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FM 6-40

DEPARTMENT OF THE ARMY FIELD MANUAL

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FIELD ARTILLERY GUNNERY

DEPARTMENT OF THE ARMY • JANUARY 1950

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FM 6-40

This manual supersedes FM 6-40, 1 June 1945, including C 1, 20 December 1945, and C 2, 20 February 1947

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BY ORDER OF THE SECRETARY OF THE ARMY:

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For explanation of distribution formula, see SR 310-90-1.

CONTENTS

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PART ONE
GENERAL

CHAPTER 1
INTRODUCTION

1. GENERAL. a. Purpose. This manual presents and explains to artillerymen the principles of field artillery gunnery. It prescribes methods, which are based on practical experience, for the application of these principles. Since prescribed methods cannot cover all situations, this manual should be used as a guide in evolving a suitable application of the principles involved.

b. Scope. This manual covers the technique of conduct of artillery fire on ground targets and the tactical maneuvering of such fires. It includes—

(1) Fundamentals of artillery fire.
(2) Conduct of observed fires.
(3) Use of map data and corrections.
(4) Fire direction.
(5) Survey for artillery.

2. REFERENCES. See appendix I.

3. GUNNERY. Gunnery is the practical handling of artillery fire. It consists generally of two phases: preparation of firing data and conduct of fire.

4. MISSION AND CHARACTERISTICS OF ARTILLERY FIRE. a. The field artillery has two principal missions in combat.

(1) It supports infantry (armored) units by fire, neutralizing or destroying those targets which are most dangerous to the supported arms.
(2) It gives depth to combat by counterbattery fire, fire on hostile reserves, restricting movement in rear areas, and by disrupting hostile command agencies (FM 100–5).

b. The primary characteristic of field artillery is its great fire power. It does not close with the enemy, but maneuvers the fire of its long-range weapons from widely dispersed positions, and shifts this fire rapidly from target to target.

c. To be effective, artillery fire of *suitable density* must hit the target at the *right time* and with the *appropriate projectile* and *fuze*.

d. Good observation permits the delivery of the most effective fire. Limited observation results in a greater expenditure of ammunition and reduces the effectiveness of fire. Lack of observation must *not* prevent the delivery of fire. Search for targets and their probable locations must be aggressive and continuous. All intelligence agencies must be exploited to the utmost. Artillery is of no value to the supported arms when appropriate targets are not available.

5. ACCURACY. Field artillery doctrine demands delivery of fire by the most accurate means which time and the tactical situation permit. Inaccurate fire wastes ammunition and weakens the confidence of the supported troops in the artillery.

CHAPTER 2

ELEMENTARY BALLISTICS

6. GENERAL. The point of impact of a projectile for a given range is determined from the firing tables when all conditions of weather, ammunition, and weapon are standard. However, the projectile is acted upon inside and outside the tube by nonstandard conditions, with resultant dispersion and a different point of impact from that predicted in the firing tables. An understanding of these factors is essential for the artilleryman; a reduction of their effects will increase accuracy.

7. INTERIOR BALLISTICS. Interior ballistics is a study of the motion and the factors affecting the motion of projectiles while they are within the tube. Certain factors are—

a. Wear of the tube. The wear of the tube, especially the forcing cone, is the normal result of firing; it is more rapid when higher charges are fired than when lower charges are fired. Undue wear of the tube is prevented by selection of the proper charge for the range desired and by cleanliness of the tube and ammunition to reduce corrosion and abrasion. A worn forcing cone will permit an increase in the volume of the powder chamber by allowing the projectile to be rammed farther forward. It also will permit uneven seating of the projectile, which may allow gases to escape; and may allow improper centering of the projectile, with resulting variations in muzzle velocity and instability in flight.

b. Ramming. Separate-loading ammunition requires hard, uniform ramming to obtain uniform seating of the projectile and hence more uniform muzzle velocity.

c. Rotating band. The rotating band must be smooth and free from burrs and scars to permit uniform seating of the projectile and to prevent the escape of gases.

d. Propelling charge. The powder should be maintained at uniform temperature and moisture content. Differences in temperature and moisture content within powder lots and between powder lots will cause variations in rates of burning with resultant variations in muzzle velocity. Charges must be placed in the powder chamber uniformly as variations in the position of the charge changes the speed of burning with a resultant variation in muzzle velocity.

e. Coppering. Firing with maximum charge will cause coppering in the tube sufficient to decrease the muzzle velocity. This coppering can be removed, for all practical purposes, by firing several rounds with minimum charge. After firing the low-charge rounds, the muzzle velocity of most calibers will return approximately to normal for all charges.

f. Weight of projectile. Variations in weights of projectiles will cause variations in muzzle velocity.

g. Manufacturers' tolerances. Slight variations from standard in the manufacture of the tube will cause minor variations in the muzzle velocity.

8. EXTERIOR BALLISTICS. Exterior ballistics is the study of the motion and the factors affecting the motion of projectiles after they have left the tube of the piece. The most important factors which affect the projectile after leaving the tube are—

a. Drift. To keep an elongated projectile from tumbling during flight, it is given a rotating motion around its axis by the rifling of the tube. The action of air resistance, rotation, and gravity causes the projectile to deviate from the plane of fire. This deviation is termed *drift*.

b. Weight of projectile. For the same muzzle velocity, a heavier projectile tends to travel farther than a lighter projectile of the same size and shape.

c. Air density. An increase in air density causes greater resistance and decreased range.

d. Air temperature. A variation in air temperature causes a variation in range.

e. Wind. Wind blows the projectile from the normal trajectory. A head wind decreases the range; a wind from the right blows the projectile to the left; the effect of an oblique wind is divided into components parallel and perpendicular to the direction of fire.

f. Muzzle velocity. A variation in muzzle velocity causes a variation in range. An increase in muzzle velocity will cause an increase in range.

g. Angle of site. When tilted to reach a target above or below the horizontal, the trajectory is altered (see par. 12).

h. Rotation of earth. The rotation of the earth affects the location of the point of impact of the projectile in range and direction. The magnitude of these effects depends upon the latitude of the gun position, the direction of fire, and the range to the target.

i. Shell surface finish. A rough surface on the projectile or fuze will increase air resistance, thereby decreasing range and causing an error in direction.

9. CORRECTIONS. The data in firing tables are based upon standard conditions for firing. Since such conditions rarely exist, corrections for nonstandard conditions must be made. The firing tables provide the factors to be used in determining corrections for the following known conditions: drift, powder temperature, weight of projectile, air density, air temperature, differences in muzzle velocity, horizontal wind, nonrigidity of the trajectory, and effects of rotation of the earth. Corrections for unknown conditions, such as manufacturers' tolerances and wear of the tube, must be determined by calibration. In spite of the application of these corrections and extreme care in the service of the piece, there are many factors for which corrections cannot be determined since they cannot be measured accurately; these factors cause dispersion (see pars. 13–21).

10. TRAJECTORY. The trajectory is the curve traced by the center of gravity of the projectile in its flight from the muzzle of the gun to the point of impact.

a. Elements of the trajectory (fig. 1).

(1) *Angle of departure.* The vertical angle, at the origin, between the line of site and the line of departure.

(2) *Angle of elevation.* The vertical angle, at the origin, between the line of site and the line of elevation. Its value, corresponding to any horizontal gun-target distance, is given in firing tables.

(3) *Angle of fall.* The vertical angle, at the level point, between the line of fall and the base of the trajectory.

(4) *Angle of impact.* The acute angle, at the point of impact, between the line of impact and the plane tangent to the surface at the point of impact.

(5) *Angle of site.* The vertical angle, at the origin, between the base of the trajectory and the line of site.

(6) *Base of the trajectory.* A straight line joining the origin and the level point.

(7) *Jump.* The angular displacement of the projectile from the line of elevation at the instant of departure from the origin. This is the angle whose vertical and horizontal components are described as vertical jump and lateral jump.

(8) *Level point.* The point on the descending branch of the trajectory which is at the same altitude as the origin; the point where the trajectory cuts the base.

(9) *Line of departure.* A line tangent to the trajectory at the instant of the projectile's departure from the origin. It is displaced vertically from the line of elevation by the amount of the vertical jump.

(10) *Line of elevation.* The axis of the bore prolonged.

(11) *Line of fall.* A line tangent to the trajectory at the level point.

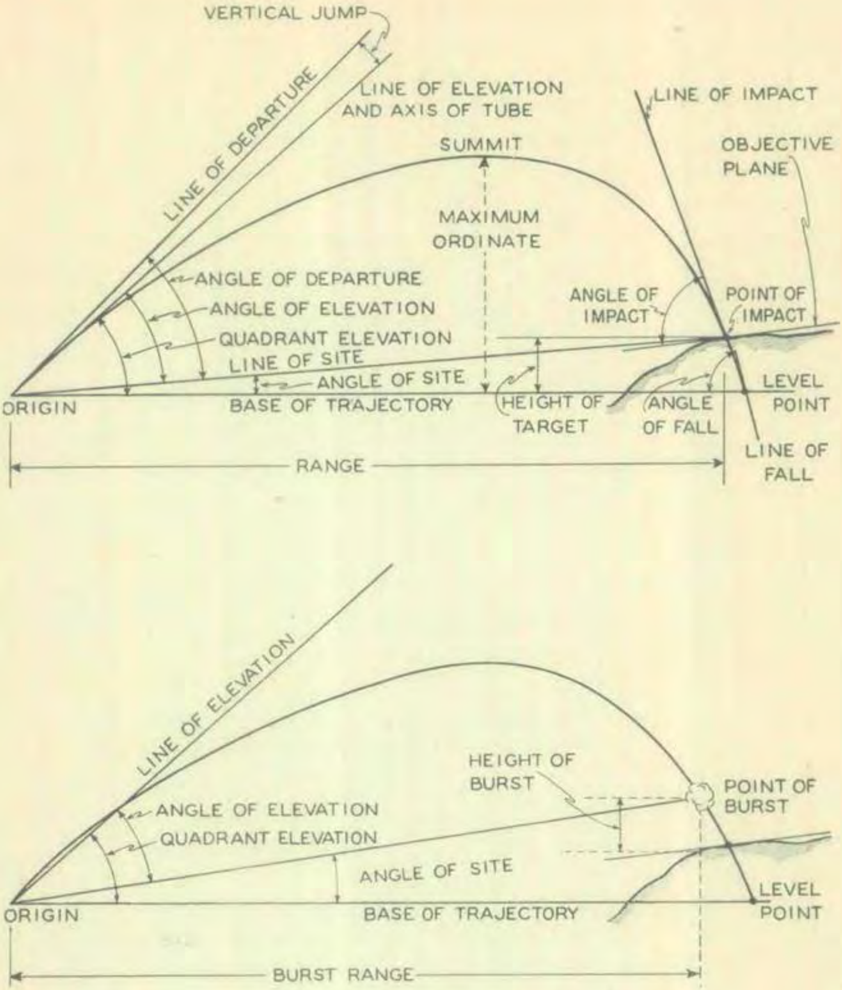

Figure 1. The trajectory.

(12) *Line of impact.* A line tangent to the trajectory at the point of impact.

(13) *Line of site.* A straight line joining the origin and a point, usually the target.

(14) *Maximum ordinate.* The difference in altitude between the summit and the origin.

(15) *Origin.* The center of the muzzle of the piece at the instant of firing.

(16) *Plane of departure.* A vertical plane containing the line of departure.

(17) *Plane of fire.* A vertical plane containing the line of elevation.

(18) *Quadrant elevation.* The vertical angle, at the origin, between the horizontal and the line of elevation.

(19) *Slope of fall.* The tangent of the angle of fall. It is expressed as 1 on 10 (or 1 on so much).

(20) *Summit.* The point at which the projectile achieves its greatest altitude; the dividing point between the ascending and descending branches of the trajectory.

b. Terms used in connection with the trajectory (fig. 1).

(1) *Complementary angle of site.* The correction to compensate for the error made in assuming rigidity of the trajectory. (See par. 12.)

(2) *Height of burst.* The vertical distance between the burst and the surface of the ground.

(3) *Height of target.* The vertical distance between the target and the base of the trajectory.

(4) *Site.* The sum of the angle of site and the complementary angle of site.

11. FORM OF THE TRAJECTORY. a. In a vacuum, the form of the trajectory would be determined entirely by the elevation, the muzzle velocity, and gravity. The form would be a parabola; the angle of fall would equal the angle of elevation; the summit would be at a point halfway between the origin and the level point.

b. Air resistance retards the projectile frcm the instant it leaves the piece. This makes the trajectory a more complex curve than it would be in a vacuum; the angle of fall is greater than the angle of elevation; the summit is closer to the level point than to the origin; and the range

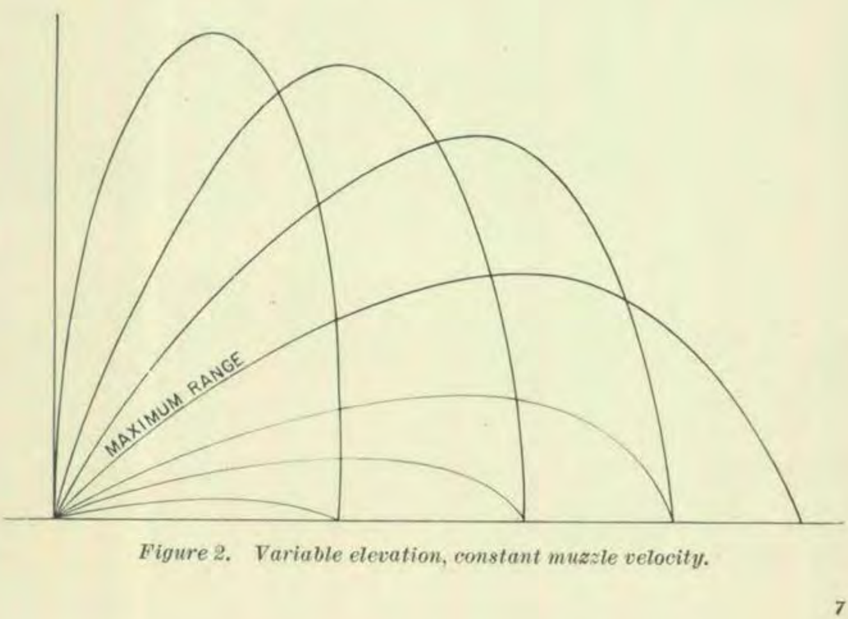

Figure 2. Variable elevation, constant muzzle velocity.

Figure 3. Variable muzzle velocity, constant quadrant elevation.

is reduced greatly (figs. 2 and 3). Air resistance is approximately proportional to the square of the velocity, and varies with the shape of the projectile. Retardation (the effect of air resistance on a projectile) depends upon the ratio of air resistance to mass of projectile. In general, retardation is less for large projectiles than for smaller ones of the same shape, because air resistance varies as the square of the caliber while mass varies as the cube.

12. RIGIDITY OF THE TRAJECTORY. The theory of the rigidity of the trajectory is the assumption that the trajectory may be tilted up or down through small vertical angles about the origin without materially affecting the shape of the trajectory. This assumption is utilized to obtain the quadrant elevation for a target above or below the piece by adding algebraically the angle of site of the target to the elevation corresponding to the measured range. When large elevations are used with large angles of site, errors will be introduced by utilizing this assumption; therefore, in carefully prepared fire, a correction for each target (the complementary angle of site) must be determined.

CHAPTER 3

DISPERSION

13. GENERAL. **a.** When several rounds are fired from a piece under conditions as nearly identical as possible, the points of impact of the projectiles will be scattered both in range and direction. This scattering is called *dispersion*. The area over which the points of impact are scattered is called the *dispersion zone*. The densest concentration of points of impact is near the center of the group with approximately as many points of impact short of the center as there are beyond, and as many to the right as to the left.

b. Dispersion is the result of variations from round to round of many elements. Among the factors which cause dispersion are errors inherent in the piece and minor variations in propelling charges, weights of projectile, and the surface finish of shells. Dispersion must not be confused with variations in points of impact caused by *mistakes* or *constant errors*. Mistakes can be eliminated by care and proper training; most of the constant errors can be compensated for by appropriate corrections (par. 9).

c. In general, the dispersion pattern of points of impact of rounds fired with the same piece settings are included in a rectangle with its longer axis along the gun-target line. The center of the pattern is called the *center of impact*. The center of impact of a small number of rounds normally will differ slightly from the center of impact of a large number of rounds fired at the same settings, since a small number of rounds cannot be expected to give a representative sample of the dispersion.

14. DISPERSION RECTANGLES. **a.** If a rectangle is constructed around a large number of points of impact excluding any erratic rounds, it is called the *100-percent rectangle* (fig. 4). If this rectangle is divided into eight equal parts by lines drawn perpendicular to the line of fire, the percentage of points of impact to be expected in each part is as indicated in figure 5. This is called a *range dispersion rectangle*. Likewise, if this rectangle is divided similarly by lines parallel to the direction of fire, the percentages will be as indicated in figure 6. This is called a *direction dispersion rectangle*. Each division of these dispersion rectangles is called *one probable error* which is defined as the error which is exceeded as frequently as it is not exceeded.

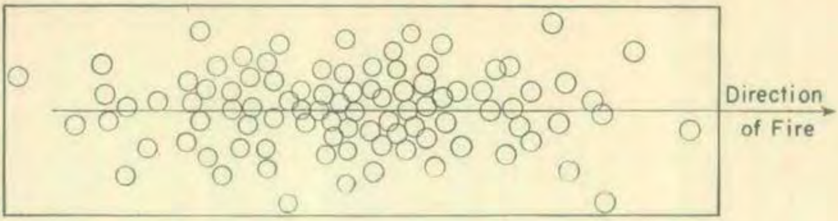

Figure 4. The 100-percent rectangle.

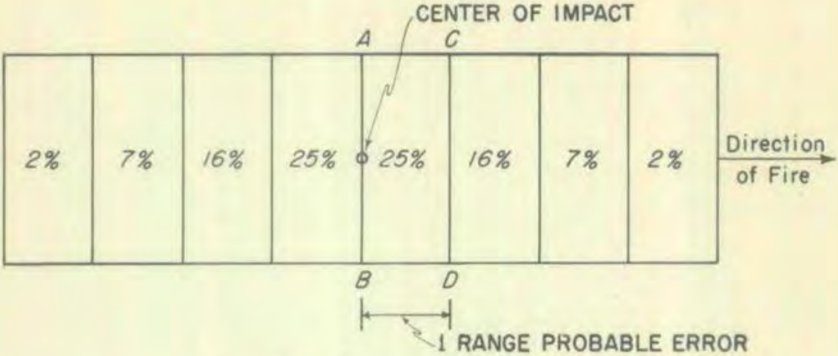

Figure 5. Range dispersion rectangle.

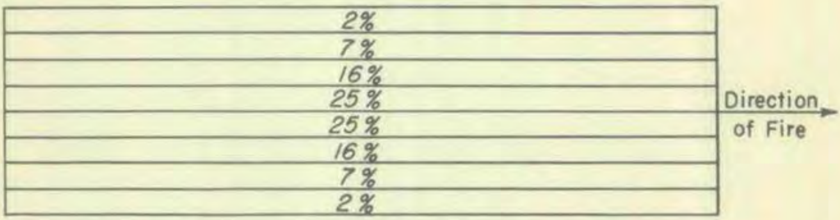

Figure 6. Direction dispersion rectangle.

b. If the range and direction dispersion rectangles are superimposed, the result is the assemblage of small rectangles shown in figure 7. This result is called the *dispersion rectangle.* The percentage of points of impact in any particular small rectangle is the product of the percentages in the two strips, range and direction, whose intersection forms the small rectangle. The application of the dispersion rectangle is covered in paragraph 21.

15. RANGE PROBABLE ERROR. a. In figure 5, the line AB through the center of impact is perpendicular to the line of fire. The area between AB and CD contains as many points of impact as there are beyond CD; that is, 25 percent of the points of impact are in the area AB–CD and 25 percent are beyond CD. The depth of the area (AC) is called one *range probable error.* The range probable error for

	.02	.07	.16	.25	.25	.16	.07	.02
.02	.0004	.0014	.0032	.0050	.0050	.0032	.0014	.0004
.07	.0014	.0049	.0112	.0175	.0175	.0112	.0049	.0014
.16	.0032	.0112	.0256	.0400	.0400	.0256	.0112	.0032
.25	.0050	.0175	.0400	.0625	.0625	.0400	.0175	.0050
.25	.0050	.0175	.0400	.0625	.0625	.0400	.0175	.0050
.16	.0032	.0112	.0256	.0400	.0400	.0256	.0112	.0032
.07	.0014	0049	.0112	.0175	.0175	.0112	.0049	.0014
.02	.0004	.0014	.0032	.0050	.0050	.0032	.0014	.0004

DIRECTION OF FIRE →

Figure 7. Dispersion rectangle.

a given charge for a howitzer or gun is different at different ranges. The approximate value of the range probable error is given in the firing tables and this value can be taken as an index of the accuracy of the piece. Firing table values for range probable errors are representative of carefully selected ammunition; the actual probable errors of an ammunition lot can be twice the firing table values.

b. It will be noted from a study of figure 5 that 50 percent of the shots will fall within one range probable error of the center of impact, approximately 82 percent within two probable errors, and 96 percent within three probable errors. For practical purposes, it is assumed that all of the shots will fall within four probable errors of the center of impact. Actually, a small percentage of the shots (about 7 in 1,000) will fall farther than four probable errors from the center of impact. About 1 in 1,000 will fall more than five probable errors from the center of impact. This probable distribution of shots (including the fifth probable error) is given more precisely in the probability tables contained in the firing tables.

16. FORK. The fork is the change in elevation necessary to move the center of impact four range probable errors. It sometimes is used as a unit of range (elevation) change in conduct of fire. The value of the fork is given in the firing tables.

17. DIRECTION PROBABLE ERROR. In the direction dispersion rectangle (fig. 6) the points of impact to the right and left of the long axis of the rectangle follow principles of distribution similar to those given in paragraph 15. For practical purposes, the direction probable error is taken as one-eighth the width of the dispersion rectangle. This value is given in the firing tables.

18. VERTICAL PROBABLE ERROR. If fire is directed against a vertical plane, the dispersion in this plane follows the same laws as dispersion in a horizontal plane. For practical purposes, the vertical

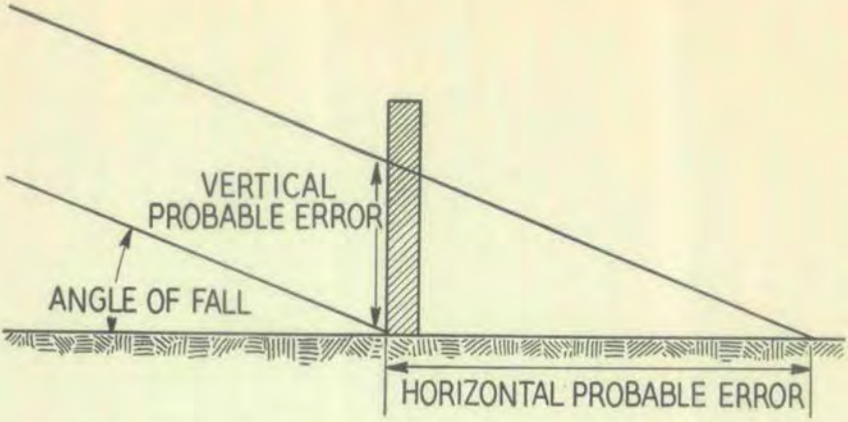

Figure 8. Relation of vertical probable error to horizontal probable error.

probable error is taken as one-eighth the height of the pattern. The vertical probable error is the product of the range probable error and the slope of fall (tangent of the angle of fall) (fig. 8). Values for the range probable error and slope of fall are given in the firing tables.

19. HEIGHT-OF-BURST PROBABLE ERROR. With shell fuzed to burst in the air, additional dispersion is introduced because of variation in the time of functioning of the fuze. This dispersion may be divided into its vertical and horizontal components and, in both planes, the points of burst follow the same laws of distribution that were discussed under range dispersion. The range component of this dispersion acts to increase slightly the range probable error determined from impact firing. For practical purposes, the height-of-burst (vertical) probable error is taken as one-eighth the height of the pattern. Values of the height-of-burst probable error are given in the firing tables.

20. DISPERSION ON A SLOPE. The dispersion pattern on a horizontal plane may be projected to a forward or reverse slope by considering that slope and the angle of fall.

21. APPLICATION OF DISPERSION. a. Location of target with respect to the center of impact.

(1) Consider the pattern of six shots fired under identical conditions (fig. 9). Four of these (66⅔ percent) have been sensed short of a target and two of them over, the exact location of the target within the pattern being unknown. For a very large number of shots, 50 percent can be expected to fall short of the line *AB*, and 75 percent short of the line *CD*; therefore (if linear interpolation is assumed to be sufficiently correct), 66⅔ percent can be expected to fall short of the line *MN*, which is two-thirds of the way from *AB* to *CD*.

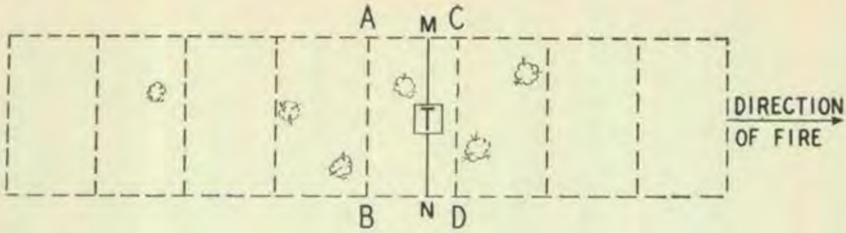

Figure 9. Determination of location of target by range dispersion rectangle.

The line *MN* then represents the most probable location of the target. Thus, the target is approximately two-thirds of one range probable error (one-sixth fork) beyond (over) the center of impact.

(2) The rule of computation of the elevation change in precision fire is based on the foregoing principle. The object of precision fire is to place the center of impact on the target. An estimate of the distance in yards from the center of impact to the target may be made by the use of the following formula:

$$\text{Distance}=\left(\frac{2\times\text{difference in number of over and short rounds}}{\text{Number of rounds fired}}\right)\times\text{Range probable error}$$

To estimate the elevation change necessary to move the center of impact to the target, this relationship is expressed as follows:

$$\text{Elevation change}=\left(\frac{\text{Difference in number of overs and shorts}}{2\times\text{number of rounds fired}}\right)\times\text{Fork}$$

Continuing the example in (1) above, and substituting known values in this equation—

$$\text{Elevation change}=\left(\frac{4-2}{2\times 6}\right)\times F=\tfrac{1}{6}\,F$$

Thus, since the preponderance of the rounds fell short, the elevation must be increased one-sixth fork to place the center of impact approximately on the target. The smaller the number of rounds fired, the less precise this estimate will be. Six rounds generally provide information of sufficient accuracy. Firing 12 rounds affords a slight increase in accuracy and permits verification of sensings. Four rounds are the minimum that should be used.

b. Dispersion as seen by an observer. Range dispersion will effect the deviations of bursts from the observer-target line as seen by the observer, especially when he is considerably off the actual gun-target line. The observer may not be aware of this but, when the condition is apparent at the fire-direction center, it should be considered in the next commands to the pieces.

c. Probability of hitting an area. The distribution of shots throughout the dispersion rectangle was obtained by applying the dispersion scale along both dimensions (par. 14). The probability of hitting a certain area within the rectangle is the product of the probability of a hit for range and the probability of a hit for direction (fig. 7); also, the probable expenditure of ammunition necessary to obtain a given number of hits in this area (assuming that the settings on the piece remain unchanged) can be computed.

d. Application of dispersion scale in determining ammunition expenditures.

(1) The dispersion scale can be of use in determining the probability of hits on a target of fixed dimensions, with respect to which the position of the center of impact can be determined. This information is useful in estimating ammunition expenditures for destruction missions. The table below gives the probable expenditure per target hit on a selected target for three weapons of different calibers. For each caliber, the location of the center of impact was assumed, in one case, to be at the target center, and in the other case to be two range probable errors (e_{pr}) over or short of the center of the target.

Target: bridge—10 yards wide, 40 yards long (long axis parallel to direction of fire).

Range: 18,000 yards.

Charge: maximum charge.

Weapon	Range probable error e_{pr}	Deflection probable error e_{pd}	Location of CI	Probability of obtaining a hit with one round (%)			Probable number of rounds required for one hit
				Range	Df	Rn and Df	
155-mm gun M1	43	9	Target center	23.3	27.8	6.5	16
	43	9	2 e_{pr} (86 yds.) over or short of target center.	10.7	27.8	3.0	34
8-inch howitzer M1 Sh HE M106.	19	6	Target center	51.6	41.5	21.4	5
	19	6	2 e_{pr} (38 yds.) over or short of target center.	24.4	41.5	10.1	10
240-mm howitzer M1.	36	8	Target center	27.8	31.3	8.7	12
	36	8	2 e_{pr} (72 yds.) over or short of target center.	12.9	31.3	4.0	25

(2) The data above for the 8-inch howitzer, center of impact located at the target center, are computed as follows:

(*a*) First determine the probability of a hit for range only. The target is 40 yards or 40/19=2.1 probable errors in length. Two probable errors of the length cover the 25-percent zones of the range dispersion scale, the remaining 0.1 probable error falls in the 16-percent zones.

% range hits=0.05 (16)+1 (25)+1 (25)+0.05 (16)=51.6%

(*b*) In like manner, determine the probability of a hit for deflection only. The target is 10 yards or 10/6=1.67 probable errors in width. The total width of the target falls in the 25-percent zones of the deflection dispersion scale.

% deflection hits=0.83 (25)+0.83 (25)=41.5%

(*c*) The product of these two probabilities is the probability of a hit for both range and deflection.

% hits=.516×.415=21.4%

(*d*) The probable number of rounds per target hit is equal to the reciprocal of the probability of a hit.

Rounds required for one hit=1/.214=4.7 or 5

(3) Computations of data for the 240-mm howitzer M1, center of impact two range probable errors (e_{pr}) over or short, are made as follows:

(*a*) As in the preceding example, first determine the probability of a hit for range only. The distance from the center of impact to the far end of the target is (2×36)+20=92 yards or 92/36 probable errors. One of the 2.56 probable errors covers the 25-percent zone, one the 16-percent zone, and the remaining 0.56 probable error falls in the 7-percent range dispersion zone.

% range hits between center of impact and far limits of target=1 (25)+1 (16)+0.56 (7)=44.9%

However, a distance of 52 yards (that is, 72 minus 20) or 52/36=1.44 probable errors of the above does not include the target, and probable hits in this space must be excluded.

% range hits between center of impact and near limit of target=1 (25)+0.44 (16)=32.0%

% range hits on target=44.9−32.0=12.9%

(*b*) The target is 10 yards or 10/8=1.25 probable errors wide. The total width of the target falls in the 25-percent zones of the deflection dispersion scale.

% deflection hits=1.25 (25)=31.3%

(*c*) The product of these range and deflection probabilities is the probability of a hit for both range and deflection.

% hits=.129×.313=4.0%

(*d*) Rounds required for 1 hit=1/.040=25.

CHAPTER 4

ARTILLERY AMMUNITION

22. GENERAL. a. Complete round. A complete round of artillery ammunition comprises all of the components necessary to fire a weapon once and to cause the projectile to function at the desired time and place. These components are the projectile, the fuze, the propelling charge, and the primer. Dependent upon both the type of propelling charge and the method of loading into the weapon, complete rounds are known as fixed, semifixed, or separate-loading (fig. 10). (See TM 9–1901 for details on artillery ammunition.)

b. Projectile. Types of projectiles include high-explosive (HE), armor-piercing (AP), high-explosive antitank (HE-AT), chemical (smoke or gas), and illuminating.

c. Fuze. A fuze is a device assembled to the nose or base of a projectile to cause it to function at the time and under the circumstances desired. Types of fuzes include combination superquick and delay, combination time (powder train) and superquick, VT, mechanical time (clockwork), concrete-piercing (CP), and quick.

d. Propelling charge. The propelling charge consists of a charge of smokeless powder in a cartridge case, cloth bag, or both.

e. Primer. A primer is used to initiate the burning of a propelling charge. It consists essentially of a small quantity of sensitive explosive and a charge of black powder.

23. HIGH-EXPLOSIVE (HE) SHELL. a. General. The filler of HE shell consists of TNT. The action of the fuze and booster causes the bursting charge to detonate, driving fragments of metal forward (*nose spray*), transverse to the trajectory (*side spray*), and backward (*base spray*) (fig. 11). The side spray consists of a narrow zone of fragmentation. The nose spray and base spray each form a narrow cone. The initial velocity of fragments is approximately 3,000 feet per second. This initial velocity is combined with the terminal velocity of the projectile—the sum for nose spray, the difference for base spray, and the resultant for side spray. Due to the shape of the fragments, their high velocity is lost quickly in flight. Incomplete detonation (*low order burst*) breaks the shell into a few large fragments.

b. Appearance of bursts (fig. 12).

(1) *HE shell, fuze quick, impact.* The black smoke is discolored by dirt, and spreads both upward and laterally.

(2) *HE shell, fuze delay, ricochet.* A fuze delay, ricochet burst is characterized by a flash, sharp explosion, and ball of smoke

(usually black) above dust kicked up by fragments. The pattern of the side and base spray is very noticeable.

(3) *HE shell, fuze delay, mine action.* A fuze delay, mine action burst usually sends up a vertical column of dirt, often with

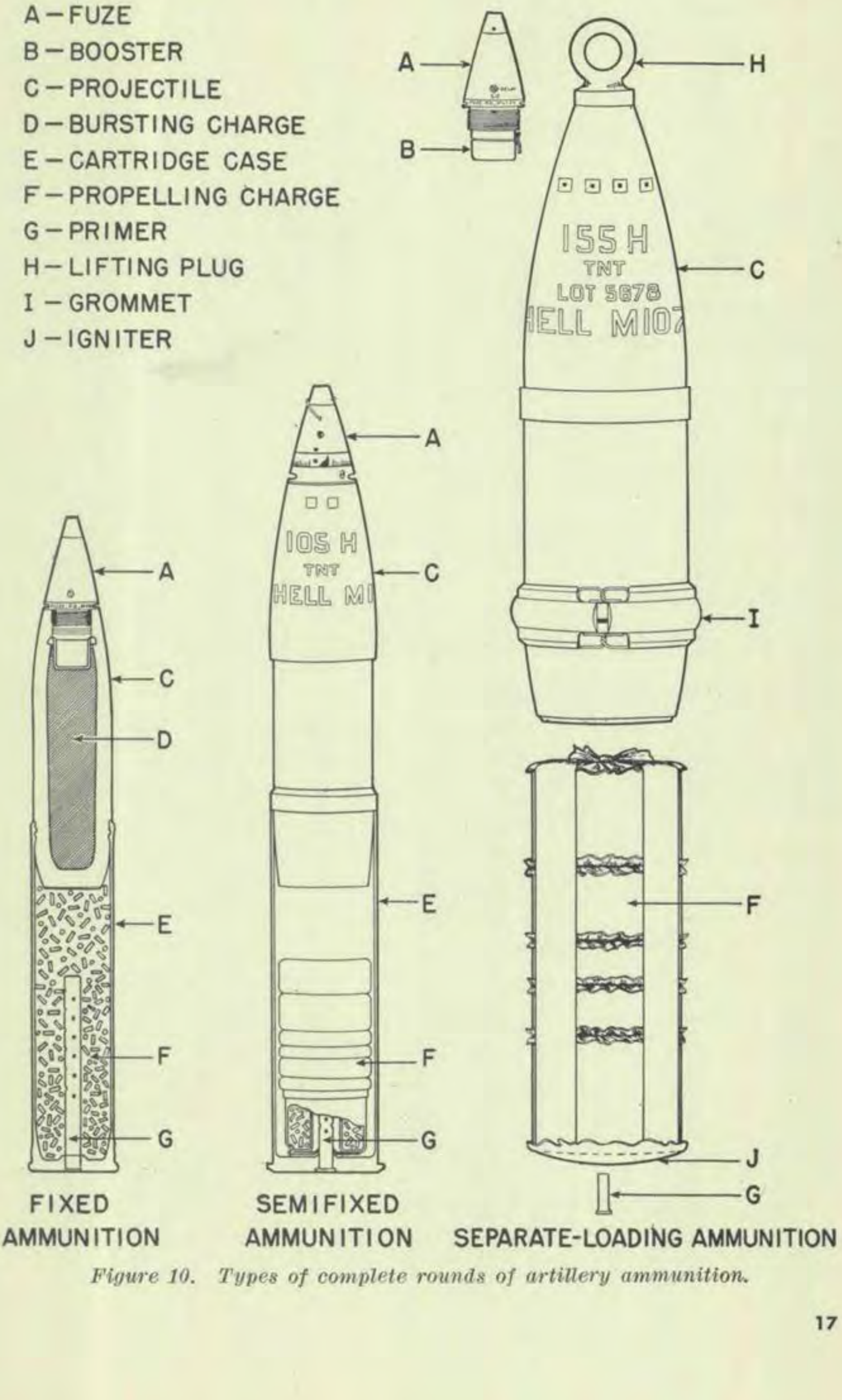

Figure 10. Types of complete rounds of artillery ammunition.

clods of earth, and with very little smoke. The explosion is muffled.

(4) *HE shell, fuze time, air burst.* The fuze time, air burst is characterized by a flash, sharp explosion, and a ball of black smoke which becomes elongated along the trajectory. The effect of fragments may be seen below the burst, if the burst is not too high. The effect of nose fragments usually can be seen in prolongation of the trajectory.

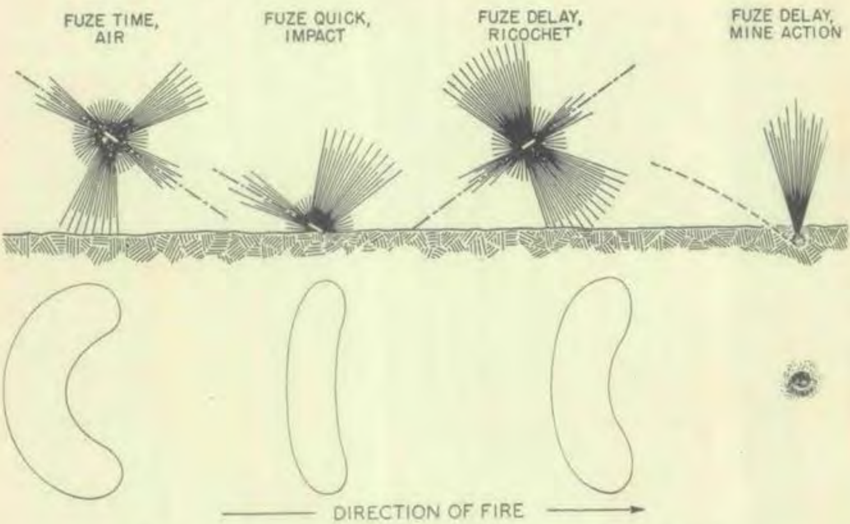

Figure 11. Fragmentation patterns of HE shell bursts.

24. EFFECT OF HE SHELL WITH VARIOUS FUZES. a. Quick fuze.

(1) With the quick fuze, projectiles burst either at the point of impact or when only a portion of the projectile has penetrated the ground. The impact must be on the nose of the present standard fuzes in order for the quick elements to operate. In these fuzes, if the quick element is not activated when impact is on the nose, the delay element will act. The fragmentation of the projectile is increased by increased angle of impact and by increased firmness of the ground. The effect is a function of the fragmentation and the density, size, and velocity of the fragments. When the projectile passes through foliage, the detonation may occur in the trees and effectiveness may be either improved or lost, depending upon the density of foliage. The HE shell with quick fuze is suitable for use in fire against—

(*a*) Personnel in the open when the angle of impact is large.

(*b*) Personnel when air bursts cannot be obtained.

(*c*) Matériel objects, such as trucks, when penetration is not required.

(2) The relative effectiveness of shells of the various calibers, with quick fuze, is indicated by the table following:

Caliber	Approximate size of area covered effectively by impact burst (yards)		Radius of large fragments (yards)
	Depth	Width	
75-mm howitzer	10	30	150
105-mm howitzer	15	50	300
155-mm howitzer	18	60	550
155-mm gun	18	60	550
8-inch howitzer	20	80	------------
8-inch gun	20	80	------------
240-mm howitzer (estimated)	25	100	------------

The area covered effectively is considered to be that area in which there is at least a 50-percent chance that a man standing will become a casualty. The area is roughly elliptical. It must be understood that the data are affected by several factors, of which the slope of fall and angle of impact generally are the most important. At best, these data are approximations.

b. Time and VT fuzes. There are two types of time fuzes—powder train and mechanical. Both are used to obtain air bursts with artillery projectiles. The powder train fuze is referred to commonly as "time fuze," and mechanical as "mechanical time fuze." VT fuze is a proximity fuze and is used to obtain air bursts.

(1) With time and mechanical time fuzes, the point of burst is determined by the quadrant elevation, charge, and time setting. Minor variations in point of burst are caused by variations in weather conditions and in the velocity of projectile. With the time fuze, quick action takes place when impact occurs before complete action of the time element.

(2) The VT fuze is activated upon approach to an object. It causes the projectile to burst at a predetermined height above the ground which varies with the angle of fall. The height of burst becomes lower as this angle increases. Firing over water, marshy ground, or wet terrain will increase the height of burst. Light tree foliage and vegetation do not materially affect the height of burst, but dense foliage and thick vegetation will increase the height of burst above the ground by approximately the height of the trees. This effect is decreased at a steep angle of fall, in which case most bursts will occur below tree-top level. Since the adjustment for height of burst is eliminated, the VT fuze is, in effect, an automatic

time fuze. Current models of the VT fuze will not arm prior to 5 seconds after firing. After arming, the fuze will function effectively at any angle of fall and will produce air bursts up to the maximum range of the weapon. The height-of-burst dispersion is considerably less than that of time fuzes. Current models of the VT fuze contain no impact element; thus, when the fuze fails to function properly, the

Figure 12. Appearance of bursts.

round results in a dud or, occasionally, in a low order burst. A small percentage of the fuzes will function prematurely and will result in random bursts along the trajectory between the minimum arming time and the normal point of burst. This percentage of random bursts may increase when firing through heavy rain. Employment of the fuze requires coordination with operation of aircraft. Necessary vertical clearance over friendly troops must be taken into consideration in choice of charges and selection of targets to be attacked with VT fuze (par. 216). The VT fuze is usable only with higher charges of each weapon because the lower charges do not provide sufficient set-back to activate the fuze. This limits the minimum ranges at which the fuze can be used with high-angle fire and makes it unsuitable for use in close-in defense of the battery position. The table below gives the proper charges to be used with the VT fuze and minimum usable ranges.

Weapon (tube)	Fuze	Shell	Proper charge	Minimum usable range (for complete arming) (*yards*)
75-mm howitzer M1A1	M97	M48	*1, 2, 3, or 4	2, 200
105-mm howitzer M2A1, M4	M97	M1	*3, 4, 5, 6, or 7	2, 700
155-mm howitzer M1	M96	M107	5, 6, or 7	4, 000
8-inch howitzer M2	M96	M106	6 or 7	6, 000
240-mm howitzer M1	M96	M114	3 or 4	9, 000

*Decreased operational efficiency will result from firing these charges.

The VT fuze does not replace time fuzes but supplements them at the longer ranges of the weapons and in high-angle fire. Present powder train fuzes are most effective to about 15 seconds time of burning. Beyond that point, the advantages of VT fuze increase while many disadvantages are reduced.

(3) The 75-second mechanical time (clockwork) fuze is used with HE shell to provide air bursts for high-burst registration of long-range weapons. Because of its large probable error, it is not satisfactory for attack of targets. The current model of the mechanical time fuze contains no impact elements; thus, when the fuze fails to function before impact occurs, the round will result in a dud or low order burst.

(4) Factors which govern the effectiveness of air bursts against entrenched targets are—

Number, size and velocity of fragments.

Height of burst above target.
Horizontal distance of burst from target.
Shape and size of trench.
Direction of fragments.

The direction of the fragments is governed by a combination of the angle of fall, terminal velocity of the projectile, and the initial velocity of the fragments due to detonation. The side spray fragments are driven in a zone roughly 15° to 20° in thickness, generally normal to the trajectory. (See fig. 13.) This direction is modified by the forward motion of the shell. The fragments which are driven upward are ineffective. The fragments which are driven laterally will be partially effective depending on final velocity, direction, and other factors. The fragments driven generally downward will be most effective.

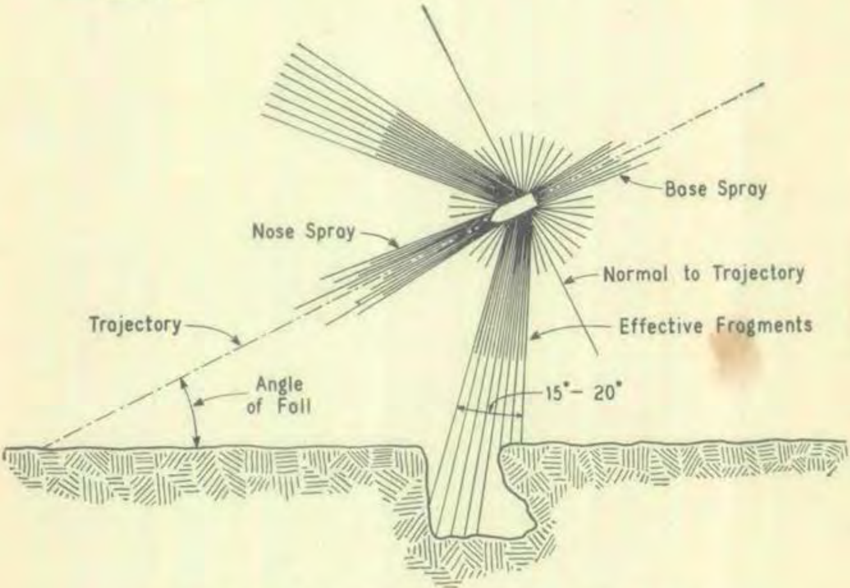

Figure 13. Effect of air burst with VT or time fuze.

(5) For each type of projectile there is a most effective height of burst. Because of dispersion, it is impossible to secure all bursts at that height. Some bursts will be lower and some will be higher than the mean height. For a given range, the probable error in height of burst is controlled by choice of charge when powder train fuzes are used, since time of flight has a marked influence on the height-of-burst probable error. The most effective mean height of burst with powder train fuzes is 20 yards. The height of burst of VT-fuzed projectiles may be controlled by varying the angle of fall.

c. Delay fuze.

(1) With delay fuze, the shell has time, before detonation, either to penetrate and produce mine action, or to ricochet. This fuze is used with HE shell for destruction missions which require penetration, and for ricochet fire.

(2) Factors which determine whether a shell will ricochet are—

Angle of impact.

Shape, weight, and terminal velocity of projectile.

Length of delay of fuze.

Condition of surface of ground.

Composition and compactness of soil.

When the angle of impact is small, the projectile tends to ricochet. When the angle of impact is moderately large, the projectile first penetrates and then tends to rise. When the angle of impact is large, the projectile continues downward until it stops or detonation occurs. If penetration is very great, the burst may produce a camouflet, that is, a hole underground, the surface of the ground remaining unbroken (fig. 14). If penetration is moderately great, a crater is produced. Whether a camouflet or a crater is produced depends upon depth of burst, character of soil, and force of detonation.

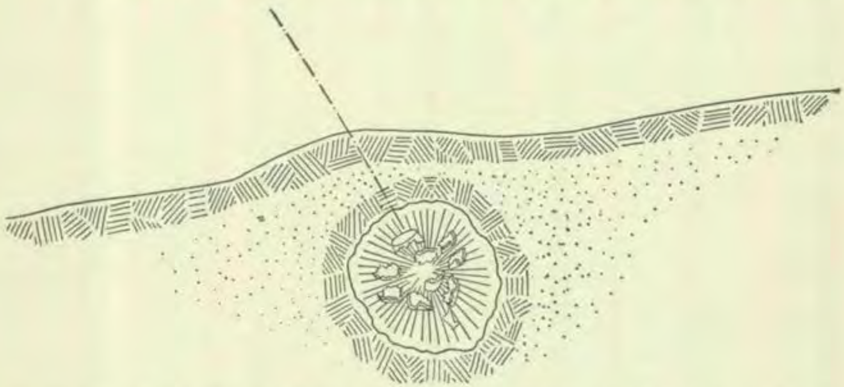

Figure 14. Effect of burst, deep penetration, steep slope of fall (cross section).

(3) The rotation of the projectile, resistance of the soil, and inequalities of resistance may cause a projectile to turn laterally from its path. The amount and direction of the deviation are unpredictable.

(4) When penetration occurs and the shell is in the earth at the instant of detonation, the fragmentation effect above ground is very small. Penetration into a bunker or dugout will produce casualties by blast effect, suffocating gases, and fragmentation. Penetration into a masonry structure which has been shattered by AP projectiles will tend to blow the shat-

tered portions apart. Penetration into earth over a dugout may result in suffocating gases entering the dugout through fissures created by the detonation. Penetration into a structure built of logs, sand bags, or similar materials results in the blowing apart of constituent units; the effectiveness depends upon the amount of high-explosive filler. The use of concrete-piercing fuze increases the depth of penetration and the angle at which penetration may be obtained against reinforced concrete or heavy masonry targets.

(5) When ricochet bursts are obtained, the effect is similar to that of air bursts obtained with time or VT fuzes. Many of the factors which determine whether a projectile will ricochet cannot be evaluated for the particular point of impact at the time of firing. Hence, ricochet fire *must be observed*, and another type of fire used if ricochets cannot be obtained from at least 50 percent of the rounds fired.

25. ATTACK OF TARGETS WITH HE SHELL. **a. Mine fields.** HE shell is ineffective for clearing mine fields, regardless of the type of fuze employed. Mines are not sufficiently sensitive to be detonated by shell bursts, except by direct hits. Artillery fire not only fails to eliminate the mine field but increases the difficulty of locating and removing mines by hand, and increases the difficulty of moving across the field.

b. Personnel. The comparative effectiveness of air bursts, ricochet bursts, and impact fire with HE shell against personnel is as follows:

(1) *Against personnel in the open.* The order of effectiveness is—

(*a*) Air bursts with VT fuze.

(*b*) Air bursts with powder train time fuze.

(*c*) Ricochet fire.

(*d*) High-angle fire with quick fuze.

(*e*) Low-angle fire with quick fuze.

This sequence may vary because of local conditions of soil, terrain, and vegetation. In ricochet fire, when fewer than 50 percent of the rounds ricochet, time fire should be used.

(2) *Against personnel in shallow trenches.* Air bursts are much more effective against personnel in shallow trenches than any other type of fire. Range dispersion of ricochet bursts is considerably greater than that of air bursts (because of irregularities in contour of ground and variations in ricochet distance) and, for entry into trenches, the angle of approach of the fragments from ricochets is much less favorable than is that from air bursts. The base spray, effective against personnel in the open, is too nearly parallel to the ground to enter fox holes. Impact fire has very little effect against personnel in trenches.

(3) *Against personnel in deep trenches.* Air bursts are outstandingly more effective than ricochet or impact fire. However, if the trenches have heavy cover, it may be necessary to utilize the penetration effect of delay fuze.

c. Fortifications and armored vehicles.

(1) *General.* High-explosive shell with concrete-piercing fuze and armor-piercing projectiles are effective against concrete. Armor-piercing projectiles and high-explosive antitank shell provide good effect against armor. Use of armor-piercing projectiles and high-explosive antitank shell against personnel or area targets is unprofitable because of its limited fragmentation.

(2) *Effect on wire.* The wire-cutting effectiveness of shell is poor. The employment of artillery fire to breach wire requires extravagant use of ammunition.

(3) *Effect on concrete.* Observed effects on reinforced concrete of excellent quality are shown in the following table.

Weapon; projectile (maximum charge)	Thickness[1] of concrete perforated by single round (face normal to line of impact) (*feet*)			Number of rounds, falling in circle of given diameter,[2] necessary to perforate various thicknesses[1] of concrete at given ranges			
	Range (*yards*)			Thickness (*feet*)	Range (*yards*)		
	1,000	3,000	4,000		1,000	3,000	5,000
105-mm howitzer M2A1 and M4; HE M1, fuze M78	2. 1	1. 6	1. 5	3	5	10	12
				5	14	27	33
				7	27	53	64
155-mm howitzer M1; HE M107, fuze M78	3. 9	3. 2	2. 7	3	1	1	2
				5	3	5	9
				7	7	11	18
155-mm gun M2; HE M101, fuze M78	6. 6	5. 6	4. 6	3	1	1	1
				5	1	1	2
				7	2	3	4
155-mm gun M2; AP M112	6. 5	5. 4	4. 5	3	1	1	1
				5	1	1	3
				7	2	3	5
8-inch howitzer M2; HE M106, fuze M78	5. 5	4. 7	4. 0	3	1	1	1
				5	1	2	4
				7	3	5	8
		12,500	15,000		10,000	12,000	15,000
8-inch gun M1; HE M103, fuze M78[3]		-----	5. 2	3	1	1	1
				5	1	2	3
				7	2	3	5
					8,000	10,000	12,500
240-mm howitzer M1; HE M114, fuze M78[3]		4. 9	4. 4	3	1	1	1
				5	1	2	3
				7	2	3	5

[1] Thicknesses perforated are based upon a line of impact normal to the surface. The effectiveness decreases rapidly when the line of impact is other than perpendicular to the surface. Ricochets will occur when the line of impact is 20° to 35° and more from the normal. The higher the striking velocity, the greater this angle may be before ricochet occurs. After the surface has been chipped, this angle may be still greater.

[2] Diameter of circles used as a basis for data:

105-mm howitzer	3 feet
155-mm howitzer and 155-mm gun	4 feet
8-inch howitzer and 8-inch gun	5 feet
240-mm howitzer	6 feet

[3] While data are not available for these weapons firing at shorter ranges, excellent performance has been observed against hard rock and heavily reinforced concrete at ranges of 2,000 to 4,000 yards.

(4) *Effect on armor* (homogeneous plate).

Weapon; projectile	Thickness of armor perforated by single round (line of impact normal to surface of armor) *(inches)*		
	Range *(yards)*		
	500	1,000	1,500
75-mm howitzer M1A1, M2; HE-AT, M66	4 to 4.5	4 to 4.5	4 to 4.5
105-mm howitzer M2A1, M4; HE-AT, M67	5 to 5.5	5 to 5.5	5 to 5.5
155-mm gun M2: AP, M112 (2745 f/s)	7.6	7.5	7.2

26. CHEMICAL SHELL. Chemical shell includes gas shell (irritant or toxic agents) and smoke shell (white phosphorus shell and base-ejection smoke shell).

a. Gas shell. The irritant or toxic agent contained in the shell is expelled when the action of the fuze and burster charge breaks open the shell. Liquid vesicants are most effective against personnel when sprayed directly on them and are very effective against personnel when sprayed on vegetation. Air bursts or quick fuze should be used. Many small projectiles are more effective than a few large ones for attack with liquid vesicants. With irritant gases, quick fuze action is preferable. Only medium and heavy artillery are capable of building up an effective concentration of these latter agents.

b. White phosphorus shell. White phosphorus produces smoke, incendiary effect, and casualty effect. In all three roles, quick fuze action is preferable. The action of the fuze and burster charge breaks the shell and scatters the phosphorus particles. The smoke rises because of the heat generated by the burning phosphorus. Below ground, the phosphorus smoulders. With a burst at medium height in the air, the small particles burn out before reaching the ground.

c. Base-ejection smoke shell. Base-ejection-type smoke shell with time fuze is more effective as a screening agent than is white phosphorus, since the former has less tendency to pillar. The action of the fuze and expelling charge ignites the smoke canisters and forces them out of the base of the shell with a relative velocity of about 200 feet per second. The empty shell case continues along the trajectory and the smoke canisters follow with reduced velocity. They fall somewhat short of the case, the distance depending upon height of burst. When the fuze functions on impact, the smoke-producing effect of the shell may be reduced considerably. The lowest practicable charge should be used with this type of shell in order that the terminal velocity of the canisters may be low and thus reduce the possibility that the canisters will penetrate the ground on impact.

27. ILLUMINATING SHELL. The projectile is a hollow, base-ejection-type shell containing a cylindrical flare attached to a cotton parachute. The action of the time fuze and the expelling charge ignite the flare and eject the flare and parachute. The flare attains full illumination about 10 seconds after being ejected and burns for about 60 seconds (155-mm).

28. CHOICE OF AMMUNITION. **a.** Choice of projectile and fuze depends upon the nature of the target and the effect sought.

b. Choice of charge is based upon consideration of the following:

(1) With projectile fuzed with powder train time fuzes, the highest practicable charge is used (except for base-ejection smoke shell) in order to reduce the height-of-burst probable error.

(2) With VT-fuzed projectiles, the necessary vertical clearances of mask and front line determine the maximum charge which may be used for low-angle fire on any particular target.

(3) To insure that the target can be reached, the maximum range of the charge selected for an adjustment should be at least four-thirds of the target range with data obtained by approximate methods, and nine-eighths of the target range with data obtained by precise methods.

(4) Better effect from fragmentation with quick fuze is obtained with a low charge which results in a greater angle of impact.

(5) When ricochets are sought, a high charge must be used in order to obtain the necessary small angle of impact.

(6) In precision fire for destruction, the charge is used which will give the greatest angle of impact without excessive dispersion.

(7) Against armor, the highest practicable charge is used to increase penetration, reduce time of flight, obtain a flat trajectory, and reduce time to prepare ammunition.

(8) In assault fire against concrete or masonry, the highest practicable charge is used to obtain maximum penetration.

(9) With base-ejection smoke shell, the lowest practicable charge is used to obtain low terminal velocity and thus minimize the possibility that the canisters will penetrate the ground on impact.

(10) Wear of the tube is reduced by use of the lowest charge consistent with the mission.

c. It sometimes is desirable to mix various types of ammunition within one mission, such as high-explosive and white phosphorous, and to mix the fuzes, such as fuze quick and delay.

d. Each item of ammunition is assigned a lot number and, in addition, each complete round of fixed or semifixed ammunition is assigned an *ammunition lot number.* In manufacture, as far as practicable, all complete rounds of any particular ammunition lot are made up of components selected from the same lot. Use of varying lots increases dispersion and the chance of erratic rounds. Since all artillery technique is based on uniform ballistics, it is essential that ammunition lots be segregated and that a single lot be used for single missions in order to obtain the most accuracy as well as the maximum safety for friendly troops during close fire.

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CHAPTER 5

FUNDAMENTALS OF ARTILLERY FIRE

Section I. GENERAL

29. GENERAL FEATURES. The procedures used in the delivery of artillery fire are based on the following principles:

a. In observed fire, the observer makes all his corrections with respect to the observer-target line. These corrections are converted by the fire-direction center to corrections with respect to the piece-target line.

b. In both observed and unobserved fire, the fire-direction center sends fire commands directly to the firing battery, including the deflection, site, and elevation (quadrant) settings which are to be set on the pieces.

30. BASIS OF FIRE COMMANDS. *Firing data* include all basic information needed for the determination of *fire commands* for the pieces. Elements of firing data consist of the direction, distribution, angle of site, and range. These elements may be determined from a map or chart, from information obtained visually by an observer, or—usually—a combination of both. Fire commands are prepared from these data; they furnish the firing battery with the orders necessary to prepare the ammunition and lay and fire the piece(s). Firing data are converted to fire commands at the battalion or battery fire-direction center.

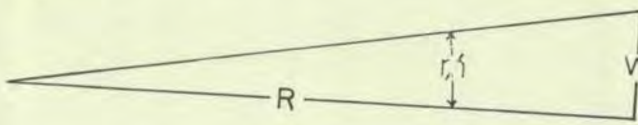
31. ANNOUNCEMENT OF NUMBERS. In order to prevent misunderstanding and to facilitate transmission, numbers are announced as illustrated in the following examples:

10	One zero.
25	Two five.
300	Three hundred.
1400	One four hundred.
6000	Six thousand.
3925	Three nine two five.
4050	Four zero five zero.
10,000	One zero thousand.
10,300	One zero three hundred.
11,000	One one thousand.

100.7 One zero zero point seven.
254.4 Two five four point four.

A discussion of pronunciation of numbers may be found in FM 24–20.

32. THE MIL. The unit of angular measure used in field artillery is the mil. It is 1/6400 part of the circumference of a circle. For practical purposes, a mil is the angle subtended by one yard at a distance of 1,000 yards. The *mil relation* (fig. 15) is expressed by $\cancel{m} = W/R$, where $\cancel{m}$ is the angular measurement in mils between two points, W is the lateral distance in yards between the points, and R is the mean distance to the points in thousands of yards. The mil relation is approximately true for angles less than 400 mils.



$$\cancel{m} = \frac{W}{R}$$

Figure 15. The mil relation.

Section II. FIRE COMMANDS

33. ORIGIN. Fire commands originate with the computer at the battalion or battery fire-direction center. Determination of firing data from maps and charts are discussed in paragraphs 116 through 123. For a complete discussion of fire commands and their execution by the firing battery, see FM 6–140.

34. INITIAL AND SUBSEQUENT COMMANDS. The initial fire commands include all data necessary for laying, loading, and firing the pieces. Subsequent commands include only such elements as are changed, except that the range or elevation always is announced and, when a change is made in pieces to fire or the method of fire, or both the commands for both elements are given. Decreasing or increasing the number of rounds in a method of fire does not constitute a change of method.

35. SEQUENCE OF FIRE COMMANDS. Fire commands are announced in the following sequence:

Example (165-mm howitzer):

a. Pieces to follow commands, special methods of adjustment, and particular missions. — *BATTERY ADJUST*,

b. Special corrections.	*SPECIAL CORRECTIONS, 100 YARDS AT 5000 YARDS,*
c. Projectile.	*SHELL HE,*
d. Charge.	*CHARGE 6,*
e. Fuze.	*FUZE TIME,*
f. Pieces to fire.	*BATTERY,*
g. Method of fire (and restrictions).	*ONE ROUND (AT MY COMMAND OR DO NOT LOAD),*
h. Direction.	*DEFLECTION 2651,*
i. Site.	*SITE 315,*
j. Time setting.	*TIME 17.1,*
k. Elevation.	*ELEVATION 258.*

Section III. ELEMENTS OF FIRING DATA

36. GENERAL. **a.** In target location and determination of initial data, the most accurate means available are employed in order to save ammunition, to save time in adjustment, and to increase effectiveness of fire. In order to obtain this initial accuracy, advantage should be taken of all previous firing in the area, as well as maps, oblique and vertical photographs, diagrams, and panoramic sketches of the area.

b. When a target is observed, the observer designates the location of the target by—

(1) Giving its coordinates from a map or photo.

(2) Designating the target with reference to a base point, check point, or other target.

(3) Giving an approximate azimuth, difference in altitude, and the observer-target distance. The observer transmits this information to the fire-direction center in his *initial fire request* (par. 52). The fire-direction center then prepares from a firing chart the initial data and fire commands for the pieces (pars. 179–214).

37. DIRECTION. In the initial occupation of a position, all pieces of the firing battery are laid parallel and referred to aiming posts at a common deflection. Thereafter, changes in direction of the gun-target line may be determined in two ways, as follows:

a. By measurement on a chart with reference to another line, such as the gun-base point line (base-point line), or grid north. This change in direction is based on an observer's initial fire request in an observed fire mission. In an unobserved fire mission, it ordinarily will be based on the plotted location of a target reported by coordinates. The measurement is sent to the firing battery as a common deflection for all pieces. Direction for the battery is established thereby.

b. By sighting on the target (direct laying), using the panoramic telescope of the piece.

38. DISTRIBUTION. a. Definitions.

(1) A *sheaf* consists of the planes of fire of two or more pieces.

(2) A *parallel sheaf* is one in which the planes of fire are parallel (fig. 16).

(3) A *regular sheaf* is one in which the bursts are approximately on a line and are equally spaced laterally (fig. 17).

(4) The *width of sheaf* is the lateral interval between the centers of flank bursts.

(5) An *open sheaf* is one covering the maximum effective front without shifting. This would appear to be the effective width of one burst multiplied by the number of pieces in the battery. However, because of dispersion and the ineffectiveness of some bursts, the width of sheaf is narrowed to provide adequate density. The following table is presented as a guide for the most desirable widths of open sheaves.

Caliber	Width (in yards) for an effective open sheaf		Front (in yards) covered effectively by open sheaf	
	4-piece battery	6-piece battery	4-piece battery	6-piece battery
75-mm	100	100	130	130
105-mm	100	150	150	200
155-mm	200	250	260	310
8-inch	300	----------	380	

(6) The *front* covered by any sheaf is the width of sheaf plus the effective width of a burst.

b. Parallel sheaf.

(1) The battery executive forms a parallel sheaf immediately upon occupation of position; he lays the battery parallel on the indicated base angle or compass, using an aiming circle or other instrument.

(2) In most cases, a parallel sheaf is sufficiently accurate and effective. This is particularly true with massed fires and fires well beyond friendly troops.

c. Regular sheaf. There will be occasions when the pieces of a battery are placed so irregularly, both laterally and in depth, that individual corrections for lateral distribution and variations in range are necessary to provide more effective fire on targets close to friendly troops, on accurately located targets, on point targets (fig. 18), and on barrages. The executive must be prepared to form a regular sheaf of the width and at the range which the observer or the fire-direction center may designate.

d. Piece corrections for a sheaf. When the sheaf is other than parallel (such as a converged sheaf), each piece carries its individual correction on the gunner's aid, and all pieces continue to apply the common deflection on the scales of the panoramic telescope.

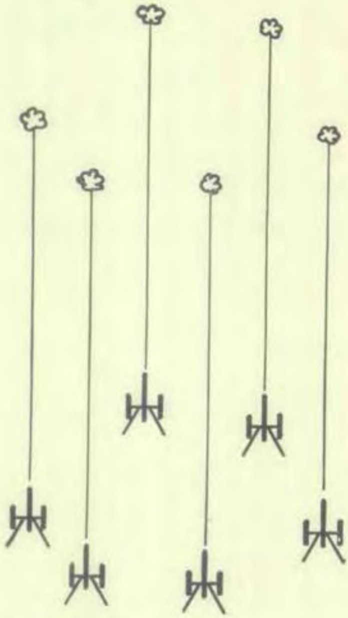


Figure 16. Parallel sheaf.

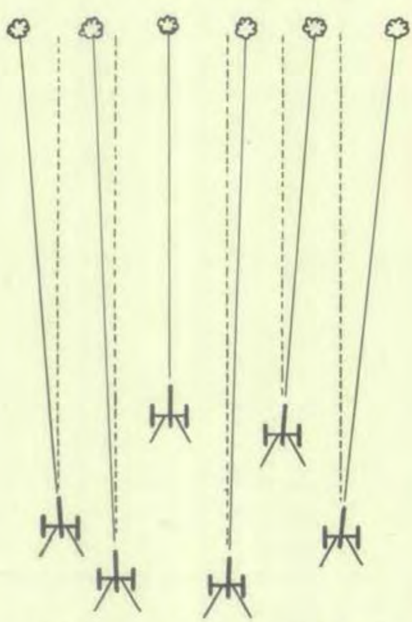


Figure 17. Individual corrections to form a regular sheaf.

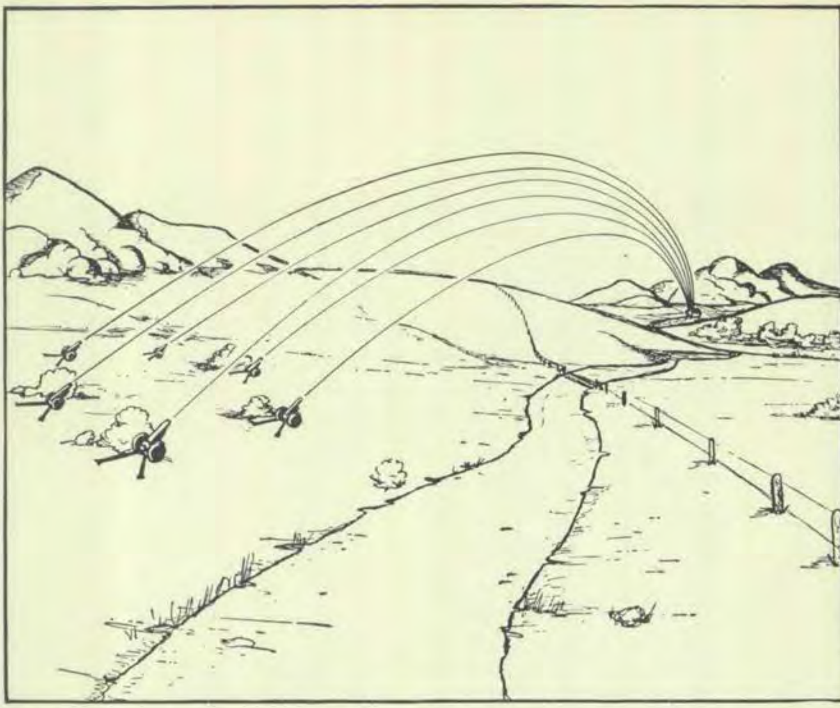


Figure 18. Result of range and distribution corrections on a point target.

39. HEIGHT OF TARGET. The height of the target with respect to the gun may be determined by comparison of—

a. Relative altitudes, using a contoured map, or using altitudes determined by survey.

b. Differences in altitude between the target and a point whose altitude with respect to the gun is known.

40. HEIGHT OF BURST. **a.** The height of burst of projectiles fuzed with powder train or mechanical time fuzes may be varied by changing the *fuze setting* or by changing the *site*. A change in the fuze setting moves the point of burst along the trajectory, which changes the range of the burst as well as the height of burst (fig. 19). A change in the site, on the other hand, raises or lowers the burst in a vertical plane (fig. 20).

Figure 19. Changing the height of burst by changing the time of burning (fuze setting).

b. Before employing time fire, the fuze setting is adjusted by a time registration to give a zero height of burst; that is, one which gives a mean height of burst at the surface of the ground. Thereafter, the fire-direction center accompanies each range change with a corresponding change in fuze setting.

41. DISTANCE (RANGE). Range may be determined by measurement on a map or chart, or by computation or estimation at the observation post.

42. CALIBRATION CORRECTIONS. In order to control the grouping of rounds within a volley or salvo, and to insure adequate density of fire, calibration corrections should be applied to all pieces. These corrections compensate for variations in the muzzle velocity of pieces within a battery or battalion, and are determined by comparison of the results obtained from firing individual pieces under similar conditions (app. V). They are applied when directed by the fire-direction center and when *special corrections* are ordered (par. 43).

Figure 20. Changing the height of burst by changing the angle of site.

43. SPECIAL CORRECTIONS. a. General. Special corrections are individual piece corrections applied in order to obtain more effective fire (fig. 18).

b. To secure desired pattern for specific targets. When it is desired to provide the most effective fire on targets close to friendly troops, point targets, unusually shaped targets, and barrages, special corrections are necessary. They are determined and applied for the current target only. These corrections compensate for dispersed battery positions and for the shape of the target, and include calibration corrections.

c. To secure proper density of fire. To secure proper density of fire on all targets, the battery executive should have individual range and/or deflection corrections applied on all missions when the depth of the battery position is greater than 100 yards and/or the battery front is greater than the width of an open sheaf. One set of corrections may be applied throughout transfer limits. Normally, prompt opening of fire should not be delayed to make these position corrections.

44. DETERMINATION AND APPLICATION OF SPECIAL CORRECTIONS.

a. General.

(1) When the desired sheaf is perpendicular to the line of fire, these corrections are determined by the executive. When the desired sheaf is other than perpendicular to the line of fire, these corrections are determined by the fire-direction center. Special corrections are applied to one or more of the following elements.

(*a*) Range.

(*b*) Deflection.

(*c*) Site.

(2) To obtain special corrections on a specific target, one of the following commands is given:

(*a*) *Special corrections.* This indicates that a regular open sheaf is desired.

(*b*) *Special corrections, converged sheaf.* This indicates that fire is desired on a point.

(*c*) *Special corrections* (so many yards). This indicates that a regular sheaf (so many) yards in width is desired.

(*d*) All commands given above indicate that the corrections are to be determined by the fire-direction center. When it is desired that the corrections be determined by the executive, the above commands are followed by the designation of the range at which the corrections are to apply; for example, *SPECIAL CORRECTIONS AT 6,000 YARDS* (range is given to nearest 500 up to 10,000 yards; beyond that, to the nearest 1,000 yards).

b. The position correction grid. The simplest method of computing corrections for echelonment laterally and in depth is with a position correction grid. This grid is a plastic device (fig. 21) upon which the pieces are plotted to scale. It then will give range and deflection corrections graphically for any direction of fire. The position correction grid is set up in the following manner:

(1) Remove the transparent rotating disk which is the upper component of the grid. (For the figures used herein, the M10 Plotting Board, modified so the disk can be removed, is used as a position correction grid. The modification consists of removing the rivet fastening the transparent disk to the grid, and replacing it with a screw-type fastener.)

(2) Place heavy vertical lines on the grid proper so that they would pass through the bursts of a regular open sheaf arranged on the center horizontal line of the grid (fig. 21).

(3) Replace the transparent disk.

(4) Plot the pieces to scale on the transparent rotating disk. The battery center is the center of the board.

(5) "Zero" the board. This is accomplished by rotating the transparent disk until the 0-3200 line coincides with the zero index of the grid, and with the red figures of the disk on the right. (The red figures are those shown in the middle row of graduations on the right, as shown in fig. 21.)

(6) With the board "zeroed," construct an index on the board opposite the *red* figure of the transparent disk which represents the deflection at which the battery has placed out its aiming posts.

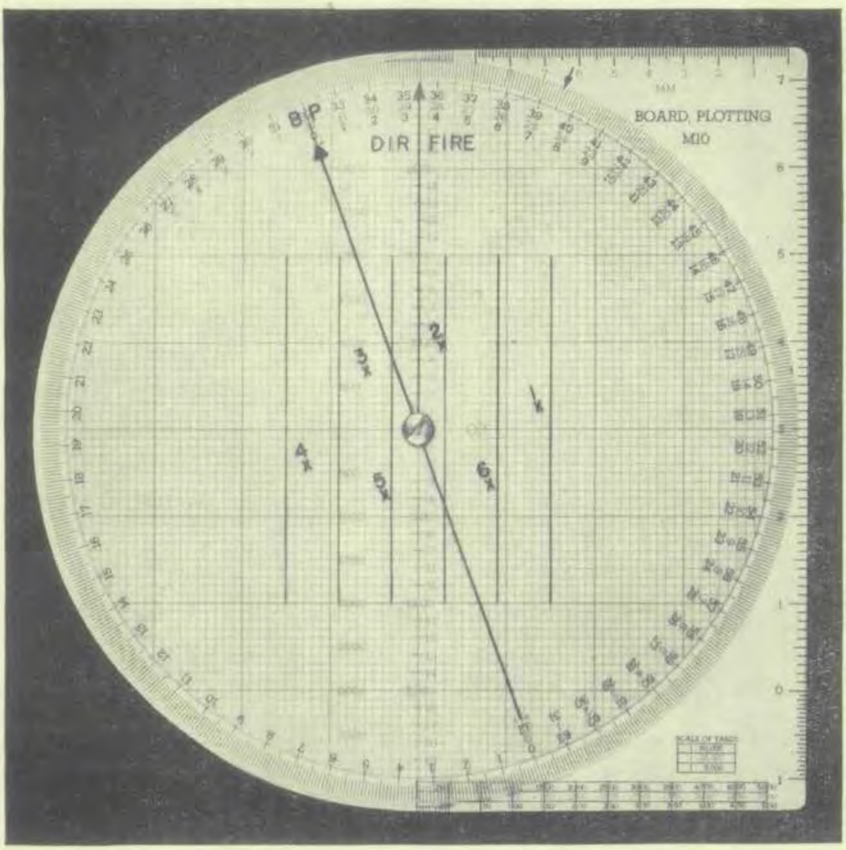


Figure 21. M10 Plotting Board used as a position correction grid.

c. Determining corrections with the positions correction grid. When the board is set up in this way, corrections for direction and range may be computed for each piece for any direction of fire in the following manner:

(1) Rotate the transparent disk until the *red* figure opposite the constructed index is the same as the deflection being used for that mission.

(2) Note the lateral displacement of each piece from its desired position in the sheaf as drawn on the grid and, using the mil relation, determine its correction for deflection.

(3) Note the displacement of each piece in range from the center horizontal line of the grid, and determine its elevation correction by dividing by the "Change in range for 1 mil change in elevation," as found in the firing tables. In time fire, individual corrections must be made in the fuze settings to correspond with the range corrections which have been applied to individual pieces.

PART TWO

OBSERVER PROCEDURE

CHAPTER 6

INTRODUCTION

45. GENERAL. **a.** This part contains the procedure, terminology, and technique to be used by an observer for the adjustment of fire.

b. The relative position of the observer-target (*OT*) line with respect to the piece-target (*GT*) line does not affect the observer procedure in the adjustment of observed fires. Errors are determined in yards, and corrections in yards are sent to the battery or battalion fire-direction center. The fire-direction center converts these corrections to appropriate fire commands for the pieces. This is accomplished by plotting the corrections on a target grid and measuring data for the resulting plot from the pieces in order to place the next burst(s) at the point designated by the observer.

46. PREARRANGEMENT. **a.** The artillery observer, ground or air, must keep himself and the organization which he represents completely informed of the tactical situation.

b. In order to perform his mission most effectively, the observer must be furnished with the best available maps, photomaps, or photos of the area in which he will adjust fire.

47. TYPES OF FIRE. **a. Precision fire.** The object in precision fire is to place the center of impact on the target. Precision fire is used for registration, attack of point targets, and destruction. It is used only against stationary objects. When more than one piece is used on a target, each is adjusted separately. Precision fire must be *accurate*, but also must be conducted *expeditiously*.

b. Area fire.

(1) The purpose of area fire is to lay down devastating fire on an area with such surprise and speed that the maximum destruction, demoralization, and casualties result. Area fire is used against personnel and matériel capable of movement or dispersed in an area. Adjustment of area fire must be accurate, particularly if fires are to be massed, using the data determined from the adjustment. The adjustment must be as rapid as is consistent with accuracy in order to insure fire for effect before the enemy can escape or take cover. The manner of attack, the type of ammunition employed, and the amount

of fire requested by the observer are determined by the nature and importance of the target.

(2) Normally, fire is opened with two-gun volleys but may be with battery volleys to insure early sensings, or with a single piece to save ammunition. Salvo fire may be ordered if adjustment will be facilitated by use of salvos rather than volleys. Adjustment is conducted with a parallel sheaf unless otherwise designated by the observer or fire-direction center.

(3) In area fire, the observer must select a well-defined point upon which to adjust. This adjusting point may be a distinctive terrain feature, or it may be some portion of the target, such as a truck or tank. The observer selects an adjusting point at or near the center of the area upon which he wishes to place fire (fig. 22). For surprise fire, he may select some nearby point (auxiliary target), adjust on it, and then shift the fire to the area which includes his target.

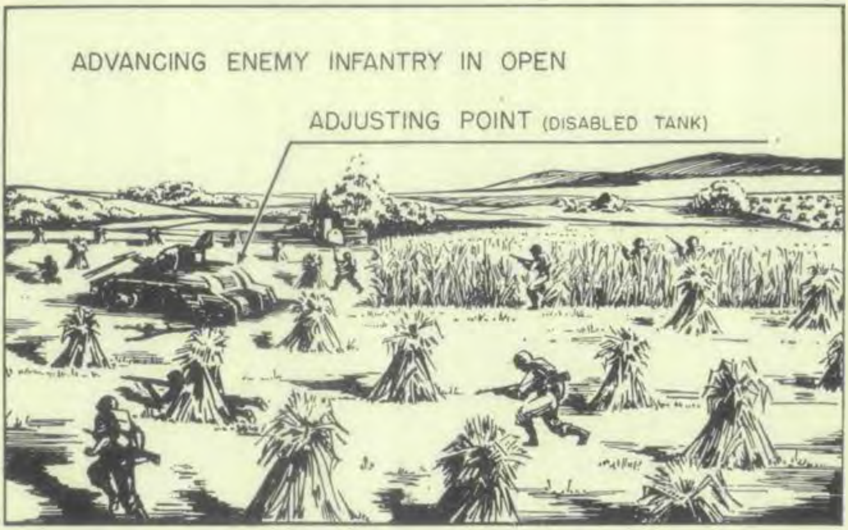


Figure 22. Adjusting point in area fire.

48. SENSING. a. General. *Sensing* is the determination by the observer of the location of a burst or group of bursts with respect to the target. The observer's sensing determines the next correction. When the burst appears, sensing must be made promptly except when it is necessary to take advantage of drifting smoke. Sensing must be based upon what the observer sees while it is before his eyes, not on what he remembers.

b. Time fire and ricochet fire. A burst in the air is sensed *air;* a burst on impact is sensed *graze*. In volley fire, if both air and graze bursts are obtained in the same volley, the sensing is *mixed* when equal numbers of airs and grazes are obtained, or *mixed air* (*mixed graze*) when a preponderance of airs (grazes) is obtained. Air bursts are sensed by observing the effect on the ground. The wide effect pattern facilitates sensings; however, the observer must make certain that he bases his sensings on the center of the effect pattern, and not on stray fragments at the edge of the pattern.

c. VT-fuzed shell. When the burst is very low, sensings may be made on the ball of smoke in the same manner as for an impact burst. When the burst is high, sensing must be made on the effect in the same manner as for time-fuzed shell. When the fuze fails to function, the round normally will result in a dud, and the observer often can see where the projectile strikes the ground by the dirt it kicks up on impact. In low-angle fire, a range sensing of *over*, based upon

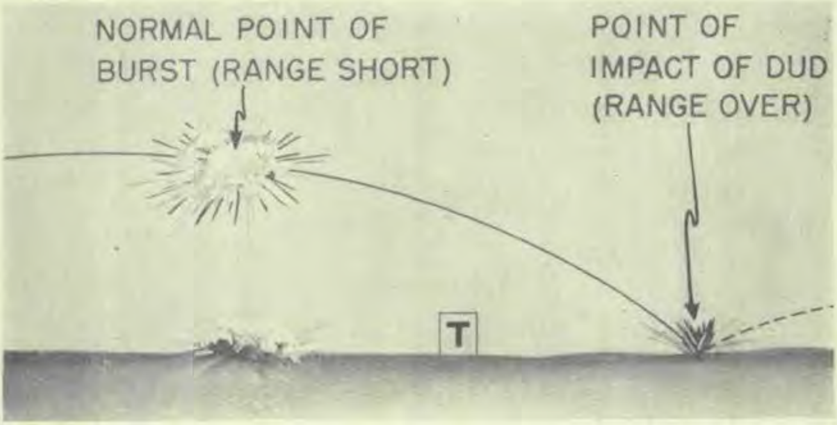


Figure 23. Possibility of erroneous sensing when a VT fuze fails to function properly.

the point of impact of a dud, must be accepted with caution, since the normal point of burst of such a round would be at a considerably shorter range (fig. 23).

d. Range sensings (fig. 24). A burst which is beyond the target from the observer is sensed *over* for range; one which is between the target and the observer is sensed *short* for range. A round which strikes the target is sensed *target;* one which is at the proper range, but is slightly off the target in direction, is sensed *range correct.* Range is sensed *doubtful* if no positive sensing is obtained. A burst on the *OT* line always gives a positive range sensing. Bursts off the *OT* line often may be sensed when the observer's position and the nature of the terrian are favorable. Such sensings are called "terrain sensings" and should be made with caution. When sensings are made on drifting smoke or on shadows, the direction of the wind and the position of the sun must be considered. In time area fire, a burst on impact between observer and target is sensed *doubtful* for range, since an error in site, rather than range, may have caused the round to strike short of the target (fig. 25); however, if the burst is so short that it is evident that range is in error, it is sensed *short* for range. In area fire, when rounds are both short and over or at the proper range in the same volley or salvo, the sensing is *range correct* for range.

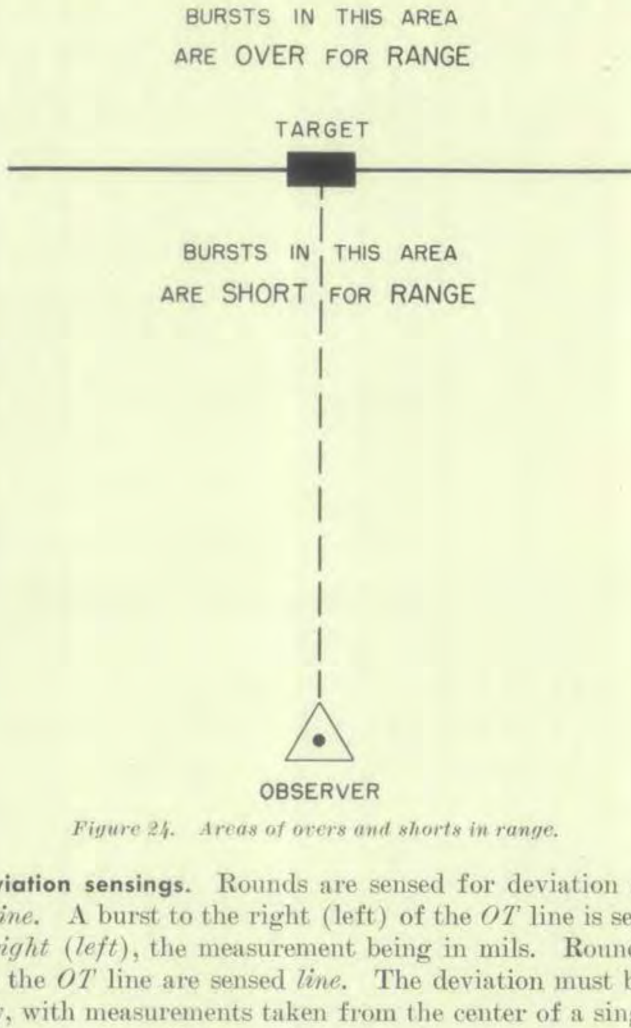


Figure 24. Areas of overs and shorts in range.

e. Deviation sensings. Rounds are sensed for deviation as *right*, *left*, or *line*. A burst to the right (left) of the *OT* line is sensed (*so much*) *right* (*left*), the measurement being in mils. Rounds which burst on the *OT* line are sensed *line*. The deviation must be sensed carefully, with measurements taken from the center of a single burst or, in the case of a volley or salvo, from the center of the group of bursts.

f. Lost. A round not seen by the observer is sensed *lost*. A sensing of *lost over* (*lost short*) may be made when the observer has accurate knowledge of the terrain.

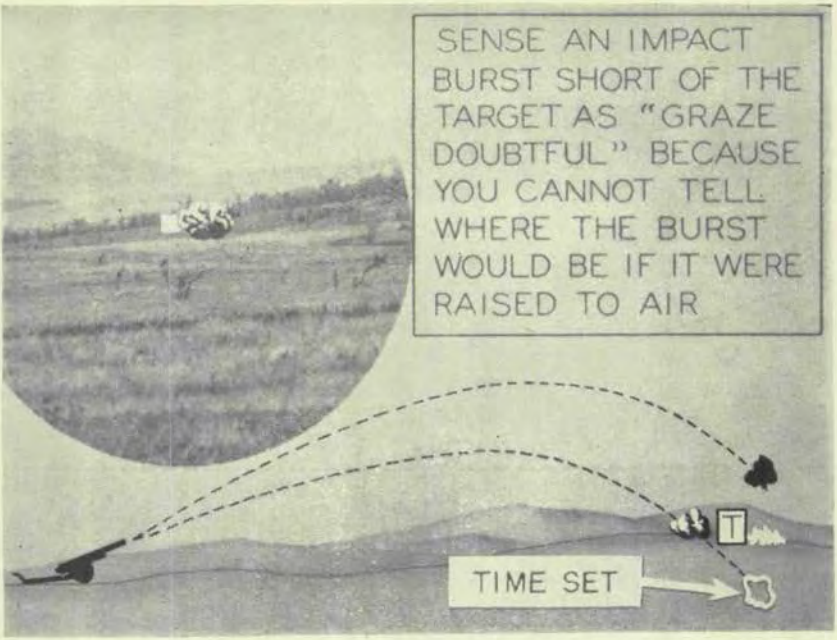


Figure 25. Error in site causing a round to strike short of the target in time area fire. With proper site, range would be over.

CHAPTER 7

TERMINOLOGY; DETERMINATION OF DATA

49. GENERAL. The use of standard phrases between observers and the fire-direction center facilitates mutual understanding and reduces the volume of communication. However, it is not intended to restrict the transmission of any additional information that would assist in bringing fire to bear on the target.

50. CORRECTIONS AND TERMS. The following are corrections and terms normally employed by the observer.

a. FIRE MISSION—Warning order to alert the fire-direction center and to indicate that the message to follow is a request for fire.

b. AZIMUTH—The azimuth from observer to target. This indicates *Y*-azimuth unless stated otherwise.

c. LEFT (RIGHT) (so many yards)—To correct the deviation as observed along the *OT* line.

d. UP (DOWN) (so many yards)—To correct for differences in altitude in the target area; to raise (lower) the height of burst in time area fire.

e. ADD (DROP) (so many yards)—To increase (decrease) the range, as observed along the *OT* line.

f. LOST—To indicate that the last round or volley was not observed.

g. CORRECTION—A term used in a fire message to indicate—

(1) That an error in data has been announced and that corrected data will follow.

(2) Any change in data to bring the center of impact or burst closer to the target.

h. CONVERGED SHEAF—To obtain the planes of fire converged on a point.

i. CONVERGE ON BASE PIECE (or other piece)—To obtain a sheaf converged on the desired piece.

j. SPECIAL CORRECTIONS—To obtain a regular open sheaf. This term indicates that individual corrections for lateral distribution, variations in range between pieces, and for calibration are necessary. SPECIAL CORRECTIONS (so many yards) may be given to obtain a regular sheaf at a designated width. SPECIAL CORRECTIONS (target description) may be given to obtain a sheaf not perpendicular to the line of fire or to fit a target of special shape.

k. REPEAT RANGE—To obtain fire at the same distance from the observer as the previous round or volley.

l. CLOSE—To indicate that the target is within 600 yards of friendly forward elements.

m. DEEP—To indicate that the target is more than 600 yards from friendly forward elements.

n. AIR (GRAZE)—To indicate that the burst is an air burst (graze burst).

o. SALVO RIGHT (LEFT)—To obtain battery (two-gun) salvos beginning with the right (left) piece, provided the observer knows the location of the battery with respect to the *OT* line; otherwise, he requests SALVO FIRE.

p. WHEN READY—To cancel AT MY COMMAND.

q. FIRE—Observer's command to fire after AT MY COMMAND.

r. FIRE FOR EFFECT—To indicate that the adjustment is satisfactory and that the unit is to fire for effect.

s. CEASE FIRING—To interrupt firing for any reason.

t. CHECK FIRE—To interrupt firing temporarily (normally a naval term).

u. COMMENCE FIRING—To begin firing as soon as ready (used with the Navy when it is desired to resume firing on the same target after CEASE FIRING or CHECK FIRE has been given).

v. CEASE FIRING, END OF MISSION—To terminate firing on a specific target.

51. DETERMINATION OF DISTANCE. a. Necessity. The observer must be able to determine quickly and accurately the distance between objects, targets, or bursts in order to determine basic data and to adjust artillery fire effectively. Distances can be determined either by estimation or by computation.

b. Estimation of distance. The estimation of distance is facilitated by having a *yardstick* on the ground. This yardstick can be established by firing two rounds from the same piece and 400 yards apart. Or the observer may establish a known distance in the target area by determining from his map or photo the distance between two points which he can identify positively both on the map and on the ground.

c. Computation of lateral distance.

(1) The observer can determine lateral distances by the use of an angle-measuring instrument such as field glasses. To determine the observed deviation (lateral distance) between two objects, the observer determines from a map or photo, or estimates, the mean distance to the objects. He then measures the angle between them and converts this measurement to yards by use of the mil relation. *Example:* An observer desires to determine the lateral distance in yards

between two objects. With his field glasses, he measures the angle between them as 110 mils. He determines from his map that the mean distance from his position is 2,000 yards. Using the mil relation $m\!\!/ = W/R$ (or $W = m\!\!/ \times R$), he computes the distance between the objects to be 220 yards (110×2).

(2) When instruments are not available, angles are measured by the hand, fingers, or a ruler held a known distance from the eye. The angle subtended by each is determined by the individual before he goes into the field (fig. 26).

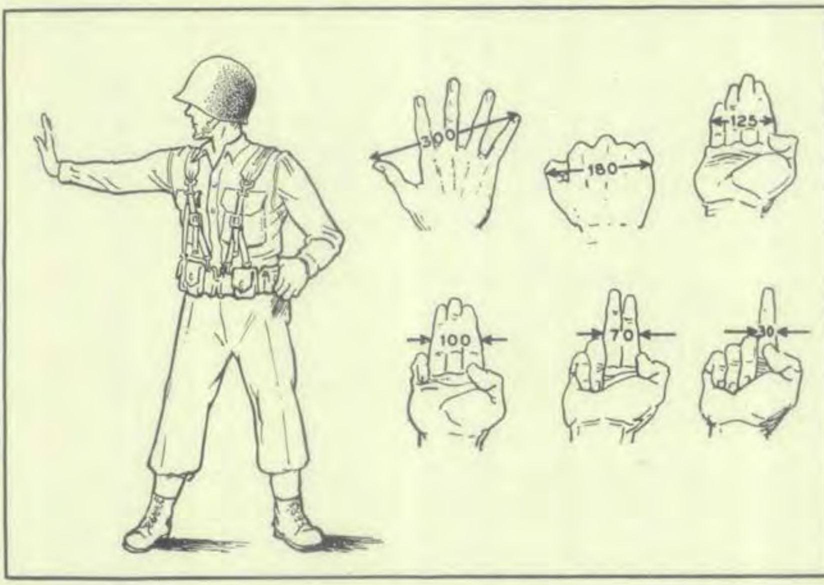


Figure 26. Examples of measuring angles with the hand.

(3) The approximate distance from the observer to a sound source (bursting shell, weapon firing, etc.) may be determined by timing sound. The speed of sound in still air at 59° F. is approximately 373 yards per second. Wind and variation in temperature alter this speed somewhat. For practical use by the observer, the speed of sound may be taken as 400 yards per second under all conditions. The sound may be timed by a watch, or by counting. For example, the observer counts "one one thousand, two one thousand," etc., to determine approximate time in seconds. The time in seconds is multiplied by 400 to obtain the required distance in yards. *Example:* The observer desires to determine the approximate distance from his position to a burst. He begins counting when the burst appears and stops counting

when he hears the sound. He counted four seconds; therefore, the burst is approximately 1,600 yards (400×4) from his position.

52. INITIAL FIRE REQUEST. The initial fire request sent by the observer to the fire-direction center includes those elements appropriate to the mission. The following are the elements which should be considered when requesting a fire mission and the sequence in which they should be transmitted.

a. Identification of observer.
b. Warning order.
c. Azimuth from observer to target.
d. Location of target.
e. Nature of target.
f. Classification of fire.
g. Type of adjustment.
h. Type of ammunition.
i. Fuze action.
j. Control.

53. IDENTIFICATION OF THE OBSERVER. When necessary, the observer identifies himself to the unit from which he is requesting fire, by appropriate call signs or code.

54. WARNING ORDER. The observer sends FIRE MISSION to alert the fire-direction center. It indicates that a request for fire follows.

55. AZIMUTH FROM OBSERVER TO TARGET. a. The observer determines the azimuth to the target from his position by use of a compass, other azimuth measuring instrument, or a map. To eliminate the necessity of taking a compass reading each time a target is to be engaged, the observer should obtain accurate azimuth readings to the base point and several other well-distributed points in the target area. Then, by measuring a deviation with his field glasses from one of these points, and applying it to the known azimuth to that point, he easily and quickly can determine the azimuth to his target. *Example:* The azimuth to the base point from the observer's position has been measured with a compass and found to be 4,130 mils. A target appears 200 mils to the right of the base point, as measured in the field glasses. The azimuth to the new target is 4,330 (4,130+200). In the initial fire request, the azimuth is announced to the nearest 10 mils; for example, AZIMUTH 4330.

b. When no azimuth measuring instrument is available, the observer must estimate the azimuth. If the announced azimuth is greatly in error, the orientation of the target grid will be corrected at the fire-direction center during the course of the adjustment.

56. LOCATION OF TARGET. The location of the target may be given in one of the following ways:

a. Coordinates. The observer may send the location of the target by grid coordinates referring to a map, photomap, or photograph; for example, COORDINATES (65.32–78.01), or COORDINATES ABLE YOKE 67 (fig. 27).

Figure 27. Designating the location of the target by grid coordinates. The observer sends the location of the road junction as COORDINATES ABLE YOKE 67.

b. Shift. The observer may shift from a reference point, which may be the base point, a check point, a numbered concentration, or any other point whose chart location is known at the fire-direction center. The shift is given as corrections in yards, usually to the nearest ten yards. If either the direction or altitude of target is the same as that of the reference point, that correction is omitted. In time fire, the fire-direction center adds the desired height of burst to the observer's correction for height of target. When several batteries are to fire for effect based upon the adjustment of one battery, it is particularly necessary for the observer to determine the correct height of the target in order to insure that the fires of the batteries will be massed accurately. The shift is determined as follows:

(1) *Direction* (fig. 28). The deviation in mils from the reference point to the target is measured and the distance to the reference point is estimated. The correction in yards from the reference point to the *OT* line then is determined by use of the mil relation and the observer-reference point range. The direction correction is included in the initial fire request;

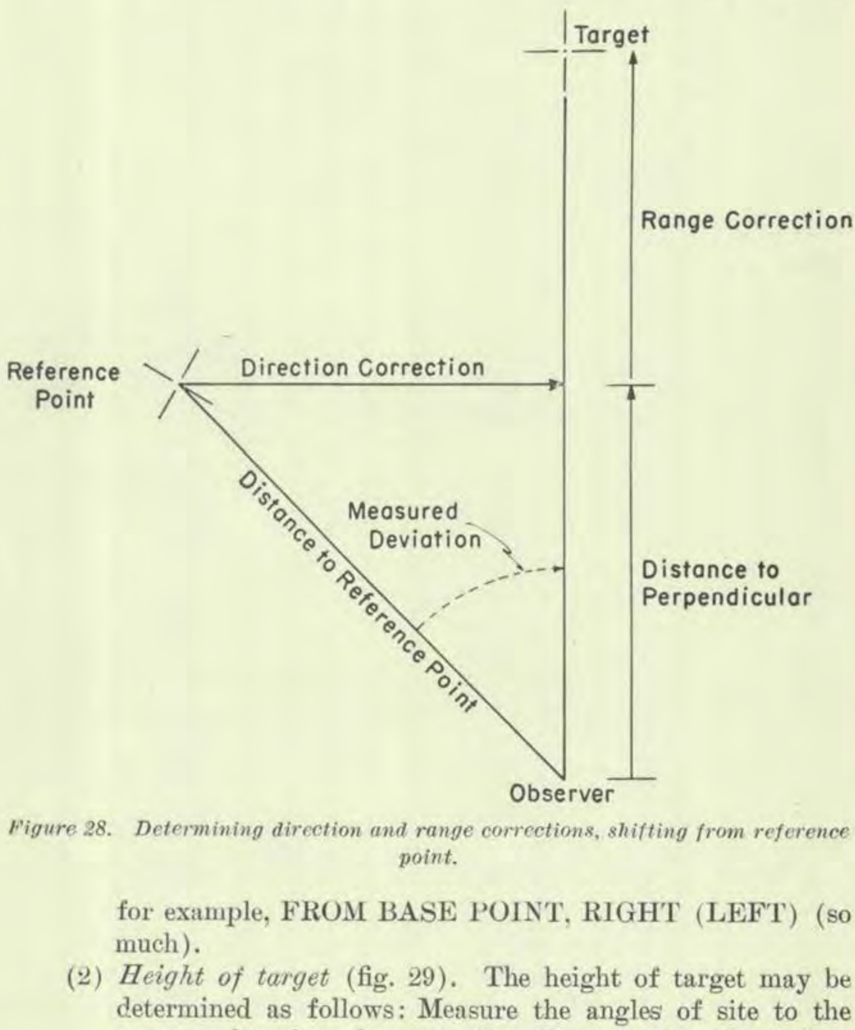


Figure 28. Determining direction and range corrections, shifting from reference point.

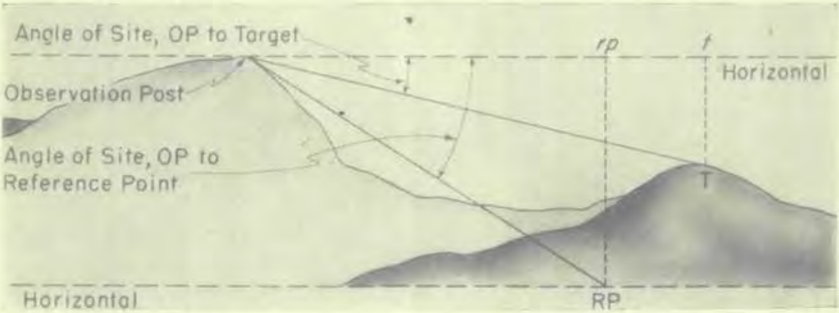
for example, FROM BASE POINT, RIGHT (LEFT) (so much).

(2) *Height of target* (fig. 29). The height of target may be determined as follows: Measure the angles of site to the target and to the reference point. Then, by the mil relation, compute the amount in yards that each is above or below the observation post. From these values, compute the cor-

rection for difference in altitude of reference point and target. This correction is announced as: UP (DOWN) (so much).

(3) *Range* (fig. 28). The observer estimates the distance along the *OT* line to his target from the point where the perpendicular line from the reference point intersects the *OT* line. This distance is the range correction and is included in the initial fire request as: ADD (DROP) (so much) or REPEAT RANGE.

(4) *Accuracy.* The foregoing method will give accurate results for shifts of 400 mils or less and acceptable results for shifts up to 600 mils. For example, if the observer-reference point distance is 2,000 yards and the deviation to a target measures 600 mils, the use of the mil relation results in a direction correction of 1,200 (2×600) yards, as compared



1. Compute value *RP–rp*
2. Compute value *T–t*
3. Difference equals difference in altitude between *RP* and *T*

Figure 29. Determination of difference in altitude between reference point and target.

to the true correction of 1,110 (2,000×sin 600) yards. Similarly, the true distance along the *OT* line to the perpendicular is 1,660 (2,000×cos 600) yards. For greater shifts in direction, the direction error and the difficulty of estimating the distance to the intersection with the perpendicular increase rapidly.

c. Rapid plotting. The observer may determine the shift from a reference point by rapid plotting. The deviation from reference point to target is measured; ranges are estimated. These data are plotted to scale and the initial deviation and range change are measured from the plot (fig. 30). A target grid (par. 186**d**) or an M–10 Plotting Board (par. 44) may be used to obtain the same results, the center of the device being taken as the observer's location.

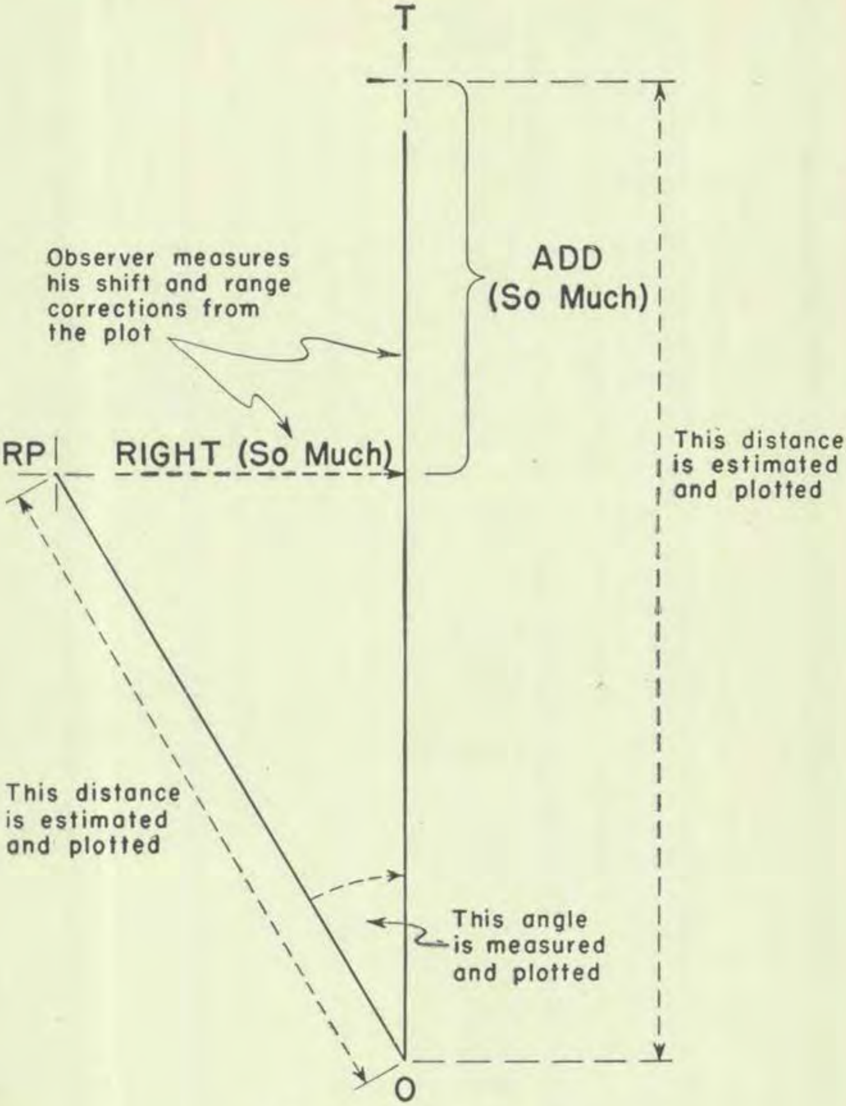


Figure 30. Rapid plotting.

d. Geographic location. The location of a target may be given by means of geographic direction and distance from a known point. For example: FROM CONCENTRATION P 22, WEST 100, SOUTH 300; FROM ROAD JUNCTION 615, AZIMUTH 1,400, DISTANCE 900; FROM CROSSROADS 932, NORTHEAST 600.

e. Marking volley. The observer may request a marking volley from which he can shift to his target. *Examples:*

MARK BASE POINT.

MARK CHECK POINT NUMBER 3.

MARK CENTER OF SECTOR. (The observer may add UP 100 (or other arbitrary amount), FUZE TIME, to obtain a high air burst which he can identify.)

CODE COMPASS RIGHT 200, UP 20, CODE RANGE ADD 800.

f. Polar coordinates.

(1) If the observer's location is known by the fire-direction center, the initial location of a target may be reported by polar coordinates. The fire-direction center plots the target on the azimuth and at the distance from the observer's location as reported by the observer. This method is particularly desirable in the case of large lateral shifts and short observing distances. *Example:* The observer reports: FORWARD OBSERVER ABLE, FIRE MISSION, AZIMUTH 2,000, *OT* RANGE 900. MORTARS, WILL ADJUST. The fire-direction center places the range-deflection fan with the vertex at the observer's position, orients the edge of the fan at an azimuth of 2,000 ₥ constructs a ray from the observer's position at an azimuth of 2,000 mils, and plots the target at a distance of 900 yards from the observer.

(2) The observer's location may be determined as follows:

(*a*) Map coordinates of his location may be sent to fire-direction center.

(*b*) The observer may measure the azimuth to a known point, or to a burst, and estimate the distance to same. The fire-direction center then plots the observer's location on its chart according to these data.

(*c*) The azimuth is measured by the observer to at least two points whose chart locations are known by fire-direction center. His location then is determined by resection.

57. NATURE OF TARGET. The nature of the target consists of a description of the enemy installation, personnel, equipment, or activity which is observed. This description should be brief, but sufficiently informative to indicate to the fire-direction center the relative importance of the target and the best manner of attack. Information of intelligence nature must be reported promptly but must not delay fire missions.

58. CLASSIFICATION OF FIRE. To indicate the relative proximity of the target to friendly troops, the observer transmits CLOSE or DEEP. The use of this element is optional when adjusting ground artillery fire but mandatory in the adjustment of naval gunfire.

59. TYPE OF ADJUSTMENT. The designation of the type of adjustment may include PRECISION REGISTRATION, DESTRUC-

TION, HIGH-ANGLE FIRE, special sheaf or range spread desired, or any other special requirement. If no specific type of adjustment is designated, area fire methods and volley fire will be used. If salvo fire is desired, the observer sends SALVO FIRE or SALVO RIGHT (LEFT). In both salvo and volley fire, the fire-direction center will determine the number of pieces to be used during adjustment. If the observer desires a specific number of pieces, he must specify the number desired; for example, BATTERY SALVO. The observer may indicate the volume of fire for effect desired; for example, REQUEST BATTALION, or ALL ADDITIONAL FIRE.

60. TYPE OF AMMUNITION. The observer may designate the type of projectile desired; for example, HE, SMOKE, ARMOR-PIERCING, ILLUMINATING, or other type. Choice of projectile depends upon effect sought. If no specific type of ammunition is designated, HE shell will be used.

61. FUZE ACTION. The observer may designate the type of fuze action desired; for example, FUZE QUICK (VT) (TIME) (DELAY) (or other type). Choice of fuze depends upon effect sought. If no specific type of fuze action is designated, fuze quick will be used. If the observer desires to adjust with fuze quick, but desires to use VT fuze in fire for effect, he includes in his initial fire request, VT IN EFFECT.

62. CONTROL. The observer's designation of control will consist of one of the following:

a. Will adjust. This indicates that the accuracy of the observer's location of the target is such that an adjustment is considered necessary, that the observer can adjust the fire, and that he will send corrections after each round, volley, or salvo. If observation is difficult or intermittent, the observer may send AT MY COMMAND, WILL ADJUST. In this event, the observer transmits FIRE after receipt of *READY* from the fire-direction center and when he is in position to observe. This procedure remains in effect until a subsequent correction is followed by the command WHEN READY.

b. Fire for effect. When transmitted as part of the initial fire request, this indicates that the observer considers his location of the target to be accurate, no adustment necessary, and surprise fire desirable.

c. Cannot observe. This indicates that the observer will be unable to adjust the fire, but that he has reason to believe that a target exists at the given location and that it is of sufficient importance to justify firing upon it without adjustment. The decision to fire the mission will be made by the fire-direction center.

63. EXAMPLES OF INITIAL FIRE REQUESTS.

a. FIRE MISSION,
AZIMUTH 3,210,
BASE POINT,
PRECISION REGISTRATION,
WILL ADJUST.

b. FIRE MISSION,
AZIMUTH 4,200,
FROM BASE POINT,
RIGHT 400,
UP 40,
ADD 600,
THREE MACHINE GUNS,
100-YARD ZONE,
WILL ADJUST.

c. FOX OBOE BAKER (Forward Observer, Battery B),
FIRE MISSION,
AZIMUTH 650,
JIG MIKE 9,763,
INFANTRY IN FOX HOLES,
SALVO RIGHT,
FUZE TIME,
AT MY COMMAND,
WILL ADJUST.

d. FIRE MISSION,
CONCENTRATION P32,
INFANTRY IN OPEN,
REQUEST BATTALION,
FUZE VT,
FIRE FOR EFFECT.

e. FIRE MISSION,
AZIMUTH 3120,
COORDINATES 47.2–93.6,
INFANTRY ASSEMBLING,
FUZE VT IN EFFECT (fire-direction center will order fuze quick in adjustment),
WILL ADJUST.

64. INFORMATION SENT TO OBSERVER. **a.** If a target is to be fired upon, the fire-direction center furnishes the following information to the observer:

	Example
(1) Battery (batteries) to fire for effect.	*BATTALION*,
(2) Adjusting battery.	*BAKER*,
(3) Projectile and/or fuze.	*FUZE TIME*,

		Example
(4)	Method of fire and range spread.	*3 VOLLEYS, CENTER RANGE,*
(5)	Time of opening fire.	*WHEN READY,*
(6)	Concentration number assigned.	*CONCENTRATION NO. 30.*

b. If the mission cannot be fired, the observer is notified, *WILL NOT FIRE.*

c. The observer is informed *ON THE WAY* as each round (volley, salvo) is fired. As each unit starts fire for effect, the observer is informed; for example, *ABLE FIRING FOR EFFECT.* When firing medium and heavy artillery at long ranges and when firing high-angle fire with all calibers, the observer is sent the warning, *SPLASH*, five seconds prior to the end of the time of flight of the round or volley. *TIME OF FLIGHT (so many) SECONDS* is transmitted to the observer at the beginning of a mission when the observer requests this information. When the observer has sent AT MY COMMAND, fire-direction center transmits *READY* to indicate that pieces are ready to fire. The fire-direction center informs the observer when fire for effect has been completed; for example, *ROUNDS COMPLETE, ABLE, BAKER, CHARLIE;* or *ROUNDS COMPLETE, ALL BATTALIONS.*

65. SUBSEQUENT CORRECTIONS. a. Subsequent corrections are transmitted in the following sequence:

(1) Deviation correction.
(2) Distribution correction.
(3) Height-of-burst correction.
(4) Change in any special requirements; for example, to change from volley to salvo fire during area adjustment.
(5) Change in number of rounds to be fired (in precision fire).
(6) Change in ammunition; for example, to change from fuze delay to fuze time.
(7) Range correction.

b. Subsequent corrections are always terminated with a correction for range, except when a change in control is given, in which case a correction for range must be given followed by the method of control; for example, REPEAT RANGE, FIRE FOR EFFECT.

c. Any element of subsequent corrections, other than the correction for range, may be omitted if no change in that element is desired. If some element is to be corrected but range is not, the observer sends the correction for that element followed by REPEAT RANGE. If it is desired to fire with the same data as the last rounds, the observer sends REPEAT RANGE.

66. CORRECTION OF ERRORS. a. Initial fire request. If the observer has transmitted his initial fire request and finds that he has made an error in one of the elements listed in paragraph 52, he sends CORRECTION, followed *only* by the information pertaining to the entire element in error. The remaining elements of the initial fire request need not be retransmitted. If any element of the request has been omitted erroneously, the observer sends that element to the fire-direction center as a separate transmission without repeating the entire initial fire request.

b. Subsequent corrections. When the observer sends erroneous data in subsequent corrections, he corrects it by sending CORRECTION, followed by the entire corrected transmission; for example, the observer has transmitted LEFT 200, UP 40, ADD 400. He desires to change ADD 400 to DROP 400. To correct his error, he sends, CORRECTION, LEFT 200, UP 40, DROP 400. The word "correction," in this case, cancels the entire transmission.

CHAPTER 8

CONDUCT OF FIRE

Section I. GENERAL

67. INTRODUCTION. The purpose of conduct of fire is to bring effective fire to the target by adjusting with observed rounds. The fact that the fire has been brought to the target is established when rounds or fragments strike the target or when the target has been enclosed by a bracket of appropriate size.

68. RANGE BOUNDS. a. First bounds. After a round or volley has been sensed, the first range bound is made large enough to bracket the target. The size of the initial range bound is based on the accuracy of the location of the target and the estimated range error of the round or volley from the target. Initial range changes are made in hundreds of yards. Unless there is definite indication as to the amount of range error, the following may be used as a guide for initial range changes:

Estimated data	400 yards
Map data, uncorrected	200 yards
Map data, corrected	100 yards

b. Bounds close to friendly troops. Fire close to friendly troops is opened with data which are surely safe. Range then is changed by bounds which are safe, until a bracket or a correct range is obtained.

Section II. PRECISION FIRE

69. GENERAL. The adjustment in precision fire is made by a single piece. The object of adjustment is to obtain a *trial range*. The trial range is the range for the center of a 100-yard bracket, or a range giving a target hit. In order to obtain a trial range, an initial range bracket is sought; thereafter, the bracked is split successively until the trial range is determined.

70. ADJUSTMENT OF FIRE. The observer makes his sensings and gives his corrections with relation to the *OT* line. An off-line burst is brought to the line by multiplying the observed deviation in mils by the estimated *OT* range in (thousands of yards) and sending a correction of RIGHT (LEFT) (so much) to the fire-direction center. Bursts are kept on the *OT* line graphically by the fire-direction center. An early bracket on the target is sought and, when obtained, is split successively by adding or dropping appropriate amounts along the *OT* line until the trial range is determined.

71. FIRE FOR EFFECT. a. General. Fire for effect is started by the observer at the trial range. During fire for effect, the observer sends no corrections to the fire-direction center but sends only his sensings of the rounds as observed. Range is sensed as OVER, SHORT, DOUBTFUL, or TARGET; deviations are sensed as RIGHT, LEFT, or LINE (fig. 31). The necessary action, based on such sensings, is taken by the fire-direction center. The observer may be instructed by the fire-direction center to sense the amount of deviation in yards from the *OT* line. In this case only, the observer senses any off-line rounds in fire for effect as DOUBTFUL (so much), RIGHT (LEFT). Rounds may be fired singly or in groups. The fire-direction center will notify the observer when more than one round is to be fired. If a target hit is obtained during adjustment, it is considered as the first round in fire for effect, and is reported to the fire-direction center as TARGET, followed by the request REPEAT RANGE, FIRE FOR EFFECT.

b. Control during a registration. When the mission is registration, fire for effect is continued until the observer is notified by fire-direction center that the adjustment is complete.

c. Control during a destruction mission. When the mission is destruction, fire is continued until the observer notifies fire-direction center that the mission has been accomplished. In order to avoid sensing on ricochet bursts, fuze quick generally is used during adjustment and in the first group of six rounds in fire for effect; fuze delay is used in subsequent fire for effect.

72. TIME REGISTRATION. a. The purpose of a time registration is to obtain a zero height of burst by correcting the time setting of a fuze. (A zero height of burst is that height at which the burst center is at the surface of the ground.) Following an impact registration, a time registration may be initiated by either the observer or the fire-direction center. *Examples:* The observer may send the following request to the fire-direction center: TIME REGISTRATION, ONE ROUND; the fire-direction center may instruct the observer: *OBSERVE TIME REGISTRATION, ONE ROUND.* The observer reports the sensings to fire-direction center as AIR or GRAZE. A group of six time sensings in fire for effect is required; rounds may be fired single or in half-groups of three. The fire-direction center computes the adjusted time based on the observer's sensings and

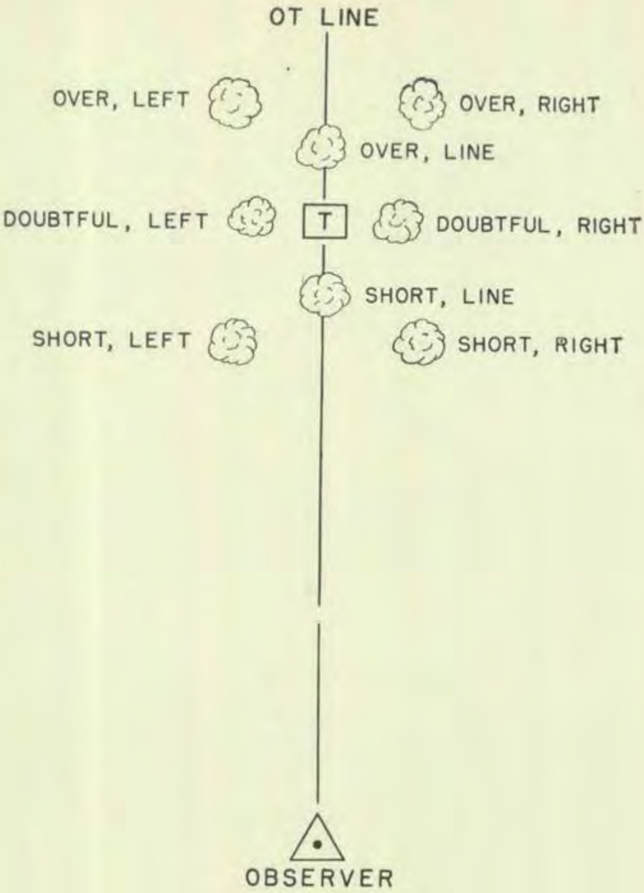
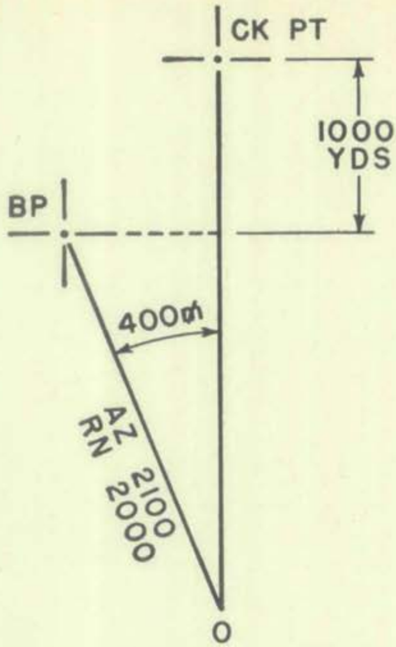


Figure 31. Sensing fire for effect in a precision mission.

notifies him when the registration is complete. Following a precision registration with fuze quick, it often is necessary to register time-fuzed shell in order to obtain both impact and time corrections. Ordinarily, the fire-direction center will begin this impact registration without notifying the observer of the change in fuze inasmuch as his procedure of reporting sensings remains unchanged.

b. Time registration is not always sufficiently accurate for surprise fires delivered close to supported troops. When such fires are to be delivered, the time correction may be verified by adjusting on an auxiliary target.

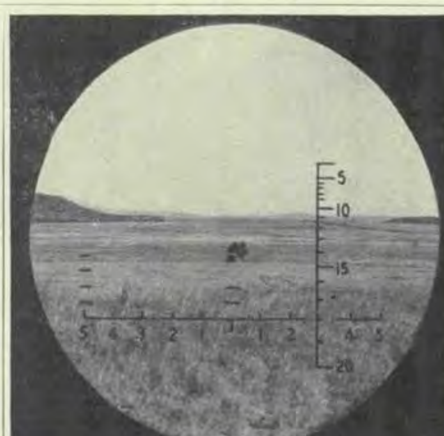
73. ILLUSTRATIVE EXAMPLES. a. Precision fire mission. Target, check point; mission, registration; matériel, 105-mm howitzer; ammunition, HE shell, fuze quick. (In the examples that follow, the symbol "+" indicates a sensing of *over;* "−" a sensing of *short;* and "?" a sensing of *doubtful.*)



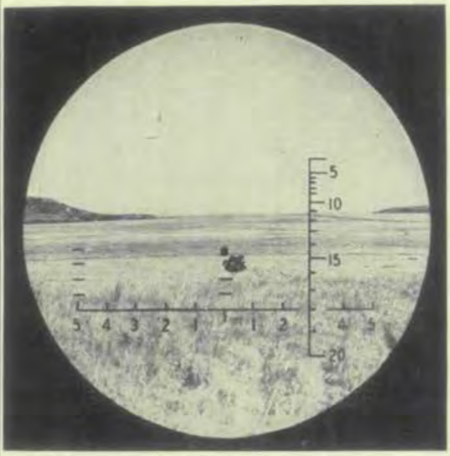
Sketch of observer-target relationship.

Transmissions	Results	Sensings	
		RN	Dev
Observer to FDC (initial fire request): FIRE MISSION, AZIMUTH 2,500, FROM BASE POINT, RIGHT 800, ADD 1,000, CHECK POINT, PRECISION REGISTRATION, WILL ADJUST. FDC to Observer: *BAKER,* *FUZE QUICK,* *PRECISION REGISTRATION,* *WHEN READY,* *CHECK POINT ONE . . .* *ON THE WAY.*		?	*15L*

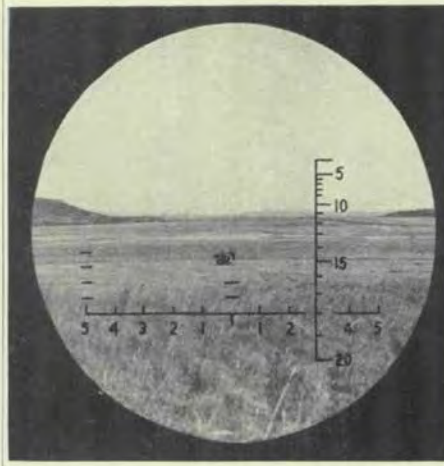
Remarks: Estimated *OT* distance = 3,000 yards. With field glasses, observer measures deviation of burst 15 mils left of *OT* line. Observed deviation = 45 yards (15×3.0). No range sensing is obtained. Observer determines shift of right 45 (50) to bring burst to the *OT* line.

Transmissions	Results	RN	Dev
Observer to FDC: RIGHT 45 (50), REPEAT RANGE. FDC to Observer: *ON THE WAY*		+	*Line*

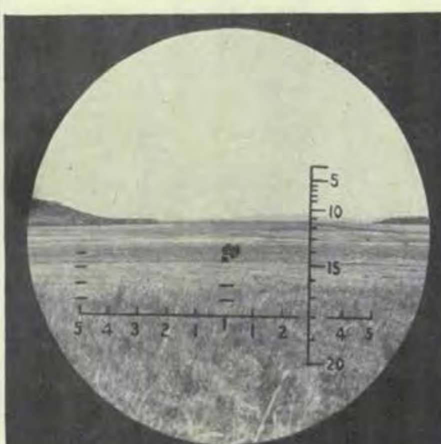
Remarks: The burst has been brought to the *OT* line. From this sensing of over, the observer decides to make a range change of 200 yards.

Transmissions	Results	Sensings	
		RN	Dev
Observer to FDC: DROP 200. FDC to Observer: *ON THE WAY.*		—	*Line*
Observer to FDC: ADD 100. FDC to Observer: *ON THE WAY.*		+	*Line*

Remarks: A 100-yard bracket now has been obtained along the *OT* line. With the next round, the observer will request a change of 50 yards which will be the first round in fire for effect (trial range).

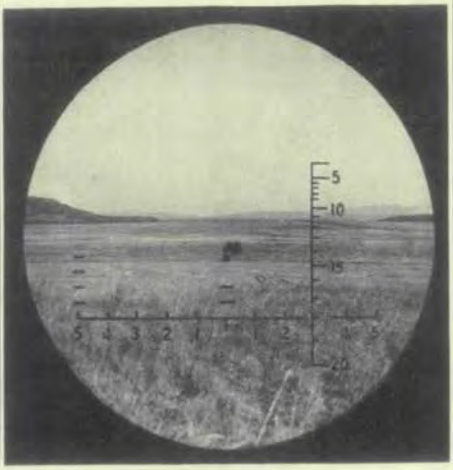
Transmissions	Results	Sensings	
		RN	Dev
Observer to FDC: DROP 50, FIRE FOR EFFECT. FDC to Observer: *ON THE WAY.* Observer to FDC: SHORT, LINE.		—	*Line*

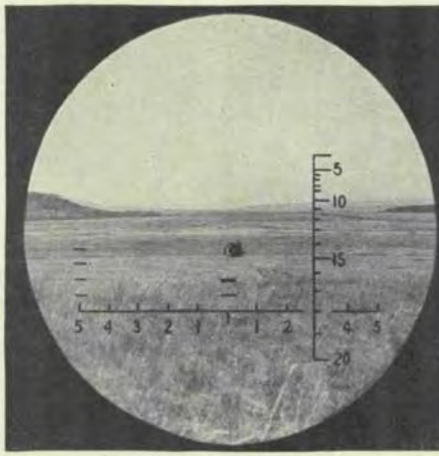
Remarks: No further corrections by the observer are given. FDC continues the mission until they have sufficient sensings from which to compute an adjusted elevation. The observer reports only his sensings.

FDC to Observer: *ON THE WAY.* Observer to FDC: OVER, LINE.		+	*Line*

Transmissions	Results	Sensings	
		RN	Dev
FDC to Observer: *ON THE WAY.* Observer to FDC: DOUBTFUL, LEFT.		?	*Left*

Remarks: This round appears off the *OT* line. The observer does not attempt to sense the range, merely reporting the round as DOUBTFUL, LEFT.

Transmissions	Results	RN	Dev
FDC to Observer: *ON THE WAY.* Observer to FDC: OVER, LINE.		+	*Line*

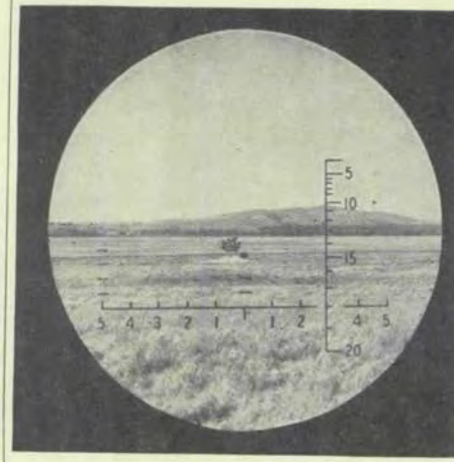
Transmissions	Results	Sensings	
		RN	Dev
FDC to Observer: *ON THE WAY.* Observer to FDC: SHORT, LINE.		—	*Line*
FDC to Observer: *ON THE WAY.* Observer to FDC: DOUBTFUL, RIGHT.		?	*Right*

Remarks: FDC has now obtained six sensings and therefore notifies the observer that the mission has been accomplished (par. 71**b**).

FDC to Observer: *END OF MISSION.*			

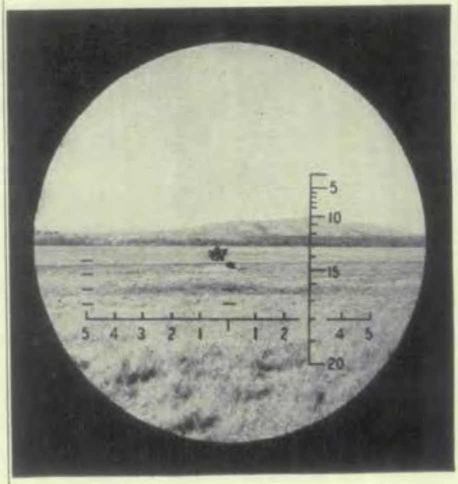
b. Time registration. Target, check point; mission, time registration (it is assumed that the observer has just completed a precision registration on the check point, using time-fuzed shell on impact); matériel, 105-mm howitzer; ammunition, HE shell, fuze M55.

Transmissions	Results	Sensings
FDC to Observer: *OBSERVE TIME REGISTRATION,* *ONE ROUND,* *ON THE WAY.* Observer to FDC: GRAZE.		*G*
FDC to Observer: *ON THE WAY.* Observer to FDC: AIR.		*A*

Transmissions	Results	Sensings
FDC to Observer: *3 ROUNDS,* *ON THE WAY.* Observer to FDC: AIR.		*A*
Observer to FDC: GRAZE.		*G*

Transmissions	Results	Sensings
Observer to FDC: AIR.		*A*

Remarks: Three more rounds will be fired at the same time setting to obtain six time sensings.

Transmissions	Results	Sensings
FDC to Observer: *3 ROUNDS, ON THE WAY.* Observer to FDC: AIR.		*A*

Transmissions	Results	Sensings
Observer to FDC: AIR.		*A*
Observer to FDC: GRAZE.		*G*

Remarks: The time sensings have been reported to FDC. Registration is now complete. Observer will be notified.

FDC to Observer: *TIME REGISTRATION COMPLETE,* *END OF MISSION.*		

74. GENERAL. Normally, fire is opened with two-gun volleys using a parallel sheaf, unless the observer designates otherwise. The object of adjustment is to enclose the target within a range bracket of suitable depth with the sheaf centered on the target, or to obtain target hits. This is accomplished by seeking an initial range bracket, and thereafter successively splitting the bracket.

75. ADJUSTMENT. a. General. To conserve ammunition, the adjustment usually is started with the two center pieces; the battery is brought in as desired. Quick, delay, time, or VT fuze may be used, depending upon the effect sought. The height of burst (in time fire) and range of the volley as a whole are sensed; for example, *mixed, short, line graze, over, 5 right.*

b. Direction and distribution. The deviation of the burst center with respect to the *OT* line is determined. The burst center then is brought to and kept on the *OT* line by the same procedure as for a single burst in precision fire (par. 70). At any time after the initial volley, the observer may alter the sheaf as desired.

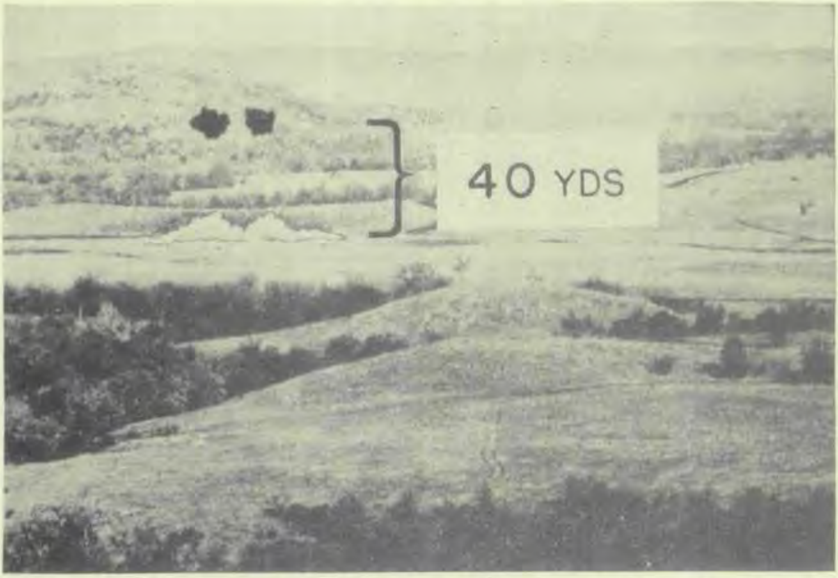


Figure 32. Adjusting height of burst. In the example above, the observer's correction for height of burst is DOWN 20.

c. Height of burst. In time fire, the height of burst is adjusted by changing site (fig. 32). Range adjustment is made preferably with air bursts. A good height of burst is one which gives range sensings. When rounds cannot be sensed on the effect pattern because of heavy foliage or wet ground, the adjustment is made with a very low height of burst (zero to ten yards), but is not conducted with a height of burst lower than a zero height of burst (half airs, half grazes). When the initial volley results in all grazes, a correction of UP 40 is given. When the volley results in mixed or mixed graze, a correction of UP 20 is given. If a volley results in mixed air, no change is made in height of burst. When a volley results in airs, the mean height of burst of the volley can be measured and site can be changed to give the desired height of burst. When firing against targets located on steep slopes or on extremely irregular ground, the observer must exercise caution in adjusting the height of burst; an air burst below the

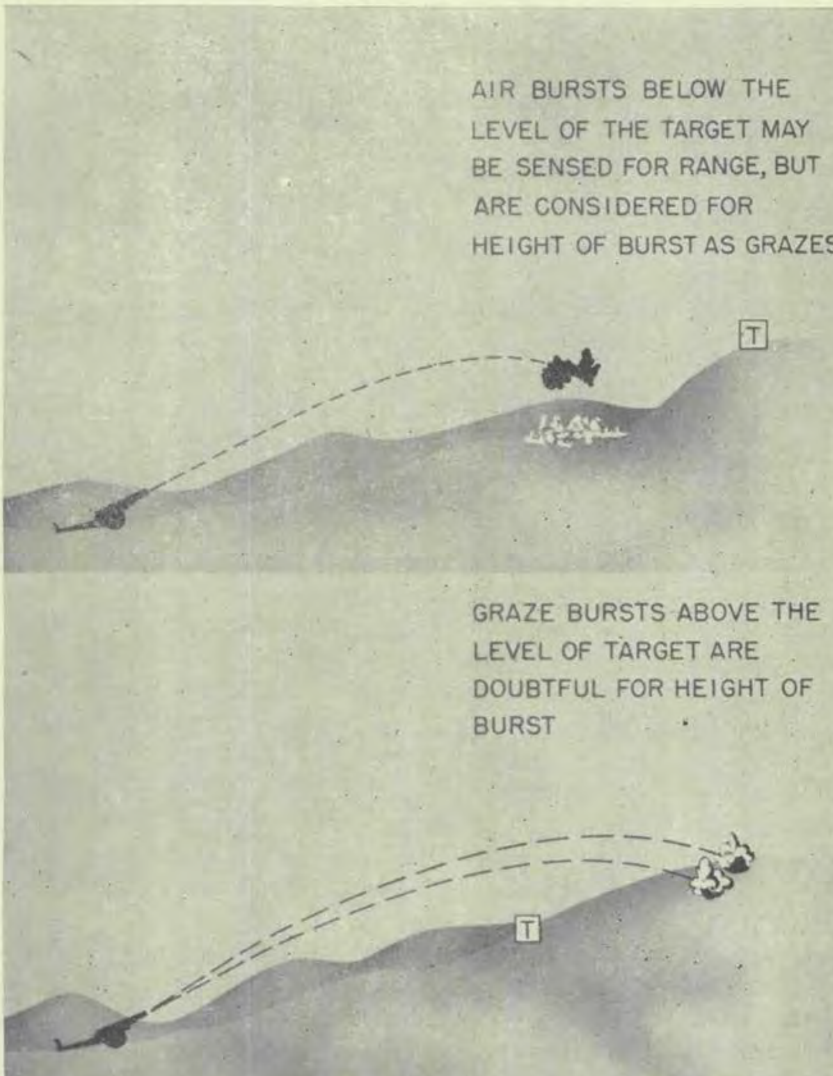


Figure 33. Sensing height of burst when firing on a steep slope.

level of the target should be treated as a graze; a graze burst above the level of the target should be treated as doubtful for height of burst (fig. 33).

d. Range. Range changes are made in hundreds of yards until a range change of less than 100 yards is indicated. Normally, a range change of less than 50 yards is not made. The bracket sought in adjustment depends upon the nature of the target and on knowledge of its location. A bracket of 100 yards is appropriate for most targets. Fire for effect is started at the center of the bracket selected. When indirect laying is used against a rapidly moving target, fire is placed in the path of the target to meet it. A deep bracket, quickly obtained, may indicate a range to be used for effect. Under certain circumstances, it may be possible to split the bracket proportionately; for example, having made a 400-yard change, ADD 400, the observer notes that the target is much closer to the resulting volley than to the previous volley. His next correction for range should be DROP 100. If, during adjustment a volley (salvo) is sensed as range correct or a target hit is obtained, fire for effect is requested immediately by the observer.

76. FIRE FOR EFFECT. a. General. Fire for effect is started when a suitable adjustment has been obtained; that is, when direction and range are correct, or if effective fire will result when the range bracket is split. In time fire, fire for effect is not started until the height of burst is correct (fig. 34), or until the observer is certain that his next correction for site will result in the correct height of burst. Fuze action (in time fire), range, and deviation are sensed for each volley as a whole; for example, *mixed air, over, line.*

b. Direction. On entering fire for effect, a shift is made which will place the burst center of the adjusting platoon on the *OT* line. Any correction necessary to center the battery around the adjusting platoon is made at fire-direction center. Direction is established properly when rounds from the center pieces bracket the center of the target.

c. Distribution. Normally, in fire for effect, a parallel sheaf is used when firing light and medium artillery. An open sheaf is used when firing heavy artillery. When appropriate, the observer may request an increase or decrease in the width of sheaf. When the target is too wide to be covered effectively by an open sheaf and additional batteries are not available, the target should be attacked by successive shifts.

d. Height of burst. In time fire, the site change upon entry into fire for effect should result in a height of burst of 20 yards at the center of the target. Fire for effect should not be started if the last volley consisted entirely of graze bursts. The height of burst above the target may be determined by measuring the vertical angle between the burst center and the target and converting this measurement to yards

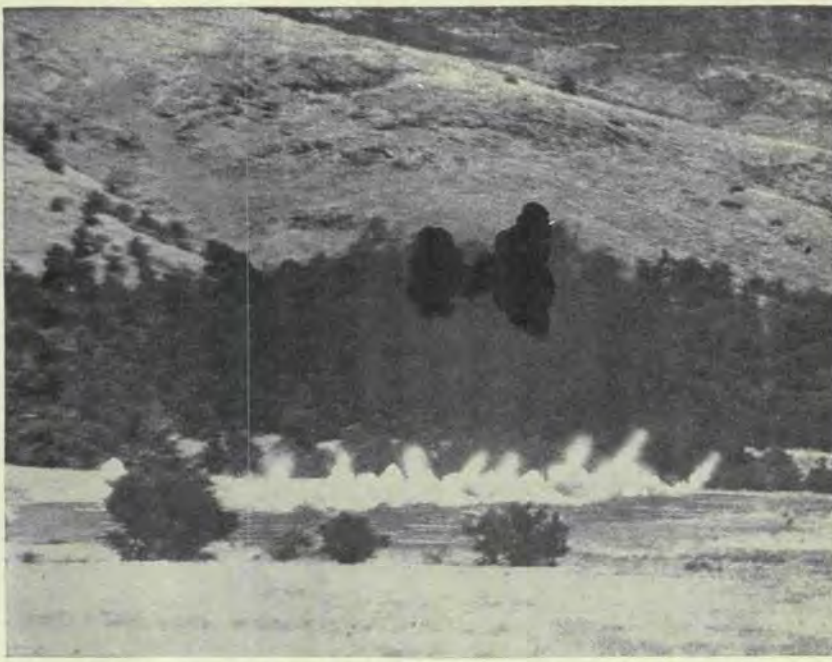


Figure 34. Height of burst correct (approximately 20 yards).

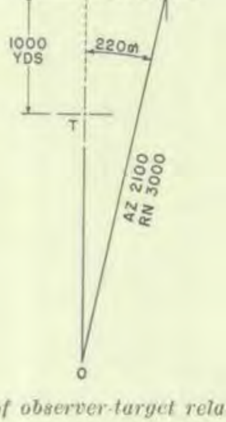
by the mil relation. Also, the height of burst may be estimated by comparison with known dimensions of objects at the same distance from the observer; the smoke of 105-mm and 155-mm HE shell air bursts is about 10 yards in diameter at the instant of bursting.

e. Fuze. If ricochet action was sought in adjustment, the use of delay fuze is continued in fire for effect when at least 50 percent of the bursts which established the bracket for fire for effect were ricochets (airs). If fewer than 50 percent of those bursts were ricochets, VT or quick fuze is used in fire for effect. If, during fire for effect, fewer than 50 percent of the bursts are ricochets, fuze is changed for subsequent fire for effect. When VT fuze is to be used in effect, the adjustment should be made with fuze quick in order to facilitate sensing. The appropriate change in site is made by fire-direction center prior to entry into fire for effect. To obtain this, the observer, in his initial fire request, should state, FUZE VT IN EFFECT.

f. Range. Fire for effect is started at the center of the bracket selected. The initial range bracket for fire for effect may be the one obtained from adjustment or one that slightly is removed, as in case of adjustment on an auxiliary target, a hillcrest, the near edge of a wood, or an adjusting point off the center of target; for example, a bracket may be obtained on the near edge of a wood, and fire for effect delivered within the wood. Unless the observes otherwise designates in his initial fire request, or directs otherwise upon entering fire for effect, a battery normally will fire at a single range; the battalion normally will fire at center range, unless coverage of a large area is desired. Other than a single range (for a battery) may be obtained by announcing 100-YARD (or other size) ZONE. In all cases, the fire-direction center will notify the observer as to single range or zone (so many yards). When a single range is used, the battery fires several volleys initially; if a preponderance of overs or shorts results, the observer sends corrections which will center the fire over the target. During fire for effect, direction and range may be changed to conform with movement of the target or with additional information on its location. However, the observer should not interrupt the fire for effect to make minor changes which will not increase materially the effectiveness of fire. If fire for effect was accurate, but insufficient, the observer may announce, REPEAT RANGE, REPEAT FIRE FOR EFFECT. If a single battery has fired through a zone, and further fire is desired, the observer may select the best single range and request further fire for effect; for example, SINGLE RANGE, ADD 50, REPEAT FIRE FOR EFFECT.

g. Report of observer. Upon completion of fire for effect, the observer sends CEASE FIRING, END OF MISSION (if fire has been effective and sufficient), and reports the effect which he has observed; for example, CEASE FIRING, END OF MISSION, INFANTRY DISPERSED. If the observer desires to make a correction to improve the accuracy of the replot of the concentration but not fire again, he announces the corrections, followed immediately by CEASE FIRING, END OF MISSION.

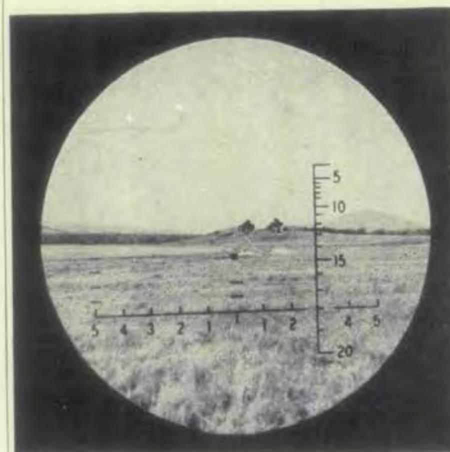
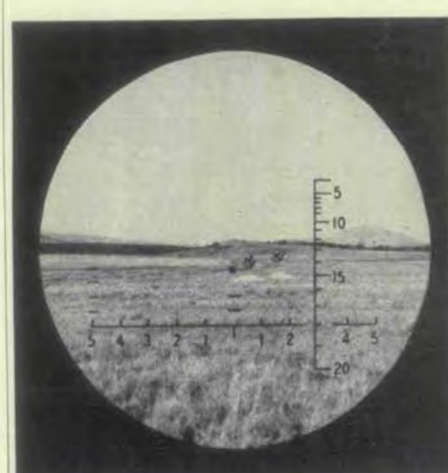
77. ILLUSTRATIVE EXAMPLE, AREA FIRE MISSION. Target, enemy machine guns; mission, neutralization; matériel, 105-mm howitzer; ammunition, HE shell (both M51 and M55 fuzes in battery). Shift from check point No. 1.

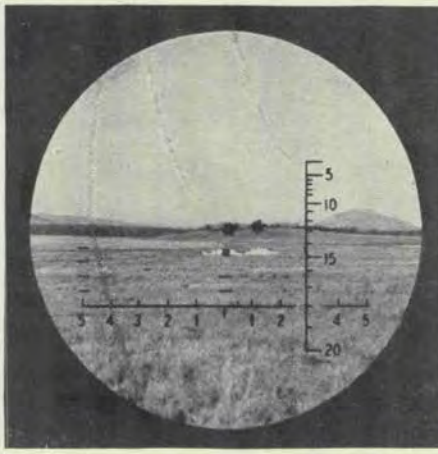


Sketch of observer-target relationship.

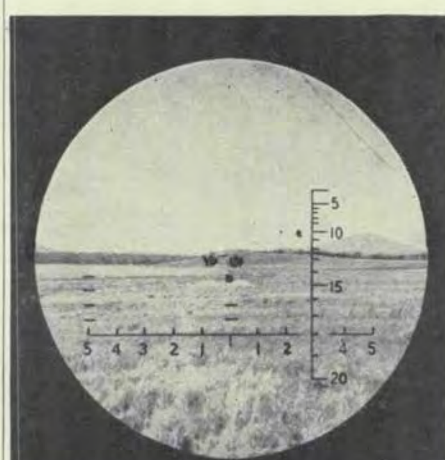
Transmissions	Results	Sensings		
		HB	RN	Dev
Observer to FDC (initial fire request): FIRE MISSION, AZIMUTH 1880, FROM CHECK POINT 1, LEFT 660, DROP 1,000, MACHINE GUNS FUZE TIME, WILL ADJUST. FDC to Observer: *BATTALION,* *BAKER,* *FUZE TIME,* *2 VOLLEYS,* *CENTER RANGE,* *WHEN READY,* *CONCENTRATION* *P2...* *ON THE WAY.*		*A*	?	*30L*

Remarks: Estimated *OT* distance =2,000 yards. With field glasses, observer measures deviation of burst center 30 mils left of *OT* line. Observed deviation =60 yards (30×2.0). No range sensing is obtained. Observed height of burst =30 yards (15×2.0).

Transmissions	Results	Sensings		
		HB	RN	Dev
Observer to FDC: RIGHT 60, DOWN 10 REPEAT RANGE. FDC to Observer: *ON THE WAY.*		*A*	+	*10R*
Remarks: Deviation of 10 mils is small The observer elects to ignore it unless it persists inasmuch as he is able to obtain sensings.				
Observer to FDC: DROP 400. FDC to Observer: *ON THE WAY.*		*A*	—	*10R*

Transmissions	Results	Sensings		
		HB	RN	Dev
Observer to FDC: ADD 200. FDC to Observer: *ON THE WAY.*		*A*	+	*8R*

Remarks: The deviation of 8 to 10 mils right still persists. The observer therefore considers it in his next correction.

Observer to FDC: LEFT 20, DROP 100. FDC to Observer: *ON THE WAY.*		*A*	—	*Line*

Transmissions	Results	Sensings		
		HB	RN	Dev
Observer to FDC: ADD 50, FIRE FOR EFFECT. FDC to Observer: *BAKER FIRING* *FOR EFFECT.*		*Mixed air*	*Correct*	*Line*

Remarks: First volley in effect sensed *mixed air, range correct, line.* Remainder of fire is observed and, if necessary, corrections are sent to FDC.

Observer to FDC: CEASE FIRING, END OF MISSION, MACHINE GUNS SILENCED.				

Section IV. SUMMARY OF PRINCIPLES

78. GENERAL. a. Adjustment of fire is conducted with relation to the *OT* line; the observer proceeds to bracket the target and to narrow the bracket systematically.

b. Bursts are brought to the *OT* line by applying corrections determined by multiplying the observed deviation in mils by the estimated *OT* range in thousands of yards.

c. Bursts are kept on the *OT* line graphically by the fire-direction center.

79. PRECISION FIRE. a. Adjustment. The object of adjustment is to determine the *trial range*. The trial range is the range for the center of a 100-yard range bracket, or a range giving a target hit.

b. Fire for effect.

(1) Fire for effect is started at the trial range. The rounds are fired singly or in groups. The observer will be notified if more than one round is to be fired.

(2) Sensings only are sent to fire-direction center.

(3) In a registration, the fire-direction center notifies the observer when the mission has been completed; in a destruction mission, the fire is continued until stopped by the observer.

c. Time registration. Following an impact registration, a time registration is begun. The observer sends *sensings* of AIR or GRAZE to fire-direction center.

80. AREA FIRE. a. Adjustment.

(1) The object of adjustment is to enclose the target within a range bracket of suitable depth with fire centered on the target, or to obtain target hits. Fire for effect generally is not called for until a bracket of 100 yards or less is split.

(2) The type of ammunition selected is that which will be most effective against the target.

(3) The burst center is brought to the *OT* line by appropriate corrections.

(4) In time fire, the height of burst is adjusted to 20 yards above the center of the target by correcting site. Fire for effect is not started until the height of burst is correct, or until the observer is certain that his next correction will result in the proper height of burst.

b. Fire for effect.

(1) Fire for effect is started when direction and range (and height of burst in time fire) are correct, or when effective fire will result from the next split in bracket.

(2) Fire for effect is started at the center range of the bracket selected.

(3) Upon entering fire for effect, the fire is centered on the target or area to be covered.

(4) The range is improved if the preponderance of the fire for effect is over or short. The direction is established properly when the sheaf is centered on the target.

(5) If fire for effect is ineffective or insufficient, necessary corrections are made and additional fire for effect is requested.

(6) Upon completion of fire for effect, the observer sends CEASE FIRING, END OF MISSION and reports the effect observed.

CHAPTER 9

AIR OBSERVATION

Section I. GENERAL

81. INTRODUCTION. **a.** An air observer may be a pilot or other individual trained in air observation of artillery fire.

b. Appropriate missions for the air observer include—

(1) Adjustment of area and destruction fires.

(2) Registration.

(3) Searching for targets.

(4) Surveillance of fire.

c. The normal means of communication between airplane and ground is a two-way radiotelephone.

82. PREARRANGEMENT. **a.** The pilot and air observer should be briefed prior to each flight. Specific missions should be assigned. The following matters, as appropriate to the mission, should be covered:

(1) Tactical situation (friendly and enemy).

(2) Location of front lines and zone of action of supported troops.

(3) Location of battery position areas.

(4) Prearranged adjustments. Description and location of targets and the type of adjustment to be used. Locations may be designated by coordinates or marked on an oblique or vertical photo.

(5) Suspected target locations and areas to be searched.

(6) Location and description of base point, check points, and other reference points from which targets of opportunity may be located.

(7) Location of prearranged concentrations and programs of fire.

(8) Flight restrictions.

(9) Known enemy antiaircraft defenses.

(10) Time of mission.

(11) Maps and photos to be used.

(12) Communication details to include location of ground radio, panel stations, channels to be used, and check-in time.

b. The organic light aviation pilot and observer normally will be briefed by his artillery S–2 and S–3; the high performance aircraft pilots and observers, by a ground liaison officer with the air force tactical reconnaissance unit.

83. PROCEDURE. a. General.

(1) Conduct of area and precision fire by the air observer follows the same procedure as for the ground observer, except that corrections and sensings by the air observer normally are given with reference to the gun-target line. The position of the observer with respect to the target continually is changing, and therefore he has no fixed *OT* line.

(2) The principles of bracketing the target apply to air observation as well as to ground observation. Although at short observing ranges the observer's commanding observation may permit him to make accurate estimations of range, he cannot make sufficiently accurate estimates of ground distances at long observing ranges. The establishment of the desired bracket prior to firing for effect is essential to avoid waste of ammunition.

(3) Differences in altitude are not apparent to the air observer and may prevent fire from being brought onto a target even though an accurate horizontal correction may have been made.

(4) A yardstick and direction of the *GT* line on the ground may be established by the correction ADD (DROP) 400 after observing the first round.

(5) Estimation of the height of air burst may prove difficult; however, the air observer can distinguish between air and graze to adjust zero height of burst.

(6) The observer must know or be informed of the approximate time of flight.

(7) An important aid to the observer and pilot is the warning SPLASH 5 seconds prior to end of time of flight of the round or volley.

(8) Well-defined reference points on the ground near the target should be used to prevent losing the target during turns of the airplane.

(9) Terrain, weather, or long observing ranges may make observation of rounds difficult. The observer may request volley fire, smoke, or air bursts to locate his rounds.

b. Adjustment. Procedure during the adjustment of either a precision or an area mission consists of determining the error in direction, correcting this error by making the indicated shifts, and bracketing the target for range on the gun-target line.

c. Fire for effect.

(1) In a precision mission, the observer calls for fire for effect when the direction of fire has been established properly and he splits a 100-yard range bracket, or when a target hit is obtained. The sensing of each round is reported to the fire-direction center. Range is sensed as *over*, *short*, or *range correct*. Deviation from the *GT* line is reported in yards. Example: OVER, 10 RIGHT; SHORT, LINE.

(2) In an area mission, the observer requests fire for effect when a suitable adjustment has been made; that is, when direction, distribution, and range are correct, or when effective fire will be obtained upon splitting the range bracket.

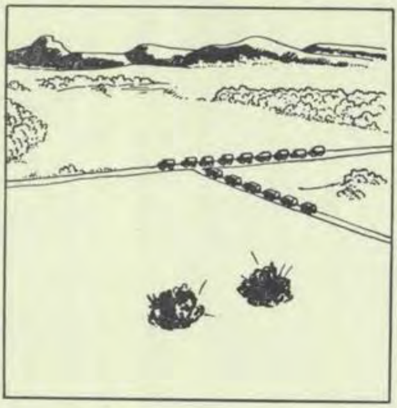
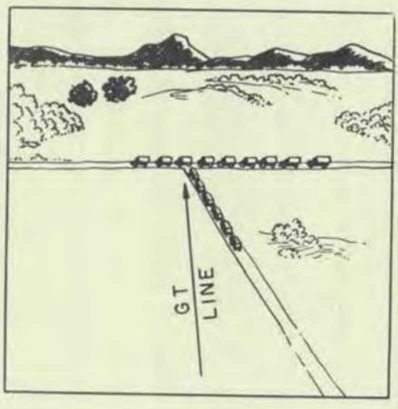
d. Center of impact registration.

(1) A single preliminary round is fired in the area where the center of impact is desired. If the burst is on or near some terrain feature identifiable on the map or air photo, the observer commands SIX ROUNDS, REPEAT RANGE. Otherwise, he moves the initial burst to a better location and fires six rounds.

(2) The observer marks the center of impact on a map or photo. He then may report the coordinates of the center of impact, drop the marked map or photo at the fire-direction center, or land and deliver the information.

e. Completion of a mission. Upon the completion of a mission, the fire-direction center may give the observer additional missions; or, if other missions have been prearranged, the fire-direction center may send *FOLLOW INSTRUCTIONS*. Upon completion of all missions, the fire-direction center sends *NO FURTHER NEED OF YOU; GO HOME*. If the plane is forced down, the observer sends GOING HOME or FORCED TO LAND.

84. ILLUSTRATIVE EXAMPLE. While on a patrol mission, an air observer of a 155-mm howitzer battalion sees a traffic jam of enemy vehicles at a road junction. He identifies the road junction on his map and establishes radio communication with the battalion fire-direction center.

Messages, corrections, and commands	Results	Sensing: Range	Sensing: Direction
Observer to FDC: FIRE MISSION, KING GEORGE 3279, TRAFFIC JAM, 15 VEHICLES, WILL ADJUST. FDC to Observer: *BATTALION,* *ABLE,* *SHELL HE and WP,* *FUZE QUICK,* *3 VOLLEYS,* *CENTER RANGE,* *WHEN READY,* *CONCENTRATION G9.* *ON THE WAY.*		—	
Remarks: FDC orders WP mixed with HE in fire for effect for incendiary effect.			
Observer to FDC: ADD 400. FDC to Observer: *ON THE WAY.*		+	*100L*

Messages, corrections, and commands	Results	Sensing	
		Range	Direction
Observer to FDC: RIGHT 100, DROP 200. FDC to Observer: *ON THE WAY.*		—	*50R*
Observer to FDC: LEFT 50, ADD 100. FDC to Observer: *ON THE WAY.*		—	

Messages, corrections, and commands	Results	Sensing	
		Range	Direction
Observer to FDC: ADD 50, FIRE FOR EFFECT. FDC to Observer: *ABLE FIRING FOR EFFECT.* *BAKER AND CHARLIE FIRING FOR EFFECT.* *ROUNDS COMPLETE, ABLE.* *ROUNDS COMPLETE, BAKER AND CHARLIE.*		*Correct*	
Observer to FDC: CEASE FIRING, END OF MISSION, SEVERAL VEHICLES BURNING, OTHERS DISPERSED.			

Section II. ORGANIC LIGHT AVIATION

85. GENERAL. Observation from light aircraft is limited to altitudes and locations which will allow the light aircraft to avoid enemy ground fire and enemy fighter aircraft. Evasive action over friendly territory is the best means of protection. Therefore, the pilot normally should not be called upon to pilot the aircraft and observe at the same time; an air observer should be furnished. Close liaison of the organic light aviation observer with his artillery headquarters will allow detailed prearrangement. Oblique photos are preferred to the vertical photos for target identification.

Section III. HIGH-PERFORMANCE AIRCRAFT

86. GENERAL. a. Characteristics. Accurate ground observation often does not cover completely the target area within the range capabilities of heavy artillery. Likewise, deep observation from organic light aircraft seldom is possible. In order to cover this dead space in observation, the use of high-performance aircraft is necessary. The pilot observer can fly over enemy territory to sufficient depth to observe and adjust long range artillery fires. A nearly vertical view of the target can be obtained. To protect the aircraft from enemy antiaircraft fire, a counterflak program may be fired by artillery during the observed mission. To reduce the danger of surprise by enemy aircraft, the missions are flown by two or more planes, one to adjust fire, the other(s) to observe for hostile aircraft. The time required for adjustment must be kept to a minimum. The battery must be laid on the target so that the first rounds may be fired as soon as the pilot is in position to observe. Fire direction may take advantage of the favorable observing position by asking for amount of range error in precision adjustment sensings.

b. Source of aircraft. All artillery adjustment missions will be performed by the pilots of the tactical reconnaissance squadrons of the air force. Requests for missions are made through army headquarters where they are processed to the appropriate air unit operating with the army.

c. Communication. Direct communication between the aircraft and the artillery unit is provided by very-high-frequency (VHF) radio sets. Because of the characteristics of the carrier wave, the location of the antenna of these sets should be such that a line-of-site electrical path between the plane and the antenna of the ground set is secured. The set in the aircraft always is the control set. The ground set is located at the fire-direction center of the firing battalion, or at the corps artillery fire-direction center.

87. PREARRANGEMENT. a. All pilots and observers flying the mission should be briefed thoroughly in a conference with the ground liaison officer on all points pertinent to the particular mission.

b. In addition to those matters covered in paragraph 82, the conference should include the following:

(1) Time of flight and expected interval between rounds.

(2) Maximum ordinate and slope of fall.

(3) Caliber of weapons to be used, projectile, and fuze.

(4) Special procedures, such as center of impact adjustment.

(5) Identification, location, and azimuth of any ground reference line (highway, railroad, canal, etc.) which is to be used by the observer in place of the gun-target line as a basis for corrections.

88. PROCEDURE. a. In special situations in which the gun-target line is not fixed or cannot be visualized on the ground, a reference line which is clearly visible, as described in paragraph 87**b**, may be used as a basis for corrections in the adjustment of fires. If the location of the reference line has not been prearranged, the observer must describe it adequately to the fire-direction center.

b. In some situations, the cardinal points of the compass may be used to make corrections in area fire adjustment. The cardinal point method has particular application in a surveillance mission on which the center of impact of a prearranged concentration fired by several battalions must be corrected.

89. PREPARATION OF VERTICAL PHOTO. a. A gridded vertical photo is a valuable aid to the observer in target identification and determination of corrections. A rectangular grid with 100-yard divisions, approximately to the scale of the photo, may be drawn on the photo. The center of the grid is placed over the target and the axis of the grid indicates the direction of fire (①, fig. 35).

① Vertical photo prepared with a rectangular grid.

Figure 35.

b. When the time or facilities are not available for the preparation of a photo as described in **a** above, a photo may be prepared with concentric circles drawn around the target with radii of 50, 100, and 200 yards. A line is drawn through the target to show the approximate direction of fire (②, fig. 35).

② Vertical photo prepared with concentric circles around target.

Figure 35—Continued.

CHAPTER 10

MISCELLANEOUS OBSERVED FIRES

Section I. DIRECT LAYING

90. GENERAL. When the target can be seen through the sight of the piece, direct laying may be employed. It is particularly effective against moving hostile vehicles, tanks, and enemy personnel attacking the battery position. Occasionally, direct laying may be employed in attacking such stationary targets as fortifications; however, assault-fire technique usually is used for such missions. Normally, direct laying is conducted by individual piece by the piece commander. For a detailed discussion of direct laying, see FM 6–140 and the pertinent field manual on the service of the piece.

91. CONDUCT OF FIRE. Each piece is adjusted individually on the target. Direction is taken from the target itself. Adjustment is made by placing the point of burst on the desired part of the target (for high-velocity and flat-trajectory weapons) or by bracketing the target (for low-velocity weapons).

Section II. ASSAULT FIRE

92. GENERAL. An artillery piece may be used for the destruction of caves, pillboxes, or other fixed fortifications. Any weapon of caliber less than 155 millimeters is uneconomical for this purpose. The weapon must be emplaced at such a range as to make possible the obtaining of successive hits on the same portion of the target. Generally, this range should not exceed 2,500 to 3,000 yards, except for the 240-mm howitzer which can be employed effectively up to 4,000 yards. Pinpoint accuracy is vital. Because of their maneuverability and the rapidity with which they may be emplaced and displaced, self-propelled weapons are much better suited to this type of mission than are towed weapons.

93. AMMUNITION. a. Projectiles. HE shell is used for the destruction of most fortifications. However, if the material to be penetrated is hard rock or heavy reinforced concrete, deeper penetration can be obtained with the use of armor-piercing (AP) projectiles fired at the highest striking velocity attainable. Since armor-piercing shell has little or no explosive filler, it tends to make a deep crater of small diameter. In order to widen this crater and clear away rubble when armor-piercing shell is used, the observer should order a round of HE shell with concrete-piercing fuze (M78) or fuze quick (M51), fired every fourth of fifth round. Armor-piercing or high-explosive antitank (HE-AT) shell should be used against steel.

b. Fuzes. Concrete-piercing fuzes normally are used in the destruction of fortifications. The nondelay concrete-piercing fuze is used in adjustment since it has a small ballistic difference from fuzes of the M51 series. Ordinary M51 delay fuzes are used only when concrete-piercing fuzes are not available, or they may be used to cut a channel through a parapet or through an earth covering. In such a case, the M51 fuze (set for superquick) is used for adjustment. If, during a mission, the fuze is changed from M51 to concrete-piercing, an arbitrary change of UP ONE (1) YARD is made to compensate for the difference in trajectory caused by the ballistic difference between fuzes.

c. Charges. The highest charge which will clear the mask and reach the desired point on the fortification is used.

94. ADJUSTMENT. **a.** Adjustment is made using a modified procedure in which the observer exercises complete control of fire, and corrections are applied to each successive round rather than determining an adjusted elevation from a group of rounds. Each piece is adjusted by an observer who should be as close as possible to the target in order to be able to make accurate estimates of error in range and direction. When the bursts are near the target, the observer usually can estimate vertical error more accurately than he can estimate range error; therefore, after bursts have been brought close to the target, the observer makes corrections of site rather than range. Corrections are given in yards and are converted into fire commands at the gun position where the target grid is used. After a range or deflection bracket of 50 yards is split, elevation and deflection changes are computed. If, after use of the target, grid has been discontinued, it still is necessary to keep bursts on the *OT* line, appropriate factors are applied by the fire-direction center at the gun position. Sample corrections are RIGHT 4, UP 5, REPEAT RANGE: LEFT 1, DOWN 2, REPEAT RANGE: RIGHT ½, REPEAT RANGE.

b. In order to make the small deflection changes which are necessary in assault fire, a special technique of laying is employed at the piece. Deflection changes are made to the nearest mil until a 1-mil deflection bracket is obtained; further changes are made to the nearest one-fourth mil. A deflection board attached to the aiming stakes is used for this purpose. The deflection board illustrated in figure 36 enables the gunner to make deflection changes of one-fourth mil. The black and white bands are one-fourth mil in width when viewed through the sight of the piece at a distance of 50 yards. The gunner lays on the desired portion of the board by centering the cross hair of the sight upon a black (white) band on the board. To move one-fourth mil, he moves the line of sight (by traversing the piece in the

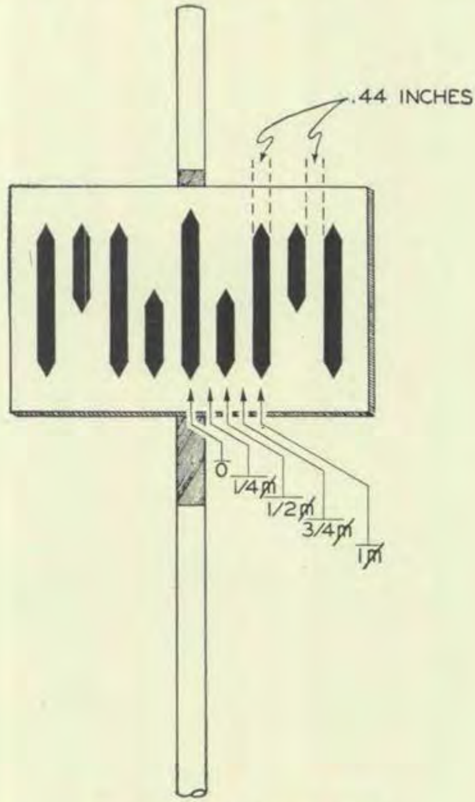


Figure 36. Deflection board.

proper direction) so that the adjacent white (black) band is covered; to move one-half mil, the cross hair is moved two bands, etc.

c. Changes in elevation are made to the nearest one-tenth mil. The gunner's quadrant is used.

95. FIRE FOR EFFECT. Fire for effect is started when the point of impact has been brought to the desired part of the target. Rounds are fired singly to permit the observer to make necessary corrections or changes in ammunition between rounds. Fire for effect is continued until the target has been destroyed.

96. ILLUSTRATIVE EXAMPLE. Target, reinforced concrete pillbox, visible side banked with 10 feet of earth; mission, destruction; matériel, 155-mm gun, self-propelled; ammunition, HE shell with M51 and M78 fuzes, and projectile, armor-piercing.

903448°—50——7

Observer's messages, corrections, and commands	Sensings	Remarks
FIRE MISSION, AZIMUTH 3700, MARK CENTER HILL 1090, PILLBOX, MAXIMUM CHARGE, FUZE QUICK, WILL ADJUST.	?, *50L*	
RIGHT 50, REPEAT RANGE.	+, *10R*	Round was close enough to target that vertical deviation could be estimated.
LEFT 10, DOWN 5, REPEAT RANGE.	*T*	Round struck earth bank. Observer places succeeding rounds to cut channel through earth to face of concrete wall.
LEFT 2, DOWN 1, FUZE DELAY, REPEAT RANGE.	*T*	After several rounds are fired, channel through dirt is cleared and the concrete wall is exposed.
UP 1, FUZE CONCRETE-PIERCING DELAY, REPEAT RANGE.	*T*	Burst raised 1 yard arbitrarily to correct for difference in trajectory caused by concrete-piercing fuze. Observer may order AP if he determines the concrete to be heavily reinforced. This will hasten the penetration. Every fourth or fifth round fired should be HE shell with concrete-piercing fuze to increase the size of the crater. As penetration continues, the observer orders an occasional round of HE with fuze quick to clear the rubble. Fire for effect is continued until penetration is accomplished and the pillbox destroyed.
CEASE FIRING, END OF MISSION, PILLBOX DESTROYED.		

Section III. HIGH-ANGLE FIRE

97. GENERAL FEATURES. a. Fire delivered at elevations greater than the elevation for maximum range is called *high-angle fire.* Its use is appropriate when fire is being conducted into or out of deep defilade such as is found in jungle, sharply eroded terrain, and cities, or over high terrain features near friendly troops.

b. When high-angle fire is desired, the observer includes in his initial fire request, HIGH-ANGLE FIRE. Adjustment is conducted using the same methods as previously described. From the point of view of the observer, high-angle fire has the following characteristics, in contrast to fire at normal elevations:

(1) Depending upon the weapon used, there is little overlap in the ranges reached by the various charges and, in some cases, there may be dead space between charges. During an adjustment, it may be necessary for the fire-direction center to change from one charge to another, unless the observer has given the *accurate* location of the target initially.

(2) Because of the steep angle of fall, ricochet fire is not possible. The long time of flight prevents the use of time fire. The steep angle of fall gives the maximum effectiveness in all directions of the side spray of quick-fuzed shell. With VT fuze, this effect is combined with a much lower point of burst than normally is obtained with the VT fuze. This makes high-angle fire less effective against personnel in trenches but more effective against exposed targets, when compared with fire delivered at normal elevations.

Section IV. CONDUCT OF FIRE WITH CHEMICAL SHELL

98. GAS SHELL. a. General. Gas shell is fired within restrictions laid down by higher authority. Velocity and direction of the wind always are considered, especially when friendly troops may be endangered. Data for firing gas shell should be the most accurate obtainable. If possible, registrations and adjustments are made with the type of shell which is to be used in fire for effect. When sensings cannot be made using gas shell, adjustment may be conducted with HE; compensation is made for the difference in ballistic properties before fire for effect is started. The quick fuze is used for gas shell.

b. Nonpersistent gas. Surprise and rapid building up of an effective concentration are essential elements in the success of an attack with nonpersistent gas. Surprise is attained by means of a transfer or by an adjustment on an auxiliary target. An effective concentration is built up rapidly by the employment of a large number of pieces of large caliber, and by rapid firing for a short time.

c. Persistent gas. When well distributed on vegetation, matériel, and ground, a persistent gas is most effective against personnel. To obtain this effect, a given amount of gas delivered with light weapons is preferable to the same amount delivered by medium and heavy weapons.

99. SMOKE SHELL (fig. 37). **a. General.** Smoke is used for screening enemy observation, for prearranged signals, and, when necessary, as an aid in the adjustment of fire. Use of smoke for screening must be coordinated with higher authority. To build and maintain a smoke screen, fire must be adjusted. The proper location of bursts relative to the target depends upon direction and velocity of the wind, volume and density of smoke produced by each burst, and rate of production of smoke. This location is determined by observation of bursts during adjustment. Adjustment is conducted with a single piece. The rate of fire necessary to maintain the screen depends upon the width of front to be screened, the direction and velocity of the wind, and the volume and density of smoke produced by each burst. The fire of a single piece, the continuous fire of several pieces, or volley fire may be used. When smoke is used to prevent enemy observation of the operations of friendly troops, the observer who is adjusting the fire should be near the troops whose operations are to be concealed. Rounds of HE shell (preferably air bursts) fired into the smoke area will prevent the enemy troops from leaving shelter to extinguish the smoke canisters.

b. Base-ejection type smoke shell.

(1) Hexachlorethane (HC), the smoke-producing agent in this type of shell, burns with relatively little heat and does not "pillar." Since it is hygroscopic, it is made more effective by rain and mist.

(2) When the objective is to build and maintain a smoke screen, fire must be observed to be effective. The lowest practicable propelling charge is used. Time fuze is used with a time setting that surely will cause the smoke charges to be ejected before impact. The setting used for time of burning should be from one to two seconds less than that for a zero height of burst. Fuze M67 without booster can be used with 155-mm shell to obtain a time of burning greater than 25 seconds.

(3) The burning qualities of the smoke charges are as follows:

	105-mm	*155-mm*
Time to emit effective cloud	1 minute	30 seconds
Time to reach maximum effectiveness	2 minutes	1 minute
Total time of burning	3 minutes	4 minutes

(4) If a wind is parallel to the front to be screened, the spacing of points of fall may be as great as 400 yards. If a wind is perpendicular to the front to be screened, the spacing may be as close as 30 yards. A rough guide for computation of

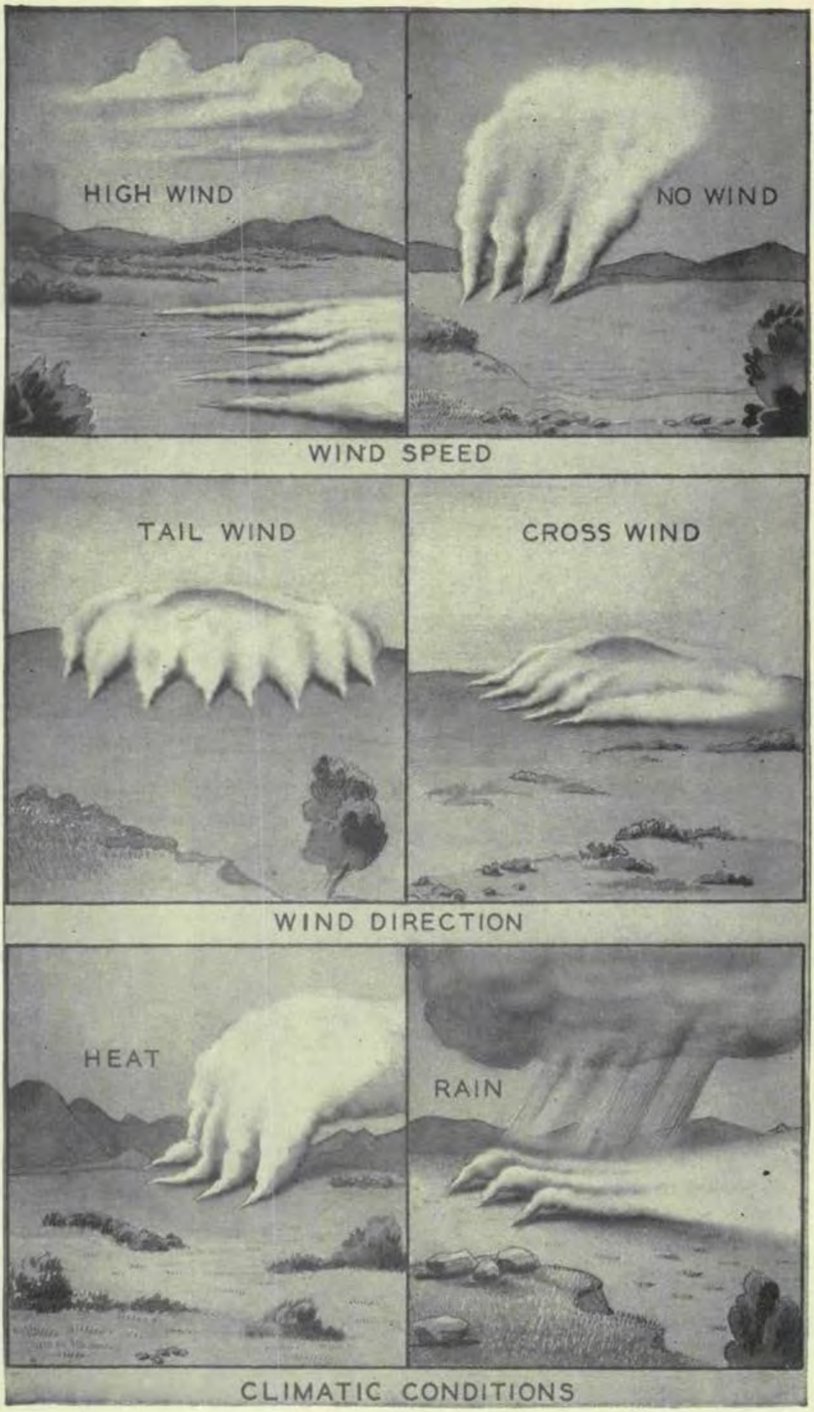


Figure 37. Weather conditions affecting smoke.

ammunition requirements for a screen for each point of fall is as follows:

Wind velocity (miles per hour)	Rate of fire (rounds per minute) 105-mm	155-mm
3	1	½
10	1½	¾
15	2	1

(5) Since the smoke is emitted from the canisters in thin streams which travel an appreciable distance before billowing out enough to form an effective screen, points of fall *must* be well upwind from the target.

c. White phosphorus shell. The white phosphorus (WP) burns rapidly and the smoke tends to "pillar." Quick fuze is used to build and maintain a smoke screen. The ammunition requirements for building and maintaining a smoke screen with this type of shell are greater than those for the base-ejection type. Casualty and incendiary effect are produced by white phosphorus.

Section V. CONDUCT OF FIRE WITH ILLUMINATING SHELL

100. USES FOR ILLUMINATING SHELL. Illuminating shell can be used to advantage for any of the following specific purposes and in any other situation where illumination is needed:

a. Illuminating areas of suspected enemy movement, attack, or counterattack.

b. Surveillance of fires at night.

c. Night adjustment of artillery fire by ground or air observer.

d. Harassing enemy positions and installations.

e. Furnishing direction to infantry for attacks or patrols. (Place flares well in advance of friendly troops to avoid illuminating them.)

101. ADJUSTMENT OF ILLUMINATION. a. The following table gives the characteristics of the illuminating shell M118 (155-mm):

Proper height of burst	700 yards.
Time of burning	60 seconds.
Rate of fire for continuous illumination	1 round every 30 seconds.
Optimum distance between adjacent bursts for volley fire	700 yards.

b. The proper height of burst is that which will allow the flare to stop burning just before it strikes the ground.

c. The correct quadrant elevation to place the point of burst at the proper height for a given range, under normal conditions, is given in the appropriate firing table or graphical firing table.

d. The correct relative position of flare and target depends upon the terrain. The point of burst should be such that it will give the most effective illumination on the target and to insure that the final travel of the flare is not between the observer and the target. In a strong wind, this will necessitate placing the point of burst some distance from the target so that the flare will drift to the desired location near the target. Generally, the position of the flare should be slightly to one flank of the target and at about the same range. If the target is on a forward slope, the flare should be on the flank and at a slightly shorter range. For a precision adjustment on a very prominent target, better visibility may be obtained by placing the flare beyond the target in order to silhouette the target. In this case, care must be taken that the adjustment is made on the target and not on its shadow.

e. A strong wind may decrease the time interval necessary between rounds when firing for continuous illumination.

f. It is best to observe in the illuminated area from a location as close as possible to this area. In the event that the observer cannot get close to the illuminated area, good observation can be obtained from ranges up to 2,500 yards. Observation on prominent targets can be obtained at ranges up to 4,000 yards.

g. The size of the area effectively illuminated depends upon the observing distance. For one 155-mm shell, it is approximately 1,000 yards in diameter, when observing from medium ranges. Two rounds bursting simultaneously at about the same place produce a better-lighted area and may be used when observing conditions are poor because of haze, smoke, dust, or long observing range. The observer obtains this type of illumination by sending TWO GUNS.

h. Two rounds fired with pieces converged set to burst simultaneously at 700 yards difference in range, or fired at the same range with a 700-yard deflection spread (for 155-mm), will give better observation than a single flare and will reduce the shadows resulting from a single flare. When this type of illumination is desired, the observer includes in his initial fire request TWO GUNS, RANGE (DEFLECTION) SPREAD. Such a pair of rounds will permit much better observation of the terrain than two single rounds fired at the same point. In searching an area, sufficient rounds, properly located to cover the area, should be fired simultaneously. Firing rounds simultaneously, each round on the corner of a square (the sides of the square being equal to the optimum distance between bursts for the caliber concerned), will illuminate an area more than 1,000 yards square with no shadows or dark areas. To obtain this type of illumination, the observer sends FOUR GUNS. When the observer calls for a range or deflection spread or a square, the center of the pattern is centered over the area indicated by the observer.

i. Illuminating shell may be adjusted over a point of known range and may be transferred to other points at known ranges. However, the effect of the wind on the flare may reduce transfer limits considerably. A correction to the range obtained from the adjustment is applied as a flat correction. This flat correction to the range is adopted rather than a percentage (K) correction because the effect of the wind upon the travel of the flare after it explodes is probably more important than the change in range to the point of burst caused by the weather. The refinement of adjusting the illuminating shell closer than 100 or 200 yards to the target usually is not justified. An adjustment must take into account the direction and velocity of the wind around the point of burst.

j. Any changes in the height of burst should be made in multiples of 30 yards. The slight variation in the time of burning of the individual flares renders useless any closer adjustment of the height of burst. When the point of burst is too high, the change required is estimated from the position of the flare when it dies out. When the point of burst is too low, the change required is estimated from the length of time the flare burned on the ground.

k. When firing illuminating shell with the 155-mm howitzer, no charge greater than 5 should be used in order to avoid ripping the parachute when it opens after ejection from the shell.

102. NIGHT ADJUSTMENT OF ARTILLERY. **a.** When the tactical situation requires, night adjustment of artillery fire and surveillance of fires can be accomplished by employing illuminating shell. If an operation includes the use of "artificial moonlight" or if the observer has control of searchlights for direct illumination, he may adjust artillery fire at night by making use of these types of illumination. However, "artificial moonlight" usually affords very limited observation since the light is diffused over a wide area and may not be controlled by the observer. Searchlights used for direct illumination may be neutralized readily by enemy fire if they remain in operation for more than a few seconds at a time. With the use of illuminating shell, these disadvantages are overcome, since the observer can obtain satisfactory and continuous illumination of the target area and has direct control of this illumination through normal channels.

b. When an adjustment mission is to be fired during darkness with the aid of illuminating shell, the observer indicates in his initial fire request that he will adjust the illuminating shell; for example, he might send—

FIRE MISSION,
AZIMUTH 3750,
KING MIKE 7,236 (to indicate point of burst of the illumination),
TANKS AND INFANTRY ASSEMBLING,
ONE GUN (to indicate that one-gun illumination is desired),
ILLUMINATING,
WILL ADJUST.

c. The observer adjusts the illuminating shell to the desired location; then, with continuous illumination, he adjusts the remaining pieces on his target, using the appropriate projectile and fuze. During the adjustment of the illumination, normally fired by flank piece, the other pieces of the battery follow all deflection commands. When the illuminating shell has been adjusted satisfactorily, the observer designates the location of his target with respect to the burst center of the illumination and begins the adjustment of HE shell; for example—

CONTINUOUS ILLUMINATION,
AZIMUTH 3650,
FROM ILLUMINATION,
LEFT 100,
SHELL HE,
DROP 200.

If desired, he may specify the length of time for the illumination to continue. The azimuth to the target is announced even though it may be close to the point of illumination.

d. When CONTINUOUS ILLUMINATION is announced, no further changes in data are made for firing illuminating shell unless called for by the observer. The piece used to fire the illuminating shell continues to fire at the rate of one round every 30 seconds (for the 155-mm howitzer).

e. The HE adjusting piece is (pieces are) fired at the deflection and range indicated by the observer's corrections. The fire-direction center determines from the illuminating shell firing table the range at which the illuminating shell is being fired, then determines from the HE shell firing table the elevation for the target corresponding to the range indicated by the observer's corrections.

f. When the piece firing the illuminating shell is from a different battery than the one firing HE, the illumination is adjusted and then initial data are sent to the battery firing HE. If the location of the target is known with sufficient accuracy, data may be sent to both batteries initially. If the situation warrants, the battery firing HE may be laid for direction by sighting on the flare.

g. If, during the adjustment, the observer desires to move the illumination and the HE, he prefaces the command pertaining to illumination with ILLUMINATING and those pertaining to HE with HE; for example—

ILLUMINATING, ADD 100;
HE, RIGHT 60, ADD 200.

Section VI. COMBINED OBSERVATION

103. GENERAL. Conduct of fire is termed *combined* when there are two or more observers placed so that their observing lines intersect at the target at an appreciable angle. Combined observation is useful for registration (center of impact and high burst); for adjustment when deviations but not sensings can be reported, as in night adjustments; for accurate surveillance of scheduled missions; and for registration and surprise area fire when the target grid is being used as described in paragraph 105. The most serious limitation is the difficulty of coordination between two or more observers, especially in regard to timing, communication, and target designation.

104. USES WITHOUT THE TARGET GRID (par. 223). The location of the observers must be known. The observer must be furnished with an angle-measuring instrument, such as an aiming circle or field glasses. Each observer reports the instrument reading and verticle angle, or deviations to each burst. From the combined information given by the observers, appropriate corrections are made to firing data.

105. USES WITH THE TARGET GRID (par. 224). Combined observation can be used without knowing the location of the observers or having their positions plotted when the target grid is used at the fire-direction center. Both precision and area missions can be fired. Area fire with surprise effect can be placed on any target that can be identified by both observers. Observer procedure is the same as that used by a single observer in making an adjustment. No special observer procedure is involved. Deviations and corrections in yards must be reported accurately to fire-direction center.

PART THREE

MAP DATA AND CORRECTIONS

CHAPTER 11

GRID SYSTEMS AND PLOTTING

106. DESCRIPTION. **a.** A grid, as used on military maps, is composed of north-south lines showing distances east of an origin, and east-west lines showing distances north of the same origin. The distance between grid lines superimposed on a large scale map (1/25,000 or larger) is 1,000 meters (or yards). A grid of this type printed on a map or on plain paper so that azimuth and scale are accurate, is a *fire-control grid*. The normal scale is 1/25,000, but scales from 1/20,000 to 1/50,000 are usable substitutes.

b. The grid lines are numbered in accordance with the grid system to which the map conforms. Military maps may be provided with a standard grid for a particular theater of operations, or with an arbitrary grid used for a single map or for a limited area.

107. COORDINATES. **a. Writing coordinates.** The distance in meters of any point east of the zero Y-line is the X-coordinate, and the distance north of the zero X-line is the Y-coordinate. In writing coordinates, the X-coordinate is written first and the Y-coordinate last with a dash between, and the whole is included in parentheses, thus: (804.729–1286.684). A decimal point is used to mark the division between thousands and hundreds of meters. When it is desired to locate a point in three dimensions, as on a survey form, the altitude above the datum plane is called the Z-coordinate. In map data and corrections, it is called the altitude.

b. Designation of sheet. The name of the sheet of the map is part of the designation of a point by coordinates; when the identity of the map is clear to all concerned, its designation need not be given.

c. Abbreviated coordinates.

(1) If location to the nearest 10 or 100 meters only is desired, or if the measurements cannot be made with greater accuracy, the digits indicating units or tens, respectively, may be omitted. Thus, the coordinates of a point may be written—

(804.729–1286.684)	to the nearest meter.
(804.73–1286.68)	to the nearest 10 meters.
(804.7–1286.7)	to the nearest 100 meters.

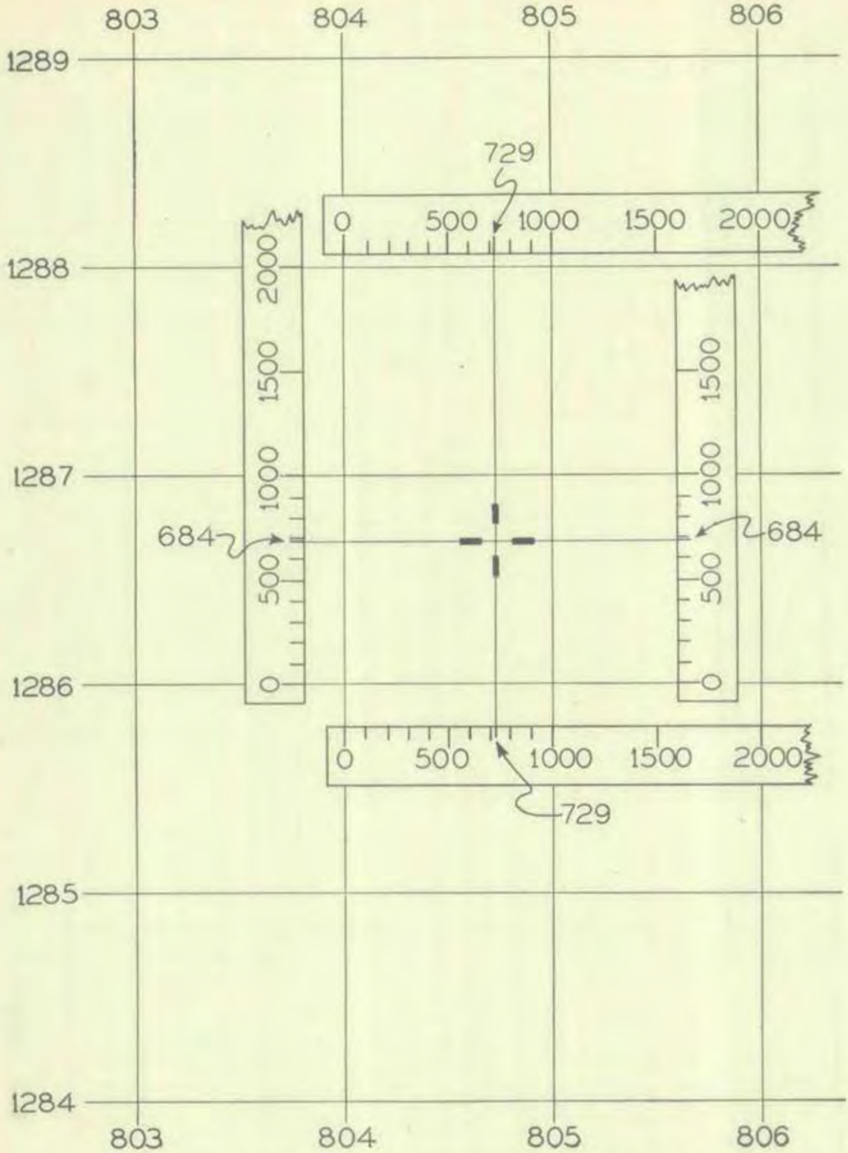


Figure 38. Plotting a point from coordinates on a normal grid.

(2) It seldom is necessary to give more than two digits left of the decimal for each coordinate. The coordinates for the point given above then would be (04.729–86.684).

(3) If the point is fixed within an area 10,000 meters square, only one digit need be given before the decimal point of each coordinate. The coordinates of the point given above would be (4.729–6.684); to the nearest 100 meters (4.7–6.7). The

decimals and the dash may be omitted (4767). These are known as abbreviated coordinates.

108. PLOTTING A POINT FROM COORDINATES. a. Normal grid. (See fig. 38.) To plot a point whose coordinates are (804.729–1286.684), place the zero of the scale on Y-line 804.000, and the 1,000-meter point on Y-line 805.000. Holding the scale about one square above the approximate location of the point, mark 729 meters with a fine-pointed pencil or plotting needle. Place the scale about one square below the approximate location of the point, repeat the operation, and connect the two marks with a fine, light line. This will be a Y-line passing through the point. In a similar manner, determine the X-line passing through the point. The intersection of these lines is the desired point. If the plotted point is to be used a number of times, the intersection of the lines is pricked with a fine needle to prevent erasure, and the lines in the vicinity of the point are accentuated with a soft pencil. These accentuations do not extend to the point.

b. Grid lines closer than normal. (See fig. 39.) Plot the point as before, inclining the scale so that zero is on one grid line and the 1,000-

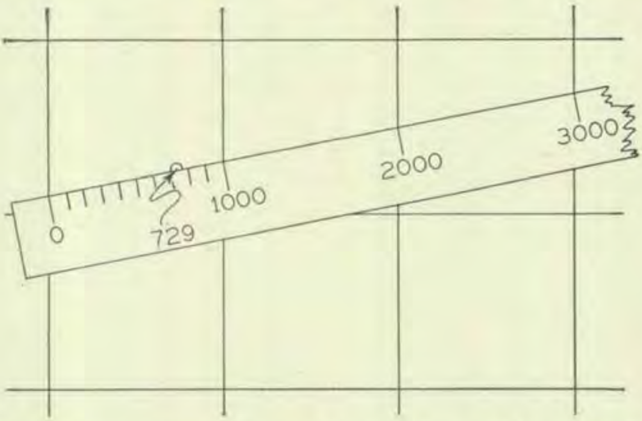


Figure 39. Plotting a point from coordinates when grid lines are closer than normal.

meter point is on the other. The point then will be plotted in its true relation to the grid, as the digits after the decimal point express the proportional part of the distance between grid lines.

c. Grid lines more distant than normal.

(1) (See *a*, fig. 40.) Measure the distance between the grid lines and find the difference from normal. The proportional part of this difference is added to a measurement. For example, if the distance between grids measures 1,020, the difference from normal is 20 meters, and the proportional part of this difference for a 400-meter measurement is 400/1000 of 20,

or 8 meters. The 400-meter measurement then is scaled as 408 meters.

(2) (See *b*, fig. 40.) Similar results can be obtained by inclining the scale so that zero is on one grid line and the 2,000-meter point is on the next adjacent grid line. The meters to be plotted are multiplied by 2, and that distance scaled. In the above example, in plotting the *X*-coordinate, the 400-meter measurement would be scaled as 800 on the inclined scale.

(3) (See *c*, fig. 40.) If a point lies about midway between the grid lines, the measurement may be made with satisfactory

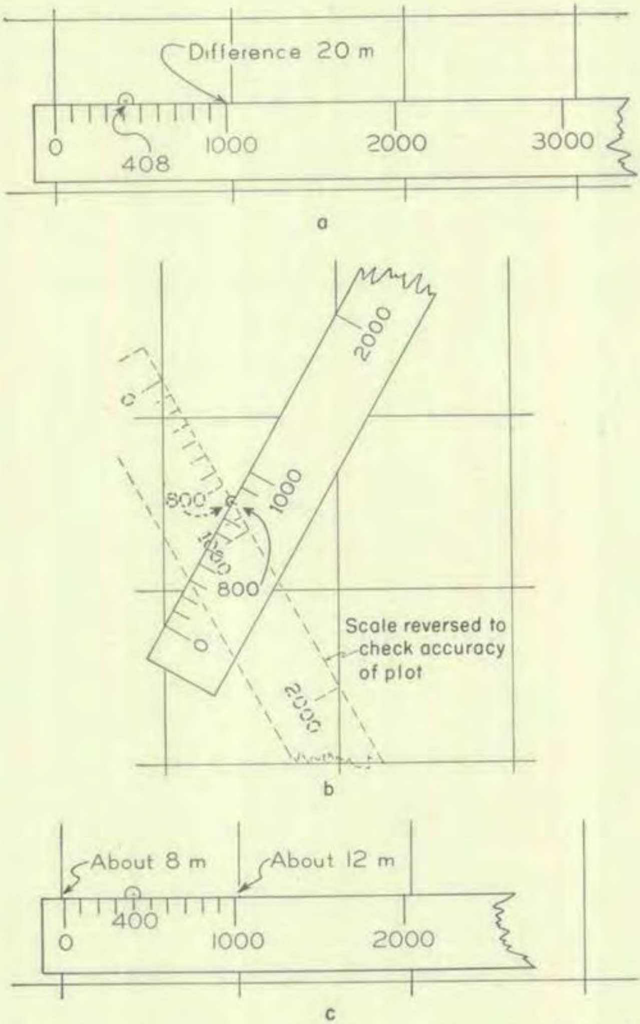


Figure 40. Methods of plotting points from coordinates when grid lines are more distant than normal.

accuracy by placing major graduations of the scale, such as 0 and 1,000 at equal distances from the proper grid lines and making a direct measurement of the distance desired. If the point is not midway between two grid lines, the distance between the grid lines first is measured and the difference from normal found. A major graduation of the scale then is offset from a grid line by that portion of the total difference which is proportional to the approximate distance to the point from the grid line. For example, in sketch *e*, figure 40, the point to be measured lies about four-tenths of the distance from the left grid line to the right grid line. With a total difference of 20 meters, the zero graduation is placed 8 meters from the left grid line ($.4 \times 20 = 8$). A direct measurement of the distance then is made with the plotting scale in this position.

109. MEASURING THE COORDINATES OF A POINT. Coordinates are measured in the same manner as they are plotted except that the distance is read directly between the point and the grid line. Write the number shown at the top or bottom of the Y-line west of the point; place a decimal point, and write the distance of the point from this Y-line. Place a dash then the number shown at the right or left end of the X-line south of the point; place a decimal point and then write the distance of the point from this line. Inclose the whole in parentheses. If abbreviated coordinates are desired, make the measurements to the nearest 10 or 100 meters, depending upon the approximation desired. If the grid lines are not a standard distance apart, the measurements are made as in plotting points.

110. USE OF THE COORDINATE SCALE. a. The method of plotting described in paragraph 108 is the accurate method used for survey and for plotting of target locations for prearranged fires. However, it is rather slow when the rapid massing of fires on targets of opportunity or on transient targets is necessary. With a coordinate scale, such as shown in figure 41, targets may be plotted more quickly and with sufficient accuracy. The scale should be placed so that its horizontal scale is in coincidence with a grid line.

b. To measure the coordinates of a point with a coordinate scale, the coordinates of the lower left-hand corner of the grid square containing the point are determined first. The readings from the coordinate scale then are added to the coordinates of the grid square (fig. 41).

111. MEASURING AND PLOTTING ANGLES WITH A PROTRACTOR. a. General. The center of the protractor must be placed exactly over the vertex of the angle and the base exactly over one side of the angle.

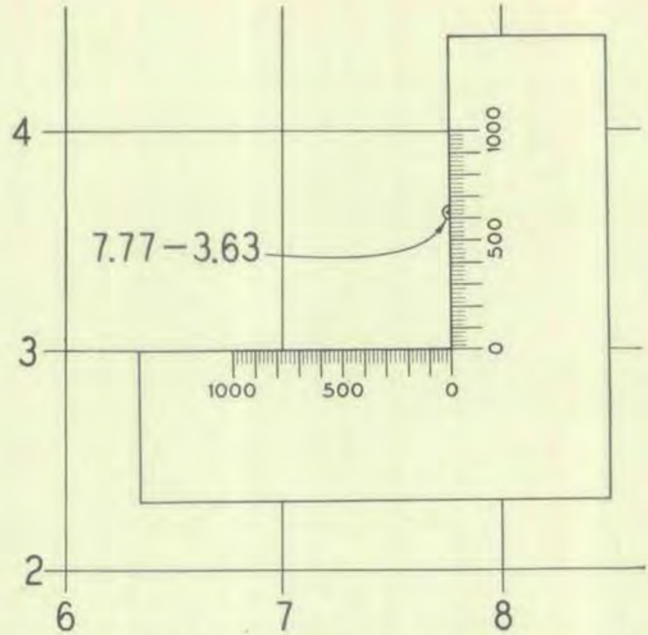


Figure 41. Method of using the coordinate scale on a normal grid.

For greater accuracy, measure the angle with both sides of the protractor and take the mean of the readings. For example, measure first with the arc to the right of the center, then with the arc to the left of the center. The difference, if any, between the readings will be small. The mean of the readings is used.

b. Measurement of a Y-azimuth.

(1) *Orienting the protractor from a Y-line.* (See *a*, fig. 42.) The *Y*-azimuth of a line can be measured by using this line's intersection with a *Y*-line as the vertex. The protractor is placed so that the clockwise angle, *Y*-line to given line, is read. If the *Y*-azimuth is greater than 3,200, the proper relation of the measured angle to 3,200 or 6,400 must be determined.

(2) *Orienting the protractor from an X-line.* (See *b*, fig. 42.) The *Y*-azimuth also may be measured by using the intersection of the line with an *X*-line. Place the center of the protractor over the intersection, and the 1,600-mil graduation of the protractor on the *X*-line; the reading of the line is the *Y*-azimuth. If the Y-azimuth is greater than 3,200, the proper relation of the measured angle to 3,200 or 6,400 must be determined.

c. To draw a line of given azimuth through a point. If the point is on either an *X*-line or a *Y*-line, the line is drawn in the same manner as described above for measurement of *Y*-azimuth. If the point is not on a grid line, the line may be drawn in either of the following ways:

(1) (See fig. 43.) The protractor is placed with its center exactly over the point, and the base of the protractor roughly parallel to either an X or Y grid line. Rotate the protractor about the point until an X-line (Y-line) cuts off the same length of arc on both ends of the protractor. In figure 43, the X-line cuts 165 mils of arc from each end of the protractor. The base of the protractor now is parallel to the X-lines (Y-lines). A line of given azimuth (or back azimuth) is

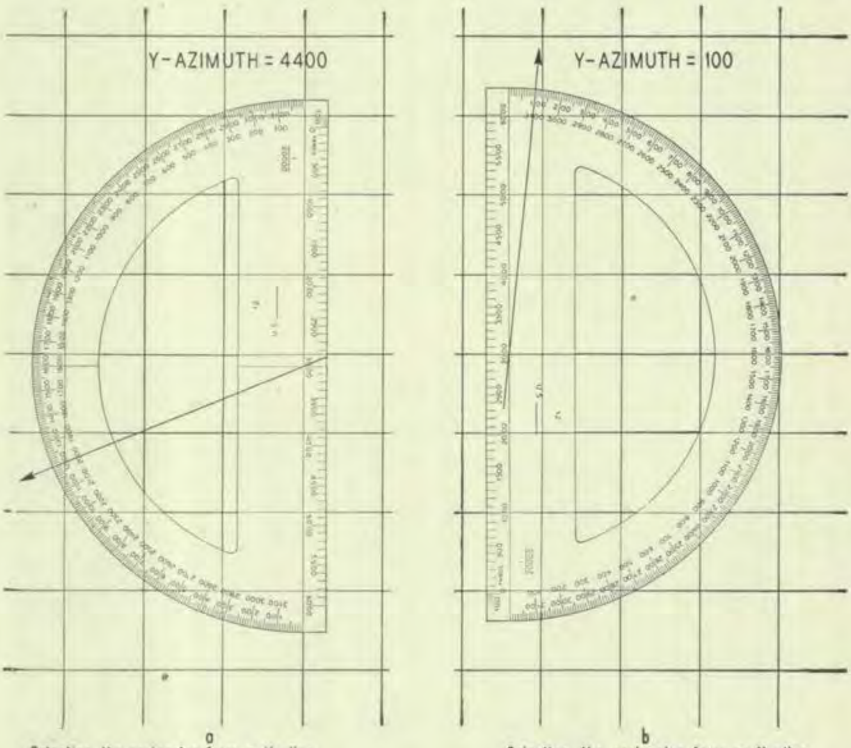


Figure 42. Methods of measuring Y-azimuth with a protractor.

drawn by marking a point at the circumference of the protractor and drawing a line through the given point and the marked point. In figure 43, the line drawn has a Y-azimuth of 5,635. Care must be taken to add or subtract multiples of 1,600, depending on the quadrant of the azimuth in question.

(2) (See fig. 44.) The protractor is placed with its center over a grid line adjacent to the point. The protractor then is revolved until the grid line passes through the angle giving the desired azimuth. The protractor is held in this position and moved along the grid line until the zero line of the protractor passes through the point. The line of

903448°—50——8

desired azimuth is drawn by marking a point at the zero line of the protractor and drawing a line through the marked point and the given point.

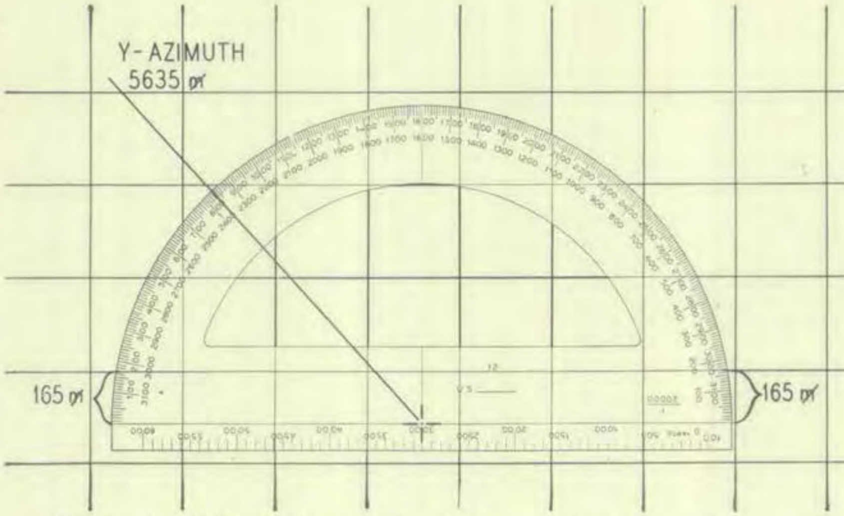


Figure 43. Method of drawing line of given Y-azimuth through a point.

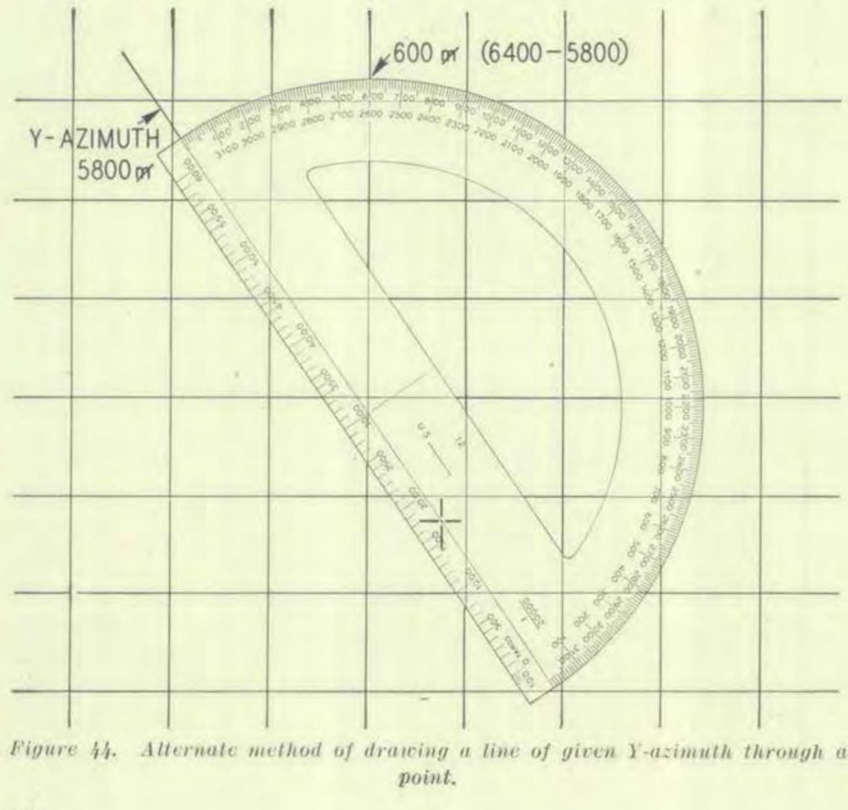


Figure 44. Alternate method of drawing a line of given Y-azimuth through a point.

112. MEASURING AND PLOTTING DISTANCES WITH THE PLOTTING SCALE. **a. Measuring.** The most accurate method of measuring distances is with the plotting scale.

b. Plotting.

(1) After the direction of a line has been established on the chart (par. 111), its length may be plotted with the plotting scale.

(2) A more accurate method of plotting a definite line for distance and direction is to plot its extremities, using coordinates. Frequently, the coordinates of the ends of a line will be too close together to provide a good base for drawing the line. In order to get points that are more widely separated but on the same line, determine the differences in the X and Y coordinates of the two points, multiply these differences by the same figure, and apply the products to the coordinates of the first point—the result is the coordinates of a third point which, when plotted, will lie on an extension of the line between the first two points. *Example* (fig. 45): The coordinates of point M are (860.200–1290.900), and the coordinates of point N are (860.500–1290.500). It is desired to plot the line MN. The points, when plotted, are too close together to allow a line to be drawn between them satisfactorily. To get points that are more widely separated, the procedure outlined above is followed.

Coordinates Point N	860.500–	1290.500
Coordinates Point M	860.200–	1290.900
Dx	+.300	
Dy		−.400
Multiply by same figure	10	10
	+3.000	−4.000
Apply to Point M	860.200–	1290.900
Coordinates N'	863.200–	1286.900

The Point N' is plotted and the line MN' is drawn. MN' has the same direction as MN.

113. MEASURING AND PLOTTING ANGLES AND DISTANCES WITH THE RANGE-DEFLECTION FAN. **a. General.**

(1) When several angles and distances are to be plotted or measured, using one point and one line of direction, the procedure is facilitated greatly by the use of the range-deflection fan. (The methods explained in paragraphs 111 and 112 will afford

a greater degree of accuracy.) The range-deflection fan is of particular value in the fire-direction center for use in determining deflections and ranges, and for plotting targets. It is graduated in mils and yards to a scale of 1/25,000. The range-deflection fan usually has three scales for measuring horizontal angles, each scale capable of measuring angles up to 500 mils. The space available on the firing chart will govern the selection of the scale to be used. If more than one scale falls on the chart, the scale most distant from the vertex should be used. The vertex of the fan always is placed against a pin in the point of origin.

(2) All scales of the range-deflection fan should be checked with scales known to be accurate. Fans with inaccurate scales should be replaced; however, small errors may be corrected or, for short periods of time, compensated for by means of a correction factor (K). The charts or maps upon which the

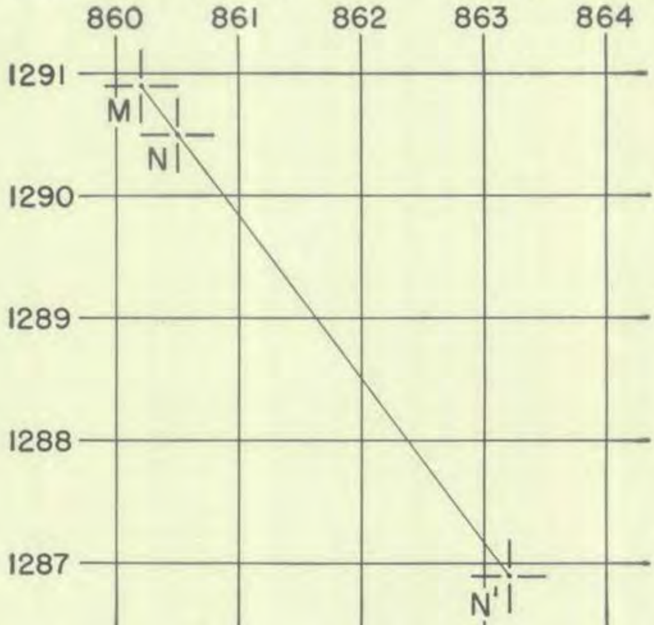


Figure 45. Method of plotting a line by coordinates.

fan is used also should be checked from time to time with the fan; for example, originally the distance between two points on the firing chart scales 6,620 yards; later, due to expansion of the paper, the distance between the same two points measures 6,680 yards. Since atmospheric changes may cause considerable distortion over a short period of time, corrections should be determined by periodically testing the charts or maps in both directions.

b. Measuring. (See fig. 46.) Assume that three points, A, B, and C have been plotted on the chart. It is desired to measure the distance from A to C and the angle between the lines AB and AC. With the vertex of the fan at A and one side running through B, a fine line is drawn along that side of the fan extending from approximately 1 inch short of to 1 inch beyond the selected deflection scale. An inverted arrow is placed on this line one-eighth inch beyond the selected scale. With the edge of the fan against a pin in C, the distance AC is read opposite the pin (8,100 yards) and the angle is read on the deflection scale opposite the arrow (240$\overline{m}$). (Note that the left side of the fan is against the pin in C. For a measurement to the left, the left side of the fan is always against the pin; for a measurement to the right, the right side of the fan is always against the pin.)

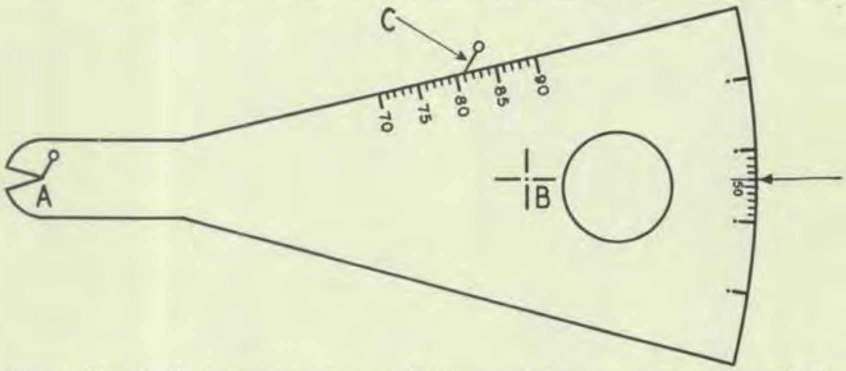


Figure 46. Method of measuring or plotting a distance and an angle with the range-reflection fan.

c. Plotting. (See fig. 46.) The procedure for plotting an angle and a distance is very similar to that used for measuring an angle. Assume in the situation above that points A and B have been plotted on the chart. It is desired to plot point C 240 mils left of the AB line at a distance of 8,100 yards from A. An extension of the AB line is made as described above. The fan, with vertex at A, is moved until the extension of AB cuts the fan at 240 mils right of the left edge. With the fan in this position, C is plotted at the left edge of the fan at a distance of 8,100 yards.

114. POINT DESIGNATION GRID (fig. 47). **a.** The printing of accurate fire-control grids on photos is impracticable because of distortion and the difficulty of reproducing a photo to a desired scale. Therefore, an arbitrary grid, known as the *point designation grid*, usually is used. This grid has no relation to the actual scale or orientation of the photo; it serves only for point or target designation and normally is not suitable for measurement of distance or azimuth. For a scale of 1/25,000 graduated in meters, use 1.575-inch grid squares; for a scale of 1/25,000 graduated in yards, use 1.44-inch grid squares.

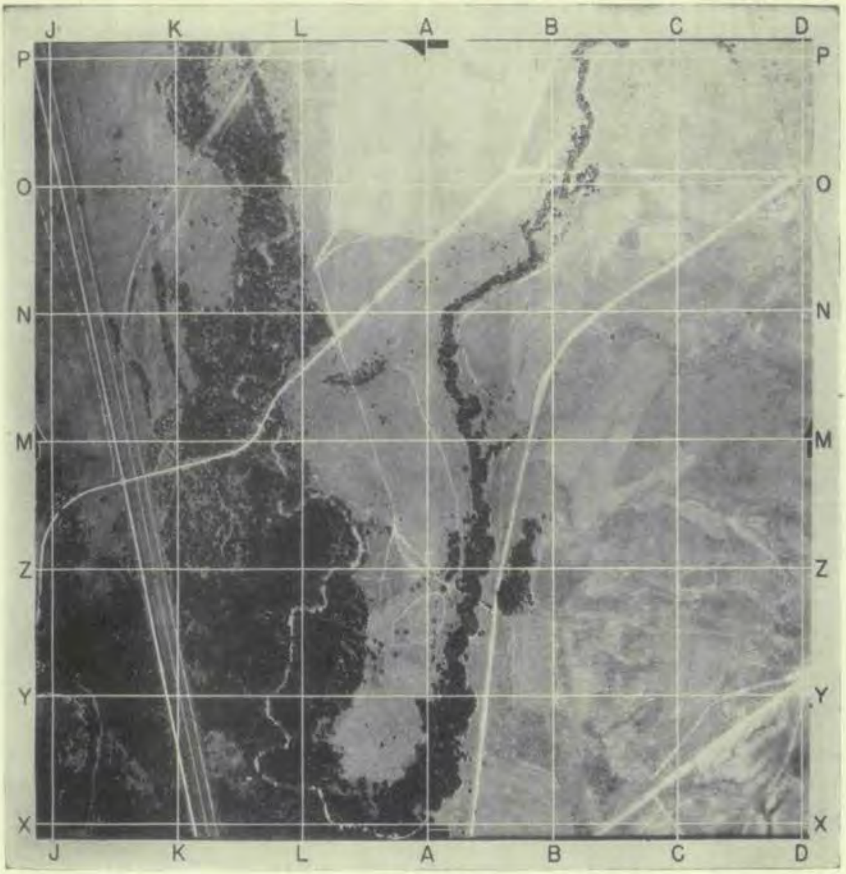


Figure 47. Photo with point designation grid.

b. The point designation grid may be printed on the photo. For ungridded photos, a transparent template with the grid printed on it may be used; it is essential that all who use this procedure place their templates in exactly the same position on the photos. The photo is held so that the marginal information is in the readable position, and the grid positioned so that A–A and M–M grid lines connect the fiducial marks as shown in figure 47.

c. The coordinate scale (fig. 48) is used to plot points or to measure coordinates on a chart having a point designation grid.

115. POLAR COORDINATES AND POLAR PLOTTING. Points may be designated by an angular measurement from a determined direction and a distance from a known point. The angular measurement and distance are known as *polar coordinates.* The angular measurements may be made from *Y*-north or clockwise from a line fixed by two known points. The distance may be measured with any predesignated scale. If the distance is measured with one scale and plotted with another, the conversion is accomplished as outlined in paragraph 327. The point of origin, the direction from which to measure the angle, and the scale to be used must be prearranged. The procedure of plotting a point with polar coordinates is known as *polar plotting.*

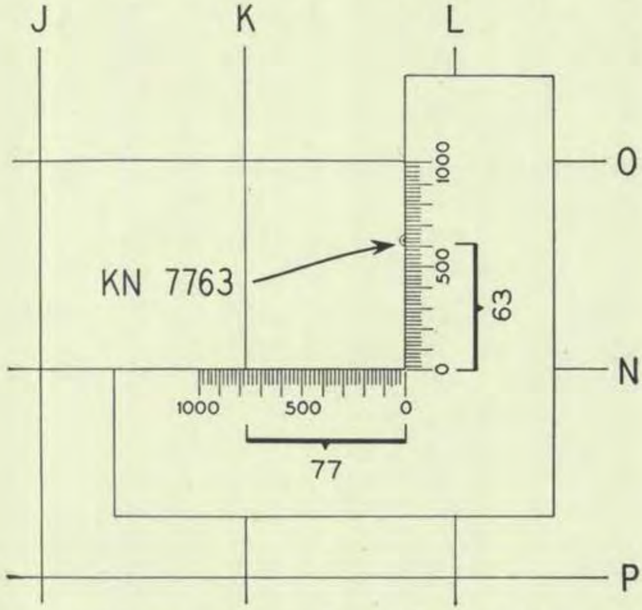


Figure 48. Method of reading coordinates with coordinate scale. The point indicated may be read, according to degree of accuracy sought, as KN 86 or KN 7763.

CHAPTER 12

FIRING CHARTS

Section I. GENERAL

116. DEFINITION. A firing chart is a map, photomap, grid sheet, or sheet of plain paper showing the relative horizontal and vertical positions of batteries, base points, check points, targets, and other details needed in preparing firing data.

117. PURPOSE. a. The purpose of a firing chart is to determine gun-target ranges, altitudes, and deflections. These data are used to lay the pieces. The accuracy of a firing chart should be verified by firing at the earliest opportunity.

b. The effectiveness of artillery fires and the amount of ammunition which must be expended in order to insure effective coverage are dependent upon the relative accuracy and completeness of the firing chart. Every effort must be made to supplement the firing chart by vertical and oblique photographs and stereoscopic pairs (or strips).

118. TYPES OF FIRING CHARTS. The two types of firing charts used in a fire-direction center are an *observed firing chart* and a *surveyed firing chart*. An observed firing chart is a chart on which the location of points and the orientation of pieces have been determined by firing. A surveyed firing chart is a chart on which the location of points are based on survey. If available, a map or photomap of suitable scale is used initially as a firing chart.

119. GRID SHEET. A grid sheet is a plain sheet of paper, printed with equally spaced horizontal and vertical lines called grid lines. The grid sheet may be assigned any scale desired. Since the grid sheet bears no relation to the ground, basic information must come from other sources. The location of all points placed on the grid sheet must be determined either directly or indirectly by survey or firing. The grid sheet frequently is used as a firing chart, supplemented by maps or photos. This procedure might be used when the accuracy or scale of the map or photo prohibits its use as a firing chart, or when the map or photo covers only a portion of the area.

120. BATTLE MAP. A battle map is a map based on ground control with detail supplied by photogrammetric means. It is as accurate as the ground survey from which it is made. Normally, the survey on which the map is based is indicated on the lower margin of the map. When one map of a series based on the same ground survey proves to be accurate, the implication is that the remainder of the series are accurate. In like manner, if one map of a series is proven to be inaccurate, the accuracy of the remainder of the series should be regarded with suspicion. A battle map based on accurate ground survey requires the least amount of additional survey, provides direction, horizontal and vertical control, and can be used as the basis for field artillery survey. If the battle map is not based on an accurate and adequate ground control, it should be used only to supplement the grid sheet for restituting points from the map to the grid sheet. Restitution does not remove errors; it merely ties individual points to a correct framework of critical points.

121. PHOTOMAP. **a.** A photomap is a reproduction of an aerial photograph or a mosaic on which grid lines, marginal information, and place names are added. The photomap provides up-to-date detail and is the best medium for designation of targets by the supported arms. Points can be located on the photomap with minimum survey, thereby facilitating horizontal control. All photomaps must be regarded with suspicion until their accuracy has been verified. Errors caused by tilt, distortion due to relief, and errors due to poor assembly may be present in mosaics. If points cannot be located on the photomap by inspection, the scale must be determined before points can be located on the photomap by survey. Normally, vertical control can be established only by estimation. Some photomaps have spot elevations but interpolation is very difficult and is not accurate. For unobserved fires, additional coverage is sought and more ammunition is expended until the accuracy of the photomap, having been checked by survey or firing, indicates that extra coverage and greater ammunition expenditures are unnecessary.

b. Even though the photomap is used initially, survey is started at once. This survey provides a check on the accuracy of the photomap. If the photomap proves to be inaccurate, a grid sheet firing chart based on survey is constructed.

(1) If the survey proves the photomap to be accurate, the photomap may continue to be the chart for maneuver of fires with normal coverage and ammunition expenditure.

(2) Although the photomap may be sufficiently accurate for a battalion firing chart, the grid sheet or battle map usually is necessary for massing or maneuvering the fires of the division artillery and those of the corps.

Section II. DETERMINATION OF MAP DATA

122. GENERAL. Data taken from a firing chart, whether the chart consists of a map, a mosaic, or an improvised chart, are described by the terms *map*, *map data*, *map range*, *map deflection*, and so on. Data normally are prepared by the battalion fire-direction center. The range-deflection fan normally is used for measuring range and deflection (fig. 49). Altitudes are taken from the chart.

123. PREPARING THE RANGE DEFLECTION FAN. Deflections, rather than shifts, are sent to the firing battery. In order to read deflections directly, the range-deflection fan is prepared as shown in figure 49; deflections are marked at hundred-mil intervals with a china-marking pencil. Either edge of the fan represents the deflection at which aiming posts have been set out by the battery. The hundred-mil intervals are numbered so that deflections to targets to the left of the base point are increasing and those to targets to the right are decreasing. Increasing and decreasing deflections should be marked in different colors; for example, if the edges of the fan represent deflection 2,800, then smaller figures, such as deflection 2,700, 2,600, etc., are marked in red, while large figures, such as deflection 2,900, 3,000, etc., are marked in black. As an aid to reading the proper scale, the letter "*T*" (target) is placed on the fan as shown in figure 49. The one on the right is red and the one on the left is black. When the side of the fan with the red "*T*" is against the target pin, the red scale is used; when the side with the black "*T*" is against the target pin, the black scale is used.

124. PREPARING THE FIRING CHART. Before the firing chart can be used for determining map data, the battery positions and certain indices as described below must be constructed. A color scheme is used for identifying battery locations, pins, and indices. The colors used are: Battery A—red, Battery B—white or black, and Battery C—blue.

a. Battery center. The chart location of the battery is the battery center. It represents a point on the ground at the approximate geometric center of the battery position.

b. Base-point line extension. The base-point line extension is the prolongation of a line passing through the battery center and the base point. A base-point line extension is drawn on the chart for each battery in such a manner that the line extends one inch on each side of the selected deflection scale of the range-deflection fan. An inverted arrow is placed one-eighth inch beyond the deflection scale, and marked with its appropriate color. This rigid system is used to facilitate measurement and to reduce the possibility of error. Figure 50 illustrates the proper method of plotting a base-point line exten-

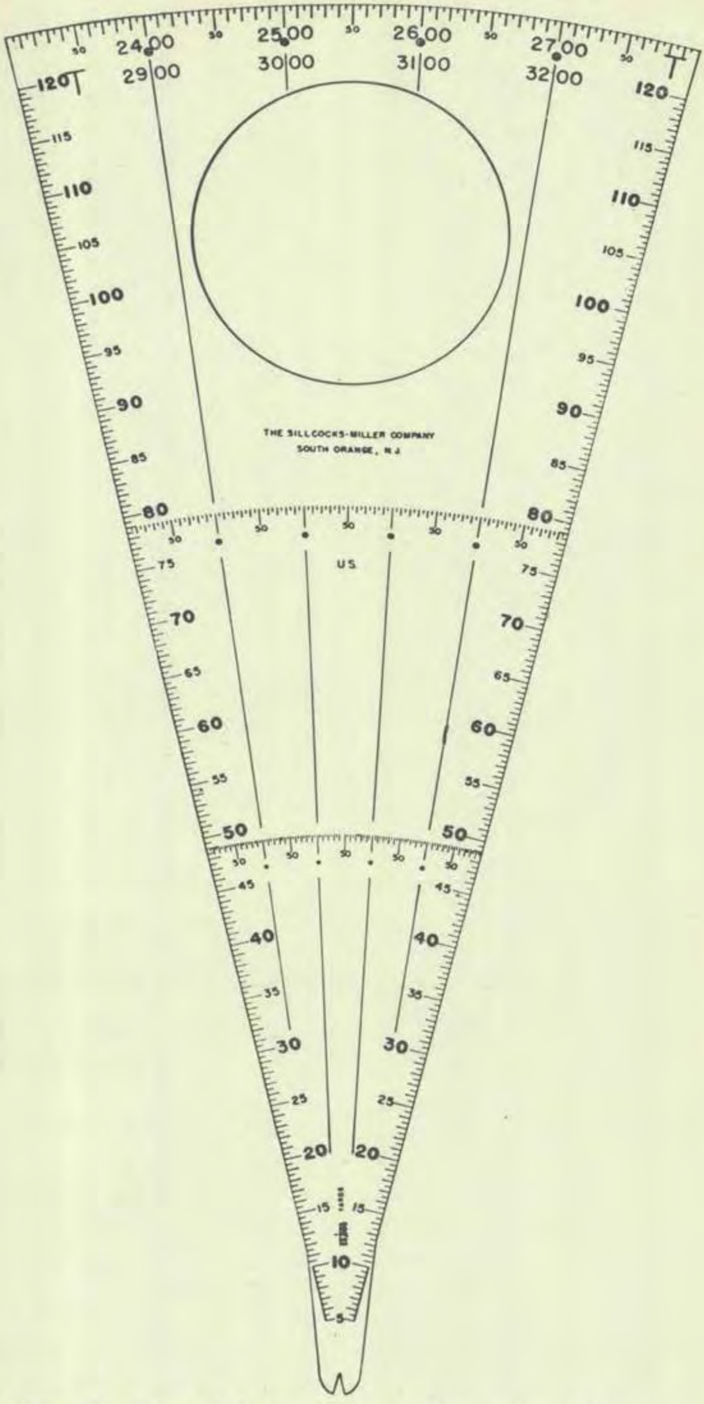


Figure 49. Range-deflection fan marked for reading deflections.

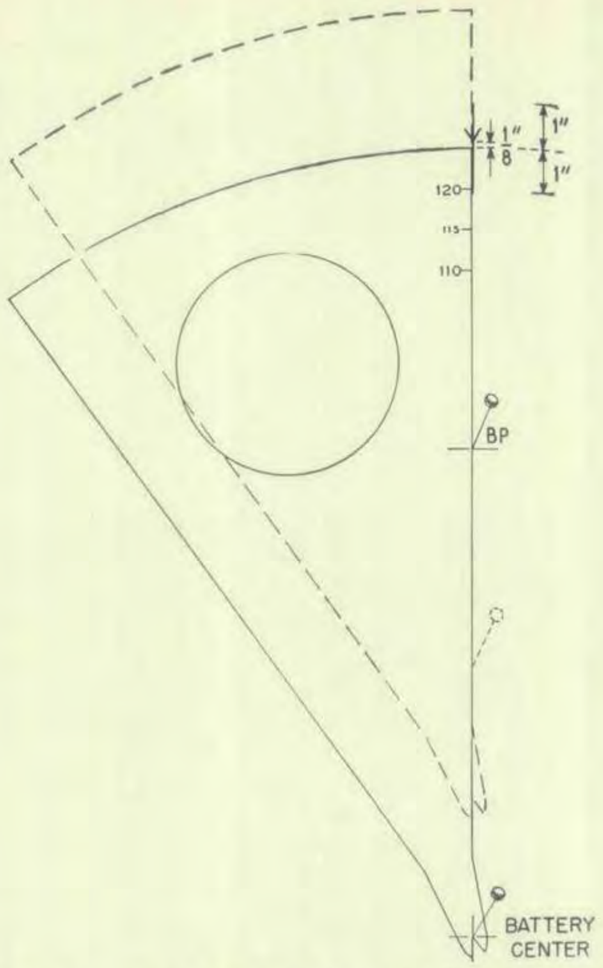


Figure 50. Method of plotting base-point line extensions.

sion. They are used temporarily as indices for all batteries in measing deflections with the range-deflection fan. Their use is continued until deflection indices are constructed.

c. Deflection index. On completion of the initial registration, an index is constructed for each battery corresponding to its adjusted deflection as reported by the battery executive. On a chart based on survey, this index is drawn opposite the adjusted deflection as read on the range-deflection fan when the edge of the fan is placed against the base point position and its vertex is at the plotted position of the battery center. (See par. 149 for construction of the deflection index on an observed firing chart.) It is constructed to extend one inch above and below the deflection scale of the fan, and is marked with an inverted arrow in the same manner as a base-point line extension. This new index is called the *deflection index* and is used thereafter in

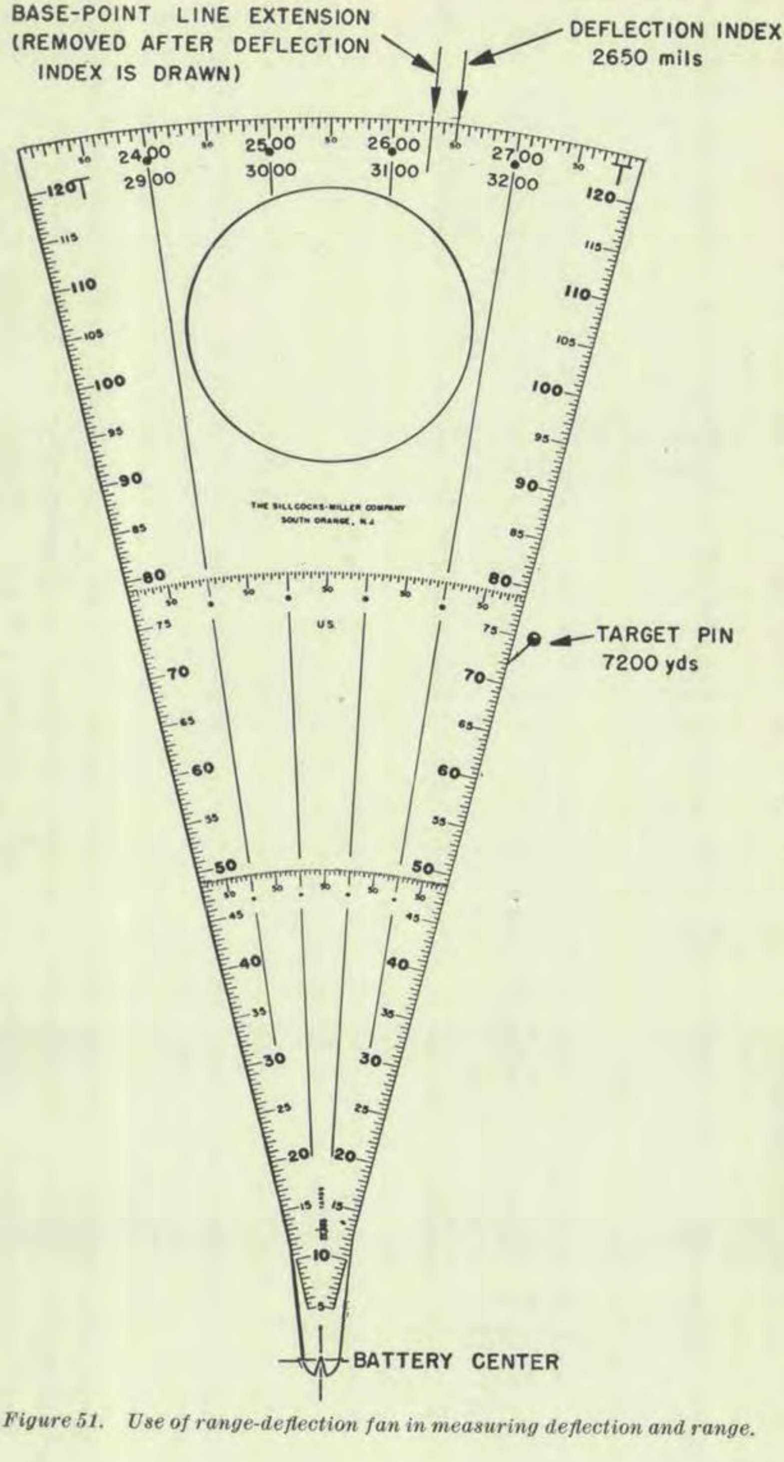


Figure 51. Use of range-deflection fan in measuring deflection and range.

reading deflections. Its use compensates for much of the deflection error that normally is found in the use of a firing chart. The base-point line extensions are removed after completing construction of the deflection indices. Figure 51 illustrates the construction and use of the deflection index.

125. DIRECTION. Measurements and computations are taken to the *nearest mil.* The deflection to the target is read from a deflection scale of the range-reflection fan (fig. 51) and is measured from the base-point line extension, or deflection index. The deflection also may be computed from the coordinates of the locations of the battery center and the target.

126. ANGLE OF SITE. The angle of site equals the difference in altitude, in *yards*, between piece and target (height of target), divided by the range (R). Altitudes are determined from a contoured map, by computation from instrument readings, from stereoscopic study of photos, by interpolation between known altitudes, or by a combination of these methods. Altitudes are taken from a contoured map to the nearest 5 feet, or nearest yard or meter. Altitudes computed by means of instruments or interpolation between known altitudes, are taken to the nearest yard. Care must be taken that the value of both vertical interval and the range are in *yards* before the angle of site is computed.

127. RANGE. Ranges are measured to the nearest 10 yards, the reading being taken from the scale along the edge of the range-deflection fan (fig. 51).

128. GRAPHICAL TABLES. The determination of data is simplified by the use of graphical tables. The two most commonly used for this purpose are the graphical firing table and the graphical site table.

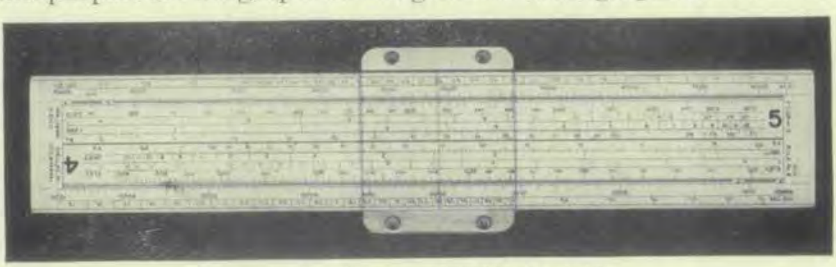


Figure 52. The graphical firing table.

a. Graphical firing table (fig. 52). The graphical firing table (GFT) is used principally for the determination of elevations and time fuze settings. Certain other data also are obtained easily from the graphical firing table. For detailed instructions on its use and nomenclature, see TM 9–526.

b. Graphical site table (fig. 53). The graphical site table (GST) is used to facilitate the determination of site (with or without complementary angle of site) and vertical intervals. Instructions for its use are written on the back of the graphical site table.

Figure 53. The graphical site table.

CHAPTER 13

DETERMINATION OF CORRECTIONS BY REGISTRATION

129. GENERAL. **a.** The most precise data result when map data are corrected by registration. A transfer of fire (K-transfer) consists of registration on a point whose position relative to the piece and targets is known and, from this registration, the determination of corrections to be applied to the map data for the targets. The adjusted data are those determined by precision registrations, or they are the piece settings and time setting actually used for a center of impact or high burst registration.

b. Site is determined from the firing chart if altitude control is available; if not, it may be obtained approximately by firing (par. 132). This site is subtracted from the adjusted *quadrant* elevation to determine the adjusted elevation if it differs from the site used during registration.

c. It is desirable to place the base piece directly over the battery center (par. 124). If the base piece does not coincide with the location of the battery center, the displacement of the base piece must be considered (fig. 54). For both the observed firing chart and surveyed firing chart, the adjusted deflection is modified by the amount necessary to center the battery on the base point or check point after a registration. This modified deflection always is used by the fire-direction center when constructing the deflection index (par. 124). When determining corrections, the map range from the battery center must be modified by the amount of base piece displacement (in yards) parallel to the direction of fire. This correction is the base piece displacement correction for range. Likewise, when plotting a battery on an observed firing chart, the range from the base point to the base piece must be modified by this correction for range.

130. COMPUTATION OF ADJUSTED ELEVATION FROM REGISTRATION.
a. With an equal number of *overs* and *shorts* during fire for effect, the adjusted elevation is the elevation (or mean elevation) at which the group was fired.

b. With an unequal number of *overs* and *shorts* during fire for effect, determine the difference between the number of *overs* and *shorts* (neglecting target hits). Apply the formula—

$$\left(\frac{\text{Difference in number of } \textit{overs} \text{ and } \textit{shorts}}{2 \times \text{number rounds used}}\right) \times \text{Fork}$$

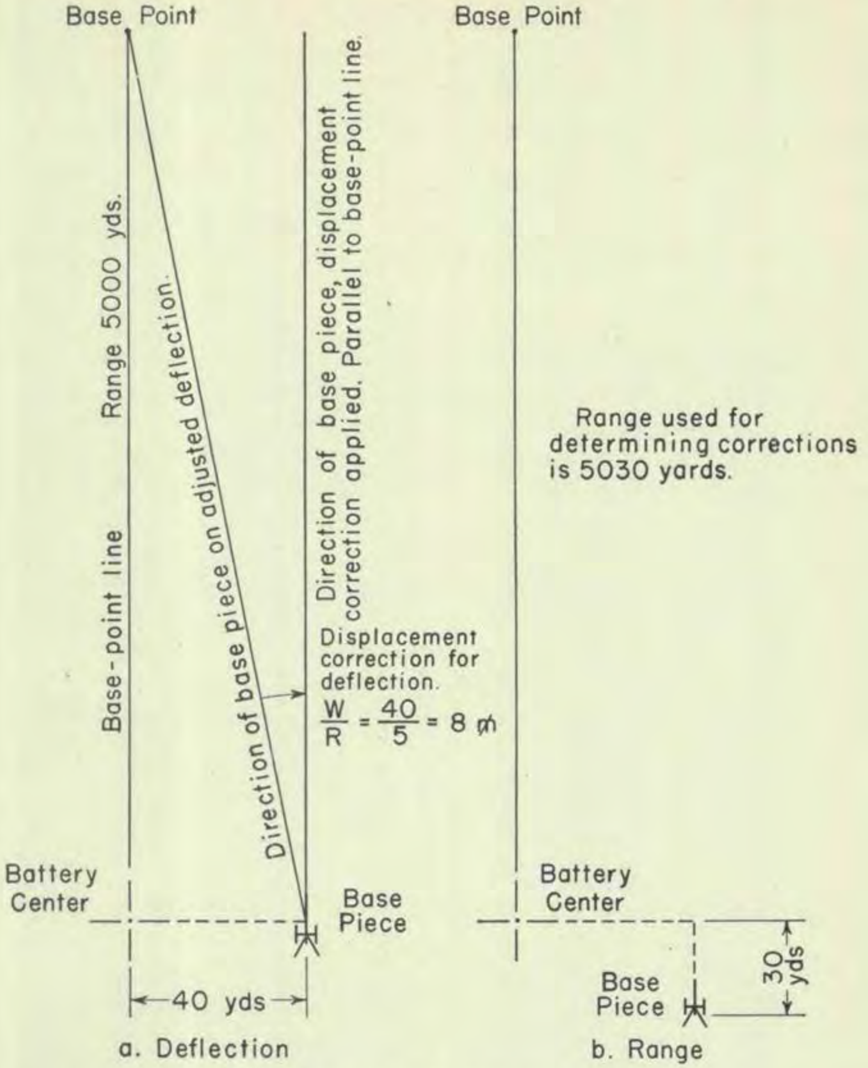


Figure 54. Base piece displacement corrections.

and add (subtract) the result to (from) the elevation (or mean elevation) used (par. 21). In low-angle fire, if the preponderance of rounds were *overs*, subtract; if the preponderance were *shorts*, add. In high-angle fire, the correction is applied in the opposite direction.

c. When two or more series of six rounds are fired during fire for effect for a more accurate adjustment, the correction is computed in the same manner each time. For the first series of six, the whole correction is applied; for the second, one-half of the correction is applied; for the third, one-third; for the fourth and all subsequent series, one-fourth.

131. COMPUTATION OF ADJUSTED TIME. **a.** The computation of adjusted time is accomplished in a similar manner to that used in paragraph 130. A slightly different formula is used:

$$\left(\frac{\text{Difference in number of } \textit{air} \text{ and } \textit{grazes}}{12}\right) \times .4 \text{ second}$$

(or size of bracket used)

b. Subsequent series of six rounds to improve accuracy have the same proportion of their correction applied as is indicated in paragraph 130.

132. DETERMINATION OF SITE BY FIRING. Registration on the base point or check point first must be made to determine adjusted deflection, adjusted time, and adjusted quadrant elevation. At the conclusion of the registration, the commands OBSERVE HIGH BURST, MEASURE ANGLE OF SITE, THREE ROUNDS, followed by the adjusted data, are sent to the executive. The executive increases the site by the amount necessary to place the bursts above the intervening mask, fires the rounds, and reports the observed angle of site to the mean burst center and the quadrant elevation at which the bursts were fired. The site from the base piece to the point of registration is determined as in the example below.

Adjusted data from registration with a 105-mm howitzer M2:

Charge 5,

Time 14.3,

Quadrant elevation 240.

Reports from executive:

Observed angle of site, +30;

Quadrant elevation at which rounds were fired, 280.

Angle of site, +30, plus complementary angle of site, $+2(+30\times .06)=\text{site}+32$.

$280-32=$ adjusted elevation 248 (adjusted elevation to mean burst center).

The site to the point of registration is determined by subtracting the adjusted elevation from the adjusted quadrant elevation.

$\text{Site}=240-248=-8$ mils.

Adjusted data: Time 14.3, site −8, elevation 248.

133. TRANSFER LIMITS. Corrections are assumed to be valid within transfer limits—namely, within ranges 1,500 yards greater or less than check point range, and within 400 mils in direction right or left of the check point, up to a range of 10,000 yards; for longer ranges, corrections apply within 2,000 yards of the check point for range and 4,000 yards for deflection. Registration corrections apply to a particular lot of ammunition. Check points usually are chosen so that any point in the target area will be within transfer limits of at least one check

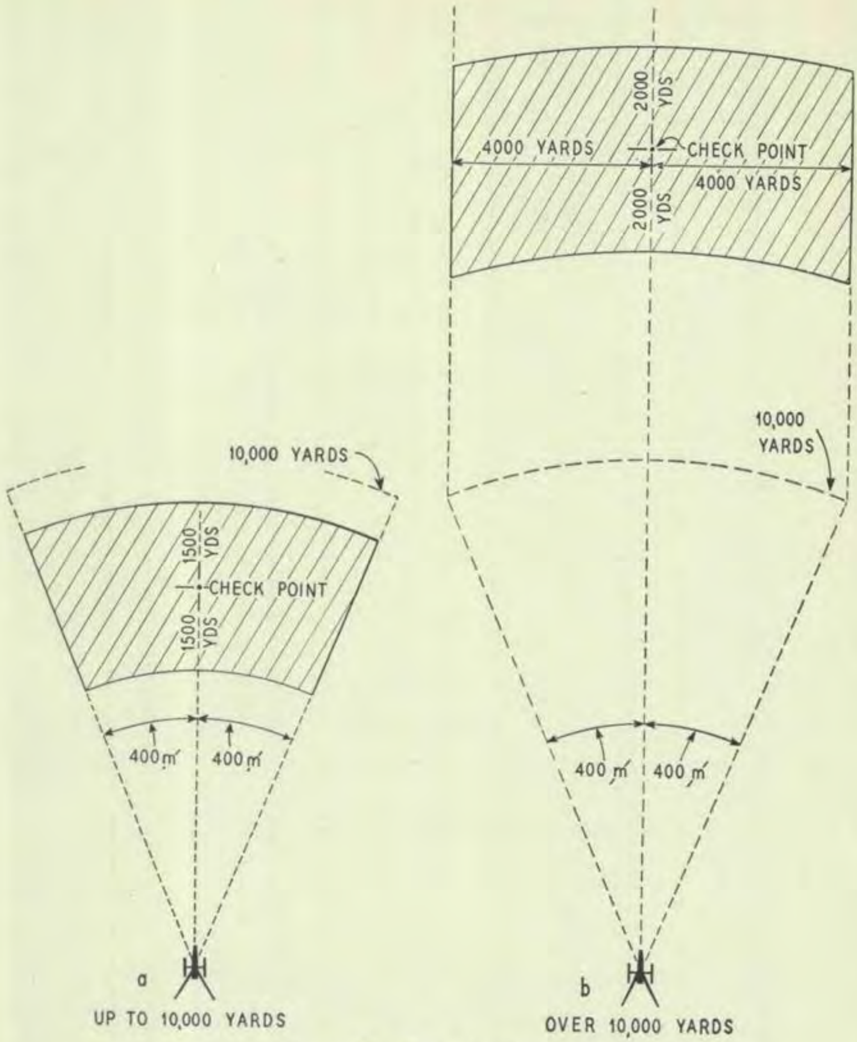


Figure 55. Transfer limits.

point; nevertheless, a minimum number of sets of corrections is desired (figs. 55 and 56). (For high-angle fire, see pars. 226–229.)

134. ELEVATION CORRECTION. a. Computation of *K*. Map range to a target is corrected on the assumption that the ratio of adjusted range to map range is a constant, K. In practice, K is expressed as plus or minus so many yards per thousand yards. It is determined as follows: Map range is subtracted from adjusted range (range corresponding to adjusted elevation). The difference is divided by map R. If the base piece is displaced from the battery center in the direction

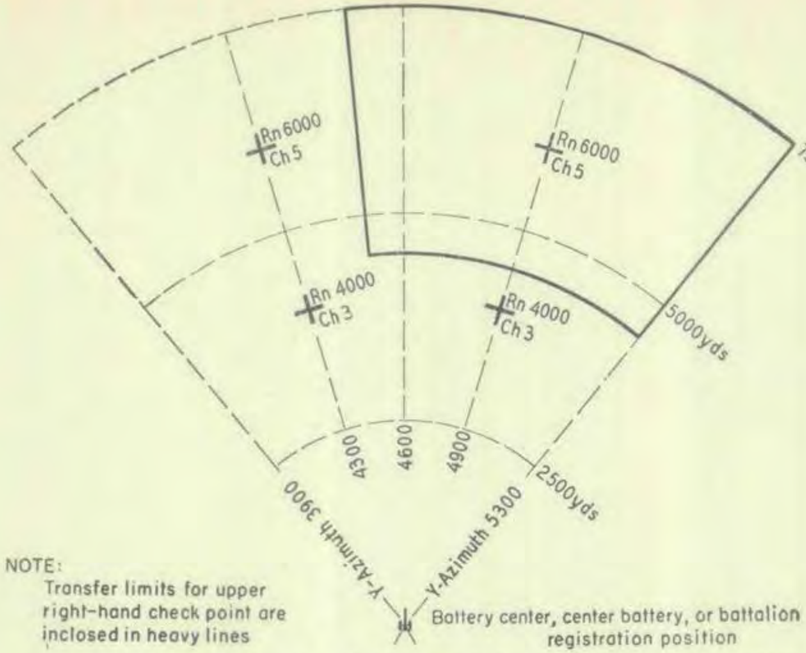


Figure 56. Ideal location of check points for use with 105-mm howitzer.

of fire, this displacement must be considered in the comparison of map and adjusted ranges (*b*, fig. 54).

b. Examples.

(1) Matériel, 105-mm howitzer, M2; charge, 4; map range from battery center to check point, 4,600 yards; gun displacement correction, +20 yards; map range from gun to check point, 4,620 yards; adjusted elevation, 395 mils. Range corresponding to elevation 395 is 4,820. K is $\frac{(4{,}820-4{,}620)}{4.6}$ or +43 yards per 1,000 yards.

(2) Matériel, 155-mm howitzer M1, firing shell HE; charge, 6. The base piece is over the battery center. A center of impact registration is fired with a quadrant elevation of 270. The map range to the plotted mean location of the rounds is 7,920. Angle of site is +17 mils. Complementary angle of site is $17\times.06=1$ mil. Elevation is $270-(17+1)=252$. Range corresponding to 252 is 7,460. $K=\frac{(7{,}460-7{,}920)}{7.9}=-58$ yards per 1,000 yards.

c. Graphical firing table. To set up the graphical firing table for determination of corrected elevation, the hairline is set over the map range corrected by any displacement of the base piece from the battery center, and a gage line is marked on the indicator over the adjusted elevation. Thereafter, the gage line shows corrected elevation for any range under the hairline.

135. APPLICATION OF ELEVATION CORRECTION. a. The determination of corrected elevation for a transfer of fire is a reversal of the process used in determining a K. To determine the corrected elevation, multiply K by map range in thousands of yards to obtain the range correction; add the correction algebraically to map range, and from the firing tables determine the elevation corresponding to the corrected range. For example: Matériel, 105-mm howitzer M2, using charge 7; $K=+24$ yards per 1,000 yards; corrected range for a target at range 9,360 yards=9,590 $(9{,}360+(24\times 9.4))$; corrected elevation=412 (tabular value for 9,590 yards). Corrected elevations may be computed for each target, or determined from an elevation correction scale.

b. With the GFT set up for the determination of corrected elevations, the corrected elevation is read under the adjusted gage line when the hairline is over the map range. With a GFT setting from registration of charge 7, range 8,550, elevation 355, the corrected elevation for a target at range 9,360 yards is read as 412.

136. TIME CORRECTION. a. Registration. The time correction at check point range is determined from a registration by comparing the adjusted time with the firing table value of time for the adjusted elevation. *Example:* Matériel, 105-mm howitzer M2, firing charge 5. The following data have been determined by precision registration on a check point:

Adjusted time	17.7
Adjusted elevation	292.

The firing table value of time corresponding to elevation 292 is 16.9. The time correction at check point range= +0.8 second (17.7−16.9).

b. Time *K*. The time correction is divided by map range to check point (in thousands of yards) to obtain the time K. In **a** above, time correction= +0.8 second; map range=5,270 yards; time $K=+0.8\div 5.3=+0.15$ second per thousand yards. Except when special corrections are applied (par. 43), it normally will be unnecessary to consider the gun displacement correction in the computation.

c. Graphical firing table.

(1) To set up the graphical firing table for the determination of corrected time, set the adjusted elevation gage line over the adjusted elevation, then mark the adjusted time gage line on the indicator over the adjusted time. In the example of **a** above, with the charge 5 graphical firing table, the adjusted elevation gage line is set over elevation 292 and the adjusted time gage line is marked over time 17.7.

(2) The time correction is represented graphically by the distance between the two gage lines, and is independent of the position of the hairline.

137. APPLICATION OF TIME CORRECTION. a. Computed. For any range within transfer limits, the time correction = time $K \times R$. This correction is applied to the firing table value of the time corresponding to the corrected elevation. For example, assume that a 105-mm howitzer battery, firing charge 5, determines a time K of +0.15 second per 1,000 yards, and a K of −44 yards per 1,000 yards; a K transfer is to be fired at map range 6,310 yards.

Corrected range (6,310 − (44 × 6.3))	= 6,030 yards
Elevation for corrected range	= 372 mils
Time corresponding to elevation 372	= 21.0 sec
Time correction = +0.15 × 6.3	= +.9 sec
Corrected time	= 21.9 sec

b. Time-correction scale. To facilitate the determination of time corrections for a number of targets within transfer limits, a time-correction scale similar to the deflection-correction scale, figure 57, may be constructed.

c. Graphical firing table. If the GFT has been set up for the determination of corrected time, the hairline is set over the map range, and the corrected time is read under the adjusted time gage line. With a GFT setting from registration of charge 5, range 5,270, elevation 292, adjusted time gage line over 17.7, the corrected time for a range of 4,800 is read as 15.9. A discrepancy between computed time setting and time setting appearing on the GFT will result from the fact that the time corrections determined by computation and determined from the GFT are not based on the same mathematical assumption. The discrepancy usually is small. Experience shows that there is little choice regarding the comparative correctness of the two methods.

138. CORRECTIONS FOR DEFLECTION. a. Deflection index. Following the initial registration on the base point, the adjusted deflection is reported by the battery executive to the fire-direction center, where the correction in mils for displacement of the base piece from the battery center is applied (*a*, fig. 54), and the deflection index is constructed (pars. 124 and 129**a**). If a subsequent registration results in an adjusted deflection which is different from that of the first registration, the value of the deflection correction is changed, as explained below, but the deflection index is not moved.

b. Deflection correction. The difference between the deflection as measured from the firing chart and the deflection which actually will place the center of impact on the target is the deflection correction.

(1) *Surveyed firing chart.* Following the initial registration, the deflection correction is zero at the map range of the point on which the registration was conducted (for example, base-point range). Variations from zero are marked on the range-deflection fan at the range corresponding to each elevation where drift changes (par. 8**a**). Corrections are applied to the left as range increases and to the right as range decreases. Subsequent registrations may indicate that the value of the total correction for deflection has changed. The deflection index is not moved, however. Instead, the old deflection correction scale is replaced by a new one which applies the latest correction. *Example:* Aiming posts were placed out at deflection 2,800 after the battery was laid for direction.

Data from initial registration		*Data from subsequent registration*	
Adjusted deflection as modified by the displacement correction	2, 810	Adjusted deflection as modified by displacement correction	2, 815
Deflection correction at the base point	0	Deflection correction at the base point	L5
Deflection index is constructed 10 mils right of the base-point line extension.		Deflection index is not moved from its original position.	

(2) *Observed firing chart.* The deflection correction is always zero at the base-point range with the variations from zero being due to changes in drift only.

c. Direction by center of impact. In case direction has not been given to the pieces by survey, direction may be established by having the location of a center of impact reported by an air observer or a ground observer having a commanding view of the area. (The ground observer should use an instrument and reference point to insure accuracy of location.) The following procedure is applicable: The adjusting piece is laid in the desired direction, and the center of impact registration is fired. Deflection is recorded. The deflection correction at the plotted position of the center of impact is zero.

139. DEFLECTION CORRECTION. a. For a range materially greater or less than check point range, differences in drift must be considered. Drift effect is always in the direction of the twist of the rifling (right for United States artillery) and increases with an increase in elevation. The application of differences in drift may be learned from a study of the following examples:

(Matériel, 155-mm howitzer M1, using charge 4. Deflection correction (from registration) = L3 at check point range of 6,000 yards.

Elevation	(Range)	Drift	Correction for difference in drift	Deflection correction
356	(6, 000)	6	0	L 3.
448	(7, 000)	8	L 2	L 5 (L3 + L2).
280	(5, 000)	4	R 2	L 1 (L3 + R2).

(2) Matériel, 105-mm howitzer M2A1, using charge 7. Deflection correction=R1 at check point range of 7,200 yards.

Elevation	(Range)	Drift	Correction for difference in drift	Deflection correction
264	(7, 200)	3	0	R 1.
275	(7, 400)	4	L 1	0 (R1 + L1).
326	(8, 300)	5	L 2	L 1 (R1 + L2).
222	(6, 400)	2	R 1	R 2 (R1 + R1).

b. The corrections may be placed on a deflection-correction scale (fig. 57). The corrections are shown at check point range, and are computed throughout transfer limits for each elevation at which the drift changes. Ranges at which these drift changes occur are shown to the nearest 100 yards, opposite the corrections, except that the ranges already appear on the range-deflection fan and are not required if the scale is drawn in its correct location on the fan. The deflection correction for any target is read opposite the appropriate range.

c. In high-angle fire, the drift changes very rapidly within each charge, and it is therefore impracticable to show the correction throughout transfer limits at each point where the drift changes. For this reason, a single deflection correction is determined for each charge and differences due to drift are applied for each individual elevation as it is fired.

140. CENTER OF IMPACT AND HIGH-BURST REGISTRATION. **a.** The most convenient method of registration and determination of corrections is to adjust a registering piece on a terrain feature identifiable on the ground and plotted on the firing chart. During the hours of darkness, however, such a method is not feasible, nor can it be used to determine corrections when no visible point exists in the target area which is suitable for registration. Such conditions do not reduce the need for registration corrections, but a different procedure must be employed to obtain them. Two methods of determining corrections under these circumstances are *center of impact* registration and *high-burst* registration. Although center of impact registration and

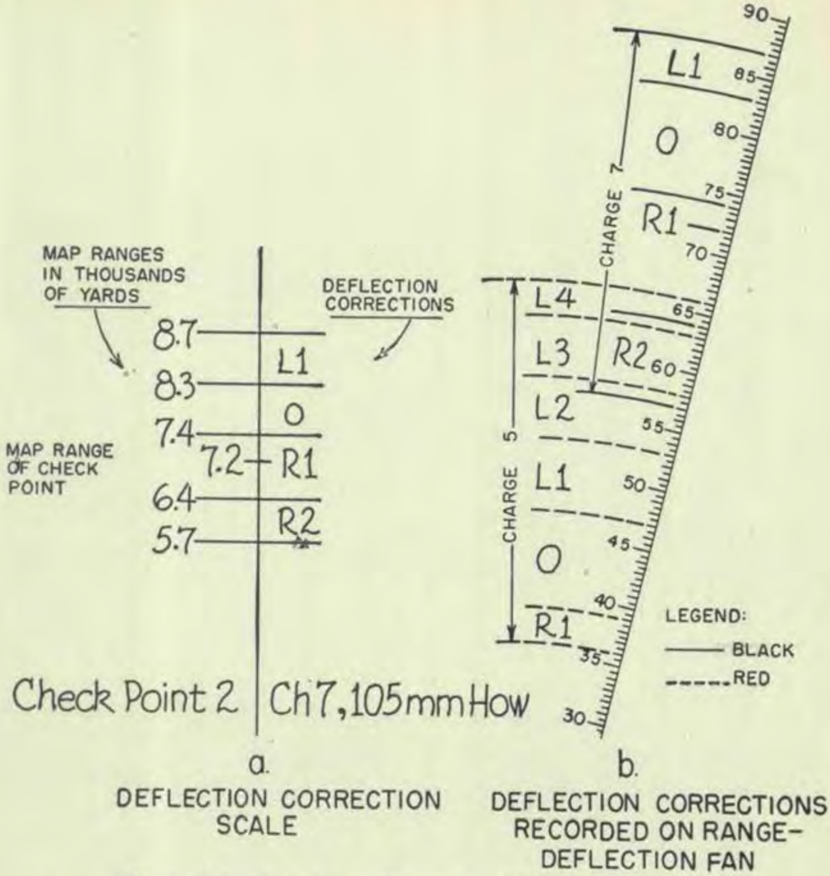


Figure 57. Methods of recording deflection corrections.

high-burst registration are identical in principle, they differ in the following particulars:

(1) A high-burst registration employs a time fuze and places a group of bursts in the air, but cannot be used if time shell is not available or if the range limitations of time shell imposd by the burning of the fuze prevent registering in the desired area. Center of impact is fired with impact fuzes and is not subject to these limitations.

(2) High-burst adjustments are suitable in a greater number of cases because air bursts are conspicuous and thus easier to observe, whereas impact bursts often are lost to one or both observers, especially in rugged terrain. At night, the air burst is a well-defined flash, easy to read in the reticle, whereas impact bursts often are a diffused glow.

(3) Time corrections may be determined by high-burst methods, but not by center of impact.

(4) High-burst registrations can provide corrections for that part of the terrain concealed to friendly observation, whereas center of impact can be conducted only on undefiladed terrain.

b. The center of the group of bursts fired by high burst (HB) or center of impact (CI), must be located by survey. Either the computed or graphic intersection method will be employed in performing the survey. The latter method entails long communication lines, widely separated points to be located by survey, and is more difficult to organize than the computed method.

c. Two observers are required. They are referred to as the left observer (OL) and the right observer (OR). The two observation posts used in the registration represent the ends of a base for survey work. These points must be selected so that the center of impact can be located by graphic or by computed intersection. An accurate firing chart is essential on which must be plotted the following points:

(1) Battery center, including altitude.

(2) One observer, including altitude.

(3) The second observer, if the graphic intersection method is to be employed.

(4) Deflection index, or base-point line extension.

(5) Reference point.

The relative altitude of the piece and the observer who is to measure the vertical angle also must be known.

d. The selection of a point on the chart, at which to fire the center of impact registration, is made with consideration being given to the terrain and the visibility from the observation posts. It is desirable that a terrain study be made during the daylight in order that the bursts may be placed at a point that will be visible to both observers. The approximate location of this point is used as a point on the chart from which data are computed for both observers and for the battery. The ideal location is a gradual forward slope that is free of heavy vegetation. The purpose of selecting such a point is to correlate the data for observers and battery. This point has nothing to do with the chart location of the center of impact for determination of corrections.

e. The observation posts should be established during daylight in order that the instruments may be oriented and a line materialized on the ground for orientation after dark. Orienting data include—

(1) Designation of the reference point.

(2) The instrument reading to the location of the center of impact (high burst) for each observation post. If both observation posts are plotted, their instrument readings may be measured from the chart. If only one observation post is plotted, an approximate instrument reading for the other may be determined by applying the apex angle at the expected

location of the center of impact (high burst) to the known instrument reading for the observation post which is plotted. The value of the apex angle is computed by the mil relation:

$$\frac{\text{Distance OL to OR}}{\text{Distance from plotted OP to target}} = \text{Apex angle}$$

(3) The vertical angle from each observation post to the location of the center of impact (high burst). This is determined by the mil relation. Communications should be established and checked prior to the registration.

f. Observation of the registration is accomplished as follows:

(1) Each observer should have an assistant if possible. Due to inaccuracies in orientation data and the brief appearance of the flash, it is difficult to place the cross hairs of the observing instrument on the initial burst, even if the burst is within the field of view of the instrument. If the observer sees the burst but cannot give a sensing, he should report DOUBTFUL.

(2) In the event that one observer obtains sensings and the other observer reports LOST on several rounds, it will be necessary to change the firing data, notifying both observers of such change.

(3) Night observation makes it impossible for the observer to place the cross hairs of the instrument on the burst. When the burst appears in the field of view of the instrument, it is possible for the observer to take a reading of the reticle scale and modify the instrument reading accordingly.

(4) Both observers may measure the vertical angle; however, it is mandatory that at least one of them makes this measurement.

(5) The message to the observers is as follows: *Prepare to observe center of impact registration. OL, instrument reading 1,780, vertical angle minus 8, measure the vertical angle. OR, instrument reading 1,592, vertical angle minus 8. Report when ready to observe.*

(6) Instrument readings and vertical angles are reported as desired to the battery or battalion fire-direction center after each round fired or as soon thereafter as practicable. This report is made in the following manner: *OL, instrument reading 1,963, vertical angle, minus 12. OR, instrument reading 1,724.*

g. In a high-burst registration, the battery executive can be used as the axial observer under certain conditions. However, when the angle of site to the burst center exceeds approximately 50 mils above the ground level of the target area, errors in elevation corrections will be obtained, especially when the maximum range for each charge is approached. Large differences in site with resultant errors are avoided by the following procedure: A round is fired high enough in the air so that the battery executive can observe it above the mask. He determines the instrument reading to the burst. (More than one round may be required to secure an accurate instrument reading.) This instrument reading fixes the axial ray for plotting the burst center. Site then is decreased and succeeding rounds are fired as nearly as possible at the site of the target area. The lateral observer obtains instrument reading and vertical angle to each burst. The mean instrument reading of the lateral observer fixes the lateral ray for plotting the burst center. The altitude of the burst center is computed from the mean vertical angle measured by the lateral observer.

141. ILLUSTRATIVE EXAMPLES. a. Matériel, 105-mm howitzer M2, firing shell HE; charge, 5; fuze M51A4; mission, center of impact registration. Both observers are lateral. Instruments have been zeroed on the reference point (preferably one in the target area) and the base piece is at the battery center. Message to observers: *OR, instrument reading 425, vertical angle +5, measure the vertical angle. OL, instrument reading 6280, vertical angle 0; report when ready to observe.* Initial commands: *No 2 ADJ, SH HE, CH 5, FQ No 2 1 RD, DF 2585, SI 300.*

Round No.	Commands		Instrument reading		Vertical angle OR	Remarks
			OL	OR		
1	El	350	6, 253	426	+5	Not counted in total.
2		350	6, 243	421	0	
3		350	6, 257	422	+2	
4		350	6, 258	421	−1	
5		350	6, 264	421	+3	
6		350	6, 258	420	+2	
7		350	6, 252	422	+2	6 rounds for effect.
Average			6, 255	421	+1	

The officer conducting fire decides that six usable rounds are sufficient and notifies the observers and battery, *END OF MISSION.* Rounds 2 through 7 are used to determine average readings to plot the center of impact which was fired at DF 2585, SI 300, EL 350. The horizontal location of the center of impact is plotted by intersection (computed or graphic). The angle of site is computed as +2 mils, which is determined by using the mil relation formula; the vertical angle reported by OR; the relative altitudes of OR, the piece, and the center of impact; and distances scaled on the chart to the center of impact. The complementary angle of site, +.30 mils ($+.15 \times +2\,m/h$) is negligible. The site then is +2 mils. Since the site fired was 300, it was incorrect and must be changed to 302. This changes the adjusted elevation to 348 (retaining the fired quadrant elevation of 350). The adjusted data then are DF 2585, SI 302, EL 348. The scaled deflection and range are DF 2576 and 5,820 yards; these are the map data. Comparisons as shown in paragraphs 134 and 138 will give corrections of L9, K = −12 yards per 1,000. GFT setting is Ch 5, FzQ, Rn 5,820, EL 348.

b. Matériel, 105-mm howitzer M2, firing shell HE; charge, 5; fuze M55; mission, high-burst registration. Both observers are lateral. Each instrument has been zeroed on a reference point (preferably one in the target area) and the base piece is at the battery center. Message to observers: *OR, instrument reading 425, vertical angle +20, measure the vertical angle. OL, instrument reading 6280, vertical angle +25; report when ready to observe.* Initial commands: *NO 2 ADJ, SH HE, CH 5, FUZE TIME, NO 2 1 RD, DF 2,585, SI 315, TIME 20.0.*

Round No.	Commands	Instrument reading		Vertical angle OR	Remarks
		OL	OR		
1	El 350	LOST	GRAZE	--------	Site raised to secure air bursts within view of left observer.
2	si 335, 350	6, 253	424	+23	Not counted in total.
3	350	6, 243	421	+18	
4	350	6, 257	422	+15	
5	350	6, 258	421	+16	
6	350	6, 264	421	+15	
7	350	6, 258	420	+17	
8	350	6, 252	422	+15	6 rounds for effect.
Average	----------	6, 255	421	+16	

The officer conducting fire decides that six usable rounds are sufficient for the registration. The observers and battery are notified, *END OF MISSION*. Rounds 3 through 8, which are used to determine average readings for plotting the burst center, were fired at TIME 20.0, DF 2585, SI 335, EL 350. The horizontal location of the burst center is plotted on the firing chart by intersection. Angle of site is computed as + 19 mils, using the mil relation formula, the vertical angles reported by OR, relative altitudes of OR and piece, and distances scaled on the chart to determine the mean altitude of the burst center. Complementary angle of site (+ .15 x + 19$\not{m}$=3$\not{m}$) is added to the angle of site (+ 19$\not{m}$), giving a site of + 22$\not{m}$. Since the site fired was 335, it must be changed to 322. This changes the adjusted elevation to 363. The adjusted data are: TIME 20.0, DF 2585, SI 322, EL 363. A deflection of 2,576 and a range of 5,820 yards to the burst center are scaled to this plotted location on the firing chart. These are the map data. Corrections are determined to be L9, K = + 17 yards per 1,000, time K = −.09 seconds per 1,000 yards (pars 134–139). The GFT setting is Ch 5, Fz M55, Rn 5,820, El 363, Ti 20.0.

CHAPTER 14

CORRECTIONS FROM A METRO MESSAGE

142. GENERAL. When firing data are corrected for conditions not standard by means of the firing table, the data are called *map data corrected.* These nonstandard conditions include weather, as given by the metro message; temperature of powder; weight of projectile; velocity error (*VE*); and rotation of the earth for long-range weapons. Metro corrections usually are computed for a point in the center of the target area. If the target area is large, it may be necessary to use several points to insure proper coverage. A metro check point is an arbitrarily selected point in the target area for which metro data are computed. Metro corrections should be computed for individual targets with heavy artillery. Time corrections cannot be determined from a metro message. All unknown errors can be corrected only by adjustment or registration.

143. SOLUTION OF THE METRO MESSAGE. a. General. The firing tables for each weapon give the type of message to be used, a wind components table, standard conditions, unit effects, and detailed explanation of the computation of data using the metro message. Direction and range to metro check points are taken to multiples of 100.

b. Procedure. A systematic procedure to speed the solution is as follows:

(1) List all pertinent known values to include shell, charge, range (elevation) to metro check point or target, altitude (and latitude) of battery, direction of fire, weight of projectile, and powder temperature.

(2) From table B, part 2 of the firing tables, obtain change in velocity due to change in temperature of powder.

(3) From tables D and E, part 2 of the firing tables, obtain range and deflection effects due to rotation of the earth for the latitude of the battery (long-range weapons only).

(4) From table A, part 2 of the firing tables, obtain line number of message to be used and standard values and unit effects for drift, lateral wind, weight of projectile, air temperature, change in muzzle velocity (yards per foot second), rear wind, and air density. The firing tables are entered at the map range taken to the nearest 100 yards.

(5) From the proper lines of the metro message, check the time that the message was completed to insure receipt of latest and proper type message. Obtain altitude of the meteorological datum plane (MDP), wind direction and velocity, ballistic density, and air temperature.

(6) Compute chart direction of wind and difference in altitude of battery and MDP in hundreds of feet. Chart direction = wind direction (from metro) less direction of fire.

(7) From part 1 in the firing tables, obtain wind components and corrections to density and ballistic temperature. The wind components are found opposite the chart direction in this table. The corrections to density and temperature are found opposite the difference in altitude between the battery and MDP. These corrections are applied with the sign they possess in the table to secure the corrected density and temperature.

(8) Obtain the variations from standard by comparing standard values with actual values. Multiply these variations by their respective unit effects and total the results algebraically. These results are the *effects* in mils for direction and in yards for range caused by known nonstandard conditions.

c. Example. Matériel, 105-mm howitzer M2; altitude of battery, 290 yards. Metro check point for charge 7; *Y*-azimuth, 2,800; range, 9,700 yards. Executive has reported powder temperature, 90°; weight of projectile, one square. The following metro message has been received:

Message	Call Sta.	Alt. MDP	Time message complete	Type
MIF 12 09303	MIF	12	0930	3
056 15 98393				
156 16 97793				
257 16 97392				
358 17 97088				

	Line No.	Wind direction	Wind velocity	Density	Ballistic temp.
456 20 96586	4	56	20	96.5	86

Solution: Charge 7, range 9,700. Line 4 of the message is to be used

DATA CORRECTION SHEET

CHART DATA	METRO MESSAGE
Charge 7 Range 9700	Line Number 4
Alt of Btry (feet) 870	12 (Alt MDP) 0930 (Time) 3 (Type)
Alt of MDP (feet) 1200	
Btry ~~above~~ (below) MDP 330	4 (Line No) 56 (Wind Dir) 20 (Wind Vel) 96.5 (Density) 86 (Temp)
Latitude of Btry —	* Corrected values: 97.4 (Density) 87 (Temp)

WIND COMPONENTS AND DEFLECTION

(If necessary, add 6400)
Dir of wind 5600
Dir of fire 2800
Chart Dir of wind 2800
LATERAL WIND 20 (velocity) x L 0.38 (component) = L 7.6 mph (Lat wind) x 0.5 (unit effect) =
RANGE WIND 20 (velocity) x + 0.92 (component) = + 18.4 mph (range wind)

ROTATION EFFECT —
DRIFT EFFECT R 7
EFFECT L 4
TOTAL DEFL EFFECT R 3
DEFL CORR L 3

RANGE

	KNOWN VALUES	STANDARD VALUES	VARIATION FROM STD	UNIT EFFECT	PLUS	MINUS
Wt of Proj	□	□ □	− 1	+ 9		9
Powder Temp	90°	X X	+ 6 F/S	+ 4.7	28	
Air Temp	87°	59°	+ 28°	+ 3.6	101	
Range Wind	+ 18 mph	0	+ 18	+ 13.8	248	
Density	97.4	100	− 2.6	− 33	86	
Rotation	X X	X X	X X	X X	−	
					463	9
					9	
				NET METRO RANGE EFFECTS =	454	YDS
	VE RANGE EFFECT = — (Known VE (f/s)) x — (unit effect)			=	−	−
				TOTAL EFFECT (METRO + VE) =	454	YDS
				TOTAL RANGE CORRECTION =		-454 YDS

* *Computations:* *Corrected density = 96.5 + (3 x 0.3) = 97.4*
Corrected temperature = 86 + (3 x 0.3) = 86.9 use 87

d. Corrections. By reversing the direction or sign of the effects determined in **c** above, *corrections* are obtained.

(1) The deflection correction is LEFT 3 at range 9,700. A deflection correction scale with this correction of L3 at its center of 9,700 yards is constructed as described in paragraphs 138 and 139.

(2) The range correction is −454 yards at range 9,700. To convert this to an elevation correction, the range correction (−454 yards) is divided by the change in range for 1 mil change in elevation (commonly called "yards per mil") found in column 5 of the firing tables (13 yards). The quotient thereby obtained is −35 ㎖ which is the elevation correction.

(3) The corrected elevation is found by applying the elevation correction to the firing table elevation. In this example, the corrected elevation for range 9,700 is 385 ㎖ (firing table elevation of 420 ㎖ minus elevation correction of 35 ㎖).

(4) The metro *K* equals −47 yards per 1,000 yards and is obtained by dividing the range correction (−454 yards) by 9.7 (*R*). For purposes of simplicity, the old *VE* has been disregarded in the above computations. For correct procedure in handling *VE*, see paragraphs 146 to 148 inclusive.

e. Graphical firing table. The hairline is set over the chart range at which the tabular tables were entered. The range correction is added algebraically to the range at which the tabular tables were entered, and an elevation gage line is drawn opposite the resulting range. *Example:* Matériel, 105-mm howitzer M2; charge 5. The range at which the tabular tables were entered is 5,100 yards; the correction from a metro message is −150 yards. The hairline is set over 5,100 yards and an elevation gage line is drawn over the elevation corresponding the range 4,950 (5,100 yards minus 150 yards). In this case, the elevation gage line would be over elevation 286 when the hairline is set at range 5,100.

f. Application of corrections. When metro data are used, the corrected elevation may be determined either by using metro *K* as in **d** above, by use of a graphical firing table, or by solution of the metro message for each target. The latter procedure is appropriate for prearranged fires when targets are scattered widely, when there is ample time for computation, and in all cases for heavy artillery. When time is limited, use the graphical firing table for targets within transfer limits.

144. CORRECTIONS FOR ROTATION OF THE EARTH. The firing tables for certain long-range weapons give the range and deflection effects of rotation of the earth. These effects may be combined with the effects due to nonstandard conditions of weather and matériel, and the corrections applied in the same manner. For heavy artillery, rotation of earth effects always should be considered and applied as additional range and deflection corrections. The latitude of the piece is obtained from a map.

145. VELOCITY ERROR (*VE*). **a.** When metro data have been in use and a registration is fired, corrections determined from the registration are put into effect. After a change in weather conditions, registration corrections determined prior to the weather change usually fail. If registration is not practicable, it is necessary to use metro data again.

b. A comparison is made between the effects determined only by metro and those determined at approximately the same time by registration. The cause of discrepancy between them presumably is unknown. In order to provide more accurate metro corrections, if it becomes necessary in the future to revert to their use, it is assumed that the unknown causes may be attributed to a variation from standard muzzle velocity. The amount of this variation is computed, and it is introduced into future metro computations as the *VE*. It is expressed in feet per second and carries the sign of an effect. In application, it is converted simply to yards at the range at which the metro was computed, and added algebraically to the metro effect.

c. The *VE* must be determined and applied judiciously. The following principles govern:

(1) When a new *VE* is to be computed after the completion of a registration, an approximately concurrent metro message must be available. Normally this message is computed as soon as received.

(2) An old *VE* may not be used if determination of a new *VE* is to follow a change of ammunition lot, but it is not discarded. The new *VE* (based on the above) is used as long as the new conditions prevail. Upon return to the old conditions (ammunition lot), the old *VE* is assumed to be more correct.

(3) A *VE* determined for a given charge is applicable only with that charge.

(4) The *VE* may be changed several times between metro messages, depending upon the number of rounds fired and the wear tables concerned. When a change is indicated, the *K* or GFT setting is changed by a corresponding amount in yards.

(5) After a registration has been fired and unobserved fires must be delivered on a target outside of transfer limits, the *VE* determined from registration and a concurrent metro message should be applied to the solution of the new metro message for that target.

d. Example of computing VE: matériel, 105-mm howitzer, firing shell HE, charge 5.

(1) Range to metro check point------------------ 4,300 yards
Adjusted elevation------------------------- 247 ₥
Metro range *effects*----------------------- −240 yards

(2) Range corresponding to adjusted elevation----- 4,400 yards

(3) Registration *effects* = −100 yards (4,400 to 4,300).

(4) Registration *effects* = metro effects + VE − 100 = −240 + VE.
VE = +140 yards.
VE in mils = +9 ₥ (140 ÷ 15, the "yards per mil" value at the chart range to the metro check point).
VE in feet per second = +23 f/s (140 ÷ 6.2, the range effect of 1 f/s in muzzle velocity).

146. EXAMPLE OF COMPUTING A METRO MESSAGE INCLUDING CORRECTIONS FOR ROTATION OF THE EARTH AND *VE*. Matériel, 8-inch gun M1; shell HE, M103; fuze PD, M51; muzzle velocity, 2,600 f/s; charge, M9; altitude of battery, 560 yards. Metro check point for charge M9; *Y*-azimuth, 5600 mils; range, 24,670 yards. Executive has reported powder temperature, 83°; weight of projectile, 239 lbs. The old VE is −6f/s. Latitude of piece, N36.5°. The following metro message has been received:

Message	Call Sta.	Alt. MDP	Time	Type
MIF 13 09304	MIF	13	0930	4
0 40 16 96194				
1 39 17 96094				
2 39 17 95993				
3 40 21 95893				
4 40 21 95892				
5 40 22 95792				
6 41 21 95691				

	Line No.	Wind direction	Wind velocity	Density	Ballistic temp.
7 43 21 98090	7	43	21	98. 0	90
8 45 22 97290					

Solution: Charge M9, range 24,700. Line 7 of message is to be used. Refer to Data Correction Sheet, page 145.

147. AVERAGE *VE*. **a.** Normally, the latest *VE* determined would seem to be the most accurate one available for computation. If there were no metro errors, this would be true, but each new metro message is apt to have unpredictable errors. For this reason, when forced to make unobserved transfers of fire without re-registration, it is advisable to smooth out the errors of metro by using the average of the last two *VE*'s (old *VE* and new *VE*) computed in the same position area, in conjunction with a new metro message. This arbitrarily gives the most weight to the new *VE* but does not disregard the previous ones. Of course, if re-registration is possible before making the transfers, these data are preferable. The use of the average *VE* is particularly applicable when considerable time has elapsed since registration, and when weather change is apparent. The average *VE* becomes the old *VE* when another comparison is made between metro and registration data. In compilation of the *VE*'s in a position area when a *VE* obtained is grossly different from that previously determined, the survey, registrations, computations, etc., should be checked for errors.

DATA CORRECTION SHEET

CHART DATA	METRO MESSAGE
Charge M9 Range 24700	Line Number 7
Alt of Btry (feet) 1680	13 (Alt MDP) 0930 (Time) 4 (Type)
Alt of MDP (feet) 1300	7 (Line No) 43 (Wind Dir) 21 (Wind Vel) 98.0 (Density) 90 (Temp)
Btry above ~~(below)~~ MDP 380	* Corrected values: 96.8 (Density) 89 (Temp)
Latitude of Btry N 36.5°	

WIND COMPONENTS AND DEFLECTION

(If necessary, add 6400)
Dir of wind 4300 (10700)
Dir of fire 5600
Chart Dir of wind 5100

LATERAL WIND 21 (velocity) x R 0.96 (component) = R20.2 mph (Lat wind) x 0.5 (unit effect) = EFFECT R 10

RANGE WIND 21 (velocity) x -.29 (component) = -6.1 mph (range wind)

ROTATION EFFECT R 2
DRIFT EFFECT R 14
EFFECT R 10
TOTAL DEFL EFFECT R 26
DEFL CORR L 26

RANGE

	KNOWN VALUES	STANDARD VALUES	VARIATION FROM STD	UNIT EFFECT	PLUS	MINUS
Wt of Proj	239 #	240 #	-1	+3		3
Powder Temp	83°	XX	+6 F/S	+13.5	81	
Air Temp	89°	59°	+30°	-6.6		198
Range Wind	-6 mph	0	-6 mph	+14.7		88
Density	96.8	100	-3.2	-136	435	
Rotation	XX	XX	XX	XX		54
					516	343
					-343	
				NET METRO RANGE EFFECTS =	+173	YDS
	VE RANGE EFFECT =	-6 (Known VE (f/s))	x +13.5 (unit effect)	=		-81
			TOTAL EFFECT (METRO + VE)	=	+92	YDS
			TOTAL RANGE CORRECTION	=		-92 YDS

* Computations: Corrected density = 98 + (4 x (-0.3)) = 96.8
Corrected temperature = 90 + (4 x (-0.3)) = 88.8 use 89°

b. *Example:* A battalion occupies a new position. The new *VE* is found to be −16 f/s. Since this is the first *VE* determined in this position, the *VE* of −16 f/s should be used in subsequent metro comparisons. When the next comparison is made between metro computations and registration data, a new *VE* of −20 f/s is determined. Since this is the second *VE* determined in *this position*, it should be averaged with the previous *VE* used to arrive at a *VE* to be used in subsequent metro computations—

$$\left(\frac{(-16)+(-20)}{2}=-18 \text{ f/s}\right)$$

When the next comparison is made between metro computations and registration data, a new *VE* of −12 f/s is determined. The average

VE to be used in subsequent metro computations is -15 f/s,

$$\left(\frac{(-12)+(-18)}{2}=-15 \text{ f/s}\right)$$

As long as the battalion remains in this position, the above procedure will be continued. Judgment must be exercised as to the validity of the VE determined.

148. CHANGE IN DEFLECTION CORRECTION DUE TO WEATHER CHANGES. **a.** When a deflection correction is determined by registration, and a concurrent metro message is available, the deflection correction from registration is used, but the deflection correction from the metro message is determined and recorded. The deflection effect of any subsequent changes in the known, nonstandard conditions can be determined by comparing the deflection correction from the latest metro message with that of the metro message obtained concurrently with the registration. If a new registration is impossible, the difference between these two is applied algebraically to the deflection correction being used, and a new deflection correction scale is constructed. *Example*: Following a registration, the deflection correction scale is constructed with a correction of zero at the center. A concurrent metro message results in a deflection correction of Left 2. This is recorded but not used. Several hours later, a change in weather occurs but no new registration is possible. A new metro message at that time gives a deflection correction of Left 6. The change in the deflection correction caused by the weather change is Left 4 (from L2 to L6=L4). Therefore, a new deflection correction scale is constructed and used. This procedure is repeated until corrections are obtained which are based on a new registration.

b. When metro data are to be used on individual targets, the deflection correction may be determined from the deflection correction scale or from a solution of the message for each target. The latter method is seldom practicable except for widely spread targets outside transfer limits and for heavy artillery. When it is used, a deflection-correction change, as explained above, should be included, if known.

CHAPTER 15

OBSERVED FIRING CHART

Section I. CONSTRUCTION

149. GENERAL. Observed firing charts based on registration are used prior to completion of the survey. When no topographical information is available, an arbitrary point on the chart is selected as the base point. The registration data of each battery, converted to back azimuth and range, then are plotted from the base point. When a map or photomap is available and the base point can be identified on it by inspection, the map or photomap is used as the observed firing chart. The battery positions may be located either by inspection or plotting back azimuths and ranges. The observed firing chart is used for massing observed fires based on an adjustment by one of the batteries. As soon as the survey is complete, the observed firing chart is replaced by the surveyed firing chart in order that unobserved and surprise fire may be executed.

a. Before initial registration. Prior to the completion of the initial registration, deflections are read directly from the top of the fan, using the base-point line extension as the index. Upon receipt of the initial fire request, the fire-direction center determines data which will be safe to fire, and plots the battery along the back azimuth at the initial range from the selected chart location of the base point. This procedure is followed with each battery.

b. After registration. The position of the base point is not changed after registration. The batteries are replotted in their proper relative locations according to the adjusted data obtained from the base-point registration.

(1) The deflection assigned to the right and left edges of the range deflection fan is the 100-mil figure nearest the adjusted deflection of the center battery. On completion of the initial base-point registration, the battery executive reports the adjusted deflection and the fire-direction center constructs a deflection index corresponding to this reported adjusted deflection. The deflection index of each battery is offset from the base-point line extension by the difference between the adjusted deflection as modified by the displacement correction (par. 129), and the deflection assigned to the edge of the fan. Each index is constructed by placing the appropriate

edge of the fan on the base point and drawing the deflection index at the adjusted deflection. If the adjusted deflection is larger than the deflection selected for the edge of the fan, the deflection index will be to the right of the base-point line extension; if the adjusted deflection is smaller, the index will be to the left of the base-point line extension. *Example*: The battery is laid on the base point and referred to aiming posts at deflection 2,800. At the conclusion of the registration on the base point, the battery executive reports the adjusted deflection as 2,843. The range-deflection fan is graduated to read deflections from 2,800 and, since the base-point line extension now represents a deflection of 2,843, an index for deflection 2,800 must be constructed 43 mils to the right of the base-point line extension.

(2) The direction specified for laying the center battery should be as near the direction to the base point as possible in order to reduce the angle between the base-point line extension and the deflection index of the center battery. This will provide nearly equal chart coverage by the fan on each side of the base point. Care should be exercised in the initial direction specified for laying the flank batteries so that the same range-deflection fan may be used for reading deflections of all batteries. *Example:* All batteries are laid on compass 4,800; aiming posts have been set out at deflection 2,800, and registration on a common base point has been completed. The adjusted deflections of the flank batteries will vary from that of the center battery by an amount approximately equal to their lateral distance from the center battery divided by the range to the base point. In this case, if the difference between adjusted deflections is too great, the aiming posts may be taken up and set out at an appropriate deflection after registration.

(3) The deflection-correction scale is constructed and applied as outlined in paragraph 139. The correction is always zero at the base-point range after the initial base-point registration.

150. CONSTRUCTION OF THE OBSERVED FIRING CHART. a. Direction. The observed firing chart may be constructed on a grid sheet, plain paper, map, or photomap. On a grid sheet, a grid intersection is selected as the location of the base point; on a piece of plain paper, any point is selected as the base point; on a map or photomap, the actual location of the base point is used. Through the base point, a line of direction to each battery is established (not drawn).

(1) On a map, photomap, or grid sheet, the batteries are plotted on the back azimuths of the adjusted compasses.

(2) On a piece of plain paper, the base-point line of the center battery is indicated in any convenient direction by constructing a tick mark which is a rearward extension of the base-point line. This tick mark must be drawn in such a position that it can be used as an index when laying off angles with the range-deflection fan for plotting the flank batteries. The direction for the flank batteries is established by placing the vertex of the range-deflection fan at the base point and plotting the angles representing the differences in adjusted compasses of the respective batteries. Orientation can be indicated by an arrow drawn to represent Y-north.

(3) To improve direction, a common orienting line may be established before or during registration. After registration, each battery reports its adjusted base angle as well as its adjusted compass (the latter for orientation of the chart and as a check against large errors). The flank batteries are plotted by differences in base angles, so that errors of the magnetic needles will not affect the relative locations of batteries.

b. Range. The following methods are used to plot the ranges to the batteries:

(1) *Time-fuzed shell unavailable, sites to base point unknown.* The ranges correspond to the adjusted quadrant elevations. *Example:* The batteries of a 105-mm howitzer battalion have registered on the base point, using shell HE, charge 3, fuze quick. All batteries have a common orienting line. Adjusted data are—

Battery	Adjusted Compass	Adjusted base angle	Adjusted quadrant elevation	Corresponding range
A	1, 055	1. 696	330	3, 460
B	1, 143	1, 610	353	3, 640
C	1, 287	1, 463	339	3, 530

An intersection of two grid lines is selected as the location of the base point. Through the base point, a line of direction is established to Battery B, the center battery, the Y-azimuth of which is 4,343 (back azimuth of the adjusted compass). The battery is located on this back azimuth at a range of 3,640 from the base point (fig. 58). The flank batteries are plotted by placing the vertex of the range-deflection fan at the base point and by laying off angles to the right and left of the rearward base-point line extension for the center battery equal to the difference between the base angle of the battery to be plotted and the base angle of the center battery. A pin point is placed along the side of the fan at the appropriate range (3,460 for Battery A and 3,530 for Battery C) (figs. 59 and 60).

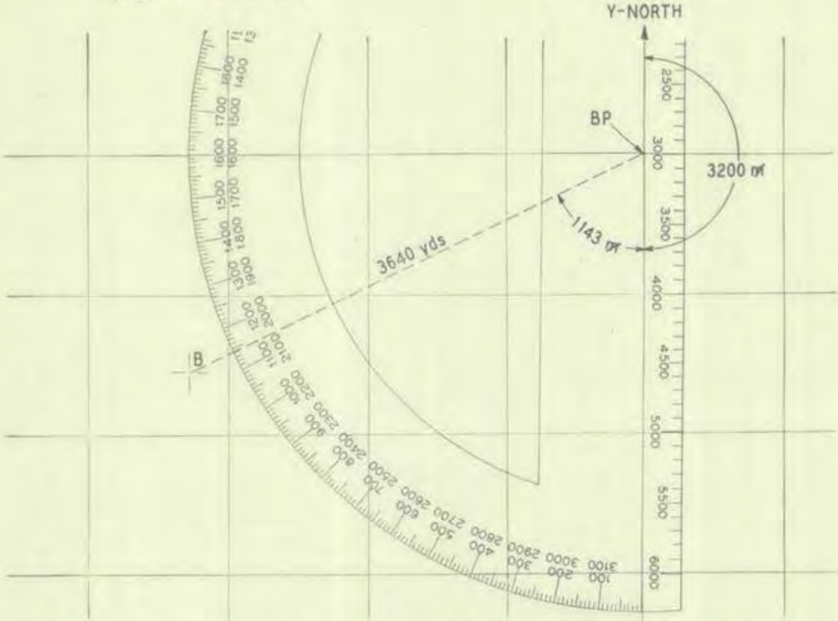


Figure 58. Plotting center battery on the observed firing chart.

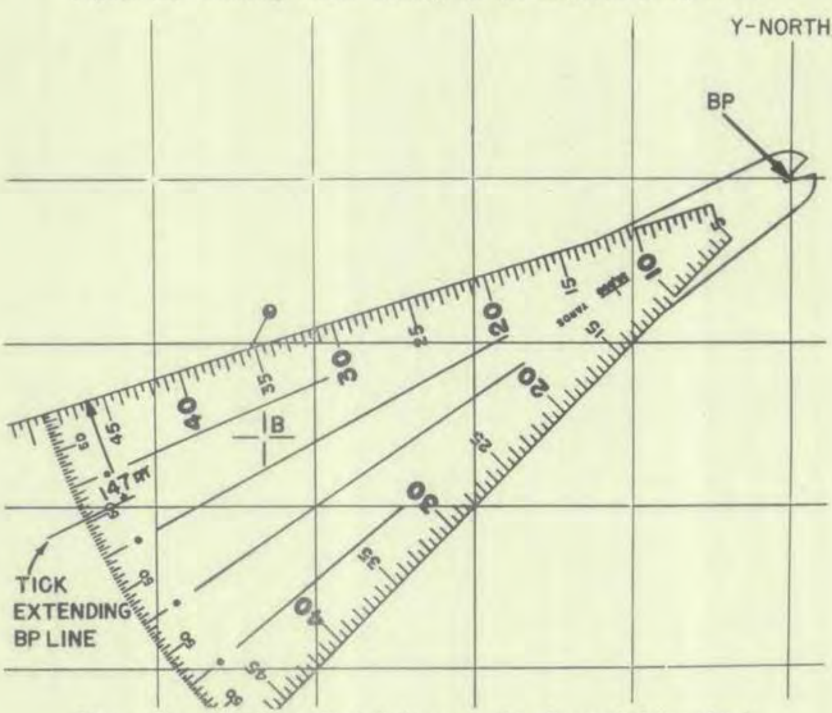


Figure 59. Plotting a flank battery on the observed firing chart.

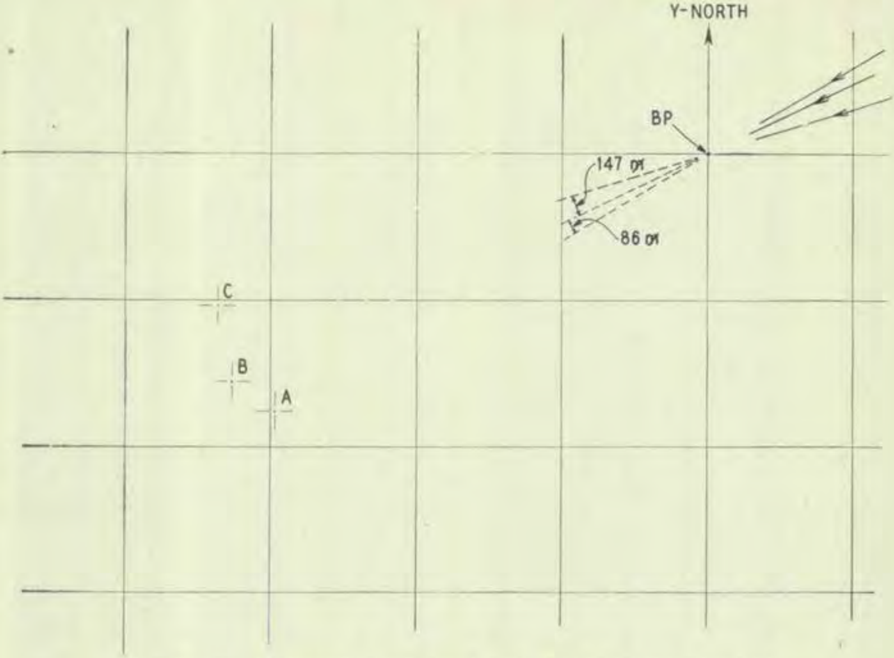


Figure 60. Observed firing chart with three batteries plotted.

(2) *Time-fuzed shell unavailable, site to base point known.* The observed firing chart is more accurate if the sites to the base point can be determined either from a small-scale map or by computation with instruments. Batteries are plotted as in (1) above, except that plotted ranges correspond to adjusted elevations instead of quadrant elevations. The base point is given an arbitrary altitude and the relative altitudes of the batteries are determined by the mil relation. The complementary angle of site must be removed from the adjusted site before making this computation. *Example:* The batteries of a 155-mm howitzer battalion have registered on the base point, using shell HE M107, charge 3, fuze quick. All batteries have a common orienting line. Adjusted data are—

Battery	Adjusted compass	Adjusted base angle	Angle of site*	Adjusted elevation	Corresponding range
A	3, 844	1, 761	296	419	5, 260
B	3, 729	1, 878	304	426	5, 320
C	3, 782	1, 824	311	455	5, 550

*Complementary angle of site has been removed from the site.

Figure 61. Construction of observed firing chart (plain paper).

In this case, a piece of plain paper is to be used for the construction of the observed firing chart. A point is selected for the location of the base point. With the vertex of the range-deflection fan at the base point, a pin point is placed along the side of the fan to represent the position of Battery C (center battery) at a range of 5,550 yards from the base point. The flank batteries are plotted by the method given in the previous example with the appropriate angles and ranges (Battery B, 54 mils to the right of C, range from base point 5,320; Battery A, 63 mils to the left of C, range from base point 5,260). An arbitrary altitude of 300 yards is assigned to the base point. The altitude of Battery A is 321 yards (300+(4+5.3)); the altitude of Battery C is 238 yards, (300−(11+5.6)). (See fig. 61.)

(3) *Time-fuzed shell available, sites to base point unknown.* Each battery makes a time registration on the base point. The procedure thereafter is similar to that in (1) above, except that the ranges plotted are the firing table values corresponding to the respective adjusted times. The firing table values for elevations corresponding to the respective adjusted times are considered the adjusted elevations; sites

are determined by subtracting each adjusted elevation from the corresponding adjusted quadrant elevation. Relative altitudes are determined from these derived sites (less complementary angles of site) and tabular ranges, using the mil relation. A large time correction will cause sites thus determined to be considerably in error. If this error occurs when batteries are echeloned in considerable depth, fire can be massed effectively only when targets are near the base-point range. *Example:* The batteries of a 105-mm howitzer battalion have registered on the base point, using shell HE, charge 5, fuze M54. Adjusted data include—

Battery	Adjusted time	Adjusted quadrant elevation
A	17. 0	308
B	17. 6	315
C	16. 3	295

The altitude of the base point is taken arbitrarily as 500 yards. Data for plotting batteries on an observed firing chart are—

Battery	Range	Elevation	Site	Altitude (yards)
A	5, 060	294	314	436
B	5, 210	305	310	453
C	4, 880	281	314	438

(4) *Time-fuzed shell available, site to base point determined.* The method given in (3) above is improved if the site to the base point for one battery can be determined from a small-scale map, by computation with instruments, or by firing (par. 132). The ranges plotted are the firing table values corresponding to the respective adjusted times. The GFT setting is determined as follows: Subtract site from adjusted quadrant elevation for the battery whose site has been determined, place the hairline over adjusted time, and draw a gage line at adjusted elevation. To determine sites of the other batteries, set the hairline over the adjusted time for the battery in question, and read the elevation under the elevation gage line; subtract this elevation from the adjusted quadrant elevation to obtain site. Altitudes are determined from these derived sites (less complementary angle of site)

and tabular ranges by use of the mil relation. An observed firing chart set up in this manner is preferable to one set up by the methods given in (1) and (3) above. *Example:* The batteries of a 105-mm howitzer battalion have registered on the base point with shell HE, charge 5, fuze M54. Adjusted data include—

Battery	Adjusted time	Site	Adjusted quadrant elevation
A	17.0	Not determined	308
B	17.6	Not determined	315
C	16.3	305	295

GFT setting is range 4,880, elevation 290, adjusted time 16.3. This setting is appropriate for all missions fired, using this charge. Altitude of base point is assumed arbitrarily to be 500 yards. Data for plotting batteries on observed firing chart are—

Battery	Range	Elevation	Site	Altitude (yards)
A	5,060	304	304	482
B	5,210	316	299	505
C	4,880	290	305	478

c. Alternate method. In some situations, time and ammunition can be saved by eliminating the registration of two batteries and substituting a position area survey. Usually, this procedure sacrifices accuracy, since the survey is to a known scale, whereas the range plot includes the registration correction (and time correction).

151. USE OF OBSERVED FIRING CHART. **a.** Target designation usually is made with reference to a target previously fired on unless both the observer and the fire-direction center are using gridded maps or photos, in which case coordinates may be given.

b. Site is assumed to be zero when a chart constructed as in paragraph 150**b**(1) is used.

c. A deflection correction scale should be used with all observed charts. The deflection correction (par. 139) compensates only for difference in drift and is removed from the adjusted data before replot. This facilitates transfer from an observed firing chart to a surveyed firing chart in that the shifts on the observed firing chart and surveyed firing chart are the same. When the deflection correction scale for the surveyed firing chart is constructed, it may differ from the one which was used with the observed firing chart. If the difference is not more than one mil, it may be disregarded in the change to the surveyed firing chart. The deflection correction scale determined from the surveyed firing chart is used for subsequent firing.

d. When targets are attacked with time fire, range for replot is read from the GFT, with the hairline over the adjusted time for the target in question. Altitudes for replot are determined by computation based on altitude of adjusting battery, adjusted site minus $20/R$, and range for replot.

152. OBSERVED FIRING CHART FOR MORE THAN ONE BATTALION. a. The common control required for massing quickly the fires of more than one battalion on the observed firing chart is secured by the uniform declination of instruments, the designation of a common check point for all battalions and the assignment of coordinates and altitude thereto, and the registration by one battery of each battalion on the common check point. After registering on the common check point, the registering battery reports the adjusted data.

b. To construct the observed firing chart, each battalion plots its adjusting battery from the division artillery check point on the back azimuth of the adjusted compass reported by the adjusting battery. The distance and the altitude of the battery are determined by one of the methods given in paragraph 150. The method used for determining the angle for plotting the adjusting batteries should be the same in all battalions. The difference in adjusted compasses or adjusted deflections to check point and base point is determined. With the vertex of the range-deflection fan at the adjusting battery, this angle is laid off from the check point in the appropriate direction. With the fan in this position, the base point is plotted by marking a pin point along its edge at the adjusted range to the base point. The remainder of the observed firing chart is constructed as set forth in paragraph 150.

c. It is important that relative altitudes of division artillery check point and battalion position areas be known if several widespread battalions are to mass their fires accurately.

d. As an example, a battalion has prepared an observed firing chart, using one of the methods outlined in paragraph 150. The division artillery commander selects a check point, assigns it arbitrary coordinates (10.0–80.0), and the arbitrary altitude of 320 yards. The battalion registers the base piece of its center battery on the division artillery check point and plots the adjusting battery from the division artillery check point on the back azimuth of the adjusted compass (fig. 62). Battery B now has made two registrations—one on the base point, and one on the division artillery check point. The difference between the two adjusted compasses (or the adjusted deflection) gives the angle 1. The distance from Battery B to the battalion base point now is plotted on the new chart as one side of the angle 1. Batteries A and C now may be plotted in their correct relative positions. The vertical control which the battalions already have established is coordinated with the altitude assigned the division artillery check point. The chart now is ready for operation. When the fire of one battery has been adjusted on a target, the coordinates and altitude of the replot can be furnished the other battalions that are to fire on the same target.

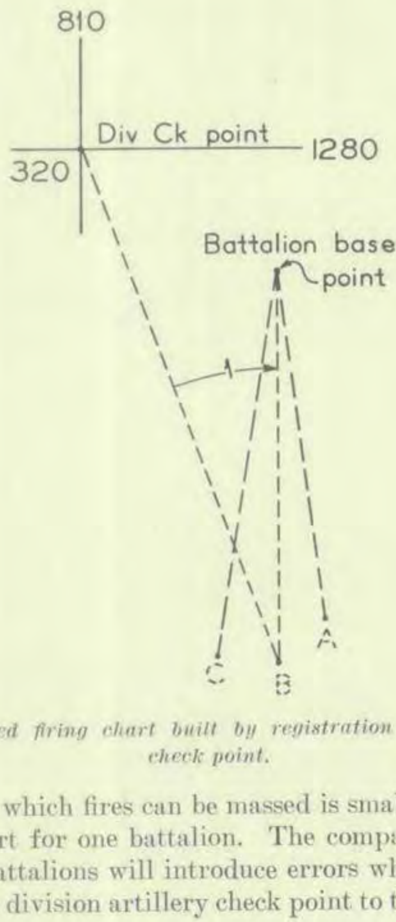


Figure 62. Observed firing chart built by registration on division artillery check point.

e. The area in which fires can be massed is smaller than on the observed firing chart for one battalion. The comparatively large distances between battalions will introduce errors which increase as the distance from the division artillery check point to the target increases.

Section II. TRANSFER TO A SURVEYED FIRING CHART

153. GENERAL. **a.** The surveyed firing chart replaces the observed firing chart as soon as it is available. Until all concentrations are transferred to the surveyed firing chart, the observed firing chart is retained for reference in case observers use such concentrations for known points in designating targets. The transfer of information is made as soon as possible.

b. Each battery maintains its own firing chart and keeps it up to date. The battalion promptly transmits any additional data to the batteries. This procedure enables fire direction to be decentralized at any time. (See par. 181**b.**)

154. USE OF CORRECTIONS AND REPLOTTING TARGETS. As soon as survey has been completed and the firing chart based on survey has been completed, the surveyed chart is used for fire direction and pertinent data from the observed firing chart is transferred to the surveyed firing chart.

a. GFT settings. The determination of GFT settings on the surveyed firing chart is accomplished in the same manner as when the surveyed firing chart is on hand at the time the registrations are fired; that is, the hairline is placed over the range measured on the surveyed firing chart, the elevation gage line is drawn over the adjusted elevation (which is the quadrant elevation minus the angle of site computed from the surveyed chart), and the time gage line drawn over the adjusted time from registration. When all three batteries have registered, each may have a different GFT setting.

b. Deflection-correction scale. The deflection-correction scale to be used with the surveyed firing chart is based on the difference in drift between various ranges from the base point (other point of registration), the value of the correction being zero at the base point range and the deflection index having been constructed as described in paragraph 124. Each battery may have its own GFT setting but the deflection-correction scale made up for the center battery is used by all three batteries of the battalion.

c. Replot of targets from observed firing chart to surveyed firing chart, computer's record being available. Targets are replotted by polar plotting at deflections, ranges, and altitudes as described below.

(1) *Deflection.* The replot deflection has been recorded on the computer's record for each mission. This deflection is used for replotting the target on the surveyed firing chart.

(2) *Range.* With the GFT set up for the surveyed firing chart as described in the preceding paragraph, range is determined by placing the elevation gage line over the adjusted elevation and reading the range under the hairline for missions fired with percussion fuze. For those missions fired with time fuze, the time gage line is placed over the adjusted time setting, and the range is read under the hairline.

(3) *Site.*

(*a*) For percussion fuze when no contoured map is available, the site used for computation of altitude is the site that was on the pieces.

(*b*) For percussion fuze when a contoured map is available, altitude is determined, using the site that was on the pieces, but this site and altitude must be verified as follows: The target is replotted at the deflection and the range determined in (1) and (2) above. The altitude of that plot on the map is used to recompute the site. If this site varies from the site fired by more than 1 mil, the target is replotted a second time at a range determined by stripping the new site from the adjusted quadrant elevation and placing the elevation gage line of the GFT over the resulting elevation (the GFT being set up for the surveyed firing chart). The altitude of this second plot is determined from the map and the process is repeated until the last site determined varies no more than 1 mil from the previous one. An adjusted elevation now can be determined by subtracting the last site from the adjusted quadrant elevation. This elevation is used to determine the final range for replot.

(*c*) For time fuze, the site announced is the difference between the adjusted quadrant elevation that was on the guns and the elevation read under the elevation gage line when the time gage line is over the adjusted time. The use of the adjusted time in a time transfer gives an accurate knowledge of the altitude on the new chart as it can be determined how much of the quadrant was site and how much was elevation. In a percussion transfer, this is not true, as the final site is arbitrary.

d. Replot of targets from the observed firing chart to the surveyed firing chart, computer's record not available. When the computer's record is not available, targets are replotted to the surveyed firing chart, using polar plotting and determining deflection range and altitude as described below.

(1) *Deflection.* The deflection for replot is measured directly from the observed firing chart and transferred to the surveyed firing chart without change, as the deflection correction for the surveyed firing chart will not differ from that for the observed firing chart by more than 1 mil.

(2) *Range.* The range is measured from the observed firing chart and the elevation that was fired is determined by using the GFT setting as it was when used with the observed firing

chart. Using this elevation, the range for replotting the target on the surveyed firing chart is determined as described in **c**(2) above.

(3) *Site.* The determination of altitude is handled in the same manner as described in **c**(3) above.

e. *Example:* 105-mm howitzer M2; shell HE; charge 6; fuze M55, computer's record available.

Data to BP from observed firing chart	*Data to BP from surveyed firing chart*
Chart range 5,340.	Chart range 5,520.
Adj time 16.1.	Time for chart range 16.7.
Adj Q El 240.	Site 304 (angle of site + comp site).

Adj El=236 (240−4).

GFT setting: Ch 6, Fz M55, Rn 5,520, El 236, Ti 16.1.

Def Corr=O (direction given to pieces from firing on BP).

Computed $K=\frac{5{,}520-5{,}260\ (\text{Adj range})}{5.5}=-47$ yds/1,000.

Time $K=\frac{16.7-16.1}{5.5}=-.11$ sec/1,000.

Note. See paragraphs 134 to 137.

Targets plotted on the observed firing chart can be placed on the surveyed firing chart by simply removing the corrections from the observed firing chart data, and then plotting them on the surveyed chart with the range-deflection fan.

CHAPTER 16

BARRAGES

155. General. A *barrage* is a prearranged barrier of fire designed to protect friendly troops and installations by impeding enemy movements across defensive lines or areas. Its normal ground use is in the establishment of prearranged close-in defensive fires which include coordinated employment of other artillery fires, mine fields, obstables, final protective machine-gun fires, and mortar barrages. Each battery is assigned only one barrage. A battery is laid on its barrage when not otherwise engaged, and fires the barrage on signal or call from the supported unit. The firing of a barrage may be repeated on call, if required.

156. VERIFICATION. Whenever possible, the data for the barrage should be verified or corrected by firing.

157. CHARACTERISTICS OF BARRAGES. The firing of a battery barrage, either individually or coordinated with other batteries, is based on the following:

a. Width of barrage. (See fig. 63.) The width of a barrage, or the length of the barrage line, which can be covered by a single battery without shifting its fire, should not exceed the width of an open sheaf. For optimum effect, the length of the barrage line to be covered by a single battery without shifting its fire is equal to the width for an effective open sheaf as shown in the table in paragraph 38**a** (5). When necessary, the length of the barrage line may be increased by agree-

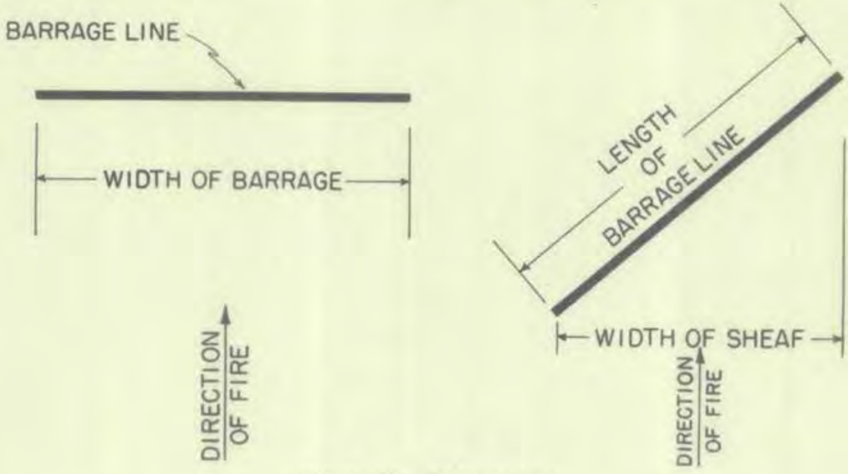


Figure 63. Barrage line.

ment between the commanders of the artillery and the supported unit, but the effectiveness of fire will be decreased.

b. Preparation of data. The barrage line may be at any angle to the line of fire. Special corrections normally are used to place each burst in the proper position. Map data for a barrage are taken from the center point of the barrage line. The angle between the barrage line and the line of fire is used to secure a plot of the barrage line on the device used to compute individual corrections for each piece (par. 44).

(1) *Deflection.* The deflection for the battery is the sum of the map deflection and the latest deflection correction.

(2) *Distribution.* A barrage is fired with a sheaf which fits the terrain to be covered.

(3) *Range.* The range for the battery is the map range corrected by the latest range correction.

(4) *Method of fire.* Fire is by volley at maximum rate.

c. Barrages of greater width than an open sheaf. When it is necessary to employ a barrage of greater width than an open sheaf, the procedure is to shift the fire from one portion of the line to the other, either by battery (shifting fire) or by individual piece (sweeping). It is emphasized that much greater protection is obtained if sufficient reinforcing artillery is assigned to allow each battery to limit its fire to the width of an open sheaf.

(1) Shifting fire is accomplished by laying the battery first on one half and then on the other half of the barrage line to be covered. Volley fire by battery is delivered alternately on each half of the target.

(2) Sweeping fire is accomplished by dividing the length of the barrage line to be covered into a number of segments equal to the number of pieces in the battery. (See fig. 64.) Each piece is laid on the right (left) of its segment and all segments are covered by successive shifts (sweeps) of individual pieces to the left (right) firing under the command of the chiefs of section. The number of rounds sweeping is the number of rounds required by each piece to cover its segment once. The number of rounds sweeping is determined by dividing the length of one segment by one half the effective width of a single burst. Fractional rounds are taken as whole rounds. The amount of sweep (shift) after each round is equal to the length of a segment divided by the number of rounds sweeping, converted to mils at the piece-target range. Fire by each piece then is delivered on its segment of the target and repeated as often as directed.

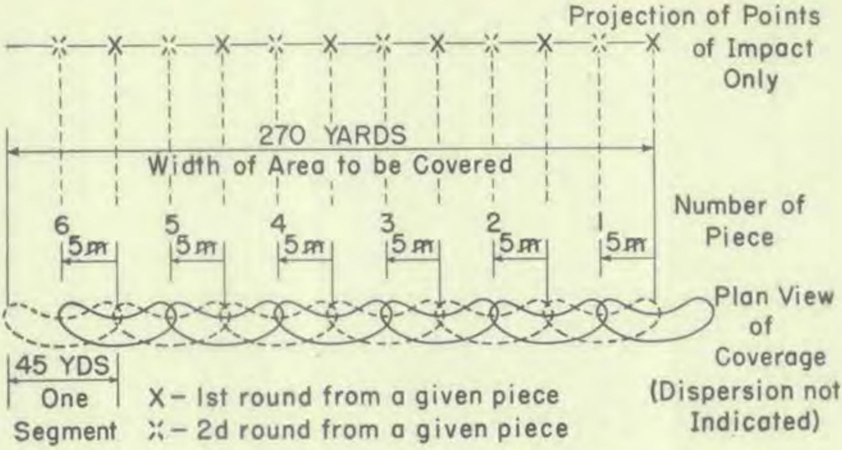


Figure 64. Diagram of sweeping fire.

(3) Example of sweeping fire: Matériel, 105-mm howitzer (effective width of burst 50 yards); six-piece battery; range, 5,000 yards.

Width of area to be covered = 270 yards.

Length of each segment 270/6 = 45 yards.

Number of rounds sweeping 45/25 = 1⅘; use 2.

Amount of sweep $\frac{45}{2 \times 5.0} = 5$ ₥.

The command to the battery for method of fire is 2 ROUNDS SWEEPING, LEFT (RIGHT) 5 MILS (FM6-140).

158. CALIBRATION AND REGULAR SHEAF CORRECTIONS. a. The computation of data for barrages normally will require special corrections for forming a regular sheaf (par. 43). If the sheaf is to be other than perpendicular to the direction of fire, the desired points of impact are plotted on a transparent straightedge to the scale of the position correction grid and placed over the grid in the desired position with respect to the direction of fire (fig. 65). The range corrections then may be read graphically by noting the distance to increase or decrease the range of each piece to bring the burst to the appropriate plot on the straightedge. These corrections also will allow correction of fuze settings for time fire. The deflection corrections can be read by noting the distance left or right each piece is from the appropriate plot on the straightedge and dividing by R.

b. *Example:* An index for reading deflections has been constructed opposite 2,800, the deflection at which the battery placed its aiming posts. With the battery plotted as shown, it is desired that the sheaf fall at an angle to the plane of fire as indicated by the transparent straightedge. The corrections shown below must be converted to mils and applied at deflection 2,450:

Piece No.	Deflection correction	Range correction (yards)
1	Right 2	−43
2	Right 2	−53
3	Left 12	−14
4	Left 7	+53
5	Right 3	+45
6	Right 1	+15

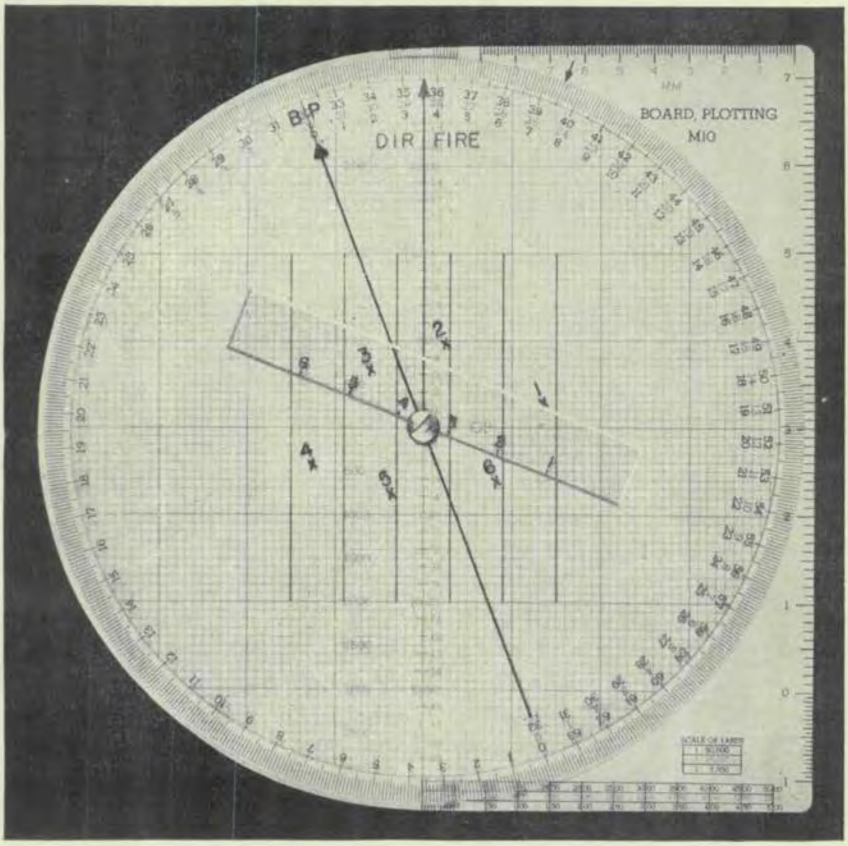


Figure 65. Sheaf other than perpendicular to line of fire.

PART FOUR

FIRE DIRECTION

CHAPTER 17

FIRE DIRECTION—GENERAL

Section I. GENERAL

159. DEFINITION. Fire direction is the tactical and technical control of the fire power of one or more artillery units. Effective fire direction depends upon thorough training, proper organization for combat, survey, communication, liaison, observation, and intelligence.

160. OBJECTIVES. The methods employed in fire direction must insure—

a. Continuous and accurate fire support under all conditions of weather, visibility, and terrain.

b. Flexibility sufficient to engage all types of targets over a wide area.

c. Prompt massing of fires of all available units in any area within range.

d. Prompt distribution of fires simultaneously on numerous targets within range.

161. COMMAND. a. Higher artillery.

(1) Division artillery and corps artillery commanders coordinate the fires of their subordinate units and allocate reinforcing artillery fires in order to further the plan of the force commander. The methods of assigning prearranged fires are illustrated in chapter 20.

(2) The group, division artillery, and corps artillery commanders centralize command when communication facilities make it possible. With centralized command, battalions may engage targets in their zones of fire within limitations imposed by the group, division artillery, or corps artillery commander. A battalion which has been given a direct-support mission fires outside of the sector or zone of the supported unit only after obtaining clearance from the division artillery commander. General-support battalions are massed on order of the group, division artillery, or corps artillery. A battalion which has a reinforcing mission answers all calls for fire

from the reinforced unit when answering such calls will not interfere with the execution of missions assigned by higher headquarters.

b. Battalion. In order to coordinate the fires of the battalion, the battalion commander normally centralizes command as soon as communication makes it possible. With centralized command, batteries may engage targets in their zones of fire within limitations imposed by the battalion commander. Observers within the battalion may be required to report all targets to the battalion. When a single battery is to fire on a target, the observers may be directed to give corrections either to the battalion fire-direction center or to the battery fire-direction center. The observer normally gives corrections to the battalion fire-direction center, from which fire commands are sent to the batteries.

c. Battery. At times (for example, in rapidly moving situations, or if communication is lacking), command must be decentralized to the batteries. In this situation, the observers report fire missions and other information direct to the battery.

162. OBSERVED AND UNOBSERVED FIRES. **a.** When fire can be observed, it is adjusted to the target. Normally, the observer who reports the target will observe and report the effect on the target. Accurate initial data by the observer will produce early and effective fire for effect.

b. When fires cannot be observed, transfers based on registrations, metro computations, or a combination of both must be used. When unobserved fires are to be delivered, it usually will be necessary to increase the area covered. In all instances, registration should be accomplished, if permissible, and appropriate corrections applied to firing data. Field artillery always seeks to register because of the resulting economy of time and ammunition and the increase in effectiveness of fire. In the absence of anything better, the corrections determined by registration of one battalion may be used by other battalions equipped with the same weapon, provided that—

(1) The battalions are connected by survey.

(2) The battalions are not widely separated laterally or in depth.

(3) The relative calibrations of the battalions are known.

(4) The same ammunition lot is used by all battalions.

163. PREPARATION OF DATA. A well-trained battalion fire-direction center can compute corrected data for a target and transmit it to the batteries as fast as it can be set off on the pieces. This should not preclude the preparation of necessary data for targets that can be anticipated because, under battle conditions, several targets may require simultaneous attack, communication may become confused, or fire-direction personnel may be reduced considerably. This is particularly true for prearranged fires which are fired on a time schedule, or for missions which are fired on call or signal. Both types of missions may require refinements in the adjustment of the sheaf or for echelonment in depth. Defensive concentrations around a newly secured objective or a barrage are examples of this latter type. The data generally are prepared by the battalion fire-direction center, although batteries also should be prepared to perform this operation.

Section II. TARGET LOCATION

164. SOURCES OF TARGETS. Targets for field artillery may be located and reported by the supported troops, by artillery liaison personnel with those troops, by field artillery ground or air observers, by personnel of the field artillery observation battalion (sound, flash, and radar), by adjacent or higher headquarters (by air and ground reconnaissance agencies), by analysis of photos and knowledge of enemy activities, and by interrogation of prisoners of war and civilians. A description of the target should accompany each report; a request or order for fire may accompany the report. The person reporting the target may recommend a method of attack. The size and importance of the target may be indicated by a request for the fire of additional batteries or battalions. To be of maximum value, the report should be transmitted promptly and the designation must be accurate. The search for remunerative targets must be vigorous and continuous.

165. TARGET LOCATION. Target locations may be pointed out on the ground, designated by grid coordinates, designated by reference to a known point (such as a check point or a target previously fired upon), designated by azimuth and range from a known point or observation post, marked on maps or photos, or traced on overlays which match such maps or photos. The reported location normally is a point at the center of the target. For a barrage, the length and direction of barrage line also must be designated and, if possible, it should be pointed out on the ground.

Section III. ATTACK OF TARGETS

166. ARTILLERY SUPPORT. The artillery is the base of fire for the infantry-artillery-tank team. Therefore, the artilleryman always must consider and anticipate the needs of the infantry and armor in order to place the artillery in the best positions to provide the most effective artillery fire support to the unit. Artillery fire must conform to the scheme of maneuver of the supported unit. Once action is started, the artillery maneuvers its fire to continue the support in accordance with reports of liaison officers and observers with the supported units.

167. METHOD. When the location of a target and the time of attacking it are known, the commander must, within the time available, consider the following pertinent points:

a. Nature of the target (type, mobility, cover, importance).

b. Results desired.

c. Registration and survey control available.

d. Area to be attacked.

e. Rate of fire.

f. Amount of ammunition available.

g. Unit or units to give desired coverage.

h. Technique of attack.

i. Conformity to scheme of maneuver of supported troops.

168. NATURE OF THE TARGET. In order to determine the proper type of projectile, fuze, caliber of weapon, and necessary ammunition expenditure, the nature of the target is considered carefully. The nature of the target is a guiding factor in determining the size of bracket sought, the type of adjustment, and the speed of attack. A study of enemy methods and equipment will assist materially in the selection of the best method of attacking the target.

169. RESULTS DESIRED. The method of attacking a target is influenced by the results desired from the fire. In general, these results are of four types which, by their description, furnish a guide for the method of attack.

a. Destruction. Fire concentrated on a target which is to be damaged physically to such an extent that it is rendered useless.

b. Neutralization. Fire of great intensity on a target with the object of causing severe losses, preventing movement or action, causing limited destruction of matériel, and, in general, destroying the combat efficiency of the enemy.

c. Harassing fire. Fire of less intensity than neutralization, designed to inflict losses, or, by the threat of losses, to disturb the enemy troops, to curtail movement, and, in general, to lower morale.

d. Interdiction fire. Fire, usually of less intensity than neutralization, laid down on lines of communication to disrupt or intermittently deny their use to the enemy.

170. REGISTRATION AND SURVEY CONTROL. The lack of adequate survey and registration may prohibit effective transfers or the use of metro data. When survey and registration are inadequate, targets are attacked with observed fires; unobserved fires are ineffective in this case.

171. AREA TO BE ATTACKED. The area to be attacked may be determined by the actual size of the target or by the area in which the target is known to be. This information is obtained from observers' reports, photo interpretation, utilization of all other intelligence agencies, and experience in similar situations.

172. RATE OF FIRE. a. General. The greatest demoralization and effect result when surprise fire is delivered with maximum density. This is best achieved with all units firing so that allowance for time of flight will cause all projectiles to strike simultaneously (time-on-target method). Because of limits to the rates of fire (see **b** below), density is best secured by massing the fires of several batteries and, in certain cases, battalions. Offsetting the advantage of great initial effect is the fact that coverage of an area by many weapons may give a beaten zone larger than the target, and is therefore wasteful of ammunition. Furthermore, effective massed fires cannot be sustained without extravagant ammunition expenditure. These factors may dictate the use of small units even when more batteries and battalions are available.

Matériel	Rounds per piece		Volleys per battery	
	First ½ minute	First 4 minutes	First 10 minutes	Prolonged fire per hour
75-mm howitzer	8	24	48	150
105-mm howitzer	4	16	30	100
155-mm howitzer	2	8	16	40
155-mm howitzer	2	8	14	40
8-inch howitzer		6	10	30
8-inch gun		3	6	20
240-mm howitzer		3	6	20

b. Maximum rates of fire. For the rates of fire shown in table below, it is assumed that pieces have been rested or cooled from previous firing. If the rate of fire of one of the first three columns is to be used in several missions, time between missions must be sufficient for cooling the pieces. Lower charges have a lesser heating effect than the higher charges, thus increasing the permissible rate of fire. The table is to be used as a guide; however, the rates of fire should not be exceeded at maximum charge.

173. AMOUNT OF AMMUNITION. **a.** The amount of ammunition available is the first consideration in the attack of targets. The available supply rate of rounds per gun per day will not be exceeded except by authority of higher headquarters.

b. When the available supply rate is small, approximately 10 to 20 rounds per 105-mm howitzer per day, missions should be limited to those which can be observed and which immediately affect friendly troops and operations. When the available supply rate is larger, 20 to 100 rounds per howitzer per day, missions fired should include the above plus those which may affect planned or future operations, as well as those which will require some massing of artillery fires without adjustment. For offensive operations and for defensive operations where a strong hostile offensive is encountered, quantities from 100 to 300 rounds per howitzer per day may be available.

c. Figures 66 and 67 show the number of rounds required for initial neutralization. The figures shown in the tables are based on experience. With more cover, difficult terrain, or a well-disciplined enemy, the amount of ammunition necessary will increase materially.

Number of pieces	Sheaf	Area, width, and depth	Volleys	Rounds
	75-mm Howitzer			
4	Converged	50 x 100	5	20
4	Open	120 x 100	12	48
6	Converged	50 x 100	3	18
6	Open	130 x 130	8	48
	105-mm Howitzer			
4	Converged	75 x 100	3	12
4	Open	150 x 100	6	24
6	Converged	75 x 100	2	12
6	Open	200 x 100	6	36
	155-mm Howitzer			
4	Converged	100 x 100	3	12
4	Open	250 x 100	8	32
6	Converged	100 x 100	2	12
6	Open	300 x 100	6	36
	155-mm Guns			
4	Converged	100 x 150	5	20
4	Open	250 x 150	11	44
	8-inch Howitzer			
4	Converged	150 x 100	3	12
4	Open	380 x 100	7	28
	8-inch Gun			
2	Converged	120 x 150	6	12
2	Open	230 x 150	12	24
	240-mm Howitzer			
2	Converged	130 x 150	6	12
2	Open	250 x 150	10	20

Figure 66. Area covered and ammunition necessary for one battery firing at center range to neutralize troops without cover.

Number of pieces	Sheaf	Range spread	Area, width, and depth	Volleys	Rounds
		75-mm Howitzer			
12	Converged	C Rn	100 x 150	4	48
12	Open	C Rn	150 x 200	8	96
12	Open	½ C	150 x 250	9	108
12	Open	1 C	150 x 300	12	144
18	Converged	C Rn	100 x 150	3	54
18	Open	C Rn	150 x 200	6	108
18	Open	½ C	150 x 250	6	108
18	Open	1 C	150 x 300	8	144
		105-mm Howitzer			
12	Converged	C Rn	150 x 150	3	36
12	Open	C Rn	200 x 200	5	60
12	Open	½ C	200 x 250	6	72
12	Open	1 C	200 x 350	9	108
18	Converged	C Rn	150 x 150	2	36
18	Open	C Rn	250 x 200	4	72
18	Open	½ C	250 x 250	5	90
18	Open	1 C	250 x 350	7	126
		155-mm Howitzer			
12	Converged	C Rn	160 x 150	2	24
12	Open	C Rn	300 x 200	5	60
12	Open	½ C	300 x 250	6	72
12	Open	1 C	300 x 350	9	108
18	Converged	C Rn	160 x 150	2	36
18	Open	C Rn	350 x 200	4	72
18	Open	½ C	350 x 250	5	90
18	Open	1 C	350 x 350	7	126
		155-mm Gun			
12	Converged	C Rn	160 x 200	3	36
12	Open	C Rn	300 x 250	6	72
12	Open	½ C	300 x 300	8	96
12	Open	1 C	300 x 400	10	120
		8-inch Howitzer			
12	Converged	C Rn	200 x 150	2	24
12	Open	C Rn	400 x 200	5	60
12	Open	½ C	400 x 250	6	72
12	Open	1 C	400 x 350	9	108

Figure 67. Area covered and ammunition necessary for one battalion to neutralize troops without cover.

174. SELECTION OF UNIT TO GIVE COVERAGE. a. General. If the unit to fire cannot mass its fire in an area as small as the target area, ammunition will be wasted. On the other hand, if the unit can cover only a very small part of the target area at a time, surprise is lost during the shifting of fire and the rate of fire for the area as a whole may be insufficient to secure effect. When the dispersion pattern is large, the direction of fire should be such that the maximum effect is obtained from the beaten zone of dispersion. The caliber and type of shell for the most effective fire must be considered. The first step in selecting the unit for a mission is to insure that it is of a proper size and caliber to cover the target area quickly and economically.

b. Battery. Figure 66 shows the area covered by a battery firing at a single range, as well as the amount of ammunition necessary to cover the area. The size of the area to be covered and the location of the pieces at the gun position govern the method of firing. By using shifting or sweeping fire, batteries may cover wider areas than those specified in figure 66; by using zone fire, or fire at successive ranges, they may cover deeper areas.

c. Battalion. When more than one battery is available, the fire of all batteries may be superimposed. In superimposing this fire, the batteries may fire at a single range or with a range spread between batteries. The range spread between batteries depends on the size of the area to be covered. Figure 67 shows areas covered by the fire of battalions of various caliber as well as the ammunition necessary to cover these areas.

d. Large area targets.

(1) *One battalion.* When the area covered by the target is too large to be covered by a single concentration, it is attacked in parts. If a battery is available for each part, and its fire is deemed sufficiently dense when zone fire is used, the entire area may be attacked at one time. Otherwise, the parts are attacked successively by the battalion. Large areas should be covered only when an important target is spread out over the area.

(2) *Additional battalions.* The fires of more than one battalion on a target increase the density and surprise effect of the fire, and the size of the area covered. Areas covered by more than one battalion firing at a single point in an area (data for all battalions computed for the same point with an open sheaf) are approximately as shown in the following table.
If the area is too large to be covered by a single concentration, it is attacked in parts. If a battalion is available for each part and its fire is deemed sufficiently dense, the entire area

903448°—50——12

may be covered at one time. Otherwise, the parts are attacked successively by all battalions.

Areas Covered, Using Open Sheaf

Number of battalions	Sheaf without special corrections (width x depth)	Sheaf with special corrections applied and within transfer limits (width x depth)
Two battalions:		
105-mm howitzer (4-piece batteries)	250 x 300	200 x 250
155-mm howitzer (4-piece batteries)	350 x 300	300 x 250
105-mm howitzer (6-piece batteries)	300 x 300	250 x 250
155-mm howitzer (6-piece batteries)	400 x 300	350 x 250
Three battalions or more (one medium or heavy)	400 x 400	350 x 300

175. CONSIDERATIONS AFFECTING UNITS TO FIRE. **a.** Most targets are of such size as to allow a wide variety of choice in the number of batteries or battalions to be used against them. Although certain limitations are indicated on large targets, the decision whether to have many units firing a few volleys, or a few units firing many volleys, is often a critical one.

b. The factors affecting the selection of units to fire on a target vary with each specific situation. Listed below are those factors which influence this decision.

(1) *Availability of artillery.* When the amount of artillery present is small, a greater number of targets per artillery unit must be attacked than is the case when greater amounts of artillery are present.

(2) *Size of area to be covered.* Several battalions used on a target cover a larger area than does a single battalion, no matter how carefully corrections are applied. The attack of a small target with the fire of a division artillery, for example, will increase density of fire on the target, but in a smaller ratio than the increase in ammunition expenditure. It will, however, increase the certainty of some effect by covering an area larger than the target area.

(3) *Caliber and type of unit.* The projectiles of larger calibers are more effective for certain destruction missions. High-velocity weapons are desired for maximum penetration in attack of fortifications. The accuracy of the weapon at the range fired, as indicated by the probable error in the firing tables, will limit the use of certain weapons. All of the above factors must be considered in selecting the caliber and type

unit to be used. If suitable calibers are not available in sufficient quantity for a specific mission, more ammunition must be expended per unit.

(4) *Surprise.* Against certain targets, short bursts from many pieces are preferable to sustained fire from a few pieces. To secure surprise, the method of attack must be varied constantly.

(5) *Accuracy of target location.* Certain important targets are so indefinite as to size and location as to justify the fire of several units to insure coverage.

(6) *Critical targets.* The emergency nature of certain targets (such as enemy counterattack formations) may justify the use of all available artillery fire, without regard to economy of ammunition.

(7) *Dispersion.* Coverage at long ranges is less dense and requires more ammunition. Firing at long ranges may require the selection of a unit to fire along the long axis of the target in order to obtain the maximum effect from dispersion.

(8) *Maintenance of neutralization, interdiction, and harassing fire.* This may require the use of small units for a long period of time so that the bulk of the artillery available is free for other missions.

(9) *Registration.* Registration reduces the number of units necessary to cover a target, with a corresponding reduction in ammunition expenditure.

(10) *Vulnerability of targets.* Some targets, such as truck parks, should be attacked with massed fire to insure immediate effect and to release the artillery for other missions.

(11) *Ammunition available.*

(12) *Effect on enemy personnel.* A strong demoralization effect can be achieved by smothering a hostile position with fire from several directions with different calibers of artillery using different types of projectiles.

176. DISTRIBUTION OF FIRE. **a.** Large targets offer a wide choice in methods of distributing the fire of units selected to fire on them. While time may be saved in some cases by designating the center of a large area for all units to fire upon, fire of more uniform density usually is secured by assigning individual target coordinates to each unit to fire.

b. Great care must be exercised in firing on area targets close to supported troops. Battalions able to fire within transfer limits or at short ranges should be chosen to cover the near edge of the area.

c. Normally, a battalion should not fire with a range spread greater than 1 *c*, since a greater spread will not give uniform coverage of the target. The probable error at the range to the target should be considered in the choice of range spread to be used.

177. TECHNIQUE OF ATTACK. The technique of attack is determined by a careful analysis of the capabilities of the weapons and ammunition available, the terrain of the target area, and the most effective method of attacking the target. High-angle fire may be necessary from defiladed positions or may be required to reach into deep ravines or irregular terrain. Time fire may be used most effectively against personnel within the limitations of the fuze. Direct or indirect fire with mobile, high-velocity guns at short range is desirable for destruction missions whenever possible. Heavy-caliber howitzers are desired for greater accuracy and blast action in destruction missions at long range.

178. TYPICAL TARGETS AND METHODS OF ATTACK. a. Tanks and combat vehicles in assembly area, rendezvous, or park.

(1) The area may be attacked, using any or all available weapons with either observed or unobserved fires, for the purpose of neutralization. HE shell fired on ricochet or with time or VT fuze (quick fuze if other methods are not practicable) are effective.

(2) If immobilized tanks can be seen, single weapons are adjusted by precision methods for the purpose of destruction. The most appropriate projectiles are HE-AT and AP. Short ranges are highly desirable. The highest practicable charge is used with AP. HE shell with quick or delay fuze may be used. The lightest HE shell normally appropriate for the destruction of tanks is the 155-mm.

(3) White phosphorus may be used for incendiary effect against tanks if combustible material can be ignited in the area.

b. Tanks and combat vehicles in an attack. Tanks usually advance by bounds, utilizing available defilade and keeping dispersed. Tank attacks frequently can be broken up by concentrations of HE shell if the attack by artillery is violent and all available weapons are used. In the approach march, tanks can be forced to "button up" by firing ricochet fire, or time or VT-fuzed HE shell. Caution should be used in firing WP as it may obscure the tanks and prevent the adjustment of fire.

c. Cannon.

(1) Antitank guns (other than armored self-propelled weapons), rocket guns, and infantry heavy weapons, when emplaced in pillboxes or bunkers, are attacked by precision methods.

(2) When the weapons listed above are in position in hasty emplacements or under light cover and are firing, the object usually is neutralization. If the weapons can be seen, destruction fire is used.

(3) Weapons having an unusual degree of mobility, such as certain rocket guns, often are brought from concealment and fired in the open. The crews load, leave their weapons during firing, and then rapidly move the matériel to new positions. Surprise fire with registration corrections applied and speedy bracket adjustment, using HE shell with quick or VT fuze, are appropriate.

(4) Light weapons are not considered separately as neutralization is effected by neutralization of personnel. Mobility is such that precision methods usually are not practicable, and a certain amount of destruction is incidental to fire for neutralization.

d. Vehicles such as trucks, prime movers, and personnel carriers.

(1) When in bivouac or park, vehicles may be attacked as an area target by observed and unobserved fire for the purpose of neutralization. If the vehicles can be seen, they are destroyed, using precision methods. HE shell of all calibers, using quick fuze, is appropriate. If combustible material can be ignited, WP is effective.

(2) When such matériel is moving, observed fire must be used. The objects are: first, to stop the column; second, to destroy the matériel. A deep bracket is sought initially. When the road can be identified on the firing chart, a battalion or several battalions may fire simultaneously, the fire of battalions and batteries being fitted to the road. Columns of widely spaced units have been attacked successfully by first registering on a definite point on the road (usually a point at which vehicles cannot leave the road, as at a defile or culvert), then timing volleys to reach that point simultaneously with each vehicle. Once a vehicle is halted, it is attacked promptly by precision methods. HE shell with quick fuze is very effective on such matériel when a hit or near hit is obtained.

(3) Landing craft may be attacked with any or all available weapons. Time and VT fuzes are most effective on personnel in open landing craft. Direct laying from carefully prepared positions should be used whenever possible.

e. Personnel.

(1) *In the open.* Personnel in the open usually are dispersed and are able to take advantage rapidly of available cover and concealment. Neutralization is effected whenever such personnel are forced to abandon their activity and seek cover. In neutralization, surprise is not an essential factor. Effective fragmentation is required against seasoned troops to produce neutralization. HE shell with time, VT, or quick fuze, or delay fuze with ricochet action, are effective. When the quick fuze is used, the charge giving the highest practicable angle of impact is used. Repeated short bursts of fire at irregular intervals have a cumulative effect and are far more effective than the same amount of ammunition expended in one long concentration. If the object is to produce casualties, surprise is essential. It is obtained by the use of accurate data, surveillance, massed battalions, and time-on-target (TOT) fire. All calibers are effective against personnel.

(2) *In trenches or fox holes.* Personnel in trenches, lightly constructed emplacements, or fox holes usually are dispersed, concealed, relatively immobile, and protected against fragments unless the fragments are descending almost vertically. Surprise usually is not essential. Fire, with time or VT fuze, and ricochet fire with HE shell are most effective. In order to produce casualties, a large number of rounds are required; hence, either many weapons or many rounds per weapon must be used. WP is effective in driving personnel out of fox holes into the open where HE shell can be used more effectively.

(3) *In dugouts or cave shelters.* Precision fire for destruction or assault fire with delay fuze should be used.

(4) *With light overhead cover.* Impact bursts will crush light overhead cover. Some neutralization and casualty effect result from any suitable method of attack.

f. Buildings.

(1) Heavy construction, such as concrete, stone blocks, or brick usually requires direct hits with 155-mm or larger shells with delay or concrete-piercing (preferred) fuzes. Precision fire is required, except in the destruction of buildings covering large areas. Several pieces may be converged on a building if calibration corrections are applied or if each piece is adjusted on the target. Before a decision is made to destroy the buildings of a city or village, consideration should be given to the fact that the rubble from masonry buildings is almost as useful in defensive fighting as the buildings themselves.

(2) Buildings of frame and other light construction are attacked with HE shell with quick fuze or with WP shell (for incendiary effect).

g. Bridges.

(1) The destruction of bridges of concrete, stone, brick, or steel is difficult and requires many hits with HE shell of heavy caliber. The concrete-piercing fuze is most effective. The probability of hitting the bridge is best when the direction of fire coincides with the long axis of the bridge. Collapse of a bridge often is effected best by knocking out a pier or other support. Precision fire is required. Quick fuze may be used for adjustment and concrete-piercing or delay fuze for effect.

(2) All calibers, projectiles, and fuzes are effective against wooden and ponton bridges.

h. Defensive works.

(1) *General.* The tactical objective of artillery fire is destruction of the defensive works and neutralization of the personnel within. The attack of a fortified area is a complex problem because the enemy has had the time, labor, and materials to fortify the area. The pillboxes and bunkers usually are mutually supporting, extend in considerable width and depth, are in communication with each other and with a central headquarters, and are coordinated with other forms of defense. Direct laying or assault fire from close-up positions is preferable. Protection for the assaulting weapons can be secured by use of smoke or coordinated attacks on all installations capable of firing on the weapons, and by attacking in periods of darkness or low visibility.

(2) *Concrete pillboxes.* Assault fire, using appropriate weapons with sufficient terminal velocity and the appropriate fuze, must be utilized in order to destroy concrete pillboxes. HE shell with quick fuze may be used to blast away camouflage or earth cover and to blast apart shattered concrete.

(3) *Armor.* Steel turrets or portable steel pillboxes are attacked successfully with 105-mm HE-AT or with AP projectiles of the 155-mm gun. Against the armor of ports and embrasures, the AP projectiles and HE-AT of all calibers are effective.

(4) *Bunkers.* For bunkers of composite construction, such as earth and logs, sand-filled oil drums, and sandbags, HE shell of 155-mm or larger caliber with delay fuze and the appropriate charge for penetration, is required. Several direct hits generally are necessary.

i. Roads and railroads.

(1) *Destruction.* Precision fire with large caliber HE shell, delay or concrete-piercing fuze, and charge suitable for penetration is used. Fire is concentrated on sensitive points—fills, defiles, bridges, culverts, junctions, or crossings. Unless the road can be attacked where it coincides with the direction of fire, excessive amounts of ammunition are necessary.

(2) *Harassing and interdiction fire.* Either observed or unobserved fire, of sufficient intensity to neutralize troops in the area, is put down at irregular intervals. The threat of losses is relied upon to curtail movement or activity during the lulls.

j. Supply installations. Harassing or neutralization fires (the distinction depending principally on the amount of fire) are employed. They consist of observed or unobserved fires of any caliber with ammunition suitable for use against personnel in the open. The object is to hamper operations at the installation. Some destruction usually results. If destruction is sought, precision fire is used with HE shell and quick fuze (unless pentration is required).

CHAPTER 18

FIRE DIRECTION—BATTALION

Section I. FIRE-DIRECTION CENTER

179. DEFINITIONS. The *fire-direction center* is that element of a command post consisting of gunnery and communication personnel and equipment by means of which the commander exercises fire direction. The fire-direction center converts target intelligence, fire missions of higher commanders, and requests for fire into the appropriate fire commands (fig. 68).

180. PURPOSE. The fire-direction center assists the battalion commander in the control and coordination of all types of fire with one or more of his batteries. He orders the execution of prearranged fires to conform to the plan of operation. He approves or disapproves fire missions reported by observers. He executes promptly all fire missions ordered by higher headquarters.

181. PROCEDURE. a. Targets from all sources are reported directly to the fire-direction center where they are plotted on the firing chart. From this plot, data are prepared and sent to the batteries as fire commands. The personnel of the fire-direction center prepare the firing data for both observed and unobserved fires.

b. The horizontal control operator (HCO) and vertical control operator (VCO) each maintains a firing chart. In addition, another chart is maintained in the fire-direction center so that three missions may be fired simultaneously. A firing chart also is maintained at each firing battery position. All charts except the HCO and VCO charts are maintained only in sufficient detail to enable occasional missions to be fired. All targets are replotted on the HCO and VCO charts.

182. EXECUTION OF FIRE MISSIONS. Accuracy, flexibility, and rapidity in the execution of fire missions depend upon—

a. The accurate and rapid preparation of firing data from the firing chart and transmission of commands direct to the firing batteries.

b. The efficient division of duties.

c. The adherence to a standard technique.

d. The efficient use of mechanical devices, such as the graphical firing table (GFT).

e. The personnel functioning as a team and operating in a definite specified sequence in order to avoid and eliminate errors.

Figure 68. Battalion fire-direction center.

Section II. FIRE-DIRECTION PROCEDURE

183. GENERAL. **a.** The personnel of the fire-direction center are assigned specific duties which are performed in a prescribed sequence and manner in order to provide efficient fire control.

b. The following paragraphs are applicable to light, medium, and heavy artillery. The principles and procedures which particularly affect heavy artillery are repeated and emphasized in paragraphs 201 to 206.

184. DUTIES OF S–2. The S–2 is the intelligence officer. FM 6–101 and FM 6–130 contain detailed description of his duties. Those duties which pertain to fire direction are to—

a. Locate and report targets and to recommend likely targets to the S–3.

b. Advise the S–3 on methods of attacking targets.

c. Obtain and distribute maps and aerial photographs and to assist in target restitution.

185. DUTIES OF S–3 AND ASSISTANT S–3. a. General. The S–3 is the operations and training officer. (For detailed duties, see FM 6–101.) He also is the gunnery officer of the battalion. The assistant S–3 is the relief and replacement for the S–3. As such, he must be able to perform the duties of the S–3. The S–3 plans, coordinates, and supervises the activities of the fire-direction center and trains the personnel. The amount of supervision required varies with the state of training.

b. Decision to fire. When a target is reported, the S–3 examines its location relative to the front line, no-fire line, zones of fire, and check points. From the foregoing information, nature of the target, ammunition available, and the policy of the commander, he decides whether or not to fire the mission.

c. S–3 fire order. When a target is to be fired on, the S–3 issues a fire order. This order consists of some or all of the following elements. They are given in the sequence set forth in order to avoid errors and confusion and to save time.

Element	*Example*
(1) Batteries to fire	*Battalion*
(2) Adjusting battery	*Baker*
(3) Salvo fire by adjusting battery	*Salvo right*
(4) Basis for corrections	*Transfer from check point one*
(5) Use of deflection corrections	*Use deflection correction*
(6) Use of special corrections	*Special corrections*
(7) Projectile to be used	*Shell HE*
(8) Charge to be used	*Charge 5*
(9) Fuze to be used	*Fuze time*
(10) Number of volleys	*Five volleys*
(11) Range spread between batteries or zone desired	*One c apart*
(12) Time of opening fire	*When ready*
(13) Concentration number assigned	*Concentration D5*

If the fire is to be observed, items (1), (2), (7), and (9) through (13) are sent to the observer conducting the mission for his information.

d. Elements of the S–3 fire order. The following considerations affect the elements of the S–3 fire order:

(1) *Batteries to fire.* The decision as to which battery or batteries will fire a mission is dependent on these factors:

(*a*) Number of batteries available to fire.

(*b*) Size of the area to be covered and its accuracy of location.

(*c*) Caliber, type, and number of weapons per battery.

(*d*) Whether or not surprise fire is indicated.

(*e*) Importance of the target.

(*f*) Range.

(*g*) Dispersion.

(*h*) Maintenance of neutralization, harassing, or interdiction fire.

(*i*) Registration.

(*j*) Ammunition situation.

(2) *Adjusting battery.* For registration or for missions requiring fires of the battalion, it is best to use the center battery as the adjusting battery.

(3) *Salvo fire.* Salvo fire by the adjusting battery is ordered when requested by the observer.

(4) *Basis for corrections.* The check point expected to give the greatest accuracy should be selected for the basis of corrections if the target is within transfer limits of more than one check point.

(5) *Use of deflection correction.* The deflection correction should be used for all fire-for-effect missions. It normally is not used in will-adjust missions (par. 186).

(6) *Use of special corrections.* Special corrections are used for barrages, targets very close to friendly troops, and targets of unusual shape or dimensions. (See par. 43.) They are applied to correct for echelonment, difference in altitude, and calibration of the pieces in order to have the range and distribution as nearly correct as possible.

(7) *Projectile.* The projectile or combination of projectiles must be selected, depending on the mission and nature of the target. Unless the observer requests a particular type shell, shell HE normally is used.

(8) *Charge.* The range, nature of target, and mission govern the selection of charge to be used.

(9) *Fuze.* The nature of the target, mission, and ammunition available govern the selection of fuze to be used. The choice will be between quick, delay, concrete piercing, armor piercing, VT, and time. Fuze quick will be used unless the observer has requested otherwise.

(10) *Number of volleys.* The mission, nature of target, ammunition available, and pertinent orders from higher headquarters govern the number of volleys to be fired. Judgment and experience will save ammunition.

(11) *Range spread or zone* (par. 176). The area to be covered, the accuracy of target location, and the probable error of the weapon should be considered to determine the range spread or zone.

(12) *Time of opening fire.* The mission, nature of target, and effect desired govern the selection of time of opening fire, such as WHEN READY, TIME-ON-TARGET (TOT), AT MY COMMAND, or any specific time according to a prearranged schedule.

(13) *Concentration number.* A number is selected for each concentration from the block of numbers assigned to the battalion unless a number has been specified by higher headquarters. This number may be preceded by a letter prefix to indicate the unit (battalion, division artillery, group, or corps artillery) which assigned the concentration number. The horizontal control operator may keep a list of the concentration numbers readily available in order to avoid duplication or confusion.

e. Verifying corrections and commands. The computation of corrections from registration or meteorological messages must be verified. Computors may be detailed to perform these computations independently while the S–3 makes approximate computations. He must listen to the commands sent to the batteries to insure they agree with his orders. By verifying the relative elevations fired and knowing the relative positions of the batteries, he may detect errors in elevation commands.

f. Records. A blackboard or sheet of acetate may be used for posting GFT settings, registration and meteorological data, and other information of use to the fire-direction personnel. A permanent tabulation of registration data should be kept for reference.

g. Assistants. The S–3 is assisted by the assistant S–3 and the chief computer in the operation of the fire-direction center and by other staff personnel as required for efficient operation.

186. DUTIES OF THE HORIZONTAL CONTROL OPERATOR (HCO). a. General. The HCO is a key member of the fire-direction center. Any error on the part of the HCO will result in poor or ineffective fire by the battalion. He must be selected carefully and trained in the duties of the vertical control operator (VCO) and the computers as well as those of the HCO. The HCO prepares the firing charts used in the fire-direction center unless they have been prepared by the survey section. A color system is used for identifying battery locations, pins, and inverted arrows on base-point line extensions. The colors used are: Battery A—red, Battery B—white or black, Battery C—blue.

b. Constructs firing chart.

(1) The HCO plots the base-point line extensions (par. 124).

(2) When the location of an observation post is established by survey, its location is plotted on the firing chart. An observer

orients his instrument at this observation post and reports the instrument reading to the reference point. The HCO and VCO draw a reference line passing through the observation post and reference point, and label the line with the instrument reading reported. With this line as a basis, other reference lines are drawn through the observation post for instrument readings in multiples of 500$\not{m}$ to cover the entire area (par. 313).

(3) The plotting of points and drawing base-point line extensions, reference lines, and deflection indices on the firing chart must be done with great care. Plotting needles should be used rather than pins to decrease the size of plotted points. All lines should be drawn with a sharp, hard pencil. Wide or poorly drawn lines will cause inaccuracies of several mils in direction. Large plotting pins may cause errors of 10 to 15 yards in location of points. To prevent enlarging of the holes at the plotted locations of the batteries, a piece of acetate or similar material pierced with a small hole should be placed with the hole over each plotted battery location and attached to the chart by transparent tape. The edges of the acetate should be beveled so that the fan may slide over it without catching. Other devices which produce the same result may be used.

c. Inspects new equipment. New plotting equipment should be inspected and checked for accuracy before use. The triangular boxwood scale may be used as a standard. The range-deflection fan should be checked for accuracy of the indicated ranges. The error should not exceed 2.5 yards per 1,000 yards. The edges of the range-deflection fan should not be altered. The coordinate scale may be checked by using the inch scale (or meter scale) on an accurate plotting scale. The angular scales of the fan may be checked against a 16-inch protractor and against a constructed right angle. The inspection of plotting equipment is especially necessary for long-range artillery.

d. Operates target grid (fig. 69). The target grid is a device for converting the observer's target locations and corrections with respect to the *OT* line to target locations and corrections with respect to the *GT* line. A target grid is operated in conjunction with each of the charts in the battalion fire-direction center and with each battery chart. An arrow extends entirely across the grid with its point at the zero mark of the azimuth circle and indicates the direction of the *OT* line. The azimuth scale is printed around the edge of the grid. It is graduated in a counterclockwise direction at 10-mil intervals from zero to 6,400 mils. The scale of the target grid must be the same as that of the firing chart. When used with a firing chart at a scale of

1:25,000, the smallest graduation of the grid represents a distance of 100 yards.

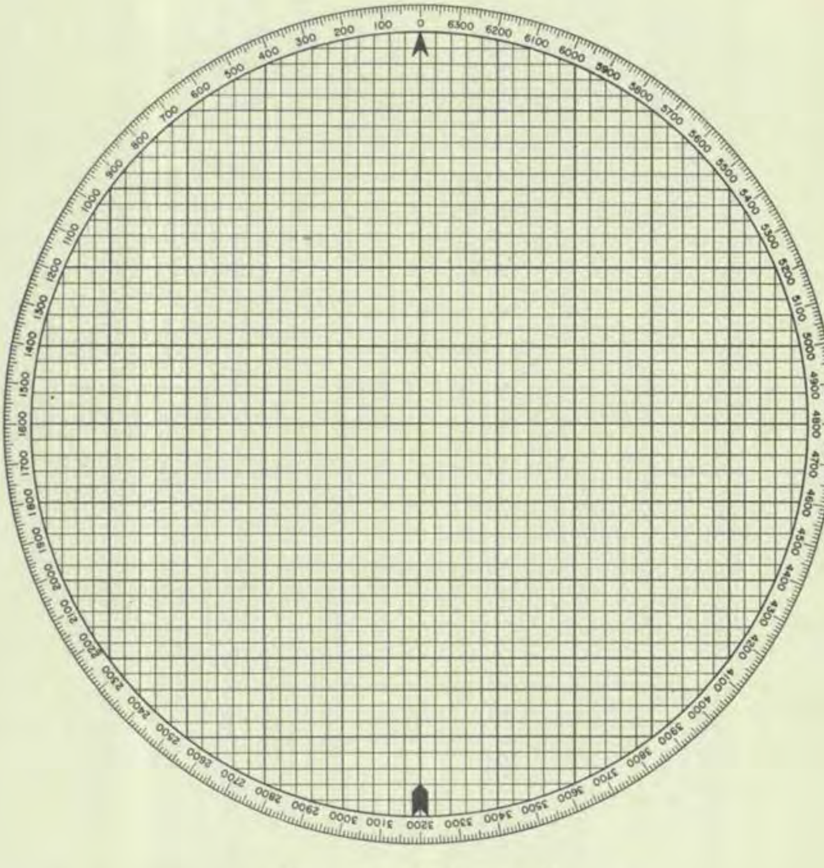


Figure 69. The target grid.

e. Places target grid. The center of the grid is placed over any point of orientation in the target area, such as the base point, a check point, a previously fired concentration, or an arbitrarily selected point, so that the target to be plotted falls beneath the grid. If subsequent corrections cause the target to plot off the grid, the grid is moved to a suitable new position and reoriented on the same azimuth given in the initial fire request.

f. Orients target grid.

(1) *Ground observers.* The HCO constructs an *azimuth index* on the chart at the edge of the target grid to indicate north, or azimuth zero. This index is located by rotating the grid until the arrow is pointing to grid north. The index then is drawn at zero azimuth as an inverted arrow and plainly

marked "N" to prevent its being confused with other indices on the chart. Orienting the target grid is accomplished by rotating it until the figure read opposite the azimuth index is the same as the *OT* azimuth announced by the observer. This operation places the arrow and all lines parallel to it on the same azimuth as the *OT* line (fig. 70).

(2) *Air observers.* Since the air observer has no stationary *OT* line, he must conduct his adjustment with reference to the gun-target line. For this reason, he will not announce an azimuth at the beginning of his fire request. The HCO orients the target grid on the gun-target line of the center battery. If the target location is given with relation to the base point, the initial plot is made with the arrow of the target grid parallel to the base-point line of the center battery. If a different reference point is used in designating the target location, then the arrow of the target grid must be parallel to the line connecting the pieces with that reference point. Subsequent shifts are made with the target grid oriented on the gun-target line of the adjusting battery. This is done by lining up by eye one of the lines which is parallel to the arrow, so that it is parallel to the edge of the range-deflection fan when placed against the target pin.

g. Prepares range-deflection fan (par. 123). If all batteries have aiming posts out on a common deflection, a single fan may be used for all batteries. For a battery not on this common deflection, the HCO must use a separate fan.

h. Constructs deflection index.

(1) Prior to completion of the initial registration, deflections are read directly from the top of the fan, using the base-point line extension as the index. On completion of the initial base-point registration, the HCO constructs a deflection index (par. 124).

(2) When a battalion is tied together by survey and only one battery is registered, the deflection indices of the other batteries are offset by the same amount and in the same direction from base-point line extensions as the adjusting battery.

i. Constructs deflection-correction scale.

(1) Since the deflection index compensates for the difference between chart deflection and adjusted deflection, only that change in deflection correction which is due to the variation in drift as the range is changed need be carried by the HCO as a deflection correction. This is accomplished by marking the range-deflection fan as shown in figure 57; the graduations marked are the ranges at which the drift changes.

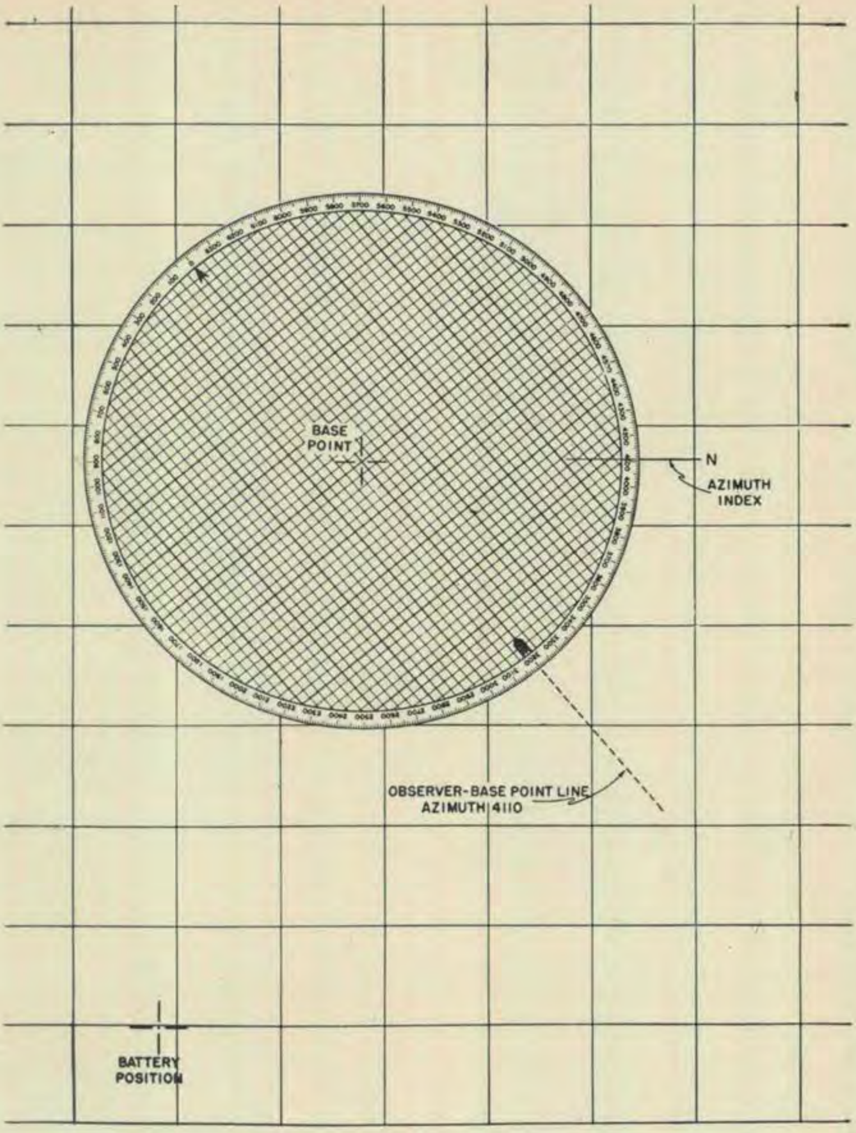


Figure 70. Orienting the target grid.

These corrections are announced to the computers as: *Corrections all batteries* (**k** below). The deflection index is not changed when a new deflection correction is determined as a result of a new registration. The deflection-correction scale marked on the range-deflection fan is altered to compensate for the difference between the old and the new adjusted deflection.

(2) For registration points, other than the base point, such as check points, the deflection correction is the difference between the adjusted deflection and the map deflection as read opposite the deflection index and is recorded as Left or Right (so much). A deflection-correction scale for each check point is constructed and recorded separately. Deflections for transfers from a check point are read from the deflection index originally constructed. This deflection index is not changed. *Example:* Adjusted deflection to check point No. 1 is 2,437. Deflection as measured from the firing chart, 2,442. Deflection correction at check point No. 1 is Right 5 (2,442−2,437=5).

j. Plots targets. The HCO plots all targets reported to the FDC.

(1) Targets reported by coordinates are plotted, using the coordinate scale.

(2) To plot targets designated with respect to a reference point, the target grid first is oriented. The HCO then plots the target location given in the observer's fire request, moving right or left so much along a line perpendicular to the arrow on the target grid, and adding or dropping so much along the directional arrow or one of the lines parallel to it. Figure 71 shows the HCO plot of an observer's fire request, AZIMUTH 4,350, FROM BASE POINT, RIGHT 600, DROP 1,000. In this manner, the target location is plotted with respect to the *OT* line. Subsequent corrections throughout an adjustment are plotted in a similar manner for each round, volley, or salvo to be fired, moving from the location of the target pin. The target grid is not used in making an initial target plot by map coordinates.

(3) The observer, at an observation post that is part of the target area base or from a position located by survey, may report a target. The report will be in the form of polar coordinates; that is, an instrument reading, a distance, and a vertical angle from the surveyed observation post. As the reference lines for direction from the surveyed observation post are on the chart, the HCO places the vertex of the fan at the observation post and, using the nearest reference line, sets off the instrument reading with one edge of the fan and plots the point at the distance reported by the observer. If the observer has been located approximately on the chart, he may send target locations for will-adjust missions in the same manner except that an azimuth is substituted for an instrument reading, and the distance is estimated. The target is plotted by placing the vertex of the fan at the observation

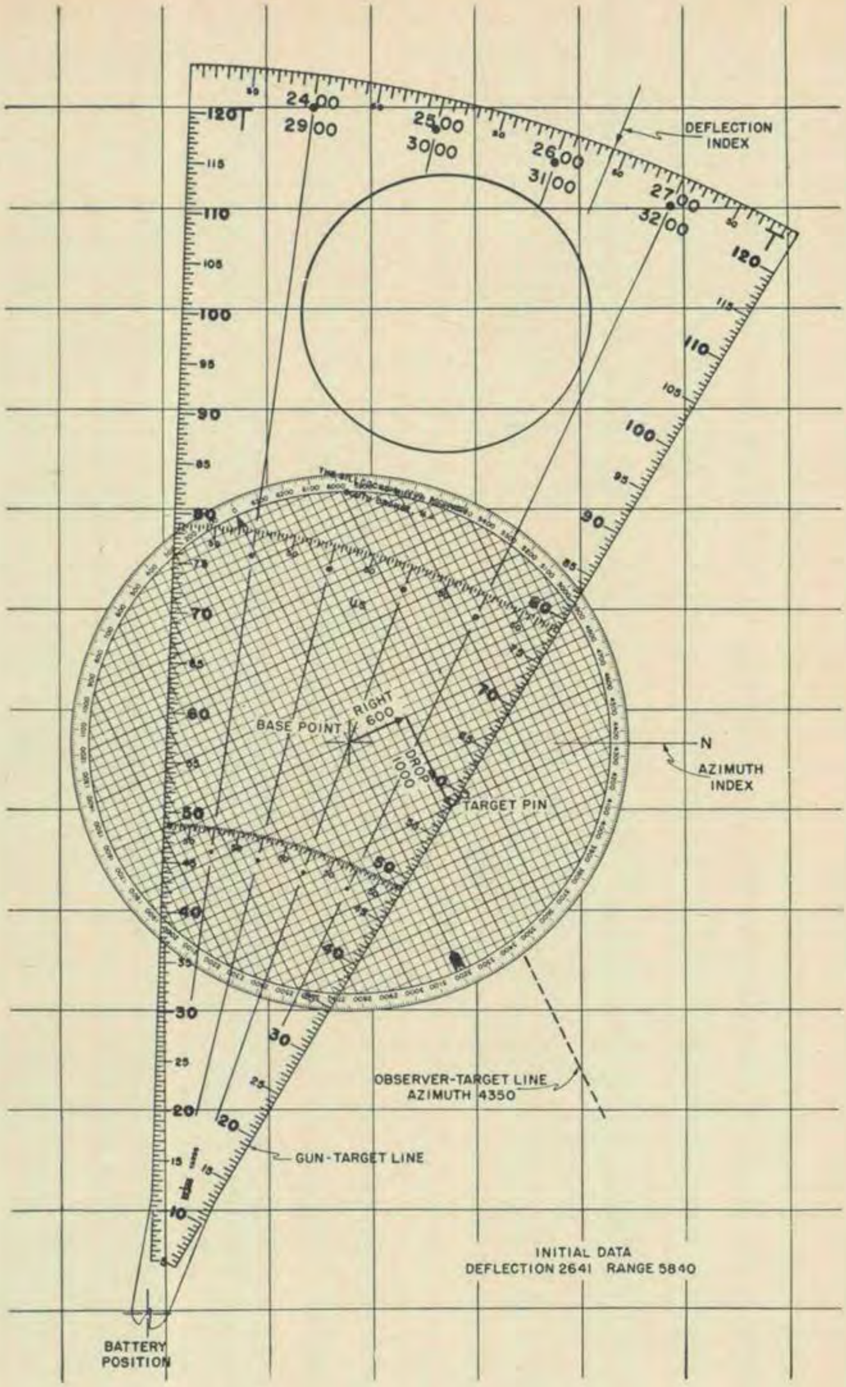


Figure 71. Plotting a target.

post and setting off the proper azimuth, using grid line and/or reference lines for orientation. The plot then is made at the range announced by the observer.

k. Determines and announces data.

(1) After completing his target plot, the HCO places the range-deflection fan against the pin which marks the target location with the vertex of the fan at the pin marking the battery position. Data are read and announced in the following sequence:

(*a*) *Deflection correction.* This is the deflection correction which is determined from the range-deflection fan and is announced as *Right* (*Left*) (*so much*). *Example: Corrections all batteries, Left 2.* The application of this deflection correction to the announced deflection results in the most accurate data. It always is applied in missions where there is no adjustment. Usually it is not considered in a will-adjust mission, as its use complicates computer procedure and increases the over-all time for a mission without yielding a compensating increase in accuracy. It is used in will-adjust missions of long-range artillery, because the deflection correction may amount to several hundred yards on the ground. The deflection correction always is announced, regardless of whether it is to be applied or not. When deflection correction is to be applied, the S–3 will direct the computers to apply the deflection correction to the announced deflections throughout the mission. The deflection correction used for all batteries is that obtained at the range of the center battery in a fire-for-effect mission and of the adjusting battery in a will-adjust mission. If considerable echelonment in depth and resultant range variation exists between batteries, separate deflection corrections may be necessary.

(*b*) *Deflection.* The HCO reads the deflection for each battery opposite its deflection index. When announced, it is preceded by the word *deflection.* Example: *Baker, Deflection 2,641* (fig. 71). In a will-adjust mission, the data for the adjusting battery are announced first, followed by the data for the nonadjusting batteries from right to left. In a fire-for-effect mission, data are announced for the center battery first, followed by that for the remaining batteries from right to left.

(*c*) *Range.* The range for each battery is read from the range-deflection fan opposite the target pin and announced to the computers by the HCO. It is announced immediately after the deflection and always is preceded by the word *range. Example: Baker, Deflection 2,641, Range 5,840* (fig. 71).

(2) During an adjustment, the HCO continues to announce deflections and ranges for the adjusting battery only.

(*3*) During a will-adjust mission, the nonadjusting batteries will have received complete commands with the restriction, *DO NOT LOAD*. Upon completion of the adjustment, the HCO gives the adjusting battery the data at which to fire for effect, then places his range-deflection fan against the final position of the target pin and determines and announces the deflection and range at which each of the nonadjusting batteries begin fire for effect.

l. Replot of targets after adjustment. The HCO receives data for replot from the adjusting computer in the following sequence and plots the location of the target as indicated below:

Item announced	*Action of HCO*
Data for replot	Pick up fan.
Baker	Put vertex on Battery B.
Deflection 2,742	Move fan to deflection 2,742.
Range 5,000	Place pin at 5,000.
Site minus 7	(For the VCO.)
Fuze delay	Mark D after tick marks are placed.
Concentration E99	Label concentration.

Replotted targets should appear as in figure 72. On the surveyed firing chart, targets which have been located by adjustment are plotted in red to distinguish them from surveyed targets. The upper left-hand corner may be used to show the charge. This is required in high-angle fire.

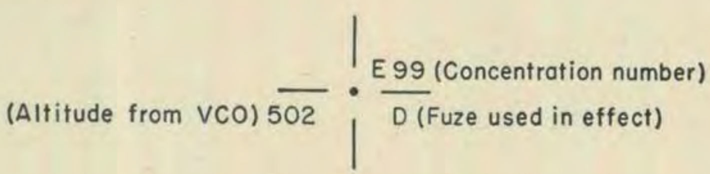


Figure 72. Replotted target.

m. Plots targets on the firing chart.

(1) On completion of a mission adjusted by an observer, data for replot is received from the computer for the adjusting battery. A permanent plot is made on the firing chart. In doing this, the HCO uses the range-deflection fan and polar

plots the target's location, utilizing the data for replot, range, and deflection, received from the computer.

(2) The battery reports its adjusted data for all targets which have been fired by the battery fire-direction center; the targets then are plotted on the battalion chart by the HCO.

n. Corrects a misorientation of the target grid. The observer may send an azimuth which is in error. The resulting error in orientation of the target grid should be corrected if it is large enough to cause the observer difficulty in adjustment. *Example* (fig. 73): The observer's first correction is ADD 400. The HCO moves the target pin 400 yards up the *OT* line and a round is fired with the data obtained. The observer's next correction of RIGHT 200, REPEAT RANGE in-

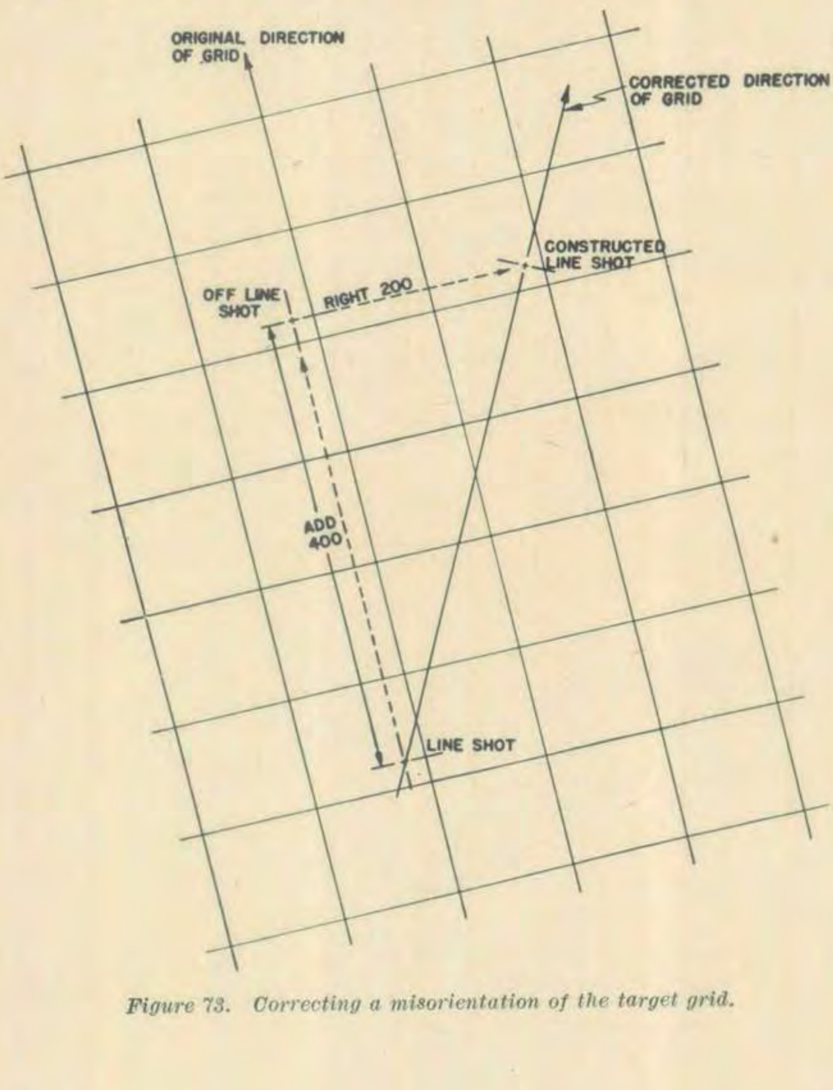


Figure 73. Correcting a misorientation of the target grid.

dicates the reported azimuth is in error. The HCO moves the target pin right 200 yards and marks the position of the constructed line shot on the firing chart. While a round is being fired with this data, the HCO draws a line on the chart connecting the constructed line shot with the previous line shot. The target grid is rotated until the arrow on the grid is parallel to this line. The grid now is oriented correctly. When the next observer correction is received, the target pin is moved from the chart location of the last round fired.

o. Data on the firing chart. The HCO will keep on his chart other information which may be of particular importance to the battalion and the S–3. Such information consists of the locations of friendly elements, observers, and limiting factors, including the *no-fire lines*. (See FM 6–20.) No-fire lines may be kept directly on the firing chart or, if they are changed frequently, it may be more convenient to keep them on an overlay.

187. DUTIES OF THE VERTICAL CONTROL OPERATOR (VCO). a. General. The VCO prepares and maintains a chart identical to that of the HCO and should be trained so that he is able to perform the duties of the HCO. He normally will be used in the capacity of HCO during displacements and for temporary relief of the regular HCO. For fire missions, the VCO determines the site for each battery.

b. Duties. The VCO performs the following duties under the supervision of the S–3.

(1) *Duties similar to the HCO.* The VCO prepares his firing chart in the same manner as the HCO (par. 186). If his chart is a photomap, the VCO should accentuate the ridge lines and stream lines. He places spot and critical altitudes on both the photomap and surveyed grid sheet, so he is able to interpolate rapidly and read altitudes from his firing chart.

(2) *Computes sites for the batteries.* The VCO computes site by first determining the altitude of the initial plot. The altitude is determined from the difference in altitude in the observer's initial fire request when the target location is given with respect to a known point. When the observer sends coordinates to locate the target, the altitude is determined from the vertical control available on the firing chart. The altitude of the target in yards, minus the altitude of the battery in yards, gives the height of target. The height of target divided by 1/1000 of the range gives the angle of site. When appropriate, the complementary angle of site is added to the angle of site to obtain the site to be used. The VCO does not include complementary angle of site in his calculations in the case of high-angle fire; in such cases, it is taken care of by the

computers. When working with an off-scale chart, he must determine ground ranges before computing site. He makes a semipermanent record of sites similar to the following:

	A	*B*	*C*
BP	+5	−1	−3
Conc D 57	+6	0	−2
Conc D 72	+5	0	−2

(3) *Announces site for the battery.* The VCO announces the site after the HCO has given his data. When the battery B computer wishes his site, he asks "*Site Baker?*" The VCO announces "*Site Baker plus* (*minus*) *6* (*or so much*)." Site is announced only when the computer asks for it.

(4) *Determines altitudes of replotted concentrations.* At the completion of any adjust mission by one of the batteries, the VCO replots the target in the same manner as does the HCO. He also must determine the adjusted altitude. This is the reverse process of computing the site. In site computation he solved for "$\not{h}$" in the mill relation formula and multiplied by 1 plus complementary site factor for the initial range. In determining adjusted altitude, he solves for "*W*" in the mil relation formula and divides by 1 plus complementary site factor for adjusted range. This quotient, the altitude difference between adjusting battery and target, is added algebraically to the altitude of the adjusting battery. The result is the altitude of the target. If the firing chart is a battle map or has sufficient vertical control, the final altitude is taken from the chart rather than being determined from the site fired (par. 154).

c. Aids. Measures which will assist the VCO to determine sites accurately include—

(1) Study of the topography of the target area from an observation post.

(2) Determination of spot altitudes by survey.

(3) Stereoscopic examination of photos.

(4) Accentuation of drainage and ridge lines on the firing chart.

(5) Study of oblique photos.

(6) Study of the record of adjusted sites for concentrations on which time fire was adjusted. (A time correction must have been determined and used in the adjustment.)

d. GST. The graphical site table may be used to perform all of the above computations. Its use will result in a great increase in speed with no loss of accuracy.

188. DUTIES OF COMPUTERS. a. General. The computers, one per firing battery, are members of the fire-direction center. These individuals accurately and rapidly convert the S–3's order, HCO and VCO data, and observer's corrections into fire commands which are transmitted to the firing batteries.

b. Recording. Computers record the following:

(1) Fire missions reported to the fire-direction center.

(2) S–3's order.

(3) HCO and VCO data.

(4) Computations and commands, including data sheets.

(5) Battery executive's report to include base angle, compass, battery front, minimum elevations for all charges, amount and type of ammunition by lot number, relative piece locations, and other pertinent data.

c. Computing. Computers must be prepared to make the following computations:

(1) Fire commands (including data sheets) from the S–3's order, HCO and VCO data, and observer's corrections.

(2) Corrections for nonadjusting batteries.

(3) Data for replot for the HCO and VCO.

(4) Registration and metro corrections.

(5) Special corrections (when the executive is not directed to compute them).

(6) Piece displacement corrections (par. 129).

(7) Necessary corrections to site when firing fuze time or VT.

d. Commands and corrections. Computers announce—

(1) Fire commands to the battery.

(2) Corrections when acting as adjusting computer, as: *Corrections; Fuze Quick, Down 2.*

(3) Data for replot when acting as adjusting computer, as: *Data for replot, Baker, Deflection 2158, Range 4760, Site plus 12, Fuze Quick, Concentration E108.* (In case of high-angle fire, the charge also must be given.)

(4) The deflection correction scale to the HCO.

e. Fire missions.

(1) The computer alerts his battery as soon as he is certain that a fire mission is to be executed. Fire commands are sent to the battery as rapidly as they are determined. The computer does *not* determine all of his commands before he commences sending them to the battery. He repeats all information received from the HCO and VCO and records these data in the computer's record (fig. 74). In missions fired with a range spread, an additional range increment is applied by the computers for Batteries A and C. The S–3 gives this in his order

as: *BATTALION, 5 VOLLEYS, 1/2-C APART.* In this case, the Battery A computer adds 50 yards to his HCO range, and the Battery C computer subtracts 50 yards from his HCO range. In a will-adjust mission, if the adjusting battery is Battery A or C, Battery B takes the normal place of the adjusting battery in the range spread position. The S–3 gives this in his order as: *BATTALION, ABLE, 5 VOLLEYS, 1/2-C APART.* Here, Battery A, the adjusting battery, shoots center range in the fire for effect; Battery C subtracts 50 yards, as usually is done; and Battery B adds 50 yards. If only one battery is to fire for effect and a zone is to be covered, the S–3 gives in his order *BATTERY, 2 VOLLEYS, 100-YARD (OR OTHER SIZE) ZONE.* The computer then fires two volleys at the adjusted range, two volleys at 50 yards greater range, and two volleys at 50 yards less range than the adjusted range. This may be given to the battery as *ZONE (SO MANY MILS)*. The number of mils is equal to 1/2-C. Normally, only 100-yard zones are fired, but in other size zones, the volleys are fired 50 yards apart until the zone is covered.

(2) After the computer has recorded the initial fire request from the observer and the S–3's order, he announces to the battery the data in the sequence given in the computer's record (fig. 74).

(*a*) The adjusting battery, ammunition, charge, and fuze (except time setting) are derived from the S–3's order.

(*b*) Deflection is announced by the HCO. If the deflection correction is to be used in adjustment, the deflection is the algebraic sum of the HCO map deflection and the deflection correction announced by the HCO. (For high-angle fire, see par. 229.)

(*c*) If the observer calls for special corrections, the computer will command *SPECIAL CORRECTIONS* to the battery. The battery normally will be fired without special corrections and with a parallel sheaf.

(*d*) The computer will request site from the VCO. For pieces which have a site and elevation scale, the computer will announce the appropriate site to the pieces. For pieces which utilize a quadrant scale, the computer will include the site with the elevation for the range to be fired and announce quadrant elevation. When fuze time is used, the computer makes the initial correction to site of UP 20/*R*. For fuze VT, the computer includes the correction 25/*R* for the 05-mm and 155-mm howitzer, or $40/R$ for the 8-inch and 240-mm howitzer.

(*e*) For the method of fire (MF), the computer must consider the S–3's order to determine the number of rounds to be fired in effect. If the mission is an adjust mission, the two nonadjusting batteries will announce *BATTERY (SO MANY) ROUNDS, DO NOT LOAD, ELEVATION (FOR APPROPRIATE RANGE)*. The adjusting battery will announce *CENTER (OR BATTERY), ONE ROUND (OR SALVO), ELEVATION (FOR APPROPRIATE RANGE)*. The adjusting computer retains this method of fire until fire for effect is called for. (*CENTER, RIGHT, OR LEFT* refers to the appropriate two pieces.)

(*f*) In a fire for effect mission, all computers will conform to the order of the S–3 pertaining to method of fire. In a will-adjust mission, all batteries are laid on the initial plot. The adjusting battery is fired with two-gun volleys or battery volleys unless the observer orders salvo fire. The observer's corrections for each round are plotted by the HCO on the target grid. The computer uses the deflections and ranges announced. The computer uses the chart range to obtain the elevation for the initial and subsequent round, salvo, or volley.

(*g*) When the observer gives *FIRE FOR EFFECT* following an adjustment, this means the two adjusting guns are on the target and, after correcting for their displacement from the battery center, the adjusting computer fires his battery the number of volleys ordered initially by the S–3. The next problem is to correct the initial fuze and/or site commands of the two nonadjusting batteries. The adjusting computer does this by announcing these changes to the computers. *Example: Corrections, Fuze Quick, Up 12.* The nonadjusting computers give the proper commands and then fire the number of volleys commanded initially.

(*h*) To determine the data for replot, the adjusting computer strips the deflection correction initially announced by the HCO from the adjusted deflections. Corrections for fuze time or VT are stripped from the site. The adjusted range is read directly from the graphical firing table. At the end of this mission the adjusting computer announces to the HCO, for example: *Data for replot, Baker, Deflection 2,843, Range 4,750 Site plus 2, Fuze Quick, Concentration E104.*

COMPUTER'S RECORD

Battery *C* Conc No *07*

Time Mission Completed *1003* Date *15 Nov '48*

FIRE MISSION: *Az 2550, From Conc 1, L 400, - 400, Inf Digging, Fz Ti, Will Adjust*	Df Corr *R4* Df *2851* Rn *5780*	*B* Adjust Sp Corr Sh *HE* Ch *6* Fz *Ti* MF *C(B)*
S3 ORDER: *Bn C, Sh HE, Ch 6, Fz Ti, 5 Volleys, 1c apart, When Ready, Conc. 07*	Si *+3* *20/R = +4* *+7*	Df *2851* Si *307* Ti *17.3* El *268*

CORRECTIONS			SUBSEQUENT COMMANDS							
Deflection	Height (Time)	Range	Df Corr	HCO Df	Piece Df	Rn	Fz Q/D/T	Si	El	Quadrant
L 200		*-400*		*2875*		*5490*	*16.3*		*251*	
R 50	*U 20*	*+200*		*2868*		*5640*	*16.8*	*311*	*260*	
L 25	*D 10*	*-100*		*2872*		*5560*	*16.6*	*309*	*255*	
R 15	*U 10*	*+50 FFE*		*B (B) 2870*		*5600*	*16 7*	*311*	*257*	
								-4	*(20/R)*	
Cease Firing, End of Mission								*307*		
Inf Dispersed										
Many Casualties										

CORRECTIONS: Fz .... Up/~~Down~~ *4*

DATA FOR REPLOT *C* Df *2874* Rn *5600* Si *+7* Fz *Ti* Conc No *07*

AMMUNITION

	HE	*HE*						
Type	*Fz M51*	*Fz M55*						
Total								
Received								
On Hand	*420*	*320*						
Expended	*–*	*38*						
Remaining	*420*	*282*						

Figure 74. Example of a computer's record.

f. Handling time fire or using VT fuze. The computer announces the time as read from the graphical firing table under the time gage line. Any change in elevation requires a corresponding change in time. Corrections and data for replot are the same as for percussion fire, except that the appropriate corrections for height of burst are stripped out of the adjusted site.

189. PLOTTING TARGETS, CHART LOCATION DETERMINED BY FIRING.

a. The target is plotted initially, based on the observer's estimate.

b. The computer of the adjusting battery must compute and announce the corrections determined from the adjustment.

c. The computer of the adjusting battery must compute and announce the data for the replot of the target.

d. The HCO and VCO plot the accurate location of the target from the data announced by the adjusting computer.

e. When using a contoured map, the VCO checks the site for the replotted location of the target (par. 154**c**(3)).

Section III. PROCEDURE IN PRECISION FIRE MISSIONS

190. GENERAL. a. Fire for effect. Fire for effect is started at the trial range and at a deflection which will place the bursts on the *OT* line (par. 71). Fire for effect is conducted by the S–3, HCO, VCO, or computers. The observer's sensings are acted upon to obtain an adjusted elevation and a correct deflection. During fire for effect, the target grid is not used.

b. Computation of adjusted elevation. Since the observer gives sensings only during fire for effect, the S–3 must fire a sufficient number of rounds to obtain six sensings. If the first three rounds all are in the same sense, the elevation is increased or decreased one-half a fork in the appropriate direction and sufficient rounds are fired to obtain three more range sensings. If the first three sensings are mixed, firing is continued at that elevation until six range sensings are obtained. If a target hit is obtained during adjustment, five more rounds are fired at the same elevation. After six range sensings are obtained, the adjusted elevation is computed as in paragraph 130**a** and **b**.

c. Additional fire for effect. When the mission is destruction or when more accurate corrections are desired, the procedure is initially the same as in **b** above; fire is continued until destruction is complete or the desired degree of accuracy is obtained. Elevation is adjusted after each group of six sensings, as in paragraph 130**c**.

d. Deflection correct. Deflection is considered correct when a target hit is obtained, when a 2-mil deflection bracket is split, or when deflection *left* and deflection *right* are obtained with the same deflection setting. After the deflection is determined to be correct, it should not be changed during additional fire for effect on the same target unless persistent deflection sensings are obtained in one sense and none in the other.

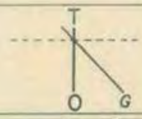
e. Angle *T*. The value of the angle *T* (angle at the target formed between the *OT* and *GT* lines) must be determined in precision fire. It may be determined from the difference between the azimuth of the gun-target line and the observer's azimuth to the target or by measuring the angle formed by the intersection of the gun-target line and the arrow of the target grid when oriented. The procedure used in fire for effect depends on the value of the angle *T*.

191. ANGLE *T* LESS THAN 100 MILS. In this case, deflection errors easily can be determined and corrected because the observer is observing along, or very close to the gun-target line. The fire-direction center instructs the observer to report the deviation in yards of each round in fire for effect. The deflection correction then is determined by use of the 100-yard scale on the graphical firing table. Since the angle *T* is small, range sensings by rule cannot be taken. Only positive range sensings of *over* or *short* can be used by the fire-direction center in computing an adjusted elevation (par. 130).

192. ANGLE *T* GREATER THAN 100 MILS. a. General. A record of the mission must be kept (fig. 75). During the adjustment, a round for which the observer does not send a deviation correction may be considered to be a line shot and the proper deflection sensing entered on the record.

RECORD OF PRECISION FIRE

S/2 = 9 F = 5
T = 780 mils



DEFLECTION	FDC SENSING	ELEVATION	FDC SENSING	OBSERVER CORRECTIONS OR SENSINGS
2800		220		R100, +400
2720(Line)	R	247		-200
2760(Line)	L	233		+100
2740(Line)	R	240		-50, FFE
2750		237	-	?, R
2750		237	-	?, R
2750	L	237	-	- Line
2745	R	240	+	+ Line
2747		240	+	?, L
2747	L	240	-	-Line
2746 =	CORRECT DEFLECTION			
4 shorts; 2 overs	preponderance, 2 shorts			Elevation fired 238.5
	$\frac{2 \times 5}{12} = \frac{10}{12} =$	+1 mil (Correction)		+1. 239.5
				Adjusted Elevation = 240

Figure 75. Example of precision fire record.

b. The factor s. The factor *s* is the deflection change in mils to keep the burst on the *OT* line for a change of range along the *OT* line of 100 yards (fig. 76).

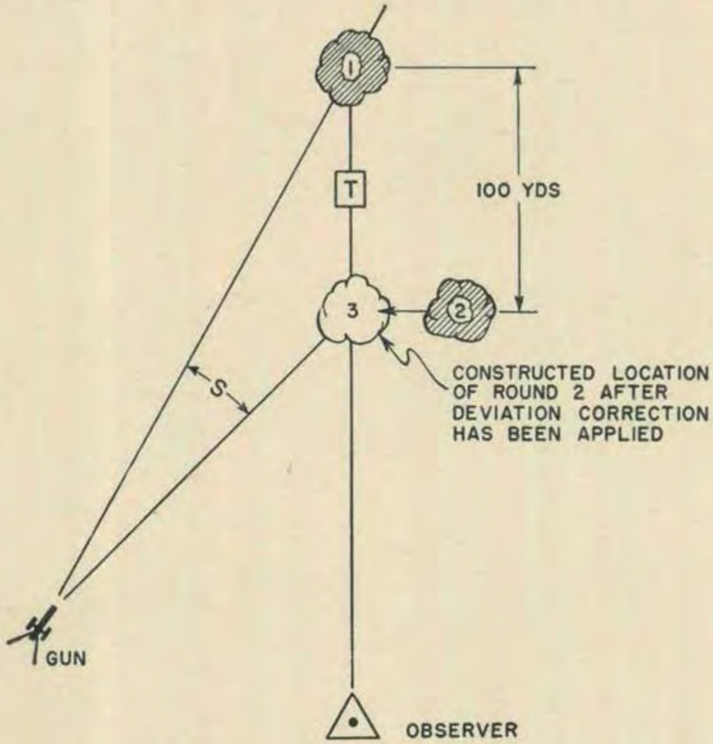


Figure 76. The factor s.

c. Deflection adjustment. In fire for effect, the deflection is changed only when a positive deflection sensing is obtained. If the first deflection sensing in fire for effect establishes a deflection bracket no larger than 1 *s*, the deflection bracket is split; otherwise, the deflection is moved ½ *s* in the appropriate direction until a deflection bracket is obtained. Thereafter, deflection is determined by progressively splitting the existing deflection bracket.

d. Range sensings. During fire for effect, the fire-direction center senses rounds with respect to the *GT* line, based on the observer's sensings and the size of the angle *T*.

(1) Angle *T* 100–1600㎖: When the observer gives a positive sensing for range followed by *line*, the sensing of the observer is accepted as the correct sensing.

(2) Angle *T* 100–800㎖: A positive range sensing by the observer is accepted as the correct range sensing.

(3) Angle *T* 100–1600⧸ₘ: When the observer's sensing for range is doubtful, rounds bursting on the side of the *OT* line away from the piece are sensed as *over* for range; those bursting on the side of the *OT* line toward the piece, as *short* for range. This is termed sensing by rule (fig. 77).

(4) Angle *T* 800–1399⧸ₘ: When the observer's sensing for range is over, and the burst is on the side of the *OT* line toward the piece, the correct sensing for range is *doubtful*; if the burst is on the side of the *OT* line away from the piece, the observer's sensing is accepted. When the observer's sensing is short and the burst is on the side of the *OT* line away from the piece, the correct sensing for range is *doubtful*; if the burst is on the side of the *OT* line toward the piece, the observer's sensing is accepted.

(5) Angle *T* 1400–1600⧸ₘ: Rounds bursting on the side of the *OT* line away from the piece are sensed as *over* for range; those bursting on the side of the *OT* line toward the piece, as *short* for range.

e. Deflection sensings.

(1) A line shot always indicates a deflection sensing.

(2) Deflection can be sensed when the observer senses over for range and the burst is on the side of the *OT* line toward the piece, or when the observer senses short for range and the burst is on the side of the *OT* line away from the piece. These are termed forced deflection sensings (fig. 78).

(3) Angle *T* 1400–1600⧸ₘ: When the observer's sensing for range is short, and the burst is on the side of the *OT* line toward the piece, the deflection is sensed as *left* if the piece is on the right; as *right* if the piece is on the left. If the observer's sensing for range is over, and the burst is on the side of the *OT* line away from the piece, the deflection is sensed as *right* if the piece is on the right; as *left* if the piece is on the left.

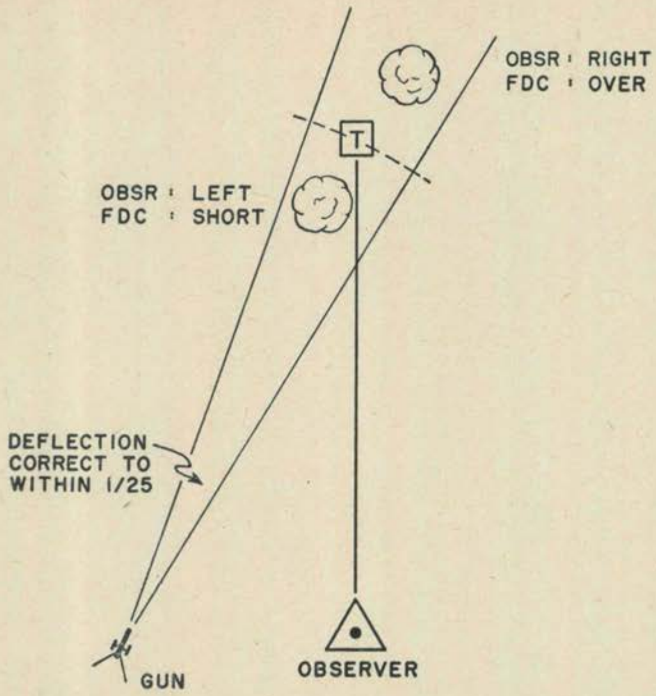


Figure 77. Sensing range by rule, when angle T is greater than 100 mils.

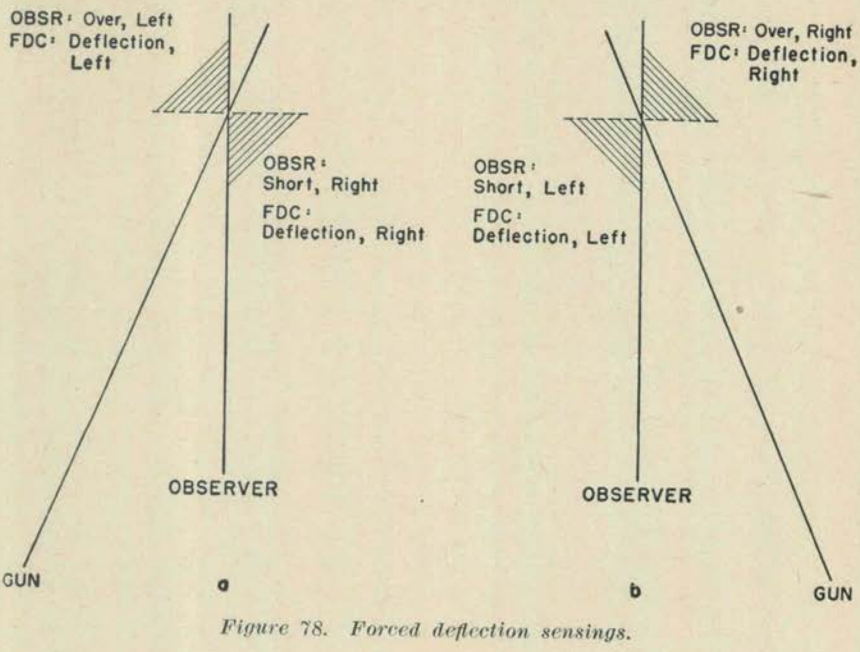


Figure 78. Forced deflection sensings.

f. Tabulation of sensings. The sensings of the observer, converted into sensings for the piece, may be shown in tabular form as follows:

FDC Sensings in Precision Fire for Effect

	Observer sensing	Fire-direction center sensing		
		100-799m̸	800-1399m̸	1400-1600m̸
Guns on left Observer on right	? Right	+ ?	+ ?	+ ?.
	? Left	− ?	− ?	− ?.
	+ Line	+ Left	+ Left	+ Left.
	+ Right	+ ?	+ ?	+ Left.
	+ Left	+ Left	? Left	− Left.
	− Line	− Right	− Right	− Right.
	− Right	− Right	? Right	+ Right.
	− Left	− ?	− ?	− Right.
Guns on right Observer on left	? Right	− ?	− ?	− ?.
	? Left	+ ?	+ ?	+ ?.
	+ Line	+ Right	+ Right	+ Right.
	+ Right	+ Right	? Right	− Right.
	+ Left	+ ?	+ ?	+ Right.
	− Line	− Left	− Left	− Left.
	− Right	− ?	− ?	− Left.
	− Left	− Left	? Left	+ Left.

For angles *T* less than 100 m̸, fire-direction center sensings coincide with observer sensings.

g. Time registration. If the observer's sensing for the initial round is GRAZE, the usual change in time made by the computer is minus 0.4 second. When an air burst is obtained on the initial round, the change made by the computer is plus 0.4 second. After a bracket of 0.4 second has been obtained, three rounds are fired at the center of the bracket. A group of six time sensings is required; normally, rounds are fired in half-groups of three. If the first half-group results in both airs and grazes, the computer fires three more rounds at the same time setting. If the first three rounds all are airs (grazes) the computer increases (decreases) the time 0.2 second and fires two rounds. (The round which established this limit of the time bracket is taken as one round in effect.) The computer then computes the adjusted time based upon the last six rounds.

193. VERIFICATION. a. Elevation. No verification of the adjusted elevation is necessary if fire for effect contains no more than five rounds in the same sense. If all rounds in fire for effect are in the same sense, the elevation is changed one-half fork in the proper direction and an additional half-group of three rounds is fired. If rounds in the opposite sense are obtained in the last group of three, the fire-direction center uses the sensings of the last six rounds fired to compute the adjusted elevation. If rounds in the opposite sense are not obtained in the last group of three, the observer is notified to initiate a new adjustment on the target. All results of the previous fire for effect are disregarded.

b. Fuze time. A time registration containing only a single graze need not be verified if the air bursts are close to the ground, as they may be assumed to verify the correctness of the graze burst. If the air bursts are high, however, it indicates that the single graze burst is erratic, and the time registration must be verified. Similarly, a time registration containing only a single air must be verified, as there can be no certainty that it is not an erratic round. The following procedure is used for verification:

(1) The adjusted time is computed, based on the first six rounds observed.

(2) Three rounds are fired at this adjusted time setting. If these produce a burst in the opposite sense to the preponderance in the previous fire for effect, the adjusted time as computed is accepted. If these three rounds all are in the same sense as the preponderance of the previous fire for effect, the fuze time is changed 0.2 second in the appropriate direction, and three more rounds are fired. If these produce sensings which are opposite to those obtained in the preceding three rounds, a new adjusted time is computed, based on the last six rounds fired. If the sensings obtained still are in the same sense as the preceding three rounds, a new time registration is begun.

Section IV. EXAMPLES OF FIRE-DIRECTION PROCEDURE

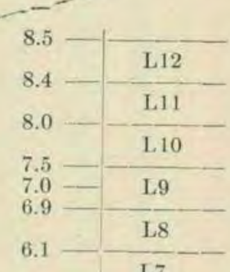
194. EXAMPLE 1: FORWARD OBSERVER MISSION. a. General information.

Unit: 105-mm howitzer battalion with 6-piece batteries.

Positions: Battery fronts are 150 yards, center two pieces 50 yards in front of battery center.

GFT settings: Charge 6, fuze M51, range 7,000, elevation 335.

Deflection-correction scale: *As shown.



*Deflection correction always is announced, but is not used unless ordered by S–3.

b. Procedure.

Observer reports:	THIS IS FOX OBOE BAKER, FIRE MISSION, AZIMUTH 1010, FROM BASE POINT RIGHT 500, UP 20, ADD 300, THREE MACHINE GUNS, FUZE DELAY, WILL ADJUST.
S–3 announces:	*BATTALION, BAKER, SHELL HE, CHARGE 6, FUZE DELAY, FOUR VOLLEYS, CENTER RANGE, WHEN READY, CONCENTRATION E201.*
S–3 to observer:	*BATTALION, BAKER, FUZE DELAY, FOUR VOLLEYS, CENTER RANGE, WHEN READY, CONCENTRATION E201.*
HCO announces:	*Corrections all batteries, Left 10;* Baker, Deflection 2716, Range 7530; Able, Deflection 2721; Range 7540; Charlie, Deflection 2715, Range 7050.*
VCO announces:	*Site Baker, plus 7; Able, plus 8; Charlie, plus 5.*

Commands by computers:	*Computer B*	*Computer A*	*Computer C*
	BA	*BA*	*BA*
SHELL	*HE*	*HE*	*HE*
CHARGE	*6*	*6*	*6*
FUZE	*D*	*D*	*D*
	C 1 RD (center guns)	*B 4 RDS, DNL*	*B 4 RDS, DNL*
DEFLECTION	*2716*	*2721*	*2715*
SITE	*307*	*308*	*305*
ELEVATION	*372*	*373*	*338*

Observer's corrections:	HCO announces:	Commands by computer B:
RIGHT 200, ADD 400.	*Df 2670, Rn 7800.*	*DF 2670, 392.*
LEFT 25, DROP 200.	*Df 2685, Rn 7630.*	*DF 2685, 379.*
ADD 100.	*Df 2678, Rn 7720.*	*DF 2678, 386.*

*Deflection correction always is announced, but is not used unless ordered by S–3.

ADD 50, FIRE FOR EFFECT.	*Df 2675, Rn 7760.*	*BATTERY FOUR ROUNDS, DF 2675, 394.**

Computer B announces:	*Corrections; none.*
HCO announces:	*Able, Deflection 2677, Range 7710; Charlie, Deflection 2674, Range 7310.*
Computer A commands:	*BATTERY FOUR ROUNDS, DEFLECTION 2677, 385.*
Computer C commands:	*BATTERY FOUR ROUNDS, DEFLECTION 2674, 356.*
Observer reports:	CEASE FIRING, END OF MISSION, MACHINE GUNS DESTROYED, NO ACTIVITY IN VICINITY.
Computer B announces:	*Data for replot, Baker, Deflection 2665, Range 7810, Site plus 7, Fuze Delay, Concentration E201.*
S–3 informs S–2:	Battalion fired four volleys on three machine guns at (16.18–88.39). Machine guns destroyed; no activity in vicinity.
VCO informs HCO:	Altitude concentration E201 is 425 (altitude of battery B (380) plus difference in altitude of target and battery (+45)).

195. EXAMPLE 2: OBSERVER NO. 1 (O1) MISSION (FIRE FOR EFFECT).

a. General information. Same as example 1, except the adjusting pieces are near battery center.

b. Procedure.

Observer reports:	THIS IS OBOE ONE, FIRE MISSION, INSTRUMENT READING 1460, DISTANCE 6200, VERTICAL ANGLE MINUS 2, INFANTRY COMPANY ASSEMBLY AREA, FIRE FOR EFFECT.
S–3 announces:	*BATTALION, USE DEFLECTION CORRECTION, SHELL HE, CHARGE 6, FUZE QUICK, SIX VOLLEYS ONE C APART, AT MY COMMAND, CONCENTRATION E203.*

*The computer adds 50 yards since the two adjusting pieces are 50 yards in front of the battery center.

S–3 to observer:	*BATTALION, FUZE QUICK, SIX VOLLEYS, ONE C APART, AT MY COMMAND, CONCENTRATION E203.*
HCO announces:	*Correction all batteries, Left 10; Baker, Deflection 2965, Range 7700; Able, Deflection 2962, Range 7900; Charlie, Deflection 2984, Range 7070.*
VCO announces:	*Site Baker, plus 6; Able, plus 7; Charlie, plus 4.*

Commands by computers:

	Computer B	*Computer A*	*Computer C*
	BA	*BA*	*BA*
SHELL	*HE*	*HE*	*HE*
CHARGE	*6*	*6*	*6*
FUZE	*Q*	*Q*	*Q*
	B 6 RDS, AMC	*B 6 RDS, AMC*	*B 6 RDS, AMC*
DEFLECTION	*2975 (2965 +L 10)*	*2972 (2962 +L 10)*	*2994 (2984 +L 10)*
SITE	*306*	*307*	*304*
ELEVATION	*384 (7700)*	*407 (8000)*	*333 (6970)*

Computers announce:	*Battery ready.*
S–3 commands:	FIRE.
Observer reports:	CEASE FIRING, END OF MISSION, INFANTRY DISPERSED.
S–3 informs S–2:	Battalion fired six volleys on infantry company assembly area at (14.19–88.88), infantry dispersed.

196. EXAMPLE 3: FORWARD OBSERVER MISSION, USING TIME FIRE.

a. General information.

Unit: 105-mm howitzer battalion, 6-piece batteries.

Positions: Battery fronts are 150 yards.

GFT Setting: Charge #7, fuze M55, range 6520, elevation 235, time 17.2.

b. Procedure.

Observer reports:	THIS IS FOX OBOE ABLE, FIRE MISSION, AZIMUTH 570, FROM CHECK POINT THREE, RIGHT 700, DROP 600, INFANTRY PLATOON IN FOX HOLES, FUZE TIME, WILL ADJUST.

S–3 announces: *BATTALION, BAKER, SHELL HE, CHARGE 7, FUZE TIME, SIX VOLLEYS, CENTER RANGE, WHEN READY, CONCENTRATION E1.*

S–3 to observer: *BATTALION, BAKER, FUZE TIME, SIX VOLLEYS, CENTER RANGE, WHEN READY, CONCENTRATION E1.*

HCO announces: *Correction all batteries, Left 6; Baker, Deflection 2721, Range 6750; Able, Deflection 2740, Range 6780; Charlie, Deflection 2710, Range 6300.*

VCO announces: *Site Baker, plus 11, Able, plus 8; Charlie, plus 10.*

Commands by computers:

	Computer B	*Computer A*	*Computer C*
	BA	*BA*	*BA*
SHELL	*HE*	*HE*	*HE*
CHARGE	*7*	*7*	*7*
FUZE	*Time*	*Time*	*Time*
	C 1 RD	*B 6 RDS, DNL*	*B 6 RDS, DNL*
DEFLECTION	*2721*	*2740*	*2710*
SITE	*314 (311+3)*	*311 (308+3)*	*313 (310+3)*
TIME	*17.9*	*18.0*	*16.5*
ELEVATION	*248*	*249*	*224*

Observer's corrections:	HCO announces:	Commands by computer B:
RIGHT 50, UP 50, DROP 100.	*Df 2719, Rn 6660.*	*DF 2719, SI 322, TI 17.6, 243.*
DOWN 20, ADD 50, FIRE FOR EFFECT.	*Df 2718, Rn 6710.*	*BATTERY SIX ROUNDS, DF 2718, SI 319, TI 17.8, 246.*

Computer B announces: *Corrections; Up 5.*

HCO announces: *Able, Deflection 2737, Range 6690; Charlie, Deflection 2705, Range 6190.*

Computer A commands: *BATTERY SIX ROUNDS, DEFLECTION 2737, SITE 316, TIME 17.7, 244.*

Computer C commands:	*BATTERY SIX ROUNDS, DEFLECTION 2705, SITE 318, TIME 16.2, 218.*
Observer reports:	CEASE FIRING, END OF MISSION.
Computer B announces:	*Data for replot, Baker, Deflection 2712, Range 6710, Site plus 16* (19–3yh for height of burst), *Fuze Time, Concentration E1.*

Note. Altitude of the battery is 382 yards. Difference in altitude between the battery and the target is 103 yards. Altitude of concentration E1 is 485 yards (382+103).

S–3 informs S–2:	Battalion fired six volleys on infantry platoon in fox holes at (84.54–45.58).

197. EXAMPLE 4: FORWARD OBSERVER MISSION, USING TIME FIRE.

a. General information. Same as example 3.

b. Procedure.

Observer reports:	THIS IS FOX OBOE BAKER, FIRE MISSION, AZIMUTH 5940, FROM CHECK POINT 2, RIGHT 600, UP 20, ADD 600, TROOPS ASSEMBLING, ESTIMATED ONE COMPANY, FUZE TIME, WILL ADJUST.
S–3 announces:	*BATTALION, BAKER, SHELL HE, CHARGE 7, FUZE TIME, FIVE VOLLEYS, WHEN READY, CONCENTRATION E5.*
S–3 to observer:	*BATTALION, BAKER, FUZE TIME, FIVE VOLLEYS, WHEN READY, CONCENTRATION E5.*
HCO announces:	*Corrections all batteries, Left 7; Baker, Deflection 2800, Range 7170; Able, Deflection 2793, Range 7250; Charlie, Deflection 2812, Range 6640.*
VCO announces:	*Site Baker, plus 16; Able, plus 14; Charlie, plus 15.*

Commands by computers:

	Computer A	*Computer B*	*Computer C*
	BA	*BA*	*BA*
SHELL	*HE*	*HE*	*HE*
CHARGE	*7*	*7*	*7*
FUZE	*TIME*	*TIME*	*TIME*
	C 1 RD	*B 5 RDS, DNL*	*B 5 RDS, DNL*

DEFLECTION	*2800*	*2793*	*2812*
SITE	*319 (316+3)*	*317 (314+3)*	*318 (315+3)*
TIME	*19.3*	*19.5*	*17.6*
ELEVATION	*271*	*275*	*242*

Observer's corrections:	HCO announces:	Commands by computer B:
LEFT 100, DROP 400.	*Df 2767, Rn 6820.*	*DF 2767, TI 18.1, 251.*
DOWN 20, ADD 200.	*Df 2789, Rn 6960.*	*DF 2789, SI 316, TI 18.6, 259.*
ADD 100.	*Df 2799, Rn 7030.*	*DF 2799, TI 18.8, 263.*
UP 10, DROP 50, FIRE FOR EFFECT.	*Df 2794, Rn 6990.*	*B 5 RDS, DF 2794, SI 317, TI 18.7, 261.*

Computer B announces: *Corrections: Down 2.*

HCO announces: *Able, Deflection 2790, Range 7070; Charlie, Deflection 2802, Range 6470.*

Computer A commands: *BATTERY FIVE ROUNDS, DEFLECTION 2790, SITE 315, TIME 19.0, 265.*

Computer C commands: *BATTERY FIVE ROUNDS, DEFLECTION 2802, SITE 316, TIME 17.0, 233.*

Observer reports: CEASE FIRING, END OF MISSION, MANY CASUALTIES, TROOPS SCATTERED.

Computer B announces: *Data for replot, Baker, Deflection 2787, Range 6990, Site plus 14, Fuze Time, Concentration E5.*

Note. Altitude of concentration E5 is 476 yards (382 + 94).

S–3 informs S–2: Battalion fired on troop concentration, estimated one company at (85.58–47.18), many casualties, troops scattered.

198. EXAMPLE 5: FORWARD OBSERVER MISSION. a. General information.

Unit: 155-mm howitzer battalion, 6-piece batteries.

Position: Battery fronts are 250 yards.

GFT settings: No corrections.

b. Procedure.

Observer reports:	THIS IS FOX OBOE BAKER, FIRE MISSION, AZIMUTH 6090, FROM BASE POINT, LEFT 400, ADD 800, INFANTRY RESERVE AREA DUG IN, FUZE TIME, WILL ADJUST.
S–3 announces:	*BATTALION, BAKER, SHELL HE, CHARGE 7, FUZE TIME, FOUR VOLLEYS, ONE C APART, WHEN READY, CONCENTRATION E104.*
S–3 to observer:	*BATTALION, BAKER, FUZE TIME, FOUR VOLLEYS, ONE C APART, WHEN READY, CONCENTRATION E104.*
HCO announces:	*Corrections all batteries, zero; Baker, Deflection 2898, Range 7940. (Data for A and C omitted.)*
VCO announces:	*Site Baker, plus 7.*

Commands by computer B:

	BA
SHELL	*HE*
CHARGE	*7*
FUZE	*TIME*
	C 1 RD
DEFLECTION	*2898*
TIME	*20.2*
QUADRANT	*198 (188+7+3)*

Note. +3 is 20/R for time fire.

Observer's corrections:	HCO announces:	Commands by computer B:
LEFT 50, REPEAT RANGE.	*Df 2905, Rn 7900.*	*DF 2905, TI 20.1, 196* (Si+10, El 186).
LEFT 50, UP 40, ADD 400.	*Df 2936, Rn 8220.*	*DF 2936, TI 21.1, 213* (Si+15, El 198).
DOWN 15, DROP 200.	*Df 2924, Rn 8050.*	*DF 2924, TI 20.6, 205* (Si+13, El 192).
DOWN 5, ADD 100.	*Df 2930, Rn 8140.*	*DF 2930, TI 20.8, 207* (Si+12, El 195).
DROP 50, FIRE FOR EFFECT.	*Df 2927, Rn 8100.*	*BATTERY FOUR ROUNDS, DF 2927, TI 20.7, 206* (Si+12, El 194).

Computer B announces: (Computer A and C commands omitted.)	*Corrections; UP 2.*
Observer reports:	CEASE FIRING, END OF MISSION.
Computer B announces:	*Data for replot, Baker, Deflection 2927, Range 8100, Site plus 9* (12–3 for 20/R) *Fuze Time, Concentration E104.*
S–3 informs S–2:	Battalion fired four volleys on infantry reserve area at (83.967–97.432).

199. EXAMPLE 6: FORWARD OBSERVER MISSION, USING VT FUZE.

a. General information. Same as example 5.

b. Procedure.

Observer reports:	THIS IS FOX OBOE CHARLIE, FIRE MISSION, AZIMUTH 5960, FROM CONCENTRATION E155, LEFT 300, ADD 400, BATTERY IN BIVOUAC, FUZE VT IN EFFECT, WILL ADJUST.
S–3 announces:	*BATTALION, BAKER, SHELL HE, CHARGE 5, GREEN BAG, FUZE VT IN EFFECT, FIVE VOLLEYS, ONE C APART, WHEN READY, CONCENTRATION E160.*
S–3 to observer:	*BATTALION, BAKER, FUZE VT IN EFFECT, FIVE VOLLEYS, ONE C APART, WHEN READY, CONCENTRATION E160.*
HCO announces:	*Corrections all batteries, zero; Baker, Deflection 2860, Range 7540.* (*A and C Batteries omitted.*)
VCO announces:	*Site Baker, plus 6.*

Commands by computer B:

	BA
SHELL	*HE*
CHARGE	*5, GREEN BAG*
FUZE	*Q, 5 RDS VT IN EFFECT C 1 RD*
DEFLECTION	*2860*
QUADRANT	*368* (*362+6*).

Observer's corrections:	HCO announces:	Commands by computer B:
LEFT 200. REPEAT RANGE.	*Df 2883, Rn 7490.*	*DF 2883, 366* (Si+6, El 360).
RIGHT 50. ADD 200.	*Df 2896, Rn 7650.*	*DF 2896, 376* (Si+6, El 370).
DROP 100. ADD 50.	*Df 2886, Rn 7580.*	*DF 2886, 371* (Si+6, El 36[illegible]).
FIRE FOR EFFECT.	*Df 2890, Rn 7620.*	*FUZE VT, BATTERY FIVE ROUNDS, DF 2890, 377* (Si+9, El 368).
Computer B announces:	*Corrections; None.*	

(Computer A and C commands omitted.)

Observer reports:	CEASE FIRING, END OF MISSION.
Computer B announces:	*Data for replot, Baker, Deflection 2890, Range 7620, Site plus 6* (9–3 for 25/R), *Fuze VT, Concentration E160.*
S–3 informs S–2:	Battalion fired five volleys on enemy battery in bivouac at (85.73–96.18).

200. SIMULTANEOUS FIRE MISSIONS. a. The procedures and examples previously given have explained and demonstrated the functioning of a fire-direction center in handling a single mission. The battalion fire-direction center should be able to process three simultaneous battery missions. This requires personnel skilled in the duties of all members of the fire-direction team and well grounded in communication procedure.

b. A diagram of a possible organization for a fire-direction center is shown in figure 79. The S–3 and one-half the S–2 command post tents are used. The sketch is to approximate scale only.

c. To expedite simultaneous missions, each chart operator should be trained to function habitually with a particular computer as a two-man team. All fire missions arriving by wire enter the fire-direction center at one of four telephones which are tended either by the chief computer or by the operations sergeant. The HCO, VCO, and third-chart operator (chief computer or operations sergeant) wear head and chest sets with cords long enough to reach any of the four telephones. If a mission arrives while the fire-direction center is idle, whoever answers the telephone repeats the fire request aloud so that both the HCO and VCO can make the plot. As soon as the S–3 issues his fire order, the head and chest set of the HCO is plugged into the telephone over which the mission is coming. If a second mission ar-

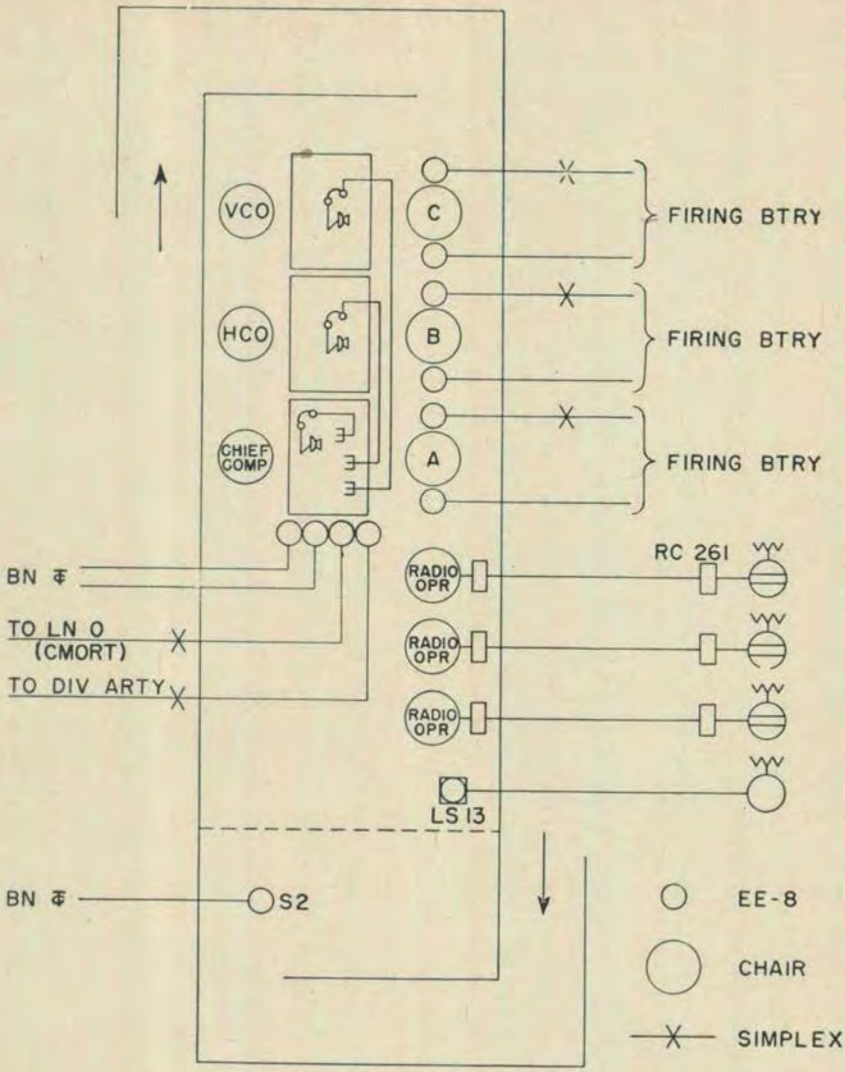


Figure 79. Type battalion fire-direction communications.

rives before the first is finished, the VCO is connected to the source of the mission in the same manner. He then must act as both HCO and VCO. A third simultaneous mission can be handled in a like manner by the third-chart operator. The S–3 message to the observer (or other target source) can be sent by either the S–3 (using the hand set of the telephone which the chart operator is plugged into) or by the chart operator himself.

d. Fire missions which reach the fire-direction center on any one of the base radio sets are received first by a radio operator. As soon as the operator hears "fire mission," he notifies the S–3, giving the identity of the source of the mission. He then is told to take the earphones and hand microphone to a designated chart operator. The chart operator will accept the mission and process it exactly as was done on the mission which came by wire. If all chart operators are busy, the radio operator may be told to record the mission himself.

e. Fire missions originating over the corps radio net are accepted by the S–3 from the loud-speaker connected to the receiver.

f. The fire-direction center should acknowledge and record all missions. When more than three missions are received, the S–3 must make a tactical decision. He may decide to refuse to fire some missions; he may stop firing on a mission in order to attack a more important target; he may take the mission and notify the observer there will be a delay; he may route missions to his battery fire-direction centers for processing; he may call on attached, reinforcing, or adjacent battalions; or he may request fire through higher headquarters (division artillery).

g. *Example:* Three battery missions processed concurrently.

Unit: 105-mm howitzer battalion, 6-piece batteries.

Positions: Battery fronts are 150 yards.

GFT setting: Ch 6, Fz M51, Rn 5180, El 230. Ch 6, Fz M54, Rn 5180, El 235, Ti 16.0.

Mission 1. Forward observer using wire. The call terminates at the fire-direction 1 telephone.

Observer reports:	THIS IS FOX OBOE ABLE, FIRE MISSION.
Chief computer:	*SEND YOUR MISSION.*
Observer:	AZIMUTH 325, FROM BASE POINT, RIGHT 250, ADD 400, ENEMY HEAVY MORTARS, FUZE TIME, WILL ADJUST.

(This is repeated aloud by the chief computer, and plotted by HCO and VCO.)

S–3 (Over hand set of fire-direction 1 telephone to observer and loud enough for fire-direction center to hear):	*BAKER, SHELL HE, CHARGE 6, FUZE TIME, 4 VOLLEYS, WHEN READY, CONCENTRATION H2.*

(Chief computer now plugs the HCO's headset into the fire-direction 1 telephone so that the mission can be continued without S–3 assistance.)

HCO announces:	*Correction Baker, zero. Baker, Deflection 2732, Range 5510.*
VCO announces:	*Site Baker, plus 11.*
Computer Baker:	*BATTERY ADJUST, SHELL HE, CHARGE 6, FUZE TIME, CENTER ONE ROUND, DEFLECTION 2732, SITE 315, TIME 17.2, ELEVATION 254.*

Mission 2. Air observer. The call terminates in the fire-direction center at one of the base radio sets.

Observer reports:	KEEL 8 THIS IS KEEL 41, FIRE MISSION, OVER.
Radio operator:	*THIS IS KEEL 8, WAIT.*

(Radio operator notifies S–3 that Keel 41 has a fire mission. S–3 knows that the HCO is busy, and has the radio operator take the headphones and hand microphone to the VCO.)

VCO to observer:	*GO AHEAD, OVER.*
Observer:	FROM BASE POINT, LEFT 600, ADD 1400, MINE RECOVERY PARTY, FUZE DELAY, WILL ADJUST, OVER.

Note. Mission 1 is being fired during this time in the normal manner, using only the HCO and Baker computer.

S–3 (over VCO's hand microphone and loud enough to be heard by fire-direction center):	*CHARLIE, SHELL HE, CHARGE 6, FUZE DELAY, 5 VOLLEYS, WHEN READY, CONCENTRATION H3, WAIT.*
VCO announces:	*Corrections Charlie, Left 1; Charlie, Deflection 2896, Range 6340. Site Charlie plus 5.*

Note. VCO also must act as HCO.

Computer Charlie:	*BATTERY ADJUST, SHELL HE, CHARGE 6, FUZE DELAY, CENTER ONE ROUND, DEFLECTION 2896, SITE 305, ELEVATION 298.*

Mission 3. Observer at O1 using wire. This call terminates at the fire-direction 2 telephone.

Observer reports:	THIS IS OBOE ONE, FIRE MISSION.

(The chief computer, knowing that both HCO and VCO are busy, accepts and plots the mission himself.)

Chief computer: *GO AHEAD.*

O1: INSTRUMENT READING 2378, DISTANCE 3840, VERTICAL ANGLE MINUS 3, INFANTRY COMPANY ASSEMBLY AREA, FIRE FOR EFFECT.

Note. Missions 1 and 2 are being fired in the normal way. S–3 notices that Charlie battery has nearly finished the mission for the air OP.

S–3 (over handset of fire-direction 2 telephone and loud enough to be heard by fire-direction center): *ABLE AND CHARLIE, USE CORRECTIONS, SHELL HE, CHARGE 6, ABLE FUZE VT, CHARLIE FUZE QUICK, 5 VOLLEYS, CENTER RANGE, AT MY COMMAND, CONCENTRATION H3.*

(Chief computer now conducts remainder of mission, using fire-direction 2 telephone.)

Chief computer announces: *Correction all batteries, Right 1; Able, Deflection 2905, Range 5420; Charlie, Deflection 2916, Range 4830; Site Able, plus 6; Site Charlie, plus 9.*

Computer Able: *BATTERY ADJUST, SHELL HE, CHARGE 6, FUZE VT, BATTERY 5 ROUNDS, AT MY COMMAND, DEFLECTION 2904, SITE 310, ELEVATION 248.*

(Charlie battery has just finished his mission for the air observer.)

Computer Charlie: *BATTERY ADJUST, SHELL HE, CHARGE 6, FUZE QUICK, BATTERY 5 ROUNDS, AT MY COMMAND, DEFLECTION 2915, SITE 309, ELEVATION 215.*

When both batteries report they are ready, the S–3 fires. At the completion of the three missions, the S–3 gives the S–2 the location and nature of the targets and any reported results.

Section V. HEAVY ARTILLERY FIRE-DIRECTION PROCEDURE

201. GENERAL. The procedures set forth in section II of this chapter apply to all field artillery; some of these principles and procedures, however, have such a pronounced effect in heavy artillery that they warrant repetition and emphasis.

202. CALIBRATION. Calibration of heavy artillery is essential. The velocity error (*VE*) of each piece must be determined.

Note. *VE* of the piece(s) may be checked when firing regular fire missions if firing with accurate survey data and surveillance of fire is executed.

203. PRECISION FIRE. a. Registration. Accurate registration for heavy artillery is vital. Observation for long-range registration of these weapons is difficult to obtain. Observation methods most commonly used are—

(1) *Flash, sound, or radar.* This method requires coordination with the observation battalion.

(2) *Organic light aircraft.*

(3) *High-performance aircraft.* This method requires coordination with the Air Force.

(4) *Combined.* This method normally is tied in to the survey of the unit.

b. Destruction. Heavy artillery is particularly effective against heavily built structures. If more than one piece is used, each is adjusted on the target.

204. DISPERSION OF PIECES. Heavy artillery batteries normally are emplaced in well-dispersed positions. This requires that displacement corrections (width and depth) be made for most fires. In some cases, it may be necessary to compute separate data for each piece of the battery (this is normal with 240-mm howitzer and 8-inch gun). With four-gun batteries, a base piece for each platoon may be used and data computed for it.

205. FIRE CAPABILITIES. a. Fire capabilities charts are constructed for medium and heavy artillery in the same manner as for light artillery, except for 8-inch guns and 240-mm howitzers. These latter weapons are located on the firing chart by individual piece, and fire capabilities are determined for each piece.

b. Ammunition must be used judiciously since it is difficult to obtain and transport, and the wear on the tubes is great.

c. The following charges are used by heavy artillery:

Weapon	*Charges*
8-inch howitzer	1 to 5, inclusive (green bag).
	5 to 7, inclusive (white bag).
155-mm gun	Normal and supercharge.
8-inch gun	Normal, reduced, and supercharge.
240-mm howitzer	1 to 4, inclusive.

903448°—50——15

d. The following fuzes are used by heavy artillery:

M51	Quick or delay.
M55	25-second time fuze (used principally in medium and light artillery).
M67	Mechanical time fuze (75 seconds).
M78	Concrete-piercing fuze, delay or nondelay.
M96	VT (for howitzers only).

206. SOME FACTORS CONSIDERED IN USE OF HEAVY WEAPONS. **a.** Except for the 8-inch gun and 240-mm howitzer, where each piece is plotted on the chart, deflection and deflection difference are handled the same as for light artillery.

b. Medium and heavy weapons are not equipped with an independent site scale; therefore, site must be added to elevation when commands are sent to the pieces. For this reason, when firing a mission requiring adjustment and involving time fire, the computer must keep a record of the site and elevation in addition to the quadrant, or the height of burst cannot be adjusted properly by the observer.

c. When map data at long ranges are determined, a small percentage error will cause a large error in data; therefore, it is better to *compute deflection* and *range* from coordinates. (This is especially true in 240-mm howitzer and 8-inch gun units.)

d. An accurate *VE* is essential as the *VE* change is very rapid; for example, the *VE* change in an 8-inch gun is −3 f/s per 10 rounds.

e. It is necessary to take into consideration the rotation of the earth when firing at long ranges. This is done in conjunction with the computation of metro corrections.

f. Each piece or platoon may have a separate deflection index.

g. Observation for heavy artillery frequently is done by high-performance aircraft because of the long ranges involved. Prearrangement is required.

Section VI. BATTERY FIRE DIRECTION

207. GENERAL. If the battalion fire-direction center is destroyed or disrupted by enemy action or by other causes, the battalion must be able to fulfill fire missions. For this reason, each battery must be able to take over its own or the battalion fire-direction center for a limited time. This means that each battery must keep a firing chart on which are plotted the three batteries, the base point, check points, and important concentrations. This information can be sent to the batteries from time to time by the battalion fire-direction center in order to keep the battery charts up to date and with sufficient detail to permit fire direction.

208. PREARRANGEMENT. Supporting fires are prearranged whenever possible; that is, the locations of these fires are fixed but the firing data are not necessarily computed. Supporting fires are delivered on a schedule, on call, upon occurrence of a specific event, or on a combination of these methods.

209. PREPARATION AND COUNTERPREPARATION FIRES. A schedule of fires is sent to the batteries to insure uninterrupted fire, especially if communications are disrupted. The procedure for preparing the schedule of fires is as follows:

a. The S–3 procures an overlay which shows the locations of targets based on the best and latest intelligence. This overlay normally is furnished by the S–2 with a list of the coordinates of the targets.

b. The S–3 makes up a work sheet (par. 253) from the overlay showing the targets to be attacked by each battery.

c. The schedule of fires then is prepared from the work sheet. Important targets may require the fire of the entire battalion; single batteries may be used when appropriate.

d. The schedule is forwarded to higher headquarters for coordination with other battalions. The schedule then is reproduced and sent to the batteries and attached battalions.

e. Counterpreparations are handled the same as preparations but always are fired on call.

210. GROUPING OF FIRES. To facilitate the tactical handling of prearranged fires, it is desirable to arrange concentrations into *groups of fires*, *series*, or *schedules*.

a. Group of fires. A group of fires consists of two or more concentrations covering a tactical locality which is too large to be covered by a single concentration. The concentrations within the group of fires may be fired consecutively or concurrently, depending upon the scheme of maneuver, the number of concentrations, the number of artillery battalions available, and whether the concentrations are battery or battalion concentrations. Groups of fires may be indicated by a letter symbol or a combination of letter symbols.

b. Series. A series consists of a number of groups of fires or concentrations planned to support a maneuver phase. The series has two purposes: First, to facilitate the operation of the fire-direction center by indicating fires that likely are to be delivered during a maneuver phase; and second, to facilitate placing fires in tactical localities too large to be covered by a single group of fires. An example of the latter would be defensive fires to protect an objective when taken, or fires to cover in depth and width a large locality under enemy attack.

(See FM 6–20.) A method of indicating a series is by an arabic number or by a code name.

c. Schedules. A schedule consists of a number of concentrations, groups of fires, or series fired in a definite sequence according to a time schedule. The time of starting the schedule may be on call. For identification purposes, schedules may be referred to by a code name, such as "Schedule Wolf."

211. CHECK CONCENTRATIONS. All prominent terrain features are assigned numbered concentrations called check concentrations. These features are identified easily by observers and serve as an aid in orientation, for the delivery of observed fires, and for the identification of less prominent points. Check concentrations should be crossroads, road junctions, stream crossings, the sides of bare hills, or prominent landmarks such as buildings and separate clumps of trees. The coordinates of these concentrations should be furnished those concerned with the adjustment of fire. This indexing of terrain enables rapid designation of targets.

212. PLANNING CLOSE SUPPORT FIRES. **a.** Prearranged fires are employed whenever the conditions of the operation permit. Planning for these fires is conducted simultaneously at all levels. The artillery battalion commander plans with the infantry regimental commander, the artillery liaison officer with the infantry battalion commander, and the forward observer with the infantry company commander.

b. The tentative plans for close support fires may be made by the artillery liaison officers and the forward observers but must be coordinated with the general plan of support. The artillery battalion commander coordinates these fires. He also may suggest additional fires or, in case there are too many requests for fire, may advise as to which requests should be filled.

c. Countermortar fire usually is delivered in two phases: First, those known or suspected enemy mortar locations fired on during the preparation; and second, those locations found after the beginning of the preparation. In the first phase, the targets usually are provided by the countermortar section; the fires are prearranged.

213. LONG-RANGE FIRES. Heavy battalions will receive most long-range targets from the intelligence agencies of the corps or division. These may be handled as prearranged fires. The heavy battalion may, in rare instances, be able to locate targets for itself. Various targets may be tabulated and data computed for them when observation is possible. The prearrangement necessary is determined by the tactical situation.

214. TECHNIQUE OF PREPARING AND ASSEMBLING DATA. The data for prearranged fires normally are placed on data sheets. The data sheet shown in figure 80 was prepared at the battalion fire-direction center. The firing chart was a grid sheet. An explanation of the data sheet follows.

a. Concentration number. The concentration number is assigned by S–3. The entries should be made in the order of firing. Remarks, such as 1 *c* apart or 200-yard zone, may be made here.

b. Coordinates. Coordinates are scaled by the HCO.

c. Time. Time is announced by the S–3. Clock time is entered when H-hour is announced. Times given are the times for the projectiles to *arrive on the target* and the times the fire must be lifted. The executive insures that the projectiles arrive on the target at the specified time by applying the time of flight.

d. Time of flight. Time of flight is given in seconds and determined by the computer.

e. Deflection correction. The latest deflection correction is used.

f. Map deflection. Map deflection is measured on firing chart to the nearest mil by the HCO.

g. Range. Range is measured on the firing chart to the nearest 10 yards by the HCO.

h. Elevation. Elevation is determined by the computer. The elevation corresponding to ground range. In this example, ground range equals chart range. The GFT setting is Ch 5, Fz M55, Rn 3540, El 203, Ti 11.8.

i. Altitude in yards. Altitude in yards is determined from the firing chart by the VCO.

j. Difference in altitude. Difference in altitude is determined by the VCO from altitudes of the batteries and targets.

k. Height of burst. When time fire is to be used, 20 yards are added.

l. Angle of site. The angle of site is determined by VCO.

m. Complementary angle of site. Complementary angle of site is determined from firing tables by the VCO; used when it is 0.5 mil or more. If the VCO determines the site in one operation by multiplying the angle of site by 1 plus the complementary angle-of-site factor, only one figure (the total site) need be entered and the appropriate change is made in the column heading.

n. Special corrections. If special corrections are to be used, a check mark will be made in this space.

o. Projectile and charge. Projectile and charge are announced by S–3.

p. Fuze. Fuze is announced by S–3.

q. Method of fire. Method of fire is announced by S–3.

r. Deflection. Map deflection and deflection correction are combined by computer.

BATTERY *Baker*
COORDINATES *849.890-1289.890*
ALT OF BATTERY *408*

DATA SHEET

TIME *1630* DATE *19 October*

		MAP DATA										COMMANDS					
CONC NO	COORDINATES	TIME FROM	TIME TO	T of F (SEC)	DEFLECTION CORR	DEFLECTION MAP DEF	RANGE / ELEVATION	ALT (YDS) / DIFF ALT / HT OF BURST	ANGLE OF SITE / COMP SITE	SP CORR / PROJ / CH	FUZE / MF	DEFLECTION INDIV SHEAF CORRECTION OR DD	SITE INDIV CORR	TIME INDIV CORR	ZONE	ELEV OR QE	REMARKS
10	49.190-92.310	H-25 0505	H-21 0509	8	R1	~~2909~~ 2919	2520 / 130	434 / +26 /	+11 / 0	/ HE / 5	Q / B / 8	~~2909~~ 2918	311			~~130~~ 138	
3	49.490-93.020	H-20 0510	H-16 0514	11	0	~~2752~~ 2762	3150 / 167	432 / +24 / 20	+14 / 0	/ HE / 5	Time / B / 8	~~2752~~ 2762	314	~~10.2~~ 10.5		~~167~~ 177	
5	49.780-93.950	H-15 0515	H-10 0520	14	L1	~~2650~~ 2660	4060 / 224	449 / +41 /	+10 / +1	/ HE / 5	Q / B / 10	~~2650~~ 2661	311		3 ⊘	~~224~~ 239	
12	50.060-93.660	H-5 0525	H-3 0527	13	0	~~2576~~ 2586	3770 / 205	470 / +62 /	+17 / +1	/ HE / 5	VT / B / 4	~~2576~~ 2586	325 (25/R+1)			~~205~~ 218	
9	49.200-93.860	H 0530	H+10 0540	14	L1	~~2797~~ 2807	4030 / 222	443 / +35 / 20	+14 / +1	✓ / HE / 5	Time / B / 20	~~2797~~ 2808 #1 L1; #2 L2 #3 R1; #5 R4 #6 R3	315 #1 UP 2 #3 UP 4 #4 DN 2 #5 UP 5	~~13.2~~ 13.6 #1 +2 #3 +3 #4 -1 #5 +4		~~222~~ 237	Fire Twice

Figure 80. Type data sheet for prearranged fire.

s. Deflection difference. Deflection difference is determined by computer (4-gun battery).

t. Individual or sheaf correction. Individual or sheaf correction are to be used when the pieces are irregularly dispersed laterally and the nature of the target or the method of attack indicate that a regular sheaf is desired.

u. Site. Angle of site and complementary angle of site are combined by computer (25/R (105-mm howitzer) also is included when VT fuze is used). Individual site corrections are entered here when special corrections are ordered. (See concentration 9.)

v. Time. When time fire is used, the time is determined by the computer and changed when new corrections are computed. Individual time corrections are entered here when special corrections are ordered. (See concentration 9.)

w. Zone. Zone is determined by computer (based on announcement of S–3). For concentration 5, the 1 *c* apart is to cover area in depth.

x. Elevation or quadrant elevation. The elevation or quadrant elevation, determined by computer, includes the latest corrections.

y. Remarks. Remarks are announced by S–3. This column contains information pertaining to firing the missions. Concentration 9 is fired the second time by repeating the elevation.

z. Latest corrections. Latest corrections are determined by the computers, based on registration or the latest metro message. They are combined with the map data and announced as new commands for time, deflection, and elevation.

CHAPTER 19

MISCELLANEOUS MISSIONS

Section I. THE VT FUZE

215. GENERAL. **a.** The use of the VT fuze, which gives air bursts up to the maximum ranges of the weapons, greatly increases the effectiveness of artillery projectiles. The limitations inherent in the fuze require close coordination and supervision of its use. Therefore, the decision to use VT fuzes based on the amount of vertical clearance over friendly troops, the horizontal clearance in front of troops, and flight restrictions for aircraft is a *command decision.*

b. The VT fuze does not replace present standard time fuzes but *supplements* them at the longer ranges of the weapons and in high-angle fire. Present powder train fuzes are more effective to about 15-seconds time of burning. Beyond that point, the advantages of the VT fuze increase while many of its disadvantages are reduced.

216. SAFETY PRECAUTIONS. **a. General.**

(1) For firing over friendly crests that are within 5-seconds time of flight, the *minimum* elevation is determined in the usual manner—site to mask, plus elevation for mask range, plus 2 forks, plus 5 yards vertical clearance.

(2) For firing low-angle fire over friendly crests that are beyond 5-seconds time of flight, the plus 5-yards vertical clearance in (1) above must be incerased to these figures:

75-mm howitzer and 90-mm gun	50 yards
105-mm howitzer	80 yards
155-mm howitzer	100 yards
8-inch howitzer and 240-mm howitzer	150 yards

(3) Wet or marshy terrain increases the sensitivity of VT fuze. Thus, the allowances above are not sufficiently safe and should be increased 50 percent when firing over wet terrain. For firing over water, the allowance should be increased 100 percent.

b. Minimum elevation. The battery executive determines the minimum elevation for clearance of the near crest (FM 6–140). The S-3 determines minimum elevations to clear critical intermediate crests. Of the minimum elevations thus computed, the one giving the greatest range is accepted as the minimum elevation for the battery. When the angle of fall is greater than 800 mils, the clearance specified in **a** above is applied as range clearance. *Example:* 105-mm howitzer, charge 4.

	Mils
Range to friendly elements, 5,000 yards	El 1132.4
Site to friendly elements	+20.0
Complementary site	−25.4
80 yards (horizontal)	−10.0
2 forks (horizontal)	−36.0
Maximum safe elevation for minimum range	1,081.0

c. Front line clearance. (See figs. 81 and 82.) The minimum elevation determined for the battery does not necessarily provide for safety of front line troops. The observer must exercise caution and judgment in firing with the VT fuze on targets near friendly front line troops. For safety, the bursts should not be brought nearer to front line troops than 200 to 500 yards, depending on the caliber of the weapon, the ruggedness of the terrain, the amount of dampness, and the presence of high trees. He may increase clearance by calling for high-angle fire. The initial location of target should be surely safe and bursts brought to the target by small changes of range. In case of doubt as to safety of front line troops, fuze VT should not be used.

d. Clearance of aircraft.

(1) When VT fuze is to be fired, the battery executive, assisted by designated sentinels, will cause fire to be suspended when friendly aircraft are in or approaching the danger area. The procedure will be followed in addition to safety regulations prescribed by higher headquarters.

(2) Adjustments of heavy artillery using VT fuze may be conducted with aircraft, providing the pilot is briefed carefully on his danger area. Briefing must include a safe altitude or safe area over the front lines.

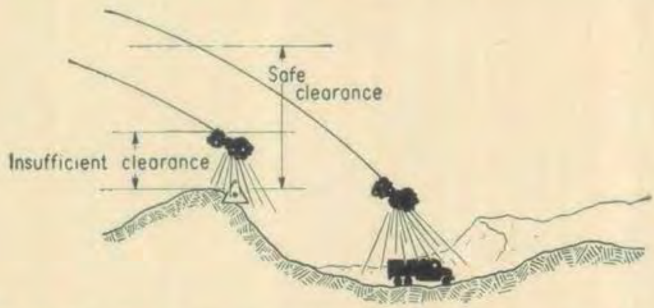


Figure 81. Safe clearance over friendly troops for low-angle fire.

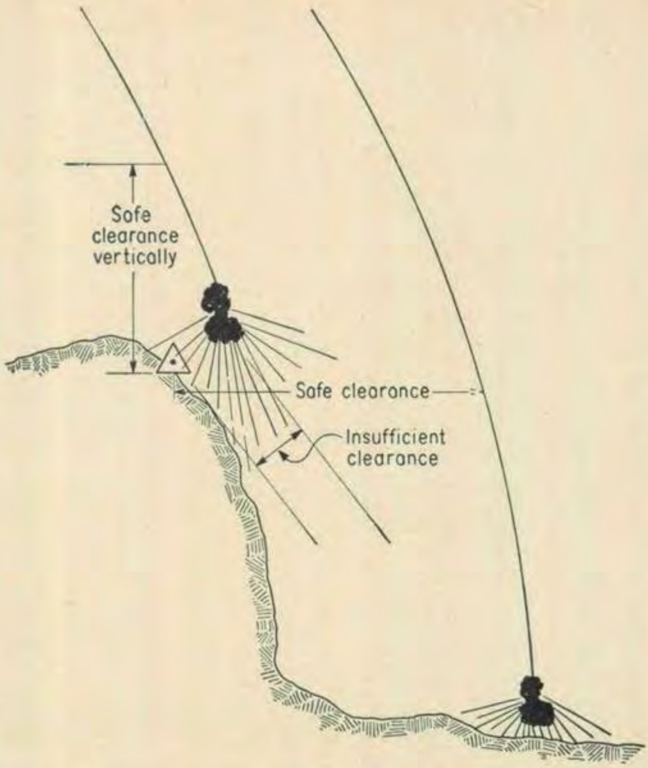


Figure 82. Safe clearance over friendly troops for high-angle fire.

217. REGISTRATION. a. Registration with VT fuze is unnecessary if an impact registration has been made with an ammunition lot cavitized for VT fuzes. If the impact registration was made with ammunition with other than cavitized shell, registration must be completed with VT-fuzed ammunition or cavitized shell, using impact fuze.

b. If ammunition cavitized for VT fuzes is available but no impact fuzes are on hand, the procedure for registration is as follows: After the impact registration is complete, using ammunition not cavitized for VT fuze, the registration is continued, using VT-fuzed shell fired at the same deflection with the site increased by the appropriate amount. The VT adjusted quadrant elevation is obtained and is stripped of the correction for height of burst, leaving the adjusted quadrant elevation which would be obtained with an impact burst and this ammunition lot.

c. A center of impact registration may be conducted, using VT fuze with normal procedure. The site to the mean height of burst is stripped from the adjusted quadrant, leaving the adjusted elevation for percussion fire, which gives a K or a graphical firing table setting.

218. FIRE-DIRECTION CENTER PROCEDURE. The following changes to the normal fire-direction center procedure are applicable when VT fuzes are to be used:

a. The S–3 is the coordinator of safety in the use of VT fuzes. He verifies that VT fuzes are to be used, verifies safe clearance of friendly terrain before VT fuze is selected for the mission, notifies unit pilots, and broadcasts the prescribed warning over the radio warning net.

b. The computer, in the preparation of initial data, includes the correction for height of burst when low-angle fire is used ($12/R$ for 75-mm howitzer, $15/R$ for 90-mm gun, $25/R$ for 105-mm and 155-mm howitzer, $40/R$ for 8-inch and 240-mm howitzer). No correction is required for high-angle missions. To replot a mission fired with VT fuze using low-angle fire, the above correction for height of burst must be stripped from the adjusted quadrant elevation.

c. The lowest usable charge which will reach the target (allowing for adjustments) should be used with VT fuzes. This procedure will give greater safe clearance and a steeper slope of fall, resulting in more uniform coverage of irregular terrain.

d. VT fuzes should be kept at a temperature between 0° F. and 120° F. They should not be left in a hot gun over 30 seconds.

e. When adjustment has been completed with impact fuze, using a different ammunition lot, the S–3 must verify that the proper correction for the difference in lots is used when data for fire for effect with VT-fuzed ammunition are transmitted to the units.

219. TACTICAL USE. The VT fuze is suitable for use against targets for which time fire is appropriate. This fuze is suitable for long-range neutralization, harassing, interdiction, and counterbattery missions requiring air bursts. Since the fuze functions at a predetermined height above the ground, it is possible to search irregular reverse slopes by using an elevation giving a steep slope of fall. With high-angle fire, air bursts may be placed near the bottom of deep ravines. Following registrations, air bursts may be placed over targets at night, in fog, or in any period of poor visibility. With long-range artillery adjusted by high-performance aircraft or by the observation battalion, air bursts may be placed over rear assembly areas or command posts. A concentration may be placed over tanks to the maximum range of the weapon, with the bursts following the profile of the ground. If arming range permits, fire against steep slopes may neutralize observation posts or blast away camouflage to make the target visible for direct laying weapons. Targets on a ridge line can be attacked more successfully with this fuze than with other fuzes, due to the fact that the ridge line causes the fuze to function directly overhead.

Section II. TIME-ON-TARGET MISSIONS

220. GENERAL. **a.** Time-on-target (TOT) is a special technique of firing the pieces of several units so that the projectiles of all the units firing arrive at the target area at the same time. This technique results in placing a maximum number of rounds on a critical area in a minimum interval of time, thereby utilizing the full value of the element of surprise. The time-on-target may be set, using synchronized time such as naval observatory time or other radio time signals which may be available to all units. For example, the order may state *TIME-ON-TARGET is 0915 HOURS.* Another method when radio syncronized time is not available is to order *TIME-ON-TARGET IS (SO MANY) MINUTES FROM . . . NOW!* The different units start their time from the word *NOW*. Generally, a maximum of ten minutes in the foregoing order will give all units sufficient time to allow for time of flight and coordination time. Of the two methods, the latter gives better results.

b. The time to fire the respective batteries is determined by subtracting the time of flight from the time designated in the time-on-target order and each battery is fired at the appropriate time for that battery. Each battery computer must add 2 seconds to the time of flight for his battery in order to allow for the time lag between his command *FIRE* and the actual firing of the pieces. The battalion S–3 starts the count by seconds, approximately 10 seconds before the battery (with the longest time of flight) must fire. Then each computer fires his battery when his time of flight plus two seconds is called out. The S–3 should include AT MY COMMAND in his order for *time-on-target* missions. The battery executive is informed when to load in order to prevent overheating of rounds.

221. EXAMPLE. A division artillery, group, or corps artillery fire-direction center may use the following procedure to fire a time-on-target mission. The target is selected and the appropriate battalions are alerted and given the following message:

FIRE MISSION;
THIS IS FORCE 3;
FIRE (NUMBER) VOLLEYS, SHELL (TYPE), FUZE (TYPE);
COORDINATES 64.542–31.420, ALTITUDE 65 YARDS;
CENTER RANGE (OR SPREAD);
CONCENTRATION NUMBER 32;
TOT; TOT WILL BE EIGHT (8) MINUTES FROM. . . . . NOW, or *TOT AT (SO MANY) HOURS.*

The battalion, group, or division artillery S–3's start their stop watches at the command *NOW* and alert their computers or battalions to fire at the appropriate time. The S–3's start their count by saying "Time-on-target is six zero seconds from *NOW* . . . five zero seconds from *NOW* . . . four zero seconds from *NOW* . . . three zero seconds from *NOW* . . . two eight—two seven—two six—two five—two four—two three—two two—two one—two zero—one nine, and so on until all batteries have fired.

Section III. COMBINED ADJUSTMENT

222. GENERAL. **a.** Conduct of fire is termed *combined* when there are two or more observers placed so that their observing lines intersect at an appreciable angle. This is a special type of adjustment controlled by the S–3 or one of the observers (pars. 103–105). The observers sense deviations in mils. The fire-direction center converts sensings into fire commands. From the combined information given by the observers, the amount and direction of the error of each round may be found. Combined observation is useful for registering with a minimum number of rounds; for adjustment when deviations, but not corrections, can be reported, as in night adjustments; and for accurate surveillance of scheduled missions. The most serious limitation is the difficulty of coordination between two or more observers, especially in regard to timing, communication, and target designation.

b. Targets or adjusting points may be designated by an observer or by the S–3 conducting fire by giving grid or polar coordinates, by designating a reference point and giving an instrument reading and vertical angle, by giving a description of the target, or by designating the target by reference to nearby objects.

c. When the targets have not been designated in advance, both observers must have communication with the S–3 conducting fire. When observers are to designate targets, direct communication between observers is desirable.

d. When the reference point cannot be seen after dark, a nearby point must be established during daylight on which to orient the instrument after dark, in order that the observer will be able to report instrument readings at night.

223. ADJUSTMENT ON TARGETS. **a.** If observation posts have been located on the firing chart and instrument directions established, observers report instrument readings or deviations. The location of each burst center is plotted by intersection, errors are determined, and appropriate changes in data are made. Fire for effect is started when a target hit or a burst near the target is obtained. The use of an auxiliary target is appropriate in area fire; under these conditions, however, transfers with surveillance will be more economical of time and ammunition.

b. To facilitate the adjustment when both observers are in a lateral position, the S–3 may conduct the fire, drawing an "X" to represent the lines of sight of the left and right observers, and a line to represent the *GT* line, if known. On the sketch, he plots the sensings roughly and makes appropriate changes in data. Paragraph 141 contains examples of the S–3 conducting fire, using combined observation.

c. The methods set forth in **a** and **b** above are applicable at night. If the relative locations of observers and pieces are unknown and if deviations are sensed in yards or mils from the *OT* lines, the method set forth in **b** above will give good results. The *OT* line is recorded on targets discovered during daylight by all observers. At night, the illuminated crosshairs of an observing instrument are placed on the flash of an enemy weapon, and site and instrument readings are recorded if adjustment is not initiated at once. As an expedient, direction to a flash may be materialized on the ground by a piece of white tape or two stakes. Adjustment of fire at night is made with quick fuze.

224. ADJUSTMENT OF TARGETS, USING THE TARGET GRID. Both precision and area missions can be fired. Area fire with surprise effect can be placed on any target that can be identified by both observers.

a. General procedure. Two observation posts must be established, but fire-direction center does not need to know their locations. The angle of intersection between lines of sight from the two observation posts may be any size greater than 200 mils but, for best results, should be at least 500 mils. If the observation posts are to be occupied at night, the instruments either must be set up and oriented during the day, or the instrument position and a line of orientation must be staked out during the day.

b. Observer procedure. This is the same as that used by a single observer in making a precision adjustment. No special observer procedure is involved. Deviations and corrections in yards must be reported accurately to fire-direction center.

c. Fire-direction center procedure during adjustment in both area and precision missions.

(1) Two target grids are superimposed. One is marked "L" for the left observer and the other "R" for the right observer.

(2) Each target grid is oriented according to the respective azimuths reported by the observers.

(3) Each deviation correction reported by the observers is plotted on the appropriate target grid. This identifies the line on the target grid along which each observer is observing. These lines are followed to their intersection which marks the desired position of the next burst.

(4) Range corrections normally are not plotted in any way, but are considered by fire-direction center as a check to assure

that both observers are adjusting on the correct target. If one observer should lose a round, the plot for the next round could be based on the deviation and range corrections of the other observer.

d. Fire-direction center procedure during fire for effect in an area fire mission.

(1) One round is fired at the approximate target location determined as indicated in **c**(3) above. Each observer reports the deviation correction in yards of this round from the target. When these deviation corrections are plotted at the fire-direction center, the lines on the target grid along which the observers are observing are established more accurately.

(2) The intersection of these last two lines gives the location of the target with sufficient accuracy to permit fire for effect, providing the angle of intersection formed by the *OT* lines of the two observers is 200 mils or more.

e. Fire-direction procedure during fire for effect in a precision fire mission. When the observer's deviation corrections indicate that the center of impact is within 50 yards of the target, fire for effect is begun.

(1) The gun-target line and a line perpendicular to it are drawn on the top target grid, so that their intersection is over the last plotted position in adjustment. This intersection thereafter is assumed to be the target location.

(2) Both observers are notified, *FOUR ROUNDS, FIRE FOR EFFECT, REPORT DEVIATIONS IN YARDS.*

(3) Each observer's deviations for the four rounds are recorded and averaged. The observer's range sensings normally are not used.

(4) The center of impact of the four rounds is plotted at the intersection of the lines on the target grids which represent the observer's average deviations. The plotting is done at a large scale (1/25,000) which makes a side of the smallest square on the target grid equal to 10 yards.

(5) The deflection error of the center of impact is measured in yards and converted to mils by dividing it by the range to the assumed target ((1) above). The result is applied as a correction to the deflection fired and is sent to the battery as a new deflection. (The deflection error in yards is the perpendicular distance from the center of impact plot to the gun-target line.)

(6) The range error of the center of impact is measured in yards and converted to mils by dividing by the "yards per mil" at the range of the assumed target. The result is applied as a correction to the elevation used in fire for effect, thereby obtaining the adjusted elevation.

225. SURVEILLANCE. Maximum effective fire results when the target location, registration, and surveillance of fire all are performed by the same observers. Fire for effect is used initially when warranted by the accuracy of target location and registration. The S–3 conducting fire notifies each observer of the number of batteries firing, and the method of firing for effect. Each observer reports the deviation or instrument reading of the mass of the initial volleys.

Section IV. HIGH-ANGLE FIRE

226. NECESSITY FOR HIGH-ANGLE FIRE. It frequently is necessary from a tactical standpoint to fire artillery at high elevations. Firing out of or into deep defilade normally requires high-angle fire. High-angle fire may be required in jungle or mountainous terrain or in city fighting. This type of fire may be requested by the observer, based on the terrain around the target, or may be ordered by the S–3 because of the terrain in the position area.

227. THEORY. Many modern field artillery weapons are capable of firing at elevations in excess of the elevation corresponding to maximum range. The principles of observed and unobserved fires applicable to normal trajectories apply in general to high-angle fire. The following points should be kept in mind and stressed while training fire-direction center personnel:

a. An increase in elevation decreases the range to the point of impact.

b. An increase in angle of site requires a decrease in quadrant elevation. The complementary angle-of-site factor is greater than unity and has a sign opposite to that of the angle of site. The complementary angle of site is added algebraically to the angle of site and results in a site of the opposite sign. The high-angle scales on the graphical firing table give the site (angle of site plus complementary angle of site.) The sign of the site is opposite to the sign of the angle of site to the target. (See TM 9–524.)

c. The practical limits of elevation restrict the ranges which can be covered with any one charge and limit the range overlap between any two consecutive charges. In the case of certain weapons, the lack of overlap causes dead space which cannot be reached by any charge.

d. High-angle fire involves extremely high maximum ordinates and correspondingly long times of flight. Also, small changes in range cause relatively large changes in maximum ordinate and time of flight. These conditions make corrections to be applied in unobserved transfers somewhat unreliable and prevent definite fixing of transfer limits. Consequently, every effort should be made to obtain observation.

e. In identifying rounds, special account must be taken of the time of flight. When the battery fires, the observer must be given *ON THE*

WAY, and should be given the time of flight. The warning *SPLASH* is sent to the observer 5 seconds prior to impact.

f. Drift is large and increases with an increase in time of flight. Thus, in high-angle fire, drift increases as the range is decreased for any one charge. In changing from a lower to a higher charge at a given range, the drift increases; in changing from a higher to a lower charge at a given range, the drift decreases. A correction for drift at the elevation to be fired is applied to each deflection to be fired.

g. Conduct of high-angle fire is facilitated greatly by the use of the graphical firing table rather than the tabular firing table.

h. (1) The majority of the fragments of HE shell fuzed with the quick fuze travel approximately parallel to the ground. HE shell fuzed with delay fuze usually penetrates the ground, trapping most fragments in the crater and giving practically no effect above the ground. Therefore, the normal fuze for high-angle fire in neutralization is fuze quick or fuze VT. The latter gives a low air burst with maximum utilization of the side spray.

(2) When firing into jungles or tall timber, the rounds fired with fuze quick have a tendency to burst in the tops of the trees, causing very little damage to troops or matériel below. Therefore, delay fuze may be used to allow the shells to penetrate through the covering branches before exploding. Combat experience has taught that a good solution is to use half fuze quick and half fuze delay when firing into jungle or heavily wooded terrain.

228. HANDLING OF SITE. **a.** For observed fires, the site may be ignored if the angle of site is plus or minus 30 mils or less. Site should be included in registrations and all transfers of fire. Whether or not site is to be included is a decision which must be made by the S–3 in each case.

b. In case site is to be included, the 10-mil site scale on the graphical firing table can be used to compute the correction to compensate for the angle of site. For example, assume that, for the 105-mm howitzer, the graphical firing tables setting is: charge 4, fuze M48, range 5,540, elevation 1,085. It is decided to fire on a target at a map range of 5,950 yards. The angle of site from the firing chart is +32 mils. From the GFT, read the 10-mils site factor as 5.4 and the elevation as 1,021. If data are sent to the battery in the form of site and elevation, the initial commands include: *SITE 283 (300+(−5.4×3.2)), ELEVATION 1021.* If quadrant elevation were used, it would be *1004 (1021+(−5.4×3.2))*.

c. When using the tabular firing tables, the site is determined by combining the angle of site and the complementary angle of site in the usual manner, paying particular attention to signs. The factor in the tabular firing table will give slightly different results than the factor on the graphical firing table because the factor used with the graphical firing tables is an average of the plus and minus site factors from the tabular tables.

d. Missions generally will be fired by one battery; if all batteries are to fire, each should be adjusted. In case the battalion is to be massed following the adjustment of one battery, the adjusting computer figures his site command, using the angle of site given him by the VCO and the 10-mil site scale on his graphical firing table. During the adjustment, the 10-mil site factor may change considerably. This will result in a different effective site at the end of the adjustment than was used in the initial commands, and this error must be corrected if the battalion is to mass on the target. An example is: Graphical firing table setting: charge 4, fuze M48, range 5,500, elevation 1,080.

Battalion mission, Battery B adjusting.

HCO: *Baker, Deflection 2,620; Range 6,000.*

VCO: *Site Baker plus 60.*

In computing his initial commands, the computer moves his indicator to 6000, charge 4, and reads 6.4 on the 10-mil site scale under the *elevation tick mark.* His site command then is 262 (300 + (−6×6.4)). The site computed in high-angle fire *always* differs in sign from the angle of site. After the adjustment is completed, the range corresponding to the apparent adjusted elevation (1,147) in charge 4 is determined as *5,000* yards. The 10-mil site factor at this range, elevation, and charge is 2.4. Therefore, the effective site is 286 (300 − (2.4×6)) instead of *262.* The corrected adjusted elevation now is—

Apparent adjusted elevation	= 1, 147 mils
Site used	= 262
	1, 409 (Adjusted quadrant elevation + 300 mils.)
Effective site	= 286
Apparent adjusted elevation	= 1, 123

The 10-mil site factor at elevation 1,123 is 2.8; therefore, the effective site is now 283 (300 − (2.8×6)) instead of 286. The correct adjusted elevation is—

	1, 409 (Adjusted quadrant elevation + 300 mils.)
Effective site	= 283
Correct adjusted elevation	= 1, 126 = 5, 170 yards

If the target had been replotted without making a correction for the change in site during adjustment, an error of 170 yards in range would have resulted.

229. DUTIES OF FIRE-DIRECTION PERSONNEL IN HIGH-ANGLE FIRE.

a. S-3.

(1) The S–3 includes in his fire order the command *HIGH-ANGLE FIRE* in place of the charge. The proper charge is selected by the computers.

(2) The batteries normally will fire at center range due to dispersion in range caused by weather and the probable use of different charges by each battery.

(3) After inspecting the plot of the target on the firing chart, the S–3 must notify the VCO and the computers to ignore or include site during observed missions.

(4) Massing of high-angle fire requires close and continuous supervision by the S–3. Small changes in weather have large effects in high-angle fire.

b. HCO.

(1) If there has been no registration with high-angle fire, the HCO announces *correction all charges, zero.* The deflection index for low-angle fire is used if a previous low-angle registration has been made.

(2) If high-angle registration has been completed with one or more charges, the HCO does not announce the correction for any charge until the computer asks for it. The correction is zero for any charge not registered. The task of recording corrections will be made easier for the HCO if he will mark the maximum and minimum range limits for each charge (high-angle fire) on the interior part of his range-deflection fan to not interfere with the deflection-correction scales on the edges of the fan. The deflection correction for each charge can be entered on the fan within the range limits of the charge (fig. 83).

c. VCO. If it is necessary to include site, the VCO figures the angle of site from the chart but does *not* compute the complementary angle of site. The angle of site is given each computer when requested.

d. Computers.

(1) When a battery has registered, using high-angle fire with a certain charge, the computer of that battery must announce to the other computers the graphical firing table setting for the charge used. He also must strip the correction for drift at the adjusted range from the total deflection correction at that range and announce the result to the HCO. For example, assume that Battery B registered on the base point, using charge 4. Map range to the base point is 6,040. Adjusted data in part were, Deflection 2,857, Site O, Elevation 982. (Aiming posts are set out at 2,800.) Computer B announces to the other computers, *GFT setting: Charge 4,*

fuze M51, range 6,040, elevation 982. He announces to the HCO, *Deflection correction charge 4, left 21 (L 57+R 36 drift)*.

(2) In selecting the charge to be used, the adjusting computer selects the charge which gives the most range on each side of the announced range. If there is no choice between two charges (the announced range in the exact center of the overlap between two charges), the lower charge is selected, due to the reduced time of flight. The computer includes in his command *HIGH-ANGLE FIRE* prior to charge. *Example: HIGH-ANGLE FIRE, CHARGE 5.*

(3) If possible, the computers of the nonadjusting batteries use the same charge as the adjusting battery.

(4) In a will-adjust mission, the nonadjusting computers should alert their batteries, warn them that high-angle fire will be

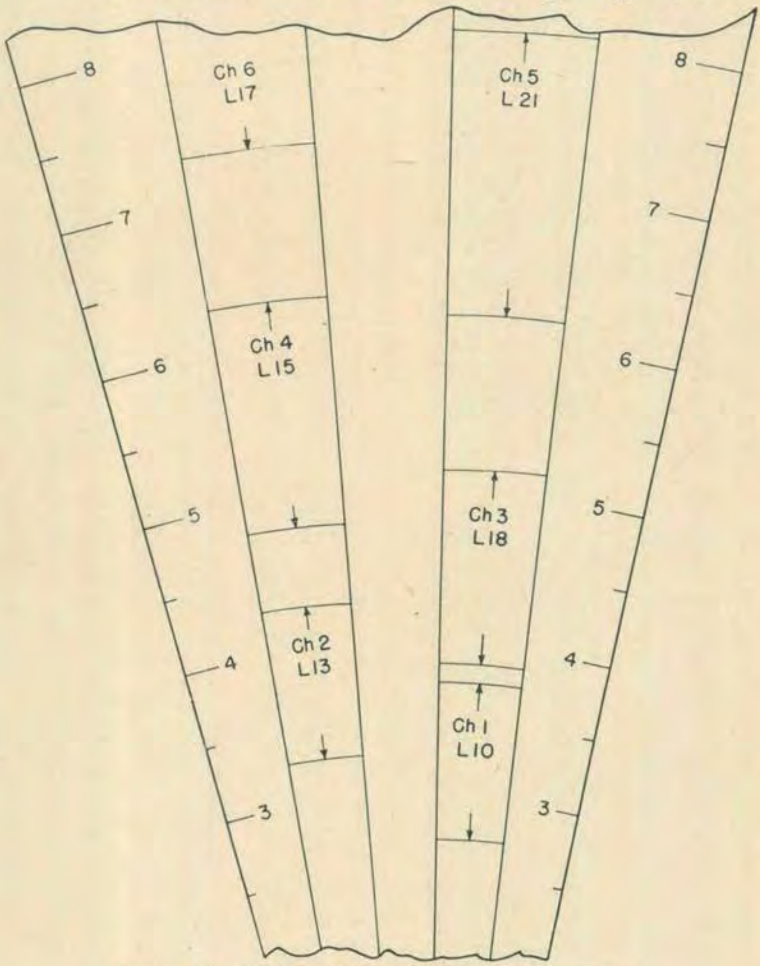


Figure 83. High-angle deflection-correction scale.

used, and give the approximate deflection, the number of volleys to be fired, and the type of fuze to be used. This warning order from the computer will save time at the batteries.

(5) Each computer determines the deflection to be fired by adding the deflection correction, the chart deflection as announced by the HCO, and the correction for the amount of drift for chart range under the elevation tick.

(6) When site is to be included, the computer requests the angle of site from the VCO. The site command is computed by using the 10-mil site scale on the graphical firing table, or by adding algebraically the complementary angle of site to the angle of site given by the VCO when the tabular firing tables are used. It must be remembered that the site command *always* will differ in sign from the angle of site.

(7) The computer makes the adjustment with the ranges announced by the HCO. If the range change makes a change in charge necessary, the command for the new charge is given. Finally, the new elevation corresponding to the new range and charge is given. The computer should be trained to anticipate changes of charge.

(8) When the adjustment is complete, the computer of the adjusting battery determines the data for replot as follows: The deflection correction for the charge and the drift correction are stripped from the adjusted deflection. The result is the deflection for replot. The range is read on the graphical firing table under the hairline. If there has been a change in the 10-mil site factor during adjustment, the adjusted elevation will be computed as in paragraph 228**d**. The charge used for effect and the concentration number are given. *Example:* Battery A adjusted on enemy troops, using charge 4 (GFT setting: Ch 4, Fz M51, Rn 5,670, El 1,050). The adjusted deflection of computer A was *DEFLECTION 2925;* deflection correction for charge 4 is right 10; drift at adjusted elevation for range (5,400), charge 4, is right 47. Computer A announces to HCO, *Data for replot, Able, Deflection 2888 (Df 2925 + R 47 + L 10), Range 5,400, High-angle, Charge 4, Fuze Quick, Concentration D1* (fig. 84).

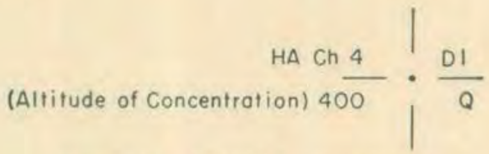


Figure 84. Replotted concentration.

Section V. MARKING TARGETS FOR FIGHTER-BOMBER ATTACK

230. GENERAL. **a.** Artillery fire may be used to identify targets to fighter-bombers. The problem of marking targets for fighter-bomber attack arises when the air force is requested to give close support to front-line elements. Because air missions must be assigned on small-scale maps, it is necessary that the targets be marked accurately for the fighter-bombers when they arrive over the area.

b. The marking of targets for fighter-bomber attack must be carefully prearranged. The prearrangement must be accomplished between the Air G–3 of the corps or division and the corps or division artillery headquarters that is to direct the marking of the targets, and will cover the following items:

(1) Location of the target.

(2) Color or combination of colors of smoke to be fired.

(3) Whether the center or the extremities of the target will be marked.

(4) Approximate time of the air strike.

(5) Communication net and procedure to be used.

c. Prior to the arrival to the striking force, arrangements are made for joint action by artillery personnel and by any forward air control party in the vicinity. Contact is established between these agencies for the purpose of making emergency corrections or taking other emergency action that may be necessary in connection with the air strike.

d. Communication from air to ground will be accomplished by means of the air-ground communication system from the striking force to Air G–3. Communication between Air G–3 and the artillery headquarters will be over normal liaison and command channels.

e. The artillery unit will be ready before the strike is due and verify communication with Air G–3. The striking force will order FIRE at the proper time for the smoke to be well defined when they arrive over the target area. If any difficulty arises in identifying the target, the striking force may order a repetition of the marking rounds.

f. When the target has been identified, the striking force reports TARGET IDENTIFIED.

Section VI. SOUND, FLASH, AND RADAR OBSERVATION

231. MISSIONS. The technique employed by field artillery observation battalions is presented in FM 6–120. The observation battalion may be used for the accurate location of targets, for the adjustment of fire, and for registration at greater distances and under more difficult conditions than is possible with organic firing battalion equipment and technique. Location of hostile artillery by sound and flash ranging, and registration of friendly artillery by flash ranging, are particularly appropriate missions. Adjustments by sound and flash ranging are time consuming and, while thus engaged, observation units are taken away from their primary mission of locating targets. Sound ranging is not recommended for registration purposes. Sound ranging units cannot determine height of burst in time fire adjustments.

232. TARGET DESIGNATION. Coordinates normally are used to designate targets in conduct of fire by observation units. In the absence of a coordinate system common to both the observation and artillery units, corrections may be made in relation to a base point, check point, or reference point. Altitudes are furnished, if known. Observation personnel estimate the degree of accuracy of target location, evaluate the mission, and send WILL ADJUST if conditions warrant adjustment. After a target is designated by a sound unit, adjustment should follow immediately to reduce errors from changes in atmospheric conditions. To eliminate errors, adjustments should be made, whenever possible, by the same unit that reported target location.

233. REGISTRATION WITH FLASH RANGING. a. Coordination. The artillery unit furnishes the coordinate and altitude of the registration point in order that observers may orient their instruments to bring the first burst into the fields of view. Time of flight and *ON THE WAY* are announced by the firing unit to assist the observers in identifying the burst. A code time of flight should be used with radio communication. Firing data with latest corrections are given to the adjusting battery.

b. Center of impact. The flash ranging unit may request one or more orienting rounds fired AT MY COMMAND in order to orient observers and to assure positive identification of the initial rounds. It commands FIRE for the initial orienting rounds and may specify the interval between rounds to be fired in the group for registration. The firing unit will specify the number of rounds (preferably six). *ON THE WAY* should be reported for each round. When the registration is completed, the coordinates and altitude of the center of impact are reported to the firing battalion. Additional rounds may be requested if the desired results are not obtained because of erratic readings, or lost or erratic rounds.

c. High burst. High-burst registration normally is used when impact bursts would not be visible to observers. Groups of rounds are fired as in **b** above, and the coordinates and altitude of the burst center are reported.

234. CONDUCT OF FIRE. a. Flash ranging adjustment. Adjustment is conducted by a single piece firing groups of two or more rounds with the best data available. The firing unit reports time of flight, direction of fire, and method of fire for effect. *ON THE WAY* is given for each round. The flash ranging unit makes necessary corrections to bring bursts to the target. The adjustment is continued until the flash ranging unit estimates that the next correction will obtain effect on the target; the next correction is followed by the command FIRE FOR EFFECT. If surprise fire is desired and the target is located accurately, preliminary adjustment of fire on the target itself may be eliminated entirely. It is the function of the firing battalion to determine whether prior registration is necessary and to choose the point for registration with benefit of recommendations from the flash ranging unit. The facilities of the flash ranging unit may be employed also to conduct precision adjustments for destruction.

b. Sound ranging adjustment. Adjustment is conducted by firing groups of two or more rounds in order to obtain a center of impact, thereby decreasing the error caused by dispersion and by plotting. Platoon or battery salvos may be used in order to assist the sound ranging unit to identify the bursts. *ON THE WAY* is given for each round. The adjustment is continued until a suitable bracket has been obtained; the next correction is followed by *FIRE FOR EFFECT*.

c. Fire for effect. Fire for effect may follow an adjustment on the target or on an auxiliary target, or may be based on a transfer from a center of impact, base point, check point, or other fire of which the flash (sound) unit has determined the location. When conditions permit, the sound ranging unit ranges on a registration and, from data so determined, corrections are computed for subsequent fire. The firing unit furnishes the coordinates of such points, preferably as determined by survey or photo restitution; otherwise, as determined by replot of adjusted data. Surveillance should be executed on all missions in order to obtain maximum effect. The method of fire and time at which fire will commence are given prior to fire for effect, and a report is made on completion of fire. With a sound ranging unit, a battery salvo for surveillance may be requested after fire for effect, since sound records of many sounds close together may not be readable.

235. EXAMPLE. **a.** An enemy battery has been located by the flash ranging platoon of Battery A, and is reported to the battalion command post as follows: FLASH REPORT, COORDINATES 96.82–79.43, ALTITUDE 315 YARDS, BATTERY, THREE PLOTS, ACCURACY 50 YARDS, TIME OBSERVED 0900, WILL ADJUST.

b. The observation battalion evaluates this report and reports to corps artillery fire-direction center: FLASH REPORT, COORDINATES 96.82–79.43, ALTITUDE 315 YARDS, BATTERY LOCATED BY ABLE FLASH, ACCURACY 50 YARDS, TIME OBSERVED 0900, WILL ADJUST.

Flash platoon to FDC	FDC to flash platoon	Remarks
	PREPARE TO OBSERVE CENTER OF IMPACT REGISTRATION, COORDINATES 96.5–79.0, ALTITUDE 300 YARDS, 6 ROUNDS.	
READY TO OBSERVE, ONE ROUND, AT MY COMMAND, REPORT TIME OF FLIGHT.	*TIME OF FLIGHT 25 SECONDS . . . BATTERY IS READY.*	
FIRE.	*ON THE WAY.*	Orienting round for flash platoon.
ONE ROUND, FIRE.	*ON THE WAY.*	Second orienting round.
5 ROUNDS AT 30-SECOND INTERVAL, FIRE.	*ON THE WAY.*	Flash plotting team plots the CI and reports the coordinates and altitude to the FDC. The FDC determines corrections from these data.
READY TO OBSERVE CONCENTRATION NO. 90.	*BATTALION FIRING FOR EFFECT . . . ROUNDS COMPLETE ALL BATTERIES.*	
CEASE FIRING, END OF MISSION.		

c. Corps artillery fire-direction center directs the 170th Field Artillery Battalion to fire the mission with surprise fire, using the flash platoon to observe registration, if necessary, and notifies the observation battalion accordingly. A concentration number is assigned and the target location is given. The type and amount of ammunition to be fired on the target and the channel of communication to be used are specified. The flash platoon is directed to perform surveillance of the mission.

d. The S–3 of the firing battalion decides to obtain corrections from a six-round center of impact registration. Direct communication is established between the fire-direction center of the firing battalion and the flash platoon of Battery A of the observation battalion.

236. LOCATION OF ENEMY MORTARS BY ORGANIC FIELD ARTILLERY BATTALION RADAR. FM 6–130 contains information concerning the tactical and intelligence considerations for employing organic field artillery radar equipment. Targets located by radar equipment are reported by *coordinates* to the battalion fire-direction center. With present organic equipment, altitudes cannot be determined but must be obtained from established maps. Adjustment of artillery fire cannot be accomplished satisfactorily. Generally, targets located by radar means are fired on as targets of opportunity.

Section VII. DETERMINATION OF DEAD SPACE AND VISIBILITY

237. DEAD SPACE. a. General. The near limit of the dead space is the *grazing point.* The far limit of the dead space is the first point of impact beyond the near limit. The determination of dead space is possible only with an accurate, contoured map.

b. Quadrant elevation method. To determine dead space by the quadrant elevation method, the procedure is as follows:

(1) Draw a ray from the plotted position of the piece through the mask. By inspection, determine the grazing point of the mask considered. Determine the quadrant elevations of points on the ray that are 50 to 100 yards short or over the initial grazing point tested; the point requiring the greatest quadrant elevation marks the beginning of dead space.

(2) The point of impact, or end of dead space, is determined by finding a point beyond the mask which requires the same quadrant elevation as that of the grazing point. The process is one of trial and error. A test point of impact is selected by inspection, based on the range corresponding to the quadrant elevation for the grazing point. The quadrant elevation for the test point is determined; if it is less than that for the grazing point, the point is in dead space; if greater, the point is beyond dead space. By repeating the process, the point of impact may be determined to any desired degree of accuracy.

c. Dead space chart. The dead space for one ray or profile is determined; the process is repeated for such additional rays as are necessary. The dead space area is outlined by connecting corresponding points on adjacent rays.

238. VISIBILITY. For a discussion of visibility and visibility charts, see FM 21–26.

CHAPTER 20

FIRE DIRECTION: DIVISION ARTILLERY, FIELD ARTILLERY BRIGADE, GROUP, AND CORPS ARTILLERY

Section I. ORGANIZATION AND OPERATION

239. GENERAL. **a.** FM 6–20 contains general information on the operation, organization, and communication for fire direction. Gunnery aspects of this subject are covered more specifically below.

b. Missions may originate within the unit or from higher or subordinate units whose intelligence agencies fix the location of the target. They are processed as follows:

(1) Battalions able to fire the missions are determined by reference to the fire capabilities chart.

(2) The location of the targets may be determined by survey, by restitution from air photographs, or from a study of the ground by commanders, ground observers, or air observers. Fire on these targets should be delivered with surprise whenever practicable.

(3) The location of the target may be determined by firing. When additional fire is requested, the battalion making the adjustment reports to the next higher artillery fire-direction center the approximate coordinates and description of the target and states that the adjusted coordinates and altitude will be reported later (par. 246).

(4) The distribution of the fire of the battalion will be governed by the size and nature of the target. For methods of attack, see paragraphs 166–178.

240. FIRE-DIRECTION CENTER. The fire-direction center is a part of the command post of the unit. It usually is located well forward and near the center of the battalion position areas in order to facilitate the maintenance of communications. It maintains fire capability charts of subordinate units. (See FM 6–20.)

241. GUNNERY DUTIES OF THE S–3, FIELD ARTILLERY GROUP OR FIELD ARTILLERY BRIGADE. Duties of the S–3 of the field artillery group or brigade are to—

a. Keep the artillery commander informed on all matters pertaining to disposition of the units of the command.

b. Control the operation of the fire-direction center.

c. Prepare fire plans and supervises their execution.

d. Keep the S–3 situation map, S–3 work sheet, and other records, as the situation requires.

e. Keep a current record of the ammunition situation.

242. GUNNERY DUTIES OF THE S–3, DIVISION ARTILLERY. In addition to the duties listed in paragraph 241, the S–3 prepares—

a. Countermortar plans and directs the execution of countermortar fires.

b. Counterbattery fires when the division is operating alone.

243. GUNNERY DUTIES OF THE S–3, CORPS ARTILLERY. In addition to the duties in paragraph 241 the S–3—

a. Receives and records data from the division artilleries and other sources pertaining to battalion fire capabilities, requests for fire, enemy and friendly information, and displacement plans.

b. Prepares counterbattery plans and supervises the execution of counterbattery fires.

c. Effects the coordination of artillery fire with air strikes and naval gunfire.

d. Coordinates fire plans prepared by divisions.

e Coordinates artillery fire laterally and in depth.

f. Obtains no-fire lines and other limitations on firing from the division artilleries and disseminates this information to the corps artillery units.

Section II. MASSING THE FIRES OF MORE THAN ONE BATTALION

244. GENERAL. The massing of the fires of more than one battalion is dependent on the following requirements:

a. Common survey control or common registration for all battalions to fire the mission.

b. Adequate communication facilities to accomplish coordination and control of the firing.

c. Sufficient time for all battalions to lay and be ready to fire.

d. Fire capabilities of the battalion.

e. Centralized command.

245. BATTALIONS TO FIRE. The battalions capable of firing on a target are determined from the artillery fire capabilities chart. In order to avoid diverting direct-support artillery from its primary mission, artillery units in general support normally are used when additional fire is necessary. When a unit requests additional fire, the artillery commander or his authorized representative at the fire-direction center must decide whether to grant the request, the number of battalions to fire, and the amount of ammunition to be expended. The unit requesting the fire is informed of the decision.

246. ASSIGNMENT OF MISSIONS. **a. Chart location of target known.** The chart location of the target may be determined by survey by restitution from air photographs, or from a study of the ground by commanders, ground observers, or air observers. In assigning missions to battalions, the fire-direction center includes in its order the coordinates and altitudes of the target, the concentration number, the nature of the target, the amount and type of ammunition, the method of fire, and the time of opening and/or lifting fire. Fire on these targets should be delivered with surprise whenever practicable.

b. Chart location of target unknown initially. A battalion adjusting on an important target may make a request to the fire-direction center of the next higher artillery headquarters for additional fire. When the battalion makes this request, it gives the approximate coordinates, concentration number, description of the target, and states that correct coordinates and altitude will be reported later. The artillery commander, or his representative, decides which battalions are to be placed on the target, sends them warning orders, and informs the requesting battalion what additional fire it will receive. Communication lines are kept open. As soon as the battalion requesting the fire determines the correct coordinates and altitude in yards, these data are sent to the fire-direction center of the next higher artillery headquarters, and from there to the battalions designated to fire the mission.

247. METHOD OF ATTACK. (See pars. 166 and 178.) The size and nature of the target will govern the distribution of the fire of the battalions. When the target area is large, each battalion may be assigned a part of the target.

248. PRECAUTIONS. **a. Massing fires in close support of troops.** When massing fires in close support of infantry, the greatest caution must be exercised. There are inherent inaccuracies in all types of firing charts. Registration near the target or the firing of check rounds on the target must be made to eliminate unnecessary casualties to friendly troops.

b. Firing of units other than direct-support artillery. The fire-direction center of a general-support or reinforcing battalion, whose observers locate targets inside no-fire lines, must coordinate with division artillery or the direct-support battalion concerned before attacking such targets.

249. EXAMPLE: PROCEDURE OF MASSING THE FIRES OF MORE THAN ONE BATTALION ON A TARGET OF OPPORTUNITY. **a.** When a single battalion takes under fire a target which requires additional fire, that battalion may request additional fire from higher headquarters.

b. The single battalion will start the adjustment and send to the fire-direction center of the next higher artillery headquarters a message which will include the following elements:

THIS IS (NAME OR NUMBER) BATTALION;
NOW ADJUSTING (OR FIRING) ON (NATURE OF TARGET);
SIZE OF AREA (MAY BE OMITTED);
APPROXIMATE COORDINATES (--------), ALTITUDE (--------);
REQUEST ADDITIONAL FIRE;
CONCENTRATION NUMBER.

c. The higher headquarters S–3 receives the above message. He plots the coordinates and, according to his fire capabilities chart, selects the additional battalions that are to fire the mission.

d. The selected battalions are alerted and given the following message:

FIRE MISSION;
THIS IS (----------);
FIRE (NUMBER) VOLLEYS SHELL (TYPE) FUZE (TYPE);
APPROXIMATE COORDINATES AND ALTITUDE (----------);
CENTER RANGE (OR RANGE SPREAD);
WHEN READY (OR AT MY COMMAND);
ADJUSTED COORDINATES LATER;
CONCENTRATION NUMBER (----------).

e. The adjusting battalion will complete the adjustment, replot the target, and send a message to the next higher artillery headquarters fire-direction center, as—

ADJUSTED COORDINATES (----------);
ALTITUDE (----------);
NOW FIRING FOR EFFECT;
CONCENTRATION NUMBER (----------).

f. The adjusted coordinates and altitude are relayed to the other battalions.

g. When an enemy battery is a target of opportunity and is listed in the hostile battery list, the S–3 may transmit the fire mission by referring to the grid square and name of battery shown in the hostile battery list.

h. After fire for effect has been completed, the adjusting battalion may be able to determine that the target has moved or is moving. In this case, the battalion fire-direction center may send to the next higher artillery headquarters fire-direction center—

THIS IS (NAME OR NUMBER) BATTALION;
TARGET HAS MOVED (SO MANY) YARDS NORTH (SOUTH) (SO MANY) YARDS EAST (WEST);
REQUEST FURTHER ADDITIONAL FIRE.

Section III. FIRE PLANS

250. METHOD OF ASSIGNMENT OF TARGETS. Enemy installations and areas suspected of containing remunerative targets are divided into areas suitable for artillery targets and assigned concentration numbers. Two or more concentrations falling within a tactical locality may be formed into a group of fires (par. 210). Groups of fires that probably will be fired simultaneously or consecutively in support of a tactical maneuver are formed into a series. Each concentration within a group of fires should be assigned to a different battalion so that all targets within a group of fires may be attacked simultaneously. The assignment of groups of fires and series to tactical units will facilitate fire execution. Important targets should be assigned to more than one unit.

251. TIME SCHEDULE. **a.** Fires may be lifted and advanced on a time schedule based on the estimated rate of movement of the supported troops. A time schedule is inflexible and difficult to adjust to the maneuver of supported troops.

b. Only minor changes in the time schedule are practicable during the attack. When extensive revision is required, abandonment of the schedule in favor of other methods or a new schedule usually will be necessary.

c. Schedule fires are planned in independent series to avoid restricting the attack to a time schedule over a long period.

252. PLANNING AND EXECUTING FIRES. Artillery fires are planned and integrated with tactical air missions, fires of auxiliary weapons, and naval gunfire in order to meet the needs of supported troops. All levels of artillery command and liaison plan artillery fires concurrently. Close-support fires are planned by direct-support artillery and the supported units. All echelons of artillery plan supporting fires continuously. Field artillery provides the primary means of fire support.

253. PREPARATION AND COUNTERPREPARATION FIRES. **a.** For preparations and counter preparations prepared by division artillery, a schedule of fires should reach the battalions at least 4 hours in advance of the starting time of the schedule. Any additional targets that may be determined after the schedules have left may be transmitted to the battalions and fitted into their fire plans. For prearranged fires ordered by corps artillery, the schedule must reach the groups and division artilleries in time to be integrated into their plans.

b. Steps necessary in preparing the schedule of fires by the S–3 at corps artillery, division artillery, and the field artillery group command echelons are as follows:

(1) As soon as the S–3 learns that a preparation is to be fired, he secures locations of targets from the S–2 based on the best and latest intelligence. Similar information is obtained from the counterbattery intelligence officer relative to enemy batteries.

(2) The S–3 prepares a work sheet showing targets to be attacked by each battalion. An example of a work sheet is shown in figure 85.

(3) The schedule is made up from the work sheet. Every effort is made to attack the maximum number of targets simultaneously, with two or more battalions firing on each target. (See figs. 86 and 87.)

(4) The schedule is reproduced and dispatched by agents to the appropriate units.

c. The corps artillery fire-direction center should prepare a counterpreparation schedule. This schedule is sent to each division and group to be fired on call.

d. General considerations of prearranged fires are that—

(1) Prearranged fires are employed whenever the conditions of the operation permit.

(2) When time permits, fires to be delivered on call are prepared for likely locations of hostile troops.

(3) When the location of the enemy is known, groups of prearranged concentrations may be fired in a definite sequence; each group is fired at the request of the supported unit.

(4) Each series of concentrations corresponds to a maneuver phase and is terminated by the capture of the objective.

e. Groups of fires and series should be planned to facilitate the maneuver of fire on the ground and to meet developments of combat. Specific battalions are assigned a specific concentration or concentrations in each group of fires in order that each battalion will not have to prepare data for all concentrations. Groups and series of prearranged fires should be coordinated in such a way that there will be at least one unit available to fire each concentration even when reinforcing units are occupied on division or corps missions.

254. COUNTERMORTAR FIRES. a. General. The fire-direction operations and organization of artillery permit heavy concentrations of surprise fire to be placed quickly on targets without prearrangement. For these reasons, artillery is especially suitable for placing prompt neutralization fire on hostile mortars. High-velocity weapons are unable to reach mortars in deep defilade, but howitzers employing high-angle fire may attack such targets effectively.

S–3 Work Sheet

(Schedule fires for preparation)

	−30	−25	On call after H−20	−20	−15	−10	−5 H
503 FA GP:							
474 FA Bn: 155-gun	474—CN	474—CHC	474—AX	474—BAC	474—BPC	474—CRC	474—CCC
811 FA Bn: 8-inch howitzer.	811—BK	811—BXC	811—BAC	811—BBC	811—BQ	811—CRC	811—CCC
812 FA Bn: 8-inch howitzer.		812—BXC	812—CLC	812—BCC	812—BRC	812—CRC	812—CSC
502 FA GP:							
472 FA Bn: 155 gun	472—CF	472—BNC	472—BSC	472—BD	472—BAC	472—CRC	472—CTC
473 FA Bn: 155 gun	473—CD	473—BSC	473—BUC	473—BE	473—BBC	473—CD	473—CTC
411 FA Bn: 155 howitzer	411—AW	411—BUC					
412 FA Bn: 155 howitzer	412—AW	412—BUC	412—BUC	412—BFC	412—BDC	412—CEC	412—CU
6th Div Arty:							
1st FA Bn (lt)			1—AX	1—BG	1—CA	1—CEC	1—CGC
51st FA Bn (lt)			51—BAC	51—BH	51—DAC	51—CEC	51—CGC
53d FA Bn (lt)			53—CLC	53—BI	53—DB	53—CF	53—CJ
80th FA Bn (med)	80—BLC	80—AS	80—AX	80—BJ	80—CR	80—CF	80—CJ
85th Div Arty:							
328th FA Bn (lt)	328—ATC	328—AS		328—BLC	328—CB	328—CHC	328—CL
329th FA Bn (lt)			329—BF	329—BOC	329—DCC	329—CHC	329—CL
910th FA Bn (lt)					910—BSC	910—CJC	910—CNC
403d FA Bn (med)			403—BF		403—BT	403—CJC	403—CNC

Figure 85. A type S–3 work sheet.

Division (Group; Corps) Assignment of Prearranged Fires

Group	Concentration No.	Battalion to fire	Time		Coordinates	Altitude	Size		Method of attack	Ammunition	Remarks
			From	To			Width	Depth			
DAA	H11	664th	on	call	51.622–95.100	433	300	300	½ c apart	48	Fuze quick, 2 RGM.
	H12	763d	on	call	51.478–95.281	437	200	200	Center range	72	Fuze quick, 3 RGM.
	H13	764th	on	call	51.718–95.395	433	200	200	Center range	72	Fuze quick, 3 RGM.
BJ	A41	764th	on	call	52.692–95.150	420	200	200	Center range	72	Time fire, maximum rate.
	G15	664th	on	call	52.900–95.184	417	300	200	Center range	48	Time fire, maximum rate.
	E15	763d	on	call	53.124–95.160	418	200	200	Center range	72	Time fire, maximum rate.
EW	A68	764th	on	call	54.839–95.665	393	200	200	Center range	72	Time fire, 3 RGM.
	E22	763d	on	call	54.904–95.439	397	200	200	Center range	72	Time fire, 3 RGM.
	G25	664th	on	call	55.063–95.570	393	300	200	Center range	48	Time fire, 2 RGM.

Figure 86. Type tabular schedule of prearranged fires.

EXPLANATION OF FIRE PLAN

Concentration No. This number should be assigned by division or corps artillery from their own block of numbers.

Battalion. This may apply to battalion, group, brigade, or division.

Time. Include here the limitations on time of firing. If it is an *on call* mission, it should be so stated. Times may be given with respect to H-hour.

Coordinates. Give the coordinates of the center of the concentration. (For assignment of area targets, see Note 2.)

Altitude. The altitude of the center of the concentration in yards.

Size. Give the size in yards. Concentrations H11, G15, and G25 are appropriate for 155-mm battalions. Concentrations H12, H13, A41, etc. are appropriate for 105-mm battalions. (See Note 2.)

Method of attack. Examples are *center range, 1 c apart*, etc. The method of attack by a range spread is applicable for attacking targets in depth; the increase in range spread increases the size of the area covered in the direction of fire only. If the area to be covered is greater than that covered by a standard battalion concentration firing at center range or with range spread, the method of attack must be decided upon by the lower unit commander who breaks it down into separate standard size battalion (or battery) concentrations. (See Note 2.) (See section II, this chapter.)

Ammunition. The amount of ammunition to be expended on the mission.

Remarks. Any additional information pertinent to firing the mission, such as rate and type of fire, and any other unit firing on the target at the same time.

Notes

1. Each unit concerned receives one copy of the fire plan and one is retained for file.

2. The assignment of prearranged fires may be made by *overlay* and graphical time schedules. This method is particularly applicable when area targets are being assigned. The use of an overlay will eliminate the coordinates, altitude, and size columns from the fire plan sheet.

3. A graphical time schedule is useful as a work sheet in planning fires, and as a quick reference for commanders to determine which units are firing.

Preparation

Battalions to fire	−30	−28	−26	−24	−22	−20	−18	−16	−14	−12	−10	−8	−6	−4	−2	H	+2
764th FA Bn						A7		A3									
						18		18									
	A15		A11			A8		A2			A5		A10			A19	
	72		90			18		18			90		90			90	
						A9		A6									
						18		18									
763d FA Bn							B26			B6							
							18			18							
		B31			B32		B50			B7		B13			B10		
		90			90		18			18		90			90		
							B46			B8							
							18			18							

762d FA Bn		E93 24			A18 24		E76 18			E61 18								
		E94 24			E41 24		E77 18			E62 18		B13 90			A10 90		A19 90	
		E95 24			B11 24		E78 18			E63 18								
664th FA Bn									*E5 12		*E1 12							
			E11 54		E10 54			*E6 12			*E2 12			B9 54		A4 54		
								*E7 12		*E3 12								

*Indicates battery concentration.

Note 1. Figures above the horizontal lines indicate concentration number; figures below lines indicate ammunition alloted. The heading shows time in 2-minute intervals with respect to H-hour.

Note 2. Size of concentration is prescribed either on a tabular schedule of prearranged fires or by standing operating procedure.

Figure 87. Type graphical time schedule of fires.

b. Technique of fire. Neutralization fire normally will be used on enemy mortars because visual observation will be difficult to obtain and the locations as reported generally will not be accurate enough to warrant the firing of destruction missions. Occasionally, observed fire will be possible by air or ground observers, but countermortar fires often will be unobserved. The terrain and the type of mortar emplacements will have influence on the method of attack.

c. Types of fire to be employed. High-angle percussion fire may be necessary if the mortars cannot be reached by low-angle fire. When information of the cover available to the mortars is known, it will aid in determining whether to use fuze quick or delay. The delay fuze is used when there is considerable overhead cover. White phosphorus shell may be mixed with high explosive shell to secure morale and incendiary effect.

d. Countermortar programs. Countermortar programs are similar to counterbattery programs.

255. COUNTERBATTERY (COUNTERFLAK) FUNCTIONS AND PROGRAMS.

a. General. Counterbattery includes the location and neutralization or destruction of enemy artillery, including antiaircraft artillery and antitank guns. All types of artillery may execute counterbattery fires; medium and heavy artillery are preferable. Against each enemy battery, at least a battalion should be used to establish the initial neutralization. One or two platoons, reinforced at intervals by additional artillery, can maintain neutralization.

b. Responsibilty and organization.

(1) Corps artillery organization provides the staff, intelligence agencies, and suitable weapons to discharge its primary responsibility for counterbattery. Division artillery may reinforce the counterbattery fires of corps artillery, or execute counterbattery fires on targets of opportunity.

(2) The S–3 of corps artillery is responsible for preparing the detailed counterbattery fire plan and for executing the counterbattery fires. He is assisted by the S–2 who furnishes information of known or suspected targets with a detailed description of each and a recommended priority of importance.

c. Execution of counterbattery fires.

(1) Counterbattery fire on active artillery preferably should be delivered while the hostile battery is firing.

(2) Hostile batteries should be attacked with surprise fire.

(3) Time, ammunition, and observation permitting, batteries once neutralized should be destroyed by fire.

(4) The observation battalion sometimes can determine the accuracy of unobserved fires by sound and flash ranging.

(5) White phosphorus, mixed with high explosive shell in ratio of about 1 to 4, adds to the effectiveness of counterbattery fires.

d. Preparation. The corps artillery S–2 determines the tactical grouping of hostile artillery from the build-up of counterbattery and counterflak intelligence. Based on this information, the corps artillery S–3 prepares counterbattery and counterflak programs. These programs are coordinated with maneuver phases and usually are put into effect on call.

256. EXAMPLES OF COUNTERBATTERY (COUNTERFLAK) PROGRAMS. This technique also may be used in countermortar programs. For the meanings and uses of the lettering of the hostile batteries, see FM 6–130. Enemy batteries usually are designated by two-letter combinations followed by letter *C*, if confirmed. Mortar locations are designated in the same manner, except the two letters are preceded by the letter *M*.

a. Example 1. The program shown below will neutralize eight hostile batteries, each by two firing units, in about 4 minutes. This program can be put into effect by the message *FIRE CATFISH, QUEEN IS (SO MANY) MINUTES FROM NOW;* or if time is synchronized, *FIRE CATFISH, QUEEN IS 2210.* Countermortar and counterflak programs are similar. The latter are used to protect preplanned air force actions. Unit S–3's study positions of targets and determine whether normal or high-angle fire should be used. If types of ammunition and fuzes differ materially for different targets, these details may be placed in the last column of the table.

Counterbattery Program "Catfish"

Units to fire	Hostile Batteries and TOT		Rounds per target
	Q hour	Q+3 min.	
631 (155H)	AAC	MQC	24
936 (155H)	DLC	BMC	24
178 (155H)	KGC	AMC	24
173 (155G)	FBC	GCC	24
527 (8″ H)	AAC	MQC	12
536 (8″ H)	KGC	AMC	12
54 (240H)	FBC	GCC	6
A/403 (90G)	DLC	BMC	20

Ammunition: Shell HE; 1/3 FQ, 1/3 VT, 1/3 FD; 155-mm howitzer and 155-mm gun battalions include 4 rounds WP, FQ, on each target. Target description: See hostile battery list 23.

b. Example 2. The program shown below is a suitable form for the initial counterbattery phase in the general preparation. It is given a code name so that it can be repeated readily in whole or in part, if required. The amount of ammunition to be expended on counterbattery missions for each caliber normally is predetermined by the corps artillery standing operating procedure or is announced in the policy of the corps artillery commander. Weight of fire on different targets is varied by assigning them to varying numbers of battalions. Most have been assigned to three battalions; for example, BFC (H–115). Suspected batteries (two-letter names) have been hit late in the program and by only one or two battalions. Similar programs must be prepared for other phases of the preparation, covering maintenance of counterbattery neutralization and other types of fire missions. It is convenient to issue separate programs assigning maintenance of counterbattery neutralization to certain units and other types of missions to other units.

Counterbattery Program "Blackjack"

Unit to fire	Time on target				
	H–120	H–115	H–110	H–105	H–85
59 (105 SP)	ABC	ADC	AFC	BGC	EL
93 (105 SP)	BDC	BAC	AHC	ARC	AN
185 (155H)	ABC	ADC	AFC	BGC	BO
403 (155H)	BDC	BAC	AHC	ARC	AQ
631 (155H)	AXC	BEC	AJC	BK	BHC
936 (155H)	BBC	AGC	BCC	AM	BHC
937 (155H)	BBC	AGC	BCC	AM	BHC
173 (155G)	ACC	BFC	AUC	ATC	ALC
932 (8″ H)	ACC	BFC	BCC	ATC	ALC
697 (240H)	AAC	BFC	AUC	ATC	ALC
A/401 (90G)	ABC	ADC	AFC	BGC	BL
B/401 (90G)	BDC	BAC	AHC	AKC	AN
C/401 (90G)	AXC	BEC	AJC	BK	AQ

Target description: See hostile battery list 42.

Ammunition on each target:

90G: 10 battery volleys, all time fuze.
105H: 5 battalion volleys, all FQ, 4/5 HE, 1/5 WP.
155H: 3 battalion volleys, 1/9 WP, FQ; 5/9 HE, VT; 1/3 HE, FD.
155G: 3 battalion volleys, all HE, 2/3 FQ, 1/3 FD.
8″H: 2 battalion volleys, all HE, 1/3 FQ, 1/2 VT, 1/6 FD.
240H: Same as 8″ howitzer.

c. Other targets. Ordinarily, targets other than hostile artillery are numbered, rather than named. A list of these concentrations similar to a hostile battery list showing coordinates, altitude, and description should be attached to the program. An overlay alone is not satisfactory as it does not give sufficient and accurate information.

257. GENERAL. a. Safety precautions. An armed VT fuze may detonate when it passes within 25 yards of an airplane. Safety precautions must be prescribed to protect both light aviation and high-performance aircraft. The plan is prescribed by the highest artillery headquarters concerned—usually corps.

b. Coordination with air force units. Air force units should be included in the warning system, if practicable. Artillery units should avoid firing VT-fuzed shell against targets under direct attack by fighter-bombers or through routes of low flying aircraft, especially at night.

c. Warning system. The following system, with modifications to fit the particular situation, will provide safety:

(1) *Overlays.* Overlays subdividing the area of maneuver into smaller areas are distributed to all artillery and air units, and division headquarters. Each fire-direction center and artillery pilot then uses the current overlay with an appropriate map.

(2) *Notification of anticipated firing.* The artillery headquarters intending to fire the VT fuze must initiate a warning to all artillery planes within the corps. Each area shown on the overlay which the VT trajectory intersects is dangerous for planes. Notification is accomplished as follows:

(*a*) The artillery unit initiating the VT mission notifies corps artillery headquarters, each division artillery headquarters, and group headquarters by radio (over the corps artillery fire-direction net) of the—

1. Time mission is to be fired.

2. Zones to be cleared of aircraft.

(*b*) Each unit rebroadcasts this warning to its own air officer, who notifies all planes under his control to clear danger areas.

(*c*) Sufficient warning notice should be allowed for airplanes to clear the danger zones. (The corps artillery commander may order emergency firing without delay.)

(*d*) The artillery headquarters initiating the VT warning notifies all concerned of the completion of the mission through the same method.

PART FIVE

SURVEY

CHAPTER 21

GENERAL

258. GENERAL. The purpose of field artillery survey is to determine the horizontal and vertical locations of points to be placed on the firing charts, and to provide a means of orienting pieces and instruments on the ground. It facilitates the massing of fires, delivery of surprise observed fires, and the delivery of effective unobserved fires. Survey must be performed with definite goals and priorities in mind and should be based upon a carefully formulated plan. After occupation of position and the completion of a firing chart, survey is continued in order to verify and improve earlier survey, augment the number of target locations, locate alternate positions, and extend common control.

259. SCOPE. **a.** This part of the manual covers survey normally employed by division artillery headquarters and in field artillery howitzer, gun, and rocket battalions. It includes the use of survey equipment, basic survey procedures, use of aerial photographs, and survey planning.

b. More accurate procedures which normally are employed by units assigned to higher echelons are covered in FM 6–120 and TM 5–235.

260. ECHELONS OF SURVEY. **a. General.** The flow of survey control is from higher to lower units. However, the subordinate units never wait for this control to commence their surveys. Survey can be initiated based on assumed control and converted to common control when it is made available.

b. Corps.

(1) *Topographic engineers.* The corps topographic engineers normally is the highest echelon from which survey sections obtain survey control information. These engineers furnish control to the corps observation battalion or, in some cases, work with the observation battalion in extending this control to divisions and separate battalions.

(2) *Observation battalion.* The corps observation battalion normally furnishes common control to the field artillery units of the corps. This is done by providing each division and

separate battalion with the coordinates, altitude, and ground location of at least two intervisible points; or the coordinates, altitude, and ground location of one point, and the Y-azimuth to another visible point. These points should be placed to facilitate the division or battalion surveys. The observation battalion, in addition to furnishing this control, frequently coordinates the survey operations of lower echelons in order to prevent duplication of survey effort.

(3) *Survey information center.* The coordination and extension of control is accomplished through a corps *survey information center* (SIC) established by the observation battalion. There, a record is maintained of all survey control available in the corps sector. All requests for control should be made to the survey information center and all survey data determined by units with the corps should be reported to it. Since the degree of accuracy of survey varies within the several echelons of survey, the source of any control obtained at the survey information center should be considered in evaluating its accuracy.

c. Division artillery. The purpose of division artillery survey is to place the field artillery of the division on a common survey control. When the division is operating as part of a corps, this should be the corps control. Such control is essential in order to mass the fire of the battalions of the division as a unit or with the fires of other artillery with the corps. To extend common control within the division, division artillery furnishes each battalion with the coordinates, altitude, and ground location of at least one point in the battalion area, and the Y-azimuth of a line from that point to another point visible therefrom. Instead of furnishing the Y-azimuth of the line between the two points, the coordinates and ground location of the second point may be furnished. The division artillery survey section establishes a division artillery survey information center where this control will be available to the division artillery units. It is the responsibility of the division artillery commander and a duty of the division artillery survey officer to insure that the control reaches each battalion. Division artillery also assists the battalions in transferring to common control by furnishing any available survey information in addition to that listed above.

d. Photo interpreter teams. The photo interpreter teams assigned to corps and division are primarily a source of intelligence. When suitable maps are available, the location of targets and other points may be determined by restitution and reported by coordinates. When maps are not available, these teams should supplement instrument survey by means of photographs. This may include assembling mosaics or extending planimetric and vertical control in the target area.

e. Battalion. Battalion survey consists mainly of the topographical operations necessary to determine with sufficient exactness the relative locations both horizontally and vertically of the pieces and targets. The actual amount of survey operations involved depends upon the type of firing chart to be used and the assistance received from higher artillery headquarters. Direction for the batteries and location of batteries, observation posts, and points in the target area must be established. The minimum amount of survey must be sufficient to deliver the types of fire desired. Survey is not concluded when the firing chart is complete. Rather, it is continuous, and ceases in one area only to begin in another.

f. Battery. Battery survey usually is an integral part of the battalion survey. When a battery is operating alone, it must perform the survey normally performed by the battalion.

CHAPTER 22

SURVEY EQUIPMENT AND ITS USE

Section I. PRINCIPAL INSTRUMENTS

261. PRINCIPAL INSTRUMENTS. The principal instruments used for survey operations are—

a. Steel tape. Detailed description is found in TM 5–235.

b. Transit. Detailed description is found in TM 5–235.

c. Aiming circle. Detailed description is found in TM 9–575.

d. Military slide rule. Detailed description is found in TM 6–240.

Section II. TAPE AND TAPING

262. TAPE AND ACCESSORIES. a. Tapes.

(1) Field artillery survey sections are equipped with 300-foot and 100-foot tapes. Both types may be graduated, throughout their length in feet, tenths, and hundredths, or only the foot marks may be shown, and one foot on one or both ends of the tape graduated in tenths and hundredths. The graduated portions may be included within the 300-foot or 100-foot length, or they may be outside the 300-foot or 100-foot length.

(2) Meter tapes are graduated in meters, centimeters, and millimeters. The arrangement of the graduations is the same as on a foot tape. Either tape is used in the manner described in the following paragraphs except that, when using the meter tape, all measurements and computations are based on the metric system.

b. Accessories. Each tapeman should be equipped with a plumb bob and notebook. The head tapeman should have a set of 11 taping pins.

263. TAPING ON LEVEL GROUND. There are several methods which may be followed to measure the distance desired. If more than one method is used, confusion and errors will result. Therefore, expedients should be avoided and a methodical procedure followed. The procedure for taping on level ground is as follows (fig. 88):

a. To determine the length of a course between two stations, the head tapeman with the zero end of the tape in his hand starts forward along the course to be taped. He has 10 of the 11 pins in his possession. The eleventh pin, which is kept by the rear tapeman, represents the first tape length. The head tapeman keeps his eyes fastened on the forward station and does not look back to see when he has reached the length of the tape. This procedure enables him to keep very close to the correct course and shortens the lining-in process.

b. Just before the whole length of the tape is drawn out, the rear tapeman calls, "Halt," at which time the head tapeman turns and alines the tape on the true course by directions from the rear tapeman. The rear tapeman then calls, "Pull," and the head tapeman pulls the tape, using about 20 pounds tension. The rear tapeman guides the end of the tape exactly over the starting point and calls, "Stick." At this instant, the head tapeman sticks a pin in the ground opposite the zero mark on the tape and responds, "Stuck." Both now proceed as before, the rear tapeman giving the preliminary "Halt" signal as he approaches the pin just set by the head tapeman. He picks up this pin as soon as the head tapeman sticks the next pin in the ground. At this point, the rear tapeman has two pins which represent the tape lengths from the starting point to the pin in the ground. At any time, the number of tape lengths from the starting point to the pin in the ground is represented by the number of pins the rear tapeman has retrieved.

Figure 88. Taping on level ground.

c. When the head tapeman has set his last pin in the ground, the rear tapeman comes forward and gives him the 10 pins which represents ten tape lengths from the starting point to the pin in the ground. Both tapemen record ten tape lengths in their notebooks and proceed as before. When the end of the course is reached, the head tapeman stops. The rear tapeman leaves his end of the tape and moves forward to the last pin. The manner of determining the last measurement, if it is not an even tape length, will depend upon the type of tape being used.

(1) If the tape is graduated in tenths of a foot throughout its entire length, the head tapeman holds the zero over the for-

ward station and the rear tapeman reads the feet and fraction direct.

(2) If only the first foot, that is from 0 to 1, is graduated in tenths of a foot, the head tapeman holds the 1-foot mark of the tape opposite the forward station, and then slacks off sufficiently to allow the rear tapeman to bring a whole foot mark into coincidence with the pin. Then the rear tapeman reads the whole number of feet and the head tapeman reads the fraction. The fraction read is subtracted from the whole number of feet to determine the last measurement.

(3) If an additional foot, that is, a foot beyond the zero, is graduated in tenths of a foot, the head tapeman holds the zero even with the station. The rear tapeman then pulls the tape until an even foot mark is opposite his pin and reads the number of feet. The head tapeman reads the tenths of a foot and the fraction is added.

d. When the last measurement has been made, the rear tapeman counts his pins, omitting the one sticking in the ground. The length of the course is the sum of the whole tape lengths plus the length of the last measurement. Both tapemen compute and enter the length of the course in their notebooks. The results of their computations are checked one against the other. Then, and not until then, is the last pin pulled from the ground.

264. TAPING ON SLOPING GROUND. a. General. It must be remembered that the distance sought is the horizontal or map distance between the two points. There are two methods of determining horizontal distance along a slope: Measure along the slope and correct this measurement by calculation, known as *slope taping;* or hold the tape horizontally and determine the horizontal distance directly, known as *breaking tape*. The methods of marking points and recording distances in taping on slopes is identical with that of taping on level ground.

b. Slope taping. In this method, the tape lies on the ground and the slope distance is measured. The angle of slope is measured with an instrument. The taped distance multiplied by the cosine of the angle of slope is equal to the horizontal distance. TM 5–236 provides tables which reduce the amount of computation. This method is suitable only for gradual and evenly sloping terrain.

c. Breaking tape (fig. 89). In this method, the head tapeman goes forward the entire length of the tape, dropping the tape approximately on line. He then comes back toward the rear tapeman until he reaches a point at which a fractional part of the tape, when held level, is not above shoulder height. In measuring downhill, the head tapeman suspends a plumb bob from a foot mark and marks this point on the ground with a pin. He keeps his finger at this foot mark until the rear tapeman comes up. In measuring uphill, the rear tapeman holds his point on the tape over the point on the ground by means of a plumb bob, while the head tapeman sets his pin. In both cases, each time the rear tapeman takes over a point from the head tapeman, the rear tapeman gives the head tapeman a pin to replace the one in the ground which represents only a fractional part of the tape length. This exchange continues until a full tape length has been measured, at which time the rear tapeman retains the pin.

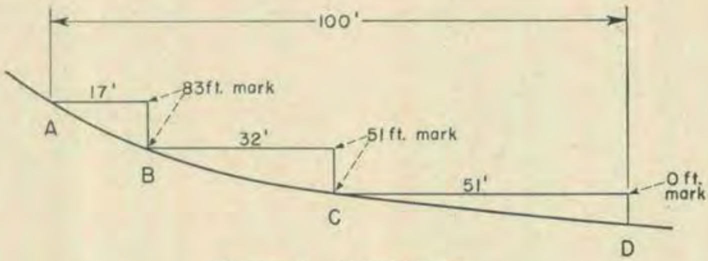


Figure 89. Breaking tape.

265. TRAINING TAPEMEN. Tapemen should be trained carefully. Prescribed methods should be enforced rigidly. Tapemen must exercise constant vigilance to avoid errors. The most common errors are either to fail to record a full tape length or to record an extra tape length. The following are DON'TS for the tapeman:

a. Don't jerk the tape.

b. Don't pull the tape when it is kinked.

c. Don't let vehicles run over the tape.

d. Don't bend the tape sharply around corners.

e. Don't split hairs in lining-in.

f. Don't permit the taping pin to be disturbed.

g. Don't pull the pin until you are sure it will not be needed again.

h. Don't break tape more often than necessary.

i. Don't fail to wipe the tape clean and dry before putting it away.

j. Don't forget that the use of a methodical procedure results in speed and prevents errors.

Section III. AIMING CIRCLE AND BATTERY COMMANDER'S TELESCOPE

266. AIMING CIRCLE. The aiming circle is used in survey to measure horizontal angles, to measure limited vertical angles, and to measure azimuths by magnetic needle.

267. MEASURING HORIZONTAL ANGLES. To obtain accurate measurements of horizontal angles, the spherical bubble must be centered and the following precautions taken:

a. When a setting is made, the last movement of the vertical hair always must be in the same direction, usually clockwise. If the object is overrun, the hair is moved well back of the object and moved up to it again. This procedure eliminates the effect of lost motion.

b. The most accurate horizontal reading is obtained by repeating the measurement three times cumulatively. Readings in excess of three do not increase accuracy with this instrument. For example, the angle between two points, *A* and *B*, is to be measured cumulatively. The scale is set at zero and the instrument is sighted at point *A* with the lower motion. The angle to point *B* then is measured by turning the upper motion (assume a reading of 206 mils). The instrument again is sighted at point *A* with the lower motion, without changing the reading, and the angle to point *B* is measured again (assume a reading of 411 mils). The angle is measured a third time in the same manner (assume a reading of 616 mils). The value of 616 mils is divided by three to give 205 mils.

268. MEASURING VERTICAL ANGLES. The vertical angle to a point is its angle of elevation or depression from the horizontal. To measure vertical angles with the aiming circle, the telescope level bubble is centered by turning the elevation knob, and the angle is read on the reticle. Angles read in this manner are limited by the size of the reticle, which is graduated 85 mils above and below the horizontal. To measure a vertical angle greater than 85 mils, the angle to some prominent feature is noted. The horizontal cross hair then is moved to this feature and the remainder of the angle is read in very much the same manner as a large angle is measured with a pair of field glasses. For reliable work in measuring vertical angles, the aiming circle must be tested for accuracy and its correction constant determined (par. 269).

269. VERIFYING LEVEL LINE OF AIMING CIRCLE. The level line of the instrument may be determined by either of the following methods:

a. If the altitudes of two points and the distance between the points can be determined, the true vertical angle may be computed. The instrument is set up at one of the points and the vertical angle to the other point is measured. To determine the correction constant, subtract the measured angle from the computed angle. The correction constant is applied algebraically to all measured vertical angles. The accuracy of this factor can be increased by using the mean of corrections obtained on a number of points. *Example:* The computed vertical angle from *A* (where the instrument is set up) to *B* is +15 mils. The vertical angle from *A* to *B*, as measured with the instrument, is +12 mils. The correction constant of the instrument is +3 mils which will be added to all vertical angles measured with this instrument.

b. The alternate method, which requires no known altitudes, is as follows: Two stations are established on the ground 75 to 100 yards apart. At each station, a stake with a flat, smooth top surface is driven or a stone with a flat top surface is seated firmly in the ground. The instrument to be calibrated is set up over station 1 and leveled with the objective lens slightly in rear of a pole held in a vertical position resting on the stake or stone. The height of instrument then is marked on the pole at the same height as the center of the objective lens, by determining the radius of the objective lens and applying it in the proper direction to the height determined for the top or bottom of the objective lens. The pole then is taken to station 2 and held vertically on the stone or stake there. The angle of site to the height of instrument mark then is measured with the instrument and noted. Clarity of sighting is improved if the edge of a card or other well-defined straightedge is held horizontally in contact with and just below the pencil mark on the pole. The instrument is set up over station 2 and the entire procedure is repeated.

Caution: The height of instrument as set up at station 2 must be marked on the pole and used as the sighting point when the pole is set up at station 1.

(1) If the algebraic sum of the two angles of site measured equals 0, the instrument is in adjustment and no correction need be applied to readings taken with it; for example—

Site measured at station 1 = +5 ₥
Site measured at station 2 = −5 ₥

Algebraic sum = 0

(2) If the algebraic sum of the two angles of site is other than 0, the instrument is in error by one-half this amount. The sign of the error is the same as the sign of the algebraic sum of the two angles of site. The correction is applied in the opposite direction; for example—

Site measured at station 1 = +5 ₥
Site measured at station 2 = −8 ₥

Algebraic sum = −3 ₥
Error (−3/2) = −1.5 ₥
Correction = +1.5 ₥

The correction is applied to each angle of site read thereafter, unless the instrument contains an angle of site micrometer which can be adjusted to the true setting.

270. CENTERING THE NEEDLE. For precise work, the average of several trials is taken as follows:

a. Set the scales at zero and center the needle with the lower motion.

b. Using the upper motion, bring the line of sighting to some well-defined object and note the scale reading.

c. Repeat the operations three to six times and take the average of the readings.

d. Set this average reading on the scales and sight on the object. The 0–3,200 line of the instrument then will point to magnetic (compass) north.

271. DECLINATION. a. Declination constant. The declination constant of an instrument is the clockwise angle between *Y*-north and magnetic north, that is, the *Y*-azimuth of magnetic north. This constant will vary slightly in any one locality for different instruments and therefore must be recorded on each instrument. The constant also varies in different localities.

b. Declination station.

(1) Declination stations are established to determine the declination constants of instruments. These stations should be utilized periodically within any one locality to correct for local attractions and annual variations. When a unit moves from one locality to another at an appreciable distance, a declination station should be established.

(2) If the declination constants of all instruments of a unit are determined at the same station, the *Y*-azimuth measured with each instrument will be in agreement with the map grid and the *Y*-azimuth measured with all instruments will be in agreement with each other.

c. Determining Y-azimuths. The point chosen for the declination station should afford a view of at least one distant, well-defined point with a known *Y*-azimuth; additional points are desirable as a check. The correct *Y*-azimuths of the distant points may be determined by any of the following methods (the methods are listed in order of preference):

(1) By computing the *Y*-azimuths to the distant points from known coordinates.

(2) By application of the known grid declination for the area to the true azimuths determined by astronomical methods. If the grid declination for the area is not shown in the marginal information on the map, it may be computed by the formula—

Grid declination=Difference in longitude between station and central meridian of grid zone × Sine of the latitude of the station.

(3) By measuring the *Y*-azimuths on a map with a protractor.

d. Procedure when the Y-azimuth to a point is known. Set up the aiming circle over the declination station. Set the scales at zero and center the magnetic needle with the lower motion. With the upper motion, turn to the point of known azimuth and record the reading.

Repeat this process three times and subtract the mean of these readings from the known Y-azimuth (adding 6,400 mils to the Y-azimuth if necessary). The result is the declination constant of the instrument. If more than one point of known Y-azimuth can be seen, readings are made to each point, the computations repeated for each, and the mean of the differences taken as the declination constant.

e. Procedure when the Y-azimuth to a point is unknown. When the Y-azimuth of a distant point cannot be determined by any of the methods in **c** above, the procedure for determining the declination constants is as follows:

(1) Measure the magnetic azimuth to any distant point with each aiming circle in the unit and list these magnetic azimuths opposite the serial number of each aiming circle.

(2) Determine the mean magnetic azimuth measured by all the aiming circles.

(3) Determine the Y-azimuth to the distant point by applying the declination shown on the map to the mean magnetic azimuth determined above.

(4) From this Y-azimuth, subtract the magnetic azimuth measured with each instrument to determine declination constants for the individual instruments. When this method is used to determine declination constants, Y-azimuths measured with all instruments will be in agreement with each other although they may or may not be in agreement with the map grid.

f. Procedure when an aiming circle is to be used in a new locality. If an aiming circle is to be declinated in one locality for use in another locality, follow the procedure below.

(1) The information found on the map of the area where the instrument is to be declinated is shown in sketch *a* of figure 90. From this, the following is determined:

Y-azimuth of magnetic north equals $360° - 11°15'$ or--- (This is the declination constant of an instrument having no error.)	6200 mils
Declination constant of aiming circle determined as in **d** above------------------------------------	6184 mils
Difference in declination of instrument and that shown on map------------------------------------	−16 mils

(2) The information found on the map of the area where the instrument is to be used is shown in sketch *b* of figure 90. From this, it is determined that the Y-azimuth of magnetic north is 6°45′ or 120 mils, which would be the declination constant of an instrument having no instrument error. Therefore, the declination constant of the instrument for the new locality equals 120 mils minus 16 mils, or 104 mils.

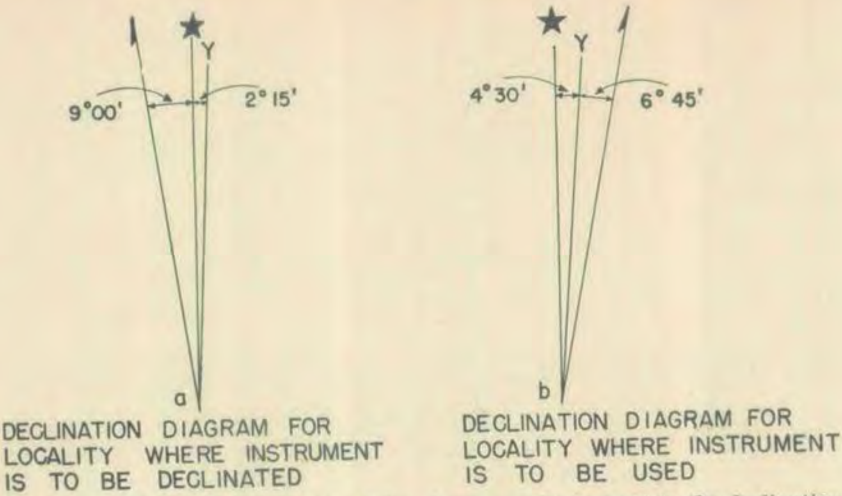


Figure 90. Marginal information taken from map, to be used in the declination of an instrument.

272. LAYING ON A GIVEN Y-AZIMUTH. To lay the 0–3200 line of the aiming circle on *Y*-north, set the declination constant on the scales and, using the lower motion, center the needle. To lay the 0–3200 line of the instrument on a line of designated *Y*-azimuth, subtract this azimuth from the declination constant (with 6400 added when necessary), set the remainder on the scales and, using the lower motion, center the needle.

273. MEASURING Y-AZIMUTH. To measure the *Y*-azimuth to a point, set the declination constant on the scales and, with the lower motion, center the needle. With the upper motion, bring the vertical hair to the point; the reading on the scales is the *Y*-azimuth.

274. BATTERY COMMANDER'S TELESCOPE. The battery commander's telescope is designed primarily for observing field artillery fire. Since it can be used for the measurement to the nearest mil of both horizontal and vertical angles, it may be used in lieu of an aiming circle for survey work, as the methods of employment are similar. The level line of the battery commander's telescope can be verified in the same manner as that of the aiming circle. A correction constant is not carried for vertical angles, since the operator can adjust the angle-of-sight micrometer to the true setting.

Section IV. THE TRANSIT

275. GENERAL. The transit is used in field artillery survey for measuring horizontal and vertical angles, for measuring distances by stadia, and to determine azimuths by solar or stellar observations (TM 5–235).

276. SCALES. The transit has two scales which are used to determine angular measurements. These are the *horizontal scale* and the *vertical scale.*

a. Horizontal scale. The horizontal scale consists of the *main scale* and a *vernier.* The main scale is a complete circle graduated primarily from 0° to 360°, clockwise and counterclockwise. The numbers on the inner set are graduated in a clockwise direction and on the outer set, in a counterclockwise direction. The main scale turns only with the lower motion of the transit. The vernier is an arc, rotating edge to edge with, and inside of, the main scale. The vernier rotates with the telescope.

b. Vertical scale. The vertical scale differs from the horizontal scale in that the main scale is inside the vernier and rotates with the telescope, while the vernier is fixed; the main scale is divided into quadrants of 90° each. The vernier is graduated to read to 1 minute. The scale is read in exactly the same manner as in the horizontal scale of the 1-minute transit.

c. Types. The two transits commonly used in field artillery survey are the 1-minute transit which can be read to 1 minute, and the 20-second transit which can be read to 20 seconds.

277. READING HORIZONTAL SCALE OF 1-MINUTE TRANSIT (fig. 91). The main scale of the 1-minute transit is graduated to 30 minutes, and the vernier to 1 minute. To read the angle when the measurement is complete, read the main scale opposite the index in the center of the vernier. If the index falls between two main scale graduations, the graduation giving the smaller angle is read. In figure 91, the main scale reading (clockwise angle) is 39°30′. The vernier is read by continuing in the same direction as the main scale reading (indicated by the arrow in figure 91). To read the vernier, follow along the scale until a graduation on the vernier is found that coincides with a graduation on the main scale (in figure 91 it is 4′) and add it to the main scale reading. The complete reading in figure 91 is 39°30′ + 4′ = 39°34′. To read the counterclockwise angle, the same procedure is followed. The counterclockwise reading in figure 91 is 320° + 26′ = 320°26′.

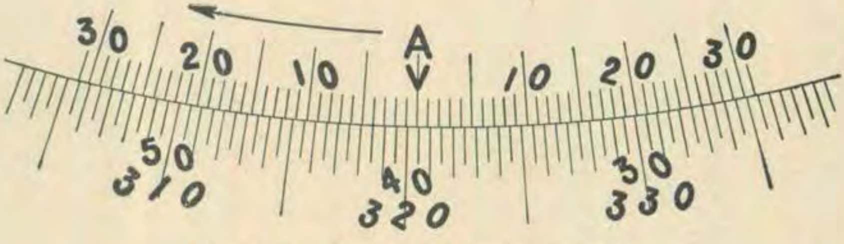


Figure 91. Scales of the 1-minute transit.

278. READING HORIZONTAL SCALE ON 20-SECOND TRANSIT (fig. 92). The main scale of the 20-second transit is graduated to 15 minutes. The vernier is graduated in minutes and each minute is graduated to 20 seconds. The procedure in reading the 20-second transit is the same as in reading the 1-minute transit. The main scale is read opposite the index in the center of the vernier. In figure 92, the clockwise main scale reading is 90°15′. The correct side of the vernier is selected as for the 1-minute transit, the coinciding graduations found and the value read from the vernier. In figure 92, the clockwise vernier reading is 11′40″. The complete clockwise reading for figure 92 is 90°15′+11′40″=90°26′40″. The counterclockwise reading in figure 92 is 269°30′+3′20″=269°33′20″.

Figure 92. Scales of the 20-second transit.

279. SETTING UP THE TRANSIT. **a.** Ordinarily, the transit is set over a sharply defined point, such as a tack in a stake. For centering the transit over the point, a plumb line is suspended from the hook and chain beneath the instrument.

b. To set up the transit, place it approximately over the point and move the tripod legs until the foot plate is nearly level. Pick up the instrument without disturbing the relative positions of the legs and carefully set it over the point, pressing each shoe firmly into the ground until the plumb bob falls within one-half inch or less of the tack and the foot plate is nearly level. Loosen two adjacent leveling screws and shift the instrument laterally until the plumb bob is over the tack.

c. To level the transit, turn the horizontal plate so that each cross-level bubble of the plate is parallel to two diagonally opposite leveling screws. To level, grasp one pair of opposite screws between the thumbs and forefingers and turn so that the thumbs move toward each other or away from each other, thus tightening one screw and loosening the other. Remember that the bubble travels in the same direction as the left thumb. After one bubble has been brought nearly to the center of its tube, the other bubble is centered in a similar manner. Instead of getting one bubble centered exactly, it is better to approximately center each bubble, after which one bubble and then the other may be exactly centered. When both bubbles are exactly centered, rotate the plate 180°. Any error in the plate levels then will be evident. To correct the error, if any, move the bubbles toward the center one-half of the deviation.

280. MEASURING A HORIZONTAL ANGLE. If a horizontal angle, as *AOB*, is to be measured, the transit is set up over *O* as described in the preceding paragraph. The upper motion or plate is clamped and, by means of the upper tangent screw, the vernier is set at 0°. The telescope is sighted approximately to *A* and the lower motion is clamped. By turning the lower tangent screw, the line of sight is set exactly on a range pole or other object marking the point. The upper clamp is loosened and the telescope is rotated until the line of sight is approximately on *B*. The upper clamp is tightened and the line of sight is set exactly on *B* by turning the upper tangent screw. The reading on the horizontal circle and vernier gives the value of the angle. The last motion of the tangent screw should be in a clockwise direction to compress the tangent spring.

281. MEASURING AN ANGLE BY REPETITION. **a.** One feature of a transit is that a horizontal angle may be multiplied mechanically and the product read with the same precision as the single value. Thus, with the 1-minute transit, an angle for which the true value is between the limits 30°00′30″ and 30°01′30″ will be read as 30°01′, the limits of possible error being plus or minus 30″. If the true angle is multiplied (by measuring without resetting to zero) six times on the horizontal circle, the product, likewise read to the nearest minute, might be 180°4′. Its true value then is within the limits 180°03′30″, and 180°04′30″, and the limits of possible error, so far as reading the vernier is concerned, being likewise ±30″. Dividing the observed product (180°04′) by 6, the single value becomes 30°00′40″ for which the limits of possible "reading" error are ± 30″/6 or ± 05″. Although it might appear, from what has been said, that the accuracy with which an angle can be measured by this method varies directly with the number of times the angle is multiplied or repeated, the precision is not appreciably increased by more than six or eight repetitions. This is due to lost motion in the instrument, errors due to setting the line of sight, and other causes. Normally, in field artillery survey, the number of repetitions is limited to two, one with the telescope direct and one with the telescope reversed. This method has several advantages over a single measurement—

(1) It refines the reading as described above.

(2) It removes errors of instrument adjustment.

(3) It affords a check on the first measurement so that gross errors are detected and corrected.

b. To repeat an angle, as *AOB*, the transit is set up at *O*, and the single value of the angle is read, as previously described, and recorded. The vernier setting is left unaltered while the telescope is plunged (rotated 180° in a vertical plane). The instrument then is turned on its lower motion and a second sight is taken to the first point, *A*. The upper clamp is loosened and the telescope again is sighted to *B*. The angle now has been doubled. The double angle is read and divided by two to obtain the correct angle. To detect mistakes, this value is compared with the angle recorded at the completion of the first measurement.

282. MEASURING VERTICAL ANGLES. Vertical angles are measured with the transit as follows: Level the horizontal plate accurately. Sight on the distant point with the telescope direct, and read the vertical angle. Plunge the telescope, rotate the instrument in azimuth 180°, sight on the point, and read the vertical angle again. The mean of the two readings is taken. This procedure will eliminate any error in displacement of the vertical vernier (index error).

283. MEASURING A BEARING WITH THE COMPASS NEEDLE. To measure the bearing of a line, release the compass needle and sight the telescope along the line. The bearing is read on the compass circle opposite the north end of the needle. The bearing is north if the N point on the compass circle is nearer the north end of the needle; the bearing is south if the S point is nearer. The bearing is read from the N point (S point) to the needle. To determine whether the bearing is east or west, continue reading in the same direction to either the E point or the W point. The bearing of *AB* in figure 93 is read N 60° E. The smallest graduation on the compass circle usually is 30 minutes. By careful interpolation, using a magnifying glass, the circle can be read to 10 minutes with a probable error in reading not to exceed ± 5 minutes. To make an accurate reading, the ends of the

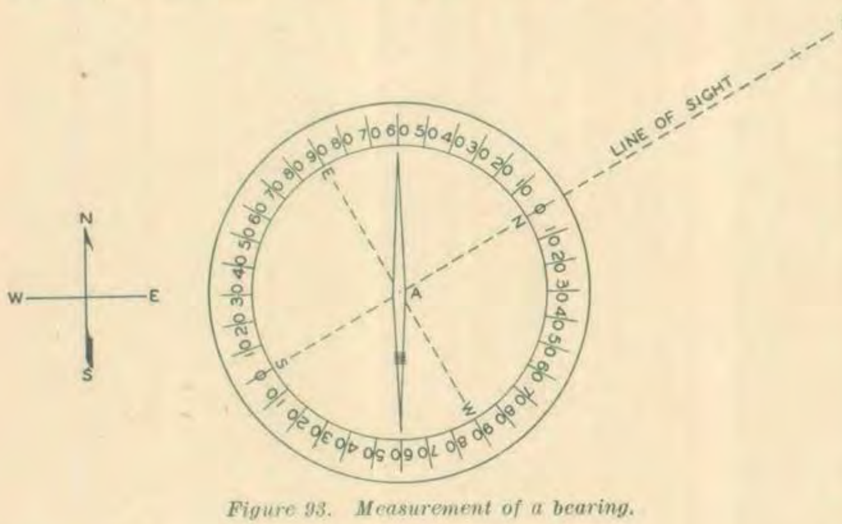


Figure 93. Measurement of a bearing.

needle should be in the same plane as the compass circle, and the eye of the observer should be above the graduations and in line with the needle. If the needle dips perceptibly, its counterweight should be adjusted.

284. DECLINATION OF THE TRANSIT. The declination constant of a transit need not be determined. Instead, the compass circle may be adjusted to read grid bearings directly. This procedure requires a declination station and line of known *Y*-azimuth or bearing. To properly adjust the transit to read grid bearings, set the instrument over the station and sight the telescope along the line of known bearing. Release the needle and turn the compass circle, without disturbing the direction of the telescope, until the known bearing is opposite the north end of the needle. This is done by turning the screw adjacent to the needle release screw. The transit now is adjusted to read grid bearings rather than magnetic bearings.

285. RANGE POLES (A, fig. 94). Range poles usually are 8 or 10 feet long, round or hexagonal in shape, and about 1 inch in diameter. They usually are made of wood and are shod with an iron point; some may be made of steel tubing. They are graduated every six inches with the graduations painted alternately red and white. They are used to mark points on the ground to make them identifiable from a distance.

286. RODS. The type of rod used in artillery survey is called a stadia rod (B, fig. 94). It is used to measure distances by a direct reading with a telescope. It consists of a single or a folding rod approximately 6 inches wide and 12 feet long. The procedure for use of stadia is discussed in paragraph 287. When the stadia rod is used, it is held vertically by a rodman and is plumbed by holding the rod between the finger tips of both hands, the rodman standing behind the rod and facing the instrument.

287. STADIA. Stadia is used for the measurement of distances. The equipment for stadia measurements consists of a telescope with two additional horizontal hairs, called stadia hairs, and a stadia rod. The process of taking a stadia measurement consists in observing through the telescope the apparent locations of the two stadia hairs on the rod which is held vertical. The interval thus determined, called the rod intercept, is a direct function of the distance from the instrument to the rod. The rod intercept, multiplied by 100, is equal to the distance between the instrument and the point on which the stadia rod is placed. Since it usually is not practical to hold the stadia rod perpendicular to the line of sighting, the rod always is held plumb. The resulting intercept is corrected according to the size of the vertical angle, either by stadia reduction tables (TM 5–236) or by stadia slide rule, to obtain both horizontal and vertical distances.

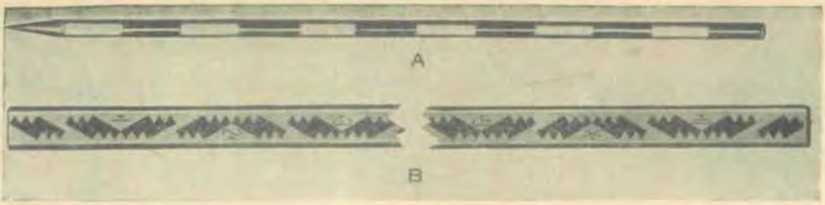


Figure 94. Range pole and stadia rod.

a. Procedure. The procedure for stadia measurement is as follows: The horizontal distance and difference in altitude between two stations (A and B in figure 95) are sought. The rod intercept is determined by setting the lower stadia hair on a foot mark and reading the position of the upper stadia hair. The intercept then is mentally computed. By following this procedure, the computation is made more easily and with less chance of mistake than would be the case if the lower stadia hair were allowed to take a random position on the rod. In reading the vertical angle, the line of sight must be inclined at the same angle as the line connecting the two stations. The horizontal cross hair must be referred to the mark on the rod corresponding to the height of the instrument above station A. The rod intercept is observed with the lower stadia hair on the foot mark that renders a minimum displacement of the horizontal cross hair from the mark to which the vertical angle is to be referred. Thus, if a vertical angle is to be taken with the line of sight cutting the rod at 5.0 feet, and for this position of the horizontal cross hair the lower stadia hair falls at 0.85 foot, the telescope should be rotated vertically until the lower stadia hair is at 1.0 foot, and the horizontal cross hair will fall at 5.15 feet.

b. Example (fig. 95).

	Feet
Reading at upper stadia hair	9.30
Reading at lower stadia hair	1.00
Rod intercept	8.30
Horizontal distance for rod intercept of 1 foot at vertical angle of 8° 30′ as taken from stadia reduction tables	97.82
Multiply by rod intercept	8.30
Horizontal distance from A to B	811.9
Vertical distance for rod intercept of 1 foot at vertical angle of 8° 30′ as taken from stadia reduction tables	14.62
Multiply by rod intercept	8.30
Vertical distance from A to B	121.3

c. Correction (c+f). With some transits, an optical correction $(c+f)$ must be added to the distance determined by stadia. The $c+f$ is recorded in the transit case by the manufacturer and seldom

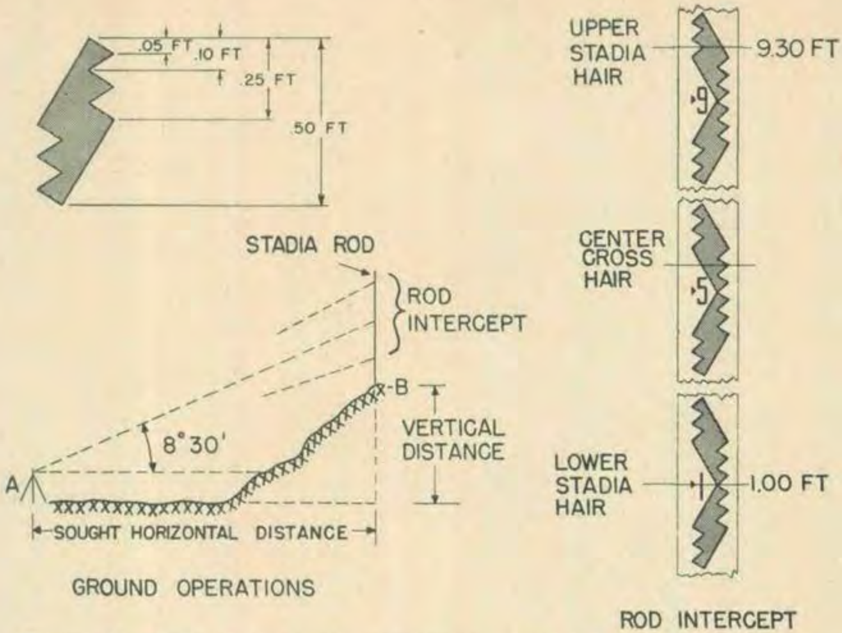


Figure 95. Determining horizontal distance with the transit and stadia.

exceeds 1.5 feet. An explanation of its derivation is given in TM 5–235.

d. Long stadia observations. When the rod intercept is in excess of the length of the rod, the separate half-intervals are observed and their sum taken. Thus, a 12-foot stadia rod theoretically could be observed at a distance of 2,400 feet (all 12 feet observed between the lower stadia hair and center cross hair, and again between the center cross hair and upper stadia hair). Long stadia observations should be avoided because of the difficulty in reading the rod.

Section V. ALTIMETER

288. ALTIMETER. a. General. The altimeter or barometer may be employed for making rough observations for difference in altitude, since the pressure of the earth's atmosphere varies inversely with the altitude. If, at a given altitude, the atmospheric pressure always remained constant, or even approximately so, the barometric method would be one of considerable precision, but the pressure within the course of a day or even in the course of an hour is likely to vary over a considerable range. The altimeter may be employed in field artillery survey to determine relative altitudes when a more accurate method is not practicable.

b. Simultaneous observations. Usually, barometric observations are taken at a fixed station during the same period that observations are made on a second altimeter which is carried from point to point in the field. This makes it possible to correct for atmospheric disturbances which could not be detected readily if a single altimeter were used.

c. Temperature correction. When each reading of the station or field altimeter is recorded, the temperature at the instrument is recorded so that the indicated differences in altitude may be corrected in accordance with the mean of the temperatures at the two instruments.

d. Technical information. For detailed information on the construction and use of the altimeter, see TM 5–9420.

CHAPTER 23

BASIC SURVEY OPERATIONS

Section I. GENERAL

289. GENERAL. Survey is accomplished in three phases—

a. Reconnaissance and planning. In this phase, the survey officer usually makes a tentative plan from a map or photo reconnaissance. The terrain then is inspected to verify the feasibility of the original plan and to make any modifications that are necessary.

b. Measurements or field work. This phase consists of measuring the angles and distances on the ground that are necessary to determine the location of the various points in the survey.

c. Computation and plotting. This phase consists of determining distances, coordinates, base angles, and the plotting of the necessary points on the firing chart. Usually, the coordinates of all points are computed. In rapid surveys, the chart may be built up by a combination of computing and plotting, or by plotting alone. When time is an important consideration and sufficient personnel are available, the computing phase of the survey is carried on simultaneously with the field work. All the field work may be completed before the computing and/or plotting are started.

Section II. MEASUREMENTS

290. TRAVERSE. A *traverse* is a series of straight lines connecting or establishing points along the route of a survey. The points defining the traverse are called *traverse stations*. Distances between traverse stations are determined either by taping or by stadia. At each traverse station, a horizontal angular measurement is taken to establish the direction of each traverse line. In order to obtain the difference in altitude between stations, the vertical angle is measured. If the traverse returns to the starting point or finishes at a point of known location, it is called a *closed traverse;* otherwise it is called an *open traverse*. Traverse stations are numbered consecutively from the point of origin.

291. METHODS OF ANGULAR MEASUREMENT. a. Deflection angles. The angle between a line and the prolongation of the preceding line is called a deflection angle. Thus, in figure 96, if 1–2 is the preceding line, the deflection angle to the line 2–3 is as indicated in the figure. Deflection angles are recorded as either right or left, depending upon whether the line to which measurement is taken lies to the right (clockwise) or to the left (counterclockwise) of the prolongation of the preceding line. Thus, in figure 96, the deflection angle at station 2 is right 22° and at station 3 is left 33°. This method is not applicable to the aiming circle because counterclockwise angles cannot be read with this instrument. When the transit is used, this method is advantageous in that it facilitates the computation of azimuths or bearings.

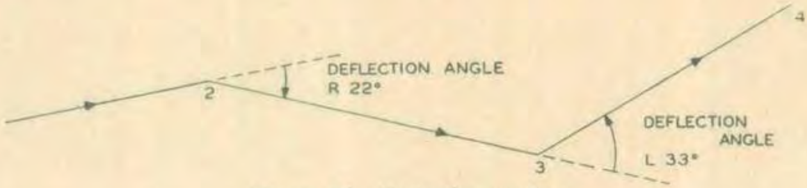


Figure 96. Deflection angles.

b. Clockwise angles. Angles in a traverse may be determined by clockwise measurements from the preceding to the following lines, as illustrated by figure 97. This method may be used either with the aiming circle or with the transit.

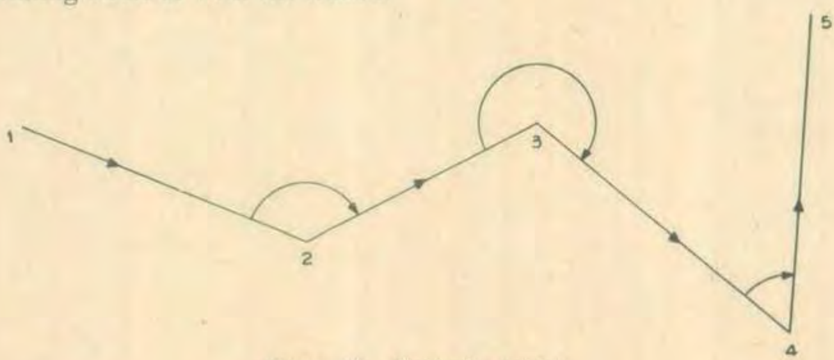


Figure 97. Clockwise angles.

292. THE TRAVERSE PARTY (fig. 98). **a.** Normally, the traverse party consists of six men as follows:

(1) *Chief of party.* The duties of the chief of party are to select the locations of the traverse stations and supervise the work of the rest of the party. The selection of traverse stations requires experience and judgment.

(2) *Instrument man.* The duties of the instrument man are to measure the horizontal and vertical angles at the traverse stations and to record them in the notes.

(3) *Head rodman.* The duties of the head rodman are to drive the stakes at the forward stations and to mark them with a range pole so they may be seen by the instrument man and tapemen. A tack is driven in the top of the stake to mark the exact location of the station. If the stake is driven flush with the ground, a reference stake is driven in the ground at

an angle to slope toward the station. A lumber crayon is used to mark the number of the station on the reference stake or on the tag tied to the reference stake. The range pole is held vertically on the tack by hand or by means of a range pole stand. The instrument man sights at the base of the range pole. Since it sometimes is impossible to see the base of the range pole, the pole must be plumb. The head rodman carries a plumb bob for this purpose.

(4) *Rear rodman.* The duties of the rear rodman are to mark the rear stations with a range pole to enable the instrument man to obtain a backsight. The method of placing the range pole and plumbing it is the same as for the head rodman. The rear rodman picks up his range pole and proceeds to the next station on the signal of the instrument man.

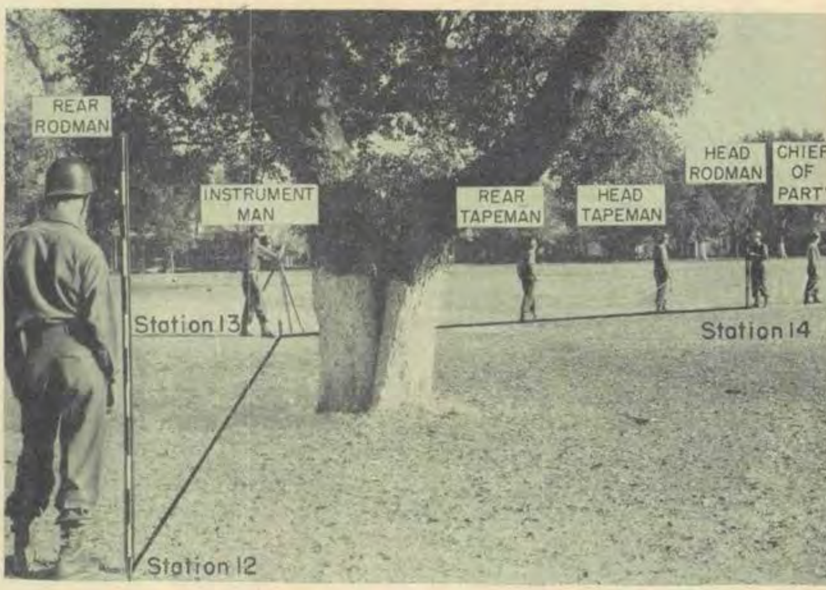


Figure 98. Traverse party.

(5) *Head tapeman.* The duties of the head tapeman are as outlined in paragraphs 263 and 264.

(6) *Rear tapeman.* The duties of the rear tapeman are as outlined in paragraphs 263 and 264.

b. When additional personnel are available, they are added to the traverse party as follows:

(1) *Recorder.* The duties of the recorder are to keep the field notes, entering the angles measured by the instrument man and distances measured by the tapemen.

(2) *Computers.* Either one or two computers are employed to compute the coordinates of the traverse stations as the traverse progresses. It is preferable that two computers be employed, each working independently of the other, their results being verified one against the other.

c. When there are not enough personnel available to form a complete traverse party, duties are redistributed as follows:

(1) *Head rodman.* When there is no head rodman, the chief of party performs his duties.

(2) *Rear rodman.* When there is no rear rodman, the instrument man marks each station as he leaves it with some temporary device as a substitute for a range pole in order that he may obtain a backsight. Such a device might be a piece of paper on a sapling; it must be placed directly over the station.

293. USE OF STADIA (par. 287). The use of stadia for measuring distances will speed up a traverse when there are insufficient personnel available. A traverse is accomplished faster by taping when there are tapemen available, because the use of stadia places an extra burden on the instrument man. Stadia is faster regardless of personnel available when the traverse is run over rough terrain which constantly necessitates breaking tape.

294. TRAVERSE FIELD NOTES. The angles and distances determined during the running of a traverse are recorded in tabular form and may be included on a sketch for clarity. The value of uniformity and clarity in field notes cannot be overstressed. An example of field notes for a deflection-angle traverse using a 20-second transit is shown in figure 99.

a. The column under "station" is used to designate each leg of the traverse by indicating the station at each end of the leg.

b. The column under "angle" is used to enter the deflection angle which established the direction of the leg concerned. The first figure is the initial reading; the second figure is the same angle measured by the second repetition, and the final figure is half the second repetition. The final angle must agree closely with the initial reading.

c. The column under "distance" is used to enter the length of each leg in feet (meters) as measured by the tapemen. If stadia is used, the rod intercept is entered in this column.

d. The column under "vertical angle" is used to enter the vertical angle which establishes difference in altitude for the leg concerned. The first figure is the vertical angle measured with the telescope direct, the second figure is measured with the telescope reversed, and the last figure is the mean of the two.

TRAVERSE
(Deflection Angles)

From Sta. 1 in vicinity of Wolf Creek Bridge to Position Area for 1st Bn

Station	Horizontal Angle			Distance (feet)	Vertical Angle
1-2	R	52-25	40		+2-11
		104-51	00		2-13
	R	52-25	30	524.3	+2-12
2-3	L	10-15	20		-00-07
		20-31	00		00-06
	L	10-15	30	614.7	-00-07
3-4	R	46-10	20		+00-47
		92-19	40		00-49
	R	46-09	50	352.4	+00-48

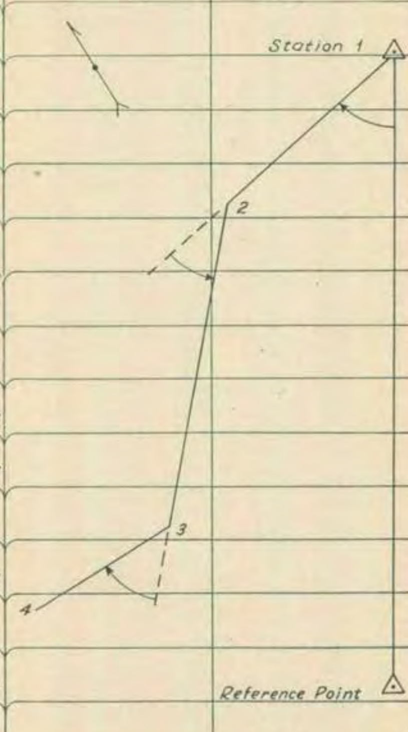


Figure 99. Example of field notes for a deflection-angle traverse.

e. The data necessary to compute coordinates and altitude of each traverse station are found in the three entries of the third line for the leg concerned. These data include the horizontal angle, the distance, and the vertical angle.

f. Figure 100 shows an example of field notes for a clockwise-angle traverse when the aiming circle is used. The method of entering data in the field notes for a clockwise-angle traverse is similar to that for a deflection-angle traverse.

TRAVERSE
(Clockwise Angles)

Station	Horizontal Angle	Distance (Feet)	Vertical Angle
9-20	645		
	1290		
	1936		
	645	521.5	+3
20-21	3728		
	1058		
	4786		
	3729	489.7	+6
21-0	1841		
	3684		
	5525		
	1842	352.0	-10

From Sta 9 at CR 1020 to Btry C

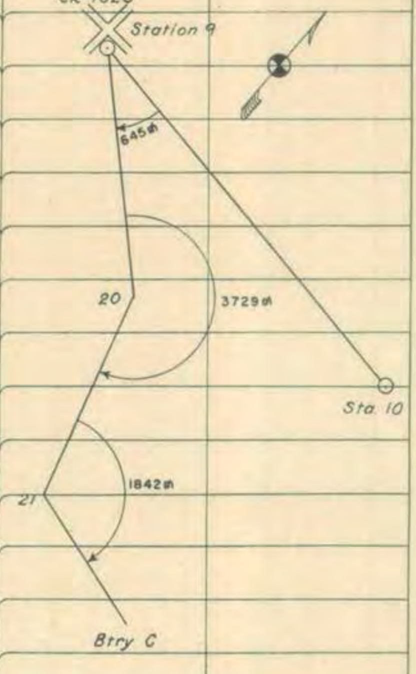


Figure 100. Example of field notes for a clockwise-angle traverse.

295. TRIANGULATION. **a.** When the lines of a survey form triangular figures, where some of the angles and sides are measured and others are computed by trigonometric computations, the operation of making the necessary measurements and computations is called triangulation. The simplest case is that of a single triangle, one of whose sides is of known length. Triangulation avoids the necessity of measuring the length of every line. The length of one line, called a base, is measured. The base forms one side of a triangle and, together with the measured angles of the triangle, is used to compute the length of either or both of the remaining sides. The system is expanded by the addition of more triangles. Only the angles need be measured as the length of at least one side of each triangle may be computed from a previous triangle. It is not necessary that every angle in a triangulation system be measured. If two angles in any triangle are measured, the value of the third can be computed since the sum of the angles in a triangle is equal to 3,200 mils.

b. The vertices of the triangles are called triangulation stations. For the purpose of identification, triangulation stations are lettered as A, B, C, etc., or each station is assigned a name. If possible, the name of a station should have some geographic significance to insure easy recognition. If a triangulation station is referred to as PINE MOUNTAIN, it is obvious to all that it is the one established on Pine Mountain. (See figure 101.)

296. INTERSECTIONS. The location of an unknown point can be established by means of the intersection of rays sighted from two or more occupied points of known location. The known points are occupied with transit or aiming circle, and angles or directions are observed. From these, the azimuths of the lines and the position of their inter-

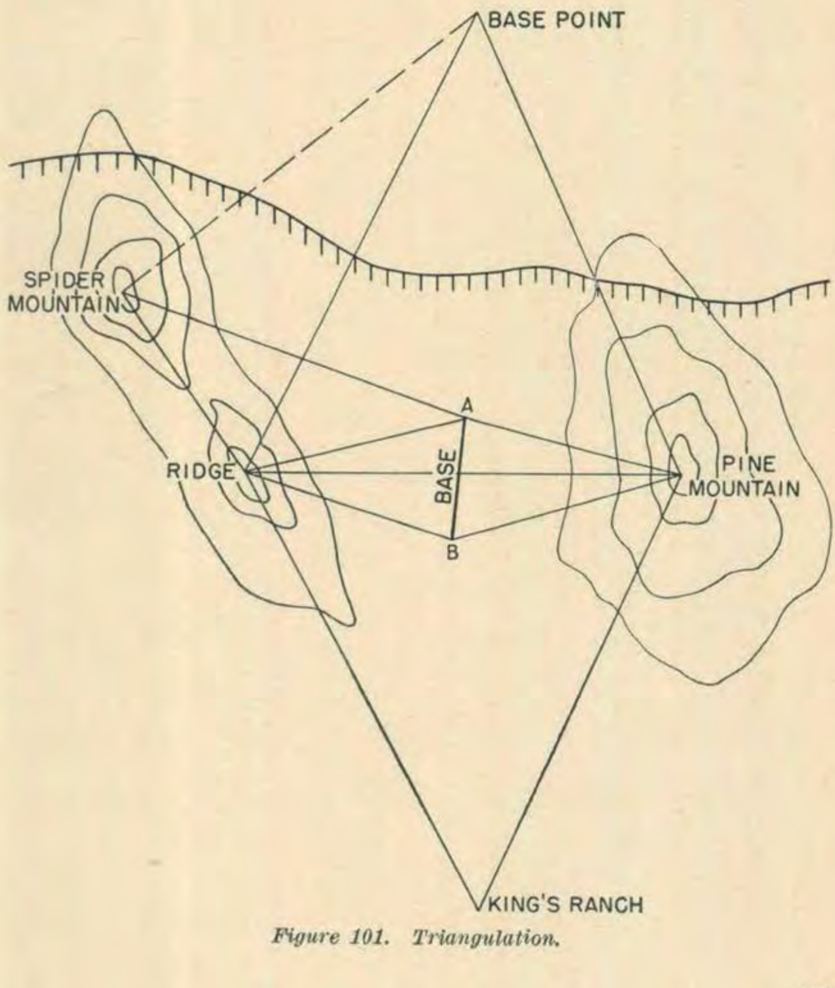


Figure 101. Triangulation.

section may be computed. Actually, intersection and triangulation are alike in that both are methods of determining distance and position by solving triangles. The term "intersection" is applied more generally to the location of points not occupied by the survey party, such as points in the target area.

297. TRIGONOMETRIC LEVELING. Trigonometric leveling is the determination of altitudes by the solution of right triangles which include the measured vertical angles. This method is used in field artillery survey for altitude determination in both triangulation and traverse work. In figure 102, *A* represents a point of known altitude and *B*, a point whose altitude is desired. In trigonometric leveling, the vertical angle at *A* is measured and the distance *AB′* is determined by survey or by measurement on a map or photo. Then the difference in altitude (*h*) is equal to the horizontal distance multiplied by the tangent of the vertical angle. If the mil relation is used, the difference in altitude in any units is equal to the horizontal distance in thousands of similar units multiplied by the vertical angle in mils. The mil relation should not be employed except in surveys of low precision.

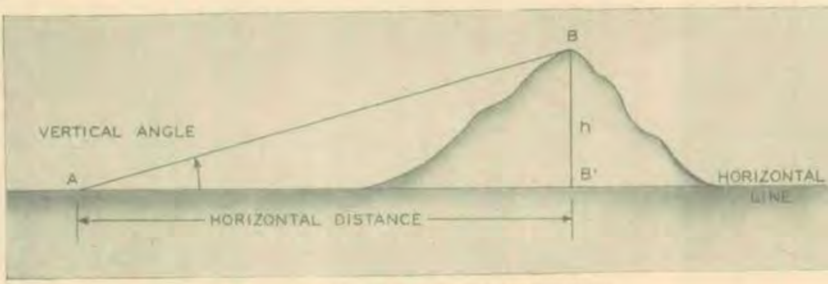


Figure 102. Trigonometric leveling.

298. GRAPHIC INTERSECTION (fig. 103). **a.** When speed is required, it sometimes is desirable to locate points on the chart by the intersection of plotted direction lines (rays) from two or more previously plotted points. The directions of these lines are determined at the known points with an aiming circle; the lines then are plotted on the chart with a protractor. In graphic intersection, it is of the greatest importance that the angle at which the rays intersect be large enough so that a slight error in direction of one of the rays will not move the position of the intersection an appreciable distance. For field artillery units other than observation battalions, 500 mils is considered the minimum angle of intersection at which accurate results may be achieved. Since observation battalions are equipped with more accurate plotting equipment and usually have more intersecting rays for any given point, they can achieve accurate results with smaller angles of intersection.

b. The graphic method has the advantage of being simpler and faster than the solution of the triangles by computation. The results obtained, however, are less accurate.

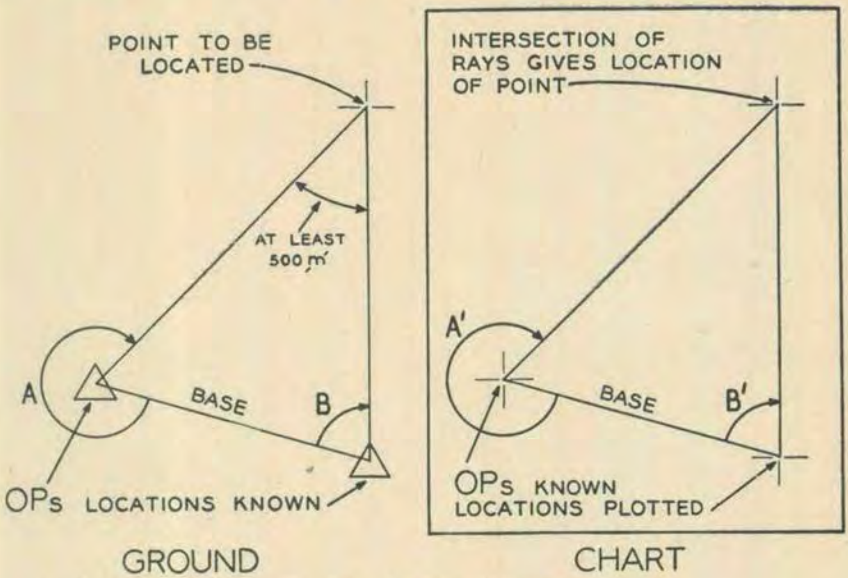


Figure 103. Graphic intersection.

299. RESECTION. Resection is the process of determining the location of a station occupied by the instrument by means of sights taken toward points whose locations already are known. Methods of resection are as follows:

a. Tracing paper method (fig. 104). The tracing paper method requires three (preferably four or five) distant visible points *A*, *B*, and *C* located on the chart as *a*, *b*, and *c*. The aiming circle is set at station *P*. The angles between the distant points are measured with the aiming circle, and plotted on transparent paper; point *P* is any convenient point on the paper. The rays going to *A*, *B*, and *C* are marked for identification. The transparent paper is placed over the chart, and

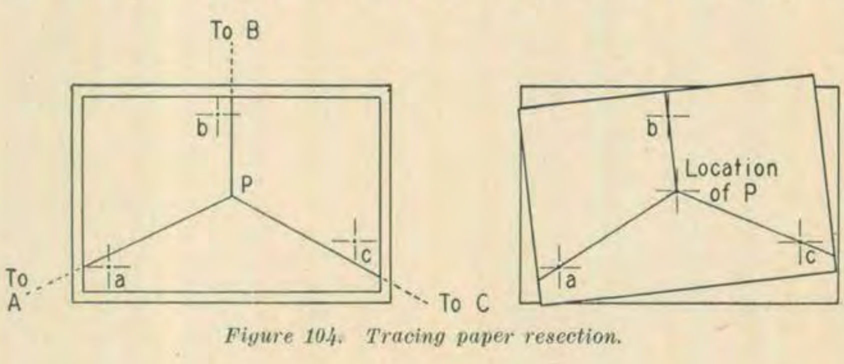


Figure 104. Tracing paper resection.

moved until each ray passes through the chart location of its respective point. The chart location of the point P then is pricked through the tracing paper at the intersection of the rays.

b. Back-azimuth method (fig. 105). The back-azimuth method requires an accurately declinated angle-measuring instrument and two (preferably three) visible points located on the chart. The rays from these points through the occupied station should intersect at angles large enough to give a reasonable intersection. The instrument is set up at the point to be located and the Y-azimuth to each of the distant points is measured. The back azimuth is found by adding (or subtracting) 3,200 mils to each Y-azimuth. Through each plotted point, a ray is drawn with the proper back azimuth. The intersection of the rays is the chart location of the occupied point.

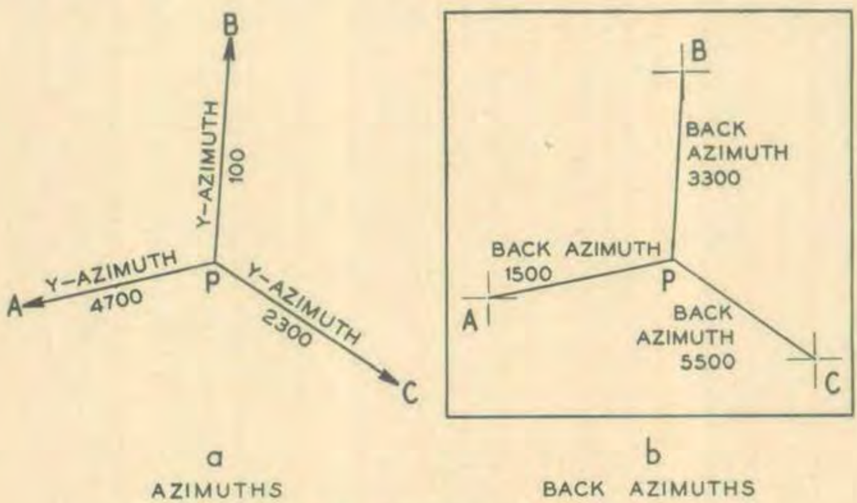


Figure 105. Back-azimuth resection.

c. Computed three-point resection. A more accurate method of resection when three known points are visible is to measure the angles between the points and compute the coordinates of the instrument station.

(1) *Construction.* In figure 106, P is the observer's position which is to be determined. A, B, and C are the three known points from left to right as viewed from P. The angles, which are measured APB and BPC, are called angles 1 and 2, respectively. The circle in both figures is constructed so that it passes through the points A, P, and C. The line BP, extended, cuts the circle at I. All situations will fall in one that it passes through the points A, P, and C. The line BP, of the two categories: *Case 1*, where P is within the triangle ABC; and *case 2*, where P is outside the triangle ABC. The

solution is indeterminate when P lies on or near the circumference of a circle which passes through A, B, and C. This condition is evidenced when the sum of angles ABC, 1, and 2, is equal to 180°.

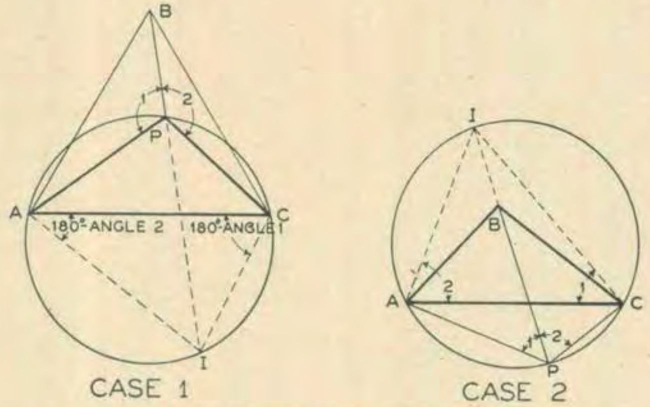


Figure 106. Computed three-point resection.

(2) *Computation.* (See TM 5–235 for a form for computation.)

(*a*) Determine the value of angles ACI and CAI.

1. Case 1. The angle ACI is equal to angle API because both angles subtend the arc AI. Angle API is equal to 180° minus angle 1; therefore, angle ACI also is equal to 180° minus angle 1. In a similar manner, it may be shown that angle CAI is equal to 180° minus angle 2.

2. Case 2. The angle ACI is equal to angle 1 because both angles are on the circumference of the circle and subtend the arc AI. Similarly, angle CAI is equal to angle 2.

3. From this point forward, the solution of case 1 and case 2 is identical. (See pars. 305 and 310 for solution of triangles.)

(*b*) Knowing the coordinates of A and C, compute the length and azimuth of AC.

(*c*) Determine the length of line AI. This is done by solving the triangle AIC, the known elements of the triangle being the side AC and the angles ACI and CAI.

(*d*) Determine the azimuth of the line AI. This is done by applying the angle CAI to the known azimuth of the line AC.

(*e*) Compute the coordinates of I, using the length and azimuth of AI.

(*f*) Compute the azimuth of the line IB (IP). Knowing the coordinates of I and the coordinates of B, the azimuth of the line connecting the two points may be computed.

(*g*) Determine the value of the angle *AIP*. This is done by comparing the azimuth of *AI* with the azimuth of *IB* (*IP*).

(*h*) Determine the length of the line *IP*. This is accomplished by solving the triangle *AIP*, the known elements of the triangle being the side *AI* and the angles *AIP* and *API*.

(*i*) Compute the coordinates of *P*, using the length and azimuth of the line *IP*.

(*j*) Check the computations. This is done as follows: Knowing the coordinates of *P* and the coordinates of *C*, compute the azimuth of the line *PC*. Compare the azimuth of *PC* with the azimuth of *BP* to deduce the value of angle 2. If this value agrees with the observed angle 2, the computations for the coordinates of *P* are correct.

d. Use of astronomic azimuths in resection.

(1) An accurate method which requires only two fixed points (fig. 107) is to observe, from the point to be resected, the astronomic azimuth to one fixed point and the angle between the two points. In this triangle, one side is known and all angles can be computed, making it possible to compute the coordinates of the instrument station. The grid declination must be considered. (See par. 302**g**.)

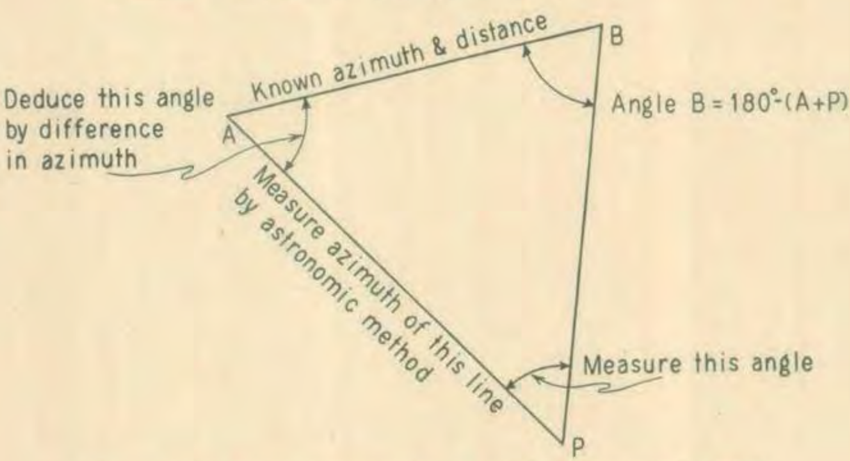


Figure 107. Two-point resection, using an astronomic azimuth.

(2) Another method is resection from a single point. It is possible to obtain an accurate resection when only one known point is visible. Such a resection requires the measurement of an astronomic azimuth and the establishment of a base (fig. 108). The coordinates of *P* are to be determined while the coordinates of the distant point, *A*, are known. A base is taped from *P* to *Q*, a point from which *A* also is visible. The distance *PA* is determined by triangulation and the azi-

muth PA is measured by astronomic methods. The grid declination must be considered. Knowing the coordinates of A and the distance and azimuth to P, the coordinates of P may be computed.

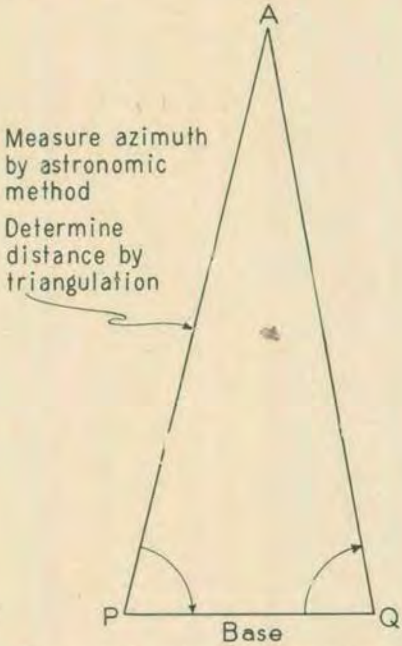


Figure 108. One-point resection using an astronomic azimuth.

(3) It must be remembered that the use of astronomic azimuths in resection problems is not possible when the coordinates of the known points are based on an assumed azimuth. If the coordinates of the known points are based on correct azimuths, the above method may be used to good advantage, greatly increasing the versatility of the field artillery surveyor. The precision of these methods meets the 1/2000 standard required of precise artillery surveys.

300. AZIMUTHS AND BEARINGS COMPARED. **a.** The Y-azimuth (grid azimuth) of a given line is the clockwise angle from grid north to that line.

b. The grid bearing of a given line is the angle and direction which the line makes with respect to grid north or grid south. Bearings are stated by quadrants and never exceed 1,600 mils or 90°. Figure 109 shows the relation between azimuths and bearings.

c. Azimuths and bearings may be expressed as grid, true, or magnetic. Usually, however, azimuths and bearings are expressed in terms of grid (Y) directions for field artillery survey to facilitate determination of grid coordinates. The back azimuth of a line is the azimuth of the line ±3,200 mils, while the opposite bearing of a line has the same angular value as the bearing with north exchanged for south and east exchanged for west. Azimuths always are used in field artillery survey when the results are to be plotted. When the results are to be computed, bearings should be used, as this greatly facilitates the computation of coordinates. The azimuth of each line first is determined and then converted to a bearing for the purpose of computing coordinates.

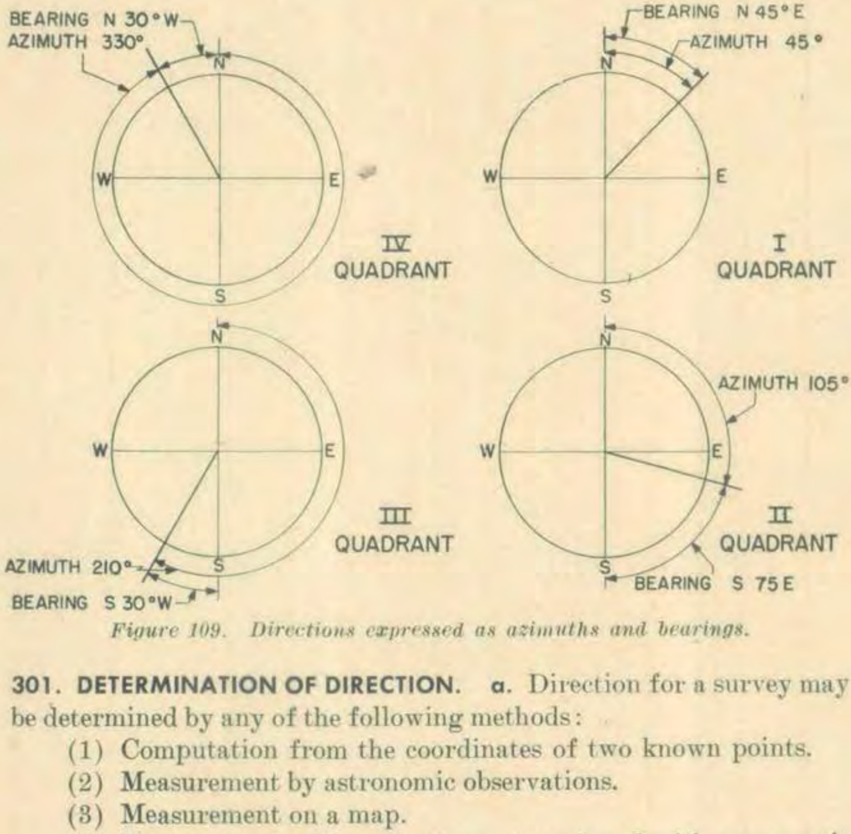


Figure 109. Directions expressed as azimuths and bearings.

301. DETERMINATION OF DIRECTION. **a.** Direction for a survey may be determined by any of the following methods:

(1) Computation from the coordinates of two known points.

(2) Measurement by astronomic observations.

(3) Measurement on a map.

(4) Measurement with an instrument equipped with a magnetic needle.

b. If direction cannot be determined by any of the above methods, it may be assumed. Usually, it is possible to get an approximate direction with a compass needle.

c. Direction taken from the coordinates of known points or by astronomic observations are the most reliable. The reliability of direction measured on a map is limited by the accuracy with which the points were plotted on the map and the distance between the points. As the distance between the points increases, the directional error intro-

One hair is set slightly in advance of the edge of the sun and becomes tangent by the sun's own motion while the other hair is kept tangent by turning the tangent screws.

c. Three factors must be known to compute the azimuth of the sun or a star by this method—

(1) *Vertical angle* (as described above). This angle, as measured, must be corrected slightly for refraction and parallax. (See app. VIII, table 1.)

(2) *Declination of sun* (*star*). The declination is the angle measured from the celestial Equator to the sun (star) and corresponds to latitude measured on the earth's surface. The sun's declination is changing constantly and varies from 23°27′ north in June to 23°27′ south in December. The declination of the sun at any instant may be found in appendix VIII, table 2. The declinations of the important stars, along with charts for finding these stars, may be found in section I and table 3 of appendix VIII.

(3) *Latitude of observer.* The latitude may be taken from any reliable map. It is not necessary to know the exact location, as an error of one mile in location will cause an error in latitude of less than one minute.

d. The following formula may be used to find the azimuth, east or west of north, of the sun (star), given the latitude of the observer, the declination and altitude of the sun (star).

$$\text{Tan } \tfrac{1}{2} A = \sqrt{\frac{\sin (s-h) \sin (s-L)}{\cos s \cos (s-p)}}$$

L = latitude of observer

h = observed altitude after applying corrections for parallax and refraction

p=polar distance of the sun (star) $=90°-d$ (declination)

(*Note.*—The polar distance is the angle from the North Pole to sun (star) when the observer is north of the Equator and the angle from the South Pole when the observer is south of the Equator.)

$s=\tfrac{1}{2}(h+L+p)$

A=azimuth angle; the smaller of the horizontal angles from north (south in the Southern Hemisphere) to the sun (star)

(1) When the observer is in the Northern Hemisphere, the azimuth angle is computed from north; when the observer is in the Southern Hemisphere, the azimuth angle is computed from south.

(2) When the sun (star) is ascending, the azimuth angle is toward the east; when the sun (star) is descending, the azimuth angle is toward the west.

(3) For the purpose of computing p, when the sun (star) is on the same side of the Equator as the observer, the declination is plus; if the sun (star) is on the opposite side of the Equator from the observer, the declination is minus.

duced by inaccuracies in plotting is reduced. The use of an assumed direction or one determined by compass needle is undesirable for the following reasons:

(1) There can be no check in direction without returning to the starting point.

(2) Direction established by one unit will not agree with direction established by other units.

(3) Conversion from assumed to common control will be complicated (par. 352).

(4) Use of astronomic azimuths in resection problems will be impossible (par. 299).

If it is at all possible, it is desirable that direction for all surveys be based on correct azimuths. Direction should be taken from the coordinates of known points if they are available. If not, direction can be determined by astronomic observations.

302. AZIMUTH BY ASTRONOMIC METHODS. a. There are many techniques for the determination of azimuth by the use of sights taken to stars or to the sun. The most widely used technique is the *altitude method* wherein the *true azimuth* of any star (or the sun) at any instant is a function of its vertical angle. The field work consists of measuring the horizontal angle *from* the line whose azimuth is desired *to* the star, and the vertical angle to the star. Having measured the vertical angle, the azimuth of the star may be computed. The horizontal angle then is applied to the azimuth of the star to determine the azimuth of the line. See TM 5-235 and DA AGO Form 6-11 for additional information and procedure for making observations.

b. When the sun is used, it is impossible to sight on the sun's center because of its size. Therefore, a sighting is made with the sun tangent to both cross hairs, and the horizontal and vertical angles are recorded. Another sighting then is made with the sun again tangent to the cross hairs but in the opposite quadrant (fig. 110). The position of the sun's center is established by the mean of the two readings for both vertical and horizontal angles. It is extremely difficult to make both hairs tangent to the sun simultaneously by turning both tangent screws.

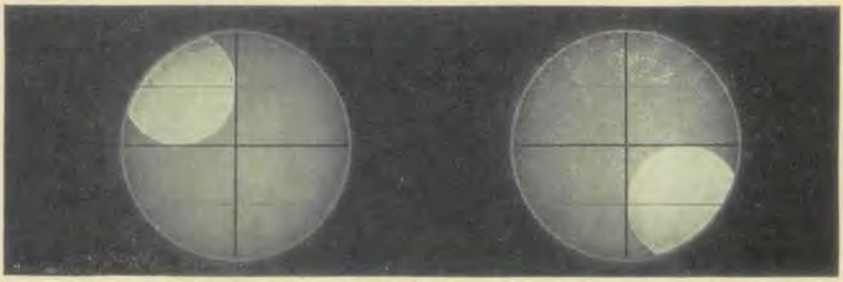


Figure 110. Position of cross hairs when sighting to the sun.

Declination 0 hours Greenwich ________________ S 6°25.9′
Change per hour is +.95′
Declination correction for 1900 hour is ______ $19 \times .95 = +18.1'$
Declination 1900 hours ________________ S 6°44.0′
The declination is minus since the observer is on the opposite side of the Equator from the sun.

(6) Polar distance (p): The value of p is the algebraic difference between 90° and the declination; that is—
$p = 90° - (-6°44.0') = 96°44.0'$

(7) Solution of equation:
$s = \frac{1}{2}(h+L+p) = \frac{1}{2}(34°11.7' + 41°05' + 96°44.0') = 86°00.4'$
$s - L = 86°00.4' - 41°05' = 44°55.4'$
$s - h = 86°00.4' - 34°11.7' = 51°48.7'$
$s - p = 86°00.4' - 96°44.0' = 10°43.6'$
(Arithmetic difference is used regardless of sign.)

(a) Substituting the above values in the equation in **d** above—

$$\text{Tan } \tfrac{1}{2} A = \sqrt{\frac{\sin 51°48.7' \times \sin 44°55.4'}{\cos 86°00.4' \times \cos 10°43.6'}}$$

(b) Logarithmic solution:

Log sin 51°48.7′ = 9.89541	Log cos 86°00.4′ = 8.84286
Log sin 44°55.4′ = 9.84890	Log cos 10°43.5′ = 9.99234
9.74431	8.83520
−8.83520	

$\text{Log tan } \frac{1}{2} A = 2 \overline{).90911}$ (divide by 2 to extract square root)
$.45456$
$\frac{1}{2} A = 70°39.2'$
$A = 141°18.4'$

Since the observation was made in the Northern Hemisphere while the sun was descending, the direction of the sun was 141°18.4′ west of north.

(8) Azimuth of the reference line: The true azimuth of the line is $360° - (122°16.0' + 141°18.4') = 96°25.6'$

f. In the following example, azimuth is determined by stellar observation (fig 112).

(1) Time of observation: July 1949 on star Vega.
(2) Latitude of observer: 30°32′ north.
(3) Temperature: 60° F.
(4) Measurements:

Horizontal angle, line to star	*Vertical angle of star*
230°50′00″	42° 10′
Parallax and refraction correction −1.1′ (app. VIII, table 1), use ________________	−1′
Corrected vertical angle ________________	42° 09′

(5) Star declination: 38°44′ north (from app. VIII, table 3).

e. In the following example, azimuth is determined by solar observation (fig. 111).

(1) Time of observation: 1400 hours Eastern Standard Time, 10 October 1949.

(2) Latitude of observer: 41°05′ north.

(3) Temperature: 40° F.

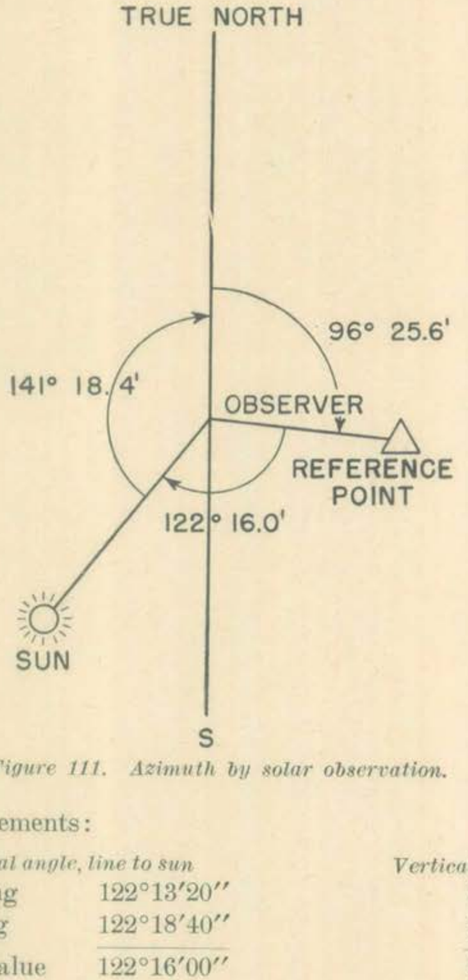


Figure 111. Azimuth by solar observation.

(4) Measurements:

	Horizontal angle, line to sun	*Vertical angle of sun*
1st reading	122°13′20″	34°17′
2d reading	122°18′40″	34°09′
Mean value	122°16′00″	34°13′
Parallax and refraction correction (app. VIII, table I)		−1.3′
Corrected vertical angle		34°11.7′

(5) Sun's declination: Eastern Standard Time is 5 hours behind Greenwich Time. Therefore, the Greenwich time of observation is 1900 hours (time of observation plus 5 hours). From appendix VIII, table 2, the following is obtained:

$\text{Log tan } \frac{1}{2}A = 9.79172$

$\frac{1}{2}A = 31° 45.6'$

$A = 63° 31.2'$

Since the observation was made in the Northern Hemisphere while the star was ascending, the azimuth of the star is 63° 31.2′.

(8) Azimuth of the reference line: The true azimuth of the line is $63° 31.2' + 360° - 230° 50' = 192° 41.2'$.

g. A formula, using the factors discussed in **c** above, that may be used to compute the *true direction* of the sun (star) is—

$$\text{Cos } B = \frac{\sin d}{\cos h \cos L} - \tan h \tan L$$

B=true direction, either east or west of true north

d=declination

The same rules as in ***d*** above, apply to this formula with the following additions:

(1) When the sun (star) is on the opposite side of the Equator from the observer, the declination is minus; therefore, the expression $\frac{\sin d}{\cos h \cos L}$ becomes minus.

(2) When cosine B is minus, the direction has the same numerical value but is taken from the opposite end of the north-south line. To obtain the *grid direction*, the grid declination, as found on the map or computed by the formula in paragraph 271, must be applied.

h. The formula used in solving the above examples is based on a solution of the astronomical triangle. This is a spherical triangle which includes three points on the celestial sphere: The observer's zenith, the celestial pole, and the sun or the star. When the sun or star is near the meridian, the three points are close to alinement which makes the astronomical triangle long and thin, and the solution weak. It is advisable to avoid observations when the sun or star is near the meridian. This eliminates the star Polaris for use with this method, as Polaris is always close to the meridian. It is advisable to avoid observations when the sun or star is within 10° of the horizon, because when the vertical angle is small, refraction becomes excessive and unpredictable. Greater accuracy will be obtained if the vertical angle to the sun (star) is between 20° and 45°.

303. TRANSMISSION OF DIRECTION. Direction may be transmitted by—

a. Measurement of angles on the ground. If the direction of any line in the survey is known, the direction of other lines may be computed from the angles measured on the ground. When a traverse is run for the sole purpose of carrying direction, it is called a direction traverse.

(6) Polar distance (p): The value of p is equal to 90°−declination of the star.

$p=90°-38°44'=51°16'$

(7) Solution of equation:

$s=\frac{1}{2}(42°09'+30°32'+51°16')=61°58.5'$

$s-L=61°58.5'-30°32'=31°26.5'$

$s-h=61°58.5'-42°09'=19°49.5'$

$s-p=61°58.5'-51°16'=10°42.5'$

(*a*) Substituting the above values in the equation in **d** above—

$$\text{Tan } \tfrac{1}{2} A=\sqrt{\frac{\sin 19°49.5' \times \sin 31°26.5'}{\cos 61°58.5' \times \cos 10°42.5'}}$$

(*b*) Logarithmic solution:

Log sin 19°49.5'	=9. 53039	Log cos 61°58.5'	=9. 67196
Log sin 31°26.5'	=9. 71737	Log cos 10°42.5'	=9. 99237
	9. 24776		9. 66433
	−9. 66433		
	2 | 19.58343	(divide by 2 to extract square root)	

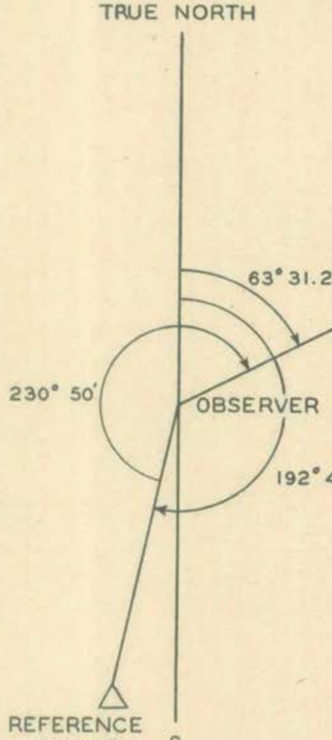


Figure 112. Azimuth by stellar observation.

b. Measurement of angles on a chart. Once a line has been plotted on a chart, its direction may be measured relative to a grid line or any other line of known direction plotted on the chart.

c. Establishing relative directions by astronomic observations. These relative directions are established in either of the following ways:

(1) By determining the true azimuths of the lines whose directions are desired (par. 302).

(2) By simultaneous observations on any celestial body. The advantage of simultaneous observations is that no computations are required. Its disadvantage is the prearrangement necessary to insure that all observations are made at the same time. As a check against mistakes and to insure satisfactory results if one observation fails, the simultaneous observations should be repeated at another time. *Example* (fig. 113): The azimuth of the line *AB* has been determined to be 5825 mils. The azimuth of *CD* is desired. Simultaneous readings are taken on the star Sirius from points *A* and *C*, with results as shown, establishing the relative direction of the two lines. The azimuth of *CD* now can be computed: 5825₥—1080₥=4745₥.)

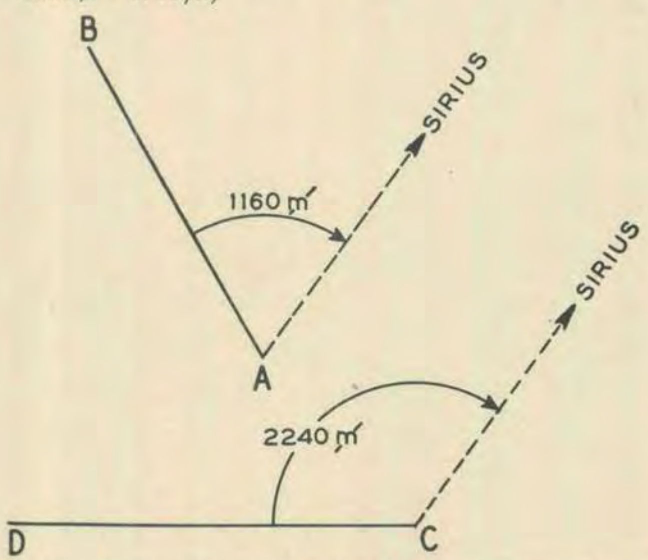


Figure 113. Transmission of direction by simultaneous observations.

Section III. COMPUTATIONS

304. TRAVERSE COMPUTATIONS. The length, bearing, and vertical angles of each traverse leg having been determined by field measurements, the next step is to compute the coordinates and altitudes of the traverse stations.

305. COMPUTATION OF COORDINATES. The computation of coordinates requires a knowledge of the solution of a right triangle by trigonometric functions (fig. 114).

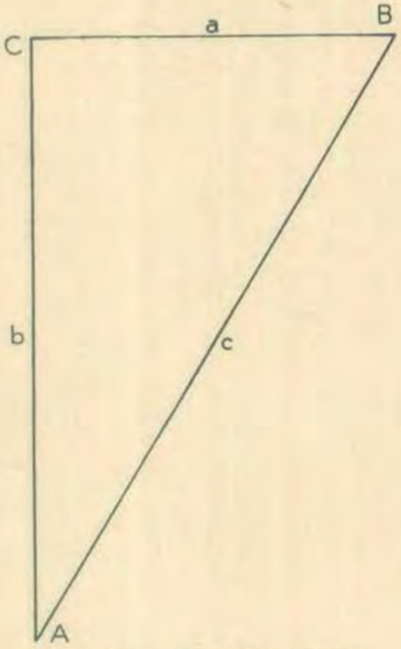


Figure 114. The right triangle.

a. Definitions.

(1) The *hypotenuse* of a right triangle is the side of the triangle opposite the right angle. In figure 114, it is the side c.

(2) The *side opposite* for either of the acute angles is the side of the triangle which is opposite that angle. The side opposite for the angle A is side a. The side opposite for angle B is side b.

(3) The *side adjacent* for either of the acute angles is the side of the triangle other than the hypotenuse which is adjacent to that angle. The side adjacent for angle A is the side b. The side adjacent for the angle B is the side a.

(4) The *sine* of an angle is the ratio of the side opposite to the hypotenuse. For angle A, the sine is a/c. For any given angle, the sine is constant and may be found opposite that angle in a table of natural trigonometric functions.

(5) The *cosine* of an angle is the ratio of the side adjacent to the hypotenuse. For angle A, the cosine is b/c. The cosine of any angle also may be found in a table of natural trigonometric functions.

(6) The *tangent* of an angle is the ratio of the side opposite to the side adjacent. For angle A, the tangent is a/b. The tangent of any angle also is found in a table of natural trigonometric functions.

(7) The value of dx for any line is the difference in X-coordinates between the ends of the line (fig. 115).

(8) The value of dy for any line is the difference in Y-coordinates between the ends of the line.

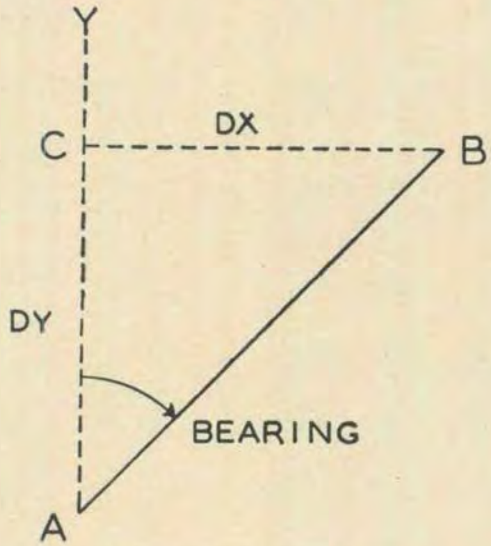


Figure 115. Computation of dx and dy.

b. Formulas. From the above definitions, it is seen that if the length and bearing of the line AB are known, the values of dx and dy may be computed by the use of trigonometric functions, and are obtained by use of the following formulas:

$$\sin A = \frac{\text{side opposite}}{\text{hypotenuse}}$$

$$\sin \text{bearing} = \frac{dx}{AB}$$

$$dx = AB \sin \text{bearing}$$

$$\cos A = \frac{\text{side adjacent}}{\text{hypotenuse}}$$

$$\cos \text{bearing} = \frac{dy}{AB}$$

$$dy = AB \cos \text{bearing}$$

It should be remembered that dx always is equal to the length of the leg multiplied by the sine of the bearing and dy always is equal to the length of the leg multiplied by the cosine of the bearing.

c. Coordinates. Having computed the values of dx and dy, these values must be applied to the coordinates of A to determine the coordinates of B. When the bearing of the traverse leg is east, dx is added; when the bearing is west, dx is subtracted. When the bearing is north, dy is added; when the bearing is south, dy is subtracted. In figure 115, the bearing of the line AB is north and east; therefore, both dx and dy are added to the coordinates of A to determine the coordinates of B.

d. Use of logarithms. In the above discussion, dx and dy are computed by multiplying the distance by the sine and cosine of the bearing. When logarithms are used, the log of dx is found by adding the *log sin* of the bearing to the log of the distance. The value of dx then is found in the logarithm tables. The value of dy is obtained in a similar manner using the *log cos* of the bearing. The log sin is the logarithm of the sine of the angle and may be found directly in the table of logarithms of functions of angles without recourse to a table of natural functions.

e. Use of the military slide rule. The values of dx and dy may be computed on the military slide rule with a single setting of the slide (TM 6–240). The slide rule should be used only when the precision required is 1/500 or less. It is useful as a rapid check on logarithmic computations.

306. COMPUTATION OF ALTITUDES. a. By trigonometry. The computation of altitudes by trigonometry requires a further knowledge of the solution of a right triangle by trigonometric functions.

(1) *Tangent functions.* The tangent of an angle is defined as the side opposite divided by the side adjacent. In figure 114, the tangent of A is a/b. The value of dz for any line is the difference in altitude between the ends of the line (fig. 116).

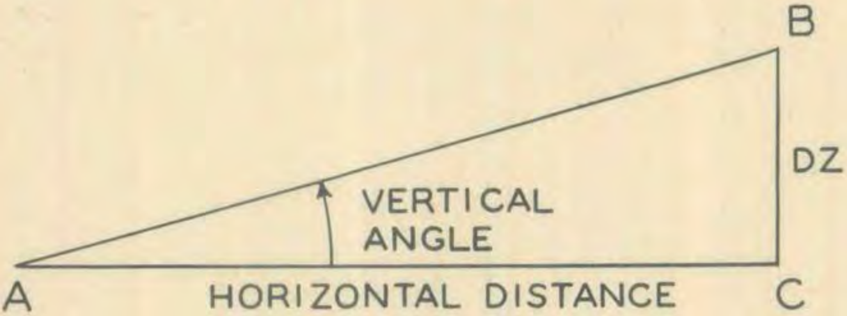


Figure 116. Computation of dz.

(2) Examination of the profile diagram (fig. 116) shows that if the horizontal distance and the vertical angle are known, dz may be computed by the following formula:

$$\text{tan vertical angle} = \frac{dz}{\text{horizontal distance}}$$

$$dz = \text{horizontal distance} \times \text{tan vertical angle.}$$

(3) The value of dz always is equal to the horizontal distance multiplied by the tangent of the vertical angle. Having computed the value of dz, it must be applied to the altitude of A to determine the altitude of B. If the vertical angle is positive, dz is added; if the vertical angle is negative, dz is subtracted.

b. By mil relation. When the aiming circle is used to measure the traverse angles, the angles will be expressed in mils; hence, the mil relation may be used to compute dz for each traverse leg, that is, $m = W/R$, or $W = mR$. Therefore, dz is equal to the vertical angle in mils multiplied by the horizontal distance in thousands of yards.

c. Use of logarithms. When logarithms are used in conjunction with the trigonometric solution above, the log tangent of the vertical angle is added to the log of the horizontal distance to obtain the log of dz. The value of dz then is found in the logarithm tables.

d. Use of the military slide rule. The value of dz may be computed on the military slide rule with a single setting of the slide (TM 6–240).

307. TRAVERSE COMPUTATION FORM. a. The form shown in figure 117 is suggested for use in computing the coordinates and altitudes of traverse stations. The data are taken from the field notes in figure 100.

(1) *Station.* This column is used to record the stations. All the computations between two consecutive entries refer to that traverse leg. The diagram in this column is an aid in converting azimuths to bearings.

(2) *Azimuth.* This column is used to record the horizontal angle and the azimuth computed for each traverse leg.

(3) *Vertical angle, distance, and bearing.* This column is used to record the vertical angle as taken from the field notes. The distance is entered in feet. The bearing is computed from the azimuth in the previous column.

(4) *Logarithms.* In this column, the logarithm of the meter conversion factor, the logarithm of the distance, and the logarithm of the appropriate trigonometric functions are added to obtain the logarithms of dx and dy. The logarithm of dz is obtained by adding the logarithm of the distance to the log tangent of the vertical angle.

(5) *Coordinates.* The values of dx, dy, and dz are found in the tables opposite their logarithms, and are entered in this column. These differences then are applied to the coordinates of the previous station to obtain the coordinates of the new station. It should be noted that the coordinates of

COORDINATES FROM AZIMUTH AND DISTANCE			FROM STATION 9		TO BTRY C				SHEET 1 OF 1 SHEETS			
STATION	AZIMUTH		VERTICAL ANGLE DISTANCE BEARING	LOGARITHMS						COORDINATES AND X, Y AND Z DIFFERENCES		
STATION 9	BACK AZ	1615		NOTE: To find dX, dY and dZ in meters, use log of distance in feet, and add 9.4840158						X 47.532 0	Y 84.236 0	Z 1137 0
X− Y+ / X+ Y+	ANGLE	645	VA 3									
	SUM	2260	D 521.5 FT		9.48402		9.48402					
	360° 6400 −		D YD	D	2.71725	D	2.71725	D	2.71725			
	AZIMUTH	2260	β S940E	SIN β	9.90163	COS β	9.78072	TAN VA	7.46912			
X− Y− / X+ Y−	180° 3200 ±	3200		dX	22.10290	dY	21.98199	dZ	10.18637	dX +.126	dY −.095 9	dZ +1 5
STATION 20	BACK AZ	5460								X 47.658 7	Y 84.140 1	Z 1138 5
X− Y+ / X+ Y+	ANGLE	3729	VA +6									
	SUM	9189	D 489.7 FT		9.48402		9.48402					
	360° 6400 −	6400	D YD	D	2.68993	D	2.68993	D	2.68993			
	AZIMUTH	2789	β S411E	SIN β	9.59399	COS β	9.96364	TAN VA	7.77016			
X− Y− / X+ Y−	180° 3200 ±	3200		dX	21.76794	dY	22.13759	dZ	10.46009	dX +.058 6	dY −.137 3	dZ +2 9
STATION 21	BACK AZ	5989								X 47.717 3	Y 84.002 8	Z 1141 4
X− Y+ / X+ Y+	ANGLE	1842	VA −10									
	SUM	7831	D 362.0 FT		9.48402		9.48402					
	360° 6400 −	6400	D YD	D	2.54654	D	2.54654	D	2.54654			
	AZIMUTH	1431	β N1431E	SIN β	9.99399	COS β	9.21789	TAN VA	7.99201			
X− Y− / X+ Y−	180° 3200 ±			dX	22.02455	dY	21.29845	dZ	10.53855	dX +.105 8	dY +.017 7	dZ −3 5
STATION C	BACK AZ									X 47.823 1	Y 84.020 5	Z 1137 9
X− Y+ / X+ Y+	ANGLE		VA									
	SUM		D FT									
	360° 6400 −		D YD	D		D		D				
	AZIMUTH		β	SIN β		COS β		TAN VA				
X− Y− / X+ Y−	180° 3200 ±			dX		dY		dZ		dX	dY	dZ
STATION	BACK AZ									X	Y	Z
COMPUTER Sgt Jones				CHECKER Sgt Smith						DATE 2 June		

DA AGO FORM 1 APR 48 6-2 REPLACES FAS FORM 2, 19 JUNE 1944, WHICH IS OBSOLETE.

Figure 117. Traverse computation form when logarithms are used

COORDINATES FROM AZIMUTH AND DISTANCE			FROM Station 9	TO Btry C	SHEET 1 OF 1 SHEETS		
STATION	AZIMUTH		VERTICAL ANGLE DISTANCE BEARING	LOGARITHMS	COORDINATES AND X, Y AND Z DIFFERENCES		
STATION 9	BACK AZ	1615		NOTE: To find dX, dY and dZ in meters, use log of distance in feet, and add 9.4840158	X 47.532	Y 84.236	Z 1137
	ANGLE	645	VA +3				
	SUM	2260	521.5 FT				
	360° - 6400		D	D / D / D			
	AZIMUTH	2260	B S5940E	SIN B / COS B / TAN VA	+415 ft	-314 ft	
	180° ± 3200	3200		dX / dY / dZ	dX +.126 m	dY -.096 m	dZ +1 5
STATION 20	BACK AZ	5460			X 47.658	Y 84.140	Z 1138 5
	ANGLE	3729	VA +6				
	SUM	9189	489.7 FT				
	360° - 6400	6400	D	D / D / D			
	AZIMUTH	2789	B S4IIE	SIN B / COS B / TAN VA	+192 ft	-450 ft	
	180° ± 3200	3200		dX / dY / dZ	dX +.059 m	dY -.137 m	dZ +2 9
STATION 21	BACK AZ	5989			X 47.717	Y 84.003	Z 1141 4
	ANGLE	1842	VA -10				
	SUM	7831	352.0 FT				
	360° - 6400	6400	D	D / D / D			
	AZIMUTH	1431	B N1431E	SIN B / COS B / TAN VA	+347 ft	+58 ft	
	180° ± 3200			dX / dY / dZ	dX + 106 m	dY + 18 m	dZ -3 5
STATION C	BACK AZ				X 47.823	Y 84.021	Z 1137 9
	ANGLE		VA				
	SUM		FT				
	360° - 6400		D	D / D / D			
	AZIMUTH		B	SIN B / COS B / TAN VA			
	180° ± 3200			dX / dY / dZ	dX	dY	dZ
STATION	BACK AZ				X	Y	Z
COMPUTER: Sgt. Jones			CHECKER: Sgt Smith		DATE: 2 June		

DA AGO FORM 1 APR 49 6-2 REPLACES FAS FORM 2, 19 JUNE 1944, WHICH IS OBSOLETE.

Figure 118. Traverse computation form when military slide rule is used.

any station are recorded exactly opposite that station in the *station* column.

b. When the military slide rule is employed in computing, the same form is used, but the column under *logarithms* is not required. In figure 118, the data are taken from the aiming circle traverse shown in figure 100. The values of dx and dy are obtained and entered in the coordinate column in feet and converted to meters by multiplying by .3048.

c. It should be noted that coordinates are in meters and altitudes are in feet.

308. ADJUSTING A TRAVERSE. a. Direction. When a traverse is closed, the directional error may be determined at the final station. Even when the traverse is not closed, the directional error may be determined at the final station or at any intermediate station by an astronomic observation. Assuming that this directional error is cumulative, the correction is divided equally among the traverse legs. For example, if a traverse of 8 legs has a directional error of left 4 minutes, the correction, then, is right 30 seconds to be applied to the bearing of each leg. This is done before the computation of coordinates is begun.

b. Position. When a traverse is closed, the linear error of closure is the difference between the computed coordinates of the final station and the known coordinates of the same station. Normally, if the error of closure is within the desired accuracy, no correction is made. If the traverse is adjusted, dx and dy are corrected separately. The correction of dx for any leg of the traverse is to the whole error in dx as the corresponding dx is to the arithmetical sum of all the dx's. For example, the total dx for a certain traverse is 4321.5 meters and the computed X-coordinate of the final station is 6.3 meters less than the known X-coordinate. The computed dx for the first traverse leg is 622.8 meters. To determine the correction to be applied to dx for the first traverse leg—

$$\frac{\text{Correction}}{6.3}=\frac{622.8}{4321.5}$$

$$\text{Correction}=\frac{(622.8)\ (6.3)}{4321.5}$$

By using the military slide rule, the correction is found to be 0.9 meters. Since the X-coordinate of the final station must be increased to agree with the known coordinate, the X-coordinate of each station must be increased proportionately. Therefore, 0.9 meters is added to the X-coordinate of the station established by the first traverse leg. Both X- and Y-coordinates for all stations are corrected in a similar manner.

c. Graphic adjustment. When the traverse is plotted rather than computed, it may be adjusted by graphic means (fig. 119). The traverse begins at station 1 and closes on station 5. As originally plotted, the traverse is shown by the solid line. The correct location of station 5 is at 5′ and the error of closure is the line 5–5′. To correct the locations of intermediate stations—

(1) Lay off successively on a straight line the various distances 1–2, 2–3, etc., representing each leg of the traverse.

(2) From the last point 5, draw a line 5–5′ equal to the error of closure and perpendicular to the line 1–5. Draw a straight line connecting 1 and 5′.

(3) Through the points 2, 3, and 4, on the straight line 1–5, draw lines parallel to 5–5′, cutting 1–5′. The lengths of those short lines represent the adjustments to be made on the corresponding points of the traverse.

(4) One the traverse, as originally plotted, draw a line through each point parallel to the error of closure 5–5′. Lay off on these parallel lines the distances determined in (3) above.

(5) Through the points thus established, draw the adjusted traverse (shown in dotted lines).

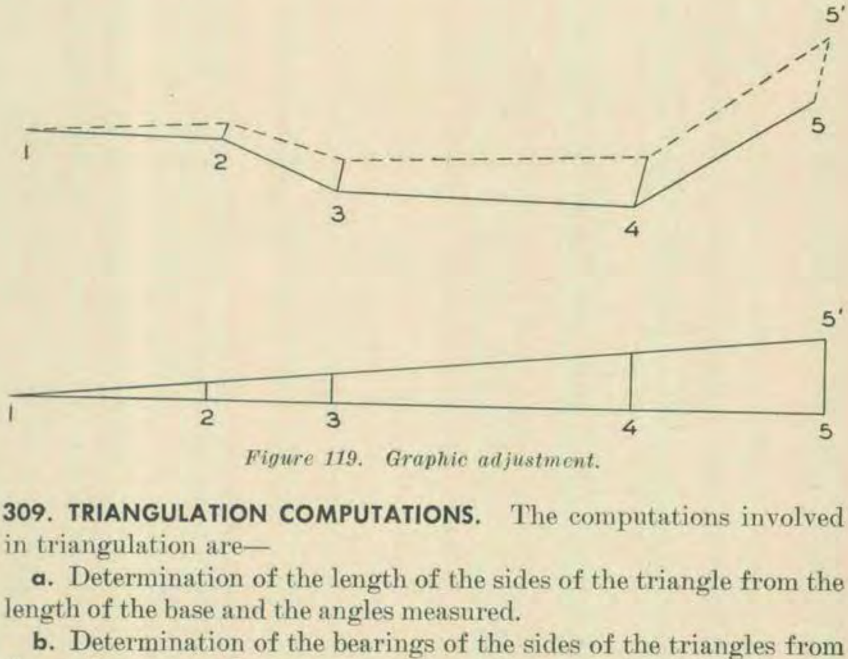


Figure 119. Graphic adjustment.

309. TRIANGULATION COMPUTATIONS. The computations involved in triangulation are—

a. Determination of the length of the sides of the triangle from the length of the base and the angles measured.

b. Determination of the bearings of the sides of the triangles from the angles measured.

c. Determination of the coordinates and altitudes of the triangulation stations from the lengths and bearings of the lines, and the vertical angles.

310. SOLUTION OF THE OBLIQUE TRIANGLE. To compute the lengths of the lines in a triangulation system, a knowledge of the solution of an oblique triangle is necessary (fig. 120).

a. Definition. An oblique triangle is one in which there is no right angle. In triangulation, all triangles are oblique unless one of the angles happens to be a right angle.

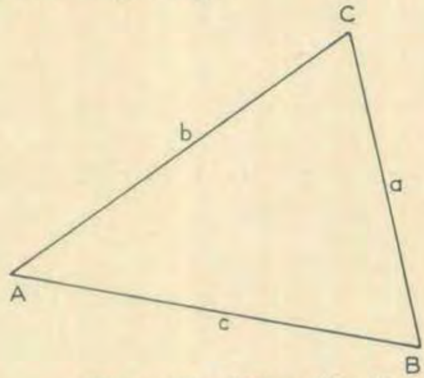


Figure 120. Oblique triangle.

b. Law of sines. The lengths of the sides of any triangle are proportional to the sines of the angles opposite. The law is written—

$$\frac{a}{\sin A}=\frac{b}{\sin B}=\frac{c}{\sin C}$$

Therefore, if the length of one side and two of the angles of any oblique triangle are known, the length of either or both of the remaining sides may be computed by using the above proportion.

c. Example (fig. 121). The length of the base (AB) has been taped and the values of angles A and B measured as shown. The lengths of the line AC and BC are determined as follows:

Angles $A + B + C = 180°$.
Angle $C = 180° - (49° 20' + 74° 32') = 56° 08'$.

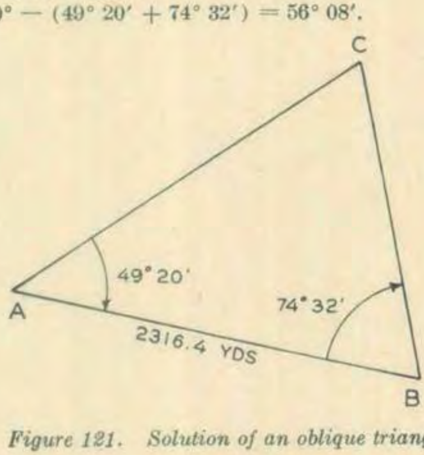


Figure 121. Solution of an oblique triangle.

(1) The length of the line AC is determined as follows:

$$\frac{AC}{\sin 74^\circ 32'}=\frac{2316.4}{\sin 56^\circ 08'}$$

$$AC=\frac{2316.4 \sin 74^\circ 32'}{\sin 56^\circ 08'}$$

By logarithms,

$$\log AC=\log 2316.4+\log \sin 74^\circ 32'-\log \sin 56^\circ 08'$$

$$\begin{aligned} \log 2316.4 &= 3.36482 \\ \log \sin 74^\circ 32' &= 9.98398 \\ \hline & 3.34880 \\ \log \sin 56^\circ 08' &= 9.91925 \\ \hline \log AC &= 3.42955 \\ AC &= 2688.8 \text{ yards} \end{aligned}$$

(2) The length of the line BC is determined as follows:

$$\frac{BC}{\sin 49^\circ 20'}=\frac{2316.4}{\sin 56^\circ 08'}$$

$$BC=\frac{2316.4 \sin 49^\circ 20'}{\sin 56^\circ 08'}$$

By logarithms,

$$\log BC=\log 2316.4+\log \sin 49^\circ 20'-\log \sin 56^\circ 08'$$

$$\begin{aligned} \log 2316.4 &= 3.36482 \\ \log \sin 49^\circ 20' &= 9.87996 \\ \hline & 3.24478 \\ \log \sin 56^\circ 08' &= 9.91925 \\ \hline \log BC &= 3.32553 \\ BC &= 2116.0 \text{ yards} \end{aligned}$$

311. BEARINGS. **a.** To determine the bearings of the lines in a triangulation system, it is easier to determine the azimuth of each line by applying the clockwise angle to the other lines in the system and then to convert these azimuths to bearings. However, bearings may be figured directly, without recourse to azimuths, by applying the clockwise angles turned on the ground to the bearing of the line used to establish direction.

b. The bearing of any line in the system also may be computed from coordinates, once the coordinates of the ends of the line are known. The bearings carried forward by measuring the angles on the ground are more reliable than the bearings computed by coordinates.

312. TRIANGULATION COMPUTATION FORMS. a. Solution of the triangles. Triangles may be solved either on forms or on scratch paper; however, if there are several triangles in the system, it is advisable to make a sketch approximately to scale and enter on this sketch the value of the bearing of each line and the length of each line as it is computed (fig. 122). The data then will be readily accessible for use in the computation of succeeding triangles. The bearing of each line is recorded on the sketch above the line, its length below the line. When logarithms are used, the logarithm of the distance is recorded rather than the distance itself and antilogs are not determined until the computation of *dx* and *dy*, since the values of *dx* and *dy* are desired rather than the length of the lines.

b. Computation of coordinates. The azimuths and lengths of lines in the system are computed, using a form similar to that in figure 124. To compute the coordinates and altitudes of stations in the system, the same form as used for a traverse (fig. 117) is employed. The coordinates of the unknown stations should be determined from both ends of the base in order to verify the computations. In the process of checking, clockwise angles measured from the known direction should be used. The bearing and distance (or log distance) of each line are taken from the sketch and the vertical angle is taken from the field notes.

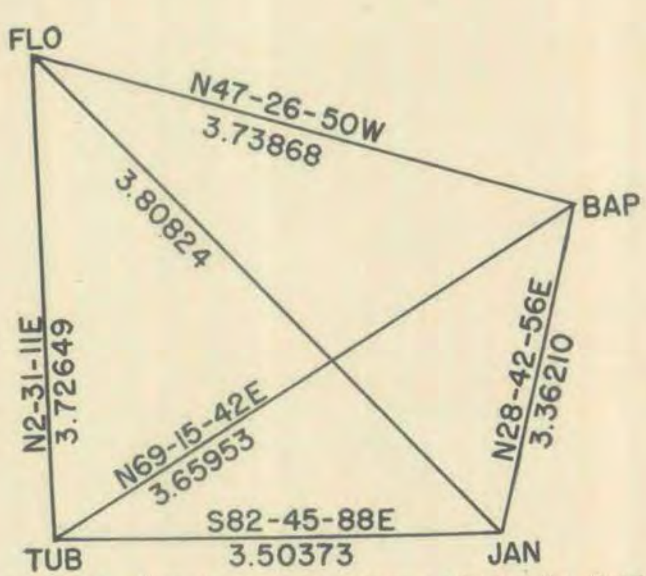


Figure 122. Method of entering data on a triangulation sketch.

c. Example of triangulation computation (figs. 123 and 124).

(1) In figure 123, the length of the known base, *TUB–JAN* is 3189.64 meters, the metric coordinates of *TUB* are (2000.00–4000.00), and the grid azimuth of the line from *TUB* to *JAN* is 97°14′32″. It is desired that the coordinates of *JAN*, *BAP*, and *FLO* be determined by triangulation; all stations are occupied.

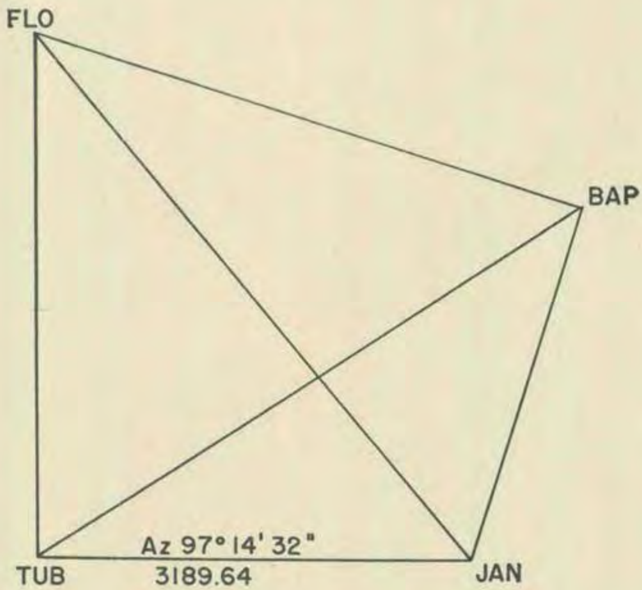


Figure 123. Triangulation field work.

(2) The angles measured on the ground are as follows:

Triangle, *FLO–JAN–TUB*,	angle *FLO* is	29°37′34″
	angle *JAN* is	55°39′08″
	angle *TUB* is	94°43′25″
Triangle, *BAP–JAN–FLO*,	angle *BAP* is	103°50′17″
	angle *JAN* is	55°49′17″
	angle *FLO* is	20°20′29″
Triangle, *BAP–JAN–TUB*,	angle *BAP* is	40°32′47″
	angle *JAN* is	111°28′25″
	angle *TUB* is	27°58′51″
Triangle, *FLO–BAP–TUB*,	angle *FLO* is	49°58′03″
	angle *BAP* is	63°17′30″
	angle *TUB* is	66°44′34″

(3) Using the "Computation of Triangles" form (fig. 124), the following steps are necessary in order to determine the lengths of the sides of the quadrilateral in meters:

(*a*) Adjust all triangles for closure (180°00′00″ in each).

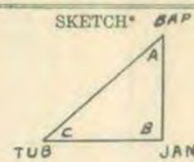
P. A. S. Form No. 6
9 June 1944

COMPUTATION OF TRIANGLES

Triangle BAP-JAN-TUB

Stations		Observed Angles °	′	″	Adjusted Angles °	′	″
BAP	(A)*	40	32	47	40	32	46
JAN	(B)*	111	28	25	111	28	24
TUB	(C)*	27	58	51	27	58	50

SKETCH*

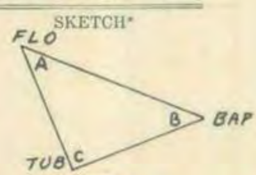


Log BC 3.50373	Log BC 3.50373
Colog Sin A 0.18704	Colog Sin A 0.18704
Log Sin B 9.96876	Log Sin C 9.67133
Sum = Log AC 3.65953	Sum = Log AB 3.36210
Stations: A BAP C TUB	Stations: A BAP B JAN

Triangle FLO-BAP-TUB

Stations		Observed Angles °	′	″	Adjusted Angles °	′	″
FLO	(A)*	49	58	03	49	58	01
BAP	(B)*	63	17	30	63	17	28
TUB	(C)*	66	44	34	66	44	31

SKETCH*

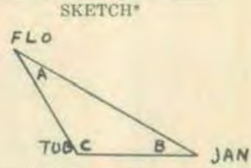


Log BC 3.65953	Log BC 3.65953
Colog Sin A 0.11596	Colog Sin A 0.11596
Log Sin B 9.95100	Log Sin C 9.96319
Sum = Log AC 3.72649	Sum = Log AB 3.73868
Stations: A FLO C TUB	Stations: A FLO B BAP

Triangle FLO-JAN-TUB

Stations		Observed Angles °	′	″	Adjusted Angles °	′	″
FLO	(A)*	29	37	34	29	37	32
JAN	(B)*	55	39	08	55	39	06
TUB	(C)*	94	43	25	94	43	22

SKETCH*

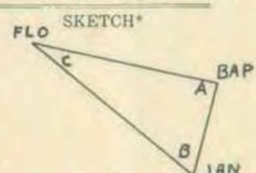


Log BC 3.50373	Log BC 3.50373
Colog Sin A 0.30598	Colog Sin A 0.30598
Log Sin B 9.91678	Log Sin C 9.99853
Sum = Log AC 3.72649	Sum = Log AB 3.80824
Stations: A FLO C TUB	Stations: A FLO B JAN

Triangle BAP - JAN - FLO

Stations		Observed Angles °	′	″	Adjusted Angles °	′	″
BAP	(A)*	103	50	17	103	50	16
JAN	(B)*	55	49	17	55	49	16
FLO	(C)*	20	20	29	20	20	28

SKETCH*



Log BC 3.80824	Log BC 3.80824
Colog Sin A 0.01279	Colog Sin A 0.01279
Log Sin B 9.91765	Log Sin C 9.54109
Sum = Log AC 3.73868	Sum = Log AB 3.36212
Stations: A BAP C FLO	Stations: A BAP B JAN

NOTE.—In each triangle, make BC the side of known length.

Computed by J. K. R. Date of Computation 1 APRIL

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Figure 124. Example of triangulation computation.

(*b*) In one triangle involving the known base, solve for both unknown sides.

(*c*) In the external triangle, using the quadrilateral-diagonal found in step (*e*) above as a known side, solve for both of the other sides.

(*d*) In the other triangle, involving the known base, solve for both of the other sides.

(*e*) In the external triangle, using the quadrilateral-diagonal found in step (*b*) above as a known side, solve for both of the other known sides. This procedure gives a check on each of the three exterior sides.

(4) Knowing grid azimuths and distances, the coordinates of *JAN*, *BAP*, and *FLO* are computed, using DA AGO Form 6–2 (fig. 117).

313. TARGET AREA BASE. A target area base is established for the purpose of rapid location of targets and the location of center of impact and high-burst registrations. It is composed of two observation posts from which other points may be located by a combination of triangulation and polar plotting principles. Distances are computed, but points are placed on the firing chart by polar plotting. The base should be sufficiently long to give an angle of intersection at the desired point of 150 mils for the aiming circle or 100 mils for the transit. If the base is to be used to determine target area distances, it should be as nearly perpendicular to the direction of fire as possible so that any errors in the distances will appear in the firing data as range errors rather than as deflection errors.

a. Definitions.

(1) *O1.* The controlling observation post, whether it be on the left or the right end of the base.

(2) *O2.* The auxiliary observation post.

(3) *Instrument reading.* The clockwise horizontal angle, for any point, from the left end of the base, or base extended, to the point. Instrument readings are measured at both observation posts. Targets may be reported by instrument reading or by azimuth.

(4) *Apex angle.* The angle of the triangle with its vertex at the point being located.

b. Determination of apex angle. In a triangle, any exterior angle equals the sum of the two opposite interior angles. In figure 125, the instrument reading at *O1* equals the instrument reading at *O2* plus the apex angle. The equation is written as follows:

Apex angle=Instrument reading *O1*—Instrument reading *O2*.

If $O1$ is on the right, the equation is the same except $O1$ and $O2$ are interchanged.

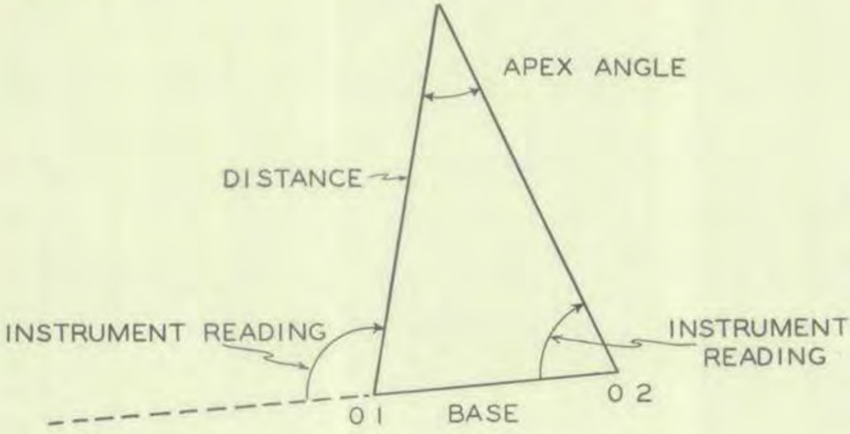


Figure 125. Target area base.

c. Solution of the triangle. The distance sought is always the distance from $O1$ to the point to be located. To solve for this distance in figure 125, the law of sines (par. 310**b**) is used.

$$\frac{\text{Distance}}{\text{Sin inst reading } O2}=\frac{\text{Base}}{\text{Sin apex angle}}$$

$$\text{Distance}=\frac{\text{Base}\times\text{Sin inst reading } O2}{\text{Sin apex angle}}$$

In applying the law of sines, an exterior angle, such as the instrument reading at $O1$, may be substituted for the adjacent interior angle, since the sines of supplementary angles are equal. The solution of the above equation is as follows:

(1) *By logarithms.* Log distance = log base + log sin instrument reading $O2$ − log sin apex angle.

(2) *By military slide rule.* The slide rule is arranged to provide a simple and rapid solution of the target area base problem (TM 6–240).

d. Plotting data on firing chart. The location of $O1$ having been determined, it is plotted on the firing chart. The location of $O2$ is not plotted since it is used only in the computations for locations of targets. The procedure is as follows:

(1) The observer $O1$ reports to the fire-direction center the instrument reading and vertical angle to a known point, preferably the base point, check point, or a reference point.

(2) The HCO places the vertex of a range-deflection fan at the plotted position of $O1$, with one edge passing through the

known point. He draws a short reference line along the edge to intercept the mil scale at the top of the fan. The line is labeled with the reported instrument reading (fig. 126). Using this line as a basis, additional reference lines are drawn for instrument readings of multiples of 500 mils and labeled accordingly. Sufficient lines are drawn to cover the target area.

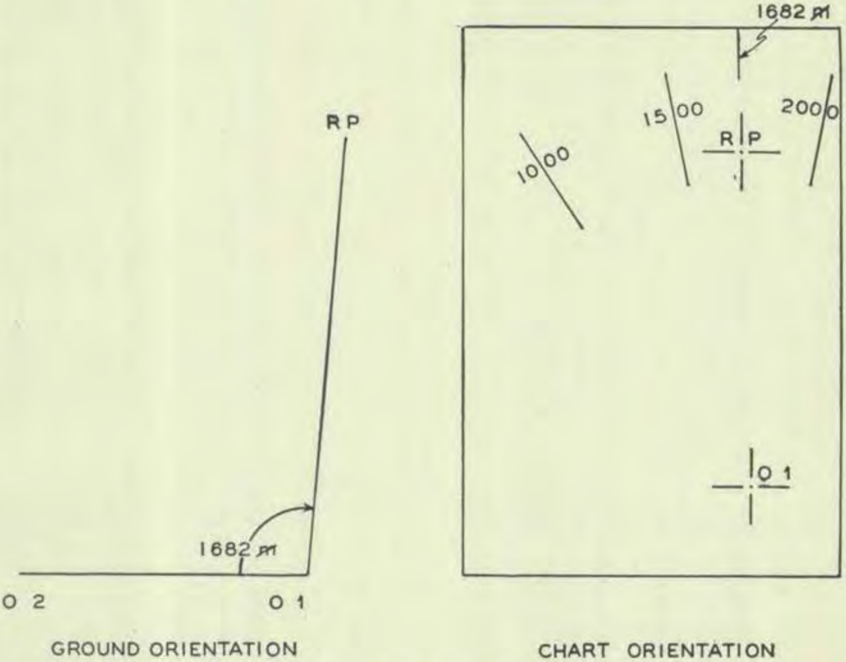


Figure 126. Orientation of target area base on chart.

e. Example.

(1) *O1* is on the right.

(2) Base (*O1–O2*) length is 625 yards.

(3) Instrument reading *O1* to target=1,520₥, vertical angle= −2₥.

Instrument reading *O2* to target=1,680₥.

(4) Solution:

$$\text{Apex angle} = 1{,}680 - 1{,}520 = 160₥$$

$$\frac{\text{Distance}}{\text{Sin } 1{,}680₥} = \frac{625 \text{ yds}}{\text{Sin } 160₥}$$

$$\text{Distance} = \frac{625 \sin 1{,}680}{\text{Sin } 160} = 3{,}983 \text{ yards.}$$

314. CALCULATION OF Y-AZIMUTHS FROM COORDINATES. The bearing of a line connecting two points may be computed when the coordinates of the points are known. Knowing the bearing, the Y-azimuth may be determined. The following example shows the procedure for making calculations:

a. Data available (fig. 127).

Coordinates: Point A=815.475–1,267.430
Point B=818.140–1,266.590.

$$\begin{array}{r} 818.140 \\ -815.475 \\ \hline dx = 2{,}665 \text{ meters} \end{array} \qquad \begin{array}{r} 1{,}267.430 \\ -1{,}266.590 \\ \hline dy = 840 \text{ meters} \end{array}$$

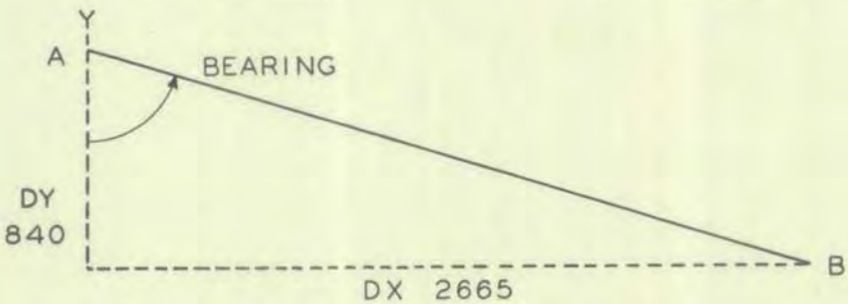


Figure 127. Computing a bearing from coordinates.

b. Procedure.

(1) Draw a sketch showing the relative positions of A and B and indicate Y-north and the bearing desired. In this case, B is east and south of A, therefore dx is plus and dy is minus with respect to point A.

(2) Using logarithms—

Tan bearing $= \frac{dx}{dy} = \frac{2{,}665}{840}$

log tan bearing = log 2,665 − log 840
log 2665 = 3.42570
log 840 = 2.92428

log tan bearing = 0.50142
bearing = S 1289 mils E
Azimuth AB = 3200 mils − 1289 mils = 1911 mils.

(3) The largest angle that may be read on the slide rule is 800 mils. Therefore, the angle at B will be computed as follows:

Tan B $= \frac{dy}{dx} = \frac{840}{2{,}665}$

Angle B = 311 mils.
Bearing = 1,600 mils − 311 mils = S 1,289 mils E.

(In the right triangle, the sum of the two acute angles equals 1,600 mils.)

315. CALCULATION OF DISTANCE FROM COORDINATES. The horizontal distance between two points may be computed when the points are known. The procedure is as follows:

a. Bearing. The bearing of the line is computed as in paragraph 314.

b. Equations.

(1) $\text{Sin bearing} = \frac{dx}{AB}$

$$AB = \frac{dx}{\text{sin bearing}}$$

(2) $\text{Cos bearing} = \frac{dy}{AB}$

$$AB = \frac{dy}{\text{cos bearing}}$$

c. Example. (Fig. 127.)

$$AB \text{ (distance)} = \frac{dx}{\text{sin bearing}} = \frac{2{,}665}{\sin 1{,}289} = 2{,}794.4 \text{ meters}$$

$$AB \text{ (distance)} = \frac{dy}{\text{cos bearing}} = \frac{840}{\cos 1{,}289} = 2{,}794.4 \text{ meters}$$

316. DETERMINATION OF BASE ANGLES. a. The base-point line for any battery is the line from the battery center to the base point. The base angle is the clockwise horizontal angle from the base-point line to the orienting line. It is used by the executive to lay the battery. The base angle never is greater than 3,200 mils. One of the missions of the survey is to establish the orienting lines on the ground and to determine the value of the base angles.

b. To determine the base angle for each battery, the azimuth of the base-point line is compared to the azimuth of the orienting line. This is done as follows:

(1) The azimuth of the base-point line is measured from the chart, or computed when the coordinates of the battery center and the base point are known.

(2) The azimuth of the orienting line is taken from the survey field notes, direction having been carried to the orienting line by any of the methods in paragraph 303.

(3) The azimuth of the base-point line is subtracted from the azimuth of the orienting line, plus 6,400 mils, if necessary, to obtain the base angle. *Examples:*

(*a*) Azimuth of orienting line = 2400 mils
Azimuth of base-point line = 810 mils
Base angle = 1590 mils (fig. 128)

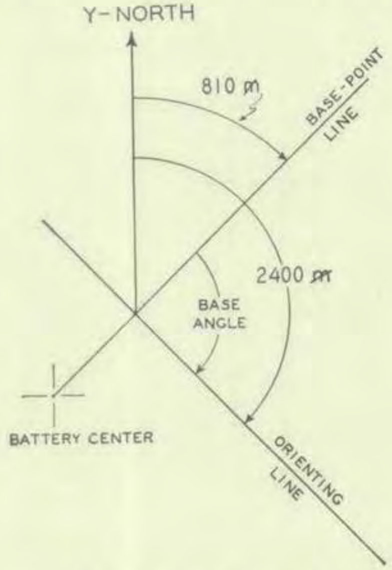


Figure 128. Computation of base angle by azimuth.

(*b*) Azimuth of the orienting line = 210 mils + 6,400 mils = 6,610 mils
Azimuth of base-point line = 6,219 mils

Base angle = 391 mils

(*c*) Azimuth of orienting line = 6,143 mils
Azimuth of base-point line = 138 mils

6,005 mils
−3,200 mils (3200 mils subtracted since computed base angle is greater than 3200 mils)

Base angle = 2,805 mils

CHAPTER 24

STANDARDS OF ACCURACY

317. GENERAL. **a.** The precision with which field artillery survey must be performed is governed by the time available and the accuracy required in determining the chart locations of pieces and targets. Since the effect which the survey operations have on this determination varies with the complexity of the particular survey problem, no fixed rule can be formulated to govern the precision to be attained by each echelon. As a basis for training, the standards listed in this chapter are those normally required.

b. The allowable error in survey usually is expressed as a ratio to the total distance covered, such as 1/2,000, or 1 part in 2,000. If the extent of the survey is 10,000 yards, and the allowable error in location is 5 yards, the surveys must be accurate to 5 parts in 10,000 or 1 part in 2,000. This ratio also is applicable to various instruments; for example, the military slide rule is accurate to 1/500. This means that if the value of a quantity computed with the military slide rule is 500 units, the correct value of the quantity lies between 499 and 501 units. This accuracy can be exceeded in many cases (TM 6–240).

318. ACCURACY OBTAINABLE WITH SURVEY EQUIPMENT. **a. 1 part in 500.**

(1) Distance may be obtained by—

(*a*) Taping, the tape being read to the nearest 0.1 foot. Slope corrections are not made for slopes less than 5 feet per 100 feet; the tape is broken for steeper slopes and leveled by eye within 5 feet per 100 feet. Tape alinement is made by eye.

(*b*) Transit stadia.

(*c*) Triangulation.

(2) Direction may be obtained by—

(*a*) Aiming circle, reading to the nearest mil (two repetitions).

(*b*) Transit reading to the nearest minute.

(3) Solutions may be obtained by—

(*a*) Plotting at a scale not smaller than 1/10,000.

(*b*) Computation with the military slide rule.

(*c*) Computation with 5-place log tables.

b. 1 part in 1,000.

(1) Distance may be obtained by—

(*a*) Taping, the tape being read accurately to the nearest 0.1 foot. Slope corrections are applied when measuring along the slope; when breaking tape, a plumb bob is used on the elevated end of the tape, and the tape is leveled by eye. Tape alinement is made by eye.

(*b*) Triangulation.

(2) Direction may be obtained by—

(*a*) Aiming circle, reading to 1 mil if the angle is measured three times and care is used in leveling the instrument. Aiming circles are not recommended for surveys of this accuracy.

(*b*) Transit, reading to one minute or less. Measure angles once direct and once reversed with either the 1-minute or 20-second transit.

(3) Solutions must be obtained by computation with 5-place log tables. Plotting and the military slide rule are not sufficiently accurate for surveys of this precision.

c. 1 part in 2,000.

(1) Distance may be obtained by—

(*a*) Taping, the tape being read accurately to the nearest 0.1 foot and estimated to the nearest 0.01 foot. When measuring along the slope, slope corrections are applied; when breaking tape, a plumb bob is used on the elevated end, and the tape is leveled by eye. A 100-foot tape should be used unless taping is on level ground, in which case either the 100-foot or 300-foot tape may be used. Aline tape by eye.

(*b*) Triangulation.

(2) Direction must be obtained with the transit measuring to 30 seconds or less. Angles are measured once direct and once reversed with either a 1-minute or a 20-second transit.

(3) Solutions must be obtained by computation with 5-place log tables. The military slide rule or plotting may be used as a check.

319. DEGREE OF ACCURACY TO BE SOUGHT BY FIELD ARTILLERY UNITS. a. Light artillery. In a rapid occupation of position, light artillery seeks an accuracy of 1 part in 500 for both position and target area surveys. However, when a deliberate occupation is made, light artillery should seek an accuracy of 1 part in 2,000.

b. Medium artillery. In a rapid occupation of position, medium artillery seeks an accuracy of 1 part in 500. In a deliberate occupation of position or when many targets are expected to be at ranges greater than 10,000 yards, medium artillery should seek an accuracy of 1 part in 2,000.

c. Heavy artillery. Heavy artillery always seeks an accuracy of 1 part in 2,000.

320. RULES FOR ACCURACY. The greatest precision consistent with the time available should be sought. The hurried use of precise methods may result in mistakes. A survey which introduces too great an error into the preparation of fire has no value. In survey work and in survey training, the following rules should be observed:

a. Use the most precise method possible in the time available.

b. Analyze and sketch what the survey is to accomplish, and select the simplest plan which will give the desired results.

c. Even though time is pressing, never use a method that does not permit obtaining satisfactory firing data.

d. Verify all work if only by a rough method. Employ completely independent checks by different men when practicable. For methods of closure, see paragraph 351.

e. Watch particularly the preparation of notes; these must be legible, accurate, systematic, and clear, and always should be accompanied by a sketch. More mistakes occur through poorly kept notes than through errors in measurements or computations.

f. Develop methods and procedures that produce accuracy and eliminate mistakes. Enforce these methods rigidly.

g. Study methods to determine and strengthen the weak link. One inaccurate step will destroy the accuracy of an otherwise precise survey.

h. Use selected men, taking into account intelligence, physique, and temperament. Relieve men who do not become methodical and precise with reasonable training.

i. In training, if it is at all possible, always complete a survey once it is started. No one factor contributes more toward carelessness than the habit of not completing and checking survey work. If survey personnel never know whether or not their work is correct, they soon become indifferent and careless.

CHAPTER 25

NIGHT SURVEY

321. NIGHT SURVEY OPERATIONS. a. General. Normally, all survey operations, with the exception of the location of points in the target area by intersection, can be performed at night. Night survey is performed in exactly the same manner as daylight survey. All work necessarily must be done with artificial light and consequently will be much slower. A night survey requires about three times as much time as the same survey would in daylight. Time and effort both, however, will be reduced if a daylight reconnaissance can be made. At night, lights must be used with extreme caution. Sound ranging, flash ranging, and radio position finding may furnish targets during darkness.

b. Traverse. At night, traverse may be started from orientation (point of origin and line of direction) established during daylight, by astronomic means, or by illuminating the initial control points if accessible. Longer sights sometimes can be made at night because conditions may be such that a flashlight is more visible at night than a range pole or flag during daylight.

c. Triangulation. Triangulation stations must be illuminated by flashlight or other means so that they may be observed from other triangulation stations. Care must be exercised to not expose these lights to the view of the enemy. Communication between triangulation stations may be established by blinking the lights and employing Morse code.

d. Target area base. If possible, the selection of the base and alinement of a stake for night orientation should be performed during the daylight reconnaissance. If no daylight reconnaissance is possible, the base may be oriented on some accessible point. Intersection in the target area at night is restricted to center of impact and high burst adjustments, and the location of the flash of firing weapons. However, when a suitable base can be established at night, other points in the target area can be located immediately after daylight.

322. USE OF INSTRUMENTS. a. Aiming circle and transit. These instruments are equipped with night lighting devices which provide illumination for the cross hairs and the scales. When an instrument lacks night lighting devices, an assistant furnishes illumination of the cross hairs by holding a flashlight to one side, directing just enough light down the barrel of the telescope to make the cross hairs visible; too much light will blot out the object sighted upon. The instrument man uses a flashlight for reading the scales. In order to permit the instrument man to accustom his eyes to darkness so that he can view the cross hairs and move around the transit without disturbing it, an assistant does the recording.

b. Range poles. The rodman provides a light upon which the instrument is sighted and upon which the tapemen may guide. An ordinary two-cell flashlight (with the beam at right angles to the barrel) fastened to the rod is just as satisfactory as an elaborate device. If, for short distances, the flashlight beam is too bright for the instrument man the light can be dimmed by a handkerchief placed over the lens, by substituting a red lens for the clear one, or by removing the reflector from the light. The rodman must place his light directly over his station point and must make sure that it is aimed in the correct direction. The instrument man cannot see the rod at night and therefore cannot correct for its deviation from vertical. Rodmen should be able to communicate with the instrument man by sending and receiving code signals with the flashlight.

c. Tape. At night, the tapeman's duties are the same as during daylight. Artificial light should be dimmed so that the tapeman's eyes are continuously adjusted to semidarkness. He then can move along the survey line rapidly, without danger to himself or his equipment. To facilitate night taping, the ends of the tape should be marked to make them more readily identifiable. A piece of white adhesive tape is satisfactory. The taping procedure is the same as in daylight with the exception that the head tapeman, after setting a pin, does not go forward until the rear tapeman has come up and identified the pin. A third man should assist the two tapemen in night taping. For horizontal taping, the extra man holds the light while the head tapeman sets his pin. When it is necessary to break tape, the extra man works with the tapeman who is using the plumb bob.

CHAPTER 26

AERIAL PHOTOGRAPHS

Section I. GENERAL

323. GENERAL. a. Air photos. Air photos furnished to the field artillery will be reproductions of either verticals or obliques, or mosaics assembled from individual verticals. Reproductions of individual photos usually are contact prints, while reproductions of mosaics usually are lithographs. The contact prints are preferable because, in the lithographic process, much clarity of detail is lost. Air photos are of great value to the field artillery in reconnaissance and in locating and designating targets. Air photos may be used as firing charts. When a map or grid sheet is used as the firing chart, air photos are used to supplement it for horizontal and vertical locations.

b. Verticals. A vertical air photo is one taken with the camera plate as nearly horizontal as possible. Normally, verticals are taken in a series of overlapping photos. A wide angle vertical is one taken with a short focal length camera, thus increasing the area photographed without increasing the height of the camera.

c. Obliques. Oblique photos are those taken with the camera plate tilted from the horizontal. A high oblique shows the horizon line. A low oblique is one on which the horizon does not appear.

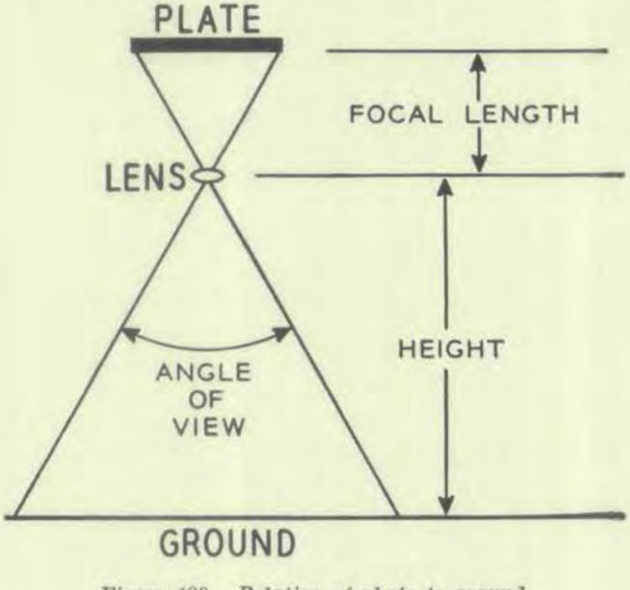


Figure 129. Relation of photo to ground.

324. TILT AND RELIEF. a. General. If a flat piece of terrain is photographed vertically, the result is a map that is perfect in all planimetric detail (fig. 129). However, the vertical air photo is subject to distortion of detail due primarily to tilt of the camera and to relief of the terrain photographed.

b. Tilt. If the camera is not level at the moment the photo is taken, the scale of the photo will not be uniform. In figure 130, it is evident that the horizontal line of a certain length near *A* will appear longer on the photo than a line of the same length near *B*, since *A* is nearer the camera than *B*. When the tilt is small, as in the case in a carefully made photo, the resulting errors are negligible for artillery work. In a series of overlapping photos taken on a single flight, excessive tilt of one photo is apparent if its center is materially out of place with reference to the line of centers established by the other photos. Field artillery units are not equipped to remove tilt from photos.

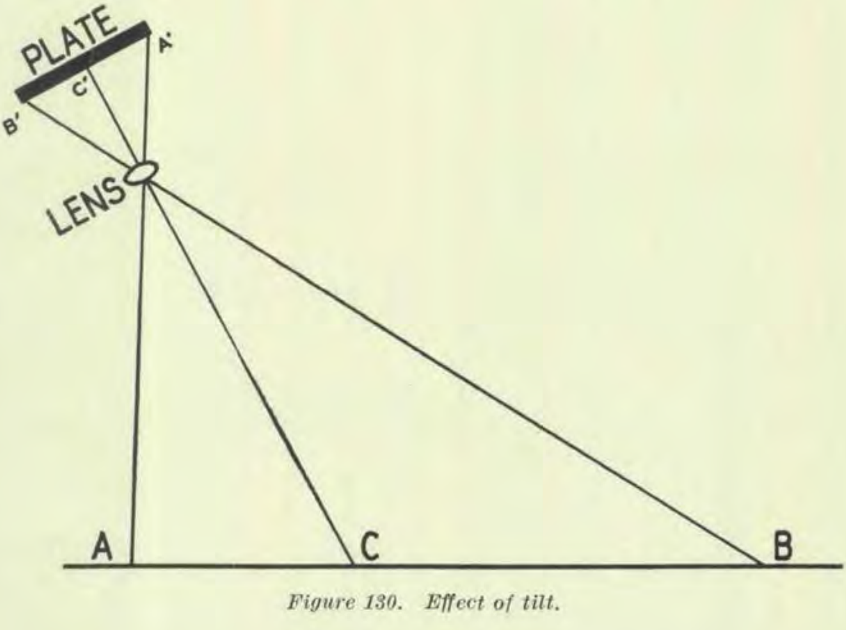
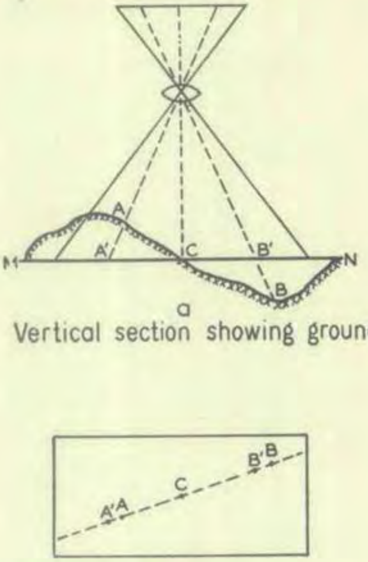


Figure 130. Effect of tilt.

c. Relief. The second important source of error is relief. Considering figure 131 as any vertical section through the axis of the lens, it is seen that *C* will be recorded in its true position, the center of the photo, regardless of its altitude. With reference to a horizontal datum plane *MN*, the object *A* at a greater altitude will record as an object located at *A′*; similarly *B* will record as *B′*. These displacements are radial from or toward the plumb point (point directly beneath the



a
Vertical section showing ground

b
Horizontal projection on chart

Figure 131. Displacement due to relief of ground.

camera at the instant the photo is taken). If the tilt is small, the plumb point and the center of the photo may be considered to be the same. For a given altitude of the airplane above the horizontal datum plane, the amount of displacement varies directly as the horizontal distance from C and the height above or below the horizontal datum plane. Note that directions of the radial lines, CA and CB, are not changed by the displacements of A and B. The relief distortion of any particular point varies inversely as the altitude of the airplane. The amount of distortion can be found by solving the following proportion (fig. 132):

$d/D = h/H$ where d is the displacement correction in yards radially toward (from) center of photo.

h is the height in feet of ground above (below) the horizontal datum plane.

D is the distance in yards from center of photo to point to be corrected.

H is the height in feet of camera lens above the horizontal datum plane. Usually, the altitude of the center of the target area is assigned arbitrarily as the mean datum plane and used as the basis for determining distortion corrections. d and D are photo distances. D may be measured in inches or in yards measured with 1/25,000 or other convenient scale; the resulting value of d will be in the same units as D.

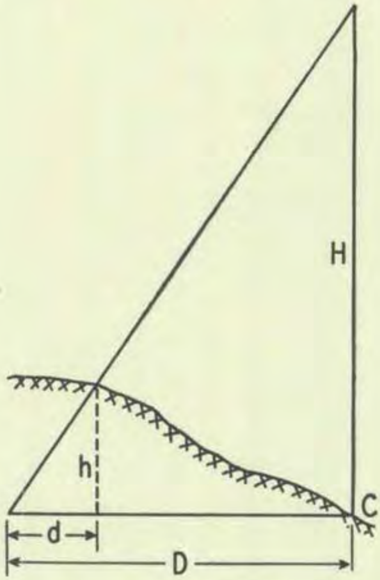


Figure 132. Determination of relief distortion.

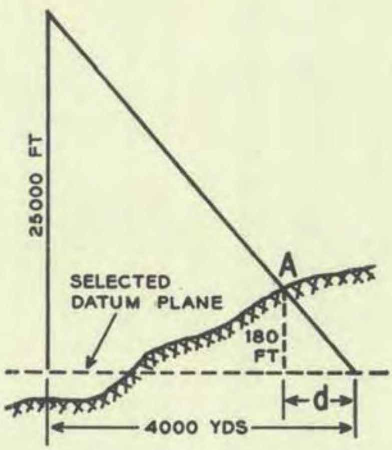


Figure 133. Example of correction for relief distortion.

d. Example. (See fig. 133.) An air photo taken at an altitude of 28,000 feet above sea level is to be used as the battalion firing chart. By survey, point A has been determined to be 180 feet above the base point. The mean datum plane, based on the approximate altitude of the base point, is selected as 3,000 feet above sea level. Therefore, the height of the camera lens is 25,000 feet above the datum plane. The distance from point A to the center of the photo is scaled as 4,000 yards.

$$\frac{d}{4{,}000} = \frac{180}{25{,}000}$$

$$d = 28.8 \text{ or } 29 \text{ yards.}$$

Point A will be plotted 29 yards toward the center of the photo from its photo location.

325. DIRECTION IN PHOTOS. The effect of relief is the displacement of images radially from or toward the center of the photo. The effects are shown in figure 134. The points a and b are on the higher ground and the point d is on lower ground than the center of the photo. In the figure, a, b, and d represent the true locations of these points, whereas a', b', and d' represent the photo locations. The lines $a'd'$ and $a'b'$ are not true direction lines, whereas ca', cb', and cd' are true and $b'd'$ is approximately true. It follows that the directions of lines passing through or near the center of an average vertical photo are substantially true. However, lines passing well away from the center and joining points of different altitudes whose images lie in the outer field of the photo may show excessive errors when the relief is considerable. If the altitude from which the photo was taken is known, the error may be corrected by a replot of the points to the same datum plane (par. 324).

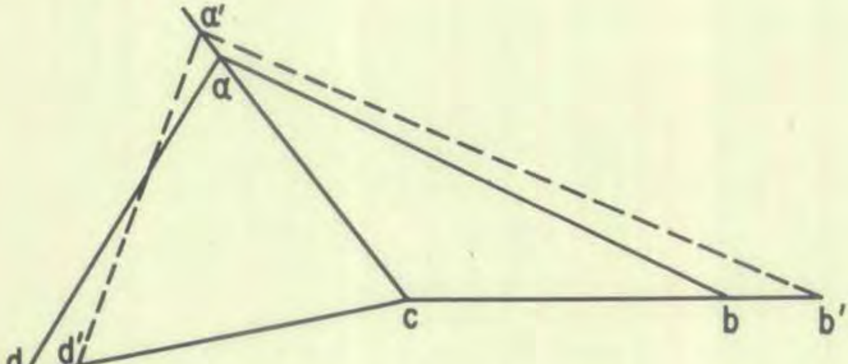


Figure 134. Effect of relief displacement on direction and scale.

326. DETERMINING SCALE OF PHOTOS. **a.** From figure 129, it is evident that the approximate scale of the photo can be expressed by the formula: RF (representative fraction) = focal length divided by height. Hence, the scale of the photo and the area covered by the photo depend upon the focal length and the height. For example, if a 7-inch by 9-inch photo is taken at a height of 20,000 feet with a camera of 6-inch focal length, the scale is .5/20,000 or 1/40,000 and the area covered is $(7\times40{,}000)\times(9\times40{,}000)$ inches, or about $8{,}000\times 10{,}000$ yards.

b. The scale of the photo as determined above may be inaccurate for any of the following reasons:

(1) Because the altimeter may not have been set accurately at zero for the area photographed.

(2) Because of barometric variations which affected the altimeter.

(3) Because of shrinkage of negative and print.

c. (1) The basic method of determining the scale of a photo is to determine the relation between a photo distance and the corresponding ground distance. For example, the photo distance between two points is 5.40 inches and the ground distance between the same points is 3,100 yards (111,600 inches). The scale is determined by solving the equation $5.40/111{,}600=1/x$. From the equation, $x=20{,}667$ and the scale is 1/20,667.

(2) The points between which the distance is measured should be selected carefully. They should be well defined both on the photo and on the ground; they should be far apart and near the average ground level, to not introduce material error through relief distortion. In flat terrain, points separated by 2,000 yards are satisfactory. In general, the greater the distance between the points, the more accurate is the scale. They should be approximately equidistant from the center of the photo and chosen so that the line joining them passes near the center of the photo. A more accurate value of the scale of the photo can be determined by averaging the scales determined by two such lines roughly perpendicular to each other.

(3) Figure 134 shows the effect of relief distortion on the scale. The lengths of the radial lines ca', cb', and cd' are not accurate from the datum plane through c. Points a and b have been moved outward and point d inward by relief distortion; thus, for the datum plane through c, the lengths ca' and cb' are too great, and the length cd' is too small. To construct an accurate chart for the datum plane through c, points a', b', and d' should be replotted at a, b, and d, respectively (par. 324). Except in comparatively flat terrain, it is necessary to consider the possibility of relief distortion when selecting points.

(4) When determining the scale of a vertical photo, it is desirable to select points of about the same altitude or, if the altitude differs materially, to replot one or both points to a selected datum plane. In case the points have the same altitude, the

scale is determined for the datum plane of these points; for example, 1/20,300 at 1,600 (feet altitude). If the locations of the points have been replotted to a selected datum plane, the scale determined is the scale for the selected datum plane.

(5) A scale determined by using one point in the target area and the other in or near the position area usually gives the best results because, while the scale obtained may not be the best for the photo as a whole, it is relatively the most accurate for determining distance from the position area to the target area.

327. CONVERTING PHOTO AND TRUE MEASUREMENTS. Photo measurements may be converted to true measurements (and true to photo) as follows:

a. By relation to any convenient scale. For example, the true ground distance between any two points identified on a photo has been determined to be 1,500 yards. Using any convenient plotting scale, the distance between the same two points on the photo measures 1,800 units. This relation is shown by the following equation:

$$\frac{\text{Photo measurement}}{\text{True measurement}}=\frac{1{,}800}{1{,}500}$$

Using the above equation, the conversion of photo measurements to true distances (and the reverse) may be accomplished quickly and accurately with a slide rule by setting the photo distance on the *C* scale over the true distance on the *D* scale (fig. 135). Using the measurements given above, the reading of 1,800 on the *C* scale is placed over the reading of 1,500 on *D* scale to set the rule for conversion. To convert a photo measurement of 2,100 units to true distance, locate 2,100 on the *C* scale and the true distance, 1,750, will appear directly below it on the *D* scale.

Figure 135. Method of using slide rule for conversion of photo measurements to true distances.

b. By use of the graphical firing table. When a photo is used as a firing chart, the conversion of photo measurements to firing data is accomplished automatically by use of the graphical firing table (TM 9–524).

328. MOSAICS. An uncontrolled mosaics is compiled by any one of several techniques involving matching of detail. A controlled mosaic is compiled by fitting the images of control points over their locations plotted on a control sheet; sometimes the prints must be rephotographed to bring them to the average scale, or must be rectified if they are appreciably tilted.

329. RESTITUTION. a. General. Restitution is the process of determining the map or chart locations of features appearing on air photos. The basic principle of accurate restitution is the assumption that, in photos taken with less than 3° of tilt, all angles measured at the center are true angles and that it is the only point on the photo where this is the case. Any method of restitution which makes use of this principle, using overlapping photos, gives accurate results. Any method which is based upon other angles or single photos will provide less accuracy, depending upon the amount of relief distortion of the given photo. Paragraph 340 describes methods of using oblique photos for this purpose.

b. Radial line method.

(1) *Use.* This method is used to restitute a point appearing in the overlap of two aerial photographs taken at different camera positions when the tilt of the camera is 3° or less.

(2) *Procedure.*

(*a*) Identify on each photograph three control points whose chart locations are known. A different set of points may be selected for each photograph or the same identical points may be used. The points selected should be well out from the center of each photo and so distributed that the rays drawn from them to the photo centers provide good three-ray intersections.

(*b*) Place tracing paper over the firing chart and prick the chart locations of the control points on the tracing paper.

(*c*) Draw rays from the center of each photo to the photo location of the control points.

(*d*) Place the prepared tracing paper over one photo so that the rays (drawn in (*c*) above) on the photo pass through corresponding control points on the tracing paper.

(*e*) Draw a ray on the tracing paper from the photo center to the point to be restituted.

(*f*) Repeat (*d*) and (*e*) above, using the second photo and the same tracing paper.

(*g*) Intersection of rays gives the tracing paper location of point to be restituted.

(*h*) Orient tracing paper over firing chart and transfer point to be restituted to the chart.

c. Polar plot method.

(1) *Use.* This method is used to locate targets when only a single vertical of the area is available or when there is insufficient overlap for radial line restitution. Since the angles used are not radial, inaccuracies from relief and tilt may be introduced.

(2) *Procedures.* Two or more well-separated points whose chart locations are known are identified on the photo. A line is drawn between these two points on both the photo and the chart. The line on the photo is extended to enable shifts and distances to be measured from either of the points with a range-deflection fan (par. 113**b**). The line on the chart is extended to enable shifts and distances to be plotted from either of the points with a range-deflection fan (par. 113**c**). The difference in scale between the photo and the chart is compensated for by measuring the photo and chart distances and by setting up a relation between the two on the slide rule. When a point is to be restituted from the photo to the chart, the photo shift and distance are measured from whichever known point will give the smallest angle and the largest distance. To reduce errors of relief and tilt, the base should be chosen to pass close to the center of the photo, and the base ends should be at about the same altitude. The photo distance is converted to chart distance by use of the established relationship. The desired point is plotted on the chart with the same measured shift and the true distance.

(*3*) *Example* (fig. 136). The chart locations of points *A* and *B*, which are identifiable on the photo, have been determined. It is desirable to restitute points to the firing chart from the photo. The *AB* line is drawn on the photo and on the chart and is extended as necessary to allow the range-deflection fan to be used with vertex at either *A* or *B*. The distance between *A* and *B* is measured on the photo (assume 4,000 yards) and on the chart (assume 5,200 yards). The photo-chart relationship is set up on the slide rule by placing 4,000 on the *C* scale over 5,200 on the *D* scale. To transfer point *T* from the photo to the chart, the fan is placed with its vertex at *B* on the photo, and the shift from *BA* line to *T* (R 405) and the distance from *B* to *T* (3,980 yards) are measured. Using the slide rule on which the photo-chart relationship is set up, the photo distance (3,980 yards) is con-

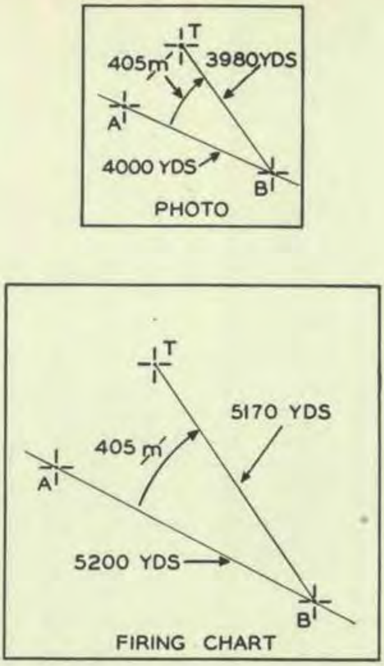


Figure 136. Polar plot method of restitution.

verted to chart distance (5,170 yards). The fan then is placed with its vertex at *B* on the chart, and *T* is plotted 405 mils right of the *BA* line at a distance of 5,170 yards from *B*. The transferred location of *T* is in error due to errors in the relative photo location of *T* with respect to the restitution points. This may be corrected as in paragraph 324.

(4) *Alternate polar plot method.* In the example above, the transferred location of *T* would include errors introduced by erroneous photomap locations of the restitution points *A* and *B*. A method of restitution, applicable to individual photos, which partially eliminates these errors is as follows:

(*a*) At least three points whose chart locations are known are identified on the photo. The photo center is determined.

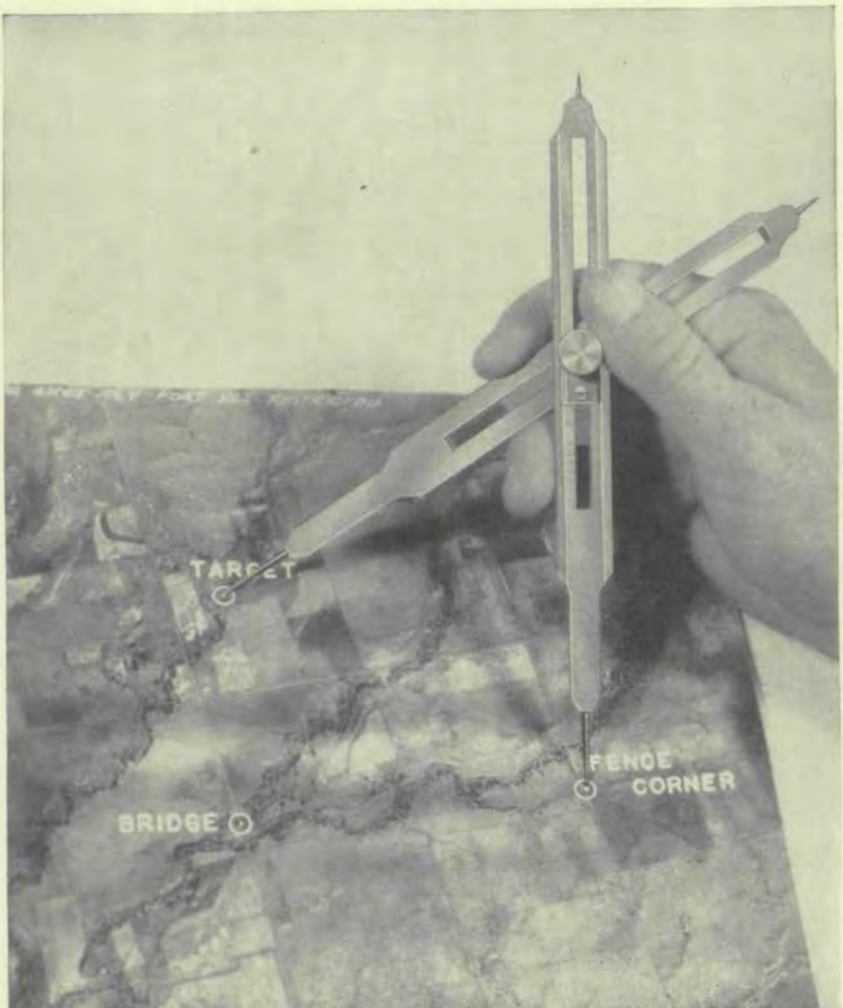
(*b*) An overlay is made from the photo showing the photo center and radial lines from the center through the three points.

(*c*) Using the overlay, the location of the photo center is resected (par. 299**a**) to the chart.

(*d*) When the photo center has been located on the chart, the procedure for transferring points is the same as in (2) above, except all measurements on the photo and all plotting on the chart are performed with the vertex of the fan at the photo center.

d. Proportional dividers.

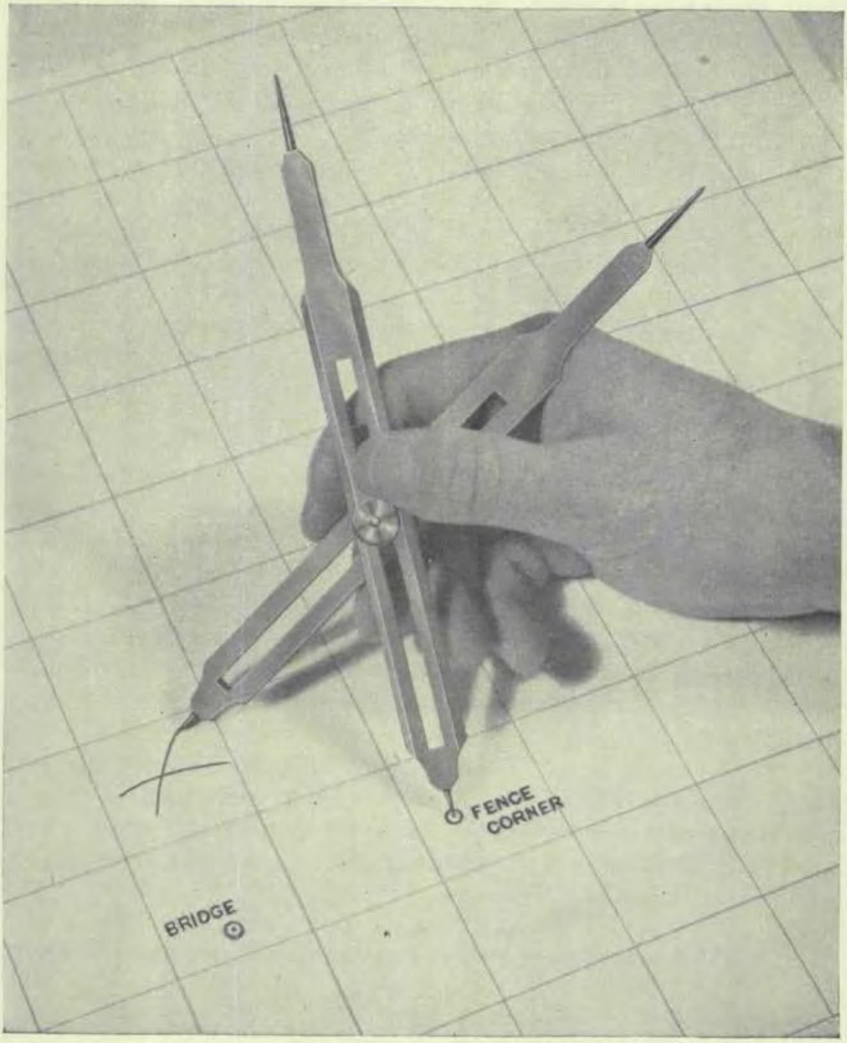
(1) *Description.* The most rapid method of restitution is by use of proportional dividers (fig. 137). This instrument consists of two legs, each pointed at both ends, which are held together by means of a central pivot. When the legs are opened in the form of an "X," either end of the instrument forms a pair of ordinary dividers. The position of the pivot along the legs can be varied to produce any desired ratio of the distance between one pair of points to the distance between the other pair of points. With the pivot at a fixed setting,



① Use of photo end of proportional dividers.

Figure 137.

distances are taken off the photo with one end of the proportional dividers, and laid off on the chart with the other end.



② Use of chart end of proportional dividers.

Figure 137—Continued.

(2) *Use.* To restitute points from photo to chart, proceed as follows:

(*a*) Select two restitution points which appear both on the photo and on the chart. In figure 137, the two points selected are the bridge and the fence corner.

(*b*) By trial and error, adjust the pivot so that, when the points on the photo end of the dividers match the two restitution points on the photo, the points on the chart end will match the two restitution points on the chart.

(*c*) Using the photo end of the dividers, lay off the distance from the first restitution point to the point to be located. Without disturbing the adjustment, reverse the dividers and strike an arc on the chart from the first restitution point through the point to be located.

(*d*) Repeat this procedure from the second restitution point. The location of the point on the chart is at the intersection of the two arcs drawn. If a third restitution point is available, another arc is drawn to give a check on the location determined from the first two.

(*e*) Once the pivot of the dividers is set to the proper photo-chart ratio, all points on any particular photo may be restituted to the chart without disturbing the adjustment of the pivot.

e. Stereoscopic coverage. Normal methods of restitution do not include adequate means of determination of vertical control. Stereoscopic coverage aids in the determination of relative altitudes and aids photo interpretation. (See FM 21–26.)

330. PHOTO STRIPS. A photo strip is a series of vertical photographs taken by a single airplane along a given course. The photographic exposures are taken at predetermined intervals to give the desired overlap between successive exposures. The percentage overlap is the amount of any one photo of the strip which appears also on the next successive photo. The ideal overlap for photo interpretation and radial line plotting is 60 percent. However, 25 percent overlap is considered sufficient for the construction of uncontrolled mosaics and reconnaissance plotting.

331. USE OF PHOTO STRIPS IN THE PREPARATION OF FIRING CHARTS. Firing charts are prepared from photo strips by the radial line method of plotting whenever possible, since this technique gives the most accurate results. The reconnaissance method, which gives fair results, is somewhat simpler. This method is applicable when the overlap is less than the 50 percent required for the radial line method.

332. RECONNAISSANCE METHOD. a. This technique may be used for constructing a firing chart from photographs overlapping only 25 to 50 percent. The first step is to mark the center of each photo. The photo center is the geometric center of the photo and is determined by the intersection of lines through the corners of the photo or through the collimation marks along the edges of the photo (fig. 138).

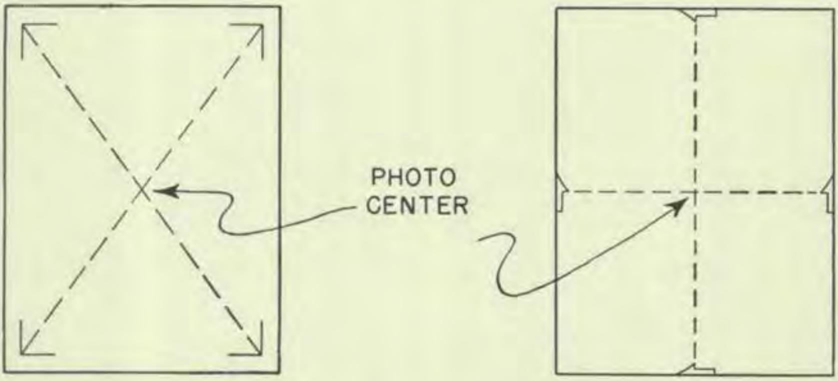


Figure 138. Locating photo centers.

b. Two common points of sharply defined detail, *a* and *b*, are selected on each pair of overlapping photographs, pricked accurately, and circled. These points must fall in the overlap, as far apart as practicable, and close to the line between the photo centers when the overlapping portions of the photographs are superimposed.

c. To plot the control (fig. 139), place a sheet of acetate over the first photo of the strip. Prick points *a* and *b* on the acetate and draw a fine pencil line through the two points. Also trace the photo center and all collimation marks. Label the photo center. Place the acetate over the second photo so that point *a* on the acetate falls on point *a* on the photo, and the line *a-b* on the acetate passes through point *b* on the photo. Point *b* on the acetate may or may not coincide with point *b* on the photo. If it does not, prick point *b′* on the acetate halfway between the two points. Shift the acetate until point *b′* coincides wih point *b* on the photo. Trace the photo center and all collimation marks. Also pin prick points *a* and *b* for the next photo and connect the two with a fine pencil line. Place the acetate over the third photo and proceed as before.

d. Orientations must be made with all possible care. This necessitates that, both on the photographs and on the acetate, dots and lines must be fine and accurately placed. It will be seen that orientations are made as accurately as the limited overlap allows, but the distances can be obtained only approximately because distortions of tilt and relief and changes of the scale of the photographs, due to variations of flight altitudes, are not corrected.

e. There are various ways in which the reconnaissance plot may be used as a firing chart.

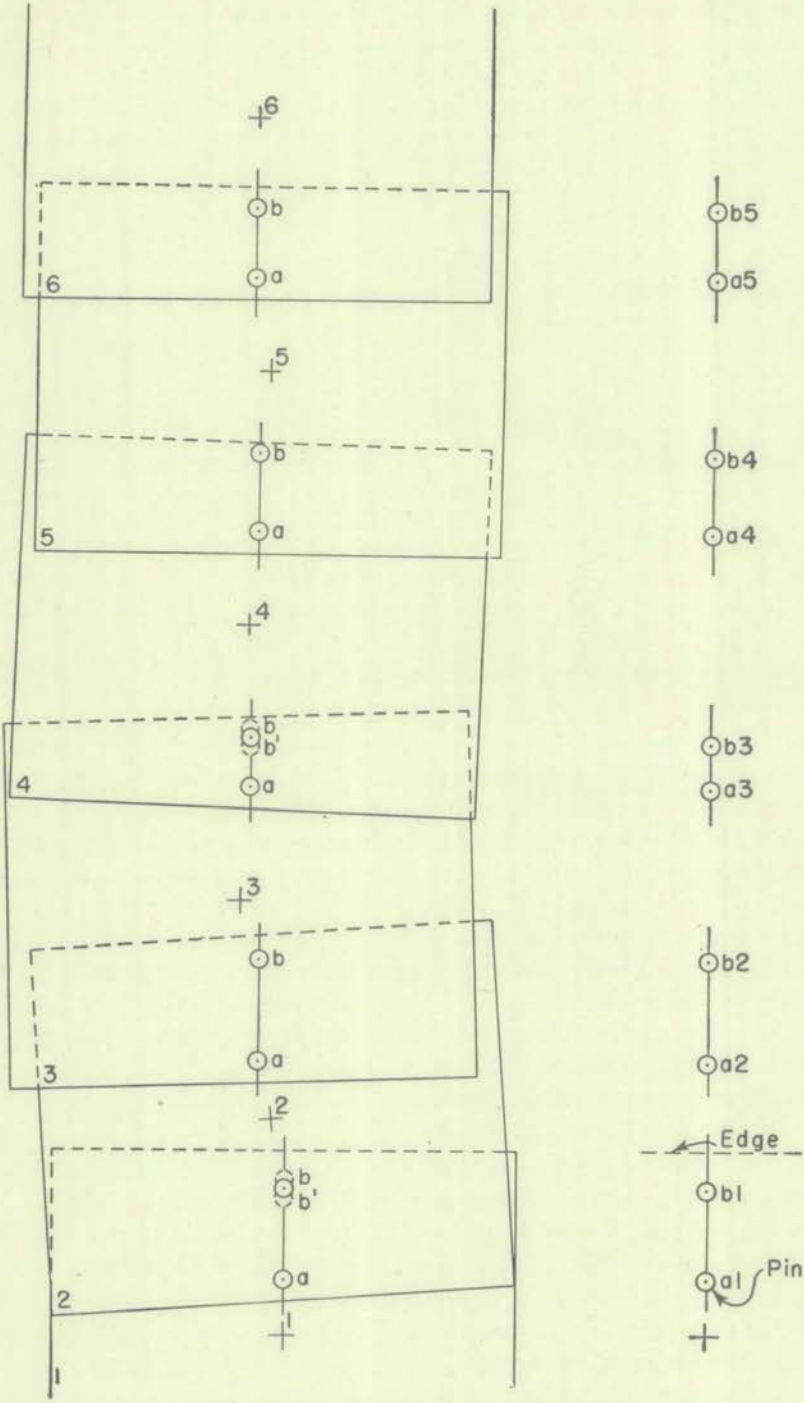


Figure 139. Reconnaissance plotting.

(1) The acetate plot may be used as a guide to assemble a mosaic which then is used as the firing chart.

(2) The acetate plot may be used as the firing chart, and points plotted on it from the individual photos.

(3) A grid sheet may be used as the firing chart, and the reconnaissance plot with a grid superimposed is used as a restitution device to transfer points from the photos to the grid sheet.

333. SUPERIMPOSING A GRID. a. General. The reconnaissance plot can be improved as a firing chart by determining its scale and superimposing a 1,000-meter grid upon it.

b. Determination of scale. The scale of the reconnaissance plot can be determined by either of two methods—the relationship of altitude to focal length, or by comparison of a photo distance with a corresponding ground distance. (See par. 326.) The first method is not reliable; whenever possible the latter method should be used.

c. Construction of the grid (fig. 140). Select at least two ground control points (photo points whose ground locations are known). Three or four will give much more accurate results and should be used when possible. Choose the X (or Y) grid line which passes nearest to all ground control points and determine the distances along the Y-axis (X-axis) to the chosen grid line from the various control points. This can be accomplished by comparing the coordinates of the ground control points to the chosen grid line. These distances then can be converted to photo units by applying the photo-ground relationship. Draw an arc from each ground control point toward the chosen grid line, using the distances in photo units corresponding to the ground distances as the radii. Using a straightedge, draw the chosen grid line, as nearly tangent to all arcs as possible. If a single line cannot be drawn tangent to all arcs, the two arcs farthest apart should establish the line's direction; the position is adjusted to balance the error. The second grid line should be perpendicular to the first and approximately centered among the ground control points. Determine the distances from the ground control points to the second grid line and draw the arcs as for the first grid line. Draw the second grid line perpendicular to the first grid line and as nearly as possible, tangent to the arcs. Use as protractor placed so that the center and the 1,600-mil mark are on the first grid line. Move the protractor along this line until the edge is tangent to the proper arcs or until the errors are balanced. In adjustment of errors, it is important not to compromise the perpendicularity of the two grid lines. These first two grid lines then are used as a framework on which to draw the remainder of the grid lines. Determine the chart distance in inches which represents 1,000 meters on the ground and lay off this distance in order to construct lines parallel to those already drawn.

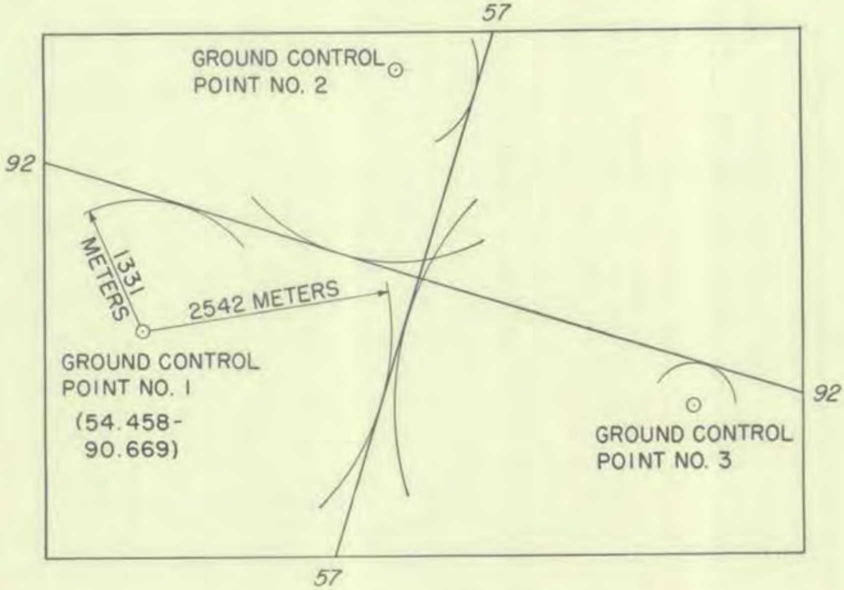


Figure 140. Superimposing a grid.

d. Use. This method is particularly applicable to the reconnaissance plot but can be used with any type of mosaic or photo if the results gained are desirable in the particular situation.

334. RADIAL LINE PLOTTING. a. General. The most accurate method of combining the data of two or more photographs to make a firing chart is by radial line plotting. This technique is applicable only when the photos have an overlap of more than 50 percent. If a photo strip has an overlap of 50 percent or less, the reconnaissance method of plotting is used.

b. Procedure. The preparation of a firing chart by this method can be broken down into three steps:

(1) *Marking the photographs.* This step consists of marking the necessary photo control on the photos.

(2) *Preparation of the radial line plot.* In this step, a tracing to the photo scale is made of the photo control points marked in the first step.

(3) *Preparation of the control sheet.* In this step, the plot of the photo control points is reduced to the scale of the firing chart and placed in its correct position relative to the grid.

c. Use of control sheet. The firing chart is either a battle map or a plain grid sheet. The control sheet is used as a restitution device for transferring points from the photos to the firing chart.

335. MARKING THE PHOTOGRAPHS. a. Marking of photo centers. The first step in the preparation of the photos is to locate and mark the center of each photo.

b. Drawing the course line. The course line may be defined as the line connecting the centers of adjacent overlapping photos. To mark the course lines on the photos, proceed as follows:

(1) Place the first two photos of the strip side by side, each oriented so the common side is toward the other photo. Fasten the photos to the drawing board by sticking a pin through the center of each photo so the photos will be free to rotate about their centers. Place a straightedge against the two pins as shown in figure 141.

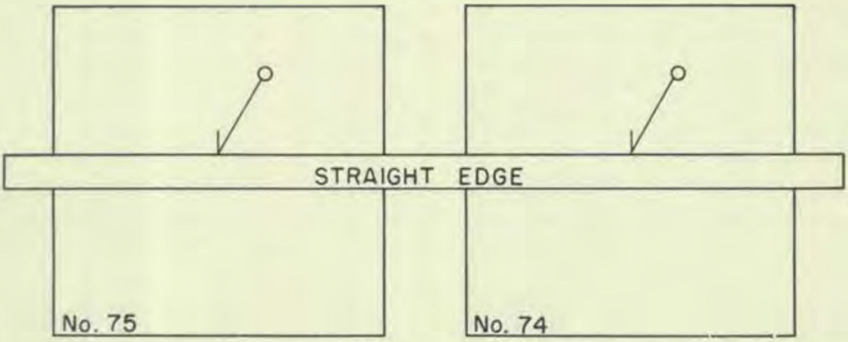


Figure 141. Placement of photos preparatory to marking the course lines.

(2) Rotate the two photos until the same photo detail of each appears along the straightedge. This can be accomplished best as follows: Examine the photo detail around the center of the first photo. Rotate the second photo until the corresponding detail is along the straightedge. Examine the photo detail around the center of the second photo. Rotate the first photo until this same detail appears along the straightedge. The photos are only approximately oriented at this point. The final orientation is made by bringing corresponding detail as near as possible to the edges of the photos into coincidence with the straightedge, thus taking advantage of the full width of the area of overlap.

(3) When the photos are oriented, pull the pins from the photo centers and mark the course line on both photos with a needle point. Also mark an extension of each course line on the

opposite side of the photo. The photos now will appear as shown in figure 142.

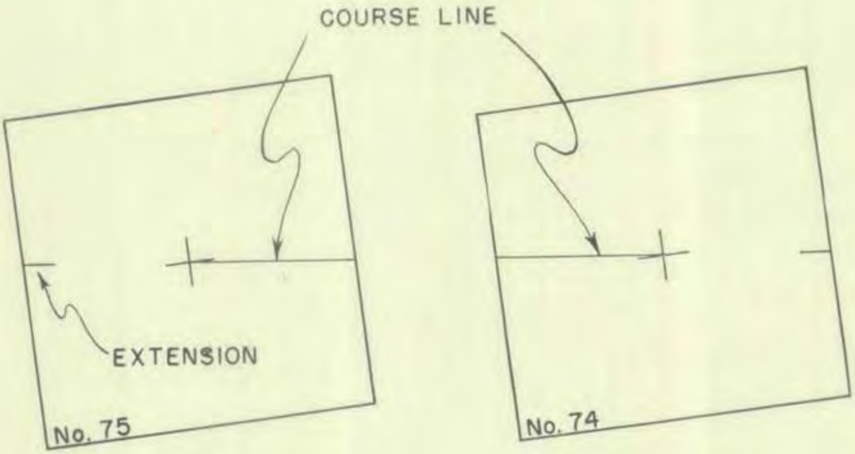


Figure 142. Marking the course lines and extensions.

(4) Mark the course lines for the second and third and all other photos of the strip in the same manner.

c. Selecting and marking wing points.

(1) Wing points are photo control points used in radial line plotting. Each photo must have two primary wing points, one near the center of each edge of the photo that is roughly parallel to the course line (fig. 143). These same wing points must appear on both adjacent photos as secondary wing points. Since the wing points will be located by intersecting rays from the adjacent photo centers, they should be selected to provide the most desirable angle of intersection.

(2) To select wing points, the photos should be arranged as shown in figure 143. In this example, the upper primary wing point for photo 74 is being selected. In this manner, it can be verified that the secondary wing points appear on both the adjacent photos, and then they are marked on all three photos.

(3) When all wing points are selected and marked, the next step is to mark a fine radial line with a needle point through each wing point directed from the photo center. These lines should be about two inches long. When this is completed, each photo (with the exception of the end photos of the strip) will appear as in figure 144. The end photos will lack the secondary wing points and course line on one side.

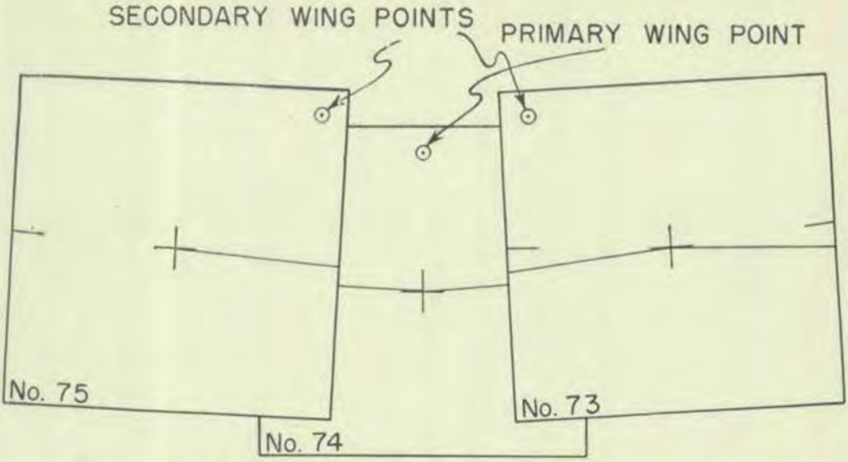


Figure 143. Selecting and marking wing points.

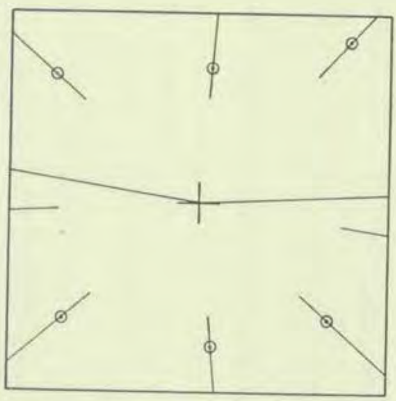


Figure 144. Photo after marking.

336. PREPARATION OF THE RADIAL LINE PLOT. a. Approximate orientation. Having prepared all of the photos in the strip as outlined above, the next step is to prepare the radial line plot. It is preferable to prepare this plot on acetate, but other materials may be used in emergencies. The photos first are fitted together roughly to determine the general direction and size of the strip, and to determine where to start the plot so that it will not run off the sheet as it is carried forward.

b. Plot of control from the first photo (fig. 145). Place the acetate over the first photo and, using a sharp, hard pencil, trace the photo center, the course line to the second photo, and the radial lines through all wing points. When alining the straightedge to trace the course line, take advantage of the course line extension on the opposite side of the photo. Trace an extension to the course line in the direction of

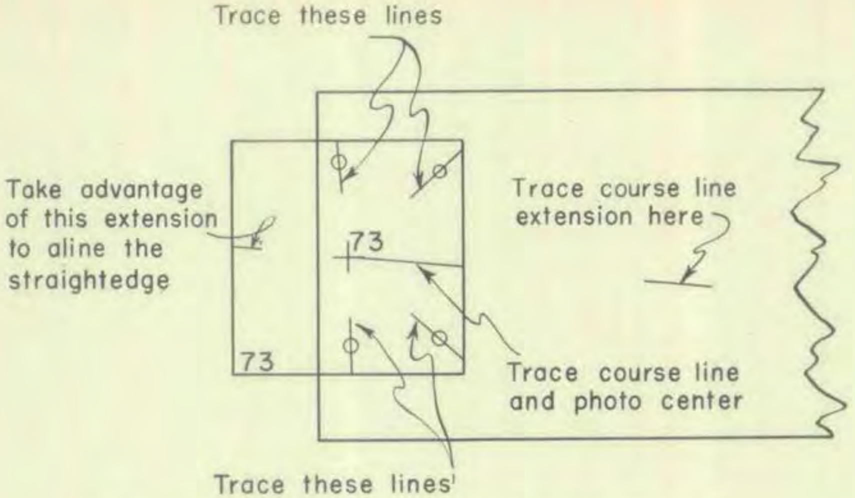


Figure 145. Control traced from the first photo of the strip.

the second photo and approximately half a photo distance beyond the first photo.

c. Orientation and plotting of control from the second photo (fig. 146).

(1) Place the acetate over the second photo so that the common course line traced from the first photo falls on the corresponding course line on the second photo. The extension traced from the first photo should fall on the course line extension on the opposite side of the second photo.

(2) Move the acetate, keeping the course lines in coincidence, until the rays traced through the wing points from the first photo pass through, or nearly through, the corresponding wing points on the second photo. If these rays do not pass through the wing points, it will be because the wing points are distorted from their true location on the photos. As long as the course lines are kept in coincidence, any position of the acetate over the second photo will yield an accurate plot. The only effect of different positions of the acetate will be to vary the scale of the plot. However, it is desirable to make the plot on the acetate as near as possible to the average scale of the photos. Therefore, the amount by which the rays traced from the first photo miss the corresponding wing points on the second photo should be balanced. In other words, one ray will pass to the left of its wing point, while the other ray will pass an equal distance to the right of its wing point. (Consider only the primary wing points of the second photo.)

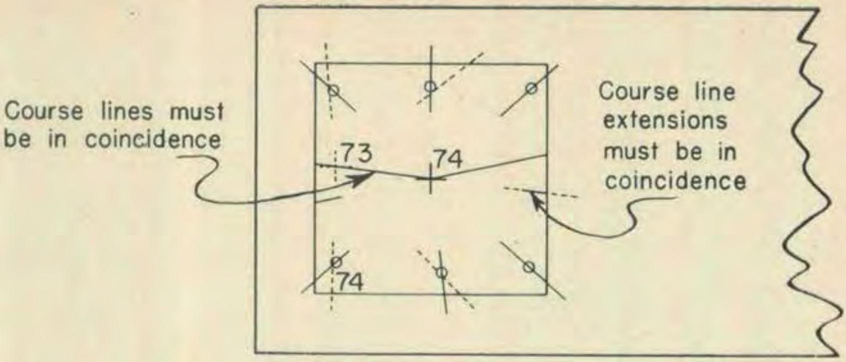


Figure 146. Orientation of the second photo of the strip.

(3) With the acetate in position over the second photo so the course lines are in coincidence and the primary wing point errors are balanced, trace the photo center, course line to the next photo, and the radial lines through all wing points. The correct relative locations of the wing points of the first two photos are at the intersection of the wing point rays.

d. Orientation and plotting of control from the third and all subsequent photos (fig. 147).

(1) Place the acetate over the third photo so that the course line on the acetate falls on the corresponding course line of the photo. Slide the acetate, carefully keeping the course lines in coincidence, until the rays on the photo through the wing points coincide, or nearly coincide, with the intersections of the corresponding wing point rays on the acetate.

(2) If it is impossible to obtain exact coincidence of the wing point rays and the intersections on the acetate, an error probably has been made. Course lines and identification of wing points should be checked. Triangles of error are permissible only if time is very limited and less than maximum accuracy

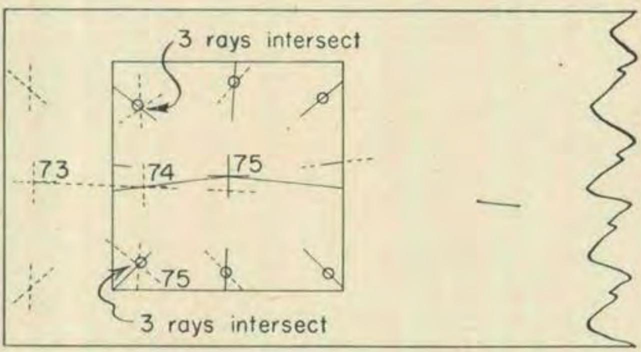


Figure 147. Orientation of the third photo of the strip.

is acceptable. In this case, slide the acetate until the smallest possible triangles of error are obtained and opposite triangles are equal.

(3) Trace all photo control on the acetate.

337. PREPARATION OF THE CONTROL SHEET. a. General. In order to reduce the plot on the acetate to a selected scale, two or more ground control points are necessary. Ground control points are points of known coordinates appearing on the photos.

b. Preparation. To prepare a control sheet, proceed as follows:

(1) Plot the ground control points on the radial line plot by intersecting radial lines in the same manner as the wing points were plotted. (See fig. 148.)

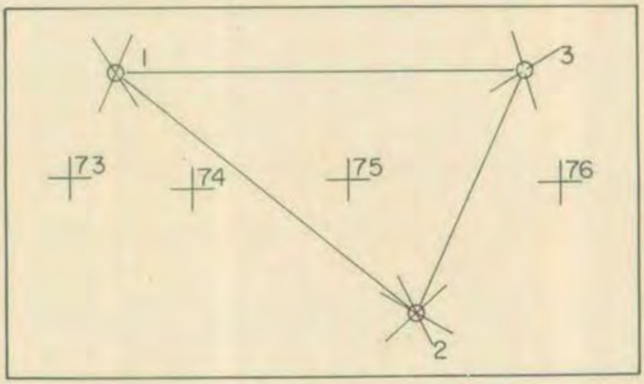


Figure 148. Radial line plot showing ground control points 1, 2, and 3.

(2) Plot the same ground control points on a sheet of gridded acetate according to their grid coordinates. The gridded acetate is called a control sheet, and the grid should be to the same scale as that of the firing chart.

(3) Place the control sheet over the radial line plot, matching one of the ground control points. Orient the control sheet so that all other ground control points lie in the direction of the corresponding points on the radial line plot. Draw rays from the first ground control point in the direction of all photo centers and wing points on the radial line plot.

(4) Repeat the above procedure, using one or more other ground control points. The correct locations of the photo centers and wing points on the control sheet are at the intersections of the rays drawn from the ground control points (fig. 149).

(5) It is possible to orient each photo under the control sheet, using both adjacent photo centers and all wing points in the

orientation. This is done as follows: Place the control sheet over the photo so that the center of the photo is under the corresponding photo center shown on the control sheet. Rotate the control sheet until the adjacent photo centers fall on the corresponding course lines. The wing points should fall on the rays marked on the photo. If all points do not match, make a slight adjustment to balance the errors. This procedure will give the best possible orientation. Place a short ink tick mark on the control sheet over each of the side collimation marks on the photo. When this is done, the wing points on the control sheet may be erased and these tick marks used for subsequent orientation. This will enable the control sheet or any reproduction of it to be used in conjunction with any copy of the photos used in its preparation, and eliminate the necessity of having course lines and wing points plotted on the photos.

c. Use of the control sheet. To locate points on the firing chart, using a control sheet, proceed as follows:

(1) Identify the point on one photo and place the control sheet over the photo, matching the photo center and orienting so that the side collimation marks are in alinement. Draw a radial line through the point to be located. Identify the same point on an adjacent photo and repeat the above procedure. The correct location of the point is at the intersection of the radial lines.

(2) Place the control sheet over the firing chart and prick the point through. Erase the pencil marks on the control sheet so they will not be confused with rays drawn for the location of subsequent points.

d. Two or more adjacent photo strips. Two or more photo strips may be plotted on the same control sheet independent of each other and regardless of their scales as long as there are at least two ground control points for each strip. Any points already plotted on the control sheet may be used as ground control points for the plotting of subsequent photo strips.

338. DISSEMINATION OF CONTROL. In order to facilitate coordination among units for the massing of fires, control may be transmitted to other units as follows:

a. Reconnaissance method. The headquarters making the original plot may send the photos to each of its subordinate units along with a copy of the reconnaissance plot with the photo centers and collimation marks plotted thereon.

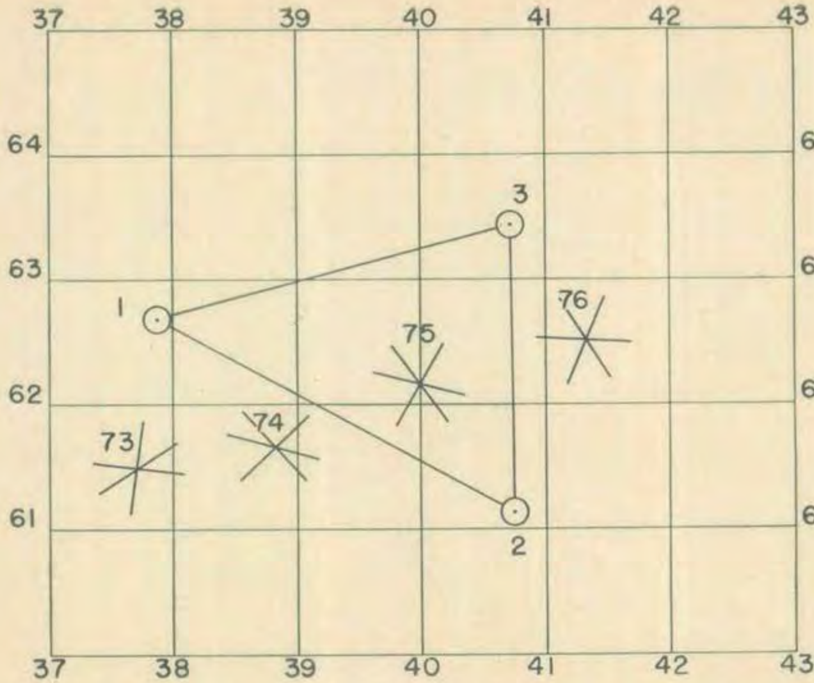


Figure 149. Control sheet showing plot of photo centers reduced to scale of the chart.

b. Radial line method. Control is furnished to subordinate units by giving them a copy of the control sheet along with copies of the photos from which it was prepared.

Section III. OBLIQUE PHOTOGRAPHS

339. GENERAL. a. The mil-gridded oblique pictures the terrain substantially as it would be seen by an observer looking through an instrument having a fully graduated reticle and located at the point occupied by the camera at the instant the photo was taken (fig. 150). The vertical and horizontal grid lines have 20-mil graduations with which horizontal and vertical angles may be read. If successive camera stations represent ends of a base, and the gridded photos include a reference point the location of which is known, the principles of graphic intersection may be employed to transfer points from mil-gridded obliques to firing charts or maps.

b. Mil-gridded obliques are used to determine the horizontal and vertical loeations of points. Horizontal locations of points obtained from gridded obliques are not as accurate as those obtained from vertical photos. Therefore, obliques should not be used for this purpose when verticals are available. Gridded obliques, however, may be used to good advantage in conjunction with charts prepared by the radial line or reconnaissance method for the purpose of determining altitudes.

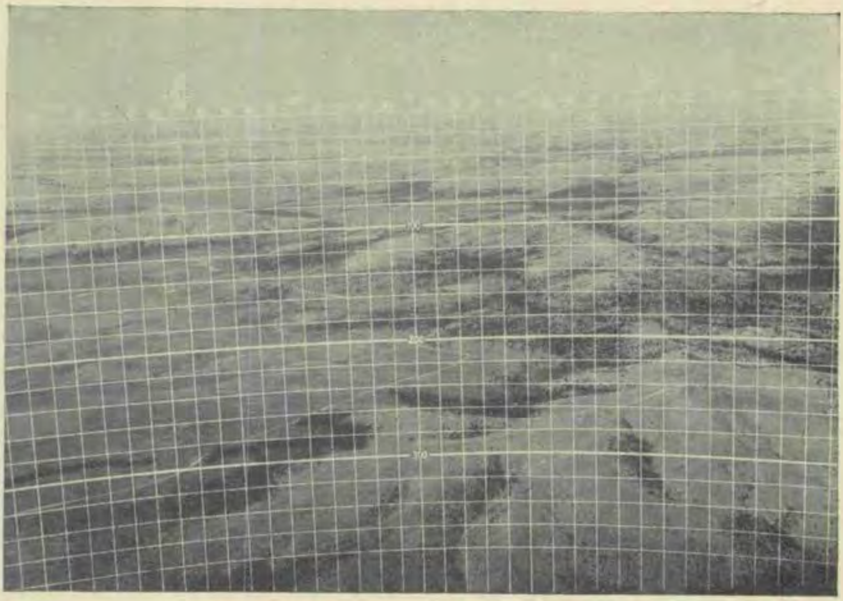


Figure 150. Mil-gridded oblique photo.

c. The following terms are used in conjunction with mil-gridded obliques:

(1) Plumb point—the map location of the camera at the instant the oblique photo was taken.

(2) Center line—the map projection of the vertical plane containing the axis of the camera at the instant the photo was taken. On the photo, the center line appears as the zero line from which right and left angular measurements are taken. On the chart, the center line appears as the direction line from which the right and left angular measurements are plotted (fig. 151).

340. HORIZONTAL LOCATIONS. a. Orientation of photographs. Orientation is accomplished by determining the chart locations of plumb points and the chart direction of center lines.

(1) *Location of plumb points.* The tracing paper method of resection (par. 299**a**) can be used to determine the chart locations of plumb points. The chart locations of three or more ground control points appearing on each photo are necessary.

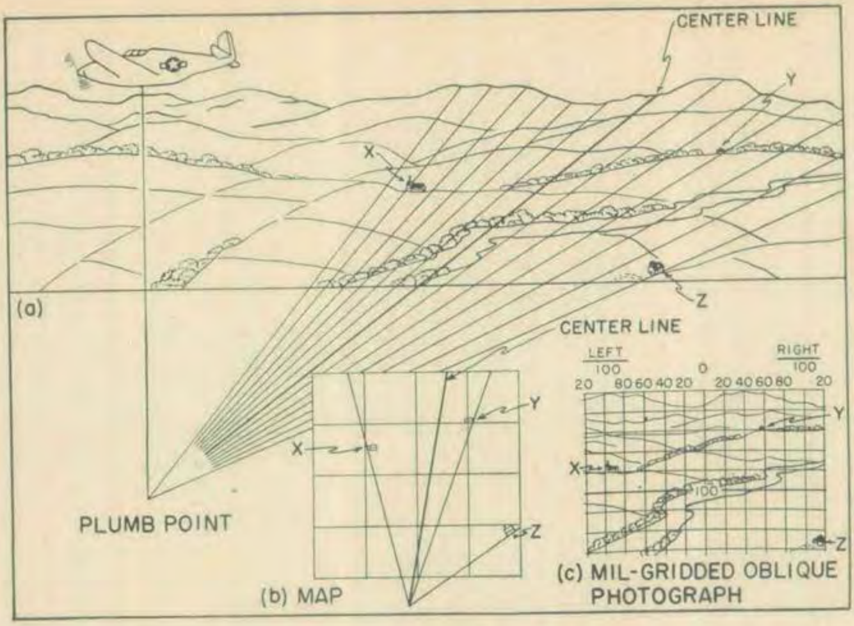


Figure 151. Plumb point and center line.

These chart locations may be determined by survey or may be taken from a map or vertical photo. In the case of the observed firing chart, the relative locations of the ground control points may be determined by firing. In preparing the tracing paper to be used in the resection, the horizontal angle from the center line to each ground control point is read on the mil grid and plotted on the tracing paper with a protractor or range-deflection fan. The tracing paper then is placed over the chart in a position so that the ray toward each control point passes through the chart location of the same point. The plumb point is pricked through to the chart.

(2) *Location of center lines.* With the tracing paper in the same position as above, any convenient point on the center line is pricked through to the chart.

(3) Each plumb point and center line must be labeled with its photo number, and center lines are marked with identifying arrows, as in fire-direction technique.

b. Transposition of points from obliques to charts.

(1) *Point designation.* Oblique coordinates are announced as "Photo 58, L156042." The photo number designates the photo from which the reading was taken. The letter "L" or "R" indicates a reading left or right of the center line.

The first three figures represent the horizontal angle from the center line. The last three figures represent the vertical angle from the zero, or level line.

(2) *Plotting the point.* Points are located from oblique photographs by the plot of the intersection of two or more lines of sight. *Example:* Assume that an observer sent in the following message, "PHOTO 59, R210118, INFANTRY PLATOON WITH HEAVY WEAPONS, REQUEST BATTALION, FIRE FOR EFFECT." Fire-direction personnel identified the same point on photo 60 as L060 and on photo 61 as L305. The target would be plotted as in figure 152.

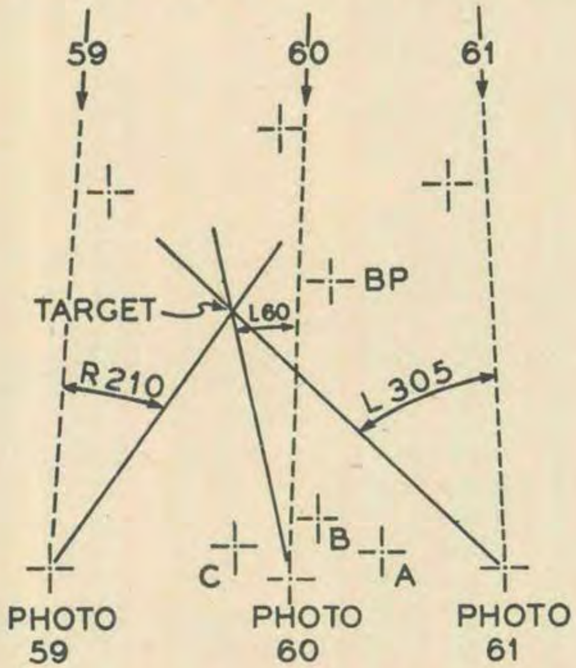


Figure 152. Location of a target on the firing chart.

341. DETERMINATION OF ALTITUDES. a. Altitude of the camera. The altitude of the camera may be determined from the altitude of the terrain appearing on the photograph Assume that a house appears at a vertical angle of 100 mils in photo 59 (fig. 153), and its distance on the firing chart from the plumb point of photo 59 is 3,500 yards. Figure 153 shows the relations that exist. From the mil relation, $W = m \times R$, the vertical interval between camera and the house is determined to be 350 yards. The altitude of the house, as established by survey, is 300 yards. The altitude of the camera is, therefore, computed to be 650 yards.

b. Altitude of the target. The altitude of a target is computed from an oblique photograph after the altitude of the camera has been

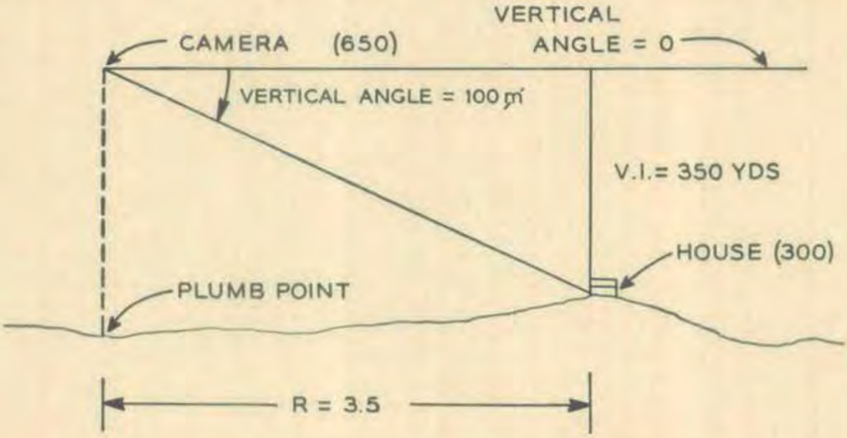


Figure 153. Determination of the altitude of the camera.

determined. *Example:* A target is reported by oblique coordinates "Photo 59, R210118." The target has been plotted and the chart distance from the plumb point to the target is 3,200 yards. By the mil relation, the vertical interval between the camera and the target is 118×3.2=378 yards. The vertical interval is subtracted from the altitude of the camera. The altitude of the target is 650−278=272 yards.

c. Determination of altitudes, using oblique photo in conjunction with chart prepared from vertical photos. The plumb point of the oblique must be located on the firing chart. This may be done by resection, using points taken from the vertical photos as ground control points. Distances from the plumb point to points whose altitudes are desired are measured on the chart. These distances then are used in conjunction with the vertical angles read on the oblique to determine altitudes.

342. CORRECTIONS FOR MISPLACED MIL GRID. a. General. A grid may be placed inaccurately because of errors of technique or because haze or ground forms may make the location of the apparent horizon uncertain. Ordinarily, placing of the grid will be performed with sufficient accuracy to reflect little or no error in horizontal angles. However, vertical angles read from a misplaced grid will, in most cases, give unsatisfactory altitudes and will require the application of corrections.

b. Camera altitude. To correct for a misplaced grid, three ground control points are required. The points must appear on the photo and have known chart locations and altitudes. In figure 154, the three ground control points are E, F, and G. Each of these points is used to compute the altitude of the camera. If the camera altitude is obtained from all three points, the grid is placed properly and no corrections are required. If different camera altitudes are obtained from each point, the middle altitude of the three is used as the *effective camera altitude*. In figure 154, the three altitudes computed are 650 yards, 638 yards, and 666 yards using E, F, and G respectively. Since the altitude computed from E (650 yards) is the middle altitude of the three, 650 yards is used as the effective camera altitude.

c. Line of zero correction. Having accepted 650 yards as the effective camera altitude, compute the altitude of F. The vertical interval remains the same; therefore, the altitude of F is computed to be 12 yards higher than it actually is. The altitude correction at F, then, is —12 yards. Similarly, it can be shown that the altitude correction at G is +16 yards. The total altitude correction from F to G is 28 yards. Since F has a minus correction and G has a plus correction, there must be some point on the chart between these two points which has a zero correction. This point, H, is found by interpolation between F and G and is 12/28 of the distance from F to G. The line EH, then, contains all points for which the altitude correction is zero and is called the *line of zero correction.*

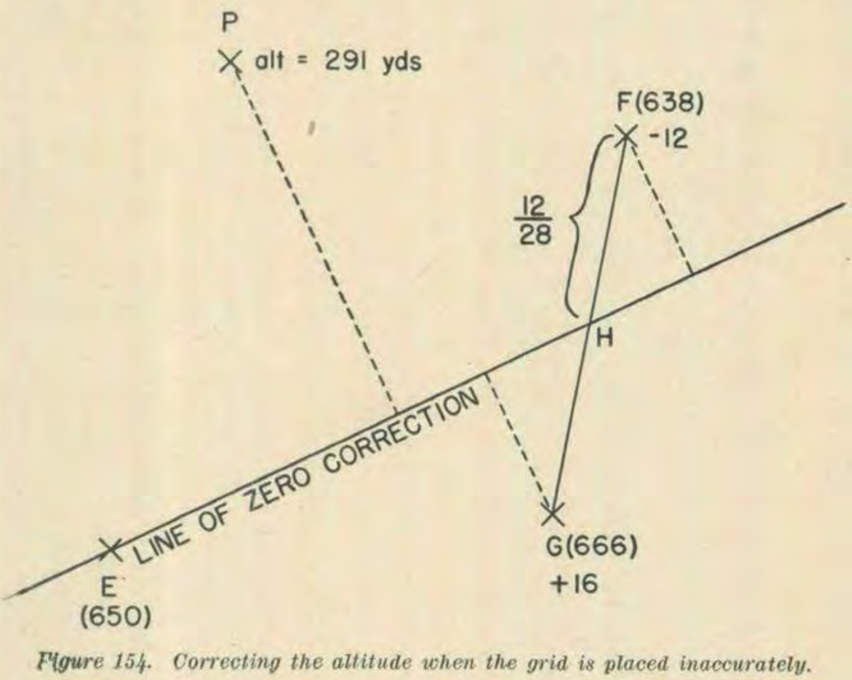


Figure 154. Correcting the altitude when the grid is placed inaccurately.

d. Altitude corrections. The correction applicable to the altitude of any point not on the line of zero correction is proportional to the perpendicular firing chart distance of the point from the line of zero correction. The altitude correction per 1,000 yards distance from the line of zero correction is established by the points *F* and *G*. The altitude correction per 1,000 yards is equal to the total altitude correction (28 yards) divided by the sum of the perpendicular distances (in thousands of yards) from *F* and *G* to the line of zero correction. Assume *F* to be 520 yards from the line of zero correction, and *G* to be 700 yards from this line. The sum of these distances is 1.220 thousands of yards. The altitude correction is $28 \div 1.220$ or 23 yards per 1,000. On the *F* side of the line of zero correction, the correction to the altitude determined, using the effective camera altitude, is -23 yards per thousand yards from the line. On the *G* side of the line of zero correction, the altitude correction is $+23$ yards per thousand.

e. Example. Based on the effective camera altitude, the altitude of point *P* is computed to be 343 yards. The chart location of this point is on the *F* (minus) side of the line of zero correction and at a perpendicular distance of 2,260 yards from the line. The correction would be $-23 \times 2.26 = -52$ yards. The corrected altitude of the point, then, is $343 - 52 = 291$ yards.

f. Correction scale. If several altitudes are to be determined from a single oblique, the determination of these altitudes will be facilitated by the construction of a vertical angle correction scale for the photo. This is done as follows:

(1) Determine the true camera altitude by applying the proportion in **d** above, to the plumb point. The correction computed for the plumb point is applied to the effective camera altitude to determine the true camera altitude.

(2) Determine the true vertical angles for each of the three ground points *E*, *F*, *G*. This is done by use of the mil relation since the altitude of each point, the altitude of the camera, and the chart distances from the camera to each point are known.

(3) Determine the vertical angle correction at each ground control point by comparing the true vertical angle (computed above) with the vertical angle measured on the oblique photo. With a grease pencil, mark these corrections on the top of the mil grid and directly above the appropriate ground control points. The vertical angle correction scale now can be filled in by inspection since the corrections change uniformly as the horizontal angle changes (fig. 155).

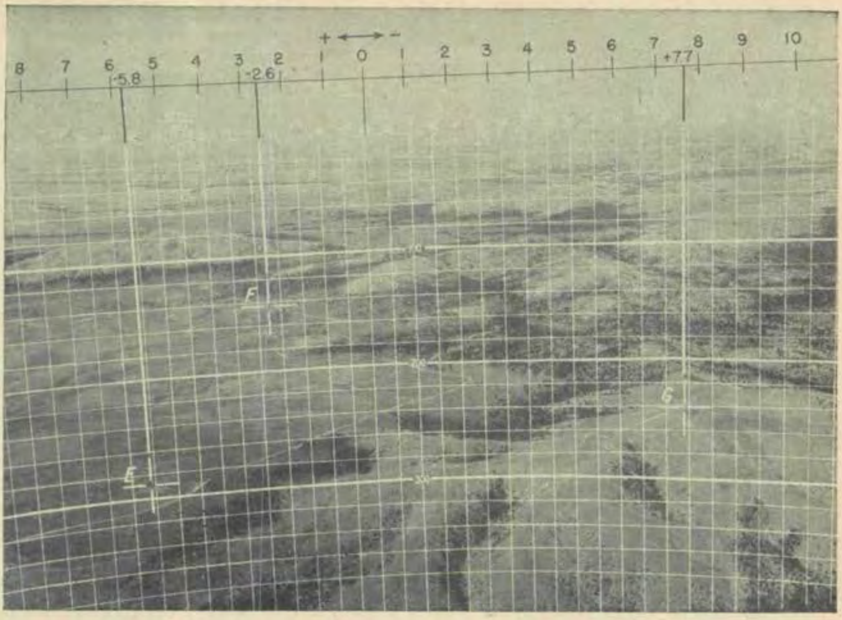


Figure 155. Vertical angle correction scale.

(4) To use the vertical angle correction scale, correct any vertical angle measured on the mil grid by the amount of the figure read on the correction scale directly above the point concerned. The correct altitude of the point is determined by using the corrected angle and the firing chart distance in conjunction with the mil relation to obtain the vertical interval between the camera and the point. The vertical interval is subtracted from the true camera altitude.

CHAPTER 27

SURVEY PLANNING AND EXAMPLES

Section I. FACTORS IN SURVEY PLANNING

343. COMMANDER'S RESPONSIBILITY FOR SURVEY. The artillery commander is responsible that his unit delivers the most effective fire support at all times (FM 6–20). In order to facilitate the delivery of such fire support, the commander has certain duties to perform with staff assistance (FM 6–101). A few requirements are as follows:

a. The commander must foresee the requirements for maps, photomaps, and battlemaps, and make sufficient distribution, in order that the best is available for use as a firing chart.

b. The commander must make plans to augment survey by obtaining proper coverages by aerial photographs, thereby permitting the location of targets beyond the normal means of ground survey.

c. The commander must establish a standing operating procedure and conduct training so that, with minor changes, the procedure will fulfill the requirements of most situations. Items which lend themselves to standardization include—

(1) Assumed control on the grid sheet.

(2) Loading charts for survey personnel.

(3) Use of battery (battalion) personnel.

d. The commander should furnish the survey officer the information necessary for preparation of a detailed survey plan and insure that the plan will enable the unit to fulfill its mission.

344. INSTRUCTIONS TO SURVEY OFFICER. The commander must furnish the following information, which is vital to the survey officer in formulating his plan:

a. Situation. The survey officer must be familiar with the situation, to include—

(1) Mission of the unit.

(2) Status of registration.

(3) Time available for survey.

(4) Normal and contingent zones of fire.

(5) Front lines.

b. Firing chart to be used. The type of firing chart to be used depends upon the topographical information available, time available, and the mission.

c. Survey control from higher echelons. This includes the location and the time survey control is to be made available. If no control is available, arrangements are made for assumed control.

d. Designation of base point and check points. The base point, reference points, and check points should be pointed out on the ground and definitely identified to the survey officer.

e. Location of observation posts and fire-direction center. The location of observation posts must be identified on the ground. The location of the fire-direction center must be known to survey personnel.

f. Location of position areas.

g. Restrictions on radio and routes.

h. Location of countermortar radar set. In the case of battalions equipped with countermortar radar, its location must be pointed out on the ground to the survey officer.

i. Assistance to be given to reinforcing or attached artillery.

j. Available personnel. The battalion (division artillery) survey officer should be informed if battery (battalion) survey personnel are to be made available to him.

345. SURVEY PLANS. The unit survey officer is responsible for the preparation and execution of detailed survey plans (FM 6–101), which must conform to instructions of the commander. Factors which affect this plan are discussed in the remainder of this chapter.

346. AVAILABILITY OF TOPOGRAPHIC INFORMATION. The amount of survey necessary and the selection of type of firing chart to be used is governed by the topographic information available from maps, photographs, or control from higher echelons.

a. Maps. The firing chart requiring the least survey is an accurate map or battlemap supplemented by aerial photographs. They afford horizontal and vertical control and direction throughout the area covered and require only sufficient survey to locate the batteries and targets with respect to details already appearing on the map or battlemap. Points may be located on the map or battlemap by inspection or short traverse from inspected locations. When the accuracy of the map or battlemap is unknown, it is verified by survey or by firing. Small-scale maps should not be used as firing charts; however, basic data may be taken from the small-scale map to initiate survey. This procedure will facilitate the delivery of fire on targets reported by coordinates from the small-scale map.

b. Photomaps. An accurate photomap provides a great amount of topographic detail and, when of suitable scale, is an excellent firing chart. However, vertical control is entirely lacking and must be provided by ground survey. The altitude of the survey control point may be assumed, determined by altimeter, or determined from control furnished by a higher echelon. Points may be located on the photomap by inspection or by short traverse from inspected locations. The accuracy of horizontal control of a photomap is verified by survey or firing. If the photomap is found to be in error, targets can be restituted from the photomap to the grid sheet firing chart.

c. Grid sheet. A complete field artillery survey must be performed when maps or photomaps are not available and a firing chart is constructed on a grid sheet. The battery centers, base point, check points, and targets are located by survey. The ability of an artillery unit to deliver surprise and unobserved fires from such a chart is limited to the targets which are located by survey. It therefore is desirable to supplement the grid sheet firing chart with vertical and oblique air photos. These photos will permit location of targets which cannot be located directly by ground survey operations. When horizontal and vertical control is not available, it may be assumed in order to determine relative locations on the firing chart by survey. Direction, or azimuth if not furnished, should be determined by astronomic methods. If this is not possible, azimuth may be determined approximately by compass needle.

347. DIVISION OF SURVEY OPERATIONS (fig. 156). Field artillery survey usually is divided into three operations: Target area survey, connection survey, and position area survey. These operations may be conducted concurrently.

a. Target area survey. The phase of artillery survey concerned with the target area survey involved the determination of the relative horizontal and vertical location of the base point, check points, targets, key terrain features, and observation posts. The location of points in the target area will, in most cases, involve triangulation with the target area base. Target area survey is continuous.

b. Position area survey. The performance of the position area survey involves the determination of the relative horizontal and vertical locations of the battery centers, establishment of the orienting lines on the ground and determination of their direction, and the computation of base angles. If the exact location of the battery center is not available at the time the survey is performed, the position of the battery orienting station is located and staked. On occupation of position, the executive will report to the fire-direction center the azimuth, distance, and difference in altitude from this stake to the location of the battery center in order that its true position may be plotted on the chart. The orienting line is materialized on the ground by means of stakes. Short stakes should be placed on the orienting line at each battery orienting station, over which the battery executive can place his instrument; tall stakes are placed on the orienting line within sight of each orienting station to furnish the battery executives

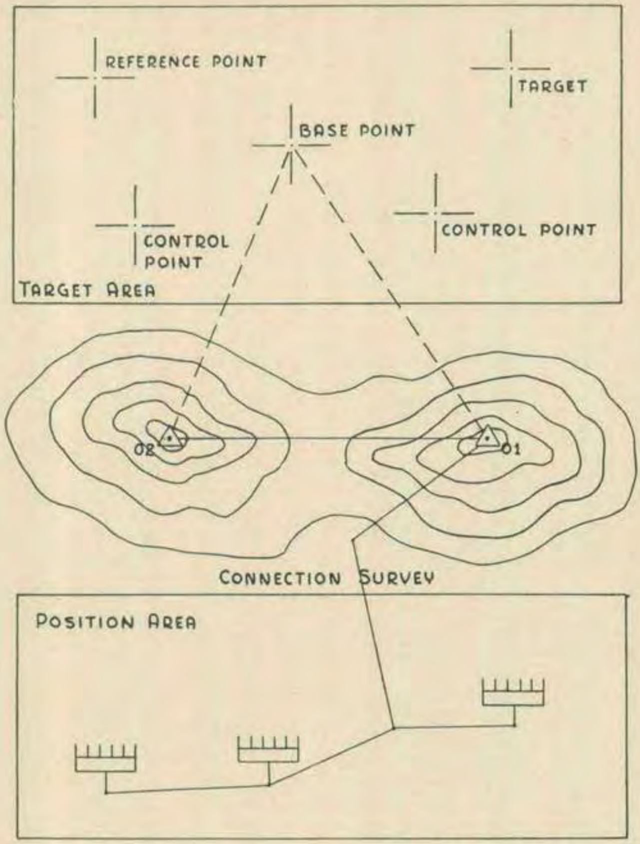


Figure 156. Division of survey operations.

a means of sighting along the orienting line. It is desirable that the stakes to be sighted upon should be located at least 200 yards from the orienting stations. The orienting line must pass conveniently near the battery which it serves. The direction of the orienting line with regard to the direction of fire is immaterial. The decisions to establish one, two, or three orienting lines for a battalion is based partly on considerations of accuracy, time, and feasibility. A single orienting line is more accurate because fewer angles are measured. Frequently, the establishment of two or more orienting lines in preference to a single orienting line will result in a great saving of time. It may be physically impossible to establish a single orienting line which will pass conveniently close to all batteries.

c. Connection survey. The performance of the connection survey involves the tying together of the target area and position area surveys.

348. EFFECT OF REGISTRATION ON SURVEY OPERATIONS. **a. General.** Registration does not affect the number of operations necessary for a complete surveyed chart. Registration, however, may affect the order in which these various operations are accomplished. If registration is permitted, the pieces may be oriented by firing. If registration is prohibited, it is necessary to orient the pieces by survey. In any event, direction eventually will be determined by survey, but firing may have been going on for some time before this is done. Assuming that time is limited, priority is given to target area and position area survey, if registration is permitted. The connection between the target area and position area can be established by firing, thus resulting in an observed firing chart which, although not as accurate as a connection survey, may be used until a connection survey can be completed.

b. Registration prohibited. Target area, position area, and connection survey must be accomplished. All charts require the maximum survey appropriate to the chart being used.

c. Registration limited. Connection survey has last priority because connection between target area and position area survey can be accomplished by firing of one piece in one battery. This requires the back plotting of the registering piece from the base point, resulting in an observed firing chart. The nonregistering batteries are located with respect to the adjusting battery by position area survey. If the firing chart is a photomap or battlemap, the batteries may be located by inspection or short traverse. They are oriented by means of a surveyed orienting line. The registering piece is oriented by firing in either case.

d. Registration unlimited. Connection survey has last priority because all batteries can be located with respect to the base point and oriented by firing. If the firing chart is a photomap or battlemap, the connection between target area survey and position area survey may be made by use of the chart. Orientation of the pieces is by firing.

349. EFFECT OF TIME AVAILABLE AND ACCURACY REQUIRED ON SURVEY OPERATIONS. Two factors which affect the survey plan are the time available, and the accuracy required. Normally, the commander gives a time limit to the survey officer, determined usually by the tactical situation. In this case, the survey officer must make his plan based upon how much of the necessary survey can be completed within the time limit. These factors may require a target area survey first. *Example*: The survey officer is able to go forward and commence the survey a short time before darkness. The target area survey should be performed first. He then, if necessary, can complete the survey in friendly territory after dark. Other circumstances may dictate position area survey initially. In any event, he must weigh carefully the factors of time and accuracy and arrive at a plan which satisfies the requirements of each in the best possible way. When time is not limited, a complete survey appropriate to the firing chart to be used, always is performed. It should be remembered that accuracies of less than a certain standard are not acceptable (pars. 317–320).

350. EFFECT OF TERRAIN. The character of the terrain in the zone of action of the supported unit will govern the methods of basic survey operations to be used. The plan can be determined in detail only by a careful ground reconnaissance.

a. Inspection. Inspection is a means of locating points rapidly and is as accurate as permitted by the skill of personnel and the amount of topographic detail available on the chart. It is difficult, in most cases, to locate, by inspection, distant, unoccupied points such as those in the target area.

b. Traverse. The location of points by traverse is a relatively slow method but should be used when visibility is limited, points can be occupied, and favorable routes are available. Careful work by trained personnel give accurate results.

c. Triangulation. A relatively fast means of survey when the terrain and visibility permit, is triangulation. It is well adapted to locating distant points such as those in the target area which cannot be occupied.

d. Resection. Resection is an advantageous method of location when known points are inaccessible.

351. VERIFICATION. A check of all survey operations must be made. The following methods should be considered:

a. Computations. Computations should be made independently by different individuals and the results checked against each other. The time available and the accuracy required will govern the choice of logarithms or military slide rule to perform calculations.

b. Traverse closure. A traverse may be closed by returning to the starting point or by traversing to another known point, thus permitting adjustment of minor errors. When large errors are detected, computations should be rechecked first and then, if necessary, the traverse rerun.

c. Triangulation closure. The location of a point by triangulation may be verified by using two separate triangles. This is the *only* means of closure in the target area. When all three points in the triangle can be occupied, the three angles should be measured and minor errors adjusted.

d. Check ray. A traverse or triangulation may be closed by the use of a check ray. Direction is measured at the terminal station to a known point. If the direction as computed by the difference in coordinates agrees with that determined by the survey, the coordinates of the terminal station and the entire survey may be assumed to be correct.

e. Firing. A check of the accuracy of survey may be made after determining corrections from registration by transferring fire to targets located by survey. If the transfers are accurate, the survey may be assumed to be correct. It is advisable for a division artillery or corps to verify its ability to mass fires by firing at least one piece from each battalion on a common check point.

352. TRANSFER TO COMMON CONTROL. a. A unit may be required to base its survey on assumed control data. When control data are received from a higher echelon, the survey should be transferred to a common control to facilitate fire direction and the exchange of survey information.

b. If the directions of the control of higher and lower echelons have been established by astronomic methods and are in agreement, the procedure is as in the following example: The battalion coordinates of a survey control station, based on assumed coordinates, are (52.431–85.330). The division artillery coordinates for the same station are (52.473–85.295). The differences are as follows:

$$\begin{array}{r} 52.473-85.295 \\ -52.431-85.330 \\ \hline +42-35 \text{ meters.} \end{array}$$

To transfer to the common control, the battalion must add 42 meters to the X-coordinate of each point in the battalion net and subtract 35 meters from the Y-coordinate of each point.

c. When directions are not in agreement, the control is transferred as follows: The survey data of the lower unit is copied on a sheet of tracing paper. The control data received from the higher echelon are plotted on a grid sheet. The tracing paper then is placed so that the location of a control station on the tracing paper falls on the corresponding station on the grid sheet and lines to the reference point on both sheets are in coincidence. Locations on the tracing paper then are pricked through to the grid sheet.

d. The difference in altitude of the common survey control point, as determined by the higher and lower echelons, is applied to all altitudes determined by the survey of the lower echelons.

353. RAPID BATTALION SURVEY WHEN NO TOPOGRAPHICAL INFORMATION IS AVAILABLE. a. Purpose. This example illustrates the amount of survey necessary to deliver artillery fire as soon as possible, using a grid sheet as a firing chart. The method combines certain features of the surveyed and observed firing charts in order to permit the early delivery of massed fires (fig. 157).

b. Mission. To deliver massed observed fires.

c. Situation. The time for survey is extremely limited, and the registration of one battery is permitted. The terrain is rolling with low scattered hills and woods. There are no photographs or maps available. Survey control from the division artillery will be available at a later time. The position area is not visible from O1.

d. Target area survey. The coordinates and altitudes of O1 are assumed. The *Y*-azimuth of the line O1–base point is measured with the aiming circle. The target area base is established, either by taping, or by triangulation, using a taped auxiliary base. The O1–O2 base is used to locate the base point, as well as to locate and report observed targets, by triangulation.

e. Connection survey. None performed.

f. Position area survey. Starting from any convenient point, a traverse is run to locate all battery positions horizontally and vertically, and all orienting lines with relation to each other. (Unless the orienting lines are legs in the traverse locating the batteries, only direction to the orienting lines is required.) The battery positions, including altitudes, and the orienting lines, are plotted on tracing paper, or any available paper, to the same scale as the chart to be used. This overlay, including the measured *Y*-azimuth of the orienting lines, constitutes the position area survey.

g. Registration. Based on the adjusted data from the registration, the registering battery ("*B*" in this case) is backplotted on the firing chart (par. 150), and a base-point line is constructed on the overlay of the position area survey. The overlay then is oriented by placing it over the chart so that the overlay location of battery *B* is over the chart location of battery *B* and the base-point line passes through the chart location of the base point. The locations of the flank batteries are pricked through the tracing paper to the firing chart. The base angles then are computed or measured.

h. Comment. This firing chart *may* permit delivery of surprise fire on targets located from the O1–O2 base. A complete survey firing chart will replace the above chart as soon as completed.

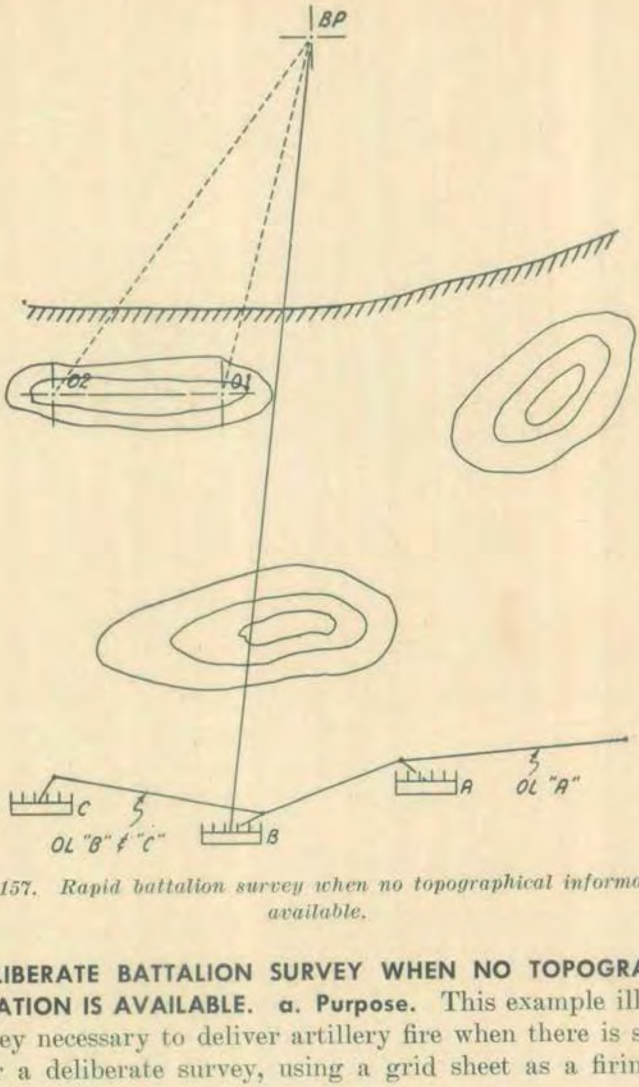


Figure 157. Rapid battalion survey when no topographical information is available.

354. DELIBERATE BATTALION SURVEY WHEN NO TOPOGRAPHICAL INFORMATION IS AVAILABLE. a. Purpose. This example illustrates the survey necessary to deliver artillery fire when there is sufficient time for a deliberate survey, using a grid sheet as a firing chart (fig. 158).

b. Mission. To deliver massed observed and unobserved fires.

c. Situation. Three hours are available for survey operations, and registration is permitted. The terrain is rolling, with scattered hills and woods. There are no photographs or maps available. Survey control from division artillery is expected in 4 hours.

d. Target area survey. A target area base O1–O2 is established by triangulation from the base *D–E*. The base point, check points, targets, and control points *K*, *L*, and *M* are located, both horizontally and vertically, by triangulation from O1 and O2.

e. Connection survey. The coordinates and altitude of station *D* are assumed. The direction of the line *D–E* is determined by astronomic observation to facilitate the transfer to division artillery control. The length of the line *D–E* is taped, or its length may be determined by triangulation, using a taped auxiliary base. A traverse is run from station *D* to station 3, carrying direction and elevation.

f. Position area survey. The orienting line(s) is (are) established and staked in on the ground. A traverse is run from station 3 to locate the battery centers and battery orienting stations. The assumed coordinates and altitudes are carried forward along with the direction determined by astronomical observation. The base angles are computed and compared to the measured base angle following registration.

g. Comment. As time permits, the target area survey will be checked by establishing O3 and verifying the location of points in the target area by triangulation. The position area traverse will be closed on point *E* or, if O2 is visible from station 6, a check ray is sighted to O2 (par. 351).

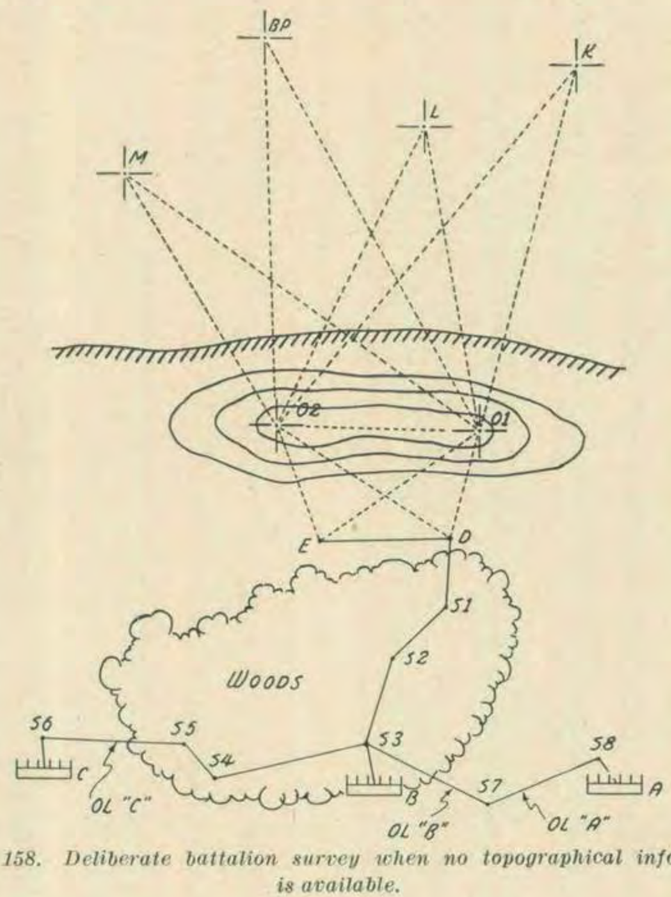


Figure 158. Deliberate battalion survey when no topographical information is available.

355. RAPID BATTALION SURVEY WHEN LIMITED TOPOGRAPHICAL INFORMATION IS AVAILABLE. a Purpose. This example illustrates the amount of survey necessary to deliver artillery fire as soon as possible, using a photomap as a firing chart (fig. 159).

b. Mission. To deliver massed observed and unobserved fires.

c. Situation. The terrain is gently rolling, with scattered woods. One hour is available for survey operations, and registration of one battery is permitted. Numerous points in the battalion area are identifiable on the photomap which is to be used as the firing chart. No survey control is available from division artillery.

d. Target area survey. The points O1, *BP*, and *Q* are located by inspection on the photomap. From O1, the vertical angles to the points in the target area are measured. Time permitting, an auxiliary observation post is established to locate additional points in the target area by triangulation.

e. Connection survey. A traverse, carrying direction and vertical angles only, is run from station 1 to O1.

f. Position area survey. The road junction, located by inspection on the photomap, is selected as the first traverse station. Its altitude is determined by use of the altimeter. The straight road running through the position area is selected as an orienting line for all the batteries. Orienting stations are located on the road by traverse from station 1. The *Y*-azimuth of the orienting line is measured from the chart and used as directional control for the balance of the survey. Battery centers are located by traverse from the orienting stations. The registering battery is oriented by firing. The base angles of flank batteries are computed by applying the base point offset to the adjusting battery's base angle.

g. Comment. A complete grid sheet survey is started as soon as possible. When it is complete, the accuracy of the photomap can be verified; and, if the photomap is found to be in error, the grid sheet survey will become the firing chart.

356. DELIBERATE BATTALION SURVEY WHEN LIMITED TOPOGRAPHICAL INFORMATION IS AVAILABLE. a. Purpose. This example illustrates the survey necessary to deliver artillery fire when there is sufficient time for a deliberate survey, using a photomap as a firing chart (fig. 160).

b. Mission. To deliver massed observed and unobserved fires.

c. Situation. The terrain is rolling, with scattered woods. Four hours are available for survey, and registration is prohibited. A controlled mosaic photomap is to be used as the firing chart. No survey control is furnished by division artillery.

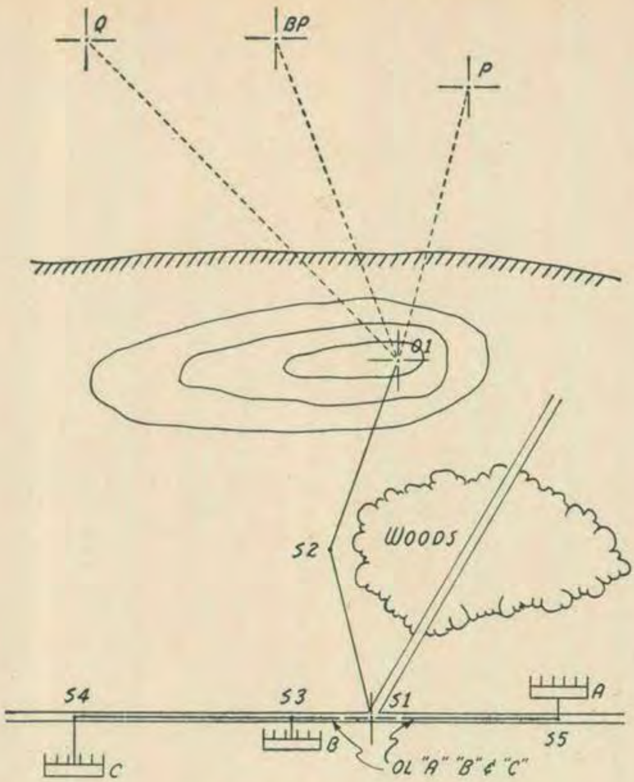


Figure 159. Rapid battalion survey when limited topographical information is available.

d. Target area survey. The location of O1 or O2 by inspection on the photomap is not practicable. The points are established and the length of the target area base is determined by triangulation, using a short base at O1. The *BP*, *X*, and *Y* are located by triangulation from the base O1–O2. Additional points are located in the target area, both horizontally and vertically, to facilitate determination of sites and interpolation between these points.

e. Connection survey. The coordinates of station 1 are determined by inspection from the photomap. The altitude of station 1 is assumed. The azimuth of the line station 1–O1 is measured with an aiming circle. Location of O1 is by traverse from station 1; O2 is located by triangulation (triangle station 1–O1–O2). A complete traverse is carried to the position area (stations 1–2–3–4–5).

f. Position area survey. Orienting lines are established, orienting stations and battery centers are located by traverse, and base angles computed for each battery.

g. Comment. Direction of lines as measured on the photomap should check those as measured or computed in the survey. Likewise, the plotted positions of points resulting from the survey should check with the location on the photo. If either of the above fail to check, the photomap should be used only as a supplement to a grid sheet firing chart.

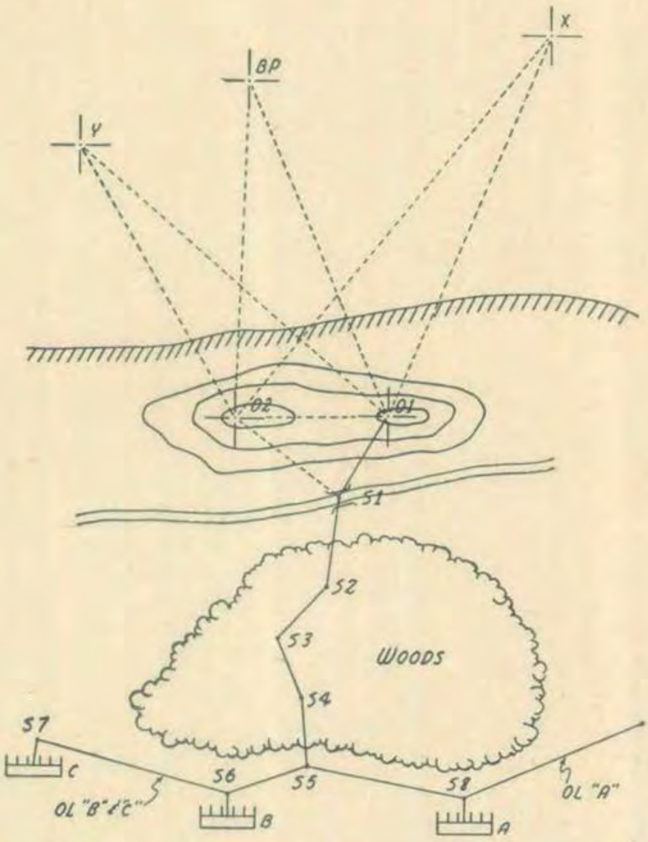


Figure 160. Deliberate battalion survey when limited topographical information is available.

357. RAPID BATTALION SURVEY WHEN TOPOGRAPHICAL INFORMATION IS AVAILABLE. a. Purpose. This example illustrates the amount of survey necessary to deliver artillery fire as soon as possible, using a battlemap as a firing chart (fig. 161).

b. Mission. To deliver massed observed and unobserved fires.

c. Situation. An accurate battlemap is available for use as the firing chart. Two hours are available for survey, and registration is permitted. A number of locations can be made by inspection. A crossroad in the position area is visible from O1.

d. Target area survey. Location of O1 (at a triangulation marker) and the base point are by inspection and their altitudes are determined from the map; O2 is established and located by setting up an auxiliary base. The length of O1–O2 is determined by triangulation. The location of O1 is verified by resection, using three distant points (*BP*, schoolhouse, and fence corner). Additional points may be located by inspection in the target area or by triangulation.

e. Connection survey. There is no connection survey; it is furnished by the map.

f. Position area survey. Station 1 (crossroads) is selected, its location is determined by inspection, and a direction computed by using coordinates of O1 and station 1. Using the direction established for the line O1–station 1, a complete traverse is run to locate each battery orienting station and each battery center. Orienting lines are staked in and base angles computed.

g. Registration. The accuracy of the survey is determined by registration.

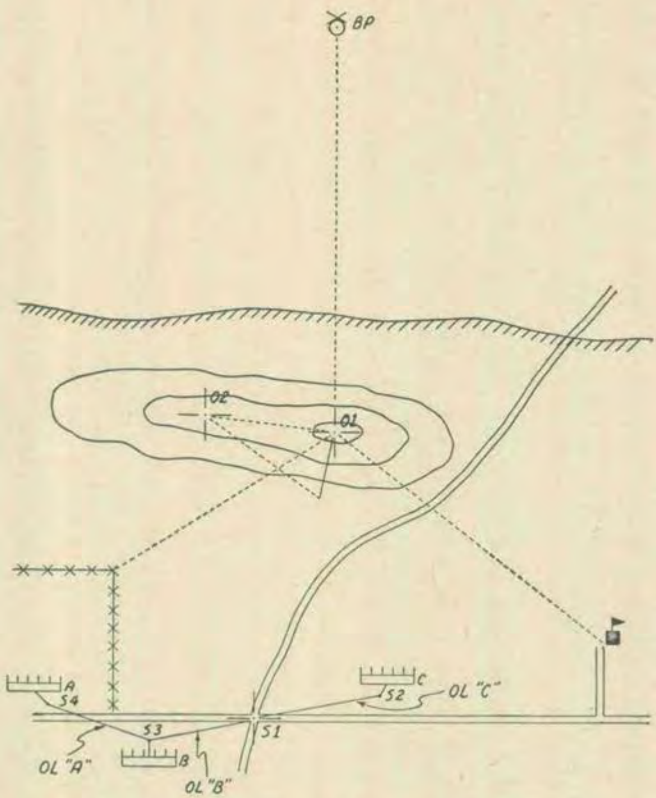


Figure 161. Rapid battalion survey when topographical information is available.

358. DELIBERATE BATTALION SURVEY WHEN TOPOGRAPHICAL INFORMATION IS AVAILABLE. a. Purpose. This example illustrates the necessary survey to deliver artillery fire when there is sufficient time for a deliberate survey, using a battlemap as a firing chart. (See fig. 162.)

b. Mission. To deliver massed observed and unobserved fires.

c. Situation. Six hours are available for survey. A battlemap is to be used as the firing chart, supplemented by aerial photographs of the target area. The coordinates and altitudes of the division artillery survey control point, with the coordinates of the reference point (*RP*), are furnished by division artillery. The terrain is rough and brushy, with few points capable of being located by inspection; O1 is at a location providing excellent observation of the target area and the reference point only.

d. Target area survey. Location of O1 and O2 is established, and the length of the base determined by computation of coordinates. The base point, division artillery check point, and control points *J* and *K* are located by triangulation, and O3 is established, located by triangulation, and occupied. Angular readings from O3 are taken to points in the target area and used to check locations made with the O1–O2 base. The altitudes of O1 and points in the target area are determined from contours.

e. Connection survey. A traverse carrying direction and distance is accomplished from the survey control point to locate O1 and O2 with a check ray to the reference point. Altitudes are determined from contour lines on the map.

f. Position area survey. A traverse is run from the survey control point to battery orienting stations, the orienting line staked in, and battery centers located by traverse. This traverse is closed by traversing to the survey control point furnished by division artillery for the adjacent battalion. Altitudes of battery centers are determined from contours.

359. DIVISION ARTILLERY SURVEY WHEN NO TOPOGRAPHICAL INFORMATION IS AVAILABLE. a. Purpose. This example illustrates the survey that is necessary to furnish common control when sufficient time is available, using a grid sheet (fig. 163).

b. Mission. To extend common control furnished by corps to all battalions of the division artillery.

c. Situation. Five hours are available for survey. The terrain is hilly and wooded. Although maps are not available, aerial photographs of the target area are available. All battalions will register by high burst after darkness on the division artillery check point.

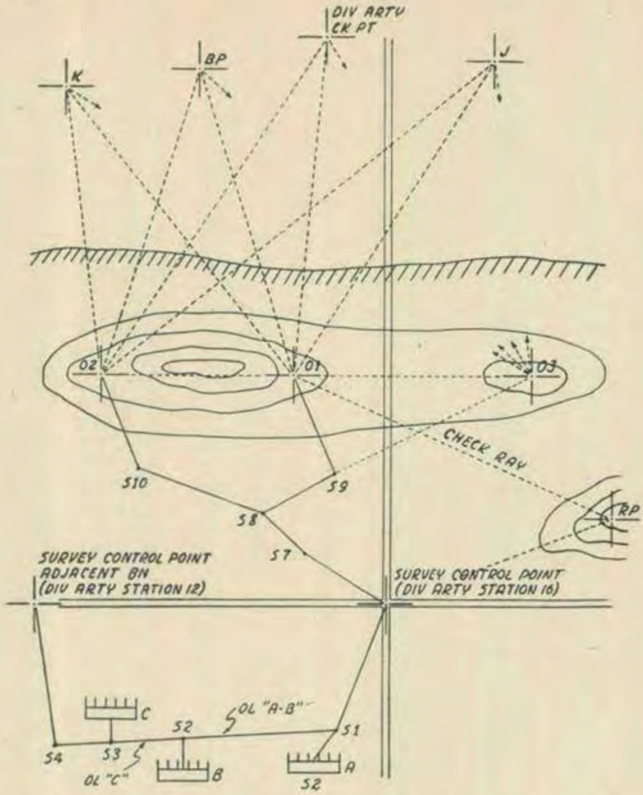


Figure 162. Deliberate battalion survey when topographical information is available.

Corps artillery has furnished the coordinates and altitude of points *S* and *T*.

d. Survey operations. The coordinates and altitude of the survey control points *T* and *S* are furnished the survey officer of the 3d FA Bn. He uses point *T* as the control point for his battalion. The division artillery runs a traverse from control point *T* to station 5 (4th FA Bn), to stations 1 and 2 (2d FA Bn), and stations 3 and 4 (1st FA Bn.) The coordinates of the stations 5, 4, and 2 are given to the survey officers of the respective battalions. The traverse is closed by check rays station 4–*S* and station 5–*S*. The points *X* and *Y* are located by triangulation from the position area traverse stations, station 1 and *T*. The location of *X* is verified by a check ray to *S*. The division artillery check point and control points are located by triangulation. The location of point *Y* is verified, using an auxiliary taped base with point *X* as one end. The location of the division artillery check point should be verified by establishing an additional base.

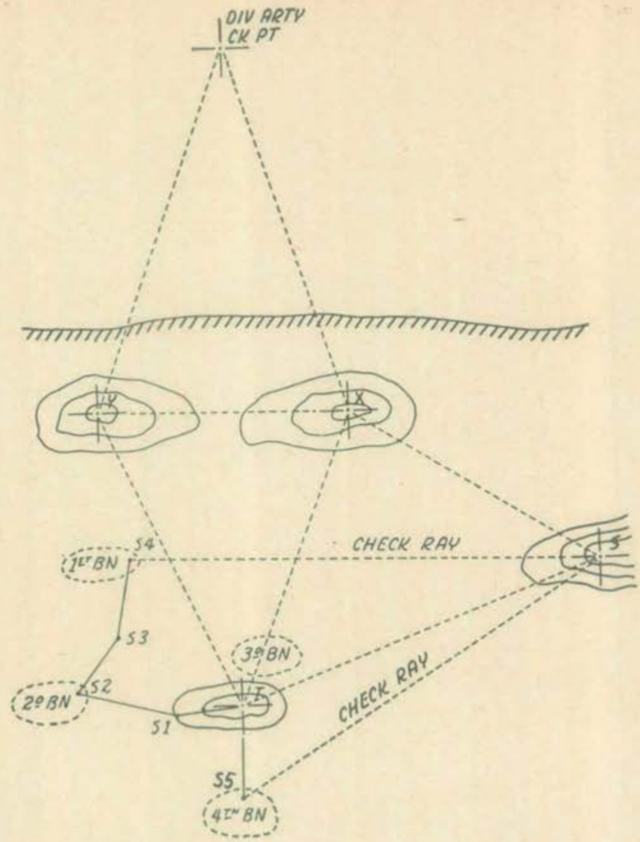


Figure 163. Division artillery survey when no topographical information is available.

APPENDIX I

REFERENCES

SR 385–310–1	Regulations for Firing Ammunition for Training, Target Practice, and Combat.
FM 6–20	Field Artillery Tactics and Technique.
FM 6–101	Tactics and Technique, Battalion and Battery, Motorized.
FM 6–120	Field Artillery Observation Battalion.
FM 6–130	Field Artillery Intelligence.
FM 6–140	The Firing Battery.
FM 21–5	Military Training.
FM 21–6	List and Index of Department of the Army Publications.
FM 21–7	List of War Department Films, Film Strips, and Recognition Film Slides.
FM 21–8	Military Training Aids.
FM 24–20	Field Wire Technique.
FM 100–5	Operations.
TM 5–235	Surveying.
TM 5–9420	Altimeter, Surveying, 6000-ft, 10-ft. Divisions, Type 6, Wallace and Tiernan, Model FA–112.
TM 6–240	Rule, Slide, Military, Field Artillery, with Case, 10-inch.
TM 6–605	Field Artillery Individual and Unit Training Standards.
TM 9–526	Graphical Firing Tables.
TM 9–575	Auxiliary Sighting and Fire Control Equipment.
TM 20–205	Dictionary of United States Army Terms.

APPENDIX II

ADJUSTMENT OF NAVAL GUNFIRE

1. GENERAL. The technique of employment of naval gunfire in support of ground operations is basically the same as for the employment of field artillery, but is subject to certain advantages and limitations inherent in weapons fired from ships.

a. Advantages. The advantages of naval gunfire support are—

(1) The variety of guns available, ranging from 20-mm machine guns to the 16-inch guns of battleships.

(2) The latitude in the choice of projectiles and fuzes.

(3) The high rate of fire.

(4) The high muzzle velocity which makes naval guns suitable for the penetration and destruction of material targets, particularly those presenting vertical faces.

(5) The small deflection pattern which is valuable when supporting fire can be delivered parallel to friendly lines.

(6) The accurate and flexible fire control which permits accurate delivery of fire while the ship is moving. Direct fire is excellent due to efficient shipboard optical instruments which are integrated with the fire-control systems.

(7) The mobility of the firing ship which enables it, within the limits of hydrography, to select the most advantageous direction of fire and firing position suitable to the mission.

(8) The employment of reduced charges and use of antiaircraft batteries with or without proximity fuzes permits the use of naval gunfire support on reverse slopes.

b. Limitations. The limitations of naval gunfire support are—

(1) The flat trajectories which render fire on defiladed targets difficult.

(2) The communication with shore agencies which must be maintained by radio or visual means.

(3) Due to the fact that the firing ship's position relative to reference points or targets cannot always be accurately determined and maintained, transfers of fire from a base point or check point, or fires based on map data corrected are not accurate. The only practicable shift of fire is from a target just fired upon (see par. **7a**, this appendix).

(*a*) The accuracy of unobserved fires is limited by the accuracy of fixing the ship's position. This precludes the delivery of unobserved fires in which accuracy is required.

(*b*) The execution of radical turns or reversal of course while firing requires a new adjustment or a delay in firing due to the lag of the fire-control system.

(4) Unfavorable hydrographic conditions' such as shallow water, reefs, or shoals, may limit the firing ship's position to undesirable locations from the standpoint of direction of fire and range.

(5) The range patterns of naval batteries are larger than the range patterns of comparable calibers of field artillery.

(6) The limited capacity of ship's magazines and the necessity for the retention of a percentage of ammunition for air defense or action against surface forces restricts the use of the available ammunition for fire support.

(7) The action of enemy air or surface forces may cause a reduction or complete discontinuance of naval gunfire support because supporting ships may have to cease supporting fires in order to defend themselves or to engage enemy naval forces.

2. NAVAL GUNFIRE CONTROL AND LIAISON. **a.** The adjustment of naval gunfire by forward observers follows the same basic technique as that prescribed for the adjustment of field artillery fire. Since it is difficult for ships to determine their locations accurately, the fires of several ships seldom are massed on a single target. However, this inability is offset by the high rate of fire of the fire-support ships.

b. The adjustment of naval gunfire and the establishment of necessary communication are performed by the naval gunfire liaison officers and forward observers. Normally, communication is by radio between the observer and the firing ship. The naval gunfire liaison officer (a naval officer), the forward observer, and the direct-support ships operate in the same naval gunfire control net.

c. Throughout an amphibious operation, an artillery liaison officer, familiar with the capabilities and limitations of naval gunfire, should work with the naval gunnery officer aboard the amphibious force flagship controlling the naval gunfire. Similarly, a naval gunfire liaison officer is located in the fire support coordination center of the direct-support field artillery battalion and in each infantry battalion command post. The naval gunfire officer (a field artilleryman) and the assistant naval gunfire officer (a naval officer) are located in the corps artillery and division artillery fire supporting coordination centers. The primary duties of the above personnel are to plan, coordinate, and conduct naval gunfire support.

3. NAVAL ORDNANCE. **a. General characteristics.** Except when firing reduced charges, naval guns have higher muzzle velocities, flatter trajectories, and shorter times of flight than comparable field artillery weapons. In adjusting naval gunfire, the observer constantly must be aware he is employing guns and not howitzers.

b. Weapons available. A variety of weapons is available for naval gunfire support, the various combinations being determined by the type of vessel. Calibers of weapons available are 3-inch, 5-inch, 6-inch, 8-inch, 12-inch, and 16-inch guns, and 5-inch rockets and 4.2 mortars on newer type vessels. Some older type vessels are equipped with 14-inch guns.

c. Ammunition available.

(1) Types of projectile, charge, and fuze available vary according to the caliber of the weapon. Generally, the usual combinations of projectile and fuze employed in field artillery are available in naval ammunition.

(2) Guns of 5-inch caliber and larger are provided with bombardment ammunition (high-capacity, H. C.), which is comparable to field artillery high explosive projectiles of equivalent size. Armor-piercing projectiles, normally used in fleet surface engagements, are available for all calibers 6-inch and larger. Illuminating shell is available for the 3-inch, 5-inch, and 6-inch guns; white phosphorous shell is available for the 3-inch and 5-inch guns, and the 4.2-inch mortar.

(3) Full and reduced charges are available for calibers of guns above 3-inch. The reduced charge for the 5-inch gun produces 1,200 f/s muzzle velocity and a trajectory similar to that of charge 6 for the 105-mm howitzer.

(4) The fuzes vary with different calibers and projectiles, but generally include quick, delay, time, and VT. A point-detonating fuze corresponding to the artillery fuze quick is available for all naval high-capacity (high explosive) projectiles. All delay fuzes are of base-detonating type and vary in length of delay according to type of projectile and caliber. The time fuze is of the mechanical type and is available for all high capacity projectiles of 5-inch and larger caliber. The mechanical time fuze does not have a point-detonating element. The VT fuze is available for the 3-inch, 5-inch, and 6-inch guns. Due to design, the height of burst varies from 10 feet at 6,000 yards to 30 feet at 12,000 yards. Use of VT fuze in shore bombardment at ranges less than 6,000 yards is not recommended. The VT fuze has no impact detonating feature.

d. Dispersion. Dispersion of naval guns is greater than that of comparable artillery pieces; for example, range dispersion at midranges may vary from 125 yards for the 5-inch to 500 yards for the 16-inch gun. Deflection dispersion is roughly 10 percent of range dispersion.

4. PREARRANGEMENT. **a.** Rehearsals for observers, communication personnel, and fire support ships should precede each operation in order to develop team work and mutual understanding. The observer must be furnished the necessary maps or map substitutes to be used in target designation. He also must be furnished the grid systems and codes that are to be used, and be familiar with them. The observer must understand the plan of communication between himself and the firing ship. He must be informed regarding the calibers of weapons available for him to fire and how he can secure the fire support of vessels other than those directly supporting his action.

b. Preparation fires (preliminary bombardment) are planned jointly in accordance with army requirements. Preplanning of naval gunfire support is initiated as soon as the directive for the conduct of an amphibious operation is received. An exchange of staff officers between appropriate headquarters facilitates the planning of naval gunfire support. (See pars. 241 to 247, incl.; also see FM's 6–20 and 6–101.)

c. In order to prevent confusion, naval gunfire support ships are assigned *fire support areas* (FSA) at sea, based on tactical and gunnery considerations. These sea areas may be considered similar to battery position areas. In addition, sectors of responsibility ashore are assigned to ships by number. These are comparable to zones of action for field artillery units. (See fig. 164.) The boundaries usually conform to preplanned unit boundaries ashore and are outlined by prominent terrain features. A direct-support ship, for example, will be assigned an FSA for its position area. It also will be assigned one or more sectors of responsibility in which it normally will place its fires. The forward observer for the direct-support ship should have the above information plotted on his map, chart, or overlay, including adjacent areas. He then will have a general idea of the *GT* line, and can ask that the direct-support or other ship be sent to a specified FSA in order to execute enfilade fire properly when firing close to front line troops or behind hills which defilade the target.

5. PRINCIPLES GOVERNING OBSERVER. In order to obtain an accurate and rapid adjustment of naval gunfire on a target, the observer must—

a. Give a brief but complete target description to the firing ship's gunnery officer so that he can make an accurate evaluation of the target. He has to determine the need for reduced charges in reverse-slope firing, the need for removing the parallax correction to cover a wider area, and the probable number of guns needed in fire for effect.

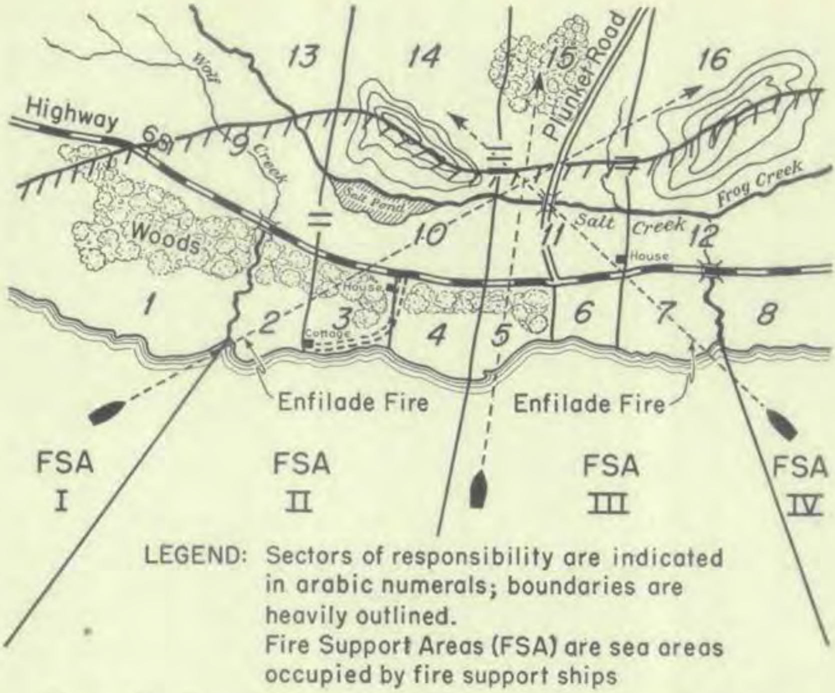


Figure 164. Example of fire support areas and sectors of responsibility.

b. Conserve ammunition.

c. Shoot fast.

d. Be alert to make compensating corrections if the center of impact tends to creep off the target due to motion of the firing ship or lag in fire-control mechanism.

e. If necessary advise the ships as to the most advantageous position for delivery of fire in order to hit the target.

(1) Position the ship to deliver direct fire (see par. 9**a**, this app.).

(2) Position the ship to deliver enfilade fire. Maximum advantage of the flat trajectories and high velocities may be taken in firing parallel to valleys and ridges. The small deflection dispersion of naval gunfire makes it possible to bring enfilade fire very close to front lines. The observer may have to request that the supporting ship be moved to another locality or he may have to request fire from a ship in another locality in order to accomplish enfilade fires.

6. DIFFERENCES IN TERMINOLOGY. Terms commonly used in the adjustment of naval gunfire are virtually the same as for artillery fire (see par. 50).

7. INITIAL FIRE REQUEST. a. The observer includes the elements listed in paragraph 52 in the initial fire message sent to the firing ship. It must be borne in mind that, when adjusting naval gunfire, a shift from the last target fired upon should not be used if END OF MISSION has been given.

b. It is *mandatory* that the observer send the classification of fire—CLOSE or DEEP. Classification of fire indicates the proximity of target to friendly troops. CLOSE means that the target is within 600 yards of friendly elements, and DEEP means that the target is over 600 yards from friendly troops.

c. The observer may request the number of guns to be used in adjustment. If more than one caliber is available, he may specify the caliber desired; for example, 2 GUNS, 5-INCH FOR ADJUSTMENT.

8. INFORMATION SENT TO OBSERVER. a. The supporting ship informs the observer whether or not it is able to fire the mission.

b. The observer is notified *ON THE WAY* when the ship fires. Five seconds before the round strikes or bursts, the warning *SPLASH* is transmitted.

c. To signify completion of fire for effect, the firing ship transmits *ROUNDS COMPLETE.*

d. When the observer has sent AT MY COMMAND, WILL ADJUST, the firing ship transmits *READY* to indicate that the ship is ready to fire.

9. ADJUSTMENT OF FIRE. a. General. Usually the adjustment is conducted by using one or two guns. Additional guns may be brought in for fire for effect. The number of guns which may be employed is dependent upon the nature of the target and the type of ship. It will vary from four to six 5-inch guns on a destroyer to nine 16-inch and ten 5-inch guns on the newer battleships. The principles of conduct of fire discussed in parts one and two of this manual are employed. If the target can be seen from the ship, the ship may take over the adjustment after it positively has identified the target. In this mannner, adjustment can be conducted most rapidly; the ground observer performs surveillance of the fire. Destruction missions may be fired most effectively if the target can be observed from the ship.

b. Deflection and range corrections. During adjustment, these corrections are determined in the same manner and are given in the same sequence as in the conduct of field artillery fire.

c. Distribution. Normally, the sheaf used in firing is converged and is not changed by the observer.

d. Height of burst. When time fire is used, height of burst is adjusted (in the same manner as in field artillery fire) so that bursts occur 25 yards above the target for 6-inch and smaller guns and 30 to 35 yards above the target for 8-inch and larger guns.

e. Fire for effect.

(1) Fire for effect is started when a suitable adjustment has been obtained; that is, when deflection and range (and height of burst in time fire) are correct, or when effective fire will result with the next split in bracket.

(2) If the target covers an area greater than the pattern of the ship's fire for effect, the entire area is covered by successive shifts; for example, the observer might command LEFT 150, NO CHANGE, REPEAT FIRE FOR EFFECT.

10. ILLUSTRATIVE EXAMPLE. Target, infantry weapons in the vicinity of a terrain feature; mission, neutralization; matériel, 5-inch gun.

Messages, corrections, and commands	Results	Sensings	
		RN	Dev
Observer to Ship: FIRE MISSION, AZIMUTH 3180 MILS, COORDINATES 1760 KING, INFANTRY WEAPONS, DEEP, ONE GUN FOR ADJUSTMENT, WILL ADJUST.			
Ship to Observer: (initial fire request is repeated for verification) *ON THE WAY . . .* *SPLASH.*		?	45 R

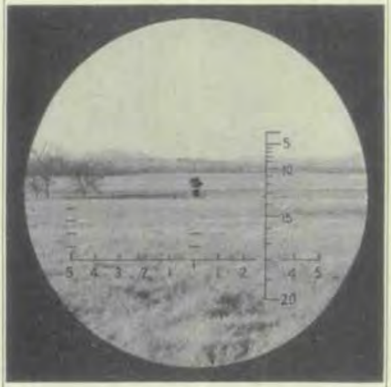
Remarks: OT distance from map is 2,500 yards. To get on the line, the observer multiplies the observed deviation in mils times the *OT* distance in thousands of yards: $45\not{m}\times 2.5=112$. The correction, therefore, is LEFT 110 (to the nearest 10 yards).

Messages, corrections, and commands	Results	Sensings	
		RN	Dev
Observer to Ship: LEFT 110, NO CHANGE (Repeat Range). Ship to Observer: (correction is repeated for verification) *ON THE WAY. . .* *SPLASH.*		—	5 R

Remarks: A range sensing has been obtained and the observer estimates that a 400-yard increase in range will bracket the target. The deviation of 5 mils×2.5=12.5. The correction, therefore, is LEFT 10 to get on the line.

Messages, corrections, and commands	Results	Sensings	
		RN	Dev
Observer to Ship: LEFT 10, ADD 400. Ship to Observer: (correction is repeated for verification) *ON THE WAY. . .* *SPLASH.*		+	5 L

Remarks: A bracket of 400 yards along the *OT* line has been obtained and is split. A deviation correction of RIGHT 10 is given (5×2.5=12.5).

Messages, corrections, and commands	Results	Sensings	
		RN	Dev
Observer to Ship: RIGHT 10, DROP 200. Ship to Observer: (correction is repeated for verification). *ON THE WAY . . .* *SPLASH.*		+	LINE

Messages, corrections, and commands	Results	Sensings	
		RN	Dev
Observer to Ship: DROP 100. Ship to Observer: (correction is repeated for verification). *ON THE WAY . . .* *SPLASH.*		?	5 R

Remarks: No range sensing obtained and the shot is brought to the *OT* line by a deviation correction of LEFT 10 ($5\times2.5=12.5$).

Messages, corrections, and commands	Results	Sensings	
		RN	Dev
Observer to Ship: LEFT 10, NO CHANGE (Repeat range). Ship to Observer: (correction is repeated for verification) *ON THE WAY . . . SPLASH.*		—	2 R

Remarks: The deviation of 5 yards (2×2.5) is ignored.

Messages, corrections, and commands	Results	Sensings	
		RN	Dev
Observer to Ship: ADD 50, TWO ZERO ROUNDS, FIRE FOR EFFECT. Ship to Observer: (correction is repeated for verification) *ON THE WAY . . . SPLASH.*			

Remarks: Pattern of 20 rounds covers the desired area and weapons are silenced. Repeat fire for effect is not indicated.

Observer to Ship: CEASE FIRING, END OF MISSION, WEAPONS SILENCED.			

APPENDIX III

FIELD ARTILLERY ROCKETS

1. GENERAL. Field artillery rocket units are employed in essentially the same roles as are field artillery gun and howitzer units. (For a general discussion of field artillery missions, see FM 6–20 and FM 6–101.) Important characteristics of rockets, as compared to other artillery pieces, are—

a. Distinctive flash and considerable blast action of the burning propellant.

b. Greater rate and volume of fire.

c. Less accuracy.

d. Shorter maximum range.

2. EMPLOYMENT. Rockets are designed to supplement the fires of other weapons, particularly those of heavy mortars and light artillery. They contribute to the action by reinforcing other fires, by adding volume, weight of metal, and concussion effect. Because of the inherently large dispersion factors of these weapons, care must be exercised in selecting and firing on targets near supported troops.

3. CAPABILITIES. **a.** Rocket launchers are capable of delivering a large volume of fire in a short period of time. For example, a 4.5-inch rocket battery equipped with 12 launchers can fire 288 rockets in 12 seconds. The battery can deliver a sustained fire of 864 rockets (3 volleys) every 4 minutes. The high-explosive 4.5-inch rocket projectile is comparable to the 105-mm howitzer high-explosive shell in both concussion and fragmentation effect.

b. The maximum effect is obtained from rockets by employing them in mass to deliver intense surprise fire upon an area target. Massed rocket fire on area targets possesses great power of neutralization and destruction, particularly against unprotected personnel and against lightly armored vehicles. A great variety of targets may be effectively attacked with high-explosive shell with quick, delay, or VT fuzes.

c. Rocket launchers are either towed or self-propelled. The towed multiple rocket launcher is compact and relatively light, has a low silhouette, and is highly maneuverable. It possesses high mobility on roads as well as cross country, and may be moved by hand for short distances. The launcher may be emplaced well forward and in concealed positions that may be inaccessible to heavier, less mobile weapons. The launcher can go into and out of position with rapidity and facility.

d. Rocket fire can be shifted in width and depth, positions can be changed, and units regrouped to bring great fire power to bear on important targets with the same facility as artillery howitzer or gun fire. This flexibility gives the commander a powerful means of influencing the course of combat. The efficiency with which rocket fires are maneuvered depends upon adequate control and effective communication.

4. LIMITATIONS. **a.** The dispersion of rocket fire makes it unsuitable for the attack of point targets. This dispersion also makes its employment for close support of ground troops exceptional. Artillery howitzers and guns are more appropriate against definitely located targets such as enemy guns, emplacements, and obstacles.

b. Rocket launcher positions may be revealed to enemy observers by the distinctive flash and considerable blast action of the burning propellant. The blast produces a cloud of smoke, dust, and debris, the size and character of which is dependent upon the type of soil, extent and variety of vegetation, weather conditions, and the slope and configuration of the ground at the launcher position.

c. The dispersion and low muzzle velocity of rockets make their employment as a close-range, direct-fire weapon impracticable.

d. Rockets have a limited range and cannot be used against distant targets. The launcher position, therefore, generally must be in or forward of the light artillery position areas.

e. The blast from the rocket propellant is dangerous to personnel and matériel 50 yards to the rear and several yards to either flank of the launcher. The service of the launcher therefore is impeded, since ammunition for successive loadings must be placed a distance from the launcher. A well-trained crew of three men can reload a 24-tube launcher in less than 1½ minutes, so that the launcher can maintain sustained fire of three volleys per 4 minutes, which normally will be the maximum required for effective neutralization of an area provided no misfires occur.

5. TYPES OF FIRE. Artillery fires may be classified as to form, effect sought, type of observation (observed or unobserved), and degree of prearrangement. (See FM 6–101.) The application of rocket fire to these classifications is considered below.

a. Form. Rocket fire usually is delivered as a concentration. It usually is unsuitable for a barrage close to friendly troops, due to its dispersion. In some situations, it is possible at short ranges to fire a close-in barrage of enfilading fire across the front of troops due to the comparatively narrow deflection dispersion and long-range dispersion (fig. 165.) Similarly, when the situation permits overhead rocket fire at maximum ranges, advantage may be taken of wire deflection dispersion and comparatively short range dispersion.

b. Effect sought.

(1) Rocket fire is best suited for neutralization of an area. It may be used advantageously for interdicting and harassing an area or to lay down a blanket of fire to neutralize an area or areas as part of an artillery preparation. It is impracticable for precision adjustments. Registration usually is restricted to avoid disclosure of the presence of rocket units and the location of launcher sites. It is accomplished by salvos from a single launcher with the center of impact being determined and corrections computed for the other launchers.

(2) Factors that should be considered both in the assignment of missions and in the selection of battery positions are that range dispersion decreases and lateral dispersion increases with an increase in range.

c. Observation. Rocket fires should be observed in order to determine their accuracy and effect. When successive salvos are to be fired, they are corrected as necessary by the observer.

d. Prearrangement. Rocket fires are prearranged, when possible, and integrated carefully into artillery fire plans. Rocket fires, as other artillery fires, may be prearranged both as to location and time of firing. Targets of opportunity usually are unsuitable for rockets.

6. SELECTION AND ASSIGNMENT OF TARGETS. a. Targets most suitable for rocket artillery are those requiring area fire. Harassing and interdiction missions of any extended duration are impracticable because of the large number of launcher positions required. Precision fire is impractical because of the large probable errors.

b. The artillery or other commander to whose command the rocket unit is attached will decide the manner of attacking a target, giving due consideration to the rocket unit commander's recommendations. The commander to whom the rocket unit is attached should ascertain the status of rocket ammunition supply before assigning targets. In assigning fire missions he should furnish the rocket unit commander the following information:

(1) Location of the center of the target.

(2) Shape and size of target; approximate dimensions or limiting points.

(3) Type and nature of target—whether personnel, matériel, vehicles, or fortifications; whether in the open, entrenched, or otherwise protected.

(4) Purpose—whether neutralization, destruction, harassing, interdiction, or screening.

(5) Time to open fire—whether on call, without delay, or prearranged with respect to time or to an event.

(6) Duration of fire, number of rounds to be fired (usually determined by rocket unit commander).

(7) Type of ammunition and fuze (determined by rocket unit commander except when firing chemical shell).

(8) Special instructions, such as restrictions on registration and responsibility for furnishing observation of fires.

7. ATTACK OF TARGETS. In order that rocket fire may be placed effectively on selected targets, a thorough understanding of the proper technique of attacking targets is necessary. The attack of a target requires an analysis and study to determine the following:

a. Type of ammunition and fuze appropriate to the mission.

b. Distribution in width and depth for proper coverage.

c. Amount of ammunition required (number of rounds).

d. Number of launchers or firing units required.

8. TYPES OF AMMUNITION AND FUZE. The type of ammunition and the fuze to be used depends upon the type and nature of the target and the effect sought from the rocket fire. In general, rocket projectiles are classified as high-explosive (HE) and chemical shell (smoke). Fuzes are point detonating (either superquick or delay action) or VT.

9. DISTRIBUTION. To determine the proper distribution of rocket fire in width and depth for maximum effect, a thorough understanding of the size and shape of the dispersion pattern at different ranges is essential. A dispersion rectangle and the expected distribution for each range may be determined for each type of ammunition.

10. DISPERSION. **a.** The shape of the dispersion pattern varies at short and long ranges. At short ranges, the longer axis of the pattern is along the line of fire. At long ranges, the longer axis of the pattern is perpendicular to the line of fire. Figure 165 shows the approximate dimensions of the 100-percent dispersion rectangle at various ranges.

b. Inspection of figure 166 (dispersion rectangle) shows that approximately two-thirds (68 percent) of the shots fall in an area a quarter of the size of the 100-percent rectangle and that the other one-third of the rounds are spread over the remaining three-fourths of the 100-percent rectangle. Obviously, the concentration in the latter area will be negligible in comparison with that within the 68-percent rectangle. Only the 68-percent rectangle need be considered for the

Table of dispersion for M16 Rockets (Spin Stabilized)

Range (yards)	Range dispersion (8 probable errors) (yards)	Lateral dispersion (8 probable errors) (yards)
1,000	900	105
2,000	815	210
3,000	720	310
4,000	580	420
5,000	380	520
5,200	340	550

Figure 165. Table of dispersion.

attack of targets, since *effective coverage* will be obtained only within this area; that is, the area bounded by two probable errors on either side of the center of impact. The determination of proper distribution of rocket fire in width and depth therefore resolves itself into properly applying to the target the 68-percent dispersion rectangle.

c. Distribution in width may call for converged, parallel, or open sheafs, or for firing units to lay on different portions of the target. In general, when the target is equal to or less than four deflection probable errors, a converged sheaf should be used. When the width of a target is greater than four deflection probable errors, a parallel sheaf is employed. When the target is wider than four deflection probable errors plus 100 yards, the width of the target is divided into zones, each zone being four deflection probable errors in width. A firing unit is assigned to each zone. If the number of firing units is limited, each firing unit may have to attack a number of zones successively.

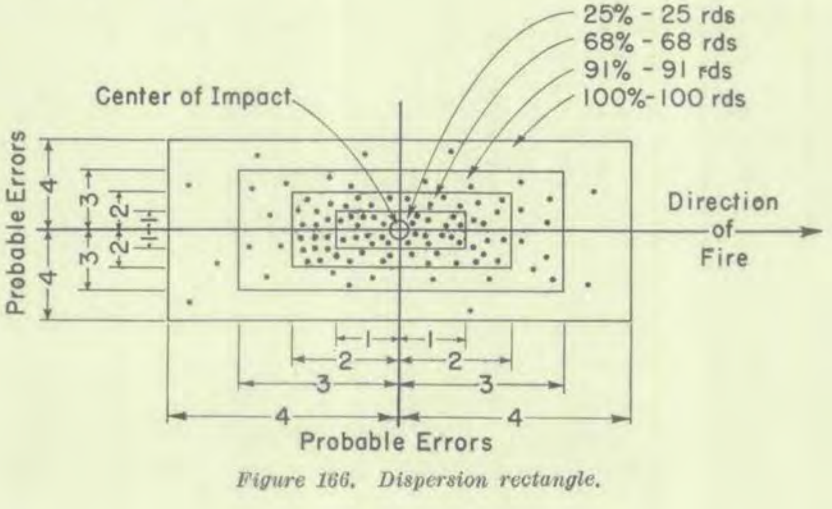


Figure 166. Dispersion rectangle.

d. Distribution in depth may call for attack of targets at center range or for targets in depth, by having a range spread between firing units. In general, when the target is deeper than four range probable errors, the target is divided into zones of four range probable errors in depth and firing units assigned to each zone or range. When the number of firing units is limited, each firing unit may have to attack a number of zones successively.

11. AMOUNT OF AMMUNITION. The amount of ammunition necessary to accomplish the effect sought will vary with the type of ammunition and fuze used as well as with the characteristics of the dispersion pattern. The number of rounds required for each type of ammunition and fuze may be determined by experience. As a guide, a distribution of 16 rounds of 4.5-inch rockets is sufficient to neutralize thoroughly an area 100 yards square.

12. LAUNCHERS REQUIRED. The number of launchers required will depend upon the effect sought, the number of rounds to be fired, and the number of launchers available to execute the fire mission. In general, since rocket fire is most effective when delivered in an intense mass, all available rocket launchers able to execute the fire mission will be used.

13. FIRE COMMANDS. a. General. The sequence and form of fire commands as outlined in paragraph 35 of the manual is followed. The charge and site are omitted, inasmuch as there is only one charge at present and the site is included in the quadrant elevation. The gunner's quadrant is not used.

b. Examples.

(1) *PLATOON ADJUST,*
SHELL HE,
FUZE QUICK,
PLATOON RIGHT 24 ROUNDS,
AT MY COMMAND,
DEFLECTION 1735,
ELEVATION 428.

(2) *PLATOON ADJUST,*
SHELL ¼ WHITE PHOSPHORUS, ¾ HE,
FUZE QUICK,
PLATOON 32 ROUNDS,
DEFLECTION 2673,
ELEVATION 470.

14. DEFINITIONS AND TERMS. a. Ripple. The term *ripple* is used as a preliminary warning to indicate the number of complete loadings to be prepared for firing in order to avoid delays between volleys or salvos. The preliminary warning *THREE RIPPLES READY* indicates that three complete loadings will be prepared for each launcher.

b. Volley. The command for volley fire is *(SO MANY) ROUNDS.* Each designated launcher fires the specified number of rounds, as rapidly as the construction of the piece and firing mechanisms permit, without regard to the other pieces. At least one-half second between rounds from each launcher should be allowed to prevent interference of projectiles and disturbances of the air through which following projectiles must pass. Where one launcher fires only a specified number of rounds (as in the firing of a center of impact adjustment) this is known as a *one-piece volley.*

c. Salvo. The command for a salvo is *RIGHT (LEFT)*, and indicates the flank from which the launchers are to be fired successively. Unless otherwise specified, each launcher fires the specified number of rounds as rapidly as possible with a time interval of two seconds between pieces. If it is desired to fire with a time interval between *round*, the command is *RIGHT (LEFT) AT (SO MANY) SECONDS.* If it is desired to fire with a time interval between *rounds* and a time interval between pieces different from normal, the command is *RIGHT (LEFT) AT (SO MANY) SECONDS, PIECES AT (SO MANY) SECONDS.*

15. SURVEY. Rocket battalions and batteries are furnished with sufficient personnel and equipment to perform their own survey. Normally, the rocket battalion and battery are charged with performing only their position area surveys. Assistance and control usually are provided by the supported or reinforced unit. The principles of field artillery survey as outlined in part five of the manual apply.

16. REGISTRATION. Registrations may be made by any one of the methods outlined below. All registrations conducted should include no more than 5 minutes active firing and are conducted from roving launcher positions.

a. Center of impact. This type of registration may be conducted and corrections determined as for other artillery weapons. A total of eight observable nonerratic rounds should be fired in this type of adjustment.

b. Bracket adjustment. A quick observed fire bracket registration is conducted by an observer. One launcher is used and four rounds fired per volley in adjustment. The quadrant elevation for the center of the bracket used (normally 100 yards) is taken as the adjusted quadrant elevation. The horizontal and vertical location of the adjusting point should be known accurately prior to firing.

17. MAP DATA. Normally, rocket fires are not adjusted with observed fire technique except for registration. Transfers of fire to targets are made from a map or map substitute. The determination of map data is the same as for field artillery fires.

18. CORRECTIONS. Deflection and elevation corrections are determined, as outlined in part three of the manual for a center of impact registration, since the probable errors are too large to permit a precision registration. Deflection corrections should be applied for all missions.

19. GRAPHICAL FIRING TABLE. On the GFT (M51), a common line through elevation, *c*, fork, and drift is necessary, since the latter three are functions of the elevation. Since the rocket GFT has only a single charge, it is much simpler to use the hairline for reading elevation, *c*, fork, drift, and probable errors and place a short range gage line on the window over the range scale. The range gage line need be only about one-fourth inch long and indicates the map range. (See TM 9–526.)

20. METRO CORRECTIONS. a. General. Only four effect factors are considered in computing metro corrections for use with the present rockets. They are—

(1) Temperature of propellant.
(2) Density.
(3) Wind.
(4) Drift.

In computing range effects, those due to density and wind are computed by the usual method of "variation from standard times unit effect." Propellant temperature is compensated for by an elevation correction, using the graphical scale on the face of the rule. Powder used for rocket propellant is so affected by temperature that one unit effect cannot be used for all temperatures.

b. Example. Range effect (wind and density) at elevation 426 (range 4,200) is minus 150 yards. Propellant temperature is 45° F. Place the hairline of the indicator over temperature 45° F. Draw the gage line over 4,050 (4,200−150). GFT setting range, 4,050, elevation 438.

21. FIRE DIRECTION. a. Battalion fire direction. The rocket battalion fire-direction center operates in a manner similar to the division artillery fire-direction center. (See part four in manual.) A suggested form for an S–3 data sheet is shown in figure 167.

Rocket Battalion S–3 Target Data

Battalion ....
Date ....
Time ....

Fire Request	*S-3 Order to Batteries*
From	Units to fire ....
Azimuth (observer to target)	Azimuth (observer to target)
....	....
Target	Target location A .... Alt ....
Location	B .... Alt ....
Altitude	C .... Alt ....
Size, width .... Depth	Nature ....
Ammunition and fuze	Sheaf ....
Duration of fire or number of rounds	Ammunition ....
....	Fuze ....
Time of opening fire	Method of fire ....
	Range spread ....
	Time of opening fire ....
	Concentration No. ....
	Time complete ....

Figure 167. A type rocket battalion S–3 target data sheet.

b. Battery fire direction. The rocket battery fire-direction center operates in a manner similar to a field artillery battalion fire-direction center. (See part four in manual.)

c. Variations. The principles and procedures of fire direction as laid down in part four of this manual apply for rocket artillery with the exception that the duties of the horizontal control operator and the vertical control operator are combined. After the battery executive's order is given (corresponds to the S–3 order), the computer alerts the platoon by giving pieces to adjust, shell, fuze, and method of fire. After the horizontal control operator data are given, the computer commands the deflection. Site then is given to the computer when called for. The computer then sends the quadrant elevation. To facilitate loading, it is usual for the platoon commander to be informed, in sufficient time prior to firing the mission, as to the type and number of rounds to prepare.

d. Computer's record. An example of a computer's record is shown in figure 168.

e. Fire capability overlays. Fire capability overlays are sent from battery to battalion. In view of the fire power of even a platoon, the fire capabilities of all platoons are entered on the battalion chart. To avoid confusion, the usual color scheme of red for "A," black for "B," and blue for "C" is used. Fire capabilities of platoons are differentiated by using solid lines for the first platoon and dotted lines for the second platoon.

Rocket Platoon Computer's Record

Date ----------

Time ----------

Battery ------------

Platoon ------------

Platoon front --------

Fire Request or Battalion S–3 Order

From --------------------------

Units to fire --------------------

Azimuth (observer to target) --------------------------------

Target location ------------------

Altitude ------------------

Width ------- Depth ------

Nature ------------------

Sheaf --------------------------

Ammunition --------------------

Fuze ----------------------------

Method of fire ------------------

Range spread --------------------

Time of opening fire --------------

Concentration No. ----------------

Preliminary warning --------------- --------------------------------

Executive's Fire Order

Platoons to fire --------------------

Basis for corrections ----------------

Projectile -------------------------

Fuze -------------------------------

Method of fire --------------------

Range spread ----------------------

Time of opening fire ---------------

Concentration No. ----------------

Computation

Df Corr --------------------------

Chart Df ------------------------

Df ------------------------------

Rn ------------------------------

El for Rn ------------------------

Rn spread ------------------------

Site ----------------------------

Quadrant ------------------------

Preliminary warning ------------- --------------------------------

Commands

Plat Adj -------------------------

Sp Corr -------------------------

Sh -------------------------------

Fz -------------------------------

Mf -------------------------------

Df -------------------------------

El -------------------------------

Ammunition

Type					
Total					
Received					
On hand					
Expended					

Figure 168. A type computer's record.

22. EXAMPLES. The following examples illustrate a method of determining the factors involved in an attack of a target. Experience will dictate how to weigh these factors properly. The factors may have to be modified by additional ammunition coverage of the target to compensate for errors in survey, laying, and firing data, and for differences in range and lateral dispersion of firing units.

903448°—50——26

a. Example 1. Target: infantry in the open, 200 yards wide, 250 yards deep; mission: neutralization; range: 4,275 yards.

(1) Distribution in width and range spread:

(*a*) From firing tables, at the center range 4,275 yards:

Deflection probable error = 56 yards.

Range probable error = 66 yards.

(*b*) The dimensions of the 68-percent dispersion rectangle are four deflection probable errors by four range probable errors. Hence, the dimensions are—

Width: $4 \times 56 = 224$ yards.

Depth: $4 \times 66 = 264$ yards.

(*c*) Inspection of the dimensions of the target reveal that they are slightly smaller than the dimensions of the 68-percent dispersion rectangle. Therefore, the sheaf will be converged and no range spread will be required.

(2) Number of rounds required:

(*a*) Assume 16 rounds per 100-yard square for neutralization. The area in 100-yard squares multiplied by 16 equals the number of rounds required.

$2 \times 2.5 = 5$, area in 100-yard squares.

$5 \times 16 = 80$ rounds to neutralize the target.

(*b*) Since only the 68-percent dispersion rectangle will cover the target, approximately one-third will fall outside the boundaries of the target. Therefore, $80 \times 3/2 = 120$ rounds are necessary for proper coverage.

(3) Number of launchers required: The number of rounds required divided by the capacity per launcher will give the number of launchers needed (for fractions use the next higher number). For example, $120 \div 24 = 5$ launchers required.

b. Example 2. Target: personnel and weapons assembled for an attack, 900 yards wide, 200 yards deep; mission: neutralization; range: 4,850 yards.

(1) Distribution in width and range spread:

(*a*) From firing tables, range 4,850:

Deflection probable error = 63 yards.

Range probable error = 52 yards.

(*b*) The dimensions of the 68-percent dispersion rectangle are—

Width: $4 \times 63 = 252$ yards.

Depth: $4 \times 52 = 208$ yards.

(*c*) Since the target is 900 yards wide and the 68-percent dispersion rectangle is 252 yards wide, the number of dispersion rectangles are—$900 \div 252 = 3.6$ or 4 rectangles.

(*d*) For proper distribution, firing units are assigned deflections so that the center of impact of one dispersion rectangle is placed approximately two deflection probable errors from the left (right) edge of the target and the remaining three dispersion rectangles distributed approximately four deflection errors to the right (left) of the preceding one. (See fig. 169.) No range spread is necessary as the 68-percent dispersion rectangles are deep enough to cover the target.

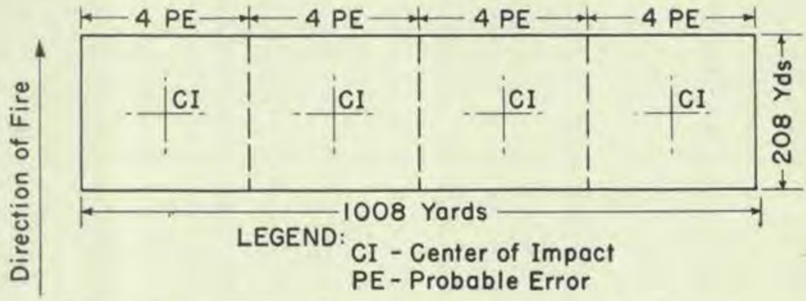


Figure 169. Area covered by four 68-percent dispersion rectangles.

(2) Number of rounds required: Use either the dimensions of the target or the dimensions of the total number of 68-percent dispersion rectangles, whichever is larger.

(*a*) Assume 16 rounds per 100-yard square for neutralization.

(*b*) Number of 100-yard squares $=4\times2.52\times2.08=20.9$ or 21.

(*c*) Number of rounds $=21\times16=336$ rounds on target, or, $336\times3/2=504$ rounds required.

(3) Number of launchers required: $504\div24=21$ launchers.

c. Example 3. Target: Personnel are in sparsely wooded assembly area, 600 yards wide, 800 yards deep; mission: neutralization; range: 4,400 yards.

(1) Distribution in width and range spread:

(*a*) From firing table, the 68-percent dispersion rectangle is 228 yards wide and 252 yards deep.

(*b*) Deflection distribution is—

With converged sheaf, $600\div228=2.6$ or 3 dispersion rectangles.

With parallel sheaf, $600\div328$ $(228+100)=1.9$ or 2 dispersion rectangles.

(*c*) Since each battery has two platoons, it is decided to divide the target into two deflection zones and use a parallel sheaf, as shown in figure 170.

(*d*) Range spread is $800\div252=3.2$ or 3 dispersion rectangles.

(*e*) Since there are three batteries available, it is decided to cover the target in depth by assigning each battery a single range, with a range spread between batteries of approximately four probable errors. The batteries then would fire at ranges of 4,150, 4,400, and 4,650 yards.

(2) Number of rounds required:

(a) Assume 16 rounds per 100-yard square for neutralization.

(b) Number of 100-yard squares are $8.00 \times 6.00 = 48$.

(c) Number of rounds are $48 \times 16 = 768$ rounds on target, or $768 \times 3/2 = 1152$ rounds required.

(3) Number of launchers required: $1{,}152 \div 24 = 48$ launchers. However, only 36 launchers are available in the battalion. To obtain an even distribution of shots in the shortest time possible, each of the 36 launchers would fire $1{,}152 \div 36 = 32$ rounds per launcher, or one complete loading of 24 rounds, followed immediately by a partial loading of eight additional rounds.

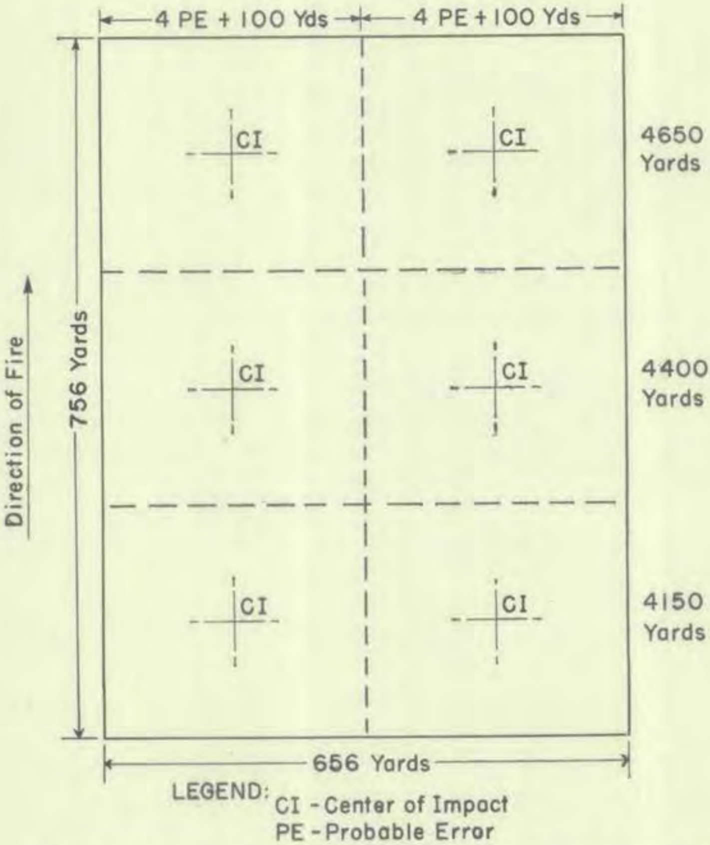


Figure 170. Area covered by six 68-percent dispersion rectangles plus 200 yards in width.

APPENDIX IV

1/2 s TABLE AND EXPLANATION

1. EXPLANATION. **a.** In figure 171, G is the position of the piece, O is the observer, A and B are two line shots 100 yards apart on the observer-target line, and a (CB) is constructed perpendicular to AG from B.

(1) Angle A (GAO) is assumed to be equal to angle T (GTO, the observer displacement, or target offset) and the length of GA is assumed to be equal to GT; T is in the vicinity of A and B. From figure 171, in the right triangle ABC—

$$\text{Sin } A=\frac{a}{c} \text{ or } \sin T=\frac{a}{c}$$

$$a=\sin T \times 100$$

(2) Since s is the deflection change, in mils, measured at the piece between two line shots, 100 yards apart on the OT line, from the mill relation ($m = W/R$)—

$$s=\frac{a}{\frac{GT}{1{,}000}} \text{ or } s=\frac{\sin T \times 100}{\frac{GT}{1{,}000}}$$

b. In a precision adjustment when no deflection bracket exists between line shots, the deflection changes made during fire for effect are in increments of ½ s. The values shown in the following table are ½ s (in mils) and are computed from the formula—

$$\frac{s}{2}=\frac{\sin T \times 100}{\frac{GT}{1{,}000}} \times \frac{1}{2}$$

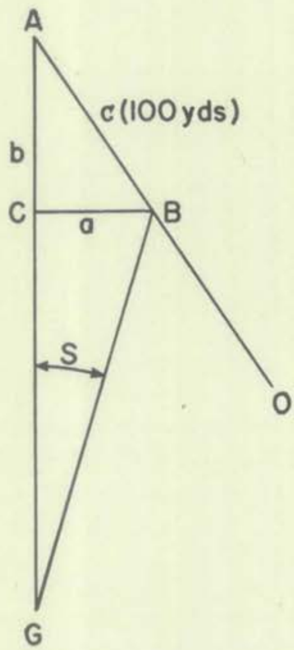


Figure 171. The deflection change, s.

2. 1/2 s TABLE.

Range *GT* in yards	*T* in mils															
	100	200	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600
2,000	2	5	7	10	12	14	16	18	19	21	22	23	24	25	25	25
2,500	2	4	6	8	9	11	13	14	15	17	18	18	19	20	20	20
3,000	2	3	5	6	8	9	11	12	13	14	15	15	16	16	17	17
3,500	1	3	4	5	7	8	9	10	11	12	13	13	14	14	14	14
4,000	1	2	4	5	6	7	8	9	10	10	11	12	12	12	12	13
4,500	1	2	3	4	5	6	7	8	9	9	10	10	11	11	11	11
5,000	1	2	3	4	5	6	6	7	8	8	9	9	10	10	10	10
5,500	1	2	3	3	4	5	6	6	7	8	8	8	9	9	9	9
6,000	1	2	2	3	4	5	5	6	6	7	7	8	8	8	8	8
6,500	1	2	2	3	4	4	5	5	6	6	7	7	7	8	8	8
7,000	1	1	2	3	3	4	5	5	6	6	6	7	7	7	7	7
7,500	1	1	2	3	3	4	4	5	5	6	6	6	6	7	7	7
8,000	1	1	2	2	3	3	4	4	5	5	6	6	6	6	6	6
8,500	1	1	2	2	3	3	4	4	5	5	5	5	6	6	6	6
9,000	1	1	2	2	3	3	4	4	4	5	5	5	5	5	6	6
9,500	1	1	2	2	2	3	3	4	4	4	5	5	5	5	5	5
10,000	0	1	1	2	2	3	3	4	4	4	4	5	5	5	5	5

APPENDIX V

CALIBRATION

1. GENERAL. Calibration is the comparison of the shooting qualities of a given piece with those of another piece accepted as standard. *Absolute calibration* is the comparison with a piece that gives firing table results under standard conditions. *Comparative calibration* is the comparison with a reference piece selected as standard; this is the usual type of calibration. A *calibration correction* is a correction applied to range or elevation to make a piece fire in agreement with a reference piece. It may be given in the form of a K correction or a VE correction. The comparative calibration corrections applicable to one charge are not necessarily applicable to another charge. If possible, weapons should be calibrated with all charges.

2. NECESSITY FOR CALIBRATION. The principles of conduct of fire are based on the assumption that if all pieces of a unit are fired under the same conditions (same ammunition lot, charge, fuze, quadrant elevation, and weather conditions) the rounds will fall at approximately the same range. This assumption usually is not true because of variations in the shooting qualities of the pieces. The variations are due to slight differences in the dimensions of the powder chambers and in wear in the tubes. When the variations are determined by calibration, compensating corrections may be made for individual pieces, or the pieces of a battalion (or larger unit) may be regrouped and allotted to batteries in accordance with their shooting qualities, in which case compensating corrections are applied by battery. The latter procedure is preferable.

3. ORDNANCE CALIBRATION. a. Mechanical calibration. This is performed by ordnance personnel. It is the determination, by measurement and computation, of the percentage of wear in the forcing cone and tube of the piece. If pieces are grouped in accordance with percentages of wear, the pieces of any particular battery will have velocity errors of approximately the same magnitude. However, the numerical values of such errors, and consequently the compensating corrections in the form of a K or a VE, cannot be determined without firing.

b. Chronograph units. Calibration may be performed by ordnance chronograph units, properly equipped to make direct measurement of muzzle velocity. This method permits the determination of a *VE* for each piece for any one ammunition lot. A comparative calibration is obtained from these measurements.

c. Wear tables. When wear tables are available for high-velocity weapons, calibration data can be corrected according to the drop in muzzle velocity expected as a result of the firing of a certain number of equivalent rounds. (An equivalent round is a round using maximum charge, or a number of rounds of a lower charge producing the same wear on the tube as a single round of maximum charge.) The actual wear rate may vary in particular tubes as much as 50 percent from the values in the tables. A new calibration is made when the correction due to wear has become large since the last calibration. These tables can be used to correct calibration data between periods of complete calibration. They give the expected loss in muzzle velocity for a round fired with a certain type of ammunition. These corrections for *VE* should be made periodically (about every ten service rounds fired). An accurate record of this firing should be kept in the gun book of the piece, and calibration corrections obtained therefrom should be kept at the battery and at the battalion fire-direction center. *Example:* An 8-inch gun M1, tube No 139, has been calibrated, using full charge M9, and full charge M10, with the following effects:

Full charge M9, -13 feet per second

Full charge M10, -28 feet per second

The gun fired eight rounds with full charge M9 and eight rounds with full charge M10. From the wear tables, the total equivalent full charge rounds of the 16 rounds fired is $(8 \times .526) + 8$ or 12 rounds. The loss in muzzle velocity for full charge M9 and full charge M10 due to the 16 rounds fired is as follows:

Loss muzzle velocity, full charge $M9 = 12 \times .24 = 2.9$ or 3 feet per second.

Loss muzzle velocity, full charge $M10 = 12 \times .4 = 4.8$ or 5 feet per second.

Therefore, the corrected *VE* for each charge is—

Corrected *VE*, full charge $M9 = (-13) + (-3) = -16$ feet per second.

Corrected *VE*, full charge $M10 = (-28) + (-5) = -33$ feet per second.

4. CALIBRATION BY FIRING. a. General. This method of calibration gives the relative shooting strength of the pieces without regard to actual muzzle velocity (comparative calibration). It consists of special calibration firing conducted by the artillery unit. Since this method is the only method under complete control of using troops, it will be explained in detail.

b. Preparation for the firing.

(1) Select a level position area and place the pieces to be calibrated about two yards apart.

(2) If possible, select a level impact area.

(3) Select at least two observation posts and a reference point for the orientation of observing instruments.

(4) Locate the positions, observation posts, and reference point accurately on the firing chart. The firing chart should be a grid sheet plotted to as large a scale as possible.

Note. If a field artillery observation battalion is available, it may execute the necessary survey, and determine the firing chart locations of the centers of impact.

(5) Check all gunner's quadrants against a master quadrant or use the same gunner's quadrant for all pieces.

(6) Obtain at least 8 rounds per piece of the same type, lot, weight of projectile, powder lot, charge, and fuze for each charge to be calibrated.

(7) Determine the data to place the burst in the impact area, and orient the observers.

c. Conduct of the firing.

(1) If more than one charge is to be fired, the lowest charge should be fired first to avoid some of the effects of coppering.

(2) Fire two rounds to warm and seat the pieces and to orient the observers.

(3) Fire 6 rounds per piece as rapidly as the observers can observe and record the readings. Readings should be recorded by tube number in order to avoid mistakes. The pieces should be fired by salvo in order that the same weather conditions affect all rounds equally.

d. Computation of the VE's.

(1) Plot the center of impact for each piece and determine the range from each piece to its center of impact.

(2) Correct each range, if necessary, for differences in altitude between the centers of impact. This correction may be made by dividing the difference in altitude (in yards) of each center of impact from the mean altitude of the centers of impact by the slope of fall (column 10 in the firing tables) and applying the result as a correction to the range.

(3) Average the corrected ranges. The average range is used as standard for all pieces.

(4) Determine the difference in range between each piece's center of impact, corrected for difference in altitude, and the average range. This difference should be expressed as an error rather than a correction.

(5) Convert this error to a *VE* by dividing the error in yards by the factor yards per foot-second taken from the firing tables for the average range.

(6) A comparison of the *VE*'s so obtained will give the relative shooting strengths of the pieces.

5. GROUPING OF PIECES. a. After the determination of the *VE* of each piece of the unit, whether determined by chronograph or special calibration firing, the pieces are grouped in the batteries on the basis of the *VE*'s. If the data from both chronograph and calibration by firing are available, the pieces should be grouped on the basis of the calibration by firing.

b. The longest shooting pieces are assigned to one battery, the average shooting pieces to another, and the shortest to another. As an exception, two batteries may have the pieces of approximately equal shooting qualities and the other the very long and very short shooting pieces. The reference or base piece for each battery should be the longest shooting piece of that battery. This piece will be used more than any other, thereby reducing its muzzle velocity. As a result, all pieces within a battery eventually should have approximately the same muzzle velocity.

c. Pieces are grouped on the basis of calibration in the charge most frequently used.

6. APPLICATION OF CALIBRATION CORRECTIONS. a. Between the pieces of the battery.

(1) The battery executive computes and the chiefs of section apply corrections for calibration between the pieces of the battery. All pieces of the battery are corrected to the shooting strength of the base or reference piece. These corrections are computed for the range and charge to the center of the zone of fire. The range and charge are given the executive by the fire-direction center or the battery commander. The corrections so determined are applied as corrections to site.

(2) *Example.* A 105-mm howitzer battalion has occupied position and the battery executive has been ordered to compute corrections for calibration for charge 6 at range 7,000. The executive has on record in the battery the *VE*'s for each of the pieces of his battery. They are as follows:

Tube No. 30735−18 f/s (1st section)
Tube No. 21932−14 f/s (2d section)
Tube No. 29015−17 f/s (3d section)
Tube No. 22811−20 f/s (4th section)
Tube No. 31953−15 f/s (5th section)
Tube No. 21153−19 f/s (6th section)

Since No. 1 shoots shorter than No. 2, it must be corrected by +4 f/s to make it shoot with No. 2. It is corrected as follows:

$$\frac{+4 \text{ f/s} \times 5.6 \text{ yds / f/s (at 7,000)}}{14 \text{ yds / } \not{m} \text{ (at 7,000)}} = +2 \text{ mils.}$$

A correction to the site of No. 1 of *UP 2* mils would be applied by the chief of section to compensate for the difference in shooting qualities between No. 1 and No. 2 pieces. A similar computation would be made to correct the other pieces of the battery in order to make them shoot with No. 2.

b. Between the reference pieces of the batteries within the battalion.

(1) Fire-direction center applies the correction for calibration between the reference pieces of the batteries to cause the batteries to fire together. This can be done by correcting the GFT setting determined by an adjusting battery so that it reflects the difference between the shooting qualities of the reference pieces of the batteries. If each piece in the battery has been corrected to the shooting strength of the reference piece of the battery, correcting the reference piece of a nonregistering battery to make it fire with the piece which has registered should place the bursts of all the pieces of the battalion in the same pattern as the pieces are in the position area.

(2) *Example* (continuation of example in **a** (2) above). The calibration of *VE's* of all the pieces of the battalion are on record in the fire-direction center. Battery B has registered on the base point and, as a result of the registration, has obtained the following GFT setting: Charge 6, Fuze M51, range 7,590, elevation 375. The calibration *VE*'s of the reference pieces of the batteries, charge 6, are as follows:

Battery A, — 8 f/s
Battery B, —14 f/s
Battery C, —22 f/s

There is a difference of 6 f/s between Batteries A and B, with A having the longer shooting piece. Battery A would fire 6×5.9 (yards per f/s at elevation 375) =35 yards over Battery B. The graphical firing table setting for Battery A would be: Charge 6, fuze M51, range 7,625, elevation 375. In the same manner, Battery C would fire: 8×5.9=47 yards short of Battery B. The GFT setting for Battery C would be: Charge 6, fuze M51, range 7,540, elevation 375.

APPENDIX VI

SERVICE PRACTICE

1. PURPOSE OF SERVICE PRACTICE. Service practice is a part of the tactical field training of field artillery units and it should combine all elements of field artillery training: tactical employment, mobility, signal communication, and preparation, execution, and conduct of fire. The preparation, execution, and conduct of fire with service ammunition by field artillery units is the final phase of training for battle.

2. QUALIFICATION OF OFFICERS FOR SERVICE PRACTICE. Field artillery must be able to deliver fire accurately and promptly. All field artillery officers must be highly skilled and disciplined in the techniques for preparing and conducting fire. Proficiency can be established and maintained only by constant practice.

3. BATTERY TRAINING FOR SERVICE PRACTICE. The degree of fire discipline and proficiency in signal communication which is required for service practice is established and maintained by daily training in the gun park and in nonfiring exercises. Accuracy in execution must be the foundation, and this principle must be emphasized from the first day of training. Before a gun, howitzer or rocket battery is designated to fire at service practice, it must be established that the unit is qualified to compute, transmit, and execute fire commands with accuracy and speed.

4. COMMANDING OFFICER. The commanding officer of a post, camp, or station is responsible for the preparation, maintenance, and assignment of field artillery ranges which are allotted to his command. If required by local conditions, the commanding officer should prescribe such additional regulations as may be necessary to insure compliance with the safety precautions prescribed in SR 385–310–1. A range officer and such other personnel as may be necessary are detailed to assist the commanding officer in the discharge of this duty.

5. OFFICER IN CHARGE OF FIRING. Safety in firing is the responsibility of the officer in charge of firing. The officer in charge of firing is the officer charged with the conduct of any exercise of training which involves the firing of live ammunition. The officer in charge of firing is assisted by a safety officer detailed for duty at each battery position.

6. THE RANGE OFFICER. **a.** The range officer is responsible to the commanding officer for the proper preparation and maintenance of the range. The range officer is responsible that the danger areas of the range are cleared of all individuals prior to firing, and that properly instructed range guards are posted to cover all normal approaches to the danger areas to prevent trespassing during firing, and that the prescribed warning signals are displayed. During the firing, the range officer is an assistant to the officer in charge of firing.

b. The range officer authenticates the safety card or otherwise assures himself that the safety limits as given to the safety officer are correct and in accordance with regulations.

7. THE SAFETY OFFICER. **a. General.** The safety officer is the representative of the officer in charge of firing at the battery position. Orders issued by the safety officer which prohibit firing are lawful and can be rescinded only by the officer in charge of firing or by the commanding officer. The safety officer and such assistants as are necessary are detailed to minimize the possibility of accidents. They are not detailed to check and correct errors or inaccuracies in the laying or serving of the pieces other than those affecting compliance with safety regulations. The safety officer (and his assistants) will perform required duties with the least interference possible to the delivery of fire. The responsibility for the accurate and prompt execution of fire commands rests with the battery executive and personnel of the firing battery.

b. Before firing. The safety officer takes the following measures prior to opening of fire to insure compliance with regulations:

(1) Verifies that the battery is in the proper position.

(2) Verifies his safety card to assure himself that it is the proper one.

(3) Verifies the initial laying of the battery.

(4) Prepares a safety diagram showing for each authorized projectile, charge, and fuze, the deflection, fuze, and quadrant elevation settings marking the limits of the impact area prescribed on the safety card.

(5) Marks on the ground the deflection safety limits for each piece.

(6) Verifies the minimum elevations and fuze settings as determined by the executive (FM 6-140) when a mask is between the battery position and the impact area. These settings will govern if they are greater than the ones determined in (4) above.

(7) Informs each chief of section of the deflection settings, minimum time fuze settings, and of the maximum and minimum quadrant elevations outside of which the pieces may not be fired.

c. During firing. The safety officer performs the following duties during firing at the battery position:

(1) Prevents violation of safety regulations, such as the careless handling of ammunition, smoking near the pieces or firing with inoperative safety features of weapons.

(2) Indicates to the executive by signal or oral expression "Safe to fire" when the pieces to fire have been laid with deflection, fuze settings, and quadrant elevation settings, and loaded with powder charges which will cause the projectiles to burst inside the prescribed impact area. The safety officer does not merely satisfy himself that safe commands are given to the pieces, but insures that the pieces are safely *laid* and *loaded*.

(3) Prohibits the execution of any fire command which will cause fire to fall outside the safety limits.

(4) Reports to the battery executive when it is unsafe for any piece to fire as laid and ordered, reporting that fact and the reason therefor; for example, "Unsafe to fire, Number four is 30 mils left of safety limit," or "Unsafe to fire, maximum elevation with charge 5, site 315 is 360."

(5) Modifies the limiting elevation, deflection, and time fuze settings by applying registration corrections (pars. 129–139) as soon as they are determined.

8. CONDUCT OF SERVICE PRACTICE. **a.** Field artillery service practice should be conducted under the direction of the battalion commander. The battalion is the fire unit, and the training of battalion personnel in preparation, execution, and conduct of fire is the responsibility of the commander.

b. It often is advisable to have service practice as the continuation of a tactical field exercise which requires that the artillery unit occupy a position and open fire in support of the action of the force it supports. Following the tactical occupation of position by the field artillery unit, the officers may be assembled at a single observation post for instruction in preparation and conduct of fire. Such service practice should be conducted as the examination phase for officers qualified to conduct fire and as the demonstration phase for those officers who are not qualified. The firing of service ammunition to teach techniques of preparation, execution, and conduct of fire is an unnecessary and wasteful procedure. The techniques must be taught and fire discipline must be established by training in the gun park, in the classroom, in nonfiring exercises, and by the use of terrain board, terrain plot, field artillery trainer, and subcaliber firing. When service ammunition is fired, special attention must be given to technique of observation, since instruction in observation and sensing cannot be duplicated on terrain boards or on other mechanical devices.

c. During early training, it is desirable to conduct service practice under conditions similar to those of a classroom in order to distract the beginner as little as possible. The introduction of a complete tactical situation seldom is of value until the officer concerned is thoroughly grounded in firing.

9. PHASES OF SERVICE PRACTICE. a. General. The conduct of any service practice is divided into four distinct phases:

(1) Preparation.

(2) Procedure at OP prior to firing.

(3) Procedure during firing.

(4) Procedure at close of firing.

Each of these phases is important from the standpoint of the officer in charge of firing (instructor) and none can be dismissed as being nonessential.

b. Preparation. Upon receipt of instruction to conduct service practice, the officer in charge should accomplish the following:

(1) *Reconnaissance.* A ground reconnaissance of the area and routes of approach for the service practice is vitally important to the officer in charge, no matter how familiar he may be with the area. The OP should be selected carefully to give the desired angle T and observation. OP's which will cause the officers to sit with the sun in their eyes should be avoided.

(2) *Maps.* The officer in charge should prepare a map with the location of the batteries, observation post, safety limits, and base point plotted on it.

(3) *Range clearance.* The officer in charge will contact the range officer to obtain clearance of the area for firing, and to have a range safety card prepared. This card will comply with SR 385–310–1. One copy of the safety card must be delivered to the battery safety officer prior to the service practice.

c. Procedure at OP prior to firing.

(1) The primary consideration in the organization of the OP is that all officers should have a good view of the target area.

(2) After the officers are seated, the officer in charge should check his range safety card with the safety officer's card. They should be identical. The officer in charge is responsible for

reporting any discrepancy to the range officer. Prior to opening fire, a check always must be made with the range officer to ascertain that the range is clear.

(3) The recorder, and telephone and radio operators should be placed so that they easily can hear the officer firing and not mask any of the target area from the observer.

(4) The officers should be oriented on the ground. This may be accomplished as follows:

(*a*) Define the limits of the target area. (A good method is by describing a tactical situation involving front lines, left and right limits, and a final objective.)

(*b*) Define reference points which will be used in target designation.

(*c*) Identify any other points which are to be used in later target designation or orientation.

(5) The officers should be given pertinent parts of the battery executive's report and any information available at the fire-direction center which will assist them in requesting fire.

(6) The base point or initial target should be designated at this time so that all officers can prepare initial data.

(7) During early stages of training, it usually is advisable to guide officers into giving correct initial fire requests.

d. Procedure during firing. The officer in charge should have a logical system for conducting the practice. In following his system, he should bear in mind that it is his duty to arouse interest in firing and to teach the officers proper technique. He must strive continually to instill confidence in the officer firing. A system for conducting service practice which has proven successful is described below.

(1) *Target designation.* All targets should be designated in a uniform manner. This enables the officers to become accustomed to a routine and to devote their effort to making precise measurements.

(2) *Accuracy of measurement.* The officer in charge always must make his measurements as accurately as possible so that the officers will have no difficulty in making their identifications.

(3) *Initial data.* All officers should prepare initial data for every problem and keep a record of the problem as it is fired. This may be accomplished by designating a target without assigning it. After all have prepared data, the assignment should be made.

(4) *Conduct of individual problems.* An individual assigned a mission must be made to understand that its successful completion is his responsibility. The officer in charge should not interfere with the conduct of a mission unless, by failing to do so, errors result which would decrease the value of the

problem as a lesson. In such cases, the officer in charge may give help or, if errors are made consistently, he may reassign or stop the mission.

(5) *Critique.* A critique which will summarize and explain the lessons learned during the firing should be given at the end of each problem.

e. Procedure at close of firing.

(1) The officer in charge should notify the unit firing that the practice is at an end.

(2) The unit firing should make a physical check of ammunition.

(3) The records of the recorder at the OP should be checked against those kept at the firing unit.

10. CRITIQUES. **a.** Good instruction at service practice requires that the officer directing the practice should be capable of conducting a critique which presents intelligent, tactful, and constructive criticism of each problem fired. Critiques should be courteous, impersonal, specific, and limited to essentials. The officer directing the service practice must be qualified professionally and especially skilled in preparation and conduct of fire.

b. Following each fire mission, a critique should be held at once, conducted generally in the following order:

(1) A brief description of the tactical situation, including the location of the elements of the supported unit; a description of the target; a statement of the *assigned mission.*

(2) How the target was to be attacked; precision or area fire.

(3) A concise statement as to whether or not the mission was accomplished.

(4) State whether the fire mission was satisfactory or unsatisfactory.

(5) Discuss the essential reasons why the mission was (was not) accomplished. Mention the good points first, then cover any bad points which will be of instructional value. Limit the number of points discussed and make at least one of them a good point.

(6) Ask questions and comments of the officer who has fired and the other officers present. If necessary, the officer in charge should stimulate a brief discussion, and answer all questions concerning the mission.

APPENDIX VII

COMMON MISTAKES AND THEIR PREVENTION OR DETECTION

1. AIMING CIRCLE. a. Common mistakes.

(1) Failure to note that turning the azimuth micrometer has moved the azimuth index to the wrong hundred, thereby setting, for example, 5,541 instead of 5,441.

(2) Setting, for example, 3,697 instead of 3,597 because the azimuth index is near 36.

(3) Turning the lower motion instead of the upper motion, or vice versa.

(4) Failure to clamp the two clamping screws and the wing nut.

(5) Bumping the instrument or tripod.

(6) Having objects containing magnetic metals on the person.

(7) Counting mils in the wrong direction from a numbered graduation on the azimuth micrometer scale, thus setting, for example, 2,373 instead of 2,367.

(8) Failure to level the bubble.

(9) Failure to follow the prescribed procedure for the elimination of lost motion.

b. Prevention. Formation of proper habits in training (consisting principally of checking operations and insisting on exactness).

c. Detection. Independent checks, repeated readings, reading settings, check of final direction by azimuth.

2. TRANSIT. a. Common mistakes.

(1) Same as in paragraph 1**a** (3), (4), (5), and (9) above.

(2) Reading the supplement of an angle because the wrong figures on the horizontal scale have been read.

(3) Reading in the wrong direction on the vernier.

b. Prevention and detection. Same as in paragraph 1**b** and **c** above.

3. OTHER OPTICAL INSTRUMENTS (INCLUDING SIGHTS). Similar to paragraph 1 above.

4. TAPING. a. Common mistake.

(1) Getting wrong number of tape lengths because pins were lost or miscounted, or counting number of tape lengths different from the number of pins.

(2) Becoming confused in breaking tape.

(3) Reading final part of tape length from wrong end of tape.

(4) Including that part of tape beyond the graduations.

(5) Taping in feet and recording the same amount as yards.

b. Prevention. Same as paragraph **1b** above.

c. Detection. Rough check by pacing; closing traverse.

5. NUMBERS. a. Common mistakes.

(1) Garbling of numbers by inversion (as for example 12,475 instead of 14,275).

(2) Garbling of numbers because digits were misunderstood or forgotten.

(3) Decimal points in wrong place.

(4) Errors in addition and subtraction.

(5) Errors in plus and minus signs.

b. Prevention and detection.

(1) Avoiding mistakes set forth in **a** (1) and (2) above; habitually recording, pausing after three digits for a repeat back, habitually repeating back; for example, the proper method of sending (56.83–46.28) is: Five six point (repeated by receiver); eight three dash (repeated by receiver); four six point (repeated by receiver); two eight (repeated by receiver).

(2) Same as for items (3), (4), and (5) in **a** above; independent checks and rechecks.

6. PLOTTING. a. Common mistakes.

(1) Using 1/21,120 scale instead of 1/25,000 scale.

(2) Using 1/25,000 instead of 1/20,000 coordinate scale on 1/25,-000 photomap having 1.8-inch point designation grid.

(3) Same as paragraph 5**a** (1) and (2) above.

(4) Considering the subdivided 1,000 as being included in the numbered thousands, on a plotting scale in such a manner that the answer determined is 1,000 units less than the correct distance.

(5) Plotting the coordinates from the wrong grid line in the wrong direction, when the map is so placed that north is toward the plotter.

(6) Putting the center of the protractor over the wrong point.

(7) Reading azimuths 1,600 or 3,200 mils in error.

b. Prevention. Covering scales which should not be used; formation of proper habits in training.

c. Detection. Independent check or supervision.

7. RANGE-DEFLECTION FAN. a. Common mistakes.

(1) Reading deflections from the base-point line extension rather than deflection index, or from the wrong battery's base-point line extension or deflection index.

(2) Wrong hundreds of mils of deflections.

b. Prevention.

(1) Removal of base-point line extension from the chart after construction of a deflection index.

(2) Formation of proper habits in training.

c. Detection. Comparison and supervision.

8. TARGET GRID. a. Common mistakes.

(1) Miscounting in increments of 100 yards in plotting shifts on the grid.

(2) Misorienting the target grid so that arrow is not pointing parallel to, and in the same direction as, the line from observer to target.

(*a*) Failing to orient properly the target grid, using the azimuth scale, which is graduated in a *counterclockwise* direction.

(*b*) Failing to construct correctly, or use, the azimuth index, especially when an *X*- or *Y*-grid line is used as an index.

(3) Reversal of observer's target location; for example, plotting "From base-point right 500" as 500 yards left (or over, or short) of the base point.

b. Prevention. Formation of proper habits in training.

c. Detection. Comparison and supervision.

9. GRAPHICAL FIRING TABLE. a. Common mistakes.

(1) Wrong table or charge.

(2) Same as paragraph 5**a** (1) and (2) above.

(3) Using drift instead of *F*, or vice versa.

b. Prevention. Formation of proper habits in training.

c. Detection. Comparison; supervision; calling for computers to read off their elevations at given ranges.

10. EXECUTION OF FIRE COMMANDS. a. Common mistakes.

(1) Wrong charge.

(2) Time which is whole seconds in error, or fractional part of a second read in wrong direction from numbered graduation.

(3) Failure to correct for lost motion as prescribed.

(4) Same as paragraph 5**a** (1) and (2) above.

(5) Failure to level all bubbles.

(6) Setting wrong elevation, site, or quadrant elevation.

b. Prevention. Formation of proper habits in training.

c. Detection. Independent check of charge and fuze within the section; frequent check of settings by executive.

11. MISCELLANEOUS. a. Common mistakes.

(1) Choosing a complex or difficult method when a simple method is available.

(2) Use of methods inconsistent with accuracy sought.

(3) Wasting time and ammunition, and losing effect on the target.

b. Prevention. Use of initiative and judgment; use of prescribed procedures; taking time to select the most effective plan.

APPENDIX VIII

STAR CHARTS AND TABLES

Section 1. STAR CHARTS

1. GENERAL. The military surveyor should be familiar with some of the bright stars in all parts of the sky and with methods of obtaining valuable data from them. The great number of stars and their general distribution over all parts of the sky make it possible to select stars in favorable positions for the required observations.

2. IDENTIFICATION OF STARS. It is assumed that everyone knows Polaris (the North Star) and the Big Dipper (Ursa Major) with its "pointers" which aid in locating Polaris. Anyone who has been in the Tropics should be familiar with the Southern Cross (Crux). With such a start and some study of the star charts (figs. 172 and 173), anyone in a few evenings should acquire sufficient familiarity with the stars visible at that time of the year to suit his needs. Star charts, unfortunately, have to be printed on flat sheets of paper and some of the relative positions consequently are distorted a little. Figure 172 is a chart showing all the stars in the Northern Hemisphere and stars in the Southern Hemisphere which are within 30° of the Celestial Equator. Figure 173 shows all stars in the Southern Hemisphere and those of the Northern Hemisphere within 10° of the Equator. The charts show the stars as viewed in the sky. The dotted lines outline the constellations.

3. EXPLANATION OF STAR CHARTS. a. Northern Hemisphere (fig. 172). This chart is to be used when the observer is in the Northern Hemisphere of the earth. The center of the figure is the North Celestial Pole which is very near the star Polaris. The concentric circles around this point are declination circles at 10-degree intervals, which facilitate the reading of approximate declinations of stars shown on the chart. The circle of 0° declination is, of course, the Celestial Equator. The dotted lines radiating from the center are called *hour circles* and correspond to circles of longitude on the earth. The hour circles are numbered from 1 to 24 on the outer circle of the chart, the zero-hour circle coinciding with the circle numbered 24.

b. Southern Hemisphere (fig. 173). This chart is to be used when the observer is in the Southern Hemisphere on the earth. The center of the chart is the South Celestial Pole which is not near any bright star. The declination circles and hour circles are as explained for the Northern Hemisphere with the exception that the hour circles are numbered in the opposite direction.

4. ORIENTATION OF STAR CHARTS. a. Northern Hemisphere.

(1) If the observer knows and recognizes one or more constellations visible in the sky, the chart can be oriented by holding the picture of the consellation on the chart between his eyes and the constellation in the sky. The chart should be turned so that the various stars of the picture have the same orientation as the stars in the sky.

(2) (*a*) If no constellation is recognized but the general direction of north is known, the chart may be oriented by using the position of the sun on the chart which readily can be determined with sufficient accuracy for this purpose. On 21 March of each year, the sun is approximately at the intersection of the zero (24) hour circle and the celestial Equator. Since it takes the sun one year to make one trip around the celestial sphere, the sun apparetly will shift eastward (to the left as one looks at the lower part of the chart) from one hour circle to the next in a period of one-half month. For example, since the constellation Orion is between hour circles numbered 5 and 6, the sun will be in the vicinity of Orion about two months and three weeks after 21 March or, roughly, on 3 June. To determine the approximate location of the sun on the chart at a given date, for example on 1 October, determine the number of months since 21 March and count twice that number of hour circles from the zero circle. From 21 March to 1 October is roughly 6 months and one week. The position of the sun is about half way between hour circles 12 and 13.

(*b*) The sun does not travel along the Equator but is north of the Equator from 21 March until 21 September and is south of the Equator the remainder of the time. The greatest declination (angular distance from the Equator) is 23.5° which occurs 3 months from 21 March or 21 September.

(*c*) The first step in orienting the star chart is to locate the position of the sun. The observer then faces south, holds the chart at arms' length, arms at about 45° above the level of his eyes, with the chart perpendicular to the line of sight. He then rotates the chart about its center until

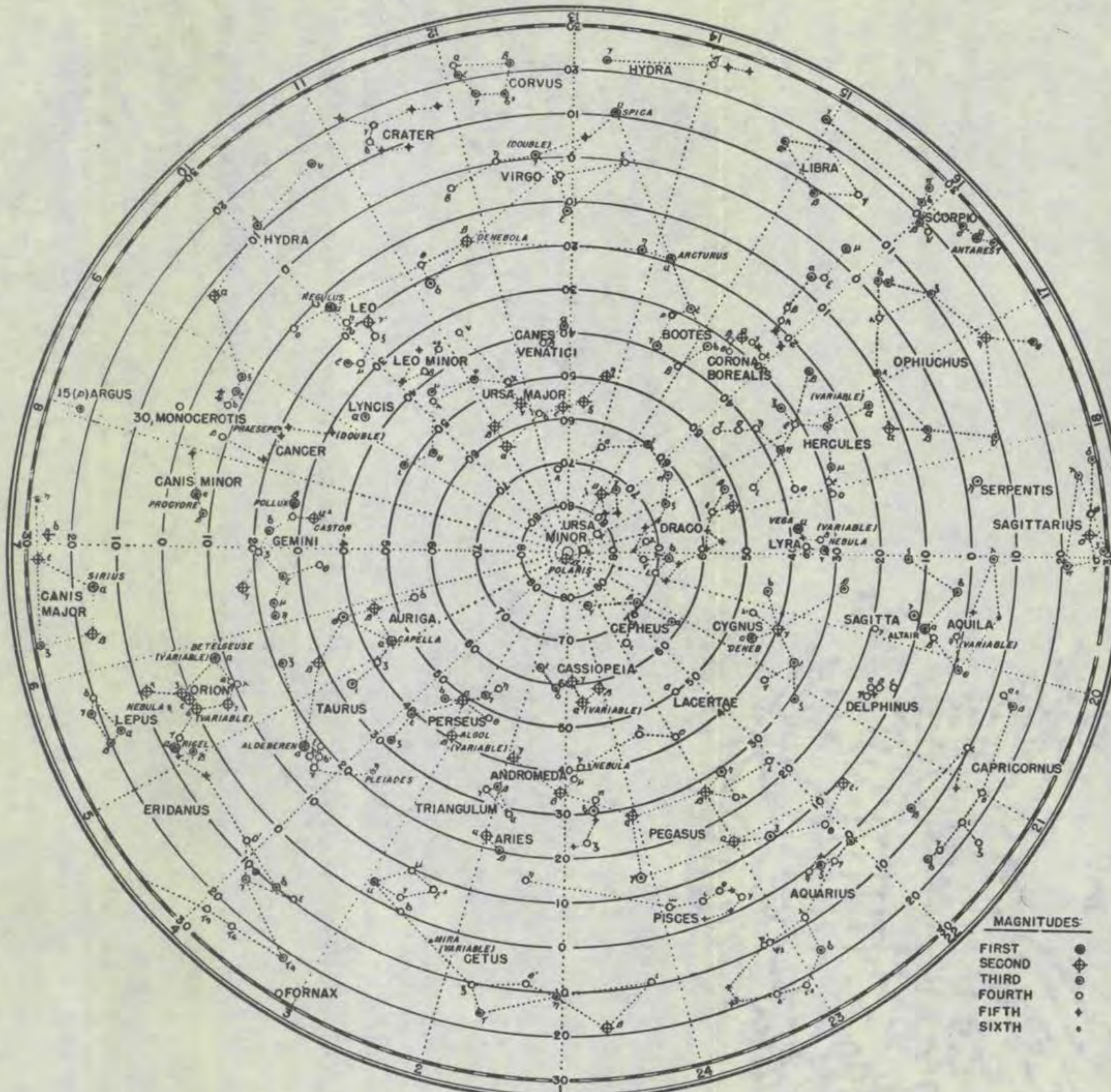


Figure 172. Star chart of the Northern Hemisphere.

863233 O - 50 (Face p. 420) No. 1

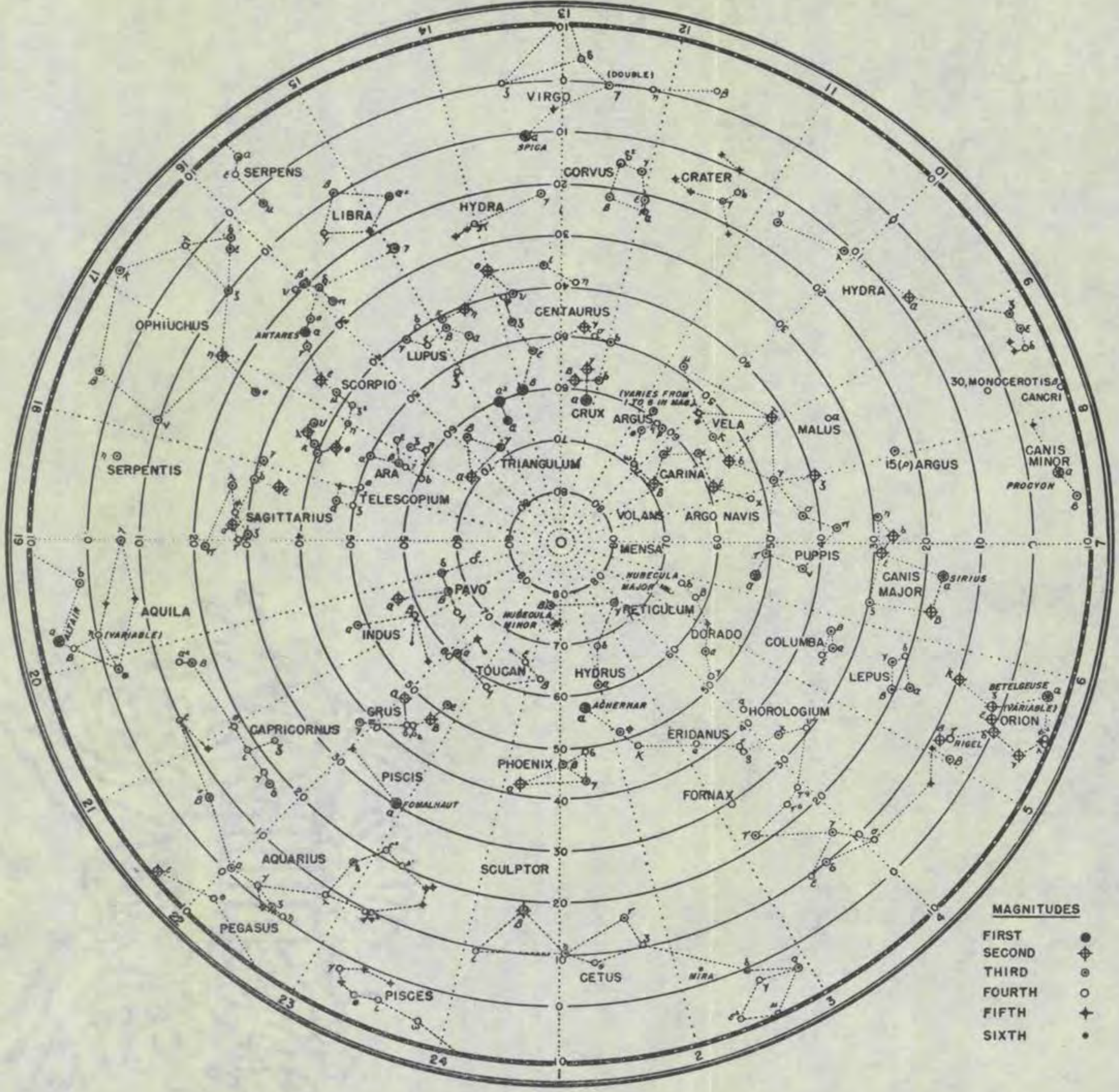


Figure 173. Star chart of the Southern Hemisphere.

the hour circle toward the previously determined position of the sun points in the direction of the azimuth of the sun at the time of observation. The azimuth of the sun during the hours of darkness is 180° greater than the azimuth of the sun 12 hours previously. For example, if the azimuth of the sun at 1000 hours is 150°, the azimuth at 2200 hours will be 330°; if the azimuth of the sun at noon is 180°, the azimuth at midnight will be 0°; if the azimuth at 1500 hours is 220°, the azimuth at 0300 hours will be 40°. The *lower part* of the chart, as now held by the observer, is a map of the stars in front of him. The height of the stars above the horizon varies with the latitude of the observer, but a study of the brightest stars should enable the observer to locate them on the chart.

b. Southern Hemisphere. The procedure explained for orienting the chart of the Northern Hemisphere is usable for the chart of the Southern Hemisphere with slight changes. On this chart, eastward is to the right of the lower part of the chart, and the hour circles are numbered to the right. In orienting the chart by means of the position of the sun, the observer faces north.

Section II. TABLES

1. Tables for computation of direction from astronomic observations comprise this section.

2. The tables are grouped as follows:

Table I. Corrections for parallax and refraction.
II. Sun's declination.
III. Declination of the stars.

Table I. Correction for Parallax and Refraction To Be Subtracted From the Observed Altitude of the Sun

(For observations to stars, these corrections must be increased 0.1′ for altitudes up to 70°)

Apparent altitude (degrees)	Temperature, Fahrenheit					
	0°	+20°	+40°	+60°	+80°	+100°
5	10. 9′	10. 4′	9. 9′	9. 5′	9. 1′	8. 8′
6	9. 3	8. 9	8. 5	8. 1	7. 8	7. 5
7	8. 1	7. 7	7. 4	7. 1	6. 8	6. 6
8	7. 1	6. 8	6. 5	6. 3	6. 0	5. 8
9	6. 4	6. 1	5. 9	5. 6	5. 4	5. 2
10	5. 8	5. 5	5. 3	5. 1	4. 9	4. 7
11	5. 2	5. 0	4. 8	4. 6	4. 4	4. 3
12	4. 8	4. 6	4. 4	4. 2	4. 1	3. 9
13	4. 4	4. 2	4. 1	3. 9	3. 7	3. 6
14	4. 1	3. 9	3. 8	3. 6	3. 5	3. 4
15	3. 8	3. 6	3. 5	3. 4	3. 2	3. 1
16	3. 6	3. 4	3. 3	3. 2	3. 0	2. 9
17	3. 3	3. 2	3. 1	3. 0	2. 8	2. 7
18	3. 2	3. 0	2. 9	2. 8	2. 7	2. 6
19	3. 0	2. 8	2. 7	2. 6	2. 5	2. 4
20	2. 8	2. 7	2. 6	2. 5	2. 4	2. 3
21	2. 6	2. 5	2. 4	2. 3	2. 3	2. 2
22	2. 5	2. 4	2. 3	2. 2	2. 1	2. 1
23	2. 4	2. 3	2. 2	2. 1	2. 0	1. 9
24	2. 3	2. 2	2. 1	2. 0	1. 9	1. 9
25	2. 2	2. 1	2. 0	1. 9	1. 8	1. 8
26	2. 1	2. 0	1. 9	1. 8	1. 8	1. 7
27	2. 0	1. 9	1. 8	1. 7	1. 7	1. 6
28	1. 9	1. 8	1. 7	1. 7	1. 6	1. 5
29	1. 8	1. 7	1. 7	1. 6	1. 5	1. 5
30	1. 7	1. 7	1. 6	1. 5	1. 5	1. 4
32	1. 6	1. 5	1. 5	1. 4	1. 3	1. 3
34	1. 5	1. 4	1. 3	1. 3	1. 2	1. 2
36	1. 4	1. 3	1. 2	1. 2	1. 2	1. 1
38	1. 3	1. 2	1. 2	1. 1	1. 1	1. 0
40	1. 2	1. 1	1. 1	1. 0	1. 0	1. 0
42	1. 1	1. 0	1. 0	1. 0	0. 9	0. 9
44	1. 0	1. 0	0. 9	0. 9	0. 8	0. 8
46	0. 9	0. 9	0. 9	0. 8	0. 8	0. 8
48	0. 9	0. 8	0. 8	0. 8	0. 7	0. 7
50	0. 8	0. 8	0. 7	0. 7	0. 7	0. 7
52	0. 7	0. 7	0. 7	0. 7	0. 6	0. 6
54	0. 7	0. 7	0. 6	0. 6	0. 6	0. 6
56	0. 6	0. 6	0. 6	0. 6	0. 5	0. 5
58	0. 6	0. 6	0. 6	0. 5	0. 5	0. 5
60	0. 6	0. 5	0. 5	0. 5	0. 5	0. 5
70	0. 3	0. 3	0. 3	0. 3	0. 3	0. 3
80	0. 2	0. 2	0. 2	0. 2	0. 1	0. 1
90	0. 0	0. 0	0. 0	0. 0	0. 0	0. 0

Table II

A. Sun's Declination, 1949 (for 0^h Greenwich civil time)

Day of month	January declination		Diff. per hr.	February declination		Diff. per hr.	March declination		Diff. per hr.
	°	′		°	′		°	′	
1	S 23	3. 1	−0. 21	S 17	15. 1	−0. 71	S 7	47. 4	−0. 95
2	22	58. 2	. 22	16	58. 1	. 72	7	24. 6	. 95
3	22	52. 8	. 24	16	40. 7	. 74	7	1. 7	. 96
4	22	46. 9	. 26	16	23. 0	. 75	6	38. 7	. 96
5	22	40. 6	. 28	16	5. 1	. 76	6	15. 6	. 97
6	22	33. 9	. 30	15	46. 9	. 77	5	52. 4	. 97
7	22	26. 6	. 32	15	28. 4	. 78	5	29. 2	. 97
8	22	19. 0	. 34	15	9. 6	. 79	5	5. 8	. 97
9	22	10. 9	. 35	14	50. 6	. 80	4	42. 4	. 98
10	22	2. 4	. 37	14	31. 4	. 81	4	19. 0	. 98
11	21	53. 5	. 39	14	11. 9	. 82	3	55. 5	. 98
12	21	44. 1	. 41	13	52. 2	. 83	3	31. 9	. 98
13	21	34. 3	. 43	13	32. 2	. 84	3	8. 3	. 98
14	21	24. 1	. 44	13	12. 0	. 85	2	44. 7	. 99
15	21	13. 5	. 46	12	51. 7	. 86	2	21. 0	. 99
16	21	2. 4	. 48	12	31. 1	. 87	1	57. 4	. 99
17	20	51. 0	. 49	12	10. 3	. 87	1	33. 7	. 99
18	20	39. 2	. 51	11	49. 3	. 88	1	10. 0	. 99
19	20	27. 0	. 53	11	28. 1	. 89	0	46. 2	. 99
20	20	14. 4	. 54	11	6. 7	. 90	0	22. 5	±. 99
21	20	1. 4	. 56	10	45. 2	. 90	N 0	1. 2	+. 99
22	19	48. 0	. 57	10	23. 5	. 91	0	24. 9	. 99
23	19	34. 3	. 59	10	1. 6	. 92	0	48. 5	. 99
24	19	20. 2	. 60	9	39. 6	. 92	1	12. 2	. 98
25	19	5. 8	. 62	9	17. 4	. 93	1	35. 8	. 98
26	18	51. 0	. 63	8	55. 1	. 94	1	59. 4	. 98
27	18	35. 8	. 64	8	32. 7	. 94	2	23. 0	. 98
28	18	20. 3	. 66	8	10. 1	. 95	2	46. 5	. 98
29	18	4. 5	. 67	------	------	-------	3	9. 9	. 97
30	17	48. 4	. 69	------	------	-------	3	33. 3	. 97
31	17	31. 9	. 70	------	------	-------	3	56. 6	. 97

Table II—Continued

A. *Sun's Declination, 1949* (for 0^h Greenwich civil time)—Continued

Day of month	April declination		Diff. per hr.	May declination		Diff. per hr.	June declination		Diff. per hr.
	°	′		°	′		°	′	
1	N 4	19. 8	+0. 97	N 14	54. 7	+0. 76	N 21	58. 9	+0. 34
2	4	43. 0	. 96	15	12. 8	. 75	22	7. 1	. 32
3	5	6. 1	. 96	15	30. 8	. 74	22	14. 9	. 31
4	5	29. 1	. 95	15	48. 4	. 72	22	22. 3	. 29
5	5	52. 0	. 95	16	5. 8	. 71	22	29. 3	. 28
6	6	14. 7	. 94	16	22. 9	. 70	22	35. 9	. 26
7	6	37. 4	. 94	16	39. 8	. 69	22	42. 2	. 24
8	7	0. 0	. 93	16	56. 4	. 68	22	48. 0	. 23
9	7	22. 4	. 93	17	12. 7	. 67	22	53. 4	. 21
10	7	44. 7	. 92	17	27. 8	. 65	22	58. 4	. 19
11	8	6. 9	. 92	17	44. 4	. 64	23	3. 1	. 18
12	8	28. 9	. 91	17	59. 8	. 63	23	7. 3	. 16
13	8	50. 8	. 91	18	14. 9	. 62	23	11. 1	. 14
14	9	12. 6	. 90	18	29. 7	. 60	23	14. 5	. 12
15	9	34. 2	. 89	18	44. 2	. 59	23	17. 5	. 11
16	9	55. 6	. 89	18	58. 4	. 58	23	20. 0	. 09
17	10	16. 9	. 88	19	12. 2	. 56	23	22. 2	. 07
18	10	38. 0	. 87	19	25. 8	. 55	23	24. 0	. 06
19	10	59. 0	. 87	19	39. 0	. 54	23	25. 3	. 04
20	11	19. 7	. 86	19	51. 9	. 52	23	26. 3	. 02
21	11	40. 3	. 85	20	4. 4	. 51	23	26. 8	. 00
22	12	0. 7	. 84	20	16. 6	. 49	23	26. 9	−. 01
23	12	20. 9	. 83	20	28. 5	. 48	23	26. 6	. 03
24	12	40. 9	. 82	20	40. 0	. 46	23	25. 8	. 05
25	13	0. 6	. 82	20	51. 1	. 45	23	24. 7	. 06
26	13	20. 2	. 81	21	1. 9	. 43	23	23. 2	. 08
27	13	39. 6	. 80	21	12. 4	. 42	23	21. 2	. 10
28	13	58. 7	. 79	21	22. 4	. 40	23	18. 8	. 12
29	14	17. 6	. 78	21	32. 1	. 39	23	16. 1	. 13
30	14	36. 2	. 77	21	41. 4	. 37	23	12. 9	. 15
31	-----	-----	-----	21	50. 4	. 36	-----	-----	-----

Table II—Continued

A. *Sun's Declination, 1949* (for 0^h Greenwich Civil Time)—Continued

Day of month	July declination		Diff. per hr.	August declination		Diff. per hr.	September declination		Diff. per hr.
	°	′		°	′		°	′	
1	N 23	9. 3	−0. 17	N 18	10. 1	−0. 63	N 8	29. 4	−0. 91
2	23	5. 3	. 18	17	55. 0	. 64	8	7. 7	91
3	23	0. 9	. 20	17	39. 7	. 65	7	45. 8	. 92
4	22	56. 1	. 22	17	24. 0	. 66	7	23. 8	. 92
5	22	50. 9	. 23	17	8. 1	. 68	7	1.6	. 93
6	22	45. 3	. 25	16	51. 8	. 69	6	39. 4	. 93
7	22	39. 3	. 27	16	35. 3	. 70	6	17. 0	. 94
8	22	32. 9	. 28	16	18. 6	. 71	5	54. 6	. 94
9	22	26. 1	. 30	16	1. 6	. 72	5	32. 0	. 94
10	22	18. 9	. 31	15	44. 3	. 73	5	9. 4	. 95
11	22	11. 4	+. 33	15	26. 8	. 74	4	46. 7	. 95
12	22	3. 5	. 35	15	9. 0	. 75	4	23. 8	. 95
13	21	55. 1	. 36	14	51. 0	. 76	4	0. 9	. 96
14	21	46. 5	. 38	14	32. 7	. 77	3	38. 0	. 96
15	21	37. 4	. 39	14	14. 2	. 78	3	14. 9	. 96
16	21	28. 0	−. 41	13	55. 5	. 79	2	51. 8	. 96
17	21	18. 2	. 42	13	36. 6	. 80	2	28. 7	. 97
18	21	8. 0	. 44	13	17. 4	. 81	2	5. 5	. 97
19	20	57. 5	. 45	12	58. 1	. 82	1	42. 2	. 97
20	20	46. 7	. 47	12	38. 5	. 82	1	18. 9	. 97
21	20	35. 5	. 48	12	18. 7	. 83	0	55. 6	. 97
22	20	23. 9	. 50	11	58. 7	. 84	0	32. 2	. 97
23	20	12. 0	. 51	11	38. 6	. 85	0	8. 9	±. 97
24	19	59. 7	. 52	11	18. 2	. 86	S 0	14. 5	+. 97
25	19	47. 2	. 54	10	57. 7	. 86	0	37. 9	. 97
26	19	34. 2	. 55	10	37. 0	. 87	1	1. 3	. 97
27	19	21. 0	. 56	10	16. 1	. 88	1	24. 7	. 97
28	19	7. 5	. 58	9	55. 1	. 88	1	48. 1	. 97
29	18	53. 6	. 59	9	33. 9	. 89	2	11. 5	. 97
30	18	39. 4	. 60	9	12. 5	. 90	2	34. 8	. 97
31	18	24. 9	. 62	8	51. 1	. 90	------	------	------

Table II—Continued

A. *Sun's Declination, 1949* (for 0^h Greenwich civil time)—Continued

Day of month	October declination		Diff. per hr.	November declination		Diff. per hr.	December declination		Diff. per hr.
	°	′		°	′		°	′	
1	S 2	58. 2	+0. 97	S 14	15. 4	+0. 80	S 21	43. 5	+0. 39
2	3	21. 4	. 97	14	34. 7	. 79	21	52. 8	. 37
3	3	44. 7	. 97	14	53. 7	. 78	22	1. 8	. 35
4	4	7. 9	. 96	15	12. 4	. 77	22	10. 3	. 34
5	4	31. 1	. 96	15	31. 0	. 76	22	18. 3	. 32
6	4	54. 2	. 96	15	49. 2	. 75	22	26. 0	. 30
7	5	17. 2	. 96	16	7. 2	. 74	22	33. 2	. 28
8	5	40. 2	. 95	16	24. 9	. 73	22	40. 0	. 26
9	6	3. 1	. 95	16	42. 4	. 72	22	46. 3	. 24
10	6	25. 9	. 95	16	59. 5	. 70	22	52. 2	. 23
11	6	48. 6	. 94	17	16. 4	. 69	22	57. 6	. 21
12	7	11. 3	. 94	17	33. 0	. 68	23	2. 6	. 19
13	7	33. 8	. 94	17	49. 3	. 67	23	7. 1	. 17
14	7	56. 3	. 93	18	5. 3	. 65	23	11. 2	. 15
15	8	18. 6	. 93	18	20. 9	. 64	23	14. 8	. 13
16	8	40. 9	. 92	18	36. 3	. 63	23	17. 9	. 11
17	9	3. 0	. 92	18	51. 3	. 61	23	20. 6	. 09
18	9	25. 0	. 91	19	6. 0	. 60	23	22. 8	. 07
19	9	46. 8	. 90	19	20. 3	. 58	23	24. 5	. 05
20	10	8. 5	. 90	19	34. 3	. 57	23	25. 8	. 03
21	10	30. 1	. 89	19	48. 0	. 55	23	26. 6	. 01
22	10	51. 5	. 88	20	1. 2	. 54	23	26. 9	−. 01
23	11	12. 7	. 88	20	14. 1	. 52	23	26. 7	. 03
24	11	33. 8	. 87	20	26. 7	. 51	23	26. 1	. 05
25	11	54. 7	. 86	20	38. 8	. 49	23	25. 0	. 07
26	12	15. 4	. 86	20	50. 6	. 47	23	23. 5	. 08
27	12	35. 9	. 85	21	2. 0	. 46	23	21. 4	. 10
28	12	56. 2	. 84	21	13. 0	. 44	23	18. 9	. 12
29	13	16. 4	. 83	21	23. 5	. 42	23	16. 0	. 14
30	13	36. 3	. 82	21	33. 7	. 41	23	12. 5	. 16
31	13	56. 0	. 81	------	------	------	23	8. 6	. 18

Table II—Continued

B. *Sun's Declination, 1950* (for 0^h Greenwich civil time)

Day of month	January declination °	'	Diff. per hr.	February declination °	'	Diff. per hr.	March declination °	'	Diff. per hr.
1	S 23	4. 2	−0. 20	S 17	19. 3	−0. 71	S 7	53. 0	−0. 95
2	22	59. 4	. 22	17	2. 3	. 72	7	30. 2	. 95
3	22	54. 1	. 24	16	45. 0	. 73	7	7. 3	. 96
4	22	48. 4	. 26	16	27. 5	. 74	6	44. 4	. 96
5	22	42. 2	. 28	16	9. 6	. 76	6	21. 3	. 96
6	22	35. 6	. 30	15	51. 5	. 77	5	58. 2	. 97
7	22	28. 5	. 31	15	33. 0	. 78	5	34. 9	. 97
8	22	21. 0	. 33	15	14. 4	. 79	5	11. 6	. 97
9	22	13. 0	. 35	14	55. 4	. 80	4	48. 3	. 98
10	22	4. 6	. 37	14	36. 2	. 81	4	24. 8	. 98
11	21	55. 8	. 39	14	16. 8	. 82	4	1. 3	. 98
12	21	46. 5	. 40	13	57. 1	. 83	3	37. 8	. 98
13	21	36. 8	. 42	13	37. 2	. 84	3	14. 2	. 98
14	21	26. 7	. 44	13	17. 1	. 85	2	50. 5	. 99
15	21	16. 2	. 46	12	56. 7	. 86	2	26. 9	. 99
16	21	5. 2	. 47	12	36. 2	. 87	2	3. 2	. 99
17	20	53. 9	. 49	12	15. 4	. 87	1	39. 5	. 99
18	20	42. 2	. 51	11	54. 4	. 88	1	15. 7	. 99
19	20	30. 0	. 52	11	33. 3	. 89	0	52. 0	. 99
20	20	17. 5	. 54	11	11. 9	. 90	0	28. 3	. 99
21	20	4. 6	. 55	10	50. 4	. 90	0	4. 5	±. 99
22	19	51. 3	. 57	10	28. 8	. 91	N 0	19. 2	+. 99
23	19	37. 7	. 58	10	6. 9	. 92	0	42. 9	. 99
24	19	23. 7	. 60	9	44. 9	. 92	1	6. 5	. 98
25	19	9. 3	. 61	9	22. 8	. 93	1	30. 2	. 98
26	18	54. 6	. 63	9	0. 5	. 93	1	53. 8	. 98
27	18	39. 5	. 64	8	38. 1	. 94	2	17. 3	. 98
28	18	24. 1	. 66	8	15. 6	. 94	2	40. 8	. 98
29	18	8. 4	. 67	------	------	-------	3	4. 3	. 97
30	17	52. 4	. 68	------	------	-------	3	27. 7	. 97
31	17	36. 0	. 69	------	------	-------	3	51. 0	. 97

Table II—Continued

B. *Sun's Declination, 1950* (for 0^h Greenwich civil time)—Continued

Day of month	April declination		Diff. per hr.	May declination		Diff. per hr.	June declination		Diff. per hr.
	°	′		°	′		°	′	
1	N 4	14. 2	+0. 96	N 14	50. 3	+0. 76	N 21	56. 9	+0. 34
2	4	37. 4	. 96	15	8. 5	. 75	22	5. 2	. 33
3	5	0. 5	. 96	15	26. 4	. 74	22	13. 1	. 31
4	5	23. 5	. 95	15	44. 2	. 73	22	20. 6	. 30
5	5	46. 4	. 95	16	1. 6	. 72	22	27. 7	. 28
6	6	9. 2	. 95	16	18. 8	. 71	22	34. 4	. 26
7	6	31. 8	. 94	16	35. 7	. 69	22	40. 7	. 25
8	6	54. 4	. 94	16	52. 4	. 68	22	46. 6	. 23
9	7	16. 9	. 93	17	8. 7	. 67	22	52. 2	. 21
10	7	39. 3	. 93	17	24. 8	. 66	22	57. 3	. 20
11	8	1. 5	. 92	17	40. 6	. 65	23	2. 0	. 18
12	8	23. 6	. 91	17	56. 1	. 63	23	6. 3	. 16
13	8	45. 5	. 91	18	11. 3	. 62	23	10. 2	. 15
14	9	7. 3	. 90	18	26. 2	. 61	23	13. 7	. 13
15	9	29. 0	. 90	18	40. 8	. 59	23	16. 8	. 11
16	9	50. 5	. 89	18	55. 1	. 58	23	19. 5	. 09
17	10	11. 8	. 88	19	9. 0	. 57	23	21. 8	. 09
18	10	33. 0	. 87	19	22. 6	. 55	23	23. 6	. 06
19	10	54. 0	. 87	19	35. 9	. 54	23	25. 1	. 04
20	11	14. 8	. 86	19	48. 9	. 53	23	26. 1	. 03
21	11	35. 4	. 85	20	1. 5	. 51	23	26. 7	. 01
22	11	55. 9	. 84	20	13. 8	. 50	23	26. 9	−. 01
23	12	16. 1	. 83	20	25. 8	. 48	23	26. 7	. 03
24	12	36. 2	. 83	20	37. 3	. 47	23	26. 0	. 04
25	12	56. 0	. 82	20	48. 6	. 45	23	25. 0	. 06
26	13	15. 6	. 81	20	59. 4	. 44	23	23. 6	. 08
27	13	35. 0	. 80	21	9. 9	. 42	23	21. 7	. 09
28	13	54. 2	. 79	21	20. 1	. 41	23	19. 4	. 11
29	14	13. 1	. 78	21	29. 9	. 39	23	16. 7	. 13
30	14	31. 8	. 77	21	39. 3	. 38	23	13. 6	. 15
31	------	------	------	21	48. 3	. 36	------	------	------

Table II—Continued

B. *Sun's Declination, 1950* (for 0^h Greenwich Civil time)—Continued

Day of month	July declination		Diff. per hr.	August declination		Diff. per hr.	September declination		Diff. per hr.
	°	′		°	′		°	′	
1	N 23	10. 1	−0. 16	N 18	13. 7	−0. 63	N 8	34. 6	−0. 91
2	23	6. 2	. 18	17	58. 6	. 64	8	12. 9	. 91
3	23	1. 9	. 20	17	43. 3	. 65	7	51. 0	. 92
4	22	57. 2	. 21	17	27. 8	. 66	7	29. 0	. 92
5	22	52. 1	. 23	17	11. 9	. 67	7	6. 9	. 93
6	22	46. 6	. 25	16	55. 7	. 68	6	44. 7	. 93
7	22	40. 7	. 26	16	39. 3	. 70	6	22. 4	. 94
8	22	34. 4	. 28	16	22. 6	. 71	5	59. 9	. 94
9	22	27. 7	. 29	16	5. 6	. 72	5	37. 4	. 94
10	22	20. 7	. 31	15	48. 4	. 73	5	14. 7	. 95
11	22	13. 2	. 33	15	30. 9	. 74	4	52. 0	. 95
12	22	5. 4	. 34	15	13. 2	. 75	4	29. 2	. 95
13	21	57. 1	. 36	14	55. 2	. 76	4	6. 3	. 96
14	21	48. 5	. 37	14	37. 0	. 77	3	43. 3	. 96
15	21	39. 6	. 39	14	18. 6	. 78	3	20. 3	. 96
16	21	30. 2	. 40	13	59. 9	. 79	2	57. 2	. 96
17	21	20. 5	. 42	13	41. 0	. 80	2	34. 0	. 97
18	21	10. 4	. 43	13	21. 9	. 81	2	10. 8	. 97
19	21	0. 0	. 45	13	2. 5	. 81	1	47. 6	. 97
20	20	49. 2	. 46	12	43. 0	. 82	1	24. 3	. 97
21	20	38. 1	. 48	12	23. 3	. 83	1	1. 0	. 97
22	20	26. 6	. 49	12	3. 4	. 84	0	37. 7	. 97
23	20	14. 8	. 51	11	43. 3	. 85	0	14. 3	±. 97
24	20	2. 6	. 52	11	23. 0	. 85	S 0	9. 0	+. 97
25	19	50. 1	. 53	11	2. 5	. 86	0	32. 4	. 97
26	19	37. 3	. 55	10	41. 8	. 87	0	55. 8	. 97
27	19	24. 1	. 56	10	21. 0	. 87	1	19. 2	. 97
28	19	10. 6	. 57	10	0. 1	. 88	1	42. 5	. 97
29	18	56. 9	. 59	9	38. 9	. 89	2	5. 9	. 97
30	18	42. 8	. 60	9	17. 6	. 89	2	29. 2	. 97
31	18	28. 4	. 61	8	56. 2	. 90	------	------	------

Table II—Continued

B. *Sun's Declination, 1950* (for 0^h Greenwich civil time)—Continued

Day of month	October declination		Diff. per hr.	November declination		Diff. per hr.	December declination		Diff. per hr.
	°	′		°	′		°	′	
1	S 2	52. 6	+0. 97	S 14	10. 7	+0. 80	S 21	41. 1	+0. 39
2	3	15. 9	. 97	14	30. 0	. 79	21	50. 6	. 38
3	3	39. 1	. 97	14	49. 1	. 78	21	59. 6	. 36
4	4	2. 3	. 97	15	7. 9	. 77	22	8. 2	. 34
5	4	25, 5	. 96	15	26. 5	. 76	22	16. 4	. 32
6	4	48. 6	. 96	15	44. 8	. 75	22	24. 2	. 31
7	5	11. 7	. 96	16	2. 9	. 74	22	31. 5	. 29
8	5	34. 7	. 96	16	20. 7	. 73	22	38. 4	. 27
9	5	57. 7	. 95	16	38. 3	. 72	22	44. 8	. 25
10	6	20. 5	. 95	16	55. 5	. 71	22	50. 8	. 23
11	6	43. 3	. 95	17	12. 5	. 69	22	56. 4	. 21
12	7	6. 0	. 94	17	29. 1	. 68	23	1. 4	. 19
13	7	28. 6	. 94	17	45. 5	. 67	23	6. 1	. 17
14	7	51. 1	. 93	18	1. 5	. 66	23	10. 2	. 15
15	8	13. 4	. 93	18	17. 3	. 64	23	13. 9	. 14
16	8	35. 7	. 92	18	32. 7	. 63	23	17. 2	. 12
17	8	57. 8	. 92	18	47. 8	. 61	23	20. 0	. 10
18	9	19. 8	. 91	19	2. 5	. 60	23	22. 3	. 08
19	9	41. 7	. 91	19	16. 9	. 59	23	24. 1	. 06
20	10	3. 4	. 90	19	31. 0	. 57	23	25. 5	. 04
21	10	25. 0	. 89	19	44. 7	. 56	23	26. 4	. 02
22	10	46. 4	. 89	19	58. 1	. 54	23	26. 8	. 00
23	11	7. 7	. 88	20	11. 0	. 53	23	26. 8	—. 02
24	11	28. 8	. 87	20	23. 7	. 51	23	26. 3	. 04
25	11	49. 7	. 86	20	35. 9	. 49	23	25. 3	. 06
26	12	10. 4	. 86	20	47. 8	. 48	23	23. 9	. 08
27	12	31. 0	. 85	20	59. 2	. 46	23	22. 0	. 10
28	12	51. 4	. 84	21	10. 3	. 45	23	19. 6	. 12
29	13	11. 5	. 83	21	21. 0	. 43	23	16. 7	. 14
30	13	31. 5	. 82	21	31. 3	. 41	23	13. 4	. 16
31	13	51. 2	. 81	-----	-----	-----	23	9. 6	. 18

Table II—Continued

C. *Sun's Declination, 1951* (for 0^h Greenwich civil time)

Day of month	January declination		Diff. per hr.	February declination		Diff. per hr.	March declination		Diff. per hr.
	°	′		°	′		°	′	
1	S 23	5. 4	−0. 20	S 17	23. 5	−0. 71	S 7	58. 6	−0. 95
2	23	0. 7	. 22	17	6. 6	. 72	7	35. 9	. 95
3	22	55. 5	. 23	16	49. 3	. 73	7	13. 0	. 96
4	22	49. 9	. 25	16	31. 8	. 74	6	50. 0	. 96
5	22	43. 8	. 27	16	14. 0	. 75	6	27. 0	. 96
6	22	37. 2	. 29	15	55. 9	. 77	6	3. 8	. 97
7	22	30. 3	. 31	15	37. 5	. 78	5	40. 6	. 97
8	22	22. 8	. 33	15	18. 9	. 79	5	17. 3	. 97
9	22	15. 0	. 35	15	0. 0	. 80	4	53. 9	. 98
10	22	6. 7	. 36	14	40. 9	. 81	4	30. 5	. 98
11	21	57. 9	. 38	14	21. 5	. 82	4	7. 0	. 98
12	21	48. 8	. 40	14	1. 9	. 83	3	43. 4	. 98
13	21	39. 2	. 42	13	42. 0	. 84	3	19. 8	. 98
14	21	29. 1	. 43	13	21. 9	. 85	2	56. 2	. 99
15	21	18. 7	. 45	13	1. 6	. 85	2	32. 5	. 99
16	21	7. 9	. 47	12	41. 1	. 86	2	8. 9	. 99
17	20	56. 7	. 48	12	20. 4	. 87	1	45. 2	. 99
18	20	45. 0	. 50	11	59. 5	. 88	1	21. 5	. 99
19	20	33. 0	. 52	11	38. 4	. 89	0	57. 7	. 99
20	20	20. 6	. 53	11	17. 2	. 89	0	34. 0	. 99
21	20	7. 8	. 55	10	55. 7	. 90	0	10. 3	. 99
22	19	54. 6	. 56	10	34. 1	. 91	N 0	13. 4	+. 99
23	19	41. 1	. 58	10	12. 3	. 91	0	37. 1	. 99
24	19	27. 2	. 59	9	50. 4	. 92	1	0. 7	. 98
25	19	12. 9	. 61	9	28. 3	. 93	1	24. 4	. 98
26	18	58. 3	. 62	9	6. 1	. 93	1	48. 0	. 98
27	18	43. 3	. 64	8	43. 7	. 94	2	11. 5	. 98
28	18	28. 0	. 65	8	21. 2	. 94	2	35. 0	. 98
29	18	12. 4	. 67				2	58. 5	. 98
30	17	56. 4	. 68				3	21. 9	. 97
31	17	40. 1	. 69				3	45. 2	. 97

Table II—Continued

C. *Sun's Declination, 1951* (for 0^h Greenwich civil time)—Continued

Day of month	April declination		Diff. per hr.	May declination		Diff. per hr.	June declination		Diff. per hr.
	°	′		°	′		°	′	
1	N 4	8. 5	+0. 97	N 14	45. 8	+0. 76	N 21	54. 9	+0. 35
2	4	31. 7	. 96	15	4. 1	. 75	22	3. 2	. 33
3	4	54. 8	. 96	15	22. 1	. 74	22	11. 2	. 32
4	5	17. 9	. 96	15	39. 9	. 73	22	18. 8	. 30
5	5	40. 8	. 95	15	57. 5	. 72	22	26. 0	. 28
6	6	3. 7	. 95	. 16	14. 7	. 71	22	32. 8	. 27
7	6	26. 4	. 94	16	31. 7	. 70	22	39. 3	. 25
8	6	49. 0	. 94	16	48. 4	. 69	22	45. 3	. 23
9	7	11. 5	. 94	17	4. 9	. 67	22	50. 9	. 22
10	7	33. 9	. 93	17	21. 6	. 66	22	56. 1	. 20
11	7	56. 2	. 92	17	36. 9	. 65	23	0. 9	. 18
12	8	18. 3	. 92	17	52. 5	. 64	23	5. 3	. 17
13	8	40. 3	. 91	18	7. 7	. 62	23	9. 3	. 15
14	9	2. 1	. 90	18	22. 7	. 61	23	12. 9	. 13
15	9	23. 8	. 90	18	37. 4	. 60	23	16. 1	. 12
16	9	45. 4	. 90	18	51. 7	. 58	23	18. 9	. 10
17	10	6. 7	. 89	19	5. 7	. 57	23	21. 2	. 08
18	10	27. 9	. 88	19	19. 4	. 56	23	23. 2	. 06
19	10	48. 9	. 87	19	32. 8	. 54	23	24. 7	. 05
20	11	9. 8	. 86	19	45. 8	. 53	23	25. 8	. 03
21	11	30. 4	. 85	19	58. 5	. 51	23	26. 6	. 01
22	11	50. 9	. 85	20	10. 9	. 50	23	26. 9	−. 00
23	12	11. 2	. 84	20	22. 9	. 49	23	26. 8	. 02
24	12	31. 3	. 83	20	34. 5	. 47	23	26. 2	. 04
25	12	51. 1	. 82	20	45. 8	. 46	23	25. 3	. 06
26	13	10. 8	. 81	20	56. 8	. 45	N 23	23. 9	. 07
27	13	30. 2	. 80	21	7. 4	. 43	23	22. 2	. 09
28	13	49. 5	. 79	21	17. 6	. 41	23	20. 0	. 11
29	14	8. 5	. 78	21	27. 5	. 40	23	17. 4	. 12
30	14	27. 3	. 77	21	37. 0	. 38	23	14. 4	. 14
				21	46. 1	. 36			

Table II—Continued

C. *Sun's Declination, 1951* (for 0ʰ Greenwich civil time)—Continued

Day of month	July declination		Diff. per hr.	August declination		Diff. per hr.	September declination		Diff. per hr.
	°	′		°	′		°	′	
1	N 23	11. 0	−0. 16	N 18	17. 2	−0. 62	N 8	39. 8	−0. 90
2	23	7. 2	. 18	18	2. 3	. 64	8	18. 1	. 91
3	23	3. 0	. 19	17	47. 0	. 65	7	56. 3	. 92
4	22	58. 4	. 21	17	31. 5	. 66	7	34. 3	. 92
5	22	53. 4	. 23	17	15. 7	. 67	7	12. 2	. 93
6	22	48. 0	. 24	16	59. 6	. 68	6	50. 0	. 93
7	22	42. 2	. 26	16	43. 2	. 69	6	27. 7	. 93
8	22	35. 9	. 27	16	26. 6	. 70	6	5. 3	. 94
9	22	29. 3	. 29	16	9. 7	. 72	6	42. 8	. 94
10	22	22. 4	. 31	15	52. 5	. 73	5	20. 2	. 95
11	22	15. 0	. 32	15	35. 1	. 74	4	57. 5	. 95
12	22	7. 2	. 34	15	17. 4	. 75	4	34. 7	. 95
13	21	59. 1	. 35	14	59. 5	. 76	4	11. 8	. 96
14	21	50. 6	. 37	14	41. 4	. 77	3	48. 9	. 96
15	21	41. 7	. 39	14	23. 0	. 78	3	25. 9	. 96
16	21	32. 5	. 40	14	4. 4	. 78	3	2. 8	. 96
17	21	22. 8	. 42	13	45. 6	. 79	2	39. 7	. 97
18	21	12. 9	. 43	13	26. 5	. 80	2	16. 6	. 97
19	21	2. 5	. 45	13	7. 3	. 81	1	53. 3	. 97
20	20	51. 3	. 46	12	47. 8	. 82	1	30. 1	. 97
21	20	40. 8	. 47	12	28. 1	. 83	1	6. 8	. 97
22	20	29. 4	. 49	12	8. 3	. 84	0	43. 5	. 97
23	20	17. 7	. 50	11	48. 2	. 84	0	20. 1	. 97
24	20	5. 6	. 52	11	28. 0	. 85	S 0	3. 3	+. 97
25	19	53. 2	. 53	11	7. 5	. 86	0	26. 7	. 97
26	19	40. 4	. 54	10	46. 9	. 87	0	50. 1	. 97
27	19	27. 4	. 56	10	26. 1	. 87	1	13. 5	. 97
28	19	14. 0	. 57	10	5. 2	. 88	1	36. 8	. 97
29	19	. 2	. 58	9	44. 1	. 89	2	. 2	. 97
30	18	46. 2	. 60	9	22. 8	. 89	2	23. 6	. 97
31	18	31. 9	−. 61	9	1. 4	. 90	------	------	------

Table II—Continued

C. *Sun's Declination, 1951* (for 0^h Greenwich civil time)—Continued

Day of month	October declination		Diff. per hr.	November declination		Diff. per hr.	December declination		Diff. per hr.
	°	′		°	′		°	′	
1	S 2	47. 0	+0. 97	S 14	6. 1	+0. 81	S 21	38. 8	+0. 40
2	3	10. 3	. 97	14	25. 5	. 80	21	48. 4	. 38
3	3	33. 6	. 97	14	44. 6	. 79	21	57. 5	. 36
4	3	56. 8	. 97	15	3. 5	. 78	22	6. 2	. 35
5	4	20. 0	. 96	15	22. 1	. 77	22	14. 5	. 33
6	4	43. 1	. 96	15	40. 5	. 76	22	22. 4	. 31
7	5	6. 2	. 96	15	58. 6	. 74	22	29. 8	. 29
8	5	29. 2	. 96	16	16. 5	. 73	22	36. 8	. 27
9	5	52. 2	. 95	16	34. 1	. 72	22	43. 3	. 25
10	6	15. 0	. 95	16	51. 4	. 71	22	49. 4	. 24
11	6	37. 8	. 95	17	8. 4	. 70	22	55. 0	. 22
12	7	0. 5	. 94	17	25. 1	. 68	23	0. 2	. 20
13	7	23. 1	. 94	17	41. 5	. 67	23	5. 0	. 18
14	7	45. 6	. 93	17	57. 7	. 66	23	9. 2	. 16
15	8	8. 0	. 93	18	13. 5	. 65	23	13. 1	. 14
16	8	30. 3	. 92	18	28. 9	. 63	23	16. 4	. 12
17	8	52. 4	. 92	18	44. 1	. 62	23	19. 3	. 10
18	9	14. 4	. 91	18	58. 9	. 60	23	21. 7	. 08
19	9	36. 3	. 91	19	13. 4	. 59	23	23. 7	. 06
20	9	58. 1	. 90	19	27. 6	. 58	23	25. 2	. 04
21	10	19. 7	. 89	19	41. 4	. 56	23	26. 2	. 02
22	10	41. 2	. 89	19	54. 8	. 53	23	26. 8	+. 00
23	11	2. 5	. 88	20	7. 9	. 53	23	26. 8	−. 02
24	11	23. 6	. 87	20	20. 6	. 51	23	26. 4	. 04
25	11	44. 6	. 87	20	33. 0	. 50	23	25. 6	. 06
26	12	5. 4	. 86	20	44. 9	. 48	23	24. 2	. 08
27	12	26. 0	. 85	20	56. 5	. 47	23	22. 4	. 09
28	12	46. 4	. 84	21	7. 7	. 45	23	20. 2	. 11
29	13	6. 7	. 83	21	18. 5	. 43	23	17. 4	. 13
30	13	26. 7	. 83	21	28. 8	. 42	23	14. 2	. 15
31	13	46. 5					23	10. 5	. 17

Table II—Continued

D. *Sun's Declination, 1952* (for 0^h Greenwich civil time)

Day of the month	January declination		Diff. per hr.	February declination		Diff per hr.	March declination		Diff. per hr.
	°	′		°	′		°	′	
1	S 23	6. 4	−0. 19	S 17	27. 4	−0. 70	S 7	41. 2	−0. 95
2	23	1. 8	. 21	17	10. 5	. 71	7	18. 4	. 96
3	22	56. 7	. 23	16	53. 4	. 73	6	55. 4	. 96
4	22	51. 2	. 25	16	35. 9	. 74	6	32. 4	. 96
5	22	45. 2	. 27	16	18. 2	. 75	6	9. 3	. 97
6	22	38. 8	. 29	16	0. 2	. 76	5	46. 1	. 97
7	22	31. 9	. 31	15	41. 9	. 77	5	22. 8	. 97
8	22	24. 6	. 32	15	23. 3	. 78	4	59. 5	. 98
9	22	16. 8	. 34	15	4. 5	. 79	4	36. 1	. 98
10	22	8. 6	. 36	14	45. 5	. 80	4	12. 6	. 98
11	22	0. 0	. 38	14	26. 2	. 81	3	49. 1	. 98
12	21	50. 9	. 40	14	6. 6	. 82	3	25. 5	. 98
13	21	41. 5	. 41	13	46. 8	. 83	3	1. 9	. 98
14	21	31. 6	. 43	13	26. 8	. 84	2	38. 3	. 99
15	21	21. 2	. 45	13	6. 6	. 85	2	14. 6	. 99
16	21	10. 5	. 46	12	46. 1	. 86	1	50. 9	. 99
17	20	59. 4	. 48	12	25. 5	. 87	1	27. 2	. 99
18	20	47. 8	. 50	12	4. 6	. 88	1	3. 5	. 99
19	20	35. 9	. 51	11	43. 6	. 88	0	39. 8	. 99
20	20	23. 6	. 53	11	22. 3	. 89	0	16. 1	. 99
21	20	10. 9	. 55	11	0. 9	. 90	N 0	7. 7	+. 99
22	19	57. 8	. 56	10	39. 3	. 91	0	31. 4	. 99
23	19	44. 3	. 58	10	17. 5	. 91	0	55. 0	. 99
24	19	30. 5	. 59	9	55. 6	. 92	1	18. 7	. 98
25	19	16. 3	. 61	9	33. 6	. 93	1	42. 3	. 98
26	19	1. 8	. 62	9	11. 3	. 93	2	5. 9	. 98
27	18	46. 9	. 64	8	49. 0	. 94	2	29. 4	. 98
28	18	31. 6	. 65	8	26. 5	. 94	2	52. 9	. 98
29	18	16. 0	. 66	8	3. 9	. 95	3	16. 4	. 97
30	18	0. 1	. 68	------	------	-------	3	39. 7	. 97
31	17	43. 9	. 69	------	------	-------	4	3. 0	. 97

Table II—Continued

D. *Sun's Declination, 1952* (for 0ʰ Greenwich civil time)—Continued

Day of the month	April declination		Diff. per hr.	May declination		Diff. per hr.	June declination		Diff. per hr.
	°	′		°	′		°	′	
1	N 4	26. 2	+0. 96	N 14	59. 7	+0. 75	N 22	1. 2	+0. 34
2	4	49. 4	. 96	15	17. 8	. 74	22	9. 3	. 32
3	5	12. 4	. 96	15	35. 7	. 73	22	17. 0	. 30
4	5	35. 4	. 95	15	53. 3	. 72	22	24. 3	. 29
5	5	58. 2	. 95	16	10. 6	. 71	22	31. 2	. 27
6	6	21. 0	. 94	16	27. 6	. 70	22	37. 7	. 25
7	6	43. 6	. 94	16	44. 4	. 69	22	43. 8	. 24
8	7	6. 1	. 93	17	. 9	. 68	22	49. 5	. 22
9	7	28. 5	. 93	17	17. 1	. 66	22	54. 8	. 20
10	7	50. 8	. 92	17	33. 0	. 65	22	59. 7	. 19
11	8	13. 0	. 92	17	48. 7	. 64	23	4. 2	. 17
12	8	35. 0	. 91	18	4. 0	. 63	23	8. 3	. 15
13	8	56. 8	. 90	18	19. 0	. 61	23	12. 0	. 14
14	9	18. 5	. 90	18	33. 8	. 60	23	15. 3	. 12
15	9	40. 1	. 89	18	48. 2	. 59	23	18. 2	. 10
16	10	1. 5	. 89	19	2. 3	. 57	23	20. 7	. 09
17	10	22. 8	. 88	19	16. 1	. 56	23	22. 7	. 07
18	10	43. 8	. 87	19	29. 5	. 55	23	24. 4	. 05
19	11	4. 7	. 86	19	42. 6	. 53	23	25. 6	. 03
20	11	25. 4	. 86	19	55. 4	. 52	23	26. 4	. 02
21	11	46. 0	. 85	20	7. 9	. 50	23	26. 8	−. 00
22	12	6. 3	. 84	20	20. 0	. 49	23	26. 8	. 02
23	12	26. 5	. 83	20	31. 7	. 48	23	26. 4	. 04
24	12	46. 4	. 82	20	43. 1	. 46	23	25. 5	. 05
25	13	6. 1	. 81	20	54. 2	. 45	23	24. 3	. 07
26	13	25. 6	. 80	21	4. 9	. 43	23	22. 6	. 09
27	13	44. 9	. 79	21	15. 2	. 41	23	20. 5	. 10
28	14	4. 0	. 78	21	25. 2	. 40	23	18. 0	. 12
29	14	22. 8	. 77	21	34. 7	. 38	23	15. 1	. 14
30	14	41. 4	. 76	21	44. 0	. 37	23	11. 8	. 15
31	------	------	------	21	52. 8	. 35	------	------	------

Table II—Continued

D. *Sun's Declination, 1952* (for 0^h Greenwich civil time)—Continued

Day of the month	July declination °	July declination ′	Diff. per hr.	August declination °	August declination ′	Diff. per hr.	September declination °	September declination ′	Diff. per hr.
1	N 23	8. 1	−0. 17	N 18	5. 9	−0. 63	N 8	23. 4	−0. 91
2	23	4. 0	. 19	17	50. 7	. 64	8	1. 6	. 91
3	22	59. 5	. 20	17	35. 2	. 66	7	39. 7	. 92
4	22	54. 6	. 22	17	19. 5	. 67	7	17. 6	. 92
5	22	49. 3	. 24	17	3. 5	. 68	6	55. 5	. 93
6	22	43. 5	. 25	16	47. 2	. 69	6	33. 2	. 93
7	22	37. 4	. 27	16	30. 7	. 70	6	10. 8	. 94
8	22	31. 0	. 29	16	13. 8	. 71	5	48. 3	. 94
9	22	24. 1	. 30	15	56. 7	. 72	5	25. 8	. 94
10	22	16. 8	. 32	15	39. 4	. 73	5	3. 1	. 95
11	22	9. 1	. 33	15	21. 8	. 74	4	40. 3	. 95
12	22	1. 1	. 35	15	4. 0	. 75	4	17. 5	. 96
13	21	52. 7	. 37	14	45. 9	. 76	3	54. 5	. 96
14	21	43. 9	. 38	14	27. 5	. 77	3	31. 5	. 96
15	21	34. 7	. 40	14	9. 0	. 78	3	8. 5	. 96
16	21	25. 2	. 41	13	50. 2	. 79	2	45. 4	. 97
17	21	15. 3	. 43	13	31. 2	. 80	2	22. 2	. 97
18	21	5. 1	. 44	13	12. 0	. 81	1	59. 0	. 97
19	20	54. 4	. 46	12	52. 5	. 82	1	35. 7	. 97
20	20	43. 5	. 47	12	32. 9	. 83	1	12. 4	. 97
21	20	32. 2	. 49	12	13. 1	. 83	0	49. 1	. 97
22	20	20. 5	. 50	11	53. 0	. 84	0	25. 7	. 97
23	20	8. 5	. 51	11	32. 8	. 85	0	2. 3	. 97
24	19	56. 1	. 53	11	12. 4	. 86	S 0	21. 1	+. 97
25	19	43. 5	. 54	10	51. 9	. 86	0	44. 4	. 97
26	19	30. 5	. 56	10	31. 1	. 87	1	7. 8	. 97
27	19	17. 1	. 57	10	10. 2	. 88	1	31. 2	. 97
28	19	3. 5	. 58	9	49. 1	. 88	1	54. 6	. 97
29	18	49. 6	. 59	9	27. 9	. 89	2	18. 0	. 97
30	18	35. 3	. 61	9	6. 5	. 90	2	41. 3	. 97
31	18	20. 7	. 62	8	45. 0	. 90	------	------	------

Table 11—Continued

D. *Sun's Declination, 1952* (for 0^h Greenwith Civil Time)—Continued

Day of the month	October declination		Diff. per hr.	November declination		Diff. per hr.	December declination		Diff. per hr.
	°	′		°	′		°	′	
1	S 3	4. 6	+. 97	S 14	20. 7	+. 80	S 21	46. 0	+. 38
2	3	27. 9	. 97	14	39. 9	. 79	21	55. 3	. 37
3	3	51. 1	. 97	14	58. 8	78	22	4. 1	. 35
4	4	14. 3	. 96	15	17. 5	. 77	22	12. 5	. 33
5	4	37. 4	. 96	15	36. 0	. 76	22	20. 4	. 31
6	5	0. 5	. 96	15	54. 2	. 75	22	28. 0	. 30
7	5	23. 5	. 96	16	12. 1	. 74	22	35. 1	. 28
8	5	46. 5	. 95	16	29. 7	. 72	22	41. 7	. 26
9	6	9. 4	. 95	16	47. 1	. 71	22	47. 9	. 24
10	6	32. 2	. 95	17	4. 2	. 70	22	53. 7	. 22
11	6	54. 9	. 94	17	21. 0	. 69	22	59. 0	. 20
12	7	17. 5	. 94	17	37. 5	. 68	23	3. 8	. 18
13	7	40. 1	. 93	17	53. 7	. 66	23	8. 2	. 16
14	8	2. 5	. 94	18	9. 6	. 65	23	12. 2	. 14
15	8	24. 8	. 93	18	25. 2	. 64	23	15. 6	. 13
16	8	47. 0	. 92	18	40. 5	. 62	23	18. 6	. 11
17	9	9. 1	. 91	18	55. 4	. 61	23	21. 2	. 09
18	9	31. 0	. 91	19	10. 0	. 59	23	23. 2	. 07
19	9	52. 8	. 90	19	24. 2	. 58	23	24. 8	. 05
20	10	14. 5	. 90	19	38. 1	. 56	23	26. 0	. 03
21	10	36. 0	. 89	19	51. 6	. 55	23	26. 6	. 01
22	10	57. 4	. 88	20	4. 8	. 53	23	26. 8	−. 01
23	11	18. 6	. 88	20	17. 6	. 52	23	26. 5	. 03
24	11	39. 6	. 87	20	30. 0	. 50	23	25. 8	. 05
25	12	0. 4	. 86	20	42. 1	. 49	23	24. 6	. 07
26	12	21. 1	. 85	20	53. 7	. 47	23	22. 9	. 09
27	12	41. 5	. 84	21	5. 0	. 45	23	20. 7	. 11
28	13	1. 8	. 84	21	15. 9	. 44	23	18. 1	. 13
29	13	21. 8	. 83	21	26. 3	. 42	23	15. 0	. 15
30	13	41. 7	. 82	21	36. 4	. 40	23	11. 4	. 17
31	14	1. 3	. 81	------	------	-------	23	7. 4	. 19

Table III. Apparent Declination of Stars, 1949–1950

Date	Achernar α of Eridani	Aldebaran α of Tauri	Alkaid η of Ursa Major	Altair α of Aquilae	Antares α of Scorpii
	Declination	Declination	Declination	Declination	Declination
1949	° ′	° ′	° ′	° ′	° ′
January	S 57 30. 0	N 16 24. 6	N 49 33. 8	N 8 43. 8	S 26 19. 3
February	57 30. 0	16 24. 6	49 33. 7	8 43. 7	26 19. 3
March	57 29. 9	16 24. 6	49 33. 7	8 43. 7	26 19. 3
April	57 29. 8	16 24. 6	49 33. 8	8 43. 6	26 19. 4
May	57 29. 6	16 24. 6	49 33. 9	8 43. 7	26 19. 4
June	57 29. 4	16 24. 6	49 34. 1	8 43. 8	26 19. 4
July	57 29. 3	16 24. 6	49 34. 1	8 43. 9	26 19. 5
August	57 29. 2	16 24. 7	49 34. 1	8 44. 0	26 19. 5
September	57 29. 2	16 24. 7	49 34. 1	8 44. 0	26 19. 5
October	57 29. 3	16 24. 8	49 34. 1	8 44. 1	26 19. 5
November	57 29. 5	16 24. 8	49 33. 8	8 44. 1	26 19. 4
December	57 29. 6	16 24. 8	49 33. 6	8 44. 0	26 19. 4
1950					
January	57 29. 7	16 24. 7	49 33. 5	8 44. 0	26 19. 3
February	57 29. 7	16 24. 7	49 33. 4	8 43. 9	26 19. 4
March	57 29. 6	16 24. 7	49 33. 4	8 43. 8	26 19. 4
April	57 29. 5	16 24. 7	49 33. 5	8 43. 8	26 19. 5
May	57 29. 3	16 24. 7	49 33. 7	8 43. 9	26 19. 5
June	57 29. 1	16 24. 7	49 33. 8	8 43. 9	26 19. 5
July	57 29. 0	16 24. 7	49 33. 9	8 44. 0	26 19. 6
August	57 28. 9	16 24. 8	49 33. 9	8 44. 1	26 19. 6
September	57 28. 9	16 24. 8	49 33. 8	8 44. 2	26 19. 6
October	57 29. 0	16 24. 8	49 33. 7	8 44. 2	26 19. 5
November	57 29. 2	16 24. 9	49 33. 5	8 44. 2	26 19. 5
December	57 29. 3	16 24. 9	49 33. 3	8 44. 2	26 19. 5
Annual change	N 0. 30′	N 0. 12′	S 0. 30′	N 0. 16′	S 0. 13′

Table III. Apparent Declination of Stars, 1949–1950—Continued

Date	Regulus α of Leonis	Rigel β of Orionis	Sirius α of Canis Major	Spica α of Virginis	Vega α of Lyrae
	Declination	Declination	Declination	Declination	Declination
1949	° ′	° ′	° ′	° ′	° ′
January	N 12 13. 1	S 8 15. 5	S 16 38. 6	S 10 53. 7	N 38 44. 0
February	12 13. 0	8 15. 5	16 38. 7	10 53. 8	38 43. 8
March	12 13. 0	8 15. 6	16 38. 7	10 53. 9	38 43. 7
April	12 13. 0	8 15. 6	16 38. 8	10 53. 9	38 43. 7
May	12 13. 0	8 15. 5	16 38. 7	10 54. 0	38 43. 7
June	12 13. 0	8 15. 5	16 38. 7	10 54. 0	38 43. 9
July	12 13. 1	8 15. 4	16 38. 6	10 54. 0	38 44. 0
August	12 13. 1	8 15. 3	16 38. 5	10 53. 9	38 44. 2
September	12 13. 1	8 15. 2	16 38. 4	10 53. 9	38 44. 3
October	12 13. 0	8 15. 2	16 38. 4	10 53. 9	38 44. 3
November	12 12. 9	8 15. 2	16 38. 4	10 53. 9	38 44. 3
December	12 12. 8	8 15. 3	16 38. 5	10 54. 0	38 44. 1
1950					
January	12 12. 8	8 15. 4	16 38. 7	10 54. 0	38 44. 0
February	12 12. 7	8 15. 5	16 38. 8	10 54. 1	38 43. 9
March	12 12. 7	8 15. 5	16 38. 8	10 54. 2	38 43. 8
April	12 12. 7	8 15. 5	16 38. 9	10 54. 2	38 43. 7
May	12 12. 7	8 15. 5	16 38. 8	10 54. 2	38 43. 8
June	12 12. 8	8 15. 4	16 38. 8	10 54. 2	38 43. 9
July	12 12. 8	8 15. 3	16 38. 6	10 54. 2	38 44. 1
August	12 12. 8	8 15. 2	16 38. 5	10 54. 2	38 44. 2
September	12 12. 8	8 15. 1	16 38. 5	10 54. 2	38 44. 3
October	12 12. 7	8 15. 1	16 38. 4	10 54. 2	38 44. 4
November	12 12. 7	8 15. 2	16 38. 5	10 54. 2	38 44. 3
December	12 12. 6	8 15. 2	16 38. 6	10 54. 2	38 44. 2
Annual change	S 0. 29′	N 0. 07′	S 0. 08′	S 0. 31′	N 0. 06′

Table III. Apparent Declination of Stars, 1949–1950—Continued

Date	Deneb α of Cygni	Denebola β of Leonis	Fomalhaut α of Piscis Aust.	Pollux β of Geminorum	Procyon α of Canis Minoris
	Declination	Declination	Declination	Declination	Declination
1949	° ′	° ′	° ′	° ′	° ′
January	N 45 05.8	N 14 51.4	S 29 53.8	N 28 09.1	N 5 21.5
February	45 05.7	14 51.3	29 53.8	28 09.1	5 21.5
March	45 05.5	14 51.3	29 53.7	28 09.2	5 21.4
April	45 05.5	14 51.3	29 53.6	28 09.2	5 21.4
May	45 05.5	14 51.3	29 53.5	28 09.2	5 21.4
June	45 05.6	14 51.4	29 53.4	28 09.2	5 21.5
July	45 05.7	14 51.4	29 53.3	28 09.2	5 21.5
August	45 05.9	14 51.4	29 53.3	28 09.2	5 21.5
September	45 06.0	14 51.4	29 53.3	28 09.1	5 21.6
October	45 06.1	14 51.3	29 53.4	28 09.1	5 21.6
November	45 06.2	14 51.2	29 53.4	28 09.0	5 21.5
December	45 06.1	14 51.1	29 53.5	28 09.0	5 21.4
1950					
January	45 06.0	14 51.1	29 53.5	28 09.0	5 21.4
February	45 05.9	14 51.0	29 53.5	28 09.0	5 21.3
March	45 05.8	14 51.0	29 53.4	28 09.0	5 21.3
April	45 05.7	14 51.0	29 53.3	28 09.0	5 21.3
May	45 05.7	14 51.0	29 53.2	28 09.1	5 21.3
June	45 05.8	14 51.1	29 53.1	28 09.1	5 21.3
July	45 05.9	14 51.1	29 53.0	28 09.0	5 21.3
August	45 06.1	14 51.1	29 53.0	28 09.0	5 21.4
September	45 06.2	14 51.1	29 53.0	28 09.0	5 21.4
October	45 06.3	14 51.0	29 53.1	28 08.9	5 21.4
November	45 06.4	14 50.9	29 53.1	28 08.9	5 21.4
December	45 06.4	14 50.8	29 53.2	28 08.9	5 21.3
Annual change	N 0. 21	S 0. 34′	N 0. 32′	S 0. 14′	S 0. 15′

Table III. Apparent Declination of Stars, 1949–1950—Continued

Date	Arcturus α of Bootis	Betelgeux α of Orionis	Canopus α of Carinae	Capella α of Aurigae	Castor α of Geminorum
	Declination	Declination	Declination	Declination	Declination
1949	° ′	° ′	° ′	° ′	° ′
January	N 19 26. 7	N 7 24. 1	S 52 39. 9	N 45 57. 1	N 32 00. 2
February	19 26. 6	7 24. 0	52 40. 1	45 57. 2	32 00. 2
March	19 26. 6	7 24. 0	52 40. 2	45 57. 2	32 00. 3
April	19 26. 6	7 24. 0	52 40. 2	45 57. 2	32 00. 3
May	19 26. 6	7 24. 0	52 40. 2	45 57. 1	32 00. 3
June	19 26. 7	7 24. 1	52 40. 0	45 57. 1	32 00. 3
July	19 26. 8	7 24. 1	52 39. 9	45 57. 0	32 00. 3
August	19 26. 8	7 24. 2	52 39. 7	45 57. 0	32 00. 2
September	19 26. 8	7 24. 2	52 39. 6	45 57. 0	32 00. 2
October	19 26. 7	7 24. 2	52 39. 6	45 57. 0	32 00. 1
November	19 26. 6	7 24. 2	52 39. 6	45 57. 0	32 00. 1
December	19 26. 5	7 24. 1	52 39. 6	45 57. 1	32 00. 1
1950					
January	19 26. 4	7 24. 1	52 40. 0	45 57. 1	32 00. 0
February	19 26. 3	7 24. 0	52 40. 1	45 57. 2	32 00. 1
March	19 26. 3	7 24. 0	52 40. 2	45 57. 2	32 00. 1
April	19 26. 3	7 24. 0	52 40. 3	45 57. 2	32 00. 1
May	19 26. 3	7 24. 0	52 40. 2	45 57. 1	32 00. 2
June	19 26. 4	7 24. 1	52 40. 1	45 57. 1	32 00. 1
July	19 26. 5	7 24. 1	52 39. 9	45 57. 0	32 00. 1
August	19 26. 5	7 24. 2	52 39. 8	45 57. 0	32 00. 1
September	19 26. 5	7 24. 2	52 39. 6	45 57. 0	32 00. 0
October	19 26. 4	7 24. 2	52 39. 6	45 57. 0	32 00. 0
November	19 26. 3	7 24. 2	52 39. 7	45 57. 0	32 00. 0
December	19 26. 2	7 24. 1	52 39. 8	45 57. 1	31 59. 9
Annual change	S 0. 31′	N 0. 01′	S 0. 03′	N 0. 06′	S 0. 13′

APPENDIX IX

MINIMUM TRAINING SCHEDULE

Section I. GENERAL

1. PURPOSE. This appendix is a general guide for technical training of elements of a field artillery unit *in the subjects contained in this manual.*

2. OBJECTIVE. It is designed to provide *minimum* instructions in technical specialties necessary for individuals and sections in the essentials of gunnery to include fire direction, conduct of fire, and survey. *Additional training beyond the scope of this appendix is necessary in order to develop efficient and fully trained individuals and sections.*

3. EQUIPMENT AND TRAINING AIDS. Appropriate equipment provided for in tables of organization and equipment, blackboards, charts, forms, and field artillery training aid kits.

4. GENERAL TRAINING NOTES. **a.** Training will be in accordance with the doctrine and procedures described in FM 21–5 and TM 6–605.

b. Training in subjects contained in this manual should be by unit schools.

c. Throughout the training period, the application of prior instruction to current training should be stressed.

d. Instruction which is common to more than one section may be combined.

e. The necessity to develop leadership and initiative in unit leaders is borne in mind constantly throughout the training.

5. PHASES. **a.** This schedule is divided into the following phases:

(1) Individual phase.

(2) Section phase.

(*a*) In the individual phase, all members of a section receive common training in order that all members will be well grounded in the duties of the section as a whole.

(*b*) In the section phase, individuals perform duties in accordance with their assignment within the section with emphasis on teamwork.

b. The schedule for liaison and forward observer personnel in conduct of fire contains only an individual phase, since this covers minimum essential training.

Section II. SUBJECT SCHEDULE

1. LIAISON AND FORWARD OBSERVER PERSONNEL (INDIVIDUAL PHASE). (Total hours, 24.)

Period	Hours	Subject	Text references	Area	Training aids and equipment
1	2	Introduction to gunnery, elementary ballistics, and dispersion (conference).	Pars. 1–21, incl.	Classroom	Blackboard.
2	2	Artillery ammunition and attack of targets (conference).	Pars. 22–28, 166–178.	Classroom	Blackboard, ammunition charts.
3	3	Fire commands and elements of firing data (conference and practical exercise).	Pars. 29–44, incl.	Classroom	Blackboard.
4	2	Observer procedure, introduction, and terminology (conference).	Pars. 45–50, incl.	Classroom	Blackboard.
5	2	The initial fire request and determination of initial data (conference and practical exercise).	Pars. 51–56, incl.	Classroom	Blackboard and cards (1 per student) with example of initial fire request.
6	2	Range estimation, angular measurements with field glasses, and determination if initial data to targets (practical exercise).	Review pars. 51–56, incl.	Field	List of known ranges, azimuths, and initial data to various targets.
7	2	Conduct of precision fire (conference and practical exercise).	Pars. 67–73, incl.	Classroom or field.	Terrain board, M–3 trainer, or blackboard.
8	2	Conduct of precision fire (practical exercise).	Review pars. 67–73; study pars. 78–79.	Classroom or field.	Terrain board, M–3 trainer, or blackboard.
9	2	Conduct of area fire (practical exercise).	Pars, 74–77, incl.	Classroom or field.	Terrain board, M–3 trainer, or blackboard.

10	2	Conduct of fire (practical exercise)	Review pars. 67–73, 74–80.	Classroom or field.	Terrain board, M–3 trainer, or blackboard.
11	3	Miscellaneous observed fires (conference).	Pars. 85–102, app. II.	Classroom	Blackboard.

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a. First period.

(1) *Objective.* To introduce liaison and forward observer personnel to gunnery and to discuss elementary ballistics and dispersion.

(2) *Outline.* This period should orient observers and liaison personnel on basic field artillery gunnery concepts and teach them sufficient elementary ballistics to understand the simplest factors affecting the motion of projectiles. It should include enough on dispersion to enable an observer to understand how the projectiles are affected by dispersion.

b. Second period.

(1) *Objective.* To teach the observer the various kinds and combinations of projectiles, charges, and fuzes, and their use in the attack of targets.

(2) *Outline.* This conference should cover basic definitions and nomenclature of projectiles and fuzes, the appearance and effect of the various projectiles, and the selection of particular combinations of projectiles and fuzes to attack various type targets.

c. Third period.

(1) *Objective.* To give the observer some knowledge of the fire commands which result from his corrections. To teach necessity of determining distances and the use of the mil relation.

(2) *Outline.* This period should show briefly the relationship between observer, fire-direction center, and firing battery. It should include initial and subsequent fire commands, their sequence and meaning. Means and importance of determining distances should be stressed. Special emphasis must be placed on the mil relation, and the students should be required to solve many examples. Elements of firing data to include direction, range, distribution, and height of burst must be explained.

d. Fourth period.

(1) *Objective.* To teach observed fire principles and terminology.

(2) *Outline.* Cover types of fire, sensings, and the standard phrases and terms which will be employed mutually by the observer and the fire-direction center.

e. Fifth period.

(1) *Objective.* To teach observers how to determine initial data and how to translate initial data into a fire request.

(2) *Outline.* Cover the initial fire request to include sequence and the meaning of each element, with special emphasis on the various methods of determining initial data. Practice should be given on the determination of initial data and preparation of fire requests. Sequence of subsequent cor-

rections and the proper way to correct errors should be covered.

f. Sixth period.

(1) *Objective.* To give practice in range estimation, use of field glasses, and determination of initial data.

(2) *Outline.* Teach the observers to apply measured angles to known azimuths in order to determine observer azimuths, proper way to determine ranges, determination of initial data, and their incorporation into an initial fire request.

g. Seventh period.

(1) *Objective.* To teach observers the principles of observed fire in general, with specific instruction on conduct of precision fire and time registration.

(2) *Outline.* This conference should be a simultaneous explanation and demonstration of precision mission to include determination of data, initial fire request, adjustment phase, and fire for effect from the observer's standpoint. This should be followed by student participation in blackboard problems. An explanation of time registrations should conclude the conference.

h. Eighth period.

(1) *Objective.* To teach observers precision and time fire procedure.

(2) *Outline.* Individuals fire problems; remainder of class follows. These problems should be fired on terrain board if available; if not, on a blackboard. Only important and pertinent points should be stressed in the critiques.

i. Ninth period.

(1) *Objective.* To teach observers the principles and procedure for the adjustment of area fire.

(2) *Outline.* This conference should be a simultaneous explanation and demonstration of an area type fire mission with fuze quick, to include determination of data, initial fire request, adjustment, and fire for effect, followed by student participation in blackboard problems. There should be an explanation and demonstration of a mission, using fuze time or fuze delay. The conference should end with individual students firing problems.

j. Tenth period.

(1) *Objective.* To summarize the principles of observed fires, both precision and area. To allow further practice in adjustment of fire.

(2) *Outline.* A concise summary of observed fire procedures, followed by individual observers firing terrain board or blackboard problems.

k. Eleventh period.

(1) *Objective.* To acquaint observers with observed fires requiring special techniques.

(2) *Outline.* Acquaint the observers with the problems encountered by the air observer (organic and high performance), by the gunner in direct fire, by the ground observer in assault fire, adjustment of high angle fire, chemical and illumination shell, and naval gunfire.

2. FIRE-DIRECTION PERSONNEL (INDIVIDUAL PHASE). (Total hours, 24.)

Period	Hours	Subject	Text references	Area	Training aids and equipment
1	2	Elementary ballistics and dispersion (conference).	Pars. 6–21, incl.	Classroom	Blackboard, trajectory charts.
2	2	Artillery ammunition (conference)	Pars. 22–28, incl.	Classroom	Blackboard, ammunition charts.
3	2	Fire commands, elements of firing data, the mil relation, and calibration and special corrections (conference).	Pars. 29–44, incl.	Classroom	Blackboard.
4	2	Observer procedure (conference)	Pars. 45–66, incl.	Classroom	Blackboard.
5	2	Grid systems and plotting (conference, practical exercise).	Pars. 106–115, incl.	Classroom	Blackboard, demonstration grid sheets, plotting equipment, maps, photomaps, grid sheets, and plotting equipment.
6	2	Firing charts and determination of map data (conference, practical exercise).	Pars. 116–127, incl.	Classroom	Same as period 5.
7	2	Use of firing tables (conference, practical exercise).	Par. 128	Classroom	Blackboard, GFT's, tabular firing tables, and demonstration GFT's.
8	2	Duties of the horizontal control operator (practical exercise).	Par. 186	Classroom	Blackboard, section equipment, demonstration grid sheets, target grid, and plotting equipment.
9	2	Duties of the vertical control operator (practical exercise).	Par. 187	Classroom	Blackboard, section equipment, maps, and demonstration GST.
10	2	Duties of the computer (practical exercise).	Par. 188	Classroom	Blackboard, section equipment, and demonstration computer's records.
11	4	Fire-direction team drill	Pars. 194–200, incl.	Classroom	Section equipment, blackboard.

a. **First period.**

(1) *Objective.* To acquaint the members of the section with elementary ballistics and dispersion.

(2) *Outline.* Cover interior and exterior ballistics, and the causes and effects of dispersion. Emphasis should be placed on the trajectory and dispersion rectangles.

b. **Second period.**

(1) *Objective.* To teach the personnel the characteristics, use, and effect of artillery ammunition.

(2) *Outline.* Cover types of artillery ammunition, types of fuzes, and the effects of various shells and fuzes.

c. **Third period.**

(1) *Objective.* To teach the personnel the mil relation, fire commands, the execution of fire commands, and elements of firing data.

(2) *Outline.* Cover the mil relation, its definition and use; basis and origin of fire commands; elements of firing data; and the announcement and execution of fire commands.

d. **Fourth period.**

(1) *Objective.* To acquaint the members of the section with the duties of the observer and the processing of the fire request.

(2) *Outline.* Cover terminology, the initial fire request, and the processing of initial fire requests at the fire-direction center.

e. **Fifth period.**

(1) *Objective.* To instruct members of the section in the use of the military grid.

(2) *Outline.* Cover coordinate systems, measuring and plotting of coordinates, measuring of distances and measuring and plotting of angles and azimuths.

f. **Sixth period.**

(1) *Objective.* To acquaint members of the section with different types of artillery firing charts and determination of map data.

(2) *Outline.* Cover the use of the grid sheet, photomap, and battlemap as a firing chart, and the determination of deflection, range, and altitude from the various types of charts.

g. **Seventh period.**

(1) *Objective.* To instruct members of the section in the data obtainable from the tabular and graphical firing table.

(2) *Outline.* Cover the contents and general use of data obtainable from the firing tables, and the comparison of tabular and graphical firing tables.

h. **Eighth period.**

(1) *Objective.* To instruct the members of the section in the duties of the horizontal control operator.

(2) *Outline.* This period should cover the duties of the horizontal control operator and largely should be practical work. No specific type of firing chart should be stressed.

i. Ninth period.

(1) *Objective.* To instruct the members of the section in the duties of the vertical control operator.

(2) *Outline.* This period largely should be practical work and should include duties of the vertical control operator that are similar to the duties of the horizontal control operator; determination of vertical interval; determination of site with tabular firing table and with graphical site table; and replot of targets.

j. Tenth period.

(1) *Objective.* To instruct the members of the section in the duties of the computer.

(2) *Outline.* Cover the duties of the computer in the order outlined in the text. All instruction should be practical work, using a surveyed firing chart with the instructor taking the parts of S–3, HCO, and VCO.

k. Eleventh period.

(1) *Objective.* To instruct the members of the section with the functioning of the fire-direction team as a whole.

(2) *Outline.* This period should be practical work and should cover the duties of the HCO, VCO, and computers working as a team. All members of the section should be rotated within the team until they have performed the duties of each member.

3. FIRE-DIRECTION PERSONNEL (SECTION PHASE). (Total hours, 24.)

Period	Hours	Subject	Text references	Area	Training aids and equipment
1	2	Fire-direction team drill, percussion fire on surveyed chart (practical exercise).	Review pars. 186–200.	Classroom	Section equipment, blackboard.
2	2	Fire-direction team drill, time fire on surveyed chart (practical exercise).	Review pars. 186–200.	Classroom	Section equipment, blackboard.
3	2	Corrections from registration (conference, practical exercise).	Pars. 129–139, incl.	Classroom	Section equipment, blackboard.
4	2	Corrections from center of impact and high burst registration (conference, practical exercise).	Pars. 140–141, incl.	Classroom	Section equipment, blackboard.
5	4	Corrections from a metro message (conference, practical work).	Pars. 142–144, incl.	Classroom	Section equipment, blackboard, and demonstration metro computation forms.
6	4	Corrections from a metro message, determination and use of *VE* (conference, practical exercise).	Pars. 142–148, incl.	Classroom	Same as period 5.
7	2	Observed firing chart (conference, practical exercise).	Pars. 149–152, incl.	Classroom	Blackboard, section equipment, demonstration grid sheets, and plotting equipment.
8	2	Transfer from observed to surveyed firing chart (conference, practical exercise).	Pars. 153–154.	Classroom	Same as period 7.
9	2	Duties of fire-direction team in high-angle fire (conference, practical exercise).	Pars. 226–229, incl.	Classroom	Blackboard and section equipment.
10	2	Fire-direction team drill in high-angle fire (practical exercise).	Pars. 226–229, incl.	Classroom	Blackboard and section equipment.

a. First period.

(1) *Objective.* To familiarize the members of the section with their duties as members of the fire-direction team.

(2) *Outline.* This period should be a practical exercise conducted from prepared notes with a discussion or critique of each problem. This period may be combined with an RSOP to add realism.

b. Second period. Same as **a** above.

c. Third period.

(1) *Objective.* To instruct the members of the section in the determination and use of registration corrections.

(2) *Outline.* This period should cover the need for registration corrections and their use in subsequent firing, and the determination of corrections from precision registration to include deflection corrections, range K or GFT setting, time corrections, and transfer limits.

d. Fourth period.

(1) *Objective.* To instruct the members of the section in the determination and use of corrections obtained from center of impact and high-burst registrations.

(2) *Outline.* This period should include explanation of center of impact registration, practical example of center of impact registration and determination of corrections therefrom, explanation of high-burst registration, and practical example of a high-burst registration and corrections therefrom.

e. Fifth period.

(1) *Objective.* To instruct the members of the section in the computation and use of metro corrections.

(2) *Outline.* This period should include an explanation of the ballistic effects of weather, an explanation and discussion of the metro message, a practical example in the solving of a metro message, the application of metro corrections, and computation of additional metro messages as time permits.

f. Sixth period.

(1) *Objective.* To instruct the members of the section in the computation of metro corrections and the determination and use of velocity error.

(2) *Outline.* This period should include reasons why metro corrections alone are not reliable, definition and cause of VE, practical example of determination of VE and change in deflection correction due to weather, practical example in the use of VE and change in deflection correction due to weather, determination and use of new VE and change in deflection correction due to weather, and use of new VE and in deflection correction due to weather.

g. Seventh period.

(1) *Objective.* To instruct the members of the section in the construction and use of the observed firing chart.

(2) *Outline.* This period should include a practical example in the construction and use of observed firing chart (percussion fire), a practical example in the construction and use of the time plot observed firing chart, and a comparison of time plot and percussion observed firing charts.

h. Eighth period.

(1) *Objective.* To instruct the members of the section in transferring from the observed firing chart to the surveyed firing chart.

(2) *Outline.* This period should include a practical example of transferring from the percussion observed firing chart to the surveyed chart, and a practical example of transferring from the time plot observed firing chart to the surveyed firing chart.

i. Ninth period.

(1) *Objective.* To instruct the members of the section in the procedure employed in handling high-angle fire.

(2) *Outline.* This period should include instructions regarding the high-angle GFT, high-angle registration corrections, and conduct of high-angle missions.

j. Tenth period.

(1) *Objective.* To train members of the section in their duties in firing high-angle missions.

(2) *Outline.* This period should be a practical period conducted from prepared notes with a discussion or critique of each mission.

4. SURVEY PERSONNEL (INDIVIDUAL PHASE). (Total hours, 31.)

Period	Hours	Subject	Text references	Area	Training aids and equipment
1	2	Introduction to survey, grid systems, and plotting (conference, practical exercise).	Pars. 106–124b, 258–260.	Classroom	Plotting equipment, maps, grid sheets, demonstration grid sheets, plotting equipment, and blackboard.
2	2	Introduction to survey equipment and its use (conference, demonstration).	Pars. 261–288	Field	One of each type of principal survey instruments.
3	2	The tape and taping (practical exercise).	Pars. 262–265	Field	Known distance taping course, tapes, plumb bobs, pins.
4	2	Use of the aiming circle (conference, practical exercise).	Pars. 266–274	Field	Aiming circles.
5	1	Basic survey operations, measurements, TRAVERSE (conference).	Pars. 289–294	Classroom	Blackboard, field notebooks (1 per student).
6	3	Basic survey operations, measurements, TRAVERSE (practical exercise).	Pars. 289–294	Field	Section equipment.
7	3	Basic survey operations, measurements, TRIANGULATION (conference, practical exercise).	Pars. 295–297	Classroom and field.	Section equipment, blackboard.
8	2	Computation: The traverse computation form, relationship between azimuths and bearings (conference, practical exercise).	Pars. 304–307	Classroom	Blackboard, demonstration DA–AGO Form 6–2 (2 regular forms per student).
9	2	Computation: The traverse computation form (conference, practical exercise).	Pars. 304–307	Classroom	Blackboard.

Period	Hours	Subject	Text references	Area	Training aids and equipment
10	2	Computation: Triangulation (conference, practical exercise).	Pars. 309–312	Classroom	Blackboard.
11	3	Computation: Triangulation (conference, practical exercise).	Pars. 309–312	Classroom	Blackboard, section equipment, demonstration triangulation computation forms. Triangulation computation forms (1 per student).
12	2	Graphic methods, (conference, practical exercise).	Pars. 115, 298, 299.	Classroom	Blackboard, tracing paper, section equipment.
13	2	The target area base (conference, practical exercise).	Par. 313	Classroom	Blackboard, military slide rule.
14	3	Calculation of *Y*-azimuths and distance from coordinates, and determination of base angles (conference, practical exercise).	Pars. 314–316	Classroom	Blackboard, section equipment.

a. First period.

(1) *Objective.* To acquaint survey personnel with the purpose of field artillery survey, and to teach them the use of plotting equipment.

(2) *Outline.* Explain to the personnel the part that the survey plays in carrying out the field artillery mission and show them how important their work is. Practical work must include—

(*a*) Plotting points on grid sheets, using the boxwood scale and the coordinate square; and reading the coordinates of plotted points, using the boxwood scale and the coordinate square. Practice should be given on standard scale grids and on those with grid lines too close together and too far apart.

(*b*) Use of the protractor to measure the *Y*-azimuth of a line and to draw a line of given *Y*-azimuth through a given point.

(*c*) Use of range deflection fan, boxwood scale, and protractor to measure distances betwen plotted points. The period should end with the complete plot of a surveyed firing chart.

b. Second period.

(1) *Objective.* To teach survey personnel the characteristics, uses, capabilities, and limitations of the principal survey instruments and their accessories.

(2) *Outline.* This is a practical outdoor demonstration in which students visit each of several stations. At each station, they receive instruction in, and a short demonstration of, one of the principal survey instruments and its accessories. The instruments demonstrated should include—

(*a*) The tape and its accessories (plumb bob, pins, notebook). Demonstrate taping several tape lengths on level and sloping ground. Show alinement, tension, sag, reading of tape (30 minutes).

(*b*) The aiming circle. Demonstrate measurement of horizontal angles by repetition, laying on a given *Y*-azimuth, measuring a *Y*-azimuth, and measuring a vertical angles (30 minutes).

(*c*) The battery commander's telescope. Demonstrate measurement of horizontal and vertical angles (10 minutes).

(*d*) The transit and accessories (stadia, range poles). Demonstrate measurement of horizontal and vertical angles, and the use of the stadia (20 minutes).

(*e*) The altimeter (10 minutes).

c. Third period.

(1) *Objective.* To train survey personnel in the use of the tape and its accessories.

(2) *Outline.* Divide survey personnel into taping teams of three each (head tapeman, rear tapeman, and recorder). Each team will take a closed course. The course should include some rough ground requiring the teams to break tape. Teams should be required to double tape a single length suitable for a target area base.

d. Fourth period.

(1) *Objective.* To teach the use of the aiming circle in survey.

(2) *Outline.* Spend the first 30 minutes giving instruction in the measurement of clockwise horizontal angles and vertical angles at several successive stations. Show how the instrument is backsighted on the station last occupied and how angles are measured by repetition. Divide survey personnel into teams of two each (one instrument operator, one recorder). Each team will run a clockwise angle traverse around a closed course measuring all angles by repetition. A sketch will be kept showing the angles measured. Each team will measure the *Y*-azimuth of a line of known direction. All work should be checked by the instructor for accuracy.

e. Fifth period.

(1) *Objective.* To teach the personnel the duties of each member of a traverse party.

(2) *Outline.* Review briefly the use of the tape and aiming circle. Explain make-up and duties of a traverse party. Explain and demonstrate proper way to build up a set of field notes, including a sketch. Have students follow in their field notebooks.

f. Sixth period.

(1) *Objective.* To train the personnel in running a clockwise aiming circle traverse.

(2) *Outline.* Divide survey personnel into traverse teams. Each team should run a traverse starting from a line of known direction. Angles will be measured by repetition, using the aiming circle; distances will be taped. Accuracy with speed should be stressed. Part of the course should be over rough ground, requiring tapmen to break tape. Notes should be kept properly and saved for future use.

g. Seventh period.

(1) *Objective.* To teach the use of, and measurements necessary for, a triangulation system. To give practice in accomplishing the field work for a triangulation system.

(2) *Outline.* This period consists of a 1-hour classroom period followed by a 2-hour field problem. The classroom conference should explain the use of triangulation as a means of survey. A step-by-step process to build up a triangulation

system, including measurement of the base and angles to be turned, should be demonstrated. The special triangulation problem of computed intersection should be demonstrated and explained. Demonstrate the proper way to make a field sketch. The last 2 hours should consist of triangulation teams accomplishing the field work with sketch for a triangulation system, including several point locations by intersection. Field notes should be saved for future use.

h. Eighth period.

(1) *Objective.* To teach the use of the traverse computation form.

(2) *Outline.* Explain the proper way to apply horizontal angles to azimuths, the meaning and use of back azimuths to carry direction, and the relationship between azimuth and bearing. The DA AGO Form 6–2 should be explained and demonstrated. Students should enter the data from the field notes prepared in the sixth period.

i. Ninth period.

(1) *Objective.* To teach the use of the survey computation form for computing a traverse.

(2) *Outline.* Period must show proper way to use the DA AGO Form 6–2, to complete computations after the field work has been entered on the form. Explain and demonstrate all columns and lines of the form. Students then should complete the computation on their form partially prepared in the eighth period. Computations should be made with logarithms and checked with the military slide rule.

j. Tenth period.

(1) *Objective.* To teach survey personnel the solution of the oblique triangle.

(2) *Outline.* Explain and demonstrate the solution of single oblique triangles. Survey personnel should be required to solve several oblique triangles, using both logarithms and the military slide rule.

k. Eleventh period.

(1) *Objective.* To teach survey personnel the use of the triangulation computation form.

(2) *Outline.* Explain and demonstrate the proper way to enter data and draw sketches on the triangulation computation form from a set of field notes. Require students to enter data on a form from the field work accomplished in the seventh period. Demonstrate solution of oblique triangles to

include the bearings of the sides of the oblique triangles in the system, and the proper way to enter the results on a traverse computation form. Have students compute the triangulation form. If time permits, complete the solution on the traverse form.

l. Twelfth period.

(1) *Objective.* To familiarize survey personnel with graphic means of locating points.

(2) *Outline.* Conference should explain and demonstrate graphic intersection, tracing paper resection, and polar plot methods of locating points. Requirements for, and the uses and accuracy of, each method should be stressed.

m. Thirteenth period.

(1) *Objective.* To teach the application to survey of the target area base.

(2) *Outline.* Explain the purpose, composition, and principles of a target area base. Explain the nomenclature and solution of the target area base triangle. Orientation on the firing chart and plotting of data on the firing chart, using the base, should be covered by examples.

n. Fourteenth period.

(1) *Objective.* To teach the calculation of direction and distance from coordinates, and the determination of base angles.

(2) *Outline.* The calculation of Y-azimuth and distance of a line between two points of known coordinates should be explained and demonstrated. Survey personnel should solve several such problems with logarithms and with the military slide rule. Define and demonstrate the use of the orienting line and base angles. Determination of base angles should be shown. Students should be required to determine several base angles, having been given the azimuth of the OL and the coordinates of the battery center and the base point.

5. SURVEY PERSONNEL (SECTION PHASE). (Total hours, 8.)

Period	Hours	Subject	Text references	Area	Training aids and equipment
1	8	Complete battalion survey	All text references listed in paragraph 4, this appendix.	Field	Section equipment.

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a. Training period.—Objective. To train the survey personnel by practical experience in performing a complete battalion survey.

b. Outline. A complete battalion survey should be laid out on the ground, including base point, targets, check points, restitution control points, O–1, and batteries. Starting control (true or assumed) should be given. Location of points to be surveyed should be pointed out on the ground. Survey personnel should be divided into groups, assigned definite tasks, and placed in charge of definite personnel. The survey should be laid out in such a manner that both traverse and triangulation must be employed. Computations will be made, base angles determined, and surveyed firing charts constructed. Accuracy will be checked by the instructor.

APPENDIX X

GLOSSARY

Section I. ABBREVIATIONS

The following abbreviations and field artillery terms appear throughout this manual. An understanding of them is necessary for a proper understanding of the subject matter contained herein. Where abbreviations are similar, the meaning will be apparent from the context.

A	Air (sensing)
ADJ	Adjust (command)
Alt	Altitude
AMC	At my command
Az	Azimuth
B	Battery (pieces to fire)
BA	Battery adjust
BL	Battery left
BP	Base point
BPL	Base-point line
BR	Battery right
C	Center pair of pieces to fire (command *CENTER*)
CI	Center of impact
c	Change in elevation for 100-yard change in range
Ca	Compass
CF	Cease firing
Ch	Charge
Cl	Close
CL	Center pair of pieces, left piece to fire first (command *CENTER LEFT*)
Conc	Concentration
Corr	Correction
CR	Center pair of pieces, right piece to fire first (command *CENTER RIGHT*)
D	Down
DD	Deflection difference
Dev	Deviation
Df	Deflection
DNL	Do not load (command)

El	Elevation
F	Fork
FDC	Fire-direction center
FFE	Fire for effect
FM	Fire mission
Fwd Obsr	Forward observer
Fz	Fuze
FzD	Fuze Delay
FzQ	Fuze Quick
G	Graze
G	Piece (gun, howitzer, or rocket position)
GFT	Graphical firing table
GST	Graphical site table
HB	High burst
HCO	Horizontal control operator
HE(HC)	High explosive (high capacity for naval gunfire)
K	A correction in units per thousand yards or range; ratio of adjusted range to map range
L	Left (sensing, deflection correction, direction correction or left two pieces)
LL	Left pair of pieces, left piece to fire first (command *LEFT LEFT*)
LR	Left pair of pieces, right piece to fire first (command *LEFT RIGHT*)
₥	Mil
MDP	Meteorological datum plane
MF	Method of fire
Mx	Mixed (sensing)
NCh	Normal charge
O	Observer
OL	Orienting line
OP	Observation post
Op	Open
Plat	Platoon
Proj	Projectile
Q	Quadrant
R	Right (sensing, deflection correction, direction correction, or right two pieces)
R	Range, in thousands of yards, from *G* to T
RR	Right pair of pieces, right piece to fire first (command *RIGHT RIGHT*)
RR	Repeat range (correction)

r	Distance, in thousands of yards, from *O* to T
RCh	Reduced charge
Rd	Round
RGM	Rounds per piece per minute
s	The deflection change required to keep a burst on the *OT* line when a range change of 100 yards is made along the *OT* line
SCh	Supercharge
Sh	Shell
Si	Site
SIC	Survey information center
SpCorr	Special corrections
T	Target (or observer displacement or target offset)
Ti	Time (fuze setting)
TOT	Time-on-target
U	Up
VCO	Vertical control operator
VE	Velocity error
VM	Volleys per minute
VT	Variable time (radioactive, proximity fuze also called *posit*)
WA	Will adjust
WP	White phosphorus
WR	When ready
Z	Zone
+	Over (sensing) Add (correction)
—	Short (sensing) Drop (correction)
?	Doubtful (sensing)

Section II. DEFINITION OF TERMS

Adjusted time gage line. A pencil line on the indicator of the GFT over the fuze setting for zero height of burst, the hairline being over the ground range.

Adjustment. The determination of corrections by, and their use in, firing to place the center of impact or center of burst on the adjusting point.

Air. A sensing which indicates an air burst or ricochet above the level of the base of the target.

Altitude. Height above sea level or other other reference plane. Symbol: *Z* or *H*.

Arming range. The range at which the fuze arms.

Auxiliary base line. A line of known distance, used in computing the length of a *base line.*

Auxiliary target. A point or object whose location relative to an actual target is known, and upon which artillery fire is adjusted before firing on the actual target; it is employed in order to gain surprise.

Azimuth (observed fires). Horizontal direction from *Y*-north measured by the observer to the target.

Azimuth index. An inverted arrow drawn on the firing chart, marked *N*, at zero azimuth from the point over which the target grid has been centered.

Base angle. The horizontal clockwise angle from the base-point line to the orienting line; it is never greater than 3,200 mils.

Base line. A line of known length and direction used as a basis for computations in triangulation.

Base piece. The piece in a battery nearest the battery center, which normally is used for registration.

Base piece displacement correction. The correction necessary to center the battery on the base point after registration; the correction to compensate for the base piece's displacement from the battery center.

Base point. A point in the target area whose location is known on the ground, on a firing chart, or on both. If its location on the ground is known, it must be readily identifiable and should be in the approximate center of the area, both horizontally and vertically. It is used as a basis for computing data and as a reference point.

Base-point line. A line connecting the base point and the battery center.

Battery center. A point materialized on the ground at the approximate geometric center of the battery; the chart location of the battery.

Below. The sensing of an air burst below the level of the base of the target.

Burst center. The center of a group of bursts.

Burst range. The horizontal distance from the piece to the point of burst.

Cant. The sidewise tilting of the axis through the trunnions of an artillery piece.

Center of impact. The mean point of impact of a group of rounds fired with the same data.

Chart deflection. The deflection measured from the firing chart from base-point line extension as an origin if no deflection index has been constructed or from the deflection index after it has been constructed.

Check Point. A visible point of known location selected as a target for registration.

Common control. The horizontal and vertical map or chart location of points in the target area and position area, tied in with the horizontal and vertical control in use by two or more units. May be established by firing, survey, or a combination of both.

Concentration. A volume of fire placed on a specific area within a limited time; an area designated and numbered for future reference as a possible target.

Deflection correction. That carried on the range-deflection fan obtained by comparing chart deflection to adjusted deflection.

Deflection difference. The amount that a piece in a battery is traversed toward or away from a given piece (usually the base piece) to vary the width of the sheaf.

Deflection index. A line constructed on the firing chart after the first registration of first metro deflection correction for purpose of measuring subsequent chart deflections.

Deviation. The angular or linear displacement of a point of impact or of burst, or a center of impact or of burst, from the target or the adjusting point, as measured by the observer.

Directional traverse. A line laid out in surveying to show the direction of one point from another without determining the distance between them.

Doubtful. Sensing of a round when no positive range sensing can be obtained.

Elevation gage line. A pencil line drawn on the window of a graphical firing table over the true adjusted elevation.

Fork. The difference in elevation required to change the center of impact by four probable errors in range.

Fuze range. The range at which a projectile will burst when its fuze is set at a given time value.

Fuze setting. The time which is to be set on the fuze.

Graphical firing table. A graphical representation of certain firing table data, for use in rapid calculation of firing data; it may be either in the form of a chart, or a specially constructed slide rule.

Graze. The sensings, in time fire, for a burst on impact with the ground or other material object; or, with fuze delay, for a mine action burst.

Graze above. The sensing, in time fire, for a burst on impact above the target; it is doubtful for height of burst.

Grazing point. In the determination of dead space, the near limit of the dead space is called the grazing point.

High oblique. Aerial photograph taken at a slant so that it includes the horizon.

Instrument direction. A recorded reference direction of a high air burst, as indicated on an instrument at the battery position, which enables the battery executive subsequently to check and correct computed or scaled deflection settings.

Instrument reading. The clockwise horizontal angle, vertex at the instrument, from a reference point to a target or other point.

Line. The observer's deviation sensing for a line shot.

Line shot. A projectile which strikes on the observer-target line.

Lost. The sensing for a round which is not seen by the observer.

Low oblique. An oblique photo which does not include the horizon.

Low order burst. An incomplete and comparatively slow explosion of the bursting charge of a projectile.

Map *K*. A proportional correction for the discrepancy between the scale of a firing chart and that of the plotting scale being used.

Mask. A terrain feature of such altitude that it restricts fire or observation in the area beyond, resulting in dead space, or limiting the minimum elevation or both.

Metro check point. An arbitrary point in the target area for which corrections for known effects are computed.

Metro data. Data to which corrections determined from a metro message and other known effects have been applied.

Metro *K*. Range correction, in yards per thousand yards, determined from computation of corrections for known effects.

Metro message. A tabulation of weather conditions from which the effects of weather on exterior ballistics can be determined.

Mine action. The explosion resulting when an HE shell penetrates the ground so that the effect and sound are muffled by the ground.

Minimum arming time. The shortest possible time in which a fuze can arm subsequent to firing.

Minimum elevation. The lowest quadrant elevation of a weapon at which the projectile safely will clear an obstacle between it and the target.

Mixed. The sensing, applied to height of burst only, for a group of rounds which result in both airs and grazes in any proportion.

Muzzle velocity. The speed of a projectile at the instant it leaves the muzzle of a weapon.

Neutralize. To destroy combat efficiency by fire.

O1. The controlling observation post of a target area base. It may be either the left or right end.

O2. The auxiliary observation post of a target area base.

Observer displacement. The angle T; the angle observer-target-piece; target offset.

Orienting line. A line of known direction established on the ground, which is used as a reference line in surveying and in laying artillery pieces for direction.

Orienting station. A point on the orienting line near the gun position from which the battery may be laid.

Over. The sensing of a round which strikes or bursts beyond the target. (*Also see* Short.)

Percussion fire. Fire with fuzes set to burst on impact.

Photo center. The intersection of lines drawn from the collimation marks or from the corners of a photo, also called the principal point.

Photo *K*. A proportional correction expressed in yards per 1,000 yards for discrepancies between the scale of a photo and that of the plotting instrument being used.

Plumb point. The point on the ground vertically below the lens of the camera at the moment of exposure.

Range spread. The arbitrarily selected difference in elevation settings of the batteries of a battalion firing at a single target, for the purpose of securing deeper coverage of the target. It is expressed in terms of *c*; for example, "½ *c* apart."

Refer. To bring the movable gun sight on a chosen aiming point without disturbing the laying of the weapon.

Reference point. A point of known location (or direction from another point) generally used as the zero line for instrument reading. A point with respect to whose location a target is located in an initial fire request.

Registration. That fire delivered to obtain corrections for increasing the accuracy of subsequent fires.

Registration position. A position used only for registration, joined by survey to the combat positions of the unit.

Ricochet. A glancing rebound of a projectile on impact.

Safety card. A card issued for a particular battery position for a particular time, prescribing the area into which the fire safely may be placed both laterally and in depth.

Salvo. A method of fire in which the pieces of a battery or a portion thereof fire successively at specified intervals; the interval is 2 seconds unless otherwise specified.

Shift. The corrections or commands given to move a burst (or bursts) from a known location to a new location and may include one or all of directions, height, and range.

Short. The sensing for range of a round which strikes or bursts between the observer and the target. (*Also see* Over.)

Surveillance. The visual or radar observation of an area or of gunfire.

Survey control point. A survey station used to coordinate survey between echelons; usually given by a higher echelon to a lower. (The *X*, *Y*, and *Z* coordinates are known.)

Survey information center. A place where survey data are collected, correlated, and made available to subordinate units.

Target area survey. That portion of a battalion survey concerned principally with the location of targets and observation posts.

Target pin. The plotting pin or needle used by HCO and VCO to plot observer's shifts and corrections on the target grid and for which location on the chart deflections and ranges are read.

Terrain sensing. A positive sensing of a round not on the observer-target line, based on a knowledge of the terrain near the target.

Time. Command or setting which controls the time of burning of a time fuze.

Time correction. The difference between the adjusted, *zero height of burst*, time setting and the firing table setting for a particular horizontal range.

Time fire. That fire in which fuzes other than VT are to act before impact.

Time K. The proportional time correction in terms of seconds (usually to hundredths) per thousand yards of range.

Time-on-target. A method employed for placing large volumes of surprise fire on targets. The pieces are fired at such a time as to cause all of the initial volleys to arrive at the target at the same instant.

Transfer limits. The maximum difference in direction and range from the location of a check point, within which corrections computed for the check point are assumed to be sufficiently accurate to warrant application to any target, justifying its attack by a transfer of fire.

Transfer of fire. *K*-transfer.

Velocity error (*VE*). The numerical difference between effects determined by metro and those determined at approximately the same time by registration, expressed in feet per second variation from standard muzzle velocity.

***VE* corrections.** The amount of the *VE*, with the opposite sign.

Volley. In volley fire, each piece fires the specified number of rounds without any attempt to synchronize with the other pieces.

Volleys per minute. Similar to rounds per piece per minute.

Wide angle photo. A vertical aerial photo with a relatively wide coverage, 70° or greater, having sufficient coverage for use as a firing chart.

Zero height of burst. A condition obtained when rounds fired with the same fuze setting and the same quadrant elevation result in an equal number of airs and grazes.

Zone. A method of fire, normally used when a single battery is firing on a target, in which different ranges, usually 50 yards apart, are fired in order to give coverage in depth.

INDEX

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