degrees and minutes.	Mils.		
	° ′			
3,100	4 59	88	2	
3,200	5 13	92	2	
3,300	5 27	96	3	
3,400	5 42	100	3	
3,500	5 57	104	3	
3,600	6 12	109	3	
3,700	6 28	114	3	
3,800	6 44	119	3	
3,900	7	124	4	

The quadrant range corresponds to the actual range.

GUN, MODEL 1897—Continued.

Shell, model 1900, nonelongated fuse, I. V.=550.				Shell, model 1900, supersensitive fuse (I. A.) 1915. I. V.=550 (real I. V.=542).			
Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.	Angle of elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.
Degrees and minutes.	Mils.			Degrees and minutes.	Mils.		
° ′				° ′			
5 32	97	4	3,300				
5 48	102	4	3,400				
			3,500				
6 5	107	4					
			3,600				
6 22	112	4					
			3,700				
6 40	117	5					
			3,800				
6 58	122	5					
			3,900				
7 17	128	5	4,000				
7 36	134	5	4,100				
			4,200				
7 56	140	6					
			4,300				

RANGE TABLES FOR 75-MM.

Range.	Shrapnel, I. V.=538.			
	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.
	Degrees and minutes.	Mils.		
	° ′			
4,000	7 16	128	4	
4,100	7 33	132	4	
4,200	7 50	137	4	
4,300	8 7	142	4	
4,400	8 25	148	5	
4,500	8 43	154	5	

The quadrant range corresponds to the actual range.

GUN, MODEL 1897—Continued.

Shell, model 1900, nonelongated fuse, I. V.=550.				Shell, model 1900, supersensative fuse (I. A.) 1915. I. V.—550 (real I. V.=542).			
Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.	Angle of elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant range.
Degrees and minutes.	Mils.			Degrees and minutes.	Mils.		
° ′				′			
8 16	146	6		8 54	157	7	
							4,600
			4,400				
8 37	152	6		9 16	164	7	
			4,500				4,700
8 59	158	7		9 39	171	7	4,800
			4,600				
							4,900
9 21	165	7	4,700	10 2	178	8	
							5,000
9 44	172	7	4,800	10 26	185	8	
							5,100
			4,900				
10 8	179	7		10 51	193	8	
			5,000				5,200

Range Tables for 75-mm.

Shrapnel I. V.=535 (Range

Shell I. V.=550 (Provisional

Range.	Shrapnel I. V.=535.					
	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant ranges for the exact angle of site.	Quadrant ranges for the angle of site increased by 70 mils.	Number of divisions to be added to the normal corrector when the fuse-setter range is increased by 1,000 m. above the quadrant range.
	Degrees and minutes.	Mils.				
	° ′					
4,500	8 43	154	5			
4,600	9 1	159	5			
4,700	9 20	165	5			
4,800	9 39	171	5			
					(3,500)	−18
4,900	9 59	177	6			
					(3,600)	
						−17
5,000	10 19	183	6			
					(3,700)	
						−16
5,100	10 39	189	6		(3,800)	−15
						−14
					(3,900)	
5,200	11 0	195	7			
					(4,000)	−14
5,300	11 21	201	7			−13
					(4,100)	

Quadrant ranges the same as the real ranges.

GUN, MODEL 1897.

table of Sept. 8, 1904).

range tables of Aug. 12, 1916).

Shell, model 1900, nonelongated fuse, I. V.=550.					Shell, model 1900, supersensitive fuse (I. A.) I. V.=550 (real I. V.=542).				
Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant ranges for the exact angle of site.	Quadrant ranges for the angle of site increased by 70 mils.	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant ranges for the exact angle of site.	Quadrant ranges for the angle of site increased by 70 mils.
Degrees and minutes.	Mils.				Degrees and minutes.	Mils.			
° ′					° ′				
10 8	179	7		(3,600)	10 51	193	8		(3,900)
			5,000					5,200	
				(3,700)					(4,000)
10 31	187	8			11 17	201	9	5,300	
									(4,100)
			5,100	(3,800)					
10 55	194	8		(3,900)	11 43	207	9	5,400	(4,200)
			5,200						
				(4,000)					
11 19	201	9			12 9	214	10	5,500	(4,300)
			5,300	(4,100)					
									4,400
								(5,600)	
11 44	207	9	5,400		12 36	221	10		
				(4,200)				(5,700)	4,500
				(4,300)					
12 10	214	9	5,500		13 3	227	11		4,600
				4,400				(5,800)	4,700
12 36	221	10	(5,600)		13 30	237	11		
				4,500				(5,900)	4,800
			(5,700)						
13 2	227	10			13 58	247	12		
				4,600				(6,000)	4,900
			(5,800)						
13 29	237	11		4,700	14 26	256	12	(6,100)	5,000
			(5,900)	4,800					5,100

RANGE TABLES FOR 75-MM.

Range.	Shrapnel I. V.=535.					
	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant ranges for the exact angle of site.	Quadrant ranges for the angle of site increased by 70 mils.	Number of divisions to be added to the normal corrector when the fuse-setter range is increased by 1,000 m. above the quadrant range.
	Degrees and minutes.	Mils.				
	° ′					
5,400	11 43	207	7			−13
					(4,200)	
5,500	12 5	213	7		(4,300)	−12
						−11
5,600	12 28	219	8		4,400	
					4,500	−10
5,700	12 51	226	8			
						− 8
					4,600	
5,800	13 14	233	8			− 7
					4,700	
5,900	13 38	240	9			− 6
					4,800	
						− 4
6,000	14 3	248	9		4,900	
						− 3
					5,000	
6,100	14 28	256	10			
						− 1
					5,100	
6,200	14 54	264	10			0
					5,200	

Quadrant ranges the same as the real ranges.

GUN, MODEL 1897—Continued.

Shell, model 1900, nonelongated fuse, I. V.=550.					Shell, model 1900, supersensitive fuse (I. A.) I. V.=550 (real I. V.=542).				
Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant ranges for the exact angle of site.	Quadrant ranges for the angle of site increased by 70 mils.	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant ranges for the exact angle of site.	Quadrant ranges for the angle of site increased by 70 mils.
Degrees and minutes.	Mils.				Degrees and minutes.	Mils.			
° ′					° ′				
13 57	247	11			14 56	264	13	(6,200)	5,200
				4,900					
			(6,000)						
								(6,300)	5,300
14 26	256	12		5,000	15 26	272	13		
			(6,100)						
				5,100					5,400
								6,400	
14 56	264	12	(6,200)		16 0	289	14		
				5,200					5,500
15 26	272	13	(6,300)	5,300	16 32	296	14		
			(6,400)	5,400					
15 57	280	13			17 5	302	15		
				5,500					
16 27	295	14			17 39	311	15		
17 0	301	14			18 14	321	16		
17 33	310	15			18 50	332	17		
18 8	320	16			19 27	342	17		

RANGE TABLES FOR 75 MM.

Range.	Shrapnel I. V.=535.					
	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant ranges for the exact angle of site.	Quadrant ranges for the angle of site increased by 70 mils.	Number of divisions to be added to the normal corrector when the fuse-setter range is increased by 1,000 m. above the quadrant range.
	Degrees and minutes.	Mils.				
	° ′					
6,300	15 21	271	10		5,300	+ 1
					5,400	+ 3
6,400	15 49	278	11			
6,500	16 17	287	11		5,500	+ 4
6,600	16 46	296	12			
6,700	17 16	304	12			
6,800	17 47	313	13			
6,900	18 18	322	13			
7,000	18 50	332	14			
7,100	19 24	343	14			
7,200	19 59	354	15			
7,300	20 36	365	16			
7,400	21 14	376	16			
7,500	21 54	387	17			
7,600	22 36	399	18			
7,700	23 21	414	19			
7,800	24 8	427	20			
7,900	24 58	443	21			
8,000	25 53	458	22			
8,100	26 52	476	23			
8,200	27 58	496	25			
8,300	29 13	517	27			
8,400	30 43	544	29			
8,500	32 41	572	32			

Quadrant ranges the same as the real ranges.

GUN, MODEL 1897—Continued.

Shell, model 1900, nonelongated fuse, I. V.=550.					Shell, model 1900, supersensitive fuse (I. A.) I. V.=550 (real I. V.=542).				
Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant ranges for the exact angle of site.	Quadrant ranges for the angle of site increased by 70 mils.	Elevation.		Number of divisions of the azimuth micrometer to correct the drift.	Quadrant ranges for the exact angle of site.	Quadrant ranges for the angle of site increased by 70 mils.
Degrees and minutes.	Mils.				Degrees and minutes.	Mils.			
° ′					° ′				
18 43	331	16			20 6	355	18		
19 19	341	17			20 46	367	19		
19 57	353	18			21 26	378	20		
20 36	365	18			22 7	389	21		
21 15	376	19			22 50	401	21		
21 56	387	20			23 84	416	22		
22 39	399	21			24 20	430	23		
23 24	414	22			25 8	445	24		
24 11	427	23			26 0	461	25		
25 0	443	24			26 56	478	27		
25 52	458	25			27 56	496	28		
26 46	475	26			29 0	514	29		
27 43	493	27			30 12	534	30		
28 43	507	28			31 30	556	33		
29 48	526	29			32 55	578	33		
30 58	549	31			34 30	608	35		
32 13	565	33							
33 38	589	35							

Table of corrections of range to be made for an increase dV_0[1]=10 m. of the initial velocity.

[Increase [2]dp=100 gr. of the weight of the projectile. Increase d_w=0.100 gr. (2) of the weight w=1.208 gr. of a liter of air; longitudinal component in the direction of fire dW_x=10 m. of the velocity of the wind.]

Ranges.		1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000
Shell: Fuse I. [3]p=5.400 kg...	dV_0 =10 m...	31	50	60	67	71	74	77	80
	dp =100 gr..	− 8	− 7	− 2	+ 4	+ 11	+ 19	+ 29	+ 39
	dw =0.100 gr.	−14	−48	−85	−122	−161	−202	−248	−294
	dW_x =10 m...	5	24	58	100	149	203	266	329
Shell: Fuse IA. [3]p=5.400 kg...	dV_0 =10 m...	30	49	59	65	67	67	65	.....
	dp =100 gr..	− 8	− 7	− 2	+ 4	+ 12	+ 22	+ 36	.....
	dw =0.100 gr.	−17	−48	−86	−122	−163	−211	−267	.....
	dW_x =10 m...	4	24	60	104	157	221	311	.....

[1] The initial velocity varies with the temperature; the variations dV_0 as function of variations of temperature dt can be roughly estimated by the aid of the formula:

$$dV_0 = 0.0011.\ V_0 dt,$$

dt being the variation of temperature from one firing to another. For the initial correction, take $dt = t - 15°$.

[2] Corresponding, for example, to $t = 0°$ and a barometric pressure of 768 mm. (see chart opposite).

[3] p is abbreviation of poids—weights.

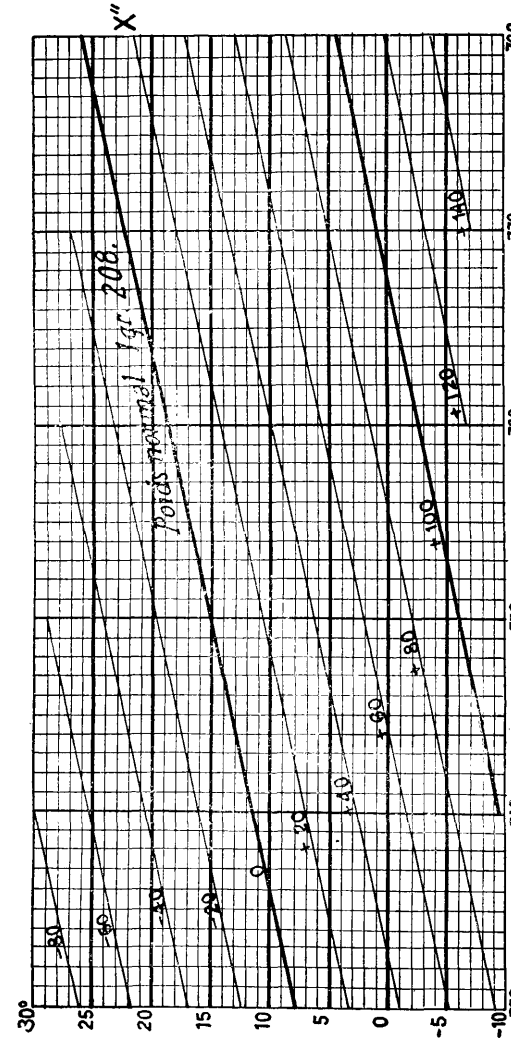
75-MM. EXPLOSIVE SHELL, MODEL 1900, ARMED WITH THE PERCUSSION DETONATOR FUSE 24/31, IA, MODEL 1915.

Standard weight of the shell: 5.550 kg. (12.23 lbs.).

A marking, painted in black on the shell, indicates the actual weight of the shell:

L	5.235 kg. to 5.385 kg. *dp.* mean=−240 gr.
+	5.386 kg. to 5.535 kg. *dp.* mean=− 90 gr.
+ +	5.536 kg. to 5.685 kg. *dp.* mean=+ 60 gr.
+ + +	5.686 kg. to 5.835 kg. *dp.* mean=+210 gr.
+ + + +	5.836 kg. to 5.985 kg. *dp.* mean=+360 gr.

Normal weight..... 1.208 gr.



Normal weight..... 1.208 gr.

VARIATIONS IN MILLIGRAMS OF THE WEIGHT OF ONE LITER OF AIR. MEAN HYGROMETRIC DEGREE ½.

APPENDIX NO. 5.

TABLES.

SAFETY ZONE.

75-mm. gun.

This zone has to be kept between the centers of impact of the fire and the most advanced infantry troops during the attacks.

The depth of this zone is half the zone of dispersion (both range and fuse) increased for shell by the distance to which may be thrown the dangerous fragments from the base cone of dispersion (about 50 m.).

A.

TABLE I.—*Open terrain.*

Range.	Safety zone.			
	Shell.		Shrapnel.	
	Percussion.	Time.	Percussion.	Time.
1°, horizontal terrain:	*Meters.*	*Meters.*	*Meters.*	*Meters.*
2,000	138	292	41	93
2,500	153	300	50	92
3,000	165	307	50	95
3,800	178	308	68	101
4,000	192	324	75	109
4,800	208	338	81	118
2°, slope 5 per cent (terrain ascending in the direction of the enemy):				
2,000	101	208	36	54
2,500	118	231	42	61
3,000	133	248	43	70
3,500	150	264	50	79
4,000	165	283	66	88
4,500	183	304	72	100
3°, counter slope 5 per cent (terrain descending in the direction of the enemy):				
2,000	406	Impossible.	325	Impossible.
2,500	257	515	184	Impossible.
3,000	235	434	153	281
3,500	225	384	142	272
4,000	234	387	140	244
4,500	244	387	144	236

On a slope greater than 5 per cent cut down the above figures a little. For counter slopes greater than 5 per cent, the terrain is in a dead angle up to about 3,000 m.; for longer ranges the safety zone is very large.

The 75 gun is of no further use for accompaniment on these counter slopes.

B.

TERRAIN UNIFORMLY COVERED BY WOODS.

To avoid premature bursts in the trees, it is necessary to increase the safety zone with percussion fire. With time fire, it is not worth while to increase it, because the mean points of burst are above the trees of average height.

The following table gives the value of the increase for trees 10 meters high:

TABLE II.

Range.	Increase in meters.		
	Horizontal terrain.	Slope 5 per cent.	Counter slope 5 per cent.
2,000	140	80	Impossible.
2,500	100	70	200
3,000	70	60	120
3,500	55	50	75
4,000	45	40	60
4,500	35	30	45

Safety zone to be maintained between the mean point of impact of the 75-mm. shells and our first lines.

[Tables for shells.]

A.

TABLE III.—*Open terrain.*

Range.	Safety zone in meters.		
	Horizontal terrain.	Slope 5 per cent.	Counter slope 5 per cent.
2,000	88	51	366
2,500	103	68	207
3,000	115	83	185
3,500	128	100	175
4,000	142	115	184
4,500	158	133	194

B.

TERRAIN UNIFORMLY COVERED WITH WOODS.

Range.	Increase in quadrant range for the height of the trees.		
	Trees of 5 meters.	10 meters.	15 meters.
2,000	130	200	280
2,500	110	160	220
3,000	90	130	170
3,500	80	110	140
4,000	80	100	130
4,500	70	90	110

TABLE IV.—*Ammunition consumption to provide for destruction of auxiliary defenses.*

Range.	Caliber.	The terrain near the target.	Ammunition.		Consumption to provide for a 30 m. wide barbed-wire entanglement.
			Projectile.	Fuse.	
From 0 to 1,000 m.[a]	58 No. 2 or Van Deusen (V. D.).	Terrain of any kind (nature and slope).	Bombs	I. T	200 [b] small [c] bombs, or 120 [b] large [d] bombs.
2,500 to 4,000 m	75	Sloping bank or slight counter slope.			600 rounds at 2,500 m.[e]
		Earth terrain	Shell	IA, I, Nondelay.	700 rounds at 3,000 m.[e]
		Clayish watered terrain	Shell	Delay.	800 rounds at 4,000 m.[e]
5,000 to 7,000 m	75	Slope or horizontal terrain. Dry terrain	Shell	I. A	1,000 rounds at 5,000 m.[e] 1,200 rounds at 7,000 m.[e]
2,000 to 4,000 m	155 how.[f]	Terrain of great counter slope.	Shell or D. shell	I. A	150 shell A, 300 shell D: At 2,000 m. 200 shell A, 300 shell D: At 3,000 m. 240 shell A, 360 shell D: At 4,000 m.
5,000 to 7,000 m	155 gun or 155 how., Schneider.[f]	Counter slope terrain	Shell or D. shell	I. A	250 shell A, 350 shell D: At 5,000 m. 300 shell A, 400 shell D: At 6,000 m. 350 shell A, 400 shell D: At 7,000 m.

a V. D. and 58 No. 2 firing the large bomb have only 600 m. range.
b To make a breach 40 m. wide.
c Bombs of 16, 18, 19.5 kilos.
d Bombs of 35 or 40 kilos.
e To make a breach of 25 m. If the barbed-wire entanglement is more than 30 m. wide, it is necessary to provide 400 rounds for each increase of 30 m. If the terrain is on a counter slope, multiply those numbers by the coefficient *a* of the table of probable errors in range.
f For making a breach of 25 m.
NOTE.—If the entanglement is made of "cheveux de frise," always use the fuse A. R. (=delayed action).

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TABLE V.—*Ammunition consumption to provide for the destruction of emplacements.*

Range.	Protection of the dugout.	Caliber.	Ammunition.		Consumption to provide for a dugout.
			Projectile.	Fuse.	
Fire through an embrasure: 0 to 3,000 m	Of any kind	75	Shell	I or IA	100 rounds.
Crushing fire: 0 to 1,000 m	Average [a]	58 No. 2 or V. D.	Small bomb [d] / Large bomb [e]	Delay	100 rounds. / 80 rounds.
	Strong [c]	240 trench or 340 trench	Bomb	do	80 rounds.
2,000 to 4,000 m	Average strong	155 how., 220, or 270	Steel shell or cast-iron steel	do	80 rounds.
Over 4,000 m	Average	155 gun	As above	do	150 rounds.

[a] Roof made of alternated layers of logs and earth.
[b] Concrete, or concrete and rail roof.
[c] V. D. and 58 No. 2, with large bomb, have only 600 m. range.
[d] Bombs at 16, 18, or 19.5 kilos.
[e] Bombs of 35 or 40 kilos.

TABLE VI.—*Consumption to provide for destruction of trenches.*

Range.	Caliber.	Ammunition.		Consumption to provide.
		Shell.	Fuse.	
0 to 1,000 m [a]	58 No. 2, or V. D, or 240 T [b].	Bomb fliche	Delay	80 to 100 rounds for each important point.[1]
		Bomb	(c)	
3,000 to 7,000 m	75	Shell	...do	10 rounds per meter.
2,000 to 4,000 m	155 howitzer[2]	Long shell	...do	80 to 100 rounds per important point; that is, 3 to 4 rounds per meter (front fire), 1.5 rounds per meter (enfilading fire).
		Cast-iron steel shell	...do	Increase these numbers by one-fourth with cast-iron steel shells.
2,000 to 5,000 m	220 [c]	Long shell	...do	70 rounds per important point.
		Cast-iron steel shell	...do	200 rounds per important point.
5,000 to 7,000 m	155 gun, or 155 howitzer, Schneider.	Long shell	...do	5 to 6 rounds per meter, according to the range (front fire).

[a] V. D. and 58 No. 2 with large bomb have only 600 m. range.
[b] To reinforce the action of the 58 on the important points.
[c] In all cases, proportion of fuses is 4/5 A. R., about 1/5 S. R.; the last are fired at the end of the bombardment to diminish the number of four gasses.
[d] Fire if possible with enfilade fire.
[e] To reinforce the action of 155 how. on the important points.
[1] A trench, or connecting trench, using enfilading fire, will be completely destroyed on a 100 m. length with 300 small bombs (58 or V. D., 150 large bombs.
[2] *Safety Zone.*—Forbid to the Infantry, during fire of the 155 howitzer, a zone of 200 m.; also shelter the troops from the fragments, which may be thrown several hundred meters to the rear.

APPENDIX No. 6.

Organization of a Sector for an Attack.

1. *Installations of artillery.*—Batteries, observation stations, communications between the batteries and the observation stations, ammunition shelters, communications (narrow-gauge line) for supplying ammunition shelters.

2. *Installations and advancing of infantry.*—(*a*) Trench or jumping-off trench, 200 to 500 meters from the first enemy trenches (steps to get over the parapet, gangways).

(*b*) Alarm post for the reenforcements and the reserves (steps to get over the parapet).

(*c*) Communication trenches for facilitating movements, strict orders for circulations, refuges for isolated soldiers, garage, bulletin board.

3. *Easy advance march of the reserve troops and the artillery.*—Ways and paths reconnoitered beforehand.

4. *Liaison between the units.*—(*a*) By the judicious choice of the command posts, established, if possible, near the observation stations and in easy communication with the main trenches, in order to facilitate the service of agents of liaison.

(*b*) By the organization of visual signaling, radio electric signals, by aeroplanes, and carrier pigeons.

5. *Supplies.*—Supply depots: Water, ammunition, tools, and different matériel depots, etc.

6. *Evacuation.*—Dressing stations.

7. *Sinks.*—Chiefly established in the zone of the jumping-off trenches and in the vicinity of the alarm posts.

8. *Plan of organization of the ground.*—Consisting of the plan of works, the plan of execution of the work, with the urgency order; the calculations of necessary tools and materials.

Principal Parts of the Sector of a Regiment.

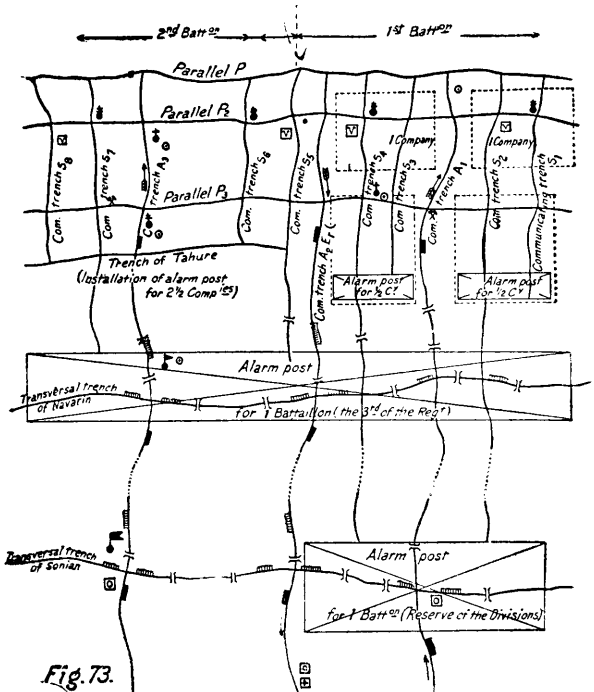


Fig. 73.

ABBREVIATIONS.

- Enlargement of trench to permit passage.
- Steps to get over the parapet.
- Passage over.
- Command post of the division.
- of the brigade.
- of the regiment.
- of the battalion.
- Observation station.
- Ammunition depot.
- Tools and materials depot.
- Supply depot.
- Water depot.
- Dressing station.

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