FM 6-40

DEPARTMENT OF THE ARMY FIELD MANUAL

FIELD ARTILLERY GUNNERY

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*This manual supersedes FM 6-40, 6 January 1950, including C 2, 24 September 1952, C 4, 4 August 1954, and C 5, 2 December 1955; chapter 7, and paragraphs 4, 5, and 6, appendix II FM 6-140, 9 March 1950, including C 1, 21 December 1950 and so much of C 2, 23 January 1952 as pertains thereto; TC 18, 21 July 1954; TC 6-1, 11 March 1955; and TC 6-3, 3 June 1955.

PART ONE
GENERAL
CHAPTER 1
INTRODUCTION

1. General

a. Purpose. This manual presents and explains field artillery gunnery and presents a solution, based on practical experience, to the gunnery problem. Gunnery includes a practical application of the science of ballistics and a system combining those principles, techniques, and procedures essential for the delivery of timely and effective artillery fire. This manual cannot cover all weapons and all situations. However, by minor modifications of the methods and principles set forth, this manual can provide a guide for solving field artillery gunnery problems within the scope set forth below.

b. Scope. Gunnery in this manual encompasses all current weapons which can be employed in a field artillery role, except the 762-mm rocket (HONEST JOHN) and guided missiles. The material presented herein is applicable without modification to both atomic and nonatomic warfare. The scope includes—

(1) Fundamentals of field artillery gunnery.
(2) Characteristics and capabilities of weapons and ammunition.
(3) Firing battery gunnery.
(4) Conduct of fire.
(5) Fire direction.
(6) Use of aerial photographs.
(7) Miscellaneous gunnery information.

c. Changes or Corrections. Users of this manual are requested to submit recommendations for changes or corrections to the Commanding General, United States Continental Army Command, Fort Monroe, Va. For format and guidance, see AR 310-3.

2. References

See appendix I for list of references.

3. Characteristics of Field Artillery

Knowing and understanding the principal characteristics and capabilities of field artillery will make possible the proper use of one of the most effective tools available to the combat commander. The principal characteristics and capabilities of field artillery are as follows:

a. Destructive power obtained through accurate and timely delivery of large numbers of heavy projectiles, regardless of visibility, weather, and terrain, in a very short period of time.

b. Versatility through rapid maneuver of massed fires over a wide front from widely dispersed positions without a change in position areas.

c. Mobility, which permits the commander to displace his artillery quickly while providing continuous fire support.

d. Demoralizing effect on enemy ground forces by fires delivered from positions some distance from the point of contact, thereby limiting their ability to strike back or to locate the source of their casualties

4. Missions of Field Artillery

In the application of gunnery, the ultimate objective is to insure that the field artillery carries out effectively its two principal missions. Those missions are—

a. To give close support to other arms by fire, neutralizing or destroying those targets which are most dangerous to the supported arms.

b. To give depth to combat and isolate the battlefield by counterfire, fire on hostile reserves, restricting movement in rear areas, and disrupting hostile command facilities and other installations.

5. Basic Principles of Employment of Field Artillery Fire Power

a. Field artillery doctrine demands the timely and accurate delivery of fire to meet the requirements of supported troops. All members of the artillery team must be continuously indoctrinated with the sense of urgency, striving to reduce by all possible measures the time required to execute an effective fire mission.

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

c. 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. Some type of observation is desirable for every target fired upon in order to insure that fire is placed on the target. Observation of close-in battle areas is usually visual; when targets are hidden by terrain features or when greater distances or limited visibility are involved, observation may be either visual (air or flash) or electronic (radar or sound). When observation is available, corrections can be made to place artillery fires on target by adjustment procedures; however, lack of observation must not preclude firing on targets that can be located by other means. For targets that cannot be observed, effective fire must be delivered by unobserved fire procedures.

d. Field artillery fires must be delivered by the *most accurate means which time and the tactical situation permit.* Whenever possible, survey will be used to locate the weapons and targets accurately. Under other conditions, only a rapid estimate of the relative location of weapons and targets may be possible. However, survey of all installations should be as complete as time permits in order to achieve the most effective massed fires. Inaccurate fire wastes ammunition and weakens the confidence of supported troops in the artillery.

e. In order to inflict a maximum number of casualties, the immediate objective is to deliver a mass of accurate and timely fire. The number of casualties inflicted in a specific target area can be increased in most instances by surprise fire. If surprise massed fires cannot be achieved, the time required to bring effective fire to bear on the target should be reduced to a minimum.

f. The greatest demoralizing effect on the enemy can be achieved by delivery of a maximum number of rounds from many pieces in the shortest possible time and without adjustment. Accurate massed fire with 1 round per weapon from 6 batteries will be much more effective than 6 rounds per weapon from 1 battery, provided that they arrive on the target simultaneously.

g. Artillery units must be prepared to handle multiple fire missions when the situation so dictates.

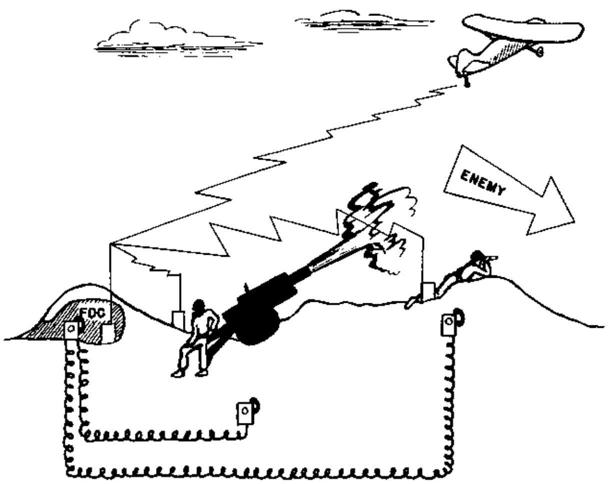


Figure 1. The field artillery gunnery team and communication facilities.

6. Field Artillery Gunnery Team

(fig. 1)

The field artillery normally emplaces its weapons in defilade so that they cannot be seen or easily located by the enemy. Since this measure precludes sighting the weapon directly at most targets (direct fire), another method of pointing the weapon, called *indirect fire*, is used. (Both methods are explained in detail in later chapters.) The use of indirect fire requires the coordinated efforts of the field artillery gunnery team which includes observers, fire direction centers (FDC's), and weapons' crews. These elements are interconnected by wire and/or radio communications. Thorough and detailed training of all elements of the gunnery team is essential to accomplishment of the artillery mission. It is only through constant and aggressive supervision of training that the highest standards of performance can be achieved and maintained.

a. Observers. Observers detect and report the locations of suitable targets to the FDC and request fire. The observers are so located that collectively they have surveillance of the zone of action.

b. Fire Direction Centers. Fire direction centers determine firing data and furnish fire commands to the weapons' crews of firing units. A firing unit may be a firing battery, a firing platoon, or an individual piece depending on the type of unit and/or the tactical situation. The term "firing battery," as used herein, includes all firing units.

c. Weapons' Crews. The weapons' crews apply the fire command data to the pieces for pointing (laying) and firing. The term "pieces," as used herein, includes individual guns, howitzers, mortars, or rocket launchers at the firing position.

CHAPTER 2
FUNDAMENTALS OF FIELD ARTILLERY GUNNERY

Section I. ELEMENTS OF FIRING DATA

7. General

a. The information necessary to point (lay) artillery weapons is termed firing data and includes direction, distribution, vertical interval, and range. These data may be obtained by computation, estimation, or graphical means based on locations obtained by observation (visual or electronic) or by map or photographic analysis (fig. 2). The pattern of burst distribution in the target area usually involves computations. The FDC converts firing data to fire commands, which are transmitted to the firing battery (weapons).

b. Tbe principal unit of angular measurement in the artillery is the mil. A mil is the angle subtended by an arc which is one-sixty-four-hundredths of the circumference of a circle. For practical purposes, 1 mil is the angle subtended by 1 yard (meter) at 1,000 yards (meters).

8. Direction (Deflection)

Direction is determined graphically, by computation, or by estimation and is always expressed as an angular measurement in mils. Later chapters explain in detail techniques of determining direction and procedures for pointing (laying) the weapon for direction.

a. Upon first occupying a position, the weapons are laid for direction with reference to one of the following:

(1) *Grid north.* Grid north is the north direction of the vertical grid lines usually found on military maps. Since determination of firing data for direction is based on grid north, the term "azimuth" is normally used to mean grid azimuth. Grid azimuth is the horizontal, clockwise angle from grid north to any designated direction. Laying with reference to grid north is normally accomplished by using an aiming circle or a compass.

(2) *Orienting line.* The orienting line is a line of known direction materialized on the ground. The horizontal, clockwise angle from the line of fire to the orienting line or orienting line extended is called the orienting angle (fig. 3). The orienting angle is never greater than 3,200

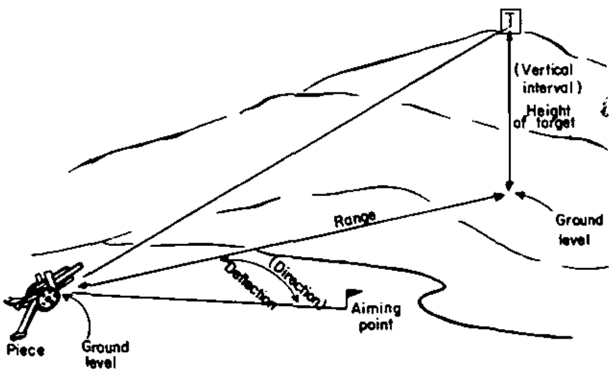


Figure 2. Elements from which firing data are determined.

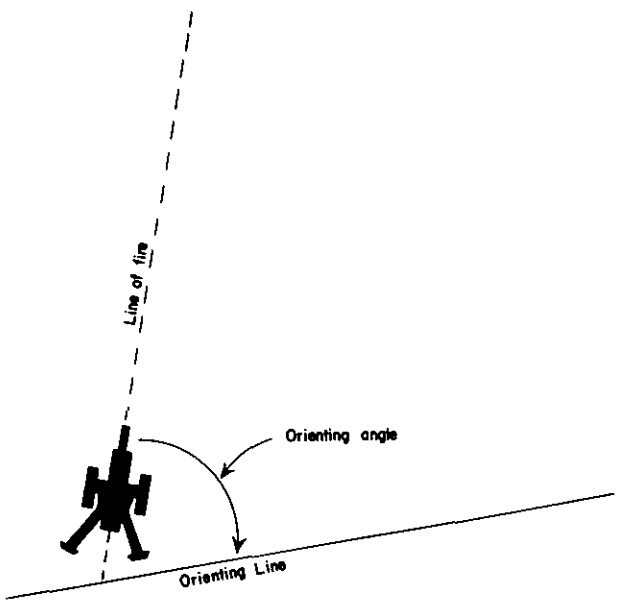


Figure 3. Orienting angle.

mils. Laying by use of orienting line (direction of which is established in reference to grid north) is accomplished by using one end of the orienting line, rather than magnetic north, as a reference point.

(3) *Distant aiming point.* The distant aiming point must be visible. It may be a lone tree, a church steeple, or any other easily identified object.

(4) *Special methods.* Sighting on an airplane, a high air burst, or a flare are special methods which may be used for initial laying for direction.

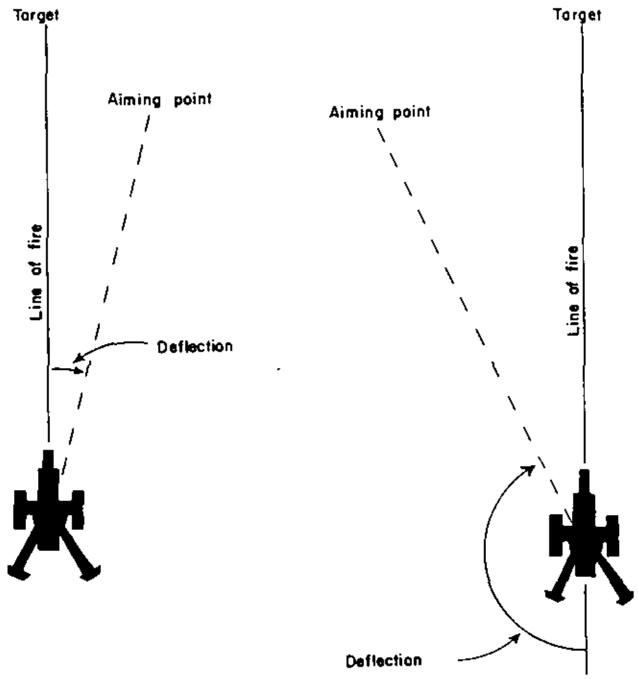


Figure 4. Deflection.

b. The horizontal, clockwise angle from the line of fire or line of fire extended to a designated aiming point is called deflection (fig. 4). A deflection set on the sight of an artillery weapon will cause the tube to be pointed in the desired direction when the tube has been traversed to the point where the sight is alined on the aiming point. The main scale of the sight (panoramic telescope) consists of 2 halves, each graduated in units of hundreds of mils from 0 to 3,200 mils in a counterclockwise direction. The applied deflection is therefore never greater than 3,200 mils.

c. Immediately upon occupation of a position, an artillery weapon is laid in a specifie direction (initial direction). This facilitates later shifts to designated targets. Any shift from the initial direction is accomplished by setting a new deflection on the sight, then traversing the tube to bring the sight back into alinement with the aiming point.

9. Distribution

Distribution is the arrangement of bursts in the target area. Since targets are of various shapes and sizes, provisions must be made for controlling the distribution of a battery (batteries) and battalions. Although time can be saved in some cases by causing all weapons to fire at the center of a large area, more effective fire may be obtained by use of a planned pattern of uniform density. This pattern may be about a point or spread to cover a desired frontage and/or depth. The fire commands determined by the FDC to provide for the desired burst distribution are applied at the firing battery as corrections to each weapon within the battery. Distribution of fire for more than one battery or battalion on a target consisting of a large or odd-shaped area is usually secured by assigning individual target grid references to each unit. In the firing battery, the coverage of a target by fire is normally obtained by the control of the sheaf. A sheaf consists of planned planes of fires which produce a desired pattern of bursts with rounds fired by two or more pieces. The width of a sheaf is the lateral interval between the centers of flank bursts of a sheaf. The front covered by any sheaf is the width of the sheaf plus the effective width of a burst. A sheaf may be formed in any of the following patterns:

a. Normal (Parallel) Sheaf. A normal sheaf consists of parallel planes of fire which produce a pattern of bursts resembling the pattern of the pieces in the position area (fig. 5). All pieces are laid parallel and are normally fired at the same elevation; however, elevation (range) may be altered to correct for large variations in shooting strength of the pieces by application of calibration corrections (ch. 28).

b. Special Sheaf. A special sheaf is any sheaf other than a normal sheaf and consists of planned planes of fire which produce a pattern of bursts providing the desired distribution of fire on a given

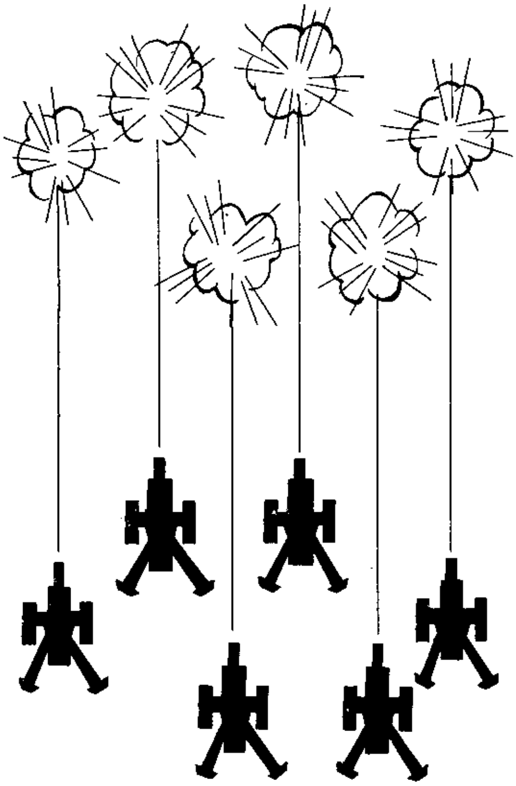


Figure 5. Normal sheaf.

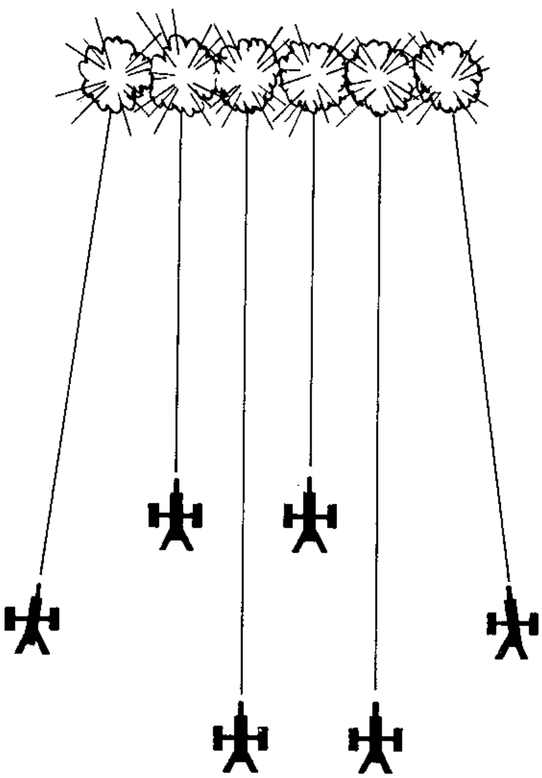


Figure 6. Linear sheaf.

target. A special sheaf is obtained by applying corrections to individual pieces for direction, height, variations in shooting strength, fuze time, and range as necessary to form the desired pattern. Special sheaves include, but are not limited to, the following:

(1) *Linear (regular) sheaf.* A linear sheaf is one in which the bursts are planned to occur on a line perpendicular to the line of fire and are equally spaced laterally (fig. 6).

(2) *Converged sheaf.* A converged sheaf is one in which all bursts are planned to occur at a common point (fig. 7).

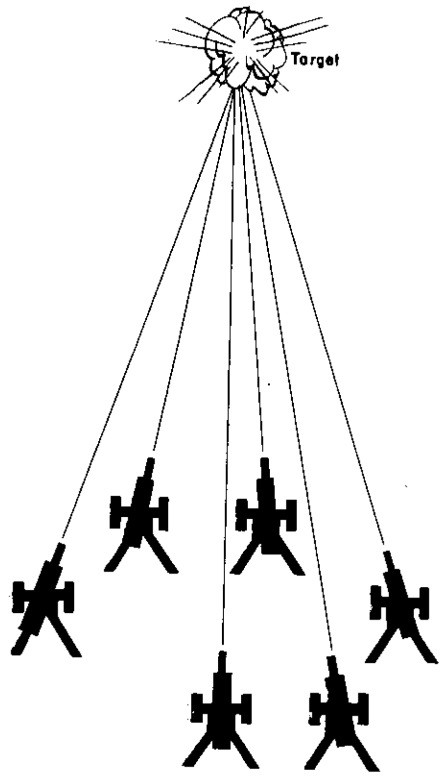


Figure 7. Converged sheaf.

(3) *Open sheaf.* An open sheaf is one in which the planned interval between the points of impact of adjacent bursts is equal to the maximum effective width of burst of the type shell being used (fig. 8). All pieces are fired at the same elevation (range), except when corrections are applied as stated in *a* above for a normal sheaf. Table I is presented as a guide for the most desirable widths of open sheaves.

Table 1. Open Sheaves

Caliber	Width (in yards) for an effective open sheaf			Front (in yards) covered effectively by open sheaf		
	2-piece battery	4-piece battery	6-piece battery	2-piece battery	4-piece battery	6-piece battery
75-mm	------	60	------	------	80	------
105-mm	------	90	150	------	120	180
155-mm	------	150	250	------	200	300
8-inch	80	240	------	160	320	------
240-mm	100	------	------	200	------	------
280-mm	60	------	------	120	------	------
4.2-inch (mortar)	------	------	250	------	------	300

10. Altitude and Height

Altitude is defined as the vertical distance or elevation of a point on the earth in its relation to sea level. For gunnery purposes, height has two uses; namely, height of target and height of burst.

a. Height of Target. The height of target is the vertical interval between the target and the horizontal plane through a weapon. The height of a target with respect to the weapon can be determined—

(1) From maps.
(2) By survey.
(3) By reference to a point of known altitude.

b. Height of Burst. The height of burst is the vertical interval from the ground or target to the point of burst.

11. Range

Range is the horizontal distance between the weapon and a target. It can be determined by—

a. Map (chart) measurement.
b. Survey.
c. Estimation.

12. Conditions Affecting Firing Data

A number of conditions can cause artillery fire to miss the target. Paragraphs 13 through 16 deal with some of these conditions and the factors involved.

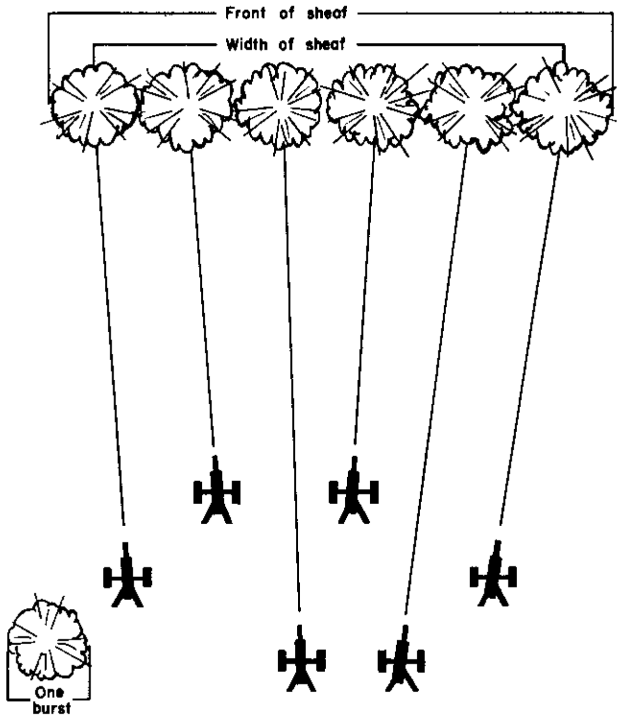


Figure 8. Open sheaf (corrections applied).

Section II. ELEMENTARY BALLISTICS

13. General

Ballistics is the science which deals with the motion of projectiles and the conditions which affect that motion. An understanding of interior and exterior ballistics and proper application of that knowledge will improve the accuracy of artillery fire. For a more advanced discussion on ballistics, see chapters 25 and 26.

14. Interior Ballistics

Interior ballistics is the science which deals with the factors affecting the motion of projectiles before they leave the muzzle of the piece. Certain factors influencing the motion of projectiles within the tube are—

a. Wear of the Tube. Wearing away of the bore (erosion) is caused by the movement of high-temperature gases and residues generated from the burning of the propellant, by chemical action, and by friction between the projectile and the bore. This enlargement of the bore allows the propelling gases to escape as the projectile moves through the tube, thereby reducing gas pressure, muzzle velocity (speed of the projectile when it leaves the tube), and range. Erosion is usually greatest at the start of rifling, allowing the projectile to be rammed further forward. This circumstance causes an increase in chamber volume and a corresponding decrease in gas pressure, resulting in decreased muzzle velocity. Tube erosion is more

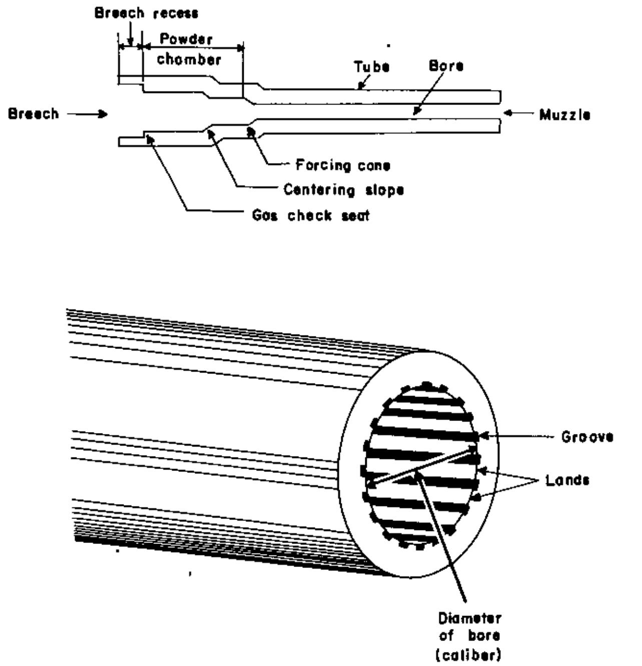


Figure 9. Interior components of a tube.

rapid when firing higher charges than lower charges. Therefore, undue wear of the tube is reduced by firing the lowest charge consistent with the effect desired and the accuracy required. Cleanliness of the tube and ammunition will reduce erosive and abrasive wear (fig. 9).

b. Ramming. Separate-loading ammunition requires hard, uniform ramming. Unless the round-to-round ramming is hard and uniform, the chamber volume will vary due to the nonuniform seating of the projectile, resulting in nonuniform muzzle velocities and range inaccuracies.

c. Rotating Band. The rotating band must be smooth and free of burrs and scars to permit proper seating of the projectile. If the projectile is improperly seated, gas will escape, muzzle velocity will decrease, and shearing and gouging of lands may result.

d. Propelling Charge. Differences in propelling charge temperature and moisture content will cause variations in rates of burning with resultant variations in muzzle velocity. Variations in the position of the charges in the powder chamber change the speed of burning with a resultant variation in muzzle velocity.

e. Coppering. Firing with higher charges will cause the rotating bands to deposit metal on the lands within the tube (coppering). This condition causes a variation in muzzle velocity. With howitzers, excessive coppering can be removed, for all practical purposes, by firing several rounds with minimum charge. Excessive coppering in high velocity weapons (guns) should be referred to ordnance for removal.

f. Weight of Projectile. Projectiles of the same caliber may vary in weight. A heavier-than-standard projectile, *all other conditions remaining unchanged,* will leave the muzzle with a lower velocity than a projectile of standard weight.

g. Manufacturers' Tolerances. Slight variations from standard in the manufacture of the tube, propellant lots, and primer lots will cause minor variations in the muzzle velocity.

h. Oily Tube. Before firing, oil must be removed from the tube of a weapon. Oil in a tube will cause abnormal variations in muzzle velocity. Projectiles should not be oiled for the same reason. A detailed explanation of the effects of an oily tube, velocity trends, and related matters is covered in chapter 25.

15. Exterior Ballistics

Exterior ballistics is the science which deals with the factors affecting the motion of projectiles after they leave the muzzle of the piece. Certain factors influencing the motion of projectiles after they have left the tube are—

a. Drift. To keep a projectile (other than one which is fin-stabilized) from tumbling during flight, it is given a rotating motion (spin) around its longitudinal axis by the rifling (lands and grooves) of the tube. In United States artillery, this spin is always to the right. The action of air resistance, rotation and gravity causes the projectile to deviate to the right from the plane of fire. This deviation is termed "drift" (fig. 10).

b. Weight of Projectile. At the same muzzle velocity, a heavier projectile tends to travel farther because it is affected less by air resistance than a lighter projectile of the same size and shape.

c. Air Density. An increase in air density causes greater resistance to the movement of the projectile and, therefore, decreases the range.

d. Air Temperature. A variation in air temperature causes a variation in range. As the air temperature increases, the range of the projectile may increase or decrease, depending on the velocity.

e. Wind. Wind will modify the normal trajectory of a projectile. For example, a headwind decreases the range; wind from the right moves the projectile to the left; and the effect of an oblique wind is divided into components parallel to, and perpendicular to, the direction of fire.

f. Muzzle Velocity. A variation in muzzle velocity causes a variation in range (fig. 11).

g. Rotation of Earth. Although the rotation of the earth is a natural phenomenon, it is treated as a nonstandard condition. This is done for simplicity in the construction of firing tables. Magnitude and direction of projectile displacement from the target owing to rotational effect are derived from azimuth of fire, time of flight, projectile velocity, and relative position of piece and target with respect to the Equator. Firing tables have combined these effects into convenient tabular form.

h. Shell Surface Finish. A rough surface on the projectile or fuze will increase air resistance, thereby decreasing range.

i. Ballistic Coefficient. The ballistic coefficient of a particular projectile is the measure of the ability of that projectile to overcome air resistance. Ballistic coefficient varies, dependent on the differences in form, shell finish, diameter, and mass of different projectiles.

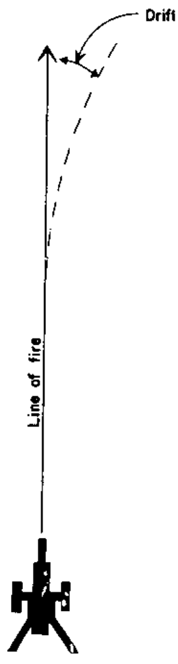


Figure 10. Drift of a projectile.

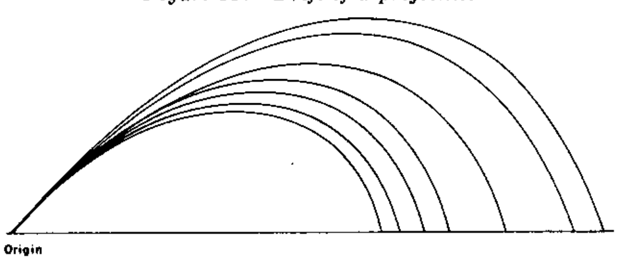


Figure 11. Variable muzzle [illegible]ity, constant elevation.

j. Ballistic Coefficient Change. The ballistic coefficient change is essentially the difference in efficiency between any given projectile lot and the specific projectile lot used for construction of the firing tables.

k. Drag. Air resistance affects the flight of the projectile both in range and deflection as compared to the hypothetical flight of the projectile in a vacuum. That component of air resistance which resists the forward motion (range) of the projectile is called drag.

16. Corrections

In paragraphs 14 and 15, certain factors were discussed which affect the motion of a projectile. Some of these factors differ from day to day, hour to hour, and lot to lot. When the variance of these factors can be determined, corrections are applied to compensate for the variations.

a. Standard Conditions. In practice, certain conditions are assumed and accepted as standard. The values assigned to these standard conditions for *weather* and *materiel* may be found in the current firing tables. Weather includes air temperature, air density, and wind. Materiel includes muzzle velocity and weight of projectile.

b. Nonstandard Conditions. Actually, all the standard conditions for which the firing tables were constructed never exist at any one time. Therefore, the difference between the nonstandard condition and a standard condition must be determined and a compensating correction applied. In the following conditions, the firing tables provide the factors to be used in determining corrections for differences:

(1) Drift.
(2) Powder temperature.
(3) Weight of projectile.
(4) Air density.
(5) Air temperature.
(6) Differences in muzzle velocity.
(7) Horizontal wind.
(8) Nonrigidity of the trajectory.
(9) Effects of rotation of the earth (some weapons).
(10) Amount of jump.
(11) Amount of variation in barrel curvature (some weapons).

Note. Corrections for other conditions, such as manufacturers' tolerances and wear of the tube, must be determined by test firing (calibration, ch. 28).

Section III. TRAJECTORY

17. General

The trajectory is the curve traced by the center of gravity of the projectile in its flight from the muzzle of the weapon to the point of impact or burst.

18. Elements of the Trajectory

The elements of a trajectory are classified into three groups: first, those which are characteristic of a trajectory by its very nature are *intrinsic elements;* second, those which are characteristic at the origin are *initial elements;* and third, those which are characteristic at the point of impact (point of burst) are *terminal elements.*

19. Intrinsic Elements

(fig. 12)

a. Origin. The origin of the trajectory is the position of the center of gravity of the projectile at the time it leaves the muzzle of the piece. However, in order to simplify other related definitions herein, the term "origin" may also be used to indicate the center of the muzzle when the piece is laid.

b. Ascending Branch. The ascending branch is that portion of the trajectory traced while the projectile is rising from the origin.

c. Descending Branch. The descending branch is that portion of the trajectory traced while the projectile is falling.

d. Summit. The summit is the highest point on the trajectory. It is the end of the ascending branch and the beginning of the descending branch of the trajectory.

e. Maximum Ordinate. The maximum ordinate is the difference in altitude between the origin and the summit. Firing tables express maximum ordinates at convenient intervals of range.

f. Level Point. The level point is the point on the descending branch of the trajectory which is at the same altitude as the origin.

g. Base of Trajectory. The base of the trajectory is the straight line from the origin to the level point.

20. Initial Elements

(fig. 13)

a. Line of Elevation. The line of elevation is the axis of the tube prolonged when the piece is laid.

b. Jump. Angle of jump, or jump, is the angular displacement of the projectile from the line of elevation and direction at the time the projectile leaves the tube. Jump is caused by the shock of firing during the interval from the ignition of the powder charge to the exit of the projectile from the piece.

c. Line of Site. The line of site is the straight line joining the origin and a point, usually the target.

d. Line of Departure. The line of departure is 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.

e. Angle of Departure. The angle of departure is the vertical angle, at the origin, between the line of site and the line of departure.

f. Angle of Elevation. Angle of elevation is the vertical angle at the origin between the line of site and the line of elevation.

g. Angle of Site. The angle of site is the vertical angle formed by the line of site and the base of the trajectory. The angle of site is plus when the line of site is above the base of the trajectory and minus when the line of site is below the base of the trajectory.

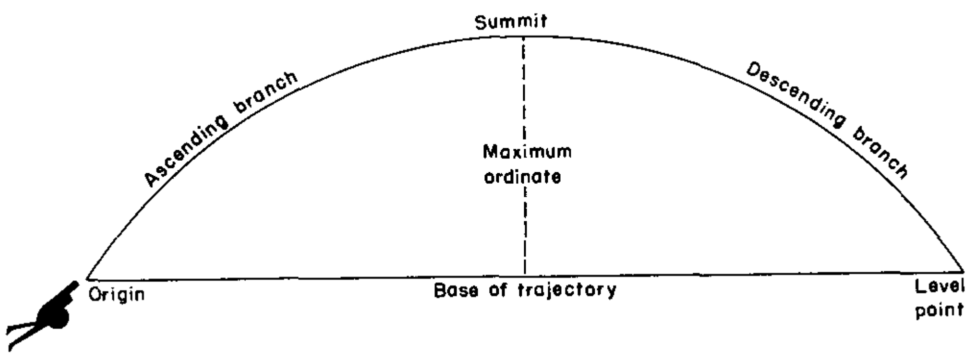


Figure 12. Intrinsic elements of a trajectory.

h. Complementary Angle of Site (Comp Site). Complementary angle of site is a correction applied to correct for the nonrigidity of the trajectory. In theory the trajectory may be rotated up or down through small vertical angles about the origin without materially affecting its shape. When large angles of site are used, this assumption will cause significant errors to be introduced.

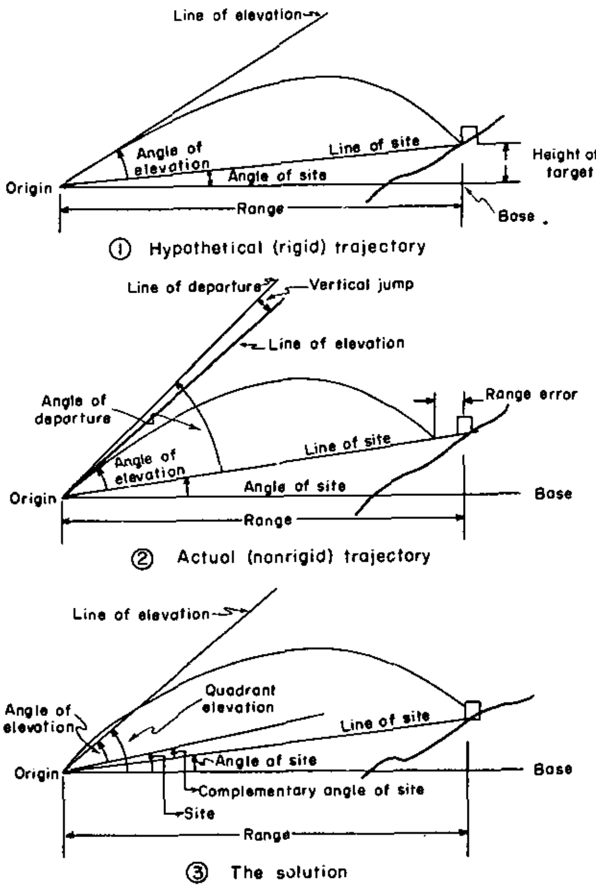


Figure 13. The initial elements.

Therefore, in carefully prepared firing data, corrections should be determined from the complementary angle of site tables listed in the firing tables.

i. Site. The term "site" as used in artillery denotes the sum of the angle of site and the complementary angle of site.

j. Quadrant Elevation (QE). The quadrant elevation is the vertical angle at the origin formed by the line of elevation and the base of the trajectory. It is the algebraic sum of the angle of elevation, the angle of site, and the complementary angle of site.

21. Terminal Elements

(fig. 14)

a. Point of Impact. The point of impact is the point where the projectile first strikes in the target area. (The point of burst is an extension of this definition to air bursts.)

b. Line of Fall. The line of fall is the line tangent to the trajectory at the level point.

c. Angle of Fall. The angle of fall is the vertical angle, at the level point, between the line of fall and the base of the trajectory.

d. Slope of Fall. Slope of fall is the tangent of the angle of fall. It is expressed as a ratio 1 : a (1 is the vertical distance and a is the horizontal distance; e. g., 1 over 9).

e. Line of Impact. Line of impact is a line tangent to the trajectory at the point of impact.

f. Angle of Impact. Angle of impact is the acute angle, at the point of impact, between the line of impact and a plane tangent to the surface at the point of impact. This term should not be confused with the term "angle of fall."

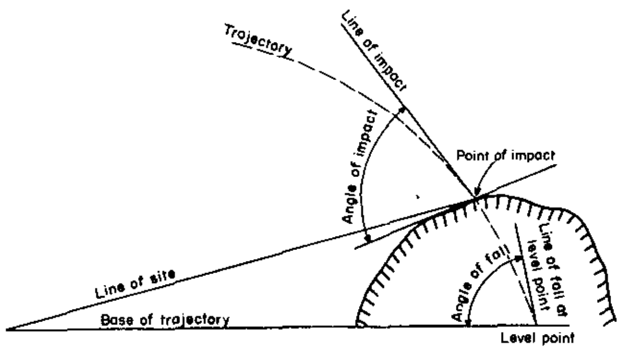


Figure 14. Terminal elements of the trajectory.

22. Form of Trajectory

a. In a vacuum, the form of the trajectory would be determined entirely by the elevation of the tube, the muzzle velocity, and gravity. The form would be parabolic with the angle of fall equal to 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 from the instant it leaves the piece. This makes the trajectory (fig. 15) 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 is greatly reduced. 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 on 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.

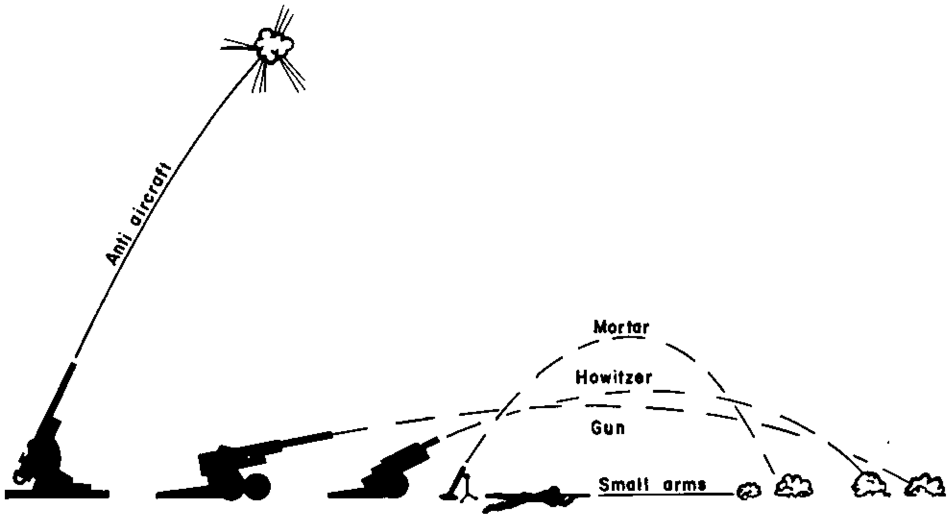


Figure 15. Typical trajectories in air.

Section IV. PROBABILITY AND DISPERSION

23. General

a. Probability is the ratio of chances favoring an event to the total number of chances for and against the event; that is, the number of times the event can occur divided by the number of times it can and cannot occur. After phenomena are observed over a period of time, a pattern becomes apparent. By tabulating the data, certain aspects of the pattern become evident.

(1) A relatively high percentage is grouped about the mean.

(2) A curve describing the pattern is similar for practically all phenomena.

(3) The curve can be described by a formula.

b. Dispersion is the scattering of points of impact when several rounds of the same propellant and projectile lot are fired from a piece under conditions as nearly identical as possible. The points of impact of the projectiles will be scattered both laterally (deflection) and in depth (range). Dispersion is caused by inherent errors and must not be confused with variations in point of impact caused by mistakes or constant errors. Dispersion is the result of minor variations of many elements from round to round. Mistakes and constant errors can be eliminated or compensated for. Those inherent errors which are beyond control and cause dispersion are caused in part by—

(1) *Conditions in the bore.* Muzzle velocity is affected by minor variations in weight, moisture content, and temperature of propelling charge; variation in arrangement of powder grains; difference in ignition of the charge; differences in the weight of the projectile and in the form of the rotating band; variations in ramming; and variations in the temperature in the bore from round to round. Variations in the bourrelet and rotating band may cause inaccurate centering of the projectile; hence, inaccurate flight.

(2) *Conditions in the carriage.* Direction and elevation are affected by play (looseness) in the mechanisms of the carriage, physical limitations on precision in setting scales, and nonuniform reaction to firing stresses.

(3) *Conditions during flight.* Air resistance is affected by differences in weight, velocity, and form of projectile and by changes in wind, density, and temperature of the air from round to round.

c. Dispersion zone is the area over which the points of impact are scattered, owing to inherent errors. The center of the dispersion zone is called the *center of impact.* Either dimension, length or

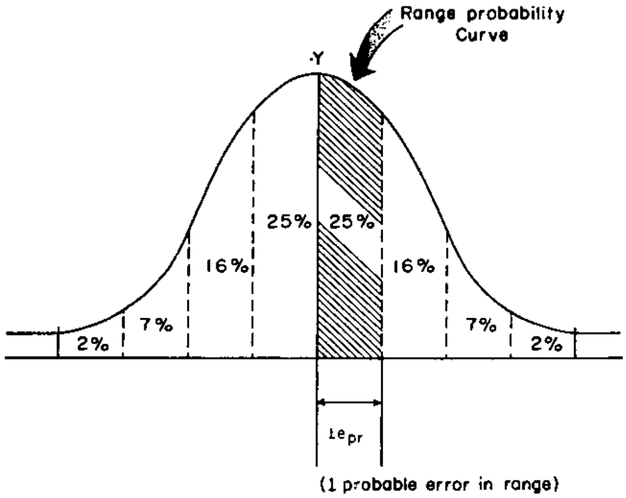


Figure 16. Areas under the normal probability curve.

width, of the zone can be described by the normal probability curve.

24. Normal Probability Curve

a. A normal probability curve is a curve that represents the probability of the occurrence of an error of any given magnitude in a series of samples.

b. Distances of points on the horizontal (base) line (fig. 16), measured to the right and left of the center, represent errors in excess and in deficiency, respectively. The area of the figure vertically above any portion of the base line represents the probability of the occurrence of any error within that portion. The curve expresses the following facts:

(1) Errors in excess and in deficiency are equally frequent and probable in a large number of samples, as shown by the symmetry of the curve.

(2) In every kind of sample, there is a limit which the greatest random errors do not exceed, as shown by the curve's approaching the horizontal line at the sides.

(3) The errors are not uniformly distributed, but the smaller errors occur more frequently than the larger, as shown by the greater height of the curve in the middle, close to the vertical axis.

25. Dispersion Rectangles

a. When numerous rounds are fired with the same piece settings, the points of impact form a pattern which is roughly elliptical, with its longer axis lying along the line of fire (except in the case of the 4.5-in. rocket). The smallest rectangle that can be constructed to include these points of impact (excluding any erratic rounds) is called a 100-percent rectangle (fig. 17). 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 18. This percentage of points of impact is the same as found under the normal probability curve. This divided rectangle is called a *range dispersion ladder.* Likewise, if this ladder is divided similarly by lines parallel to the direction of fire, the percentages will again be the same as found under the normal probability curve as indicated in figure 19. This divided rectangle is called a *deflection dispersion ladder.* Each division of these dispersion ladders is called *one probable error.* A probable error is an error in range (deflection, height of burst) that a weapon may be expected to exceed as often as not.

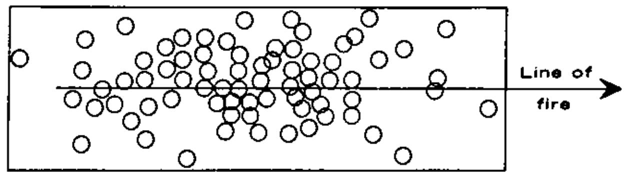


Figure 17. The 100-percent rectangle.

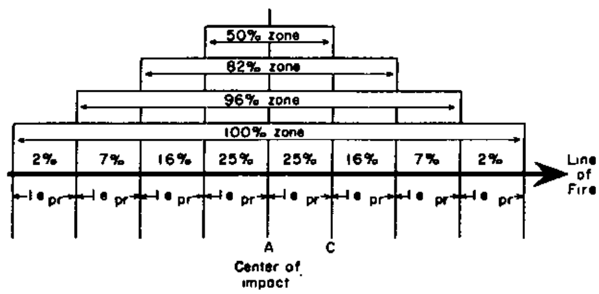


Figure 18. Range dispersion ladder.

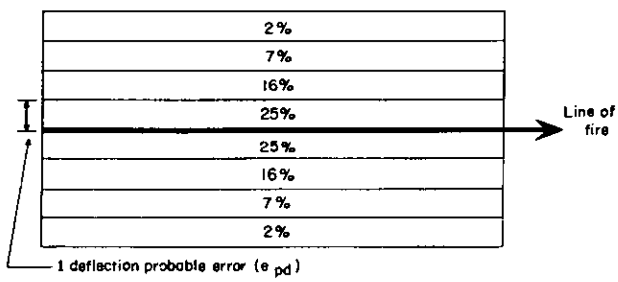


Figure 19. Deflection dispersion ladder.

b. If the range and deflection dispersion ladders are superimposed, the result is the assemblage of small rectangles shown in figure 20. This result is called the *dispersion rectangle.* The percentage of points of impact occurring in any particular small rectangle is the product of the percentages in the two strips, range and deflection (figs. 18 and 19), whose intersection forms the small rectangle. The application of the dispersion rectangle is covered in chapters 23 and 27.

	.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

Line of fire

Figure 20. Dispersion rectangle.

26. Range Probable Error (e_{pr})

a. The range probable error is the error in range that a weapon may be expected to exceed as often as not. In figure 18, the line A through the center of impact (CI) is perpendicular to the line of fire. The distance between A and C contains as many points of impact as there are beyond C; that is, 25 percent of the points of impact fall within the distance A–C and 25 percent beyond C. The distance (AC) is *one range probable error*. The value of the range probable error for a given charge for a gun, howitzer, or mortar varies with the range. The approximate value of the range probable error is found in the firing tables and can be taken as an index of the precision of the piece. Firing table values for probable errors were based on the firing of carefully selected ammunition under controlled conditions. The actual probable errors experienced in the field will vary from the firing table value and may be as large as twice those listed in the firing tables.

b. From a study of the range dispersion ladder, it will be noted that, for any given range, 50 percent of the projectiles fired will fall beyond and 50 percent will fall short of the center of impact. Fifty percent of the projectiles fall within the 50-percent zone. Further, 50 percent of these projectiles fall within a zone which includes 1 range probable error beyond and 1 range probable error short of the center of impact; 82 percent fall within 2 range probable errors beyond and 2 range probable errors short; 96 percent fall within 3 range probable errors beyond and 3 range probable errors short; and 100 percent fall within 4 range probable errors beyond and 4 range probable errors short. Actually, a small number of projectiles (about 7 in 1,000) fall outside the 100-percent rectangle, but, for convenience of computation, these are counted within the 2-percent zone. For example, in firing a 105-mm howitzer, charge 5, at a range of 5,000 yards, from the tabular firing tables it is determined that 1 range probable error is 20 yards. In other words, 50 percent of the projectiles fired will hit within 20 yards of the center of impact and 96 percent will hit within 60 yards. For practical purposes, it is assumed that all of the projectiles will fall within four probable errors of the center of impact.

27. Fork

Fork is the term used to express the *change in elevation in mils necessary to move the center of impact four range probable errors*. The value of the fork is given in the firing tables. For example, in firing a 105-mm howitzer, charge 5, at a range of 5,000 yards, from the tabular firing tables it is determined that the fork is 6 mils or, converted to yards, 80 yards.

28. Deflection Probable Errors (e_{pd})

In the deflection dispersion ladder (fig. 19), the points of impact to the right and left of the line of fire follow the principles of distribution given in paragraph 26. For practical purposes, the deflection probable error is taken as one-eighth the width of the deflection dispersion ladder. The value of the deflection probable error is given in the firing tables. For example, in firing a 105-mm howitzer, charge 5, at a range of 5,000 yards, from the firing tables it is determined that the deflection probable error is 3 yards. In other words, 50 percent of the projectiles fired will hit within 3 yards of the center of impact, 82 percent will hit within 6 yards, and 96 percent will hit within 9 yards.

29. Circular Probable Error (CPE)

A circular probable error is the radial error that a weapon may be expected to exceed as often as not. The term "circular probable error" is normally used in the high level bombing and guided missile fields. When several missiles (bombs) are fired (released) under conditions as nearly identical as possible, the points of impact form a pattern

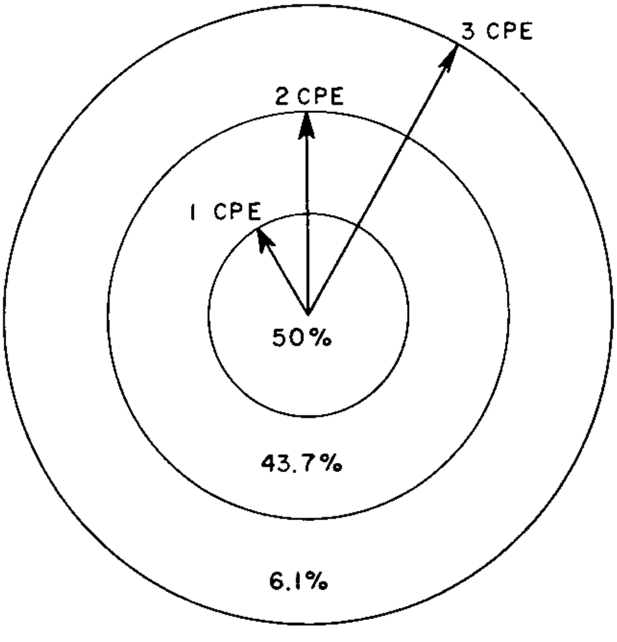


Figure 21. Circular probable error.

called a normal circular distribution. The radius of the smallest circle that can be constructed to include 50 percent of these points of impact is 1 circular probable error. The center of the circle is the center of impact (fig. 21).

30. Vertical Probable Error (e_{pr})

a. Firing at a vertical plane, for example, a wall, results in a vertical dispersion pattern which is directly related to a corresponding range dispersion pattern (fig. 22). The vertical probable error is the vertical expression of a range probable error at a given angle of fall.

b. Sometimes it is desirable to convert the height of a target into an expression of horizontal range as shown in figure 23. This is helpful, for example, in firing at the vertical surface of a target. Rounds which miss the target in deflection but may be correct for range (elevation) will appear to have been fired with too great an elevation because they will land beyond the target. A knowledge of the

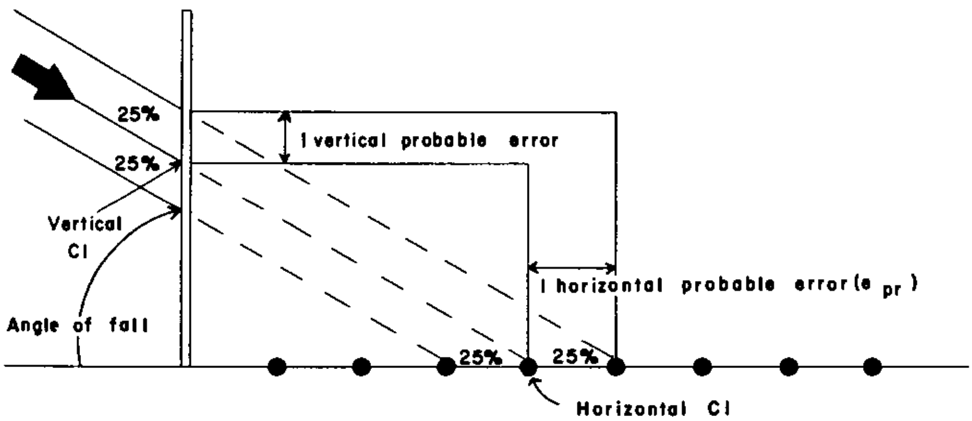


Figure 22. Relation of vertical probable error to horizontal (range) probable error.

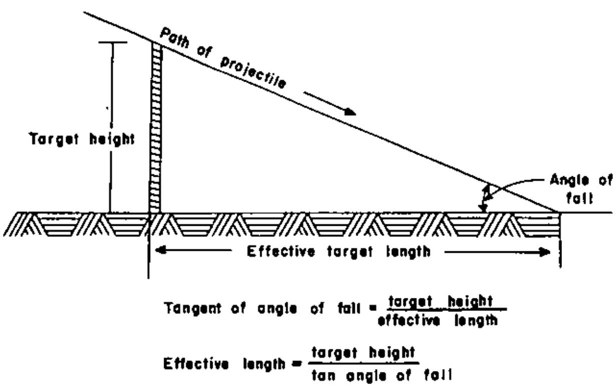
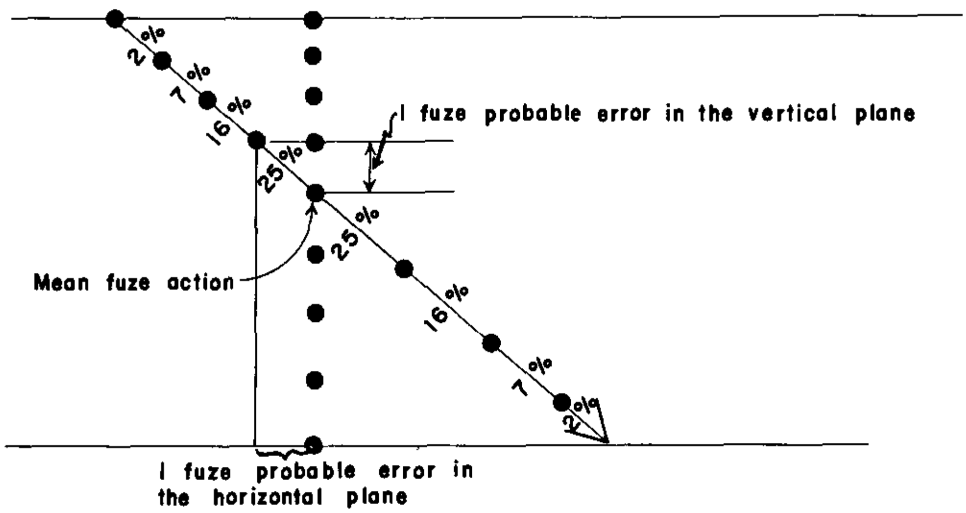


Figure 23. Target height converted to range.

magnitude of the horizontal range equivalent to the height of a target will facilitate adjustment.

31. Height of Burst Probable Error (e_{ph})

With shell fuzed to burst in the air, vertical and horizontal dispersion is increased due to the variations in the time of functioning of the fuze (fig. 24). Thus, the height of burst probable error reflects the combined effects of dispersion caused by variations in the functioning of fuzes (fig. 24) and of dispersion due to the factors discussed in paragraph 23. Height of burst dispersion follows the same laws of distribution that were discussed under range dispersion. For practical purposes, the height of burst probable error is taken as one-eighth the height of the total pattern. Values of the height of burst probable error for a particular time fuze are given in the firing tables. Height of burst probable error for the variable time (VT) fuze cannot be predicted because the height of burst for this particular fuze is dependent on the angle of fall of the projectile and the type of terrain over which the projectile is falling. By observing and analyzing results obtained from firing on a given terrain, the height of burst probable error can be estimated.



Note. Height of burst probable error is a combination of the vertical probable error related to range probable error (fig 22) and the vertical probable error related to fuze probable error (fig 24).

Figure 24. Relation of fuze probable error to height of burst probable error.

CHAPTER 3

CHARACTERISTICS AND CAPABILITIES OF FIELD ARTILLERY WEAPONS AND AMMUNITION

Section I. FIELD ARTILLERY WEAPONS

32. General

a. Field artillery weapons in the United States Army include towed guns and howitzers, self-propelled guns and howitzers, pack howitzers, mortars, free rockets, and guided missiles. The weapons are classified according to caliber and weight as light, medium, heavy, or very heavy. Self-propelled versions are given the same classifications as their towed counterparts.

(1) Light artillery is under 115-mm caliber, which, in the trailed mount, normally does not exceed 7,000 pounds in weight.

(2) Medium artillery is 115-mm caliber or larger, which, in the trailed mount, normally is greater than 7,000 but does not exceed approximately 18,000 pounds in weight.

(3) Heavy artillery is 155-mm caliber and larger, which, in the trailed mount, normally is greater than 18,000 but does not exceed approximately 50,000 pounds in weight.

(4) Very heavy artillery is larger than 200-mm caliber, which, in a trailed mount, normally weighs more than 50,000 pounds.

b. Field artillery weapons are also classified according to their organic transport as towed, self-propelled, or pack.

c. Rockets are classified as either free rockets or guided missiles. The surface-to-surface free rockets or guided missiles are classified as field artillery free rockets or guided missiles.

33. Characteristics and Capabilities

Some of the characteristics and capabilities of field artillery weapons and other weapons employed in the field artillery role are listed in table II. More technical details may be found in references listed in the table. Additional information on antiaircraft and tank weapons is covered in appendixes V and VI.

Section II. AMMUNITION

34. General

a. Complete Round. A complete round of artillery ammunition is a projectile with all of the components necessary to propel it from the weapon and burst it at the desired time and place. These components are the primer (ignition cartridge), propelling charge, projectile, and fuze. Dependent on the manner in which these components are assembled for firing, complete rounds of field artillery ammunition are known as fixed, semifixed, or separate-loading (fig. 25). Some antiaircraft rounds are referred to as separated. See TM 9–1901 for details on artillery ammunition. Rocket ammunition information is published in TM 9–1950.

b. Primer. Primers are used to ignite the propelling charge. They vary in size and complexity, depending on the type and the quantity of propelling charge to be ignited. Percussion primers are ignited by a sharp blow with a firing pin. In fixed or semifixed ammunition, they are placed in the cartridge case. For weapons employing separate-loading ammunition, they are placed in the breechblock. Electric primers, used only in the breechblock of the weapon, are ignited by sending a small electric current through a resist-

Table II. Characteristics and Capabilities of Artillery Weapons

FIELD ARTILLERY WEAPONS

Classification as to caliber and weight	Caliber, type, and carriage model	Tube assembly model No.	Weight in travel position (pounds)	Time to emplace (minutes)	Elevation (mils) Min	Elevation (mils) Max	Traverse (mils) Left	Traverse (mils) Right	Recoil (inches) Min	Recoil (inches) Max	Range Max (yards)	Rate of fire—max (rd/min)	Principal references SNL	Principal references FM	Principal references TM
Light artillery	75-mm how M1A1, carriage M8 (pack).	M1A1	1,440	3	−89	+800	53L	53R	25	32	9,620	6	C-20	6-110	9-319
	105-mm how M2A2, carriage M2A2.	M2A2	4,980	3	−89	+1156	400L	409R	39	44	12,330	4	C-21	6-75	9-325 9-3007
	105-mm how M4, motor carriage M37.	M4	46,000	1	−178	+750	486L	442R	12⅞	14	12,330	4	C-63 G-238	6-76	9-324 9-717
	105-mm how T96E1 motor carriage M52.	T96E1	54,100	1	−89	+1156	1066L	1066R	12	13½	12,330	4	C-86 G-258	6-77	9-324A 9-717A
	4.2-inch mortar M30, mount M24.	M30	654	1-3	+706	+1156	125L	125R	0		6,000	15-20	A-85	23-92 6-50	9-2008 9-2009
	4.5-inch multiple, rocket launcher M21.	M21	1,530	5	0	+1333	57L	64R	0		9,000	25	C-90	6-55	9-3036
Medium artillery	155-mm how M1 or M1A1, carriage M1A2.	M1 or M1A1.	M1—12,700 M1A1—12,950	5	0	+1156	418L	448R	41	60	16,355	3	C-39	6-81	9-331A
	155-mm how M1, motor carriage M41.	M1	42,500	1	−89	+800	302L	365R	41	60	16,355	3	C-39 G-236	6-82	9-331B 9-744
	155-mm how M45, motor carriage M44.	M45	42,500	1	−89	+1156	533L	533R	19¼	19⅜	16,355	3	D-63 G-279	6-92	9-7004
Heavy artillery	155-mm gun M2, carriage M1.	M2	30.100	½ to 6 hours	−36	+1156	533L	533R	29	70	25,715	2	D-24	6-90	9-350
	155-mm gun M2, motor carriage M40.	M2	81,000	1	−89	+800	320L	320R	29	70	25,715	2	D-24 G-232	6-87	9-350 9-747
	155-mm gun T80, motor carriage M53.	T80	96,000	1	−89	+1156	534L	534R	18	20	25,715	2	D-49 G-259		9-7212
	8-inch how M2, carriage M1	M2	32,000	½ to 6 hours	−36	+1156	533L	533R	29	70	18,510	1	D-29	6-90	9-3004
	8-inch how M2, motor carriage M43.	M2	80,000	1	−89	+800	320L	320R	29	70	18,510	1½	D-29 G-232	6-87	9-3004 9-747
	8-inch how T89, motor carriage M55.	T89	96,000	1	−89	+1156	533L	533R	18	20	18,510	1½	D-49 G-259		9-7220
Very heavy artillery	8-inch gun M1, carriage M2	M1	G—52,620 C—51,100	1 to 6	+178	+890	356L	356R	50		35,490	1	D-33	6-95	9-336
	240-mm how M1, carriage M1	M1	H—47,720 C—51,100	1 to 6	+267	+1156	400L	400R	60		25,255	1	D-31	6-95	9-341
	280-mm gun T131, carriage T72.	T131	166,638	12	0	+978	6400 267 fine		Secondary 40	95	31,200	½	D-57	6-96	9-338-1
									Primary 32	42					

ANTIAIRCRAFT ARTILLERY WEAPONS USED IN THE SURFACE ROLE

Classification as to caliber and weight	Caliber, type, and carriage model	Tube assembly model No.	Weight in travel position (pounds)	Time to emplace (minutes)	Elevation (mils) Min	Elevation (mils) Max	Traverse (mils)	Recoil (inches) Min	Recoil (inches) Max	Range Max (yards)		Rate of fire—max (rd/min)	SNL	FM	TM
Light	40-mm gun M2 (twin), carriage M42.	M2	48,500	1	−89	+1547	6400	7.4	8.3	Mk 11	H 5,200 V 5,100	120 per bbl	G-253	44-61	9-761A
										M3A1	H 5,700 V 5,400				
	75-mm gun T83E7, mount T69.	T83E7	19,200	3-5	−106	+1511	6400	24	32		15,000 Time fire 13,000	45-55	D-48	44-69	9-361
Medium	90-mm gun M2A1, AA mount M2.	M2A1	32,300	(On-carriage fire control equipment) 5.	−178	+1420	6400	26	44	Hor	19,560 TF 13,100	28	D-38	44-27	9-372
										Ver	13,426 TF 11,800				
Heavy	120-mm gun M1, AA mount M1A1.	M1	61,500	(On-carriage fire control equipment) 40.	−89	+1420	6400	33	36	Hor	27,160 TF 15,900	10-16	D-32	44-28	9-380
										Ver	19,150 TF 15,500				

TANK WEAPONS USED IN THE FIELD ARTILLERY ROLE

Classification as to caliber and weight	Caliber, type, and carriage model	Tube assembly model No.	Weight in travel position (pounds)	Time to emplace (minutes)	Elevation (mils) Min	Elevation (mils) Max	Traverse (mils)	Recoil (inches) Min	Recoil (inches) Max	Range Max (yards)	Rate of fire—max (rd/min)	SNL	FM	TM
Light gun tank	Tank, 76-mm Gun, M41A1	M32	52,000	1	−173	+351	6400	9	12	15,680	4	C-82	17-12 17-80	9-730 9-308A
Medium gun tank	Tank, 90-mm Gun, M47	M36	98,000	1	−173	+351	6400	12	14	13,967	4	D-52	17-12 17-78	9-718A
Medium gun tank	Tank, 90-mm Gun, M48	M41	99,000	1	−173	+351	6400	12	14	13,967	4	D-58	17-12 17-79	9-7012

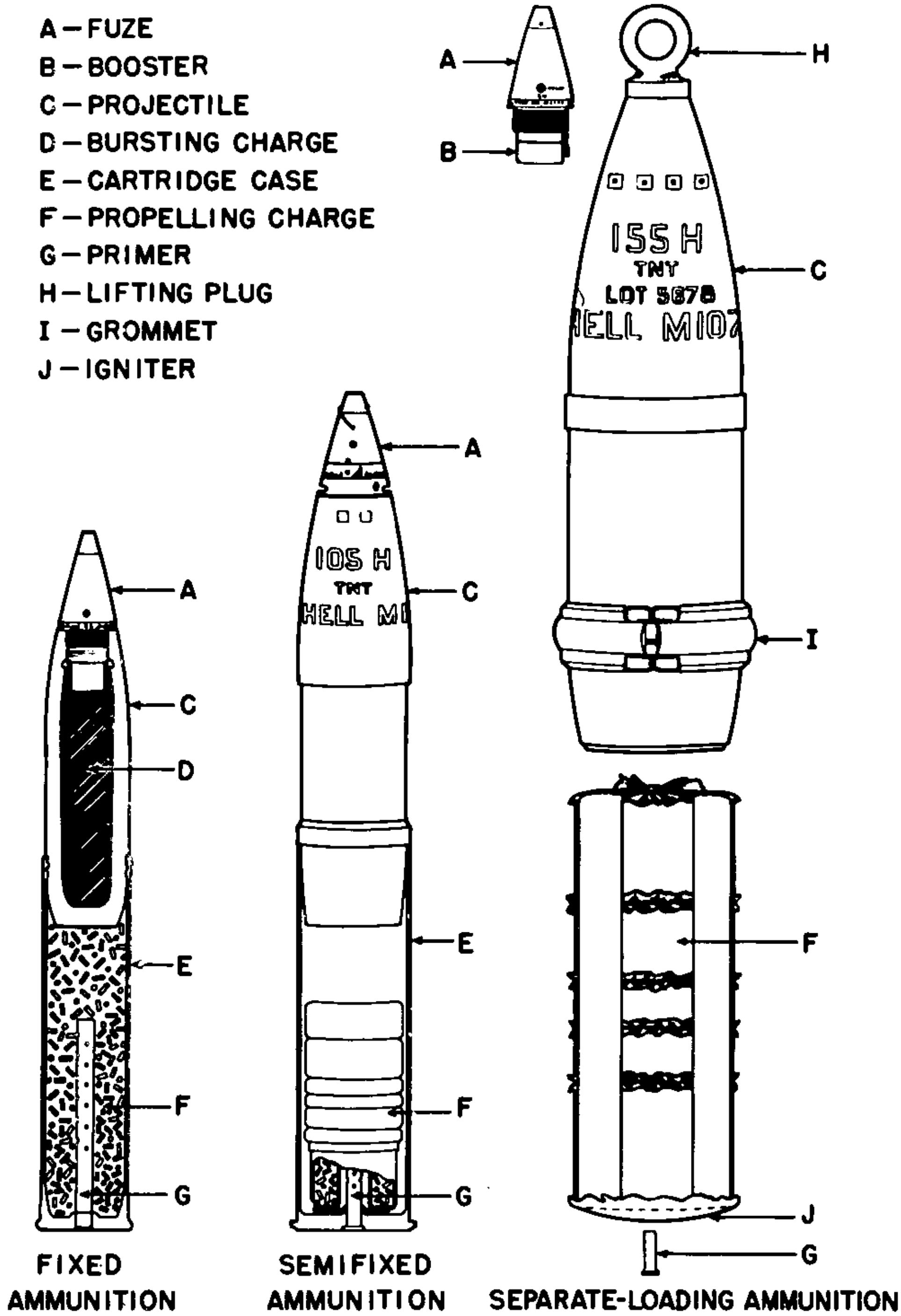


Figure 25. Types of complete rounds of artillery ammunition.

ance wire embedded in an explosive. If sufficient black powder cannot be loaded into the primer body to insure proper ignition, a separate bag of black powder, called an igniter charge assembly, is placed with the propellant.

c. Propelling Charge. A propelling charge is a low-order explosive which burns rather than detonates. The burning propellant in a closed chamber generates tremendous pressure, furnishing the energy to propel the projectile.

(1) *Increments.* Propelling charges are packaged in cloth bag increments (semifixed or separate-loading ammunition), loose in shell cases (fixed ammunition), or, in

the case of the 4.2-inch mortar, in sheet-like bundles attached to a cartridge container. Greater flexibility in projectile range and angle of fall is provided by varying the muzzle velocity through varying the number of increments to be fired.

(2) *Positioning propelling charge.* In fixed and semifixed ammunition, the propellant has a relatively fixed position with respect to the chamber. In the case of separate-loading propellants, the farther forward in the chamber the propellant is placed, the slower the rate of burning, the lower and more erratic is the subsequent velocity. In order to provide uniform positioning and to insure uniform propellant performance, the base of the powder bag should be flush against the mushroom head at the instant of firing.

(3) *Tie straps and wrappings.* Loose tie straps or wrappings have the effect of allowing an increase in bag diameter from the original. A change in bag diameter will change the time of burning for a given propellant and may result in erratic velocity.

d. Projectile. A projectile is a missile for discharge from a cannon (mortar, launcher). Some types of projectiles are listed in table III. Although differing in characteristic details, projectiles are of the same general shape in that they have a cylindrical body and an ogival head. The principal characteristic differences in projectiles are in—

(1) Fuzing—point or base.
(2) Radius of ogive—smaller for low velocity projectiles, larger for high velocity projectiles.
(3) Rotating band—narrow for low velocity projectiles, wide for high velocity projectiles (free rockets fired from smoothbore launchers are fin-stabilized and have no rotating bands).
(4) Base tapering (boattailed)—for improved ballistics or cylindrical (square base).
(5) Armor-piercing cap—only for certain armor-piercing projectiles.
(6) Windshield, ballistic cap, or false ogive—when required for improved ballistics.

e. Fuzes. A fuze is a device used to set off an explosive in the projectile at the time and under the circumstances desired. Artillery fuzes are classified according to their location on the projectiles as base or point detonating (det) and according to the method of functioning as impact, time, or variable time (VT) or as a combination of these.

(1) Impact fuzes are classified as superquick, nondelay, or delay.
(2) Time fuzes contain a graduated time element in the form of a compressed black powder train or a mechanical clockwork mechanism which may be set to a predetermined time. In addition, time fuzes may contain an impact element.
(3) VT fuzes contain self-powered radio transmitting and receiving units which cause the projectile to burst on approach to the target or any reflecting object. In addition, VT fuzes used by field artillery contain certain impact elements and mechanical time elements.

f. Lot Number. Each component of ammunition is assigned a lot number, and, in addition, each complete round of fixed or semifixed ammunition is assigned an ammunition lot number. To provide for the most uniform functioning, all of the components in any one lot are manufactured under as nearly identical conditions as practicable. Complete rounds of any one lot are similarly manufactured and consist of components, each type of which is of one lot. Hence, to obtain accuracy when fixed or semifixed ammunition is fired, successive rounds must be of the same lot number; when separate-loading ammunition is fired, successive rounds must consist of projectiles of one lot number and propelling charges of one lot number. Segregation of ammunition by lot numbers is a mandatory requirement for accurate fires.

35. Types of Projectiles

a. General. The artillery projectile is painted primarily to prevent rust. Secondary purpose of painting is to provide, by color and marking, a ready means of identification. For example, the color schemes include olive drab for high explosive (HE), black for armor-piercing (AP), and gray for chemical shell. TM 9–1901 explains in detail the marking of artillery projectiles. Projectiles of all types must be kept clean and the rotating bands must be kept free of nicks or burrs if optimum accuracy is to be expected during firing. Projectiles should not be oiled.

Table III. Ammunition Chart

Weapon	Ammunition item	Item designation	Weight of projectile (pounds)	Weight of projectile per pound of bursting charge	Weight of complete round	How shipped	Fuzes: Point-det	Fuzes: Base-det	Fuzes: Time (powder)	Fuzes: Time (mech.)	Fuzes: VT	References TM 9-1900 and TM 9-1901 plus	Remarks
40-mm gun M2	High explosive	Cartridge, HE-T, SD, Mk 11, Mk 2.	1.985		4.58	Fuzed	Mk 27, M66A1					SM 9-5-1310, TM 9-761A	Range limited to 5,200 yards by Shell destroying element Mk 11.
		Cartridge, HE-T, SD, M3A1, Mk 2.					Mk 27, M66A1						Range limited to 5,700 yards by Shell destroying element M3A1.
	Armor-piercing shot	Cartridge, AP-T, M81A1	1.96		4.58	Complete							
75-mm gun T83	High explosive	Shell, HE, T50E2	12.21		22.24	Fuzed	*T177E3, *M51A5			T286E1 (M518) MTSQ		SM 9-5-1315, TM 9-361	Use for battle emergency only.*
75-mm howitzer, M1A1, M3.	High explosive, antitank	Shell, HEAT-T, M66	13.37	13. 37	16.26	Fuzed	M91					SM 9-5-1310, TM 9-319	
	High explosive	Shell, HE, M48	14.7	9. 86	18.24	Fuzed	M51A4, A5, CP, M78, M78A1.		M54, M55A3	M500A1	M97A1, T226 (M513)		Normal, deep, and deep w/supplemental charge cavities available.
	Smoke	Shell, smoke, WP, M64	14.7		18.89	Fuzed	M48A3, M57						
	Blank	Ammunition, blank			2.68 or 3.07	Complete							
	Drill	Cartridge, drill, M19	18.24		18.24	Complete							
		Cartridge, drill, M19B1	18.24		18.24	Complete							
76-mm Gun M41A1	High explosive	Shell, HE, T64	15.00		25.83	Complete						SM 9-5-1310, TM 9-730, TM 9-308A.	
	Smoke	WP 140	15.00		25.83	Complete	M48A3						
	Armor-piercing projectile	AP-T, T128	15.06		27.40	Complete							
	Armor-piercing shot	HVAP-DS-T, MVT 3,900.	8.12		20.07	Complete							
		HVAP-T, M319 (T166E3).	7.02		18.97	Complete							
	Practice	HVTP-T, M320 (T74E1).	6.94			Complete							
		TP-T, T64	15.00		25.83	Complete							

Table III. Ammunition Chart—Continued.

Weapon	Ammunition item	Item designation	Weight of projectile (pounds)	Weight of projectile per pound of bursting charge	Weight of complete round	How shipped	Fuzes: Point-det	Fuzes: Base-det	Fuzes: Time (powder)	Fuzes: Time (mech.)	Fuzes: VT	References TM 9-1900 and TM 9-1901 plus	Remarks
90-mm gun M1, M1A1, M1A2, M2, M2A1, M3, M3A1, M47, M48.	High explosive	Shell, HE, M71	23.40	11.81	41.93	Fuzed	M51A3, A4, A5, CP, M78, M78A1, T177E3.		M55A3	M43A3, A4, M500A1, M502A1, M67A3.	M97, M97A1, T226 (M513), T225 (M515).	SNL G-262, SNL G-254, TM 9-372, TM 9-718A, TM 9-7012.	Normal, deep, and deep w/supplemental charge cavities available.
		Shell, HE-T	18.05										
	High explosive marker	Shell, HE, marker, M71, red, T49, yellow, green.	Red 23.5. Green 23.5. Yellow 23.6.		42.03	Fuzed	M78, CP, M51A4, A5		M55A3	M500A1, M502A2, M43A3, A4, M67.			
	Armor-piercing projectile.	Projectile, APC-T, M82	24.11		43.87 (MV 2800). 42.75 (MV 2600).	Fuzed		M68					May be obtained with either flashless or smokeless propellant.
		Projectile AP-T, T33E4	24.21										
	Armor-piercing shot	Shot, APC-T, M77	23.40		44.98	Complete							Use of armor-piercing shot requires adjustment of recoil system owing to high muzzle velocity developed.
		Shot, HVAP-T, M304	16.80		37.13	Complete							
		Shot, HVAP-T, M332, M333.	12.40		32.44	Complete							Projectiles identical except for tracer element.
	Smoke	Shell, smoke, WP, M313	23.40		41.93	Fuzed	M48A2, A3, M57						
	Target practice	Shot, HVTP-T, M317A1	16.62		37.13	Complete							
		Shot, TP-T, T225	24.21		44.86	Complete							
	Blank	Ammunition, blank			8.23	Complete							
	Drill	Cartridge, drill, M12B2			42.04	Fuzed				M43A2 (inert)			
105-mm howitzer, M2A1, M2A2, M4, T96E1.	High explosive	Shell, HE, M1	33.00	6.82	42.0	Fuzed (will be unfuzed in the future).	M51A4, A5, CP, M78, M78A1.		M55A1, A2, A3	M500A1, M67A3	M97, M97A1, T226 (M513).	SM 9-5-1310	Normal, deep, and w/supplemental charge cavities available.
	High explosive, antitank.	Shell, HEAT-T, M67	29.29	10.00	37.06	Fuzed		M91					
	Smoke	Shell, smoke, HC, M84B1	32.86		42.72	Fuzed			M54	M501A1			
		Shell, smoke, WP, M60	33.00		44.20	Fuzed	M51A4, A5, M57						
	Colored smoke	Shell, smoke, M84B1	30.48		Red 40.55. Yellow 40.15. Green 40.35.	Fuzed			M54	M501A1			Violet also available for training only.
	Gas	Shell, gas, M60	33.00		43.27	Fuzed	M51A4, A5, M57						Cases loaded, H and HD.
	Chemical	Shell, chemical, M360					T237E1						All details classified.
	Illuminating	Shell, illuminating, M314A1.	36.55		46.43	Fuzed			M54	M501A1			Produces 600,000 cp for 60 seconds.
	Target practice	Shell, TP-T, M67	29.29		37.06	Complete							
	Blank	Ammunition, blank			5.74 (charge 1.5 lb). 6.24 (charge 2.0 lb).	Complete							
	Drill	Cartridge, drill, M14	42.06		42.06	Complete	M59 (inert)		M54 (inert)				

Table III. Ammunition Chart—Continued.

Weapon	Ammunition item	Item designation	Weight of projectile (pounds)	Weight of projectile per pound of bursting charge	Weight of complete round	How shipped	Fuzes: Point-det	Fuzes: Base-det	Fuzes: Time (powder)	Fuzes: Time (mech.)	Fuzes: VT	References TM 9-1900 and TM 9-1901 plus	Remarks
4.2-inch mortar M2, M30	High explosive	Shell, HE, M3	23.8	2.87	24.5	Fuzed	M9, M5					SM 9-5-1310, TM 9-2008	
		Shell, HE, M3A1	23.8	3.01	24.5	Fuzed	M51A5, M3						
		Shell, HE, M329	23.8	3.01	25.0	Fuzed	M51A5			M500A1	T226 (M513) T113E1		
	Smoke	Shell, smoke, WP, M2	24.8		25.5	Fuzed	M8						
		Shell, smoke, WP, M2A1	24.8		25.5	Fuzed	M8						
		Shell, smoke, PWP, M2	23.1		23.8	Fuzed	M8						
	Gas	Shell, gas, M2	CNB 22.8 CNS 24.3. CQ 23.55. H 23.0. HD 23.5. HT 22.6.		CNB 23.5 CNS 25.0. CQ 24.25. H 23.7. HD 24.2. HT 23.3.	Fuzed	M8						
		Shell, gas, M2A1	H 23.00 HD 23.5.		H 23.7 HD 24.2.	Fuzed	M8						
4.5-inch rocket launcher M21.	High explosive	Rocket, HE, M16A2	37.7	2.77	42.5	Unfuzed	M81, M81A1				M402	SM 9-5-1340, TM 9-3036	Deep cavity w/supplemental charge.
	High explosive	Rocket, HE, M32	37.7				M81, M81A1				M402		
	Practice	Rocket, practice, M17A2	37.7		42.5	Unfuzed	M73 (dummy)						
120-mm gun M1	High explosive	Shell, HE, M73	49.74	9.47	99.45	Fuzed	M507			M61, M61A1, M506	M96, M97, T226 (M513) T227 (M514) T75E6.	SM 9-5-1315, TM 9-380	Normal and deep w/supplemental charge cavities available.
	Dummy	Projectile, dummy, M15	49.53		99.24	Complete				M79 (inert)			
155-mm howitzer, M1, M1A1, T186E1.	High explosive	Shell, HE, M107	94.75	6.26			M51A4, A5, CP, M78, M78A1.		M55A3	M67A3, M500A1	M96, T227 (M514)	SM 9-5-1320, TM 9-331A, TM 9-331B.	
	Smoke	Shell, smoke, HC, M116	94.35		108.57	Unfuzed			M54	M501A1			
		Shell, smoke, WP, M110	98.39		111.87	Unfuzed	M51A4, A5						
	Colored smoke	Shell, smoke, M116	86.44		99.9	Unfuzed			M54	M501A1			Violet also available for training only.
	Chemical	Shell, chemical, M121					T237E						Details classified
	Gas	Shell, gas, M110	94.49		CNS 110.78 H 107.96.	Unfuzed	M51A4, A5		M55A3	M67A3, M500A1			
	Illuminating	Shell, illuminating, M118A1.	103.06		116.53	Unfuzed			M54	M501A1			Produces 1,000,000 for 75 seconds.
	Dummy	Projectile, dummy, M7	95.00		102.37	Complete							

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Table III. Ammunition Chart—Continued.

Weapon	Ammunition item	Item designation	Weight of projectile (pounds)	Weight of projectile per pound of bursting charge	Weight of complete round	How shipped	Fuzes: Point-det	Fuzes: Base-det	Fuzes: Time (powder)	Fuzes: Time (mech.)	Fuzes: VT	References TM 9-1900 and TM 9-1901 plus	Remarks
155-mm gun M2, T80	High explosive	Shell, HE, M101	95.59	6.15	126.59	Unfuzed	M51 series, CP, M78, M78A1.			M67 series, M500A1	M96, T227 (M514)	SM9-5-1320, SM 9-5-1315, TM 9-350.	Normal and deep w/supplemental charge cavities available.
	Armor-piercing	Projectile, AP, M112	100.00	71.40	131.0	Fuzed	M60						
	Smoke	Shell, smoke, WP, M104	98.71		129.71	Unfuzed	M51A4, A5						
	Empty	Shell, empty, M101			126.59	Unfuzed							For target practice, load with sand to weight of HE rounds.
	Gas	Shell, gas, M104	94.81		125.81	Unfuzed	M51A?, A4, A5						
	Chemical	Shell, chemical, M122					T237E1						Details classified.
	Illuminating	Shell, illuminating, M118A1.	103.06		134.06	Unfuzed			M54	M501A1			Use normal charge only.
	Dummy	Projectile, dummy, M7	95.00		127.2	Complete							
8-inch howitzer, M2 T89	High explosive	Shell, HE, M106	200.00	5.45	228.3	Unfuzed	M51A4, A5, CP, M78, M78A1.			M67 series, M500A1	M96, T227 (M514)	SM 9-5-1315, SM 9-5-1320, TM 9-3004.	Normal and deep w/supplemental charge cavities available.
	Dummy	Projectile, dummy, M14	200.00		228.75	Complete							
8-inch gun M1	High explosive	Shell, HE, M103	240.00	11.48	330.0	Fuzed	M51A5, Mod 3, CP, M78, M78A1.			M67A3, M500A1		SM 9-5-1320, SM 9-5-1315, TM 9-336.	
	Dummy	Projectile, dummy, M13	240.00		330.0	Complete							
240-mm howitzer, M1	High explosive	Shell, HE, M114	360.00	6.65	438.12	Unfuzed	M51A4, A5, CP, M78, M78A1.			M67A3, M500A1	T227 (M514)	SM 9-5-1320, SM 9-5-1315	Normal and deep w/supplemental charge cavities available.
	Dummy	Projectile, dummy, M12	360.00		440.0	Complete							
280-mm gun T131	High explosive	Shell, HE, T122	600.00	5.88	756.76	Unfuzed	T177E3			T288E1	T227E2 (M514E2) (T227 (M514) not adequate).	SM 9-5-1320, SM 9-5-1315, TM 9-338-1.	Deep cavity w/supplemental charge.
	Atomic explosive	Shell, AE, M354											Details classified.

Table IV. Fuze Interchangeability Chart

CODE

X Authorized fuzes, as issued.
S Authorized fuzes if supplementary charge is present in shell. For fuzes without boosters, boosters must be assembled to fuzes before use.
P Authorized fuzes if supplementary charge is not present in shell.
E Fuzes for battle emergency only, without additions or modifications. If deep-cavity shell, supplementary charge must be in shell.
A Fuzes for battle emergency only, after addition of M20, M21, or M24 types of boosters. For deep-cavity shell, the supplementary charge must be in shell.
R Fuzes for battle emergency only, after removal of M20, M21, or M24 types of boosters from fuzes with booster assembly.
B Authorized fuzes with addition of boosters.

Weapon	Projectile	T286E1 (M518) MTSQ	T177E3 PD	MK27 PD	M67 Series MT	M78 and M78A1, CP Nondelay and 0.025 Delay	M96 VT	M97 and M97A1 VT	M402 VT	T75E6 VT	T76E6 VT	M504A1 VT	T226 (M513) VT	M2 PD	M3 PD	M4, M4A1, M4A2 PD 0.015 and 0.10 Delay	M5 PD	M8 PD	M9 PD	M43A3 MT	M43A4 MT	M48A2 and A3 0.05 Delay SQ
40-mm gun	Cartridge, HE-T, MK2			X																		
75-mm howitzer	Shell, HE, M48, normal cavity		X		X	X														X	X	A
	Shell, HE, M48, w/supp charge		X		X	X		P				P								X	X	A
	Shell, HE, M48, deep-cavity		S		S	S		X				X								S	S	A
	Shell, smoke, M64		R		R	R														R	R	X
	Shell, HEAT and HEAT-T, M66																					
75-mm gun	Shell, HE, T50E6	X	X									X										
90-mm gun	Shell, HE, M71, normal cavity	X	X		X	X														X	X	A
	Shell, HE, M71, w/supp charge	X	X		X	X		P				P								X	X	A
	Shell, HE, M71, deep cavity	S	S		S	S		X				X								S	S	A
	Projectile, APC-T, M82																					
	Shell, HE marker, M71		X		X	X														X	X	A
	Shell, smoke, WP, M313		R		R	R														R	R	X
105-mm howitzer	Shell, HE, M1, normal cavity		X		X	X														X	X	A
	Shell, HE, M1, w/supp charge		X		X	X		P				P								X	X	A
	Shell, HE, M1, deep cavity		S		S	S		X				X								S	S	A
	Shell, HEAT-T, M67																					
	Shell, smoke, WP, or gas, M60		X		E	E														E	E	A
	Shell, smoke, M8481				R																R	E
	Shell, illuminating, M314A1																					
4.2-inch mortar	Shell, HE, M3, normal cavity														E		X		X			
	Shell, HE, M3A1, w/supp charge											P			E		X		X			
	Shell, HE, M329, w/supp charge				X							P										
	Shell, smoke, WP or gas, M2													E			E	X				
	Shell, smoke, WP or gas, M2A1													E			E	X				
120-mm gun	Shell, HE, M73, normal cavity																					
	Shell, HF, M73, w/supp charge						P	P		P		P	P									
155-mm howitzer	Shell, HE, M107, normal cavity		X		X	X														E	E	A
	Shell, HE, M107, w/supp charge		X		X	X	P				P		P							E	E	A
	Shell, HE, M107, deep-cavity		S		S	S	X				X		X							E	E	A
	Shell, smoke, M116				R															R	R	E
	Shell, smoke, WP or gas, M110				E	E														E	E	A
	Shell, illuminating, M118A1																					
155-mm gun	Shell, HE, M101, normal cavity		X		X	X														E	E	A
	Shell, HE, M101, w/supp charge		X		X	X	P				P		P							E	E	A
	Projectile, AP, M112																					
	Shell, smoke or gas, M104		X		E	E														E	E	A
	Shell, illuminating, M18A1																					
8-inch howitzer	Shell, HE, M106, normal cavity		X		X	X														E	E	A
	Shell, HE, M106, w/supp charge		X		X	X	P				P		P							E	E	A
8-inch gun	Shell, HE, M103, normal cavity		E		X	X														E	E	A
240-mm howitzer	Shell, HE, M114, normal cavity		X		X	X														E	E	A
	Shell, HE, M114, w/supp charge		X		X	X	P				P		P							E	E	A
280-mm gun	Shell, HE, T122, w/supp charge		X																			
4.5-inch rocket	Rocket, HE, M16A2, w/supp charge								P							X						B
	Rocket, HE, M32								P							X						B

Weapon	Projectile	M48A2 0.15 Delay SQ	M51A1 and A3 Mod 3 0.05 and 0.15 Delay SQ	M51A4 0.05 Delay SQ	M51A4 0.15 Delay SQ	M51A5 0.05 Delay SQ	M54 TSQ	M55A1 and A2 TSQ	M55A3 TSQ	M57 SQ	M61, M61A1 and A2 MT	M81 and M81A1 0.05 Delay SQ	M500 Series MTSQ	M501 Series MTSQ	M502 Series MTSQ	M506 MTSQ	M507 PD	M60 BD Delay	M66 BD Delay	M91 BD Nondelay	M514E2 VT	T288E1 MTSQ
40-mm gun	Cartridge, HE-T, MK2																					
75-mm howitzer	Shell, HE, M48, normal cavity	A		E	X	X	A		X	A		E	X	A	E							
	Shell, HE, M48, w/supp charge	A		E	X	X	A		X	A		E	X	A	E							
	Shell, HE, M48, deep-cavity	A		E	S	S	A		S	A		E	S	A	E							
	Shell, smoke, M64	E		R	R	R	E		R	X		R	R	E	R							
	Shell, HEAT and HEAT-T, M66																			X		
75-mm gun	Shell, HE, T50E6			E	E	E							E		X							
90-mm gun	Shell, HE, M71, normal cavity	A		X	X	X	A		X	A		E	X	A	X							
	Shell, HE, M71, w/supp charge	A		X	X	X	A		X	A		E	X	A	X							
	Shell, HE, M71, deep cavity	A		S	S	S	A		S	A		E	S	A	S							
	Projectile, APC-T, M82																		X			
	Shell, HE marker, M71	A		X	X	X	A		X	A		E	X	A	X							
	Shell, smoke, WP, M313	X		R	R	R	E		R	X		R	R	E	R							
105-mm howitzer	Shell, HE, M1, normal cavity	A		X	X	X	A		X	A		E	X	A	E							
	Shell, HE, M1, w/supp charge	A		X	X	X	A		X	A		E	X	A	E							
	Shell, HE, M1, deep cavity	A		S	S	S	A		S	A		E	S	A	E							
	Shell, HEAT-T, M67																			X		
	Shell, smoke, WP, or gas, M60	A		X	X	X	A		X	A		E	X	A	E							
	Shell, smoke, M8481	E		R	R	R	X		R	E		R	R	X	R							
	Shell, illuminating, M314A1						X							X								
4.2-inch mortar	Shell, HE, M3, normal cavity																					
	Shell, HE, M3A1, w/supp charge			X	X	X																
	Shell, HE, M329, w/supp charge			X	X	X			E				X									
	Shell, smoke, WP or gas, M2																					
	Shell, smoke, WP or gas, M2A1				X																	
120-mm gun	Shell, HE, M73, normal cavity										X					X	X					
	Shell, HF, M73, w/supp charge										X					X	X					
155-mm howitzer	Shell, HE, M107, normal cavity	A		X	X	X	A		X	A		E	X	A	E							
	Shell, HE, M107, w/supp charge	A		X	X	X	A		X	A		E	X	A	E							
	Shell, HE, M107, deep-cavity	A		S	S	S	A		S	A		E	S	A	E							
	Shell, smoke, M116	E		R	R	R	X		R	E		R	R	X	R							
	Shell, smoke, WP or gas, M110	A		X	X	X	A		X	A		E	E	A	E							
	Shell, illuminating, M118A1						X							X								
155-mm gun	Shell, HE, M101, normal cavity	A		X	X	X	A	E	E	A		E	X	A	E							
	Shell, HE, M101, w/supp charge	A		X	X	X	A	E	E	A		E	X	A	E							
	Projectile, AP, M112																	X				
	Shell, smoke or gas, M104	A		X	X	X	A	E	E	A		E	X	A	A							
	Shell, illuminating, M18A1						X							X								
8-inch howitzer	Shell, HE, M106, normal cavity	A		E	X	X	A		X	A		E	X	A	E							
	Shell, HE, M106, w/supp charge	A		E	X	X	A		X	A		E	X	A	E							
8-inch gun	Shell, HE, M103, normal cavity	A	X	E	E	E	A		E	A		E	X	A	E							
240-mm howitzer	Shell, HE, M114, normal cavity	A		E	X	X	A		E	A		E	X	A	E							
	Shell, HE, M114, w/supp charge	A		E	X	X	A		E	A		E	X	A	E							
280-mm gun	Shell, HE, T122, w/supp charge			E	E	E							E	A							P	X
4.5-inch rocket	Rocket, HE, M16A2, w/supp charge	B										X										
	Rocket, HE, M32	B										X										

b. High Explosive Shell.

(1) HE shell is a hollow shell which is filled with either Composition B or TNT. The terminal ballistics and effects analysis of this shell are discussed in chapter 27.

(2) High explosive cavitized shell has a deep fuze cavity in its bursting charge which is required to accommodate the increased length of VT fuzes. A supplementary charge of TNT is provided to shorten the cavity for use with point detonating impact or time fuzes. When VT fuzes are used, this supplementary charge must be removed.

c. Base Ejection Shell. Base ejection shells are smoke, propaganda, or illuminating. Since the fuze cavity is very shallow in these shells, a fuze without a booster must be used. To provide effective action of the projectile, a time fuze must be used. While the projectile is still well above the point of impact, the action of the fuze and expelling charge ignites the canisters (with the exception of the propaganda shell) and/or forces them out of the base of the shell with a relative velocity of about 200 feet per second. The empty projectile continues along the trajectory, and the canisters follow with reduced velocity, emitting their contents (parachute flare, smoke, or leaflets). The lowest practical charge should be used with base ejection shells in order that the terminal velocity of the projectile may be low and thus reduce the possibility of damage to the expelled portion of the shell (e. g., the parachute for flares).

d. Burster-Type Chemical Shell. Burster-type chemical shells include gas shell or smoke shell. A burster charge running through the long axis of the shell is exploded by the activation of a fuze with booster. Superquick, delay, or time action may be used. The white phosphorus, irritant, or toxic agent contained in the shell is expelled upon action of the burster.

e. Armor-Piercing Shell. Projectile, AP, M112, for 155-mm guns is designed for use against armored targets, concrete emplacements, and similar targets. This projectile consists of a hardened steel body, which contains a cavity in the base filled with an explosive, and a base detonating fuze, which functions with delay action. For better ballistic qualities, a steel windshield is employed on this shell. A base cover is fitted over the fuze in the base of the projectile.

f. Shell, High Explosive Antitank (HEAT). Shell, HEAT, is provided for the 75-mm and 105-mm howitzers for use against tanks and other armored materiel. The construction of the shell differs materially from the standard types of armor-piercing projectiles. The shell body is a thin-walled casing containing a shaped, high explosive filler and is closed off at the forward end by a ballistic cap in the form of a thin steel cone. The base is boattailed and fitted with a base detonating fuze which functions with nondelay action.

36. Types of Fuzes

The proper fuze must be used with the selected projectile to cause the projectile to function at the time and under the circumstances desired. Table IV lists the more common fuzes available for each projectile, their interchangeability, and the modifications which may be made thereto.

37. Fuze Wrenches and Fuze Setters

Description and operation of the various fuze wrenches and setters may be found in the specific technical manual for the weapon.

a. Fuze Wrenches. Fuze wrenches are required to insure a tight fit of the fuze to the projectile and are used for screwing the fuze to and unscrewing the fuze from the projectile.

(1) M18 fuze wrench is standard for use with the M51, M54, M55, M67, M81, M500A1, M501A1, M513, and M514 fuzes. The screwdriver end of this wrench is used for setting the M51 fuze selective setting sleeve from SQ to DELAY, or vice versa.

(2) M16 fuze wrench is for use with the CP fuze M78 series. The booster end of the wrench is used for the M20 series type of boosters, if they are not secured to the fuze, and the M25 boosters.

b. Fuze Setters. Fuze setters for use on field artillery fuzes are of two types—hand (wrench) and hand (mechanical). Some fuze setters are constructed for a particular fuze or type of fuze. Other models are built for several different types of fuzes. When a choice exists between the use of a hand (wrench) and a hand (mechanical) type of setter, the mechanical type of setter will give more consistent, accurate and finer readings and should be used. A knowledge of the inner mechanism of the fuze is helpful in determining which direction to turn the fuze setter to obtain the proper setting (for details, see TM 9-1901). The fuze setter must be turned so that the reading will increase as the setter is applied to the lower cap or movable time ring.

(1) M14 is a hand (wrench) type of fuze setter which is placed on the fuze with the key engaging the slot in the fuze. It can be used on all time fuzes but should not be used if other types of fuze setters are available.

(2) M22 is a hand (mechanical) type of fuze setter for use on fuzes M54 and M55. It has 2 separate scales and indices which permit the making of fuze time and corrector settings independently—time scale 0–25 seconds at 0.1-second increments.

(3) M23 is a hand (mechanical) type of fuze setter for use on fuzes M67, M500A1, and M501A1; its mechanical function is identical to the M22 setter but offers a time scale of 0–75 seconds in 0.2-second increments.

(4) M26 is a hand (mechanical) type of fuze setter for use on all time fuzes 0–25 seconds or 0–75 seconds in time range. It has two time scales but no corrector scale.

(5) M27 is a hand (wrench) type of fuze setter for use on all field artillery time fuzes.

(6) M28 is a hand (mechanical) type of fuze setter which may be used on fuzes M513 and M514. It has 2 time scales—0–45 seconds and 0–100 seconds in 0.2-second increments.

PART TWO

FIRING BATTERY

CHAPTER 4

FIRING BATTERY GENERAL

Section I. GENERAL

38. Introduction

a. Effective fire on a target is achieved by a smooth-working, 3-component team: the observer, who selects, reports, and requests fire on a target; the fire direction center (FDC), which converts fire requests and subsequent corrections into fire commands; and the firing battery which executes the fire commands.

b. The firing battery consists of the firing battery headquarters, the weapon sections, and, in some units, an ammunition (ammo) section. The battery FDC does not function as part of the firing battery.

c. Field artillery procedures are simplified by the use of common map and firing battery terms.

39. Map and Azimuth Terms

(fig. 26)

a. Grid Line. A grid line is a line extending north and south or east and west on a map, photo map, or grid sheet and is used in locating points (fig. 27).

b. Magnetic North. Magnetic north is the direction to the magnetic North Pole.

c. True North. True north is the direction to the geographic North Pole.

d. Grid North. Grid north is the north direction of the vertical grid lines on a military map, photomap, or grid sheet.

e. Azimuth. Azimuth is a horizontal clockwise angle measured from north. This angle may be a—

(1) *Magnetic azimuth,* measured from magnetic north.

(2) *True azimuth,* measured from true north.

(3) *Grid azimuth,* measured from grid north. This is the azimuth normally employed in the field artillery. The artilleryman uses the term "azimuth" to mean "grid azimuth." The command to the executive to indicate the grid azimuth of the direction of fire is AZIMUTH (SO MUCH).

f. Back-Azimuth. The back-azimuth is equal to the azimuth plus or minus 3,200 mils. The azimuth of line AB (fig. 27) is 500 mils. The back-azimuth of line AB is 3,700 mils (500 plus 3,200). The azimuth of line CD is 3,700 mils, and the back-azimuth is 500 mils (3,700 minus 3,200).

g. Magnetic Declination. Magnetic declination is the smallest angle between true north and magnetic north. On maps, this angle is indicated in the marginal data as east or west of true north. As the magnetic declination varies slightly from year to year, a correction factor—the annual magnetic change—also is shown in the marginal data of military maps.

h. Grid Convergence. Grid convergence is the smallest angle between true north and grid north. On maps, grid convergence east or west of true north is indicated in the marginal data.

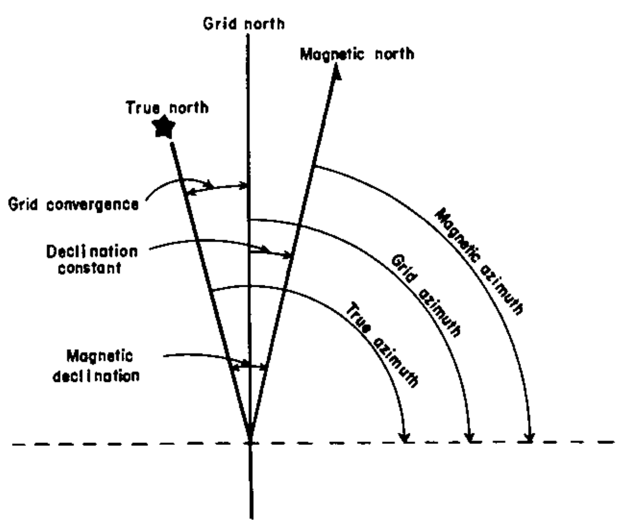


Figure 26. Map and azimuth terms.

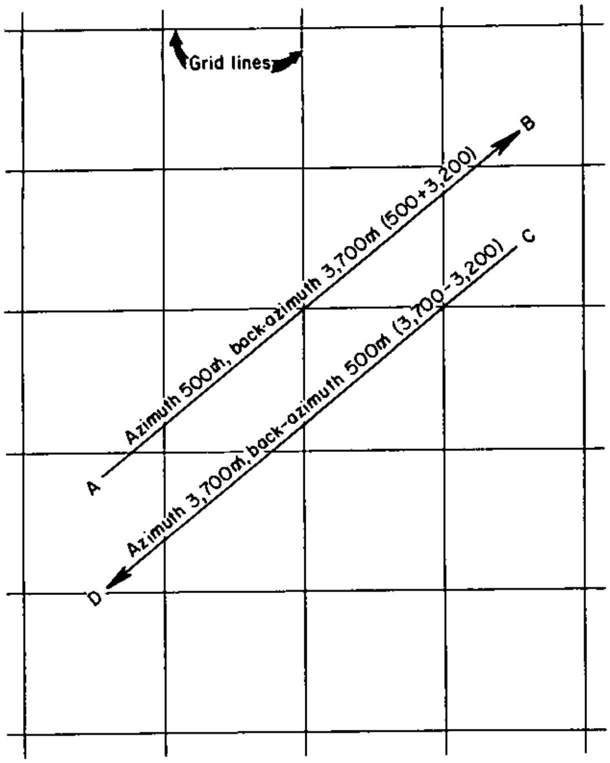


Figure 27. Back-azimuth.

i. Declination Constant. Declination constant is the horizontal, clockwise angle from grid north to magnetic north; in other words, the grid azimuth of magnetic north. This constant is recorded for any instrument equipped with a magnetic needle. The constant for any one instrument will vary in different localities; the constants of different instruments in the same locality will vary also.

40. Common Firing Battery Terms

a. Aiming Point. An aiming point must have a sharply defined point or vertical line clearly visible from the pieces so that the vertical cross hair of the panoramic telescope can be accurately alined on it. There are two general types of aiming points—*distant* and *close-in.*

(1) *Distant aiming point.* A distant aiming point is one at sufficient distance (2,000–3,500 yds) so that normal displacements of the piece in firing or traverse will not cause a horizontal angular change in direction (with the same settings on the azimuth scales) of more than one-half mil. An advantage is that it may be used immediately upon occupation of position. Disadvantages are that it may be obscured by darkness, dust, fog, or smoke; illumination, when needed, is not practicable; and pieces will not be parallel when they are laid with a common deflection.

(2) *Close-in aiming point.* A close-in aiming point requires 2 fixed points, normally 2 aiming posts, 1 of which is at a greater distance from the piece than the other. The two points establish a line along (or parallel to) which the panoramic telescope is sighted. The near aiming post must be alined and located at a point exactly one-half the distance between the telescope and the far aiming post. To facilitate the use of aiming post lights, the far light should be installed so that it will appear above the near light. It may be necessary to remove the upper section of the near aiming post to prevent its obscuring the far light.

b. Battery Center. The battery center is a point materialized on the ground at the approximate geometric center of the pieces of the battery—the chart location of the battery.

c. Base Piece. The base piece is the piece nearest the battery center, which is normally used for registration.

d. Registration Point. A registration point is a point in the target area whose location is known on the ground and on a firing chart. This point is used as a basis for computing data resulting from registration on that point and as a reference point. Some of the desirable characteristics of a good registration point are that it is—

(1) Readily identifiable.

(2) Located horizontally and vertically in the approximate center of the target area or zone(s) of action.

(3) Semipermanent or permanent in nature.

e. Meteorological (Met) Check Point. A met check point is an arbitrary point in the target area for which corrections for known variations from standard conditions are computed.

f. Orienting Line. An orienting line is a line of known direction materialized on the ground near the firing battery, which serves as a basis for laying for direction. The azimuth of the orienting line is stated as the direction from the orienting station to a designated end of the orienting line.

g. Orienting Station. An orienting station is a point on the orienting line established on the ground, over which the battery executive sets up an aiming circle to lay the pieces.

h. Orienting Angle. An orienting angle is the horizontal, clockwise angle from the line of fire to the orienting line or the orienting line extended; it is never greater than 3,200 mils.

i. Reference Point. A reference point is a prominent and easily located point on the terrain which is used for orientation to locate targets or other points.

j. Deflection. Deflection (par. 8*b*) is the horizontal, clockwise angle from the line of fire to a designated aiming point (post), with the vertex at the sight. Deflection never exceeds 3,200 mils.

k. Refer. To refer is to measure (by using the panoramic telescope) the deflection to a given aiming point without moving the tube. The command REFER means to measure and to report the deflection. If it is desired to record this deflection, the command is RECORD REFERRED DEFLECTION.

l. Indirect Laying. When indirect laying procedure is used, the piece is laid for direction by setting a given deflection on the sight and traversing the tube until the line of sight of the telescope is on the aiming point with the appropriate bubbles leveled. The piece is laid for elevation by setting off the elevation or quadrant on the range quadrant or gunner's quadrant and elevating or depressing the tube until the appropriate bubble is level.

m. Direct Laying. When direct laying procedure is used, the piece is laid by sighting directly on the target (pars. 96–110).

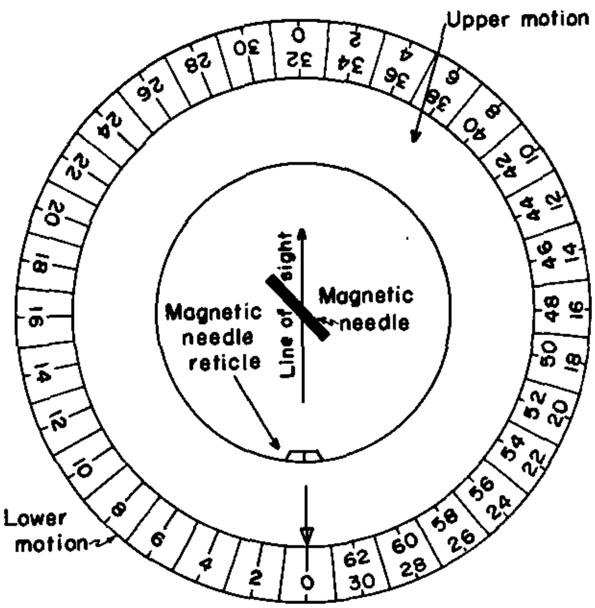


Figure 28. Schematic diagram of aiming circle.

41. Aiming Circle
(TM 6–200)

a. The aiming circle is an instrument for measuring horizontal and vertical angles. The head of the instrument consists of two sections defined as the lower motion and the upper motion (fig. 28). The lower motion has an azimuth scale. The upper motion has an index in relation to this azimuth scale and an azimuth micrometer scale and contains a compass and a telescope. All horizontal angles measured with the aiming circle are clockwise from the 0–3200 line.

b. When the compass of the aiming circle is used, steel helmets, small arms, steel-rimmed eyeglasses, and other objects which may affect the magnetic needle must be kept away from the instrument. The aiming circle should be set up at least the following minimum distances from objects that will affect the magnetic needle:

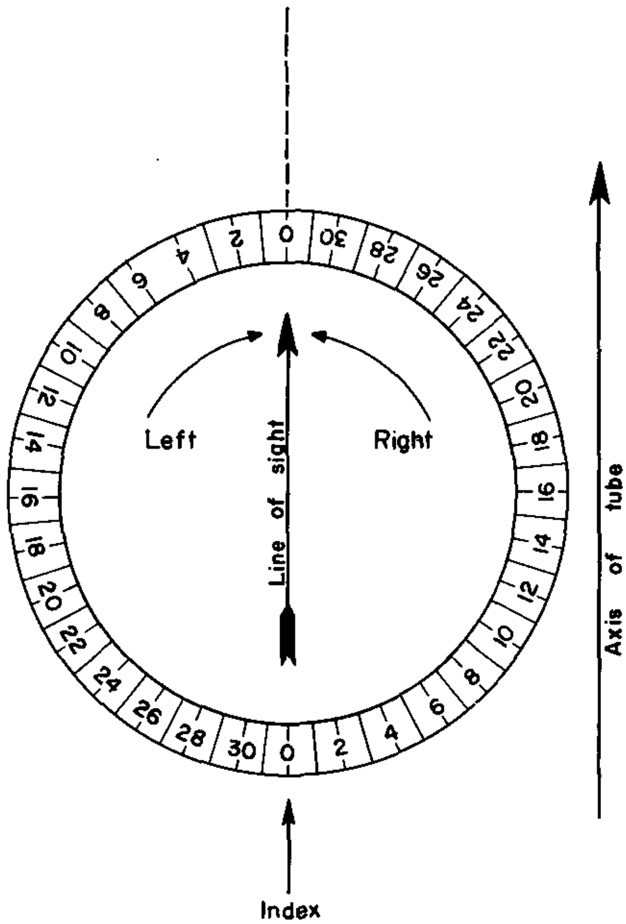


Figure 29. Panoramic telescope main scale.

	Yards
High-tension powerlines	150
Railroad tracks or very heavy pieces	75
Medium and heavy pieces	60
Light pieces, telegraph wire, or vehicles	40
Barbed wire and small metal objects	10

42. Compass M2

(TM 9–575)

The compass M2 is similar in principle to the aiming circle. The compass M2 has a circular level which is used in measuring azimuths and a tubular level which is used in measuring angles of site. This instrument has an azimuth scale adjuster for setting off the declination constant so that grid azimuths may be read directly. The same precautions stated in paragraph 41*b* must be observed when the magnetic needle of the compass is employed.

43. Panoramic Telescope

The panoramic telescope (usually called the *sight*), mounted on the piece, is used to measure horizontal, clockwise angles. The main scale of the telescope consists of 2 halves, each half graduated in 100-mil increments from 0 to 3,200 mils in a counterclockwise direction. A micrometer scale, graduated in 1-mil increments from 0 to 100 mils, is geared to the main scale. When a zero of the

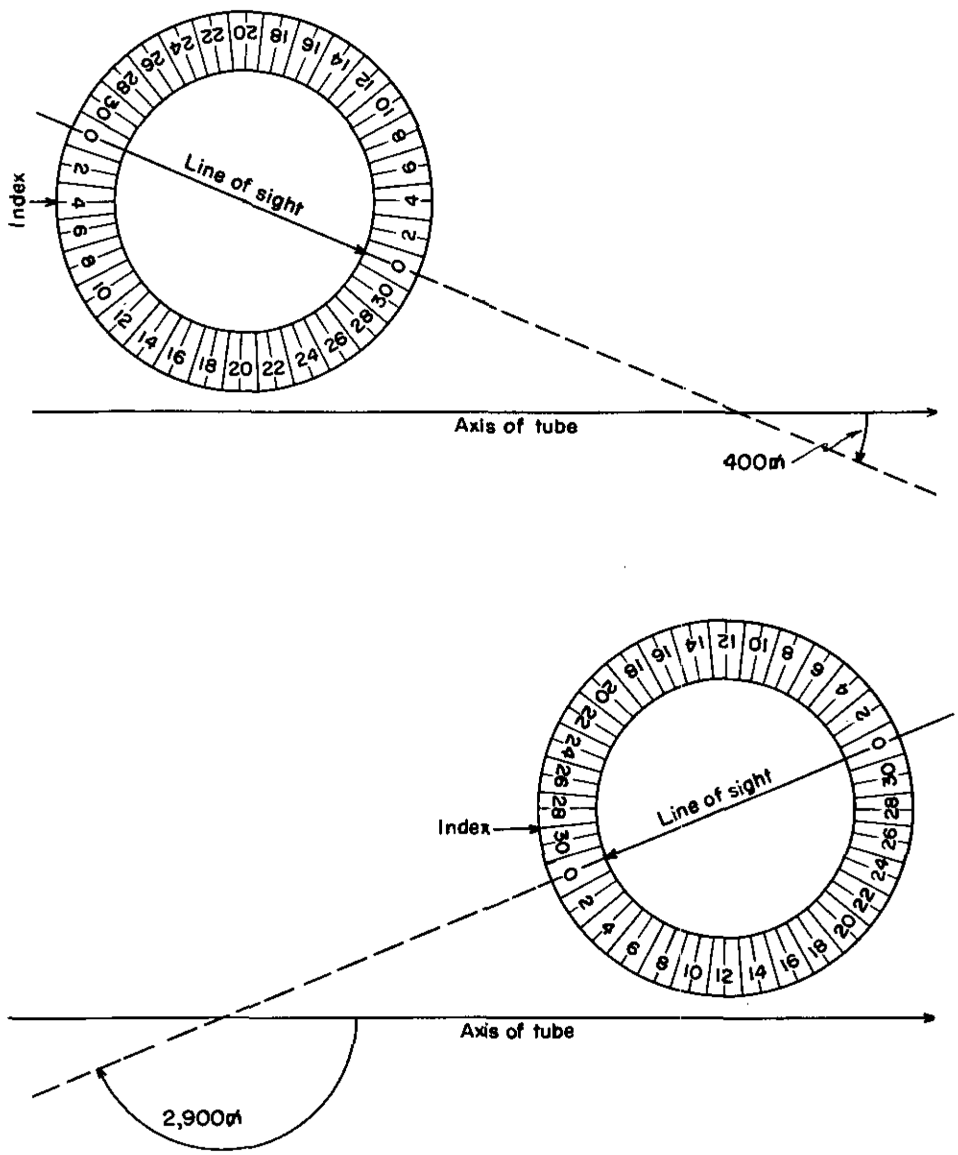


Figure 30. Clockwise angle from axis of tube to line of sight.

main scale is opposite the stationary index, the zero of the micrometer scale is also opposite its index, and the line of sight is parallel to the axis of the tube (fig. 29), the telescope is in proper adjustment. When the telescope head is rotated horizontally, the scales turn with it, and the clockwise angle from the axis of the tube to the line of sight is measured and indicated opposite the indexes (fig. 30). (For details of operation, see the field manual for the weapon.)

Section II. FIRE COMMANDS AND THEIR EXECUTION

44. Introduction

a. Fire commands convey all the information necessary for commencement, conduct, and cessation of fire. Initial fire commands include all elements necessary for laying, loading, and firing the pieces. Subsequent fire commands include only those elements that are changed, except that the range, quadrant, or elevation is always announced.

b. The basis for fire commands is the data processed in an FDC. These data are received in requests for fire; e. g., from an observer, the FDC of another headquarters, or a supported unit. The fire commands are sent to the battery executive by the best available means of communication. The executive insures that the weapon sections receive and execute the fire commands as prescribed in this manual and unit SOP's.

c. Accuracy in the firing battery is dependent on complete understanding of commands by all personnel. Since numbers make up a large portion of all commands received or given in the firing battery, they must be announced in a clear, precise manner, in a tempo consistent with the execution of the command, and sufficiently loud to be properly understood. Numbers are announced as follows:

Number	*Announced as—*
0	Zero
1	Wun
2	Too
3	Thuh-ree
4	Fo-wer
5	Fi-yiv
6	Six
7	Seven
8	Ate
9	Niner
44	Fo-wer fo-wer
80	Ate zero
100.7	Wun zero zero point seven
136	Wun thuh-ree six
500	Fi-yiv hun-dred
1478	Wun fo-wer seven ate
7000	Seven thow-zand
16000	Wun six thow-zand

45. Sequence

a. Information given in fire commands to a firing battery is announced in the following sequence:

	SEQUENCE		WHEN ANNOUNCED	
No.	*Element of fire command*	*Example (initial fire commands)*	*Initial fire commands*	*Subsequent fire commands*
1	Pieces to follow commands	BATTERY ADJUST	Always	Never.
2	Special corrections	SPECIAL CORRECTIONS	When applicable	When applicable.
3	Projectile	SHELL HE	Always	When changed.
4	Ammunition lot	LOT X	When applicable	When changed.
5	Charge	CHARGE 5	Always (except in fixed ammo.).	When changed.
6	Fuze	FUZE TIME	Always	When changed.
7	Pieces to fire	CENTER	Always	When changed.
8	Method of fire	1 ROUND	Always	When changed.
9	Direction	CORRECTION L1 DEFLECTION 2500.	Always	When changed.
10	Site	SITE 305	When applicable	When changed.
11	Time setting	TIME 18.0	When applicable	When changed.
12	Elevation	ELEVATION 293	Always	Always.

b. A list of all elements of the fire commands with explanation and examples is presented in paragraphs 46 through 57. Some of the elements listed are used only under special circumstances and are not announced when they have no practical application.

46. Pieces to Follow Commands

The element designating the pieces to follow the commands indicates and alerts those pieces that are to follow commands and is always announced in the initial fire command and is not repeated thereafter. A change of the element (all pieces to follow the commands) during a mission constitutes a new mission, and a new series of commands is given. The command consists of two parts, first, designation of pieces to follow the commands and second, the word ADJUST. Examples of pieces to follow designations are as follows:

a. To alert all pieces, the command is BATTERY ADJUST.

b. To alert base piece, the command is BASE PIECE ADJUST (NO. 3 ADJUST).

c. To alert the left (right) (center) pair of pieces, the command is LEFT (RIGHT) (CENTER) ADJUST.

d. To alert any other combination of pieces, the pieces are designated by number; e. g., No. 2, 3, 4, and 5 ADJUST.

47. Special Corrections

a. The command SPECIAL CORRECTIONS indicates that individual piece corrections will be applied during the fire mission. These corrections compensate for individual piece displacements in range or height of weapon and/or muzzle velocity variations in individual weapons as related to the base piece. Special corrections are computed at the FDC and are normally announced as part of the element to which they pertain. For examples of special corrections, see paragraphs 54, 55, 56, and 57. The procedure indicated in these paragraphs may be altered to allow announcement of separate corrections for each piece for each element of the command. However, this is done only when time allows and extreme accuracy is desired. To insure greater accuracy in applying special corrections as parts of a command, the executive officer may allow the applicable special corrections to be written on a convenient part of the weapon, e. g., the weapon shield, or combined with the common command by the chief of section. The determination and application of special corrections are covered in chapters 19 and 28.

b. The command SPECIAL CORRECTIONS is announced for each mission in which special corrections are to be used. Once the command is given it need not be reannounced during the mission.

48. Projectile

The type of projectile that will be used to attack the target is always announced in the initial fire command and is not repeated thereafter, unless a change is desired.

Example: SHELL HE; SHELL WP.

49. Ammunition Lot

The element, ammunition lot, indicates the ammunition lot number. Lot number may be announced in the initial fire command and is not repeated thereafter, unless a change is desired. In fixed and semifixed ammunition, the lot number pertains to an assembled projectile—propellant combination and, for simplicity, may be coded as lot X, lot Y, etc. In separate-loading ammunition when a specific projectile-propellant combination is desired, the lot code may be X–Y with "X" the projectile lot and "Y" the propellant (charge) lot. Large quantity lots are reserved for registration and subsequent transfer of fires, and the lot number will be announced or prearranged between the FDC and the firing battery. Small quantity lots should be used on battery *will adjust* missions and lot numbers may be omitted. The weapons' crews must segregate ammunition by lot number and keep an accurate record of lots available.

50. Charge

a. The element, charge, indicates the type or number of charge. Charge is always announced (except with fixed ammunition) in the initial fire command and is not repeated thereafter, unless a change is desired.

b. The command may specify the type of charge when more than one type is available. With ammunition having numbered charges, the command specifies the number of charges to be fired. If the charges are designated as super, normal, or reduced, they are designated as such instead of by numbers.

Example: Commands with numbered charges: CHARGE 4; CHARGE 5, GREEN BAG; CHARGE 6, M4. Commands with charges not numbered: SUPER CHARGE, REDUCED CHARGE, NORMAL CHARGE.

51. Fuze

A command indicating the type of fuze to be employed is always announced in the initial fire command and is repeated only when changed.

Example: FUZE QUICK (DELAY), FUZE TIME, FUZE VT, FUZE CP DELAY (NONDELAY).

52. Pieces to Fire

a. Any or all of the pieces alerted under the first element of the fire commands may be further designated to do the actual firing. If an adjustment is to take place, usually no more than two pieces will be fired during the adjustment.

b. The element designating the pieces to fire is always announced in the initial fire command and is reannounced only when the number of pieces firing will be changed or when the method of fire is changed. To fire the battery, the command is BATTERY. To fire any combination of pieces within the battery, the pieces are specified by platoon or by number.

Example: LEFT (RIGHT) (CENTER); BASE PIECE; No. 2, 3, and 4; No. 2; etc.

53. Method of Fire

There are a number of methods of fire which can be selected depending on the size, shape, and nature of the target; observation conditions, and other considerations. Although the command for each method is distinctive, it generally consists of two parts—the number of rounds to be fired and the method in which these rounds will be fired. The command is always given in the initial fire commands. The method of fire must be reannounced when changed or when the number of pieces to fire is changed.

a. Volley Fire. To fire volley fire, the command is (SO MANY) ROUNDS. Fire is opened at the executive's command FIRE, given after the elevation, unless a command for holding fire is prescribed. Each round is fired at the command of the chief of section: No. 1 (OR OTHER PIECE) FIRE. Each designated piece fires the specified number of rounds as rapidly as consistent with accuracy and without regard to the readiness of other pieces. The command for a specific time interval is (SO MANY) ROUNDS AT (SO MANY) SECONDS or (SO MANY) ROUNDS PER MINUTE. In this case, a single round per piece, at the time interval indicated, is fired at the executive's command. This method may be used to maintain a smoke screen or night illumination.

b. Salvo Fire. To fire salvo fire, the command is RIGHT (LEFT). Each piece fires in a definite sequence. The designated flank piece (right or left) will fire first, followed at 2-second intervals by each succeeding piece. If a time interval other than 2 seconds is desired, it must be announced as LEFT (RIGHT), AT (NO) SECONDS. If more than one round per weapon is to be fired, the command would be LEFT (RIGHT), (NO) ROUNDS, AT (NO) SECONDS.

c. Continuous Fire. When it is desired to fire continuously at a target, the command is CONTINUOUS FIRE. This command will cause the weapons' crews to load and fire as rapidly as consistent with accuracy within the prescribed rate of fire for the weapon (ch. 23). The crews will continue to fire until commanded CEASE FIRING.

d. At My Command. AT MY COMMAND may be announced from the FDC immediately after the method of fire is announced. AT MY COMMAND is then part of the method of fire. When the pieces are ready to fire, the executive reports BATTERY IS READY to the FDC and fires when he receives the command FIRE from the FDC. AT MY COMMAND continues in effect until a new method of fire not including AT MY COMMAND is ordered.

e. By Piece At My Command. To fire each piece individually at a time to be controlled from the FDC, the command is BY PIECE AT MY COMMAND. The pieces are fired by number as ordered from the FDC to the executive; e. g., NO. -- FIRE. When BY PIECE AT MY COMMAND is in effect, the executive will report BATTERY IS READY when all pieces are prepared to fire.

f. Fire At Will. If the method of fire is for pieces to fire at will, the command is TARGET (SO-AND-SO) FIRE AT WILL. If a method of close defense has been prearranged, the command is simply FIRE AT WILL. At this command, the designated piece or pieces will fire under the control of the chief of section as the situation and target necessitate.

g. Zone Fire.

(1) Zone fires are delivered in a constant direction at varying ranges. The normal command consists of three parts—the number of rounds, the zone, and the initial elevation (quadrant). The announced elevation or quadrant establishes the center of the zone. The executive has the designated pieces fire at three elevations, in the sequence—center elevation and then the elevations differing from the center elevation by the announced number of mils, in any order. To attack a target deployed in depth, the command is (SO MANY) ROUNDS,

ZONE (SO MANY) MILS, ELEVATION (SO MUCH); e. g., BATTERY, 3 ROUNDS, ZONE 5 MILS, ELEVATION 190—the executive has the battery fire 3 rounds at elevation 190, 3 rounds at 195, and 3 rounds at 185. In some cases, the executive may receive the command (SO MANY) ROUND(S), ZONE (SO MANY) MILS, 5 ELEVATIONS, ELEVATION (QUADRANT) (SO MUCH). The announced elevation is the elevation for the center of the zone. The executive has the designated pieces fire at 5 elevations, the announced number of mils apart in the sequence—the center elevation, then the 4 other elevations in any order; e. g., if the command is BATTERY 1 ROUND, ZONE 5 MILS, 5 ELEVATIONS, ELEVATION 190, the executive has the battery fire 1 round at elevations 190, 200, 180, 185, and 195.

(2) The executive may keep close control of the battery by announcing the separate elevations or quadrants. He may (except during time fire) repeat the entire zone command and require the chiefs of section to give the elevation or quadrant commands.

h. Shifting Fire.

(1) When the width of the target is too great to be covered with an open sheaf, the target may be attacked by successive shifts.

(2) Shifting fire is accomplished by laying the battery first on one portion of the target and then successively laying it on the other portions to be covered. Volley fire by battery is delivered alternately on each portion of the target.

i. Do Not Load. When exact firing data or time of firing has not been determined it may be desirable for the pieces of a unit to be laid but not loaded. In such a case, preliminary data must be sent to lay the tubes approximately on the target and the command DO NOT LOAD (DNL) is announced after the method of fire is announced. As soon as the weapons are laid, the executive reports BATTERY IS LAID. When the exact data have been prepared and immediate firing is desired, the necessary elements in the sequence of commands will be reannounced without the command DO NOT LOAD.

j. VT in Effect. When VT fuze is to be used after an impact fuze adjustment, it is necessary to include the warning phrase VT IN EFFECT in the method of fire so that the weapons' crews will be prepared to fire VT. This warning is given as a part of the method of fire, after the method commanded for the impact adjustment.

Example: FUZE QUICK, CENTER 1 ROUND, BATTERY 3 ROUNDS, VT IN EFFECT.

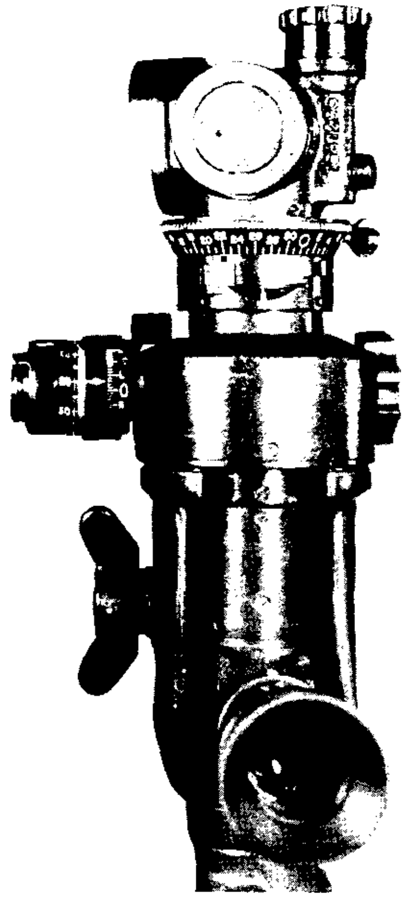


Figure 31. Corrections L3, deflection 2,720.

54. Direction

a. To lay the tube for direction, the command is DEFLECTION (SO MUCH). This element is always given in the initial fire commands and is reannounced only when changed. Deflection correction is always announced with this element; e. g., CORRECTIONS L3, DEFLECTION 2720 (fig. 31), or AIMING POINT, MARKER ON HILL 609, CORRECTIONS 0, DEFLECTION 2644. The announced deflection correction is set on the gunner's aid and carried throughout the mission.

b. If a deflection correction and a special correction for deflection are applicable, they will normally be combined in the FDC and announced as CORRECTIONS 0, DEFLECTION (SO MUCH): NO. 1, LEFT 1; NO. 2, LEFT 2; NO. 3, 0; etc. The announced special correction is set on the gunner's aid and carried throughout the mission.

55. Site

a. For those weapons equipped with an on-carriage site scale, site is handled as a separate element when the gunner's quadrant is not used (fig. 32). Site is always announced with the initial fire commands and is reannounced only when changed.

Examples: SITE 300 (this is actually a site of 0 mils; the horizontal setting is marked 300).

A site below the horizontal plane is subtracted from 300; one above the horizontal plane is added, as SITE 287 (−13 mils of site), SITE 310 (+10 mils of site).

b. For those weapons not equipped with an on-carriage site scale, or when the gunner's quadrant is used, site is combined with elevation.

c. When special corrections have been ordered, the command for site for weapons having an on-carriage site scale is a common site plus individual site corrections for each piece; e. g., SITE 310; NO. 1, UP 2; NO. 2, UP 3; NO. 3, 0; NO. 4, DOWN 1; NO. 5, DOWN 3; NO. 6, DOWN 5. The No. 1 cannoneer will apply the individual site correction to the site announced. Individual site corrections announced with the initial commands are carried throughout the mission. For pieces that do not have an on-carriage site scale, these special corrections are incorporated as part of the elevation or quadrant command. In this case, each piece is given a different elevation or quadrant.

d. These special corrections, applied as stated in *c* above, are to compensate for range and height displacement and muzzle velocity variation of individual weapons as related to the base piece.

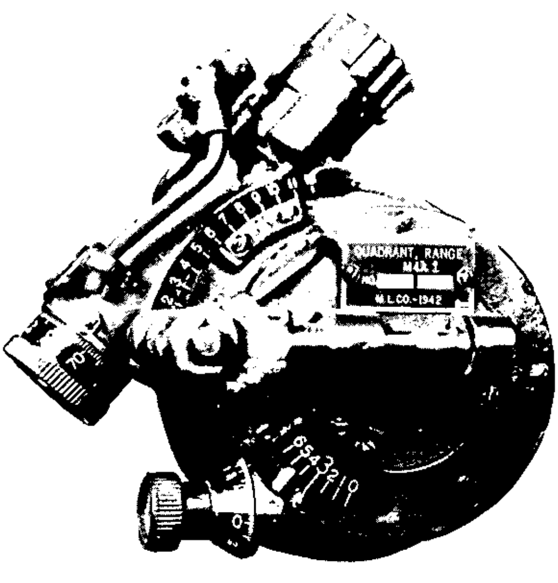


Figure 32. Site 305, elevation 864, 105-mm howitzer.

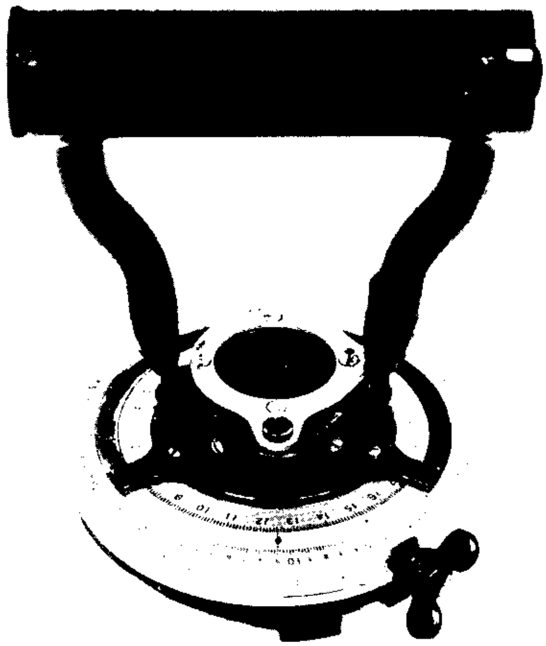


Figure 33. M26 fuze setter set at Time 9.0.

56. Time Setting

a. When a time fuze has been specified, a time setting will be required (fig. 33) in the initial fire commands. This element is announced with the initial fire commands and is reannounced only when changed. The same procedure applies when a time setting with variable time fuze is used.

Examples: TIME 17.4, TIME 11.9, TIME 26.0.

b. When special corrections have been ordered, the command for time setting consists of a common time plus individual time corrections for each piece. The appropriate cannoneer will apply the individual time correction to the time announced; e. g., TIME 18.2, No. 1, PLUS .1; No. 2, 0; No. 3, PLUS .1; No. 4, MINUS .2; No. 5, MINUS .3; No. 6, MINUS .5.

c. These special corrections applied as individual time corrections are to compensate for the variations in time of flight corresponding to varied ranges resulting from the special corrections applied to site or elevation.

57. Elevation

a. The command to lay the piece for range is ELEVATION (SO MANY MILS) or QUADRANT (SO MANY MILS). The use of the gunner's quadrant (fig. 34) is mandatory when the command QUADRANT (SO MANY MILS) is given; otherwise, the on-carriage elevation scale is used (fig. 35). This element is always given in fire commands except when salutes are being fired (par. 58*c*). When the command is announced as elevation, if the weapon has an on-carriage site scale, the number of mils announced represents only elevation; if the weapon has no on-carriage site scale, the number of mils announced is the algebraic sum of site and elevation. For application of special corrections pertaining to range, see paragraph 55.

b. The command ELEVATION (QUADRANT) is also the command for weapons' crews to load the weapons, provided that DO NOT LOAD was not announced. It should be noted that a separate command to load is not used (except in firing salutes).

c. ELEVATION (QUADRANT) is the command to the executive to fire except when the method of fire is BY PIECE AT MY COMMAND, AT MY COMMAND, or FIRE AT WILL and, when salutes are being fired, in which case the command is FIRE. The executive's command which always must be given to the chiefs of sections is FIRE. This command immediately follows the command ELEVATION unless a command for holding fire has been announced. When the command FIRE has been given, the weapons' crews will load and fire at the command of the chief of section as soon as they are ready. This command FIRE should be delayed by the executive only when a reason exists; for example, safety or accuracy check.

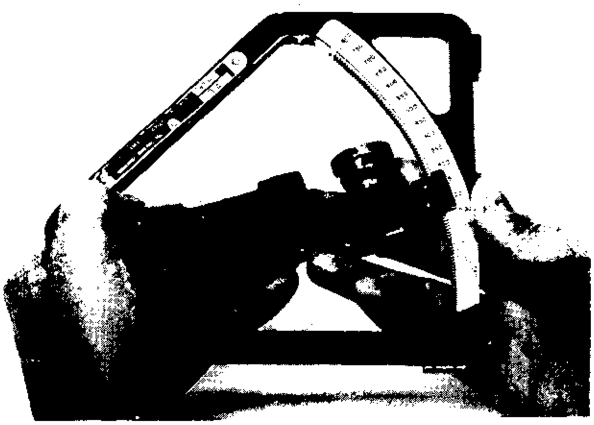


Figure 34. Setting the gunner's quadrant.

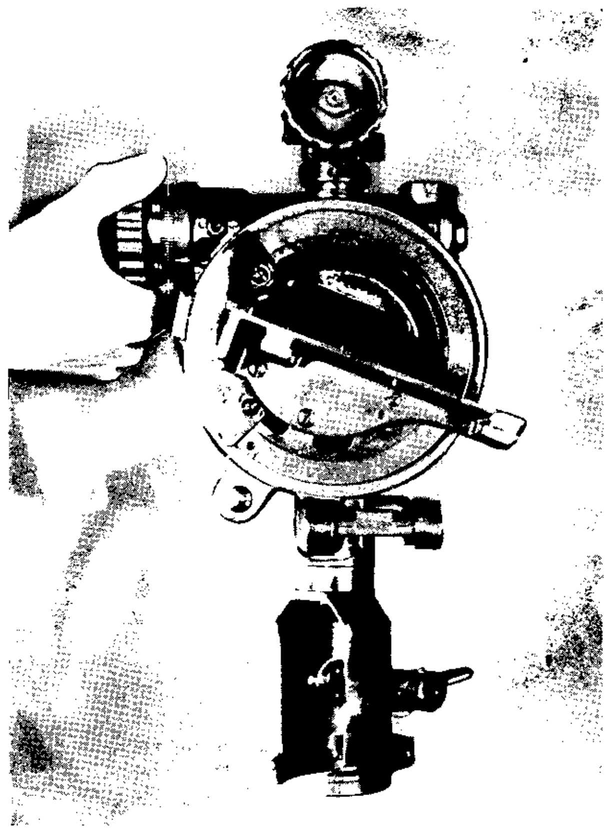


Figure 35. On-carriage elevation scale—elevation 373, 155-mm howitzer.

58. Examples of Typical Fire Commands

In the examples in *a* through *c* below, a particular weapon is indicated in most cases, but the commands generally are applicable to all calibers. All commands are repeated by the executive or designated personnel of the firing battery unless otherwise stated.

a. Example of commands for precision adjustment for registration for the 105-mm howitzer are—

BASE PIECE ADJUST
SHELL HE
LOT X
CHARGE 4
FUZE QUICK
BASE PIECE, 1 ROUND
CORRECTIONS 0
DEFLECTION 2850
SITE 305
ELEVATION 210
FIRE

b. Example of commands for zone fire, 105-mm howitzer, are—

BATTERY ADJUST
SHELL HE
LOT Y
CHARGE 5
FUZE QUICK
BATTERY 1 ROUND
ZONE 4 MILS
CORRECTIONS 0
DEFLECTION 2680
SITE 307
ELEVATION 268 (elevations 268, 272, and 264 will be fired)
FIRE

c. Example of commands and the methods used for firing a salute are as follows:

(1) *Commands.*

WITH BLANK AMMUNITION
21 (OR SO MANY) ROUNDS
BATTERY BY PIECE AT MY COMMAND, LOAD
NO. 1 FIRE
NO. 2 FIRE
NO. 3 FIRE
NO. 4 FIRE
NO. 5 FIRE
NO. 6 FIRE
NO. 1 FIRE
END OF MISSION (after the required number of rounds have been fired)

(2) *Method.* The method of fire may also be CONTINUOUS FIRE, RIGHT AT 5 (OR SO MANY) SECONDS. In this case it would not be necessary for the executive to command FIRE for each piece.

59. Cease Firing

The command CEASE FIRING normally is given by the executive but in an emergency may may be given by anyone present. This command is immediately repeated to the battery by the first individual receiving it. At the command, regardless of its source, firing will cease immediately. If this command originated from the observer or FDC and the piece is loaded, the executive reports No. 2 (OR OTHER PIECE) LOADED. If firing is stopped by someone at the position, the executive reports that fact and the reason therefor to the FDC. Firing is resumed at the announcement of elevation.

60. End of Mission

The command END OF MISSION means that the fire mission has been completed and, if a barrage has been assigned, the battery will lay on its barrage. However, the command CEASE FIRING, END OF MISSION may be used for added emphasis.

61. Repetition of Commands

a. By Chief of Section.

(1) *Voice communication.* Chiefs of sections repeat the commands FIRE and CEASE FIRING. Any other commands given by the executive are repeated only when requested, or when they obviously have not been heard or understood. The request for repetition is a question.

Example: DEFLECTION NO. (SO-AND-SO)? ELEVATION NO. (SO-AND-SO)?

(2) *Intrabattery communication.* When wire communication is used between the battery executive and the individual weapon sections, the repeat back of elements of the fire commands will be governed by unit SOP. Each chief of section must announce each element of the fire commands to his section.

b. By Executive Officer. The repetition of commands by the executive officer is always preceded by THE COMMAND WAS . . .

Example: THE COMMAND WAS DEFLECTION 2768.

62. Signals

A chief of section extends his right arm vertically, with palm of hand toward the executive (the *ready* position), to indicate that his piece is ready to fire. When he cannot be seen by the executive, he reports orally NO. (SO-AND-SO) READY. The commands FIRE and CEASE

FIRING usually are given by arm signals as well as by voice. The signal for FIRE is to drop the right arm sharply from the *ready* position to the side or to point with the right hand at the piece to be fired, extend the arm to the *ready* position, and drop it sharply to the side. The signal for CEASE FIRING is to raise the hand in front of the forehead, palm to the front, and swing hand and forearm up and down in front of the face. Another signal for CEASE FIRING is one long blast on a whistle.

63. Barrages

a. The battery barrage is designed to be fired quickly on a critical line. It is a high priority fire, usually taking precedence over all other fire missions. When the battery is not firing other missions, it is laid on its barrage and appropriately prepared rounds are kept by the pieces.

b. The barrage may be initiated by the command BARRAGE or by a prearranged signal. When personnel are resting, the piece sentinels begin firing immediately on the command BARRAGE or on receipt of the prearranged signal.

64. Reports

The executive reports to the FDC all actions that affect the firing of the battery. In addition to those reports previously mentioned (BATTERY IS READY, BATTERY IS LAID, CEASE FIRING), the following specific reports are made:

a. ON THE WAY (NO. 1 ON THE WAY)—when the first round of salvo, volley, zone, or other series of fire has been fired. This method is preceded by the piece that is firing only when information is necessary for coordination; for example, BY PIECE AT MY COMMAND.

b. ROUNDS COMPLETE—when the final round of fire for effect (other than one volley) has been fired.

c. MISFIRE NO. (SO-AND-SO)—when there has been a misfire. NO. (SO-AND-SO) IS READY—when again ready to fire, if fire mission has been completed.

d. NO. (SO-AND-SO) IS OUT (REASON)—when a piece has been called out.

e. Number of rounds expended, by type (and lot number when required)—at the completion of each fire mission.

f. Chiefs of sections must report immediately to the executive all errors that have caused a round to be fired with improper data. The executive has these errors corrected and reports to the FDC; e. g., NO. 2 FIRED 20 MILS RIGHT: ERROR HAS BEEN CORRECTED.

65. Checking Settings During Firing

The executive usually checks settings and laying during lulls in firing. When the executive questions the accuracy of the laying of any piece, he calls that piece out, reports to the FDC (par. 64*d*), and has the necessary checks made. When the battery is firing close to friendly troops, frequent checks must be made to insure safety.

66. Correcting Fire Commands by Executive Officer

a. If an incorrect command has been given but FIRE *has not been given,* the correct command is given preceded by CORRECTION.

b. If FIRE has been given, the executive will announce CEASE FIRING. He will then give the proper commands, the elevation, and repeat the command FIRE.

CHAPTER 5
FIRING BATTERY PROCEDURES

Section I. LAYING THE BATTERY

67. Introduction

Training, control, and operation of the firing battery involve the use of procedures and various terms that must be understood by all personnel concerned. This chapter presents the systems and techniques and the terms and definitions that must be understood and observed by proficient artillerymen.

68. Reciprocal Laying

Reciprocal laying is a procedure by which the 0–3200 line of an instrument (aiming circle, etc.) and the axis of the tube of a weapon are laid parallel, or the tube of one weapon is laid parallel to another and in the same direction, or the 0–3200 line of one instrument is laid parallel to another. This procedure is based on the following geometric principle: If parallel lines are cut by a transversal, the alternate interior angles are equal. The line of sight between an instrument and a weapon sight is considered as the transversal. When the scale readings of the two are equal when they are sighted on each other, the 0–3200 line of the instrument and that of the sight will be parallel (fig. 36). The methods in *a* through *c* below may be used in reciprocal laying.

a. Reciprocal Laying by Means of an Aiming Circle.

(1) *Procedure.* The 0–3200 line of the instrument is established in the desired direction. The operator, using the upper motion, turns the head of the aiming circle until the line of sight is on the panoramic telescope of the piece (objective lens), reads the azimuth scale (scale with smaller numbers because deflection is never greater than 3,200 mils) and the azimuth micrometer scale, and announces the reading as a deflection. Setting off

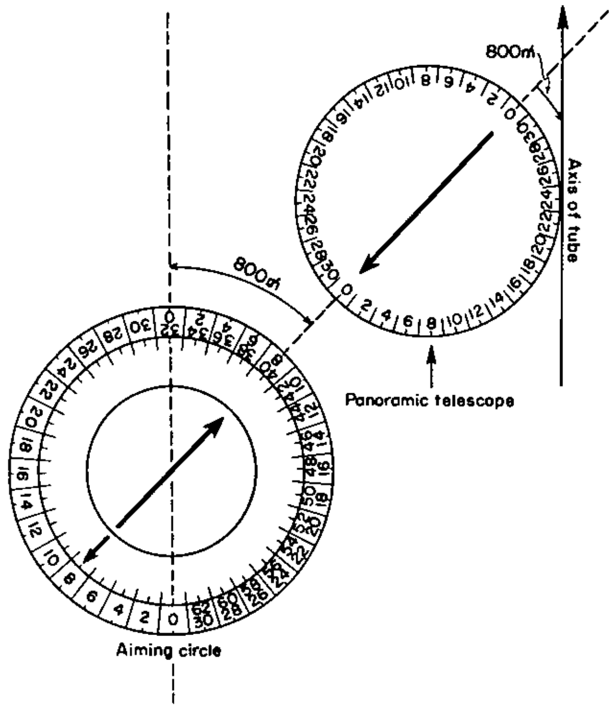


Figure 36. Reciprocal laying.

this deflection on the sight, the gunner lays on the instrument (objective lens) and announces NO. (SO–AND–SO), READY FOR RECHECK. The line of sight of the instrument is again referred back to the panoramic telescope, and a deflection is announced. This process is repeated until the gunner reports no difference between successive deflections announced by the operator.

(2) *Commands.* The following commands are used in laying a battery parallel by means of an aiming circle:
Executive: BATTERY ADJUST, AIMING POINT THIS INSTRUMENT.

All gunners identify the aiming point. (It is desired to lay the center platoon first.)

Gunner of No. 3: NO. 3, AIMING POINT IDENTIFIED.

Executive: The executive by using the procedures in (1) above determines the deflection to No. 3 and announces NO. 3, DEFLECTION 3091.

Gunner of No. 3: NO. 3, DEFLECTION 3091. The gunner assures that the tube is approximately in the center of traverse. He sets this deflection on the panoramic telescope of the piece and causes the trails to be shifted until he can sight approximately on the aiming circle. He then traverses the tube until he is sighted exactly on the aiming circle.

Executive: NO. 4, DEFLECTION (SO MUCH). The executive continues giving readings until each piece has been given a deflection. By this time the gunner of No. 3 has completed his laying with deflection 3091 and announces NO. 3, READY FOR RECHECK.

Executive: Sights (refers) the aiming circle again on the sight of No. 3 and commands NO. 3, DEFLECTION 3093.

Gunner of No. 3: NO. 3, DEFLECTION 3093, 2 MILS. This indicates a difference of 2 mils from the original deflection of 3091 which the gunner now has on the panoramic telescope. Therefore, the gunner sets 3093 on the telescope and again traverses the tube until he is sighted on the aiming circle. The gunner then states NO. 3, READY FOR RECHECK.

Executive: Having rechecked some or all of the other pieces, turns the head of the aiming circle, using the upper motion, until the line of sight is on the telescope of No. 3 and announces NO. 3, DEFLECTION 3093.

Gunner of No. 3: NO. 3, DEFLECTION 3093, 0 MILS. (Rechecking of each piece must continue in this manner until the deflection announced by the executive and the deflection on the panoramic telescope are identical.)

Executive: NO. 3 IS LAID, AIMING POINT, AIMING POSTS, DEFLECTION 2800, REFER. (Aiming post deflection will vary with the weapon.)

b. Reciprocal Laying by Means of the Telescope of a Piece. The tube of No. 2 piece having been laid in the desired direction, the gunner refers to the telescope of No. 1 piece which is pointed in the same general direction and reads and announces the deflection on the No. 2 piece telescope. The gunner of No. 1 piece sets the announced deflection on the No. 1 piece telescope and lays on the telescope of No. 2 piece (center of traverse). No. 1 and No. 2 recheck; the gunner of No. 1 re-lays if necessary, and, when the two telescopes are sighted on each other with the same deflection settings, the pieces are laid parallel. The process may be repeated for as many pieces as are visible through the telescope of No. 2 piece, or No. 1 piece may lay others reciprocally. This method should not be employed when it is possible to lay all pieces parallel by using a single aiming circle. The command is ON NO. 2 (OR OTHER PIECE), LAY PARALLEL.

c. Orienting an Aiming Circle by Means of a Piece. The tube of a piece is laid for direction, and it is desired to point the 0–3200 line of an aiming circle in a parallel direction. The operator of the aiming circle commands NO. 3, AIMING POINT, THIS INSTRUMENT, REFER. The No. 3 gunner refers to the aiming circle and announces the deflection on the No. 3 piece telescope. The operator of the aiming circle sets this deflection on the scales of the aiming circle and then turns the lower motion until he is sighting on the telescope of the piece. The 0–3200 line of the aiming circle is now parallel to the axis of the No. 3 piece tube. This process is used in executing the commands MEASURE AZIMUTH and MEASURE ORIENTING ANGLE.

69. Initial Laying of Battery for Direction

a. The battery may be laid initially by an azimuth; an orienting angle; an aiming point and a deflection; or sighting on an airplane, a high air burst, or a flare. Upon occupying position, when only a general direction of fire has been designated, the executive does not await directions for laying the battery. He lays it parallel on an arbitrary direction as nearly as possible in the center of the zone of fire and with the pieces approximately in the center of traverse. When he receives an order to lay the battery on a different direction, he need only command a new deflection and realine the aiming posts. To facilitate subsequent laying, he should lay the battery initially on an azimuth which is a multiple of 100 mils.

b. If it is impracticable to place the aiming circle so that it is visible from all pieces, the following methods are appropriate:

(1) When a part of the battery is *not* visible from the aiming circle and *none* of the pieces are intervisible, the executive lays the visible part of the battery with the aiming circle. He then uses the aiming circle to lay a second aiming circle placed so that it will be visible to the remainder of the battery. Using the second aiming circle, he lays the other pieces.

(2) When a part of the battery is not visible from the aiming circle but the pieces in this part and *one or more* pieces visible from the aiming circle are intervisible, the executive lays the visible part of the battery with the aiming circle. The piece (pieces) visible from the remainder of the battery then lays the other pieces reciprocally.

70. Laying for Direction by Grid Azimuth (Aiming Circle Method)

a. The command to the executive to lay the battery by grid azimuth is LAY ON AZIMUTH (SO MUCH). This command is not repeated.

b. The aiming circle is set up at a point which is—

(1) Away from all magnetic attractions.

(2) Preferably visible from the sights of all pieces.

c. The executive subtracts the announced azimuth from the declination constant, adding 6,400 if necessary; for example—

(1) Declination constant is 200.

(2) Announced azimuth is 4,000.

200	Declination constant
+6, 400	
6, 600	
−4, 000	Announced azimuth
2, 600	Clockwise angle between the announced grid azimuth and magnetic north.

d. Using the upper motion, the executive sets the result (2,600) on the azimuth scale and azimuth micrometer scale of the aiming circle and centers the needle by using the lower motion. The 0–3200 line of the aiming circle now is directed to the desired azimuth of 4000.

e. Subsequent procedure and commands are similar to those in paragraph 68*a*.

71. Laying for Direction by Grid Azimuth (M2 Compass Method)

a. The command to the executive to lay the battery by grid azimuth is LAY ON AZIMUTH (SO MUCH). This command is not repeated.

b. The executive places the compass on a steady object, away from objects which might affect the needle, and in a place where it can be used as an aiming point for the base piece. He then—

(1) Measures the grid azimuth to the telescope of the base piece.

(2) Subtracts the announced grid azimuth from the grid azimuth which he measured (adding 6,400 if necessary).

(3) Uses the remainder (minus 3,200 if necessary) as the deflection and the compass as an aiming point, to lay the base piece (fig. 37).

Note. The commands are similar to those in paragraph 68*a*(2).

72. Laying for Direction by Orienting Angle

a. The command to the executive to lay the battery by orienting angle is LAY ON ORIENTING ANGLE (SO MUCH). This command is not repeated.

b. The executive sets up the aiming circle (or other fire control instrument) over the orienting station or other point on the *orienting line* where it can be seen from all pieces. The executive must be certain that he has identified the stakes or points which mark the orienting line and knows the general direction of fire.

c. Using the upper motion, the executive sets the announced orienting angle on the azimuth scale and azimuth micrometer scale of the instrument.

d. Using the lower motion, the executive sights on one end of the orienting line. This places the 0–3200 line of the instrument *parallel* to the direction in which the pieces are to be laid.

Caution: The general direction of fire must be known. If this operation causes the 0–3200 line (line of sighting) of the instrument to be in the opposite direction from the direction of fire, the

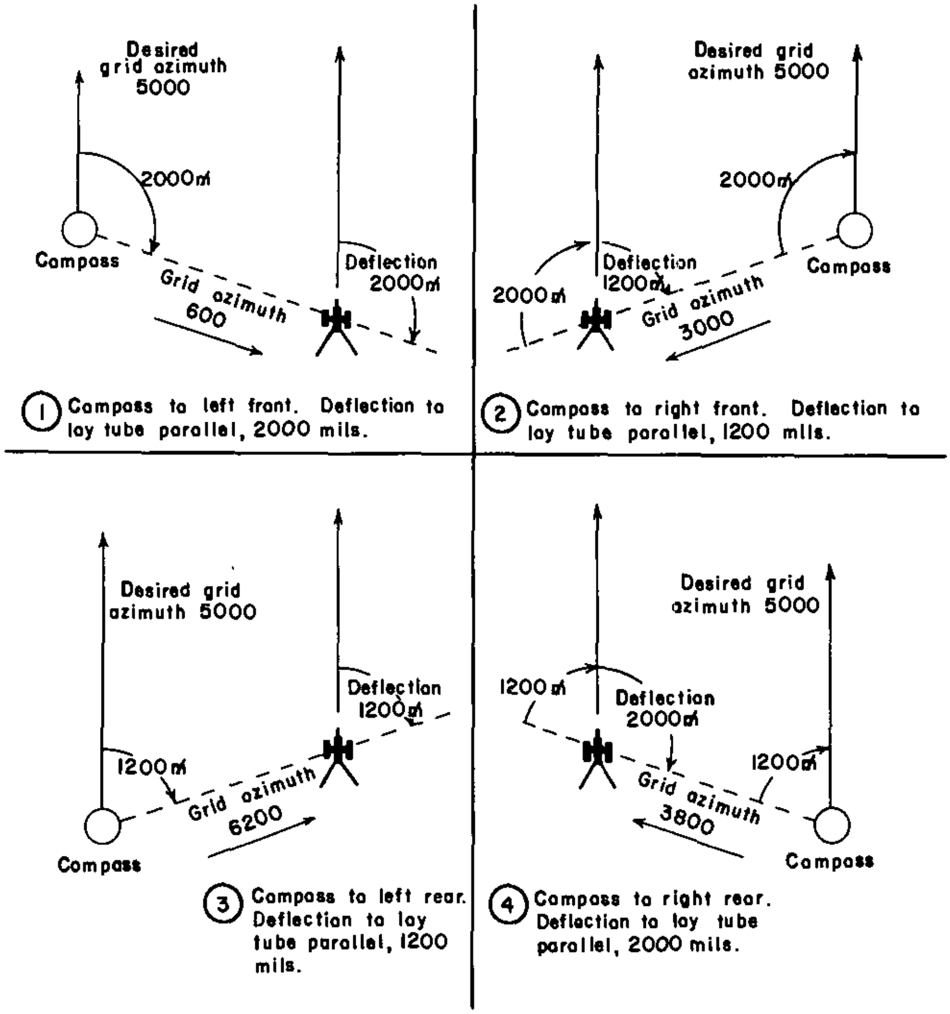


Figure 37. Use of M2 compass to lay by grid azimuth.

instrument line of sighting must be turned 3,200 mils.

e. Subsequent procedure and commands are similar to those in paragraph 68*a*.

73. Other Methods of Laying for Direction

a. Laying by Aiming Point and Deflection. The command to the executive to lay the battery by aiming point and deflection is AIMING POINT (SO-AND-SO), DEFLECTION (SO MUCH).

(1) *By using the aiming circle.*

(*a*) The executive does not repeat the command. The executive sets up the aiming circle within communicating distance of the pieces and where the aiming point is visible.

(*b*) With the upper motion, the executive sets the deflection announced on the azimuth and azimuth micrometer scales of the instrument.

(*c*) Using the lower motion, the executive turns the head of the aiming circle until the line of sight is on the aiming point. This action orients the 0–3200 line in the desired direction (fig. 38).

(*d*) The executive then lays the pieces reciprocally (par. 68*a*).

(2) *By using a panoramic telescope.*

(*a*) The executive repeats the command to the base piece.

(*b*) The gunner sets the deflection on the telescope of the piece and sights on the aiming point by traversing the tube. This action lays the tube of the base piece in the desired direction.

(*c*) The executive commands ON NO.

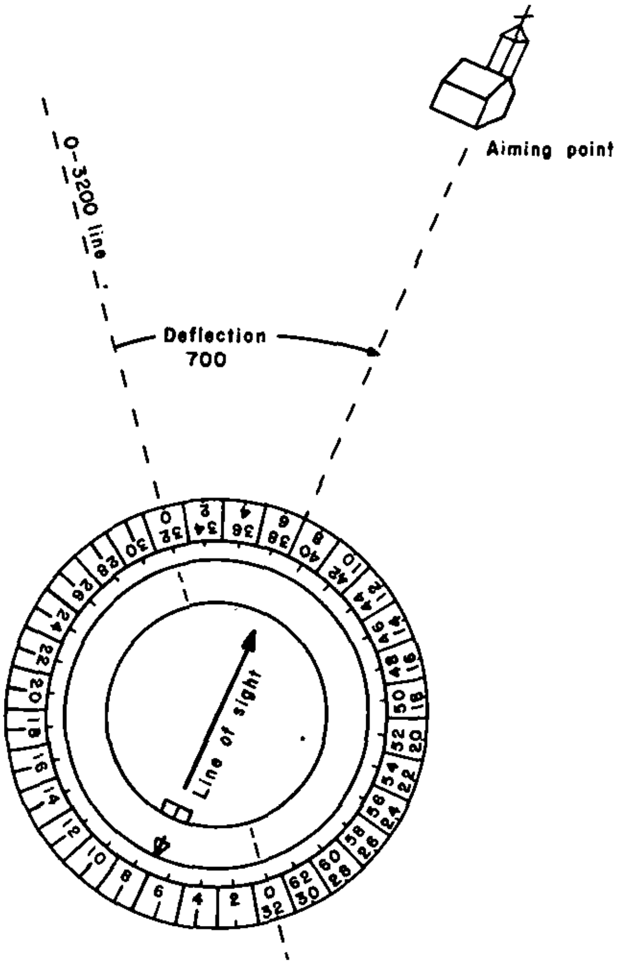


Figure 38. Laying by aiming point and deflection, aiming circle method.

(BASE PIECE), LAY PARALLEL.

(*d*) The gunner of the base piece lays the other pieces reciprocally (par. 68*b*).

(3) *By individual shifts.*

(*a*) The executive repeats the command to the battery. All pieces are laid on the aiming point with the announced deflection set on their telescopes.

(*b*) If the aiming point is to the front, the sheaf is converged at aiming point range in the target area, as shown by the exaggerated diagram (fig. 39①). The convergence is corrected and sheaf is formed parallel (opened, in this case) by means of individual shifts (fig. 39②).

Example: It is desired to form the sheaf parallel on the No. 3 piece (fig. 39). The shifts are determined for each piece by the mil relation (par. 155*d*), R being the range to the aiming point and W the perpendicular distance from the piece concerned to a line through the aiming point and No. 3 piece.

(*c*) If the aiming point is to the rear, the sheaf will diverge (fig. 40). Individual shifts are computed as in (*b*) above to form the sheaf parallel.

b. Initial Laying by Aircraft, High Air Burst, or Flare.

(1) No specific command is prescribed for laying the battery by sighting on aircraft, air burst, or flare. The executive may lay the battery initially for direction by sighting with an instrument on the aircraft, high air burst, or flare. When no visible point is suitable for use as an aiming point, an aircraft may be employed to fly over the battery position towards, or away from, a point in the target area. The line of flight is used to establish a line of direction. The high air burst or flare should be over the target area. The high air burst is fired by another unit, which has been laid previously for direction. The flare may be fired by an air or a ground observer.

(2) The executive sets up an instrument (usually in rear of the battery center) where it can be used as an aiming point by all pieces. The executive zeros the azimuth and the azimuth micrometer scales, and, by using the lower motion, places the vertical hairline on the aircraft, burst, or flare at the proper instant. Using the upper motion, the executive lays the pieces reciprocally (par. 68*a*).

74. Verifying Laying for Direction

a. After the battery has been laid, the executive will verify the laying to insure proper direction and parallelism.

b. If time permits, the executive may make the following check:

(1) With the aiming circle (or instrument used to lay the battery initially) still set up, the executive commands NO (BASE PIECE), AIMING POINT THIS INSTRUMENT, REFER.

(2) The gunner of the piece indicated turns the sight of the piece until the line of sight is on the designated instrument and announces the reading on the sight scale

as NO. (SO-AND-SO), DEFLECTION (SO MUCH).

(3) The executive sets this reading on the azimuth and azimuth micrometer scales of his instrument and with the lower motion sights on the panoramic telescope of the piece indicated, thus establishing the 0–3200 line of his instrument parallel to the direction of fire. He can now verify the azimuth (orienting angle) (deflection).

(4) The executive repeats the command in (1) above to the other pieces in turn, checking the deflection of each.

(5) If the deflection read by the gunner does not agree with that read by the executive, he can correct the laying of that piece for direction by giving the gunner the proper deflection.

(6) The executive should also make a visual check, lining in the tubes with a point on the horizon to insure that gunners have not used the wrong aiming point. The executive should be able to determine visually large errors in laying for direction by comparing the direction in which the tubes are pointed.

c. If time does not permit the entire check prescribed in *b* above, a quick check may be made by

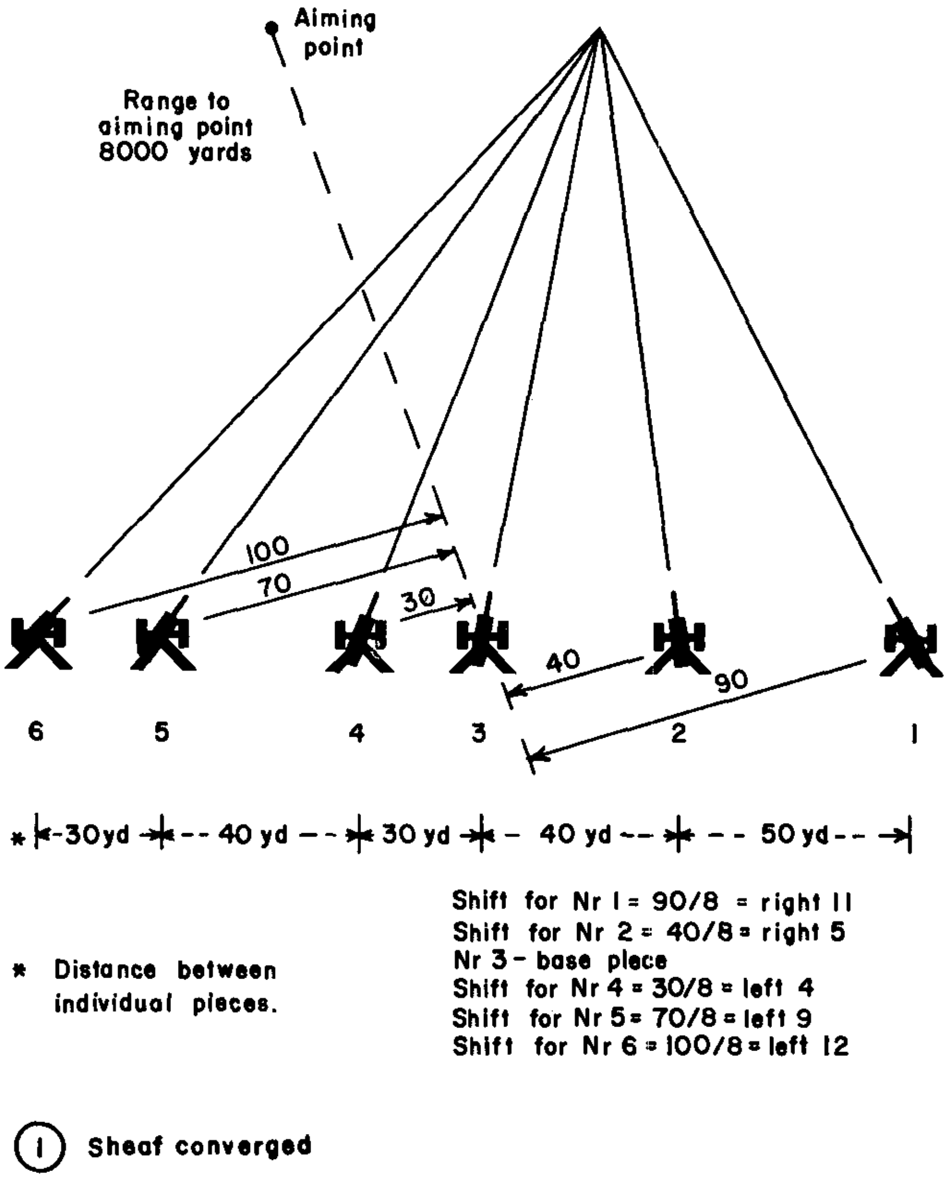
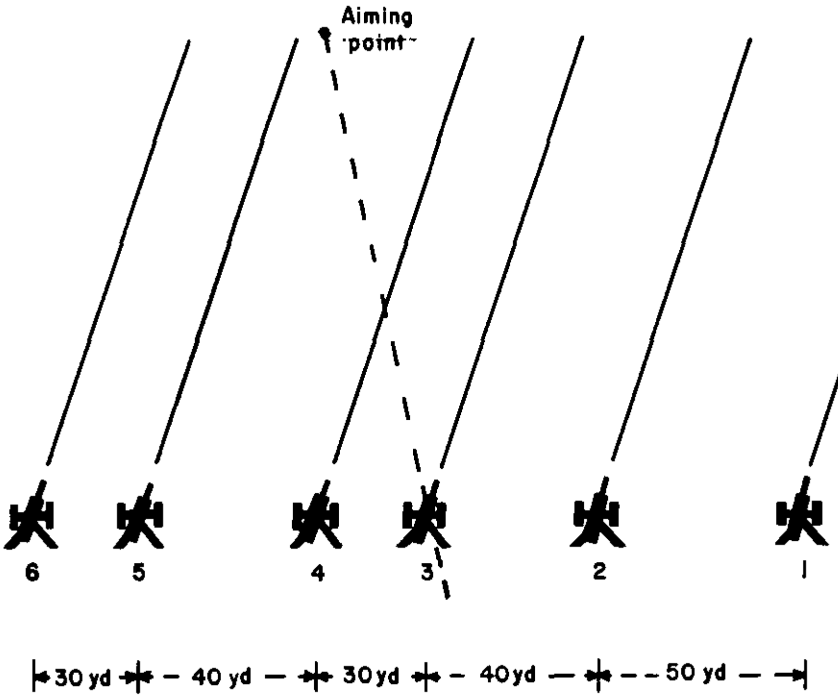


Figure 39. Opening a converged sheaf by individual shifts to obtain a normal sheaf.



(2) Normal sheaf

Figure 39—Continued.

having all pieces referred to a common distant aiming point. The referred readings of all pieces should agree within a few mils; the exact difference may be determined by the mil relation.

d. A knowledge of the general direction of fire and a visual check of the laying is the minimum essential verification.

75. Recording Laying for Direction

a. Once the battery has been laid parallel, the executive will have each piece referred to an aiming point, usually the aiming posts, with a common deflection. The command is AIMING POINT, AIMING POSTS, DEFLECTION (SO MUCH), REFER. Without traversing the tube, the gunner of each piece will set the announced deflection on the panoramic telescope and have aiming posts set out along this line. The gunner, after executing the above command, reports NO. (SO-AND-SO), DEFLECTION (SO MUCH). It is highly desirable to have the far aiming post at least 100 yards from the piece. Regardless of the distance at which the far aiming post is set, the near aiming post *must* be exactly one-half the distance to the far aiming post. When a distant common aiming point is used, the differences in deflection from the deflection of the base piece are applied by adjusting the slipping micrometer scale on the panoramic telescope. This adjustment provides a common deflection for all pieces when laid parallel.

b. The deflections which keep misalinement of the aiming posts to a minimum and are found to be the most convenient as the piece is traversed are shown below:

Weapon	*Deflection*
75-mm howitzer	2,200.
105-mm howitzer	2,600 or 2,800.
4.2-inch mortar	2,800.
155-mm howitzer	2,400 (M44–600).
155-mm gun	2,600 (M53–600).
8-inch howitzer	2,600 (M55–600).
8-inch gun	2,200.
240-mm howitzer	2,200.
280-mm gun	2,200.

c. If the aiming posts of the piece cannot be placed on the common deflection announced because of ground contour, foliage, trees, or other conditions, the gunner, supervised by the chief of section, turns the azimuth micrometer knob until the slipping azimuth scale is on another even 100-mil graduation. The aiming posts are alined at this new deflection. The chief of section reports the altered deflection to the executive: "No. (so-and-so) aiming posts at (so many hundred), deflection (common deflection) in lake (or other reason)." The executive will then command NO. (SO-AND-SO), DEFLECTION 2800, REFER. At this command, the gunner loosens the slipping azimuth scale locking screw and moves the slipping azimuth scale to the common deflection. He then tightens the locking screw and verifies the adjustment.

d. If a piece *is not* equipped with a slipping scale on the sight and the crew is unable to place its aiming posts on the common deflection announced because of ground contour, foliage, trees, or other conditions, the chief of section determines the deflection at which the piece can be referred to aiming posts and the posts are alined at this deflection. The chief of section reports this deflection to the executive and the reason therefor; e. g., "No. (so-and-so), aiming posts at deflection (so much), deflection 2,800 in ravine." (This deflection should be a multiple of 100 mils.) The gunner then determines the constant correction for the piece and applies it to any deflection commanded by the executive. This constant should be recorded by the gunner and the battery recorder.

Example: The battery has been laid and commanded to refer to aiming posts at deflection 2,800. All gunners can comply, except the gunner of No. 2 piece, whose visibility is blocked by foliage. No. 2 piece gunner has emplaced the aiming posts at 2,400 and reported this data to the executive. The constant correction for No. 2 piece is, therefore, minus 400 (2,400—2,800). The executive now gives the command for a fire mission, which includes DEFLECTION 2912. All pieces in the battery except No. 2 are laid on the announced deflection 2,912. No. 2 is laid on deflection 2,512 (2,912—400).

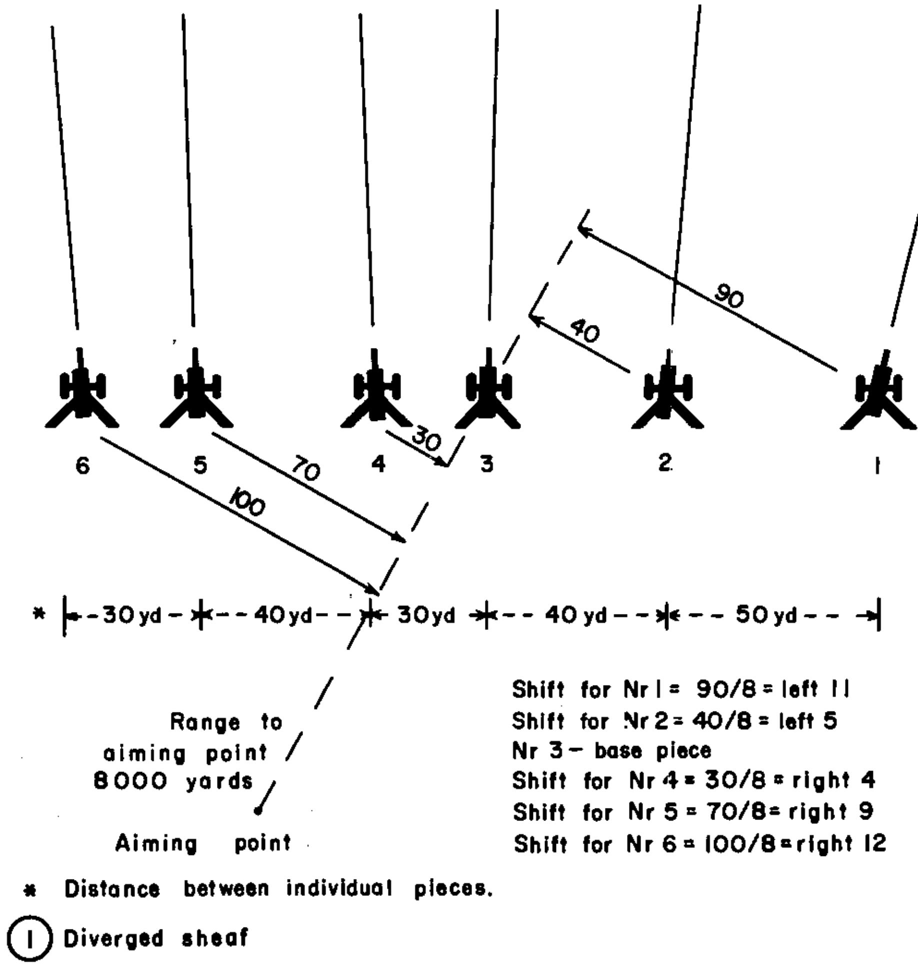


Figure 40. Closing diverged sheaf by individual shifts to obtain a normal sheaf.

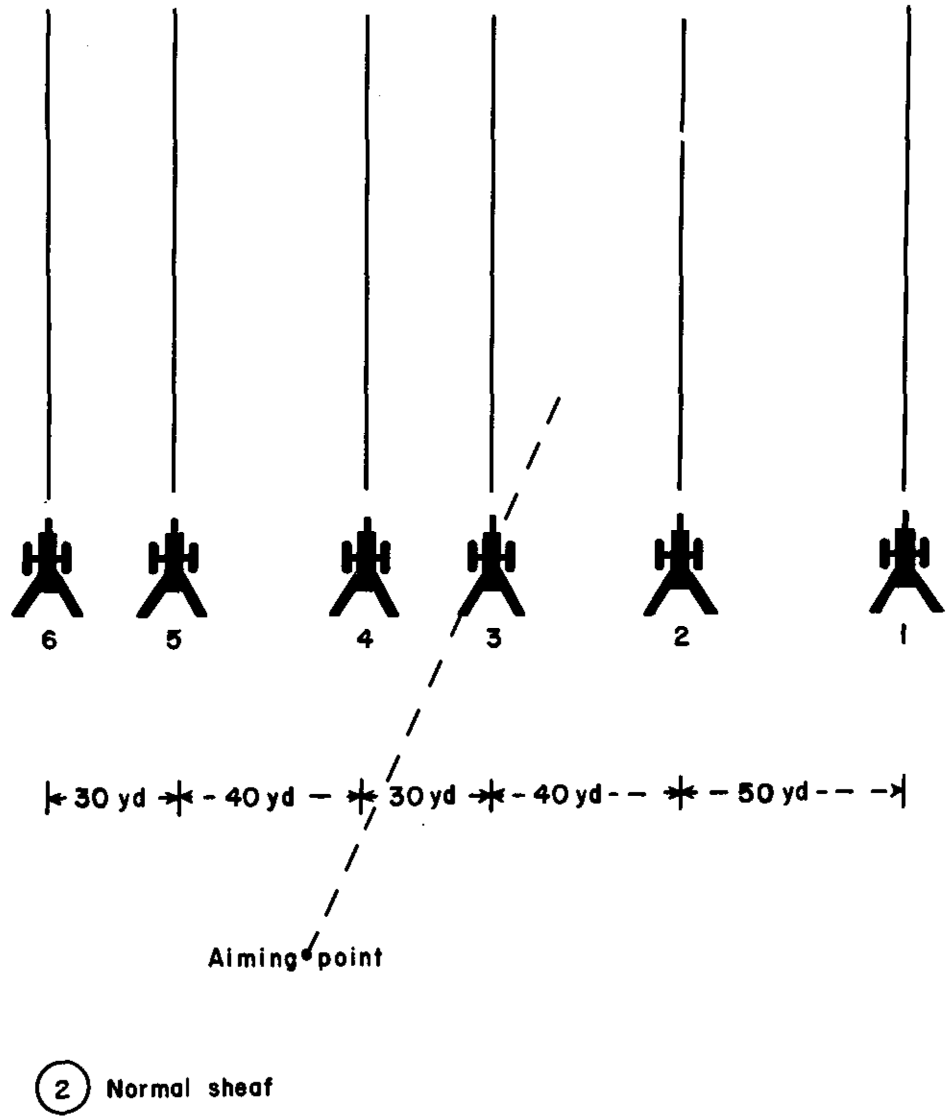


Figure 40—Continued.

e. As soon as the battery has been laid parallel and referred to aiming posts, the executive will have the gunners of all pieces refer to a distant aiming point. For example, he may command AIMING POINT, STEEPLE, RIGHT FRONT, REFER, RECORD REFERRED DEFLECTION. The gunners refer to the steeple and read and report the deflection; e. g., NO. 3, STEEPLE, DEFLECTION (SO MUCH). These deflections are recorded by the chief of section and the battery recorder for future use. Should the aiming posts of any section be rendered useless, the executive can maintain parallelism and control of direction by using this deflection and aiming point. This information is used for reemplacing the aiming posts at the earliest possible time.

Section II. DETERMINING MINIMUM ELEVATION (ME)

76. Introduction

The safe firing of a battery is the responsibility of the executive (AR 385-63). In garrison firing, the officer in charge of firing is assisted by a safety officer. The safety officer is responsible for insuring that persons and property are not endangered by the fire. One of the prime considerations in safe firing is the determination of minimum elevation. Such determination is necessary in order to clear terrain masks surrounding the battery position and to insure the safety of friendly forces which may be occupying the terrain in question. Minimum safe ranges and no-fire lines to protect friendly elements are determined at the FDC and/or higher headquarters. Determination of elevation to insure rounds clearing established minimum safe ranges is a responsibility of the FDO in combat and the safety officer in garrison. This section sets forth the procedures required to clear crests in the firing battery area.

77. Responsibility for Computing Minimum Elevation

a. Minimum Elevation to Clear Mask Visible From Battery Position. The executive will determine and report to the FDC the minimum elevation to clear the mask visible from the battery position. The minimum elevation must be computed for each charge to be fired, the computation varying with the fuze employed (pars. 80, 81, and 82).

b. Minimum Elevation to Clear Crests not Visible From Battery Position. A corrected minimum elevation based on clearance of crests beyond the visible mask may be transmitted to the executive from the FDC. The executive will then use the corrected minimum elevation.

c. Modification of Minimum Elevation. For additional safety, the need to modify minimum elevation(s) by all known weather and calibration corrections must be considered in the FDC. These corrections cannot be ignored without endangering friendly elements close to the trajectory. Determination and application of corrections are explained in chapter 19.

78. Measuring Angle of Site to Mask

As soon as a piece is laid for direction, the chief of section determines the angle of site to the highest mask for his piece, as prescribed in the field manual appropriate for the weapon, and reports it to the executive.

79. Measuring Range to Mask

Range to the mask may be determined by one of the following methods:

a. Obtaining Distance From a Map. To obtain distance to a mask from a map, plot the location of the position area and determine the highest point of the mask. Measure the distance with an appropriate scale. This method is fast and accurate and is not affected by adverse terrain features as in *b* and *c* below.

b. Pacing the Distance. Pacing the distance to a mask requires no equipment; time to complete measuring the range will depend on distance to mask and accessibility of route to mask.

c. Taping. Taping the distance to a mask is accurate but time-consuming and is used only when time and terrain permit.

d. Use of the Mil Relation. Determining the range to a mask by using the mil relation is a particularly good method when the tactical situation does not permit actual measurement by one of the methods in *a* through *c* above. The mil relation method may be accomplished by the use of the panoramic telescopes of the flank pieces, by 1 aiming circle and 1 panoramic telescope, or by 2 aiming circles. Usually, the most practical means is the use of the panoramic telescopes of the flank pieces. For example (fig. 41), the battery has been laid parallel; the paced distance between flank pieces is 150 yards.

(1) The gunners of the flank pieces refer to exactly the same point on the crest.

(2) Each of the flank gunners announces the deflection to the point on the crest from his piece.

(3) The apex angle is determined from these two deflections as indicated in figure 41.

(4) The range in thousands of yards to the mask is determined by dividing the battery front in yards by the apex angle in mils, applying the mil relation.

80. Computation of Minimum Elevation for Firing Projectiles With Fuzes M51 and M500

a. Elements involved in the computation of minimum elevation for firing projectiles with fuzes M51 and M500 (fig. 42) are as follows:

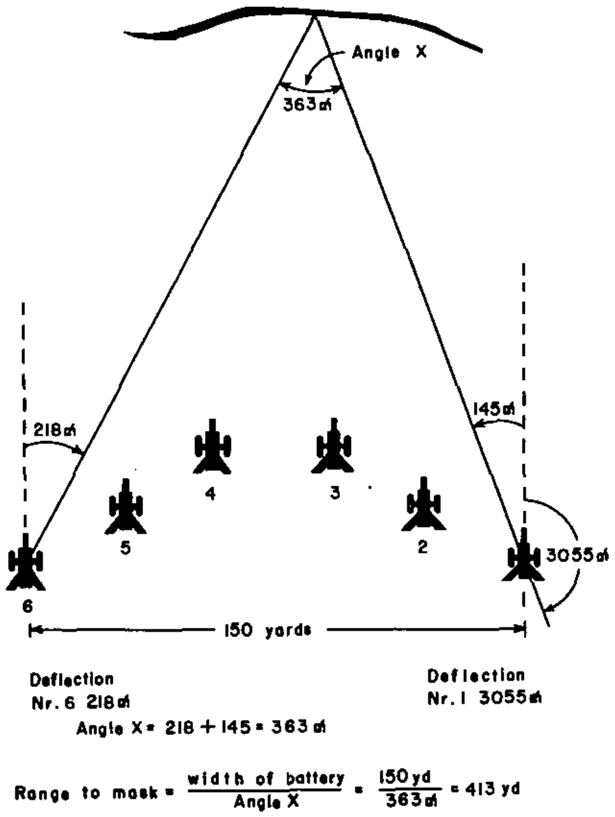


Figure 41. Determining range to mask.

(1) *Angle 1.* Greatest angle of site as measured by the chiefs of section.

(2) *Angle 2.* Vertical clearance of friendly elements (5 yards at mask range).

(3) *Angle 3.* Comp site (comp site factor for appropriate charge at mask range x (angle 1+angle 2)).

(4) *Angle 4.* Elevation for mask range, using appropriate charge(s).

(5) *Angle 5.* Two forks at mask range, using appropriate charge(s).

b. In determining the value of elements in the computation of minimum elevation for firing projectiles with fuzes M51 and M500 (assume range to mask to be 1,100 yards; minimum elevation to be computed for 105-mm howitzer, charge 3), the executive—

(1) Selects the greatest angle of site (angle 1) to the mask reported by the chiefs of sections	+16.0m̸
(2) If the mask is occupied or is to be occupied by friendly troops (always assumed in the absence of information to the contrary), adds the value in mils (angle 2) of a height of 5 yards at the piece mask range (using mil relation 5 yards/1.1)	+4.5m̸
(3) Adds the comp site (angle 3) for the piece mask range for the sum of angle 1 and angle 2. (Tabular firing table 105–H–4, page 46, column 16, range 1,100 yards gives value of comp site for each 1 mil of site to be +.01 mil.) Angle 1+Angle 2=16+4.5 or 20.5 Angle 3=20.5 x +.01 or	+0.2m̸
(4) Determines elevation for piece mask range (angle 4) from tabular firing table 105–H–4, page 46, column 2	+91.7m̸
(5) Adds two forks at piece mask range (angle 5) from tabular firing table 105–H–4, page 46, column 4	+6.0m̸
Total	+118.4m̸

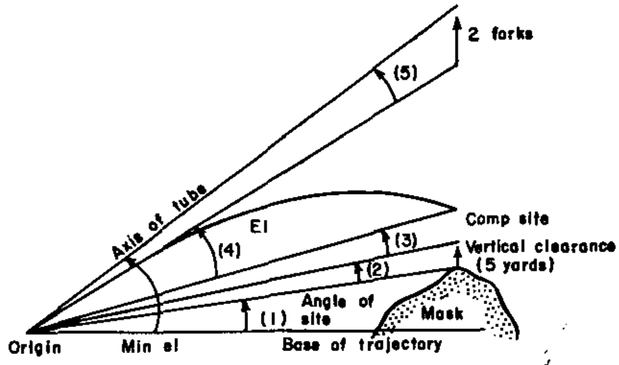


Figure 42. Minimum elevation, except VT.

c. On completion of the computation of minimum elevation, the executive will report the minimum elevation for each charge to the FDC. If the sum is fractional, he reports it as the next higher whole mil. From the computations in *b* above, the executive reports the minimum elevation for charge 3 to be 119.

d. Sometimes it will be necessary to determine more than one minimum elevation for the sector of five. In this case, the executive reports, for example: AZIMUTH 4850 to 5200, MINIMUM ELEVATION CHARGE 3, 100; AZIMUTH 5200 to 5650, MINIMUM ELEVATION CHARGE 3, 119.

e. A single narrow obstruction, such as a tree, which will mask only one piece at a time, is not considered in computing minimum elevation. If a piece cannot fire safely, it is called out of action.

81. Computation of Minimum Elevation for Firing Projectiles With VT Fuzes (Low-Angle Fire)

a. Minimum Elevation. The method of computing minimum elevation for firing projectiles fuzed with T226 (M513) or T227 (M514) fuze, or their modifications, depends on the method of employing the fuze.

(1) If the projectile is to be fired with a time setting on the fuze corresponding to the time of flight to the target, ME is computed as for fuze M500 (par. 80). Minimum elevation computed in this manner requires that the minimum time setting for VT fuzes be greater than the time of flight to the piece mask range plus 5.5 seconds.

(2) If the projectile is to be fired with the fuze set on the 0 setting line or set on a time smaller than minimum time in (1) above, the ME is computed by the method in paragraph 82.

Note. If the urgency of the situation is such that time is not available to apply a time setting to each fuze, projectiles with fuzes T226 (M513) or T227 (M514) may be fired as shipped, on the 0 setting. Projectiles fired with fuzes at this setting will become fully armed 2 seconds after firing. Models with a safety setting are completely inoperable when set on S.

(3) If the projectile is to be fired with fuze T226E2 (M513E2) or T227E2 (M514E2) set on point detonating (PD), the ME is determined as for any PD fuze.

b. Crest Clearance. There is little danger in firing VT fuzed projectiles over friendly territory except in clearing crests. An armed VT fuze will function on passing within activating proximity to a terrain obstruction, such as a crest or ridge. The fuze will not function if arming can be delayed until the shell has passed the crest. To insure delayed arming, the time setting must be at least 5.5 seconds more than the time of flight to the crest (fig. 43) or the elevation must be greater than the minimum elevation computed as set forth in paragraph 82. This fuze when set for delayed arming will function upon impact with the crest or ridge.

c. Angle of Fall. When projectiles are approaching the target at small angles of fall, the area between the point of full arming of the VT element and the target may be sprayed by fragments from occasional early bursts; at larger angles of fall, these early bursts do not constitute a

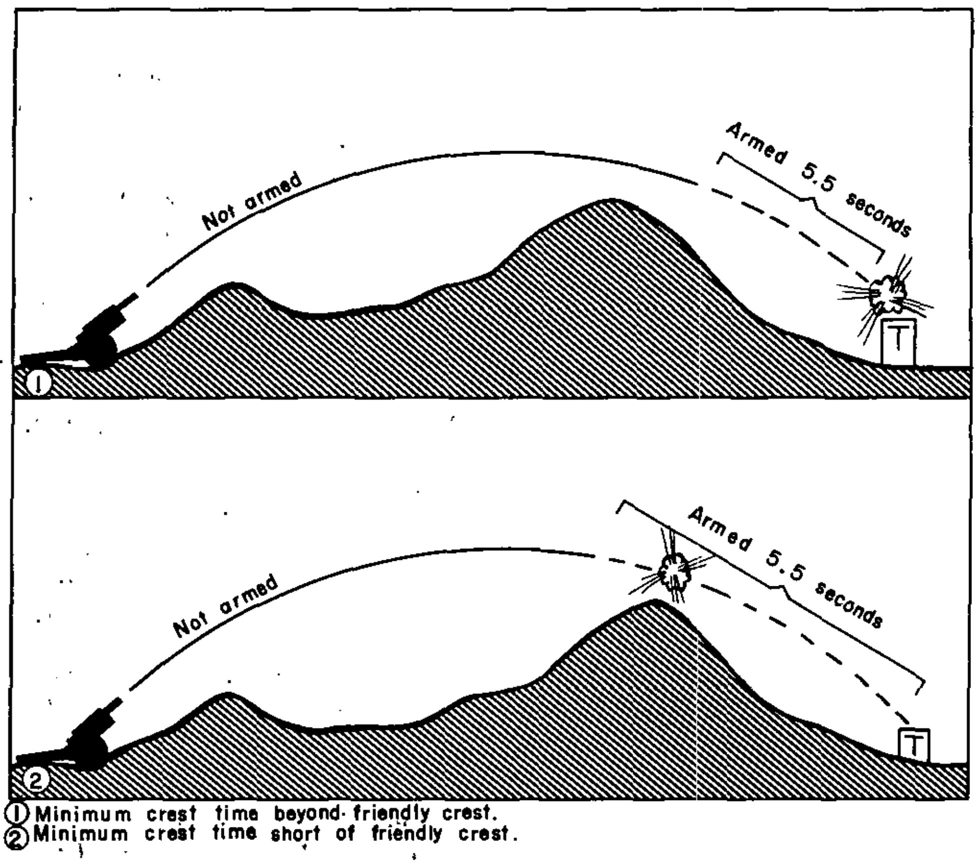
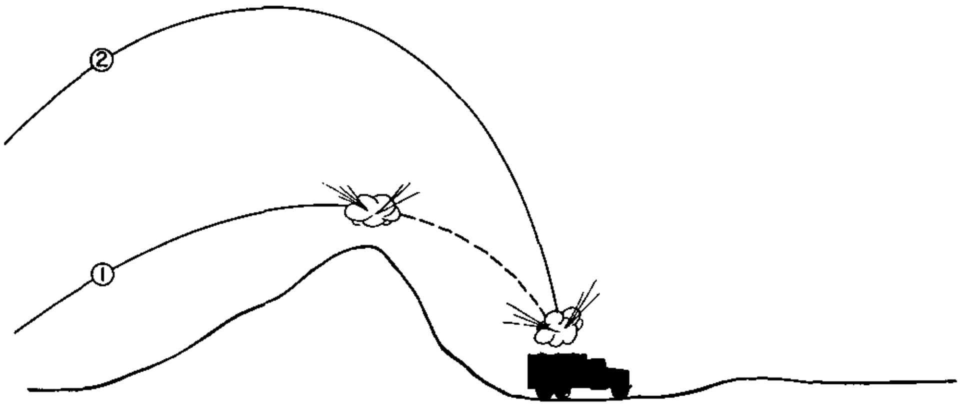


Figure 43. Crest clearance, delayed arming VT fuze.



① Small angle of fall--insufficient crest clearance

② Large angle of fall--sufficient crest clearance

Figure 44. Normal functioning of VT fuzes relative to angle of fall and crest clearance.

serious hazard. Figure 44 illustratest he normal functioning of VT fuzes.

d. Proximity to Friendly Troops. Caution should be used in firing projectiles with VT fuzes at targets extremely close to friendly positions. VT fuzed projectiles may burst at varying points, along the trajectory after arming takes place resulting in a somewhat larger fragmentation pattern. The tactical situation, terrain, and angle of fall are factors to be considered in this connection. For a more detailed discussion on the fuze, see TB ORD 419.

82. Computation of Minimum Elevation for Firing Projectiles With VT Fuzes Based on Arming Time

a. When a projectile is fired with VT fuze set on the 0 setting line or on a time lesser than the time to the piece mask range plus 5.5 seconds, allowance must be made for vertical clearance of friendly elements beyond the range corresponding to the minimum arming time of the fuze. Vertical clearances when low-angle fire is used are—

Weapon	*Vertical clearance*
75-mm howitzer, 90-mm gun	70 yards.
105-mm howitzer	80 yards.
155-mm howitzer and gun	100 yards.
8-inch howitzer and gun, 240-mm howitzer, and 280-mm gun.	150 yards.

b. If the terrain is marshy or wet, detonation occurs at an increased vertical distance; therefore, for safety, the vertical clearance should be increased by 50 percent. For firing over water, the vertical clearance should be increased by 100 percent.

c. The minimum arming time (2 seconds time of flight) is converted into a minimum arming range. This range, being directly affected by muzzle velocity, will vary for different weapons and charges. The range so determined is compared to the piece mask range in determining the final minimum safe elevation.

Note. Minimum arming time for M96 and M97 fuzes is 5 seconds.

d. Arming time range is always considered as that range which corresponds to a time of flight of 2 seconds for a given charge. Column 5, tabular firing table 105–H–4, gives the time of flight for the 105-mm howitzer projectile. To determine the arming time range, enter the tables for the particular charge, locate a time of flight of 2 seconds in column 5, and determine range corresponding to the arming time range in column 1. If an exact time of flight of 2 seconds is not shown in column 5, as in case of charge 5, the range corresponding to the next greater time of flight (2.1) must be used. The arming time range to be used would be 700 yards.

e. The executive must determine the arming time range before beginning his computation of minimum elevation for firing a projectile with a VT fuze.

(1) If the piece mask range is equal to or greater than the minimum arming range (fig. 45), the executive will determine and report the minimum elevation for the mask based on the piece mask range.

Example: 105-mm howitzer, charge 4, piece mask range, 1,700 yards, minimum arming time range 600 yards.

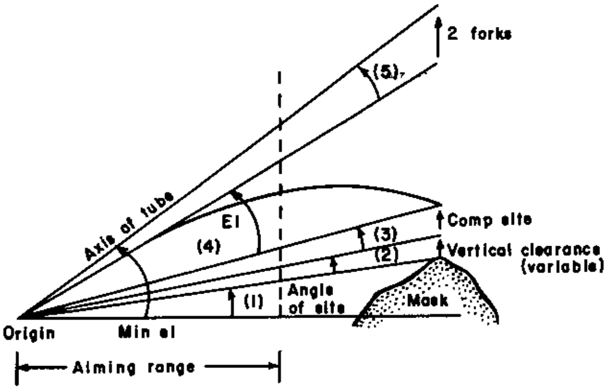


Figure 45. Arming time range less than range to the mask.

(*a*) Angle 1: Executive selects the greatest angle of site to the mask reported by the chiefs of sections. +16.0m̸

(*b*) Angle 2: If the mask is occupied or is to be occupied by friendly troops (always assumed in absence of information to the contrary), add the value in mils of a height of 80 yards at the *piece mask range* 1,700 yards (using mil relation) .... 80/1.7 = +47.1m̸

(*c*) Angle 3: Comp site at *piece mask range* 1,700 yards for the sum of angle 1 and angle 2. (Column 16, charge 4, FT 105–H–4, gives a comp site factor of +.01 for each mil of site.) ... 16.0+47.1= 63.1×(+.01) = +0.6m̸

(*d*) Angle 4: Elevation for the *piece mask range* (column 2, charge 4, FT 105–H–4) .... +114.7m̸

(*e*) Angle 5: Two forks at the *piece mask range* (column 4, charge 4, FT 105–H–4) .... +6.0m̸

Total .... +184.4m̸

(*f*) Executive will report to the FDC, ARMING TIME MINIMUM ELEVATION, VT FUZE, CHARGE 4, 185M.

(*g*) With the 2-second arming time and a crest beyond the arming range, all the area between the arming range and the crest is made safe by the minimum elevation computed for the crest.

(2) If the piece mask range is less than the minimum arming range (fig. 46), the minimum arming range and the angle of site to the mask at arming range are used to compute the minimum elevation. Since the executive cannot observe the terrain beyond the mask, he must assume (for maximum safety) that the angle of site to piece mask range is also applicable at arming range. Comp site factor is determined at arming range. Data are corrected accordingly as soon as the angle of site to mask at arming range is determined. The FDC or the executive can determine (by map study or survey) the angle of site to the mask at arming range. The minimum elevation is then adjusted to maintain safe clearance at the arming range but is limited by mask clearance the same as for fuze quick and time.

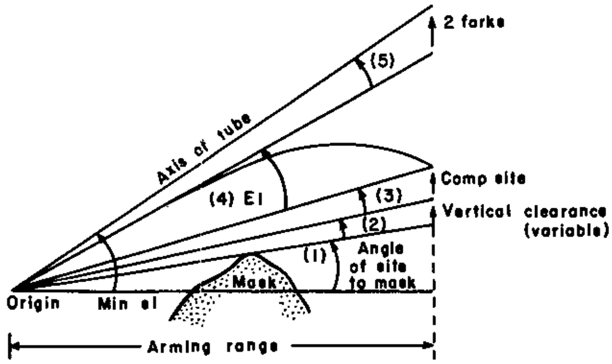


Figure 46. Arming time range greater than piece mask range

Example: 105-mm howitzer, charge 5, piece mask range 500 yards, arming time range 700 yards.

(*a*) Angle 1: Greatest angle of site to the mask reported .... +16.0m̸

(*b*) Angle 2: Eighty-yard clearance at *arming time range* .... 80/.7 = +114.3m̸

(*c*) Angle 3: Comp site at *arming time range* for the sum of angle 1 and angle 2. (Column 16, charge 5, FT 105–H–4, gives a comp site factor of .00) .... 0.0m̸

(*d*) Angle 4: Elevation for *arming time range* (column 2, charge 5, FT 105–H–4) .... +33.8m̸

(*e*) Angle 5: Two forks at *arming time range* (column 4, charge 5, FT 105–H–4) .... +2.0m̸

Total .... 166.1m̸

(*f*) Executive reports to the FDC, ARMING TIME MINIMUM ELEVATION, VT FUZE AT ARMING RANGE, USING SITE TO VISIBLE CREST, CHARGE 5, 167M.

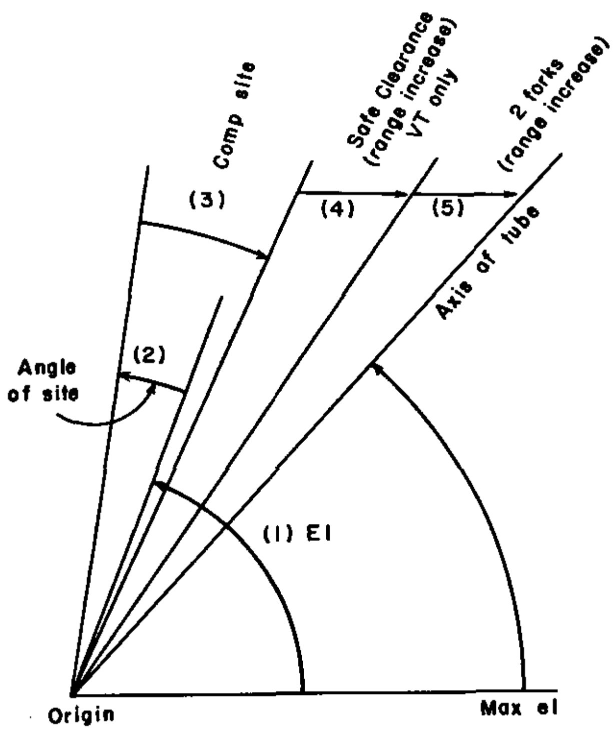


Figure 47. Maximum safe elevation, high-angle fire.

83. Computation of Maximum Elevation for Minimum Range in High-Angle Fire

When high-angle fire (quadrant elevation approximately 800 mils or greater) is employed, the maximum safe elevation is computed in much the same manner as for low-angle fire. For all fuzes, except VT, the vertical safety clearance for friendly troops is omitted. For VT fuze, the clearance for friendly troops (par. 82*a*) is *always* applied as a *range* increase (decreased elevation) for additional safety to prevent premature detonation. For all fuzes, two forks are applied as a *range* increase; the angle of site and comp site are determined by using the range to frontline elements, *not* the range to the mask.

Note. In determining the minimum safe range, an additional safety factor for fragmentation danger area (AR 385–63) should be added to the range to frontline elements. Minimum safe range, no-fire lines, and range to frontline elements furnished by the FDC will include any necessary range modifications (par. 391). The algebraic total of all elements will be the maximum safe elevation (fig. 47).

Example: 105-mm howitzer, charge 4, high-angle fire, fuze VT, range to minimum safe range 5,000 yards.

Angle of site to minimum safe range	+32. 0 mils
Comp site	−40. 3 mils
80 yards (range increase) (computed by using yds/mil column 24 of FT 105–H–4)	−10. 0 mils
Elevation (5,000 yards)	+1,145. 8 mils
2 forks (range increase)	−26. 0 mils
Total	+1,101. 5 mils

Maximum safe elevation per minimum range reported, charge 4, is 1,101 mils (always rounded off to lower whole number).

Section III. MEASURING AND REPORTING

84. Introduction

The FDC requires data from the firing battery for various purposes; for example, construction of firing charts, checks on laying, and data fired. The responsibility for reporting the necessary data rests with the battery executive officer. As soon as possible after occupying a position, the executive submits to the FDC information required to initiate and control fire. This section outlines the duties of the executive in measuring and reporting data.

85. Reporting Adjusted Deflection

When the executive receives REPORT ADJUSTED DEFLECTION from the FDC, he reads the deflection from the sight of the adjusting piece, verifies correctness of the sight picture, and reports ADJUSTED DEFLECTION (SO MUCH).

86. Reporting Adjusted Azimuth

The adjusted azimuth is usually determined immediately after a fire mission—normally a precision adjustment mission. When the executive receives REPORT ADJUSTED AZIMUTH from the FDC, he reads the deflection from the sight of the adjusting piece and verifies correctness of the sight picture. The executive *computes* the adjusted azimuth by comparing the adjusted deflection with the deflection of initial laying. The difference, left or right, is applied to the azimuth on which the weapon was initially laid. *Example:* Battery is laid on azimuth 5,000, deflection 2,800. After adjustment, the final deflection is 2,915. Command from the FDC is REPORT ADJUSTED AZIMUTH.

Deflection 2,800 to deflection 2,915=left 115
From azimuth 5,000—left 115 (5,000—115)=4,885

Executive reports ADJUSTED AZIMUTH 4885.

87. Measuring Azimuth of Direction of Fire

a. When the command MEASURE THE AZIMUTH is received from the FDC, the executive measures the direction of the tube of the base piece with an aiming circle.

b. The procedure for measuring and reporting the azimuth is as follows:

(1) Set up the aiming circle away from magnetic attractions and where it can be seen from the base piece. Place the 0–3200 line approximately parallel to the tube.

(2) Direct the gunner to refer the sight of his piece to the aiming circle.

(3) Set the announced deflection on the aiming circle with the upper motion.

(4) With the lower motion, turn the vertical hairline of the aiming circle to the sight of the piece (0–3200 line of the aiming circle is now parallel to the tube of the piece).

(5) With the upper motion, release and center the magnetic needle.

(6) Subtract the final instrument reading from the declination constant of the aiming circle (adding 6,400 if necessary). The result obtained is the measured azimuth.

(7) Executive reports AZIMUTH (SO MUCH).

Example:

FDC:	MEASURE THE AZIMUTH.
Executive:	NO. 3 (BASE PIECE), AIMING POINT, THIS INSTRUMENT, REFER.
Gunner:	NO.3, AIMING POINT IDENTIFIED ———, NO. 3, DEFLECTION 2415.
Executive:	NO. 3, DEFLECTION 2415.
Executive:	Sets 2415 on azimuth and azimuth micrometer scales, sights on piece sight with lower motion, and centers needle with upper motion.
	Final reading is 1,531. (Declination constant is 151.) (151+6,400)—1,531= 5,020m̸.
Executive:	Reports AZIMUTH 5020m̸.

88. Determining Instrument Direction

When the 0–3200 line of the aiming circle is pointing in an unknown direction and it is desired to determine the grid azimuth of that direction, the following procedure is used:

a. Center the needle by using the upper motion.

b. Subtract the reading on the scale from the declination constant, adding 6,400 if necessary. The remainder is the grid azimuth of the 0–3200 line of the instrument. For example—

(1) The declination constant is 100.

(2) When the needle is centered, the reading on the scale is 1,200.

100	Declination constant
+6, 400	
6, 500	
—1, 200	Scale reading
5, 300	Grid azimuth of 0–3200 line of instrument.

(3) The diagram in figure 48 shows the relationship.

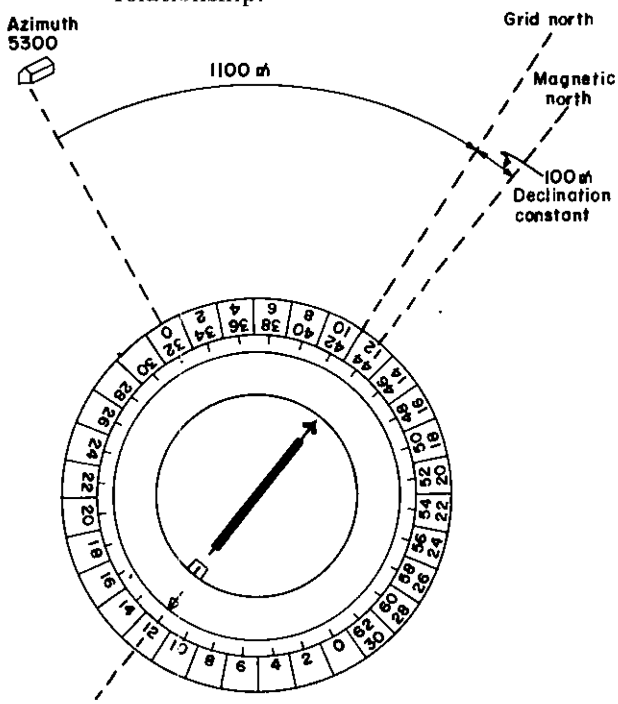


Figure 48. Determining instrument direction.

89. Measuring Azimuth to a Point

The following procedure is used to measure the azimuth to a point (fig. 49):

a. Place the aiming circle with the 0–3200 line in an approximate north-south direction with the large 0 of the scale toward the south.

b. With the upper motion, set off the declination constant (fig. 49①).

c. Unlock the needle and, with the lower motion, center the needle thus directing the line of sight to magnetic north and the 0–3200 line of the instrument to grid north (fig. 49②).

d. Lock the needle and, with the upper motion, refer the line of sight to the desired point. The grid azimuth of the designated point is read on the 0–6400 scale opposite the index (fig. 49③).

e. For greater accuracy, repeat this operation three times and take the average of the readings.

90. Measuring Orienting Angle

a. When the command MEASURE THE ORIENTING ANGLE is received from the FDC, the executive sets the aiming circle over the orienting station on the orienting line (OL)

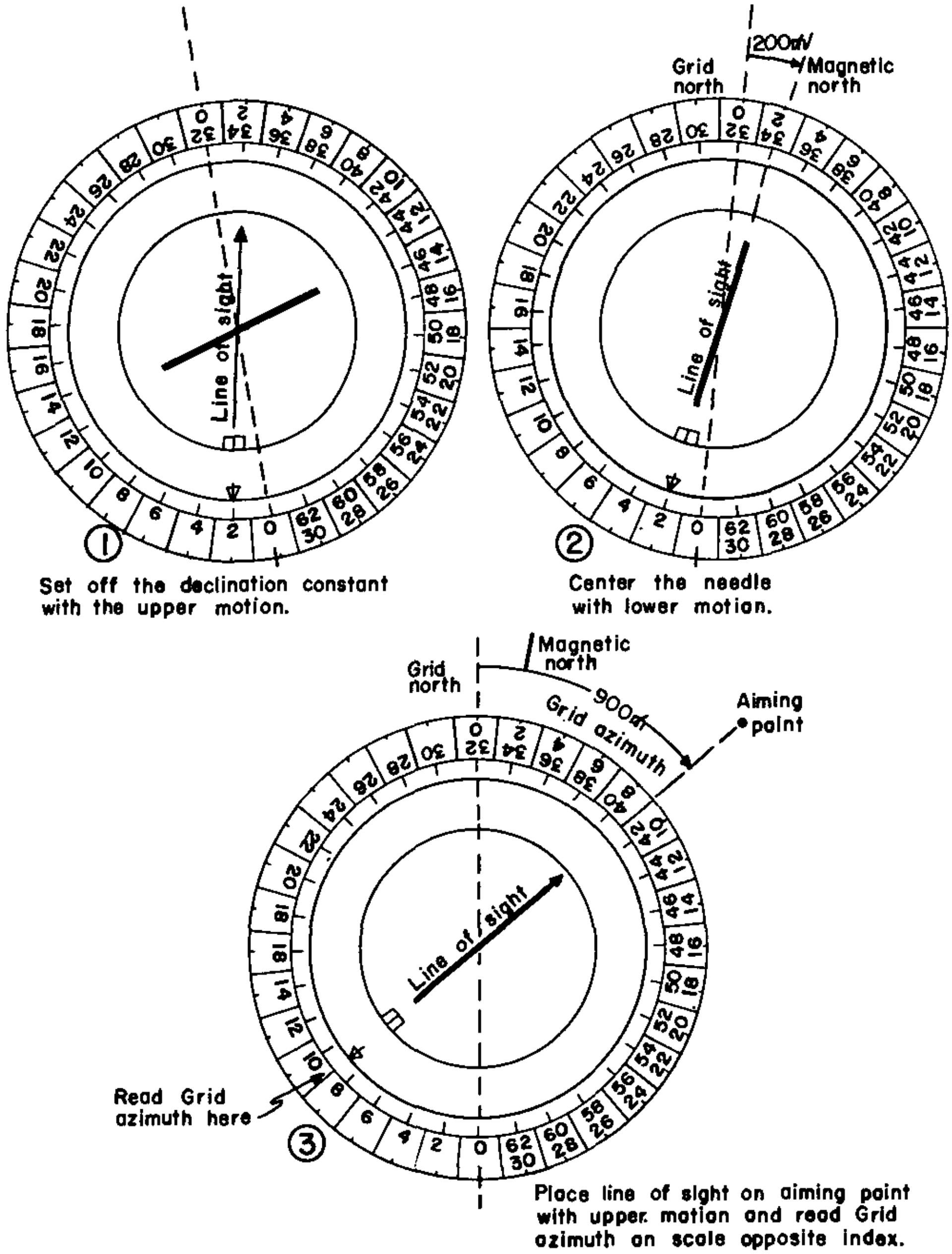


Figure 49. Measuring azimuth to a point.

where it can be seen from the base piece and directs the gunner of the base piece to refer the sight of his piece to the aiming circle.

b. The deflection announced by the base piece gunner is set on the aiming circle with the upper motion.

c. With the lower motion, the executive sights on the panoramic telescope of the base piece.

d. With the upper motion, the executive refers to designated end of OL.

e. The executive reports the readings on the azimuth and azimuth micrometer scales as ORIENTING ANGLE (SO MUCH) (never greater than 3200) (fig. 50).

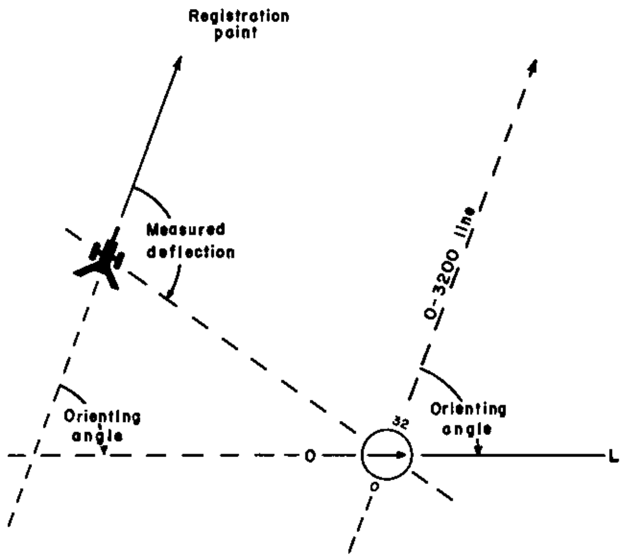


Figure 50. Measuring the orienting angle with aiming circle.

91. Recording Instrument Direction

a. After a registration, the command RECORD INSTRUMENT DIRECTION REGISTRATION POINT 1, TIME 11.2, ELEVATION 218 may be received from the FDC.

(1) The executive determines the site necessary to observe a burst above the mask, in this case 40 mils; he then would command NO. 3 (BASE PIECE) 1 ROUND, SITE 340, TIME 11.2, ELEVATION 218.

(2) An instrument is set up near the piece indicated and laid reciprocally by the gunner of the piece so that the 0–3200 line and line of sight is in the direction of fire. The executive commands NO. 3 (BASE PIECE), FIRE. The vertical hairline of the instrument is placed on the burst, with the lower motion. The burst serves to establish a direction for the 0–3200 line of the observer's instrument.

(3) Having marked the position of the instrument with a stake and having referred to a fixed aiming point, the executive records the referred reading and reports to the FDC, INSTRUMENT DIRECTION RECORDED REGISTRATION POINT 1. The direction of the reference point should be materialized by stakes for night use.

b. Deflection corrections may be checked by observing single air bursts over the registration point; for example, the command CHECK DEFLECTION REGISTRATION POINT 1, CHARGE 5, DEFLECTION 2810, TIME 11.2, ELEVATION 218 is received from the FDC.

(1) The executive determines a site that will enable him to see the burst and, having oriented his instrument by use of the previously recorded instrument direction, gives the commands necessary to fire the base piece.

(2) The executive measures the deviation of the burst from the line of sight and reports the deviation to the FDC; for example, 5 LEFT.

92. Site by Firing (Executive High Burst)

Upon completion of an observed firing chart registration with time fuze on a registration point, the command OBSERVE HIGH BURST, MEASURE ANGLE OF SITE, 3 ROUNDS, followed by the adjusted data may be received from the FDC. This command indicates that the FDC desires the executive to report the observed angle of site to the *mean burst center* of three rounds. The actions of the executive are as follows:

a. Orient instrument in the same manner as that used in recording instrument direction (par. 91).

b. Determine and apply to adjusted quadrant elevation the site necessary to make the burst visible from the weapon position.

c. Fire three rounds and report to the FDC the mean observed angle of site to burst and the quadrant elevation used in firing.

93. Axial Observer in High-Burst Registration

The executive may be used as an axial observer for a high-burst registration. He must be furnished an azimuth from which to report the direction to the bursts. The executive reports to the FDC the direction and angle of site to the burst. The precise procedures for an observer in high-burst registration are set forth in chapter 13.

94. Conversion of Data for Direction

a. Preparation for Converting Data. If no direction has been given the executive upon occupation of position, he lays the battery parallel in a direction which appears to be most feasible, considering his knowledge of the situation, and records a referred deflection. When a fire command prescribing a *different direction, a different method of laying, or both,* is received, he can accomplish the change by announcing a new deflection with reference to the aiming posts. This method will also insure parallelism in the new direction. In order to be prepared for any eventuality, the executive—

(1) Determines the azimuth on which the battery is laid.

(2) Determines the orienting angle on which the battery is laid (if an orienting line has been established).

(3) Has the base piece gunner measure the deflection (refer) to visible aiming points. (Has another piece gunner also measure these deflections to serve as a check against large errors.)

b. Shift from One Grid Azimuth to Another. If the battery is laid on 1 grid azimuth and a command for another grid azimuth is received, the executive computes the difference between the 2 azimuths. He next applies this difference to the original deflection in the proper direction. The result is the deflection necessary to lay the battery on the new grid azimuth. The proper direction is determined from the fact that an increase in grid azimuth decreases the deflection and a decrease in grid azimuth increases the deflection (fig. 51).

c. Shift from One Orienting Angle to Another. If the battery is laid on 1 orienting angle and a command for another orienting angle is received, the executive computes the difference between the 2 orienting angles. He next applies this difference to the original deflection in the proper direction. The result is the deflection necessary to lay the battery on the new orienting angle. The proper direction is determined from the fact that an increase in orienting angle increases the deflection and a decrease in orienting angle decreases the deflection (fig. 52).

d. Shift from One Grid Azimuth to Orienting Angle. A shift from grid azimuth to orienting

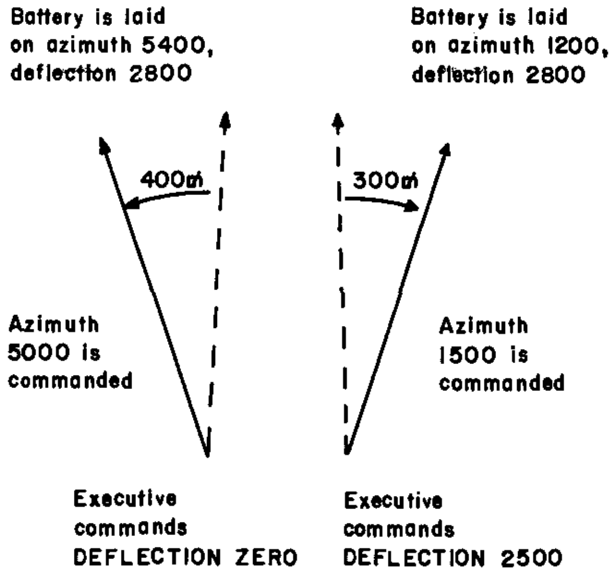


Figure 51. Shifts to compensate for difference in grid azimuth.

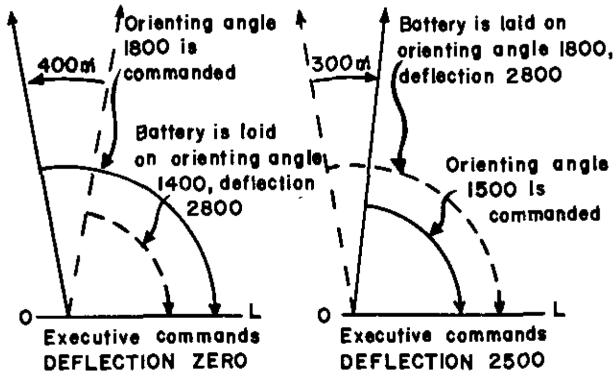


Figure 52. Shifts to compensate for difference in orienting angles.

angle may be necessary when the battery is laid parallel on a grid azimuth and, after an orienting line is established and an orienting angle is announced. The executive sets the aiming circle on the orienting line and measures the orienting angle on which the battery is laid. He compares this angle with the announced orienting angle and commands an appropriate deflection to lay the battery on the announced orienting angle.

95. Executive's Report

a. As soon as the information is available, and without delaying the preparation for delivery of fire, the executive reports to the FDC, BATTERY IS LAID, AZIMUTH (ORIENTING ANGLE) (SO MUCH), DEFLECTION (SO MUCH); MINIMUM ELEVATION(S), CHARGE (SO–AND–SO) (SO MUCH); DISTRIBUTION OF

PIECES, NO. 1 (SO MANY) YARDS RIGHT (LEFT) (SO MANY) YARDS BEHIND (AHEAD OF) BATTERY CENTER; NO. 2 (ETC.) (TO NEAREST 5 YARDS). The indicated direction of fire is used as an origin of direction. When time permits, the distribution of pieces should be submitted as a diagram or overlay (fig. 53). When the location of each piece is surveyed and plotted on the firing chart, as with heavy or very heavy artillery, the distribution of pieces information is omitted.

b. When directed, the executive reports the—

(1) Amount, type, lot numbers, and weight of projectiles.

(2) Powder temperature.

(3) Lateral limits—azimuth (so much) to (so much) or deflection (so much) to (so much). These limits indicate the azimuths or deflections on which the battery can be laid by using the on-carriage capabilities of the weapon and within which at least two-thirds of the pieces can deliver fire at and above the minimum elevation.

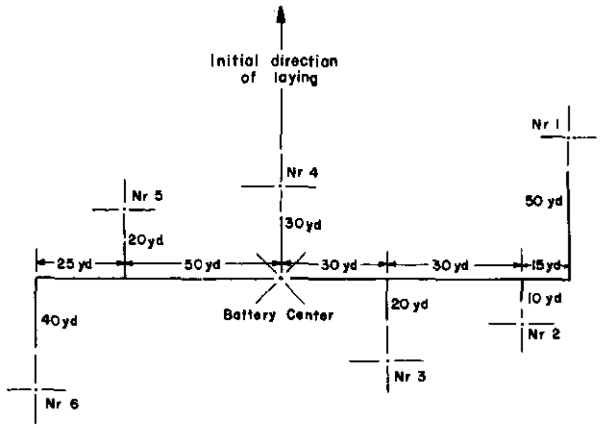


Figure 53. Position area sketch.

(4) Maximum elevation when high-angle fire is to be used or when maximum range is indicated on safety card.

(5) Visible aiming points and referred deflections thereto.

Section IV. DIRECT LAYING

96. General

Firing by direct laying is a special technique that demands a high standard of training. Field artillery weapons are designed primarily for firing indirect fire, but they *can* and *must* be used for firing by direct laying, principally against moving targets. Targets taken under fire by the section in direct laying are usually those which present an immediate threat to the section at pointblank range; therefore, the speed and accuracy required in indirect laying become even more important for direct laying missions.

97. Sectors of Fire

a. The battery commander must provide for all-around defense of his position. An attack may come from any direction. Positions, especially in bivouac, should be chosen so that weapons may be fired in any direction with the least possible delay. The battery commander or executive assigns a sector to each section. The chief of section is responsible for defense in his assigned sector and should be prepared to fire on targets in other sectors.

b. The sector of fire for the weapon should, if possible, be cleared of all obstructions that might hinder observation or endanger battery personnel when the weapon is fired. Care should be taken not to give away the location of the position.

98. Range Card

After sectors are assigned, the executive requires each chief of section to prepare a range card, which is kept at the piece. To prepare a range card, the chief of section measures or estimates the ranges to critical points in likely avenues of approach and prepares a range card on which he notes the range and/or elevation for quick reference. Estimated ranges are modified as more accurate data become available (fig. 54). Fire that is based on a range card derived from estimated data must be conducted with bold range changes to rapidly establish a bracket.

99. Selection of Targets

a. Normally, first priority is given to targets within the assigned sector of the weapon and second priority is given to those in the sectors of the other weapons. Priority within the assigned sector is given to—

(1) Tanks at short ranges, threatening to overrun the position.

(2) Hull down, stationary tanks covering the advance of other tanks.

(3) The commander's tank, if identified.

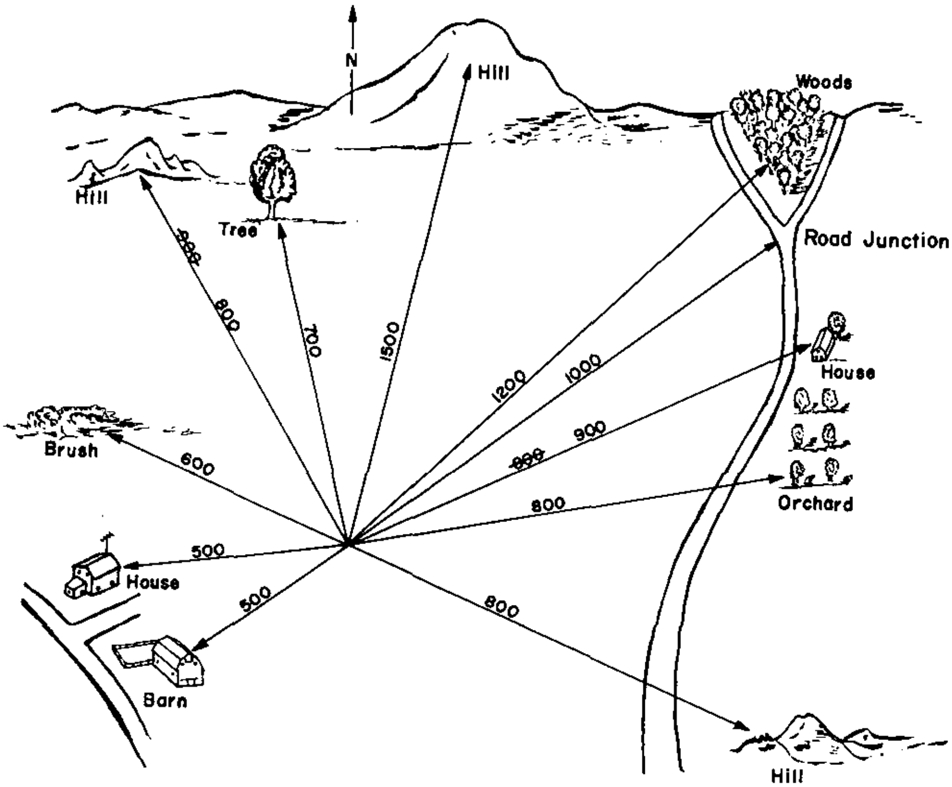


Figure 54. Range card for direct laying.

(4) The tank nearest to cover which may disappear and reappear at unexpected places.

(5) The rear tank of a column moving across the front of the position (to minimize the possibility of attracting attention of the tank column to the weapon position).

b. Fire on a tank that has been hit is continued until the tank and its crew are completely out of action, unless a more active threat appears.

100. Sight Systems for Direct Laying

There are 3 basic systems of direct laying—the 1-man, 1-sight system; the 2-man, 1-sight system; and the 2-man, 2-sight system. With the 1-man, 1-sight system, a single cannoneer lays the piece for both direction and range by using the sight; with the 2-man, 1-sight system, one cannoneer lays for direction by using the sight and another lays for elevation by using the range quadrant; with the 2-man, 2-sight system, one cannoneer lays for direction and the other cannoneer lays for range by using separate sights. For a particular weapon, the appropriate systems of direct laying are determined by the laying equipment and are described in the field manual for that weapon. Training should include all systems, if applicable.

101. Laying on Moving Target

In direct laying on a moving target, the tube is traversed smoothly through the target from rear to front until the intersection of the correct lead and range lines is placed on the center of the visible portion of the target. If the lead is taken on the telescope reticle, the vertical center line of the reticle will be ahead of the target; if the lead is set off on the azimuth micrometer, the vertical center line of the reticle will be on the center of the target. Tracking is continuous if the stability of the weapon permits. If the weapon is unstable, the gunner should keep his head a short distance from the eyeshield to prevent eye injury when the piece is fired. If the gunner traverses the tube ahead of the target, he should not stop tracking but should slow down until the target reaches the correct lead.

102. Laying on Stationary Target

In direct laying on a stationary target, the piece is laid for direction by sighting on the target and laid for range by placing the appropriate horizontal line of the telescope reticle on the target. For precise laying, the gunner's quadrant is used. If the quadrant seats cannot be cross-leveled, there must be little or no cant present in the piece.

Where extreme accuracy is required, for example, when the target is a disabled tank, the quadrant elevation should be determined and the panoramic telescope referred to an aiming point before opening fire; adjustment is by bracket fire or by correction of the vertical point of impact by using indirect laying.

103. Method for Determining Quadrant Elevation

a. The method to be used for determining quadrant elevation for pieces on which the panoramic telescope and mount move with the tube when elevated is as follows:

(1) Place the line of sight parallel to the axis of the bore.

(2) Place the intersection of the horizontal and vertical hairs of the panoramic telescope on the target.

(3) Measure the elevation of the tube with the gunner's quadrant. The angle of elevation of the tube is the angle of site.

(4) Add the angle of site to the firing table elevation corresponding to the range and charge to be fired.

Note. When the panoramic telescope reticle is graduated for the charge to be fired; the range line corresponding to the target range may be placed on the target and the quadrant elevation measured directly with the gunner's quadrant.

b. The method used to determine quadrant elevation for pieces on which the panoramic telescope and mount do not move with the tube when it is elevated is as follows:

(1) Sight along the lowest element of the bore directly on the target.

(2) Measure the elevation of the tube with the gunner's quadrant. The angle of elevation of the tube is the angle of site.

(3) Add the angle of site to the firing table elevation corresponding to the range and charge to be fired.

104. Observation

Muzzle blast often prevents the gunner from observing the point of impact or burst of the projectile. The chief of section must station himself where the muzzle blast will not obscure his view of the target and where he can observe his sector. The chief of section should always be located so that he can take advantage of all available observation and, at the same time, control the fire of his weapon. When muzzle blast does not obscure the gunner's vision for as long as the time of flight of the projectile, the adjustment of fire may be conducted by the gunner on the order of the chief of section.

105. Fire Commands

Fire commands in direct laying are given by the chief of section. The executive may give the preliminary command TARGET (THOSE TANKS), FIRE AT WILL, or he may simply command FIRE AT WILL. The chief of section then announces whether he or the gunner will make the adjustment and designates the system of laying to be used for those weapons for which there is more than one system. For details of fire commands used in direct laying, see the appropriate field manual.

106. Targets With Vertical Profile

a. In firing against a vertical surface, such as the side of a tank, the observer must adjust the *vertical point of impact*. Securing hits on a target of considerable height at close range is a relatively simple matter. When the target is low, the observer must estimate the height of the trajectory above or below the target and adjust accordingly.

b. Figure 55 shows the paths of three rounds of HE shell fired from a 105-mm howitzer M2 at a tank. A round aimed at a point 1 foot from the bottom of the tank travels more than 30 yards beyond the tank before hitting the ground if it misses the tank. Range is correct when the trajectory will pass through any portion of the tank. Since the point of aim is above the ground, a round which is correct for elevation will strike beyond the target if the deflection is in error. *Do not decrease range on the basis of a round falling beyond the target, unless the round sensed is far enough beyond the target to clearly indicate that it passed over the target.*

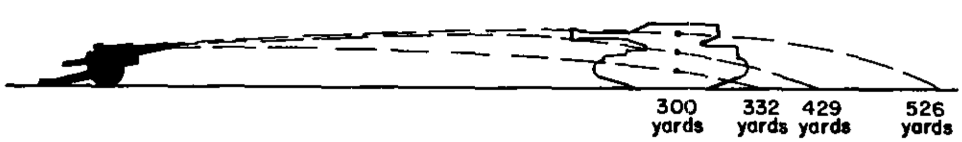


Figure 55. Trajectory, 105-mm howitzer M2, shell HE, charge 6. Three rounds—1, 4, and 7 feet off the ground—passing an 8-foot tank.

107. Vertical Displacement

a. If the vertical displacement of the trajectory can be estimated in feet or yards, the mil relation can be used to determine the amount to raise or lower the trajectory so that rounds will strike the center of the target. If the command for range is given in yards, then the appropriate range change can be determined from tabular firing tables. Sometimes it is not possible to estimate the needed vertical displacement of the trajectory. When this happens a knowledge of the vertical displacement in feet for a 100-yard range change or the vertical displacement in feet for a 1-mil elevation change at various ranges will enable the observer to raise or lower the trajectory as needed. The observer must know and make use of the characteristics of the trajectory for the weapon and ammunition to be used.

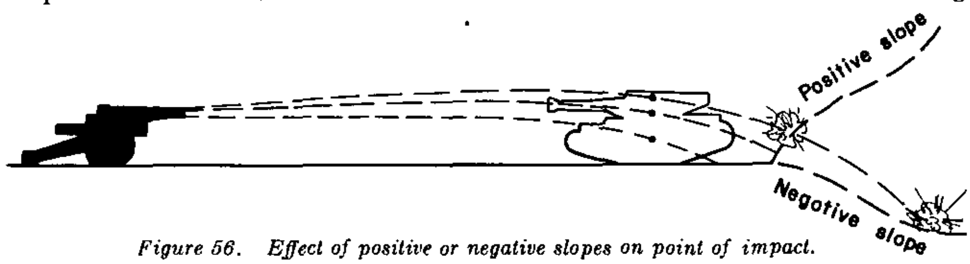


Figure 56. Effect of positive or negative slopes on point of impact.

b. In using range sensings to adjust the height of the trajectory at the target, the observer must consider the effect of the slope of the ground beyond the target. Figure 56 illustrates the effect of positive and negative slopes on the point of impact. When the piece is considerably higher than the target, the effect on range sensings is the same as the effect of a positive slope. When the piece is considerably lower than the target, the effect on range sensings is the same as the effect of a negative slope. In such cases, the chief of section must watch the flight of the projectile at the target, since the effective range beyond the target is not apparent. The chief of section must adjust his fire by raising or lowering the path of the projectile in accordance with his observations at the target range.

108. Bracket Methods

Although it is desirable to move the rounds to the target at once without bracketing, *the observer must obtain a bracket* unless he can estimate the error with sufficient accuracy to assure a target hit with the next round. Bracketing is necessary when the observer cannot accurately estimate the range error and, usually, when a 50-yard range change raises or lowers the center of impact more than the height of the target. In general, bracketing is not necessary when range errors can be estimated accurately or when the target has considerable height or is at a short range. For weapons not equipped with the means of making changes in range, the executive and the chief of section should know the *average* change in elevation for a 100-yard change in range between certain limits. For example, for the 155-mm howitzer M1, charge 7, the average change in elevation for a 100-yard change in range between 400 and 1,500 yards is 1.5 mils.

109. Ammunition and Fuzes

a. General. For close-in fires, a variety of fuzes and shells are available. When high explosive shell is used, maximum charge is used for speed, ease in adjustment, and imparting forward motion to fragments. The flat trajectory resulting from the use of maximum charge may make extremely close-in fire on personnel targets difficult owing to projectiles skipping without detonating on impact. In this case a lower charge may be used. At ranges of 200 to 400 yards, fuzes may fail to function on hard, flat ground unless the terrain is prepared for direct fire by placing mounds of dirt, logs, or sandbags in the weapons' sectors of responsibility.

b. Ammunition. Ammunition may be high explosive (HE), high explosive antitank (HEAT), armor-piercing (AP), or white phosphorus (WP), depending on availability and caliber. HEAT and AP are designed for, and are highly effective in, antitank and antivehicle fires. HE is ideally suited for antipersonnel fire and is effective against vehicles and tanks. WP may be used to set immobile tanks and vehicles on fire, to further restrict defiles, and to produce casualties. However, when WP is used, the resulting smoke screen may be more advantageous to the attacking force.

c. Fuzes. Base detonating fuzes are contained in both the HEAT and AP projectiles. WP ammunition is fuzed with a superquick-delay fuze. In direct fire, shell HE may be used with fuzes superquick, delay, or time.

(1) Fuze superquick is the most desirable fuze to use with HE shell for close-in fires. This fuze is highly effective and, since no fuze setting is required, fast to use.

(2) The time required both to set the fuze and adjust the point of impact for maximum ricochet effect makes the use of fuze delay less desirable than fuze quick. When fuze delay is used to gain ricochet effect, the point of impact is adjusted from 10 to 30 yards in front of the target. If less than 50 percent of the bursts are ricochet, the fuze should be changed to fuze quick.

(3) Fuze time is the least desirable type of fuze for close-in fires. Because of the wide range dispersion resulting from variations in time of burning with short fuze settings, fuze time should be used only for ranges of more than 1,000 yards. Effective areas of coverage by air and ricochet bursts are similar.

(4) The M78 concrete-piercing (CP) fuze with HE shell should be used against concrete pillboxes or fortifications; however, if the material to be penetrated is hard rock or heavy reinforced concrete, AP or HEAT can be used and HE with superquick fuze can be used to clear away rubble.

110. Night Firing

a. Night Lighting Devices. If night lighting devices are used for sighting equipment, normal methods of direct laying may be employed when the target is illuminated sufficiently by moonlight or flares.

b. Initial Data. When a tank weapon fires, it may be possible to lay the piece for direction by sighting on the flash. The piece also may be laid on the flash of machine guns. Range estimation will be difficult, but, if the sector is studied carefully during daylight and a range data card is constructed, a satisfactory range for opening fire may be determined by observing the flash in relation to terrain features. If the flash of an enemy weapon is observed, the initial range may be determined by multiplying the number of seconds it takes the sound to reach the observer by 400 (the approx. distance in yards sound travels per second).

c. Sensing.

(1) The chief of section can avoid the blinding effect of muzzle blast by closing his eyes as the piece is fired, by sighting through the telescope of a piece not firing, or by posting himself a sufficient distance from his weapon. When tracer shell is available, sensing will be facilitated by observing the flight of the projectile in the vicinity of the target.

(2) During periods of poor visibility (twilight, haze, etc.) caution must be exercised in sensing a ricochet burst; for example, a burst may be over the target but the point of impact could have been short.

(3) For a method of bilateral adjustment, particularly applicable to night adjustments on small targets, see chapter 13.

Section V. ASSAULT FIRE

111. Introduction

a. Assault fire is a special technique of indirect fire. Fire is conducted with a defiladed gun at a relatively short range to attain pinpoint accuracy against a stationary target. The gun-target range is sufficiently short to make possible successive hits on the same portion of the target. Only one weapon is used on a mission and the FDC for the mission is normally located at the weapon position. Thorough planning, reconnaissance, and coordination must be completed before the weapon position is occupied.

b. Any artillery cannon can be used for assault fire; however, any caliber smaller than 155-mm is considered uneconomical. The most efficient weapons, in order of preference, are the 8-inch howitzer, the 155-mm gun, and the 155-mm howitzer. Self-propelled versions of these weapons are best suited in many instances for this task because of their maneuverability and ease of emplacement and displacement. When the maximum charge is used, maximum effective assault fire ranges are 3,000 yards for the 8-inch howitzer and the 155-mm gun and 2,500 yards for the 155-mm howitzer.

112. Procedure

a. 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 an aiming post is used for this purpose. The deflection board illustrated in figure 57 enables the gunner to make deflection changes of one-fourth mil. The black and white bands (lines) are one-fourth mil in width when viewed through the sight of the piece at a distance of *exactly 50 yards.* The gunner lays on the desired portion of the board by centering the vertical 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 proper direction) so that the adjacent white (black) band is covered; to move one-half mil, the vertical cross hair is moved 2 bands, etc.

b. Changes in elevation are made to the nearest 0.1 mil. The gunner's quadrant is used.

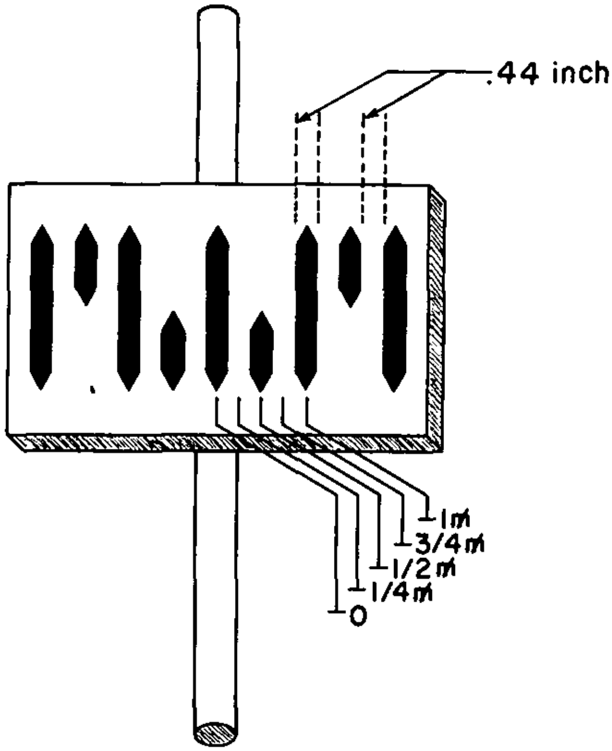


Figure 57. Deflection board.

CHAPTER 6
CONTROL OF FIRING BATTERY

Section I. GENERAL

113. Introduction

Control of the fire of the firing battery is maintained through the use of fire commands. Placing effective fire on a target depends on the prompt and unerring execution of fire commands by the weapon sections. The executive is normally in direct charge of the training and operation of the firing battery. Training must be intense, precise, and continuous to insure adequate fire support to front line elements under any type of combat conditions. Only through the adoption of standard practices and procedures will speed and accuracy be attained. All members of the battery must be skilled in their MOS assignment and should be able to perform the duties of other members of the battery.

114. Training

a. The ability to deliver timely and accurate fires is the yardstick by which artillery units are measured. The highest standards of discipline, performance, precision, and accuracy are essential. The operation of the firing battery will depend largely on the training technique employed and the habits formed during training. Habits formed in training should be so ingrained in the individual that they will not be altered by the stress of combat. The manner of performance of each duty in the service of the piece should be such as to develop maximum speed and economy of effort consistent with accuracy. Supervision and on-the-spot corrections by the chiefs of sections, the chief of firing battery, and the executive are required during all phases of training to develop accuracy (par. 117) and speed. Chiefs of sections should be aware of the common mistakes and malpractices that occur in the firing battery (pars. 136–138) so that these errors may be eliminated by constant supervision of their sections.

b. In all firing battery training (in fact, all training), the best training aid is usually the materiel itself. In addition, enough materiel items should be used to permit the assembly of small groups of cannoneers about each training aid. The training of the firing battery must be organized efficiently to keep all personnel productively occupied at all times. Areas selected for training should be such that time lost for transportation can be kept to a minimum.

c. Individual duties in service of the piece vary with each weapon and are covered in detail in the field manual appropriate to the weapon. The gunner's qualification examination included in the field manual for the weapon provides a means of determining the relative proficiency of the individual soldier in the performance of the duties of the gunner.

d. Proper training of the firing battery personnel starts with the training of each individual in specific duties as prescribed in the appropriate manual for the weapon. The next phase of training is service of the piece drill with the weapon section working as a team, first, as an individual section, followed by integration in the firing battery. The leader of this team is the chief of section; he must understand thoroughly, and be expert in, the duties of all members of his section. The chief of section trains the members of his section and closely supervises their drill to insure proficiency, particularly with regard to accuracy and precision. The chief of section must not become just a member of the section but must actively and continuously supervise all members of his section. It is his responsibility to prevent errors and mistakes. He must be trained to do this. He in turn is supervised by the chief of firing battery, the assistant executive, and the executive.

e. The initial stages of training should be deliberate with stress on the importance of accuracy.

Personnel should learn their duties in detail. For example, the gunner should know the number of mils of traverse for each turn of the handwheel so that he can lay the piece in the approximate direction expeditiously. Speed is acquired gradually through the use of correct procedures, reduction of wasted motion, and practice. Supervision must be continuous to insure that accuracy is not sacrificed.

f. As service of the piece drill progresses, additional commands are given. The commands should be more difficult as speed is acquired. Commands should include all variations possible (pars. 45–58) to insure that all members of the firing battery know and understand in detail the action to be taken for each command. A standing operating procedure for organizing the position, especially placing equipment and ammunition and installation and use of telephones, must be developed for drill periods. Night drill periods should be instituted, stressing occupation of position and firing at night.

g. The battery commander and his executive must seek to develop proficiency in service of the piece during basic training and maintain it in subsequent training and combat. The end product of service of the piece training is actual firing.

115. Conduct of Service of the Piece Drill

a. The success of service of the piece drill depends primarily on the ability of the chiefs of section and the executive and his assistants to recognize unsafe, incorrect, inaccurate, or careless performance of duties by individuals. These drills provide practice and test the team as a whole as well as the individual members. Pieces should be placed close together to facilitate observation and supervision; nevertheless, telephone communications always should be installed. This helps to train section personnel in use of telephones for receipt of commands and to simulate firing conditions. When chiefs of section are used as telephone operators this duty must not affect their primary responsibility for their sections. They should not be merely telephone operators or repeaters of commands; their freedom of movement must not be reduced. They must actively and continuously supervise their sections and insist on the highest standards attainable. Deficiencies in the training of individuals should be noted and, when feasible, corrected on-the-spot.

b. The drills should be kept interesting, short, and snappy, with frequent rests. The gunner and all cannoneers may exchange positions after personnel have gained fair proficiency. The executive frequently should use a stop watch to time the sections to emphasize speed as well as accuracy. Although the scheduled training time normally will be at least 1 hour, this time should be broken into separate phases. For example, a drill period may consist of 10 minutes for prepare for action and laying; 45 minutes for service of the piece drill, with rests between problems, broken into section drill and battery drill; and 5 minutes for march order of the pieces. Checks of settings and laying for accuracy and correctness must be made frequently and unexpectedly during the drill by chiefs of section, chief of firing battery, assistant executive, and executive. Several times during the drill, when all pieces are ready to fire, the command to fall in at the rear of the pieces should be given, and, with the sections at rest, the laying and settings in each section should be verified by the chief of section. Prior planning will enable specific individuals to observe and check specific items, and the use of command cards will speed up and improve the conduct of the drill. Occasionally, the chief of section should be drilled separately in the setting of the gunner's quadrant. This drill should not exceed 5 minutes' duration and should include settings to the nearest 0.1 mil.

c. Fire command cards prepared in advance are used during all drill periods. The cards should contain complete sets of fire commands which will train the battery in all fire commands and situations. Large changes in deflection and elevation (greater than 100 mils) should be included in some commands to facilitate checking for 100-mil errors. Changes in deflection which require shifting of trails should be avoided except when training is being conducted in trail shifting. Method of fire (MF) should be changed frequently to teach the methods of fire, to increase alertness, and to insure familiarity with all commands so that no command during firing will surprise any member of the firing battery. As training progresses, more difficult commands should be included and more difficult situations presented than are found in actual service practice. These cards must be revised periodically to insure that commands are not memorized. Examples of type fire command cards are shown in (1) through (3) following:

(1) *Fire command card for 105-mm howitzer battery without special corrections.* Rnd 1—btry adj, sh HE, lot X, chg 5, fz ti, btry ①, corr R2, df 2810, si 310, ti 15.5, el 251.

Rnd	*MF*	*Df*	*Site*	*Ti*	*El*
2	B L	2842	308	16. 7	271
3	R L, C R, LL	2838	306	16. 3	264
4	L ①, R ②	2832	308	16. 6	268
5	B ②	2836	307	16. 4	266

END OF MISSION

Note. Deflection correction of R2 carried on the gunner's aid. No special corrections announced.

(2) *Fire command card for 105-mm howitzer battery with special corrections.* Btry adj, sp corr, sh HE, lot X, chg 5, fz ti, btry right, corr 0, df 2935—, si 295—, ti 17.0—, el 275.

No. 1, R2	No. 1, U3	No. 1, +.2
No. 2, L2	No. 2, 0	No. 2, ∅
No. 3, R2	No. 3, D2	No. 3, −.1
No. 4, L1	No. 4, D3	No. 4, −.2
No. 5, L2	No. 5, U1	No. 5, +.1
No. 6, L3	No. 6, U2	No. 6, +.1

Fire Commands						*Data by Piece*											
						Site						*Time*					
Rnd	*MF*	*Df*	*Si*	*Ti*	*El*	*No. 1*	*No. 2*	*No. 3*	*No. 4*	*No. 5*	*No. 6*	*No. 1*	*No. 2*	*No. 3*	*No. 4*	*No. 5*	*No. 6*
1	BR	2935	295	17. 0	275	298	295	293	292	296	297	17. 2	17. 0	16. 9	16. 8	17. 1	17. 1
2	BL ② at 4 Sec	2971	298	15. 7	253	301	298	296	295	299	300	15. 9	15. 7	15. 6	15. 5	15. 8	15. 8
3	1, 3, 5 L Corr 2, 4,	2967	298	16. 0	258	301	298	296	295	299	300	16. 2	16. 0	15. 9	15. 8	16. 1	16. 1
	6 R				258												
4	B ①	2969	297	15. 8	255	300	297	295	294	298	299	16. 0	15. 8	15. 7	15. 6	15. 9	15. 9

END OF MISSION

Note. Deflection correction and special corrections for deflection combined and carried on the gunner's aid. Data by piece for site and time *not* announced.

(3) *Fire command card for 155-mm howitzer battery with special corrections.* Btry adj, sp corr, sh HE, lot X, chg 5, fz ti, btry right, corr 0, df 2610—, ti 17.5—, el—.

No. 1, L2	No. 1, +.2	No. 1, 253
No. 2, R1	No. 2, +.1	No. 2, 252
No. 3, L3	No. 3, 0	No. 3, 251
No. 4, R2	No. 4, −.1	No. 4, 250
No. 5, R4	No. 5, +.2	No. 5, 253
No. 6, L5	No. 6, −.2	No. 6, 249

Fire commands					*Data by Piece*											
					Time						*Elevation*					
Rnd	*MF*	*Df*	*Ti*	*El*	*No. 1*	*No. 2*	*No. 3*	*No. 4*	*No. 5*	*No. 6*	*No. 1*	*No. 2*	*No. 3*	*No. 4*	*No. 5*	*No. 6*
1	BR	2610	17. 5		17. 7	17. 6	17. 5	17. 4	17. 7	17. 3	253	252	251	250	253	249
2	B ① By piece at my command	2628	16. 8		17. 0	16. 9	16. 8	16. 7	17. 0	16. 6	242	241	240	239	242	238
3	B ② DNL	2618	17. 2		17. 4	17. 3	17. 2	17. 1	17. 4	17. 0	248	247	246	245	248	244
4	B ①	2614	17. 4		17. 6	17. 5	17. 4	17. 3	17. 6	17. 2	251	250	249	248	251	247

END OF MISSION

Note. Separate elevation command *announced* for each round. Data by piece for time *not* announced. For any weapon, check of deflection includes the deflection correction carried on the gunner's aid that is announced in the initial fire commands. Although frequent changes in method of fire are not typical of normal fire missions, changes during service of the piece drill will insure that all members of the firing battery are familiar with all commands.

d. No smoking, unnecessary talking, or loafing about the pieces is permitted. Personnel fall out away from the pieces during rest periods.

116. Checks and On-the-Spot Corrections

All fire control equipment must be in correct adjustment. All section equipment, especially sighting and laying equipment, should be checked frequently for serviceability and completeness. If the tactical situation permits, all sighting and laying equipment should be tested immediately after the battery goes into firing position. Some tests and adjustments are made periodically or when the need is evident. Only those adjustments authorized in the technical manual for the weapon may be made by battery personnel.

a. Bore Sighting. Bore sighting is the process by which the optical axes of the panoramic and elbow telescopes are made parallel (vertically and horizontally) to the axis of the bore with the scales of the mounts and telescopes set at zero. (See specific weapon field manual for methods of bore sighting.)

b. Detection of Errors. The success of drill depends primarily on the ability of all personnel to recognize any action which is incorrect, inaccurate, or careless. Prior planning will enable specific individuals to observe and check specific items (to include movement of the tube in the proper direction for the commands given), thus giving the best possible coverage of the drill. This planning will also speed up and improve the conduct of the drills.

c. Correction of Errors. Errors must never be ignored. By leadership and example and by making on-the-spot corrections himself and insisting that his assistants do likewise, the alert executive can create a well-trained, smooth-functioning, disciplined firing battery.

117. Accuracy Requirements

Some of the standards which must be met during all service of the piece training (firing or drill) are listed in *a* through *h* below.

a. Bubbles. After the breech is closed, the bubbles must be centered exactly (setting 1 graduation off center can cause an error of 1 or 2 mils); they are checked from the same eye angle each time.

b. Indexes. The indexes must be alined exactly with the proper graduation; they are checked from the same eye angle each time to prevent parallax errors.

c. Micrometer Knobs. In setting scales with the micrometer knobs, the last motion must be from the lower to the higher reading. This applies to deflection scales, elevation scales, angle of site settings, gunner's quadrant, and all other fire control instruments.

d. Traverse. The last motion of the traversing handwheel should cause the vertical hairline of the panoramic telescope to approach the aiming posts or aiming point from left to right. If the vertical hairline passes the aiming point, the handwheel should be turned back one complete turn and a new approach made. The gunner must be trained to habitually lay with the right edge of the vertical hairline on exactly the same portion of the aiming point (left edge on aiming posts when exactly vertical). He must then insure that both bubbles are *exactly* centered.

e. Fuze. Settings on the fuze setter should be made with the last motion in the direction of increasing readings.

f. Elevation. In elevating or depressing the tube of any field artillery piece, the last motion of the handwheel should be in the direction which offers the greatest resistance. If the level point is passed, the handwheel should be turned back one complete turn before centering the bubble.

g. Aiming Posts. The far aiming post should be approximately 100 yards from the sight of the piece. The near aiming post must be exactly one-half the distance to the far aiming post. The chief of section and the gunner must check to see that aiming posts are placed at the proper distances and are exactly vertical and alined.

h. Uniformity in Ramming. Uniform ramming is essential to safety. Uniform ramming also helps to preclude unusual variations in muzzle velocity. If the projectile is not firmly seated, particularly at high elevations, it may slip back into the powder chamber and rest on the charge. If the weapon is fired with the projectile in this position, premature detonation may occur, causing a serious accident. Nonuniform ramming may cause variations in seating, escape of propellant gases around the projectile, and variation in the effective size of the powder chamber. These factors will in turn cause range inaccuracies. The executive must insure that all ramming be hard and uniform.

Section II. FIELD OPERATION OF FIRING BATTERY

118. Duties of Battery Executive

The duties of the battery executive are as follows:

a. Before leaving the motor park or rendezvous area—

(1) Insures that personnel check tire pressures, recoil mechanisms, bore sighting, adjustment of instruments, quadrants, and fuze setters and that they check for completeness, serviceability, and proper storage of all equipment and ammunition.

(2) Makes a reconnaissance of position and determines zone of fire or safety limits, if feasible.

b. At the battery position—

(1) Supervises occupation of position.

(2) Lays the battery.

(3) Checks communications.

(4) Has personnel recheck recoil mechanisms, bore sighting, and adjustment of instruments.

(5) Determines minimum elevations.

(6) Makes executive's report to the FDC.

(7) Is prepared to report amounts and types of ammunition, weights of projectiles, and powder temperature.

(8) Controls the delivery of fire as requested by the observer or as commanded from the FDC.

(9) Is responsible for compliance with safety rules.

(10) Insures uniform and adequate storage of ammunition.

c. Prior to entering combat (actual or simulated), insures that the firing battery is capable of—

(1) Twenty-four hour operation.

(2) Efficient occupation and organization of the position.

(3) Passive defense of the position through proper camouflage discipline and other measures.

(4) Active defense of the position by direct laying of the pieces, by use of other organic weapons (machine guns, rocket launchers, small arms), and by use of mines and trip flares.

(5) Operating efficiently within safety rules.

119. Records and Data the Battery Executive Must Check

a. Firing Battery Section Data Sheets. Data cards and sheets kept by chiefs of sections for prearranged fires and close-in defensive fires must be checked for completeness and accuracy (fig. 58).

(1) If time is available, a DA Form 6–13 (Firing Battery Section Data Sheet) is prepared at the FDC for each section on which all special corrections applying to that piece have been incorporated. In some cases, only a battery data sheet containing information for all pieces is prepared at the FDC.

(2) The chiefs of sections are responsible for announcing data and giving commands to fire as directed on the section data sheet.

b. DA Form 6–17 (Firing Battery Recorder's Sheet). The firing battery recorder's sheet is a record of fire commands, ammunition, and other data pertinent to the laying of the battery (fig. 59). This form serves as a permanent record of all firing and is a ready reference for the settings that should be on any weapon. The recorder's post is near the executive, telephone operator, and radio operator. The duties of the recorder are to—

(1) Record all fire commands (on recorder's sheet) and messages.

(2) Record and, when required, announce the correct settings for any weapon.

(3) Record the minimum elevation and referred deflection for each weapon.

(4) Keep a file of prearranged fires.

(5) Keep the ammunition record. (This record is also kept separately by the chief of ammunition section.)

(6) Keep a record of instrument direction.

c. Weapon Record Book, Part I—Major Item Complete Record (DA Form 9–13), Weapon Record Book, Part II—Cannon Data (DA Form 9–13–1) (SR 750–1000–8). The weapon record book is a 2-part log which records the history of the carriage or mount and the tube data. This log serves as a permanent life history of a weapon and must accurately reflect the ammunition fired and the date of firing. All entries must be checked peri-

FIRING BATTERY SECTION DATA SHEET (FM 6-40)								SECTION 1			BATTERY B			DATE 13 March	PAGE NO.
CONC NO.	TIME		AMMUNITION					METHOD OF FIRE	CORR	DF	SITE	TIME	EL OR QE	REMARKS	
	FROM	TO	SH	LOT	CHG	FZ									
AB 403	0515	0519	HE	X	5	Ti		B ⑧	L1	2762	314	16.5	260		
AB 405	0522	0524	HE	X	5	Q		B ②	0	2661	311		236		
AB 412	0525	0527	HE	Y	5	VT		B ④	R1	2586	325		221 219 215	Zone ~~M~~	
AB 410	0528	0530	HE	X	5	Q		B ④	L3	2918	311		338		

DA FORM 1 MAR 57 6-13 EDITION OF 1 OCT 52 IS OBSOLETE

Figure 58. Firing battery section data sheet.

odically, especially calibration data and ordnance service entries. Maintenance records that are kept by the artillery mechanic must be current to supplement data in the gunbook.

120. Special Considerations During Firing

a. *Control of Fire at Extreme High Angles.*

(1) High-angle fire at elevations greater than those for which the piece is designed may be necessary.

(2) The minimum range of the piece with high-angle fire without special preparation may be well beyond the target range. It will be necessary, therefore, to emplace the piece on a slope or to dig in the trails and construct a recoil pit. It is important that the trail pits be so dug that the trunnions are approximately level at the center of traverse. When a pintle traverse weapon is emplaced for extreme high angles of elevation, the traversing pintle is tilted to the rear and accurate maintenance of direction becomes difficult.

(3) Difficulty in longitudinal- and cross-leveling increases with the elevation. Therefore, it is necessary to detail a cannoneer to assist the gunner. The cannoneer levels the bubbles as the gunner traverses the tube and alines the telescope with the aiming posts.

b. *Correction for Misalinement of Sight Error After Registration.* Tactical consideration may require registration prior to making tests and adjustments. In such cases, pieces must be boresighted at the earliest practicable time, usually during a lull in firing. If bore sighting discloses that the sight of the adjusting piece was not in correct alinement for direction at the time of registration, the executive takes corrective measures. In order to bore sight the base piece and correct the misalinement error, the executive must

FIRING BATTERY RECORDER'S SHEET

Battery: B | Date: 6 FEB 57 | Page number: 1

Battery laid on — Azimuth: 1600 | Orienting angle: 735 | Deflection: 2800

Fire commands: Pieces to follow	Sp corr	Sh	Lot	Chg	Fz	MF	Corr	Df	Si	Ti	El or QE	Individual piece correction: Piece	Df	Si	Ti	QE	Ammunition on hand: M51	M500	(M513) T226	WP
																	400	300	100	50
																	Ammunition expended			
BA		HE	X	5	TI	CR	R2	2874	302	12.4	207							2		
								2894		12.7	214							4		
						B 2		2884		12.5	210							16		
							END	OF		MISSION							400	284	100	50
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
BA	✓	HE	X	6	TI	C 1	0	2744	307	14.6	216	#1	R4	D2	-.1			2		
								2752	309	14.9	222	#2	L2	U1	0			4		
						B 3		2748		14.8	219	#3	R1	U4	+.3			22		
												#4	0	D3	-.2					
												#5	L4	0	0					
												#6	L1	D1	-.1					
							END	OF		MISSION							400	262	100	50
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

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Figure 59. Firing battery recorder's sheet.

be sure that the cross-level position of the trunnions is not disturbed after registration. The executive is responsible for determining and correcting errors in bore sighting at the battery and for reporting them to the FDC. For example—

(1) A battery occupied position, battery was laid parallel, and battery referred to aiming posts at deflection 2,800. While other sections were bore sighting and making adjustments, a registration was fired by No. 3 weapon. At the conclusion of the registration, No. 3 piece deflection was 2,795. The executive then measured the azimuth on which No. 3 weapon was laid as 1,800. When No. 3 weapon was bore sighted, it was found that, with the line of sight parallel to the axis of the bore, the reading on the sight was 3,192 (fig. 60).

(2) A piece laid with the sight out of adjustment as described in (1) above would be laid to the left of the measured azimuth by the amount of the error in the telescope, 8 mils in this case. Therefore, the correct azimuth when No. 3 piece completed adjustment on the registration point is 1,792. When the sight of No. 3 is properly adjusted, the correct deflection with which to re-lay on the registration point is 2,803. The executive must correct the bore sighting of No. 3 piece and report to the FDC, ERROR OF 8 MILS IN BORE SIGHTING ON NO. 3, CORRECT AZIMUTH WHEN LAID ON REGISTRATION POINT IS 1792, CORRECT ADJUSTED DEFLECTION IS 2803, BORE SIGHTING HAS BEEN CORRECTED. He also corrects any recorded data at the battery position.

(3) Assume in the example in (2) above that an orienting line was established and the orienting angle measured and determined to be 853 before the error in bore sighting of No. 3 piece was discovered. Because of this error, the piece actually is laid too far left by 8 mils and the correct orienting angle is 861. The executive corrects the bore sighting of No. 3 piece as indicated in (2) above and reports to the FDC, ERROR OF 8 MILS IN BORE SIGHTING OF NO. 3, CORRECT ORIENTING ANGLE IS 861, CORRECT ADJUSTED DEFLECTION 2803, BORE SIGHTING HAS BEEN CORRECTED. He also corrects any recorded data at the battery position.

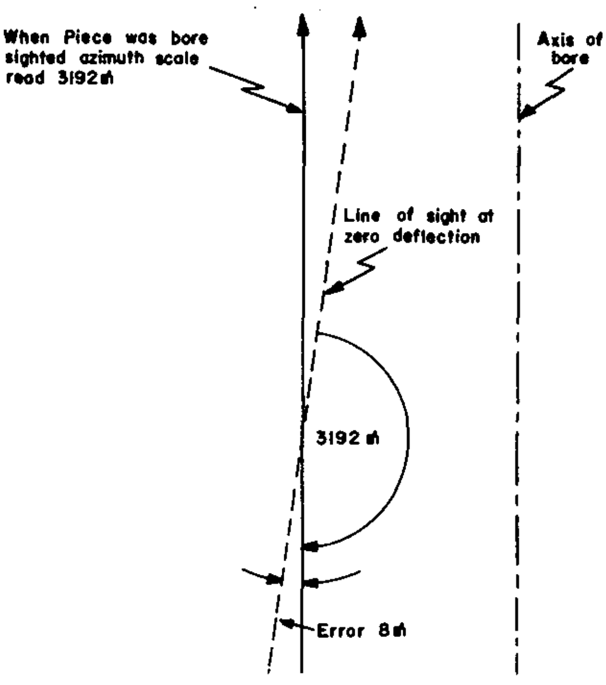

Figure 60. Example of an error revealed by bore sighting.

c. Displacement of Aiming Posts. Owing to the short distance to the aiming posts, slight movements of the panoramic telescope from shock of firing or from traverse move it off the line formed by the two aiming posts. For procedure in correcting for displacement, see the field manual appropriate to the weapon.

Section III. CARE AND HANDLING OF AMMUNITION

121. Ammunition References

a. Technical Manuals. The technical manual issued with each weapon lists the authorized ammunition and the marking, packing, and other technical information which the executive should know. For a general discussion of ammunition, see TM 9–1900; and for characteristics of all types of artillery ammunition, see TM 9–1901.

b. Supply Manuals (SM's). Supply manuals contain the ammunition identification code symbols and information on packing and are used in making up requisitions. Supply manuals pertaining to ammunition used by field artillery are—

SM 9-5-1305 Ammunition, for Artillery through 30-mm.

SM 9-5-1310 Ammunition, for Artillery 30-mm up to 75-mm.

SM 9-5-1315 Ammunition, for Artillery 75-mm through 125-mm.

SM 9-5-1320 Ammunition, for Artillery over 125-mm.

SM 9-5-1330 Grenades, Hand and Rifle, and Related Components.

SM 9-5-1340 Rockets and Rocket Ammunition.

SM 9-5-1345 Land Mines and Components.

SM 9-5-1375 Ammunition Explosives, Bulk Propellants, and Explosive Devices.

SM 9-5-1390 Ammunition, Fuzes, and Primers.

122. General Safety Precautions

a. Careful handling of ammunition is necessary to insure proper functioning and to avoid accidents. Since accuracy of fire is affected by damaged ammunition, the care and handling of artillery ammunition must be carefully supervised. A detailed knowledge of the marking, purpose, and functioning of each component is important.

b. Basic principles of ammunition handling include the following:

(1) Know in detail the assembly and proper preparation of the ammunition for use.

(2) Never use bale hooks. Do not tumble, drag, throw, or drop boxes or components.

(3) Do not allow smoking, open flames, or other fire hazards around ammunition.

(4) Keep ammunition in sealed containers as long as possible before use. Return to containers and reseal if not used (par. 131).

(5) Check and list all lot numbers of projectiles, fuzes, propellants, and primers.

(6) Inspect each round prior to use to insure that it is clean, properly assembled, and otherwise suitable for use.

(7) Protect all components from moisture, extremes of temperature, and corrosive chemicals.

(8) Never make unauthorized alterations on the ammunition.

123. Projectiles

a. Projectiles must be inspected to insure that there is no leakage of the contents, that they are correctly assembled, and that bourrelets and rotating bands are smooth and free of burrs and large dents. If rotating bands are burred or nicked they should be smoothed with a flat, fine-grained file or with crocus cloth backed with a small block of wood. In separate-loading ammunition, every effort must be made to segregate projectiles by lot number and weight zones. Projectiles, especially those with no fuze and booster assembled, are relatively safe from detonation by small-arms fire or shell fragments. Lifting plugs on separate-loading ammunition should be kept tight in the shell nose until ready for use, to prevent moisture from affecting the explosive and to prevent rust from freezing the lifting plug in place. All rotating band grommets must be secure and tight to prevent nicking and scarring of the comparatively soft rotating bands. Windshields must be tightened flush with the shell body and locked by the setscrews. Care must be taken that the false ogive is not broken loose from the threaded ring by which it is attached to the shell body.

b. High explosive shells issued for use with VT fuzes are standard shells with the fuze and booster cavities deepened to accommodate the longer VT fuze. These deep cavity shells are issued with a removable supplementary charge so that they may be used with either standard time or impact fuzes or with VT fuzes. With the supplementary charge placed in the deep cavity, shells are packed, shipped, and issued in the usual manner (fixed or semifixed rounds fuzed with standard time or impact fuzes (sometimes with no fuze) and separate-loading shells closed with a cardboard spacer and the usual eyebolt lifting plug). The supplementary charge is removed only when the shell is used with VT fuzes and must be in place when used with standard time or impact fuzes. The deep cavity may be lined with a paper tube and bottom cup which helps support the high explosive filler. This lining will not be removed at any time.

124. Propelling Charges

a. Care must be exercised to insure that all increments of propelling charges are present and of the same lot number and that only the proper increments are removed from the complete charge before firing. The cannoneer preparing propelling charges for firing must count and identify by number not only the increments removed from a charge as it is to be fired but also all increments. This precaution will help eliminate mistakes in the preparation of the charges and will also detect missing or duplicate increments. Powder bags should not be torn or ripped, and there should be no leakage of contents. With separate-loading ammunition, the data tag and igniter pad cover must be removed before the charge is loaded. Ammunition which has been prepared for a certain charge should be carefully segregated from other charges. Charges for which firing is not immediately planned should be resealed. Increments removed from a prepared charge are left with the charge until the charge is fired so that, if necessary, higher charges than originally planned may be fired or ammunition repacked conveniently. Increments left over from charges already fired are immediately removed to a point at least 30 yards from the nearest weapon or ammunition until they can be disposed of.

b. It is not practical to salvage unused increments. Unused increments may be burned in the open in small quantities. If large quantities are ignited, a dangerous explosion may result. When it is necessary to destroy igniter pads, they should be separated from the base charge and handled in accordance with the provisions of TM 9–1900. Igniter pads should never be cut open with a metallic object, such as a knife, for premature ignition may result.

c. Propelling charges absorb moisture and should be kept in the containers until just before use. This precaution reduces the danger of fire from sparks, blowbacks, small-arms fire, and hot shell fragments. Propellants must also be protected from excessive and rapid changes in temperature. High temperatures greatly accelerate the normal rate of deterioration and cause excessive and irregular chamber pressures in firing, resulting in erratic ranges. Sudden changes in temperature may also cause moisture to condense on the charges. To obtain powder temperature at the battery position, powder temperature should be taken of ready ammunition (powder charges) that is representative of ammunition that is due for early use and should be checked periodically (approx. every 30 min.). The rounds or powder charges so checked should not be removed from the rest of the ammunition but should be measured in place to get a true mean. The thermometer should penetrate the charge that is being used, and it must not touch any metal.

125. Cartridge Cases

Cartridge cases should be inspected carefully for cracks or dents which might affect their functioning. Care is necessary in handling cartridge cases for they are easily dented. Care must be taken to protect the bases of cartridge cases, which, if struck, may cause accidental firing of the primer. Badly corroded cartridge cases will make extraction from the chamber difficult and may result in ruptured cases. With semifixed ammunition, it is important that the mouth of the case is not deformed. A deformed case is difficult to load and may result in a serious blowback if fired.

126. Fuzes

a. General. Fuzes are sensitive to shock and their functioning is likely to be impaired by moisture and high temperature. Fuzes should be inspected carefully to ascertain that they are properly assembled and set. Separate fuzes should be tightened as much as possible by hand and then firmly seated with a fuze wrench. Care must be taken to start the mesh of the threads properly. When fuzes are not tightly seated, premature detonation may occur through sudden seating from rotation in the bore. With fixed and semifixed ammunition, the packing stop must be removed before firing. To prevent excessive cutting of mechanical time and VT fuzes which may cause malfunction of the fuzes, time settings for nonadjusting pieces in a WILL ADJUST mission, or a mission prefaced by DO NOT LOAD (DNL), will be set on the fuze setters only. The fuze setter is set at the time announced, but the fuze is not cut until the command to fire the round is received. This will preclude the setting of the fuze more than once if a different time setting is required when the final time is announced. Time fuzes which have been cut but not fired are reset to SAFE and the safety pin inserted before replacing fuzes in the containers.

b. Time Setting. For accurate and rapid setting, time fuzes require a fuze setter graduated to suit the fuze. A number of models of fuze setters have been standardized. The details of the use of fuze setters are contained in chapter 3 and the appropriate field manual for the weapon.

c. VT Fuzes. VT fuzes belong to a class of special fuzes which require specially loaded projectiles. The fuzes have a plastic nose fitted into a metal base. When VT fuzes are assembled to shells, they provide the same contour as standard fuzes. No safety cotter pins or adjustments are provided or required. The length of the fuze booster assembly is longer than that of standard impact fuzes. The ogives of some of the fuzes have a heavy coating of wax that must not be removed. The fuzes are completely bore and muzzle safe. The arming mechanism provides an additional safe period during the first 2 T226 (M513) and T227 (M514)) or 5 (M96 and M97) seconds' time of flight, depending on the type of fuze. VT fuzes T226 (M513) and T227 (M514) series can be distinguished from VT fuzes M96 and M97 in that they have a settable arming time (fig. 61). Each fuze is stamped with the nomenclature, an alphabetical classification letter, and a manufacturer's lot number. In addition, the ammunition caliber is stenciled on the fuze body. For details on the care and use of VT fuzes, refer to appropriate ordnance technical publications. Time settings are made manually with a mechanical fuze setter. It is important that the time scale of the fuze setter employed correspond to the time ring of the fuze (0–100

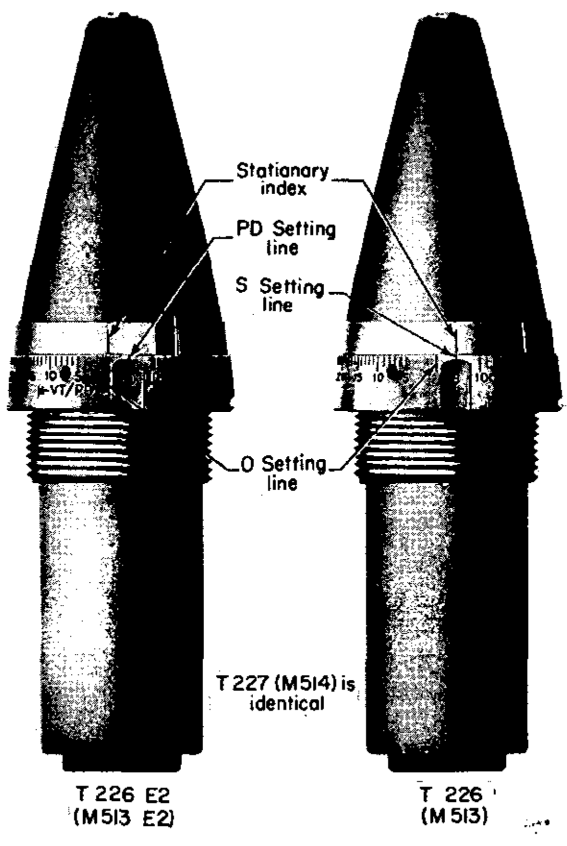

Figure 61. VT fuzes T226 (M513) and T226E2 (M513E2).

with fuzes T226 (M513) and T227 (M514), all modifications). Time settings are made in the same manner as those for mechanical time fuzes; while looking down on the nose of the fuze, the individual setting the fuze rotates the cap in a clockwise direction which is the direction of increasing readings. In the event the fuze setter M14 or M27 is used and the desired setting is passed, the clockwise rotation of the cap is continued until the desired setting is again reached. The cap should not be "backed up" to the setting because this introduces backlash and reduces timing accuracy. *The arming delay time should not be set more than twice on any fuze.* The zero setting line is the lowest point at which VT action can be expected from the fuze.

127. Primers

Primers are sensitive to shock and moisture. Primers should be carefully cleaned and inspected for signs of corrosion and to insure that the seal is firmly in place. Primers will be kept away from powder bags and left in their sealed containers until ready for use.

128. Flash Reducers

The strips containing flash reducing chemicals should be tied tightly and smoothly to the propelling charge so that the diameter of the whole charge is equal throughout its length. Because of its hygroscopic qualities, the flash reducer must not be removed from the container until just before it is to be used. The flash reducer must not be allowed to contact damp ground. Discarded increments should be disposed of in the same manner as discarded igniter pads.

129. Chemical Shells

When gas shell is being fired, all personnel will be provided with gas masks and personnel handling the ammunition should wear gloves. Decontaminating agents should be held in readiness. White phosphorus (WP) shells will be stacked vertically and protected from high temperatures. If WP shells are stacked horizontally in the hot sun, the WP filler (melting point 110° F.) may shift to one side of the shell cavity, resulting in an unbalanced projectile.

130. Segregation of Lot Numbers

Owing to different ballistic qualities between lot numbers of projectiles, charges, and fuzes, segregation of ammunition by lot number must be a standard practice.

131. Replacing Ammunition in Containers

Great care must be exercised in returning ammunition to containers to insure that it is completely serviceable. Before a round is replaced in its container, an officer of the battery will prepare a certificate, which is inserted under the sealing tape used to seal the container so that it will be visible, certfying that—

a. All increments are present.

b. Increments are serviceable and undamaged.

c. Increments are in proper numerical order.

d. Increments have the same lot number.

e. Lot number of the ammunition is the same as that on container.

132. Data for Met Messages

The executive supplies the FDC with the following ammunition data for computing corrections (*a* and *b* below):

a. Weight of Projectile. Weight of projectile is reported as marked on the projectiles, e. g., 1 square, 2 square, No. (pounds).

b. Powder Temperature. The powder temperature reported should be a representative figure for the charges to be fired by the battery, considering variations within stacks and differences between sections. The method of sampling with the powder thermometer will vary with the type of ammunition. Powder temperatures are taken as follows:

(1) *Separate-loading.* Insert the thermometer in end of charge and replace the charge in container.

(2) *Semifixed.* The charge, with thermometer inserted, is replaced in cartridge case. Care should be exercised to see that powder temperature thermometer does not contact cartridge case and thus measure temperature of the cartridge case rather than temperature of the charge.

(3) *Fixed.* With fixed ammunition, there is a temperature lag between the inside and outside of the cartridge case. Powder temperature can be approximated by placing the cased thermometer inside an empty ammunition container.

133. Field Storage of Ammunition

Ammunition at the battery position must be protected from enemy fire and the weather. Only enough ammunition to meet current needs is placed at the pieces. Other ammunition is held either in the ammunition vehicles or stored at a battery dump as the situation dictates. Proper cover reduces the risk of damage by enemy fire and also serves to protect ammunition from moisture and extremes of temperature.

134. Unloading the Piece

When practicable, a piece is fired rather than unloaded. A piece is not unloaded for a fuze setting change unless friendly troops are endangered. Details on unloading are contained in the appropriate field manual for the weapon.

135. Accidents

SR 700–45–6 prescribes the method for reporting a premature explosion or other ammunition accidents. The officer in charge at the battery position must—

a. Render first aid to those injured.

b. Notify immediate superior.

c. Obtain statements from eyewitnesses while details are clearly in mind.

d. Preserve all evidence in as nearly the original state as possible until it can be inspected by the ordnance officer.

e. Record all data required by SR 700–45–6.

Section IV. COMMON MISTAKES AND MALPRACTICES

136. General

Inaccuracies and waste in artillery fire too often occur from mistakes and malpractices of a recurring nature. A mistake is an unintentional error in action or perception committed while following correct procedure. A mistake usually indicates carelessness or lack of concentration and can be detected only by a positive, independent check or very close supervision. A malpractice is a procedural error and usually indicates incomplete or incorrect training. The best preventive for mistakes and malpractices is the formation of proper habits in training by insisting on exactness and allowing no deviation from correct procedures. This section is a tabulation of some of the more common firing battery errors.

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137. Preparation for Firing and Execution of Fire Commands

a. Common Mistakes. Some of the common mistakes made by personnel of the firing battery in executing fire commands are—

(1) Firing wrong charge.

(2) Missetting fuze, especially by reading in wrong direction from numbered graduation.

(3) Making a 100-mil error in deflection or elevation.

(4) Setting deflection correction in wrong direction on gunner's aid.

(5) Failing to zero gunner's aid when deflection corrections are no longer desired.

(6) Moving in wrong direction from numbered graduations on micrometer scales (panoramic telescope, site, elevation).

(7) Reading wrong colored figures on 10-mil micrometer of gunner's quadrant.

(8) Leveling gunner's quadrant in wrong direction or using wrong base, especially in high-angle fire.

(9) Laying on wrong aiming posts, especially at night or when there is little lateral interval between pieces.

(10) Failing to take up lost motion correctly.

(11) Failing to center all bubbles.

b. Malpractices. Malpractices which may result in serious accidents are—

(1) Attaching lanyards on 105-mm howitzers directly to the trigger shaft rather than to the firing shaft bracket assembly. This permits firing the weapon before it has returned to battery. The result is damage to the recoil mechanism and carriage and injury to the loader from the recoil.

(2) Inserting the trigger shaft to test the functioning of the M13 firing lock of the 105-mm howitzer. This practice breaks the lugs forming the "T" on the end of the firing pin holder.

(3) Attempting to gain greater ranges by using 2 charges of green bag or 2 charges of green bag less 1 increment in 155-mm howitzers and adding an eighth-charge increment in 105-mm howitzers. This results in excessive heat and chamber pressures which cause metal fatigue, which is difficult to detect even by experts. When the metal ~~has become~~ sufficiently weakened, the gun blows up.

(4) Hand loading of the 155-mm howitzer may result in burred breech threads, damaged rotating bands, and improper seating. Erratic fires result.

(5) Removing the safety latch firing mechanism plunger so that the firing mechanism and primer can be inserted prior to closing the breech. This practice may result in blown breechblocks and housings.

(6) Exceeding the maximum rates of fire thus causing the gun tubes to become extremely hot. Shells, cool from having been stored in an open battery dump, may crack when placed in the hot gun tubes, permitting the filler to melt and run out of the cracks into the powder chamber making an explosion likely. If fired, the broken shell endangers friendly troops.

(7) Digging gun pits so that the bottom of the pit is on a slant causing the front of the gun to rest on lower ground than the trail spades. The trails then do not have the same angular relationship to the carriage as they do on level ground. As a result, the shock of recoil, particularly with high charges at high elevations, is not properly transmitted to the spades and this excessive downward stress exerted on the front of the trails may cause the trails to break near their junction with the carriage.

138. Optical Instruments

a. Aiming Circle. Some of the errors made by the firing battery personnel in using the aiming circle are—

(1) Failing to clamp vertical shaft securely.

(2) Failing to clamp the wingnut (lower fast motion) securely.

(3) Turning sight head with the wrong motion when sighting through the eyepiece; i. e., upper motion instead of lower motion.

(4) Failing to level the longitudinal bubble before reading angles of site.

(5) Failing to determine and apply the vertical angle correction to measured angles of site.

(6) Having objects containing magnetic metals on the person, especially eyeglasses.

(7) Making a 100-mil error in setting by failing to note that turning the azimuth micrometer has moved the azimuth index to the wrong hundred or setting; for example, 3697 instead of 3597 because the azimuth index is near 36.

(8) Failing to take up lost motion correctly.

(9) Failing to set up instrument with one leg pointing in approximate direction of sighting.

(10) Failing to set up instrument at least 40 yards from nearest piece.

b. Other Optical Instruments. Battery commanders (BC) telescopes and panoramic telescopes are subject to aiming circle setting and reading errors.

139. Miscellaneous

Some of the miscellaneous errors made by the firing battery personnel are—

a. Reading powder thermometer incorrectly.

b. Setting aside one specific case or propellant for powder temperature control for too long a period of time.

c. Firing rounds from oily tubes.

d. Failing to set near aiming post one-half the distance to the far aiming post.

PART THREE

OBSERVER PROCEDURE

CHAPTER 7

INTRODUCTION

140. General

a. Field artillery usually is employed in a manner requiring some type of observation. This observation may be visual, in which case an observer actually looks into the target area; it may be electronic, in which case target location is determined by electronic devices; or it may be indirect observation through study of aerial photographs.

b. Electronic devices generally fall into two classes—radar ranging equipment and sound ranging equipment. Employment of these devices is described in FM 6–120.

c. Observer procedures discussed in this manual pertain solely to visual observation and include both air and ground observer techniques. Whenever appropriate, these techniques are explained in the light of their relationship to other phases of gunnery, primarily the fire direction phase.

d. Target grid procedures, on which fire direction (part four) and observation (part three) are based, relieve the observer of many functions normally required of him by other gunnery systems. Nevertheless, the importance of the observer as a vital member in the gunnery team must be emphasized. The observer is the only member of the gunnery team who can actually see the enemy forces, the friendly forces, and the fires placed on the enemy by all combat arms. The observer is normally a junior member on the gunnery team. However, his ability to observe and his knowledge of the battle situation must be exploited to assist in keeping his unit adequately informed at all times. Moreover, the observer must know and understand the problems and procedures of the FDC. He can then combine this knowledge with his own judgment to effectively assist the gunnery team in fulfilling its purpose.

141. Purpose

Observation is employed by artillery for three purposes—target acquisition, adjustment of fires when necessary, and surveillance of fire for effect.

a. Target acquisition is concerned with detecting suitable targets and determining their ground locations. This information is reported to the FDC where it is used in the production of firing data.

b. Adjustment of fires is necessary to obtain effect on the target when the accuracy of target location data is questionable.

c. Surveillance of fire for effect is a follow through of target acquisition. Since the observer can see the target, he can direct fire and report its effect to the FDC. This report should include an accurate account of damage and any appropriate shifts necessary to make the fire more effective.

d. Battlefield intelligence is a very important by-product of artillery observation. Observers must be aware of their responsibility to report everything which they observe. Information not necessary for the conduct of fire must be reported promptly, but such action must not delay fire missions.

142. Briefing

Prior to the establishment of an observation post (OP), the artillery observer must obtain the information and equipment necessary for the accomplishment of his mission. Whenever possible, the information should include a thorough briefing on the tactical situation, designated zones of observation, and communication plans. This briefing is given by the S2 and the S3 of the artillery unit to which the observer is assigned. If the observer is to work directly with the frontline units, he will be told where and to whom to report for additional information.

143. Equipment

The equipment issued to the observer party includes observation and communications equipment, extracts of signal operation instructions, maps, accessory plotting equipment, arms, ammunition, and transportation. The amounts and types of specific items are prescribed in the applicable tables of organization and equipment and tables of allowances.

144. Personnel

Each artillery observer party consists of the minimum number of specialists required for around-the-clock observation. The senior member is usually a lieutenant, who, in addition to supervising the overall operation of the OP, spends a great deal of his time actually observing. This officer's principal assistant, a reconnaissance sergeant, relieves him of appropriate duties and acts as observer and senior member in his absence. The party also includes a liaison specialist and a radiotelephone operator (driver). Each member of the party is trained in the duties of every other member and in the use and maintenance of all equipment issued to the observer party.

145. Selection of Position

Forward observers (FO's) with direct support artillery battalions select their OP's in the zone designated by the appropriate artillery liaison officer with the supported unit. The selection is closely coordinated with the supported infantry (tank) company commander. This is done to insure observation within the zone of action of the supported unit. Other observers' locations will normally be designated by the artillery S2. The observer conducts a map reconnaissance of the designated area to select the OP location which appears to satisfy the requirement. The observer selects the exact location after making a ground reconnaissance. The final location is reported to the FDC.

146. Relationship With Supported Unit

a. Each direct support artillery battalion commander sends a liaison party and observer parties to each of the supported infantry (tank) battalions. The liaison party is normally located at the infantry (tank) battalion headquarters. The liaison officer coordinates operations between the infantry (tank) battalion commander and the artillery commander.

b. Forward observer (FO) parties are assigned on the basis of one per infantry (tank) company. These parties work closely with the infantry (tank) company commander in reporting suitable targets to the FDC. A communications net is established, including both infantry (tank) and artillery units (fig. 62).

c. Units not in direct support maintain liaison and send observer parties, depending on the mission assigned (FM 6–20).

147. Procedure Upon Occupation of Position

a. The observer and his party move into position as soon after reconnaissance as possible. Radio is normally employed until wire becomes available. On occupation of the OP, the radiotelephone operator checks radio communications, giving particular attention to siting the radio. Wire communications to observers are established rapidly. Wire lines to observers with frontline units are established as directed by the liaison officer. The artillery communications officer supervises laying of wire lines to artillery OP's. When he can, the observer with a frontline unit will establish a wire to the supported unit.

b. While the communication check is being made, the observer studies the terrain and improves the orientation of his maps by checking them against the ground features. The observer must be prepared to report targets and other information (FM 6–20) at all times; hence, his first consideration is orientation, i. e., the establishment of grid direction and the identification of ground objects which are (or can be) plotted on his maps and those of the FDC. One of these points is the map (chart) location of the observer. This study of the terrain assists the observer in furnishing the FDC with map (chart) locations of points of activity.

c. As time permits, the observer and his party improve the natural protection which the position affords. Initially, they occupy the position with a minimum of protection consistent with their mission. Usually this protection consists of foxholes for personnel and portable equipment and concealment for the heavier materiel (vehicle, trailer) (fig. 63).

148. Observer's Role in Firing

When the observer sees a likely target for artillery fire, he sends the FDC a fire request containing all the information needed by the fire direction officer (FDO) to decide if and how the target will be attacked. When the accuracy of initial data does not warrant immediate fire for effect, the observer adjusts the fire and at the appropriate time requests FIRE FOR EFFECT. If the FDO decides that the target does not warrant artillery fire, the observer is notified and his fire request is considered only for its intelligence value. If the FDO decides to fire on the target, he immediately issues instructions, termed collectively as the *fire*

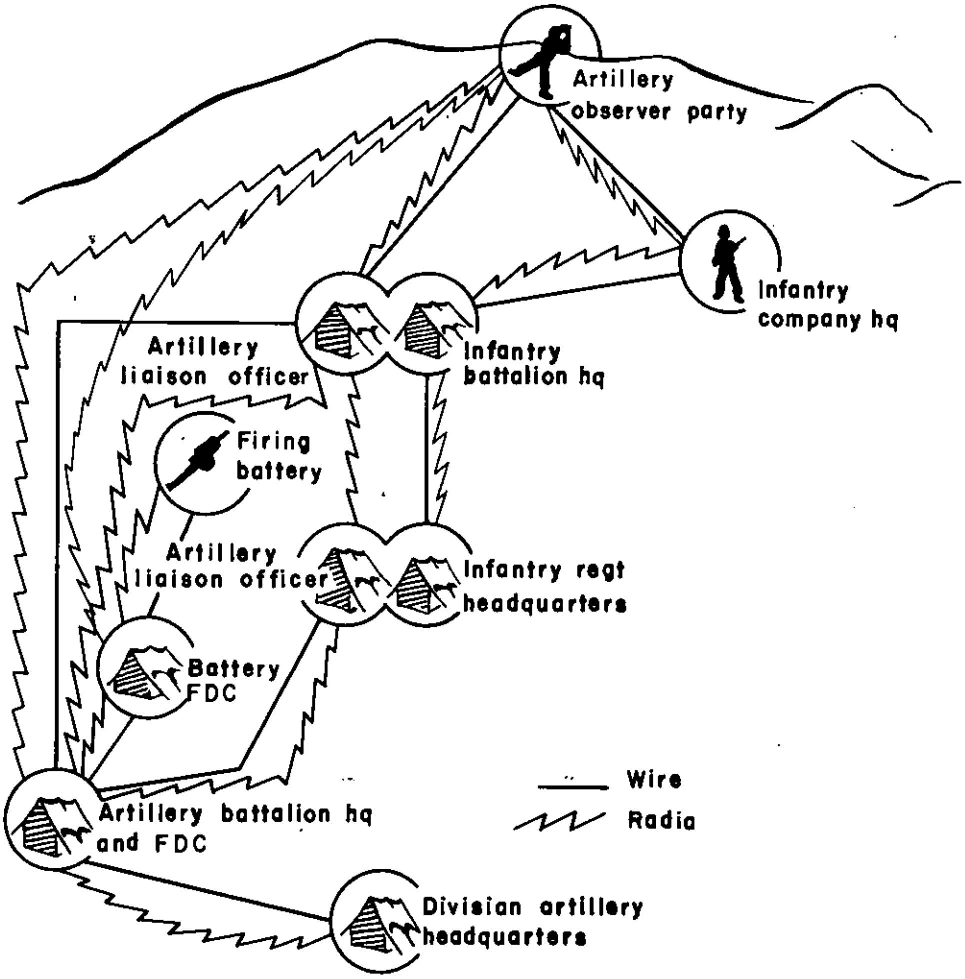


Figure 62. Communications nets available to a forward observer.

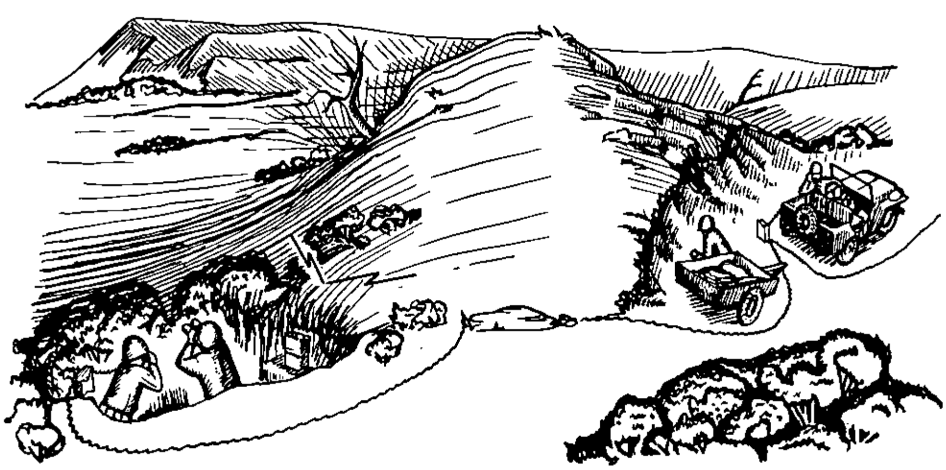


Figure 63. Typical initial disposition of forward observer party.

order. From this order the fire commands for the pieces are prepared. Certain elements of the fire order are needed by the observer to inform him of the amount and type of fire which will be delivered. The fire order, or parts of it, is transmitted to the observer at the same time that it is being announced to the FDC personnel. When the pieces have fired, the FDC personnel alert the observer by transmitting ON THE WAY. If the time of flight of the projectile is comparatively long, the FDC personnel may give a warning by transmitting SPLASH, 5 seconds before the projectiles detonate. When other units are firing in the same impact area, the observer may request SPLASH and/or SALVO FIRE to facilitate identification and sensing of the proper rounds. The observer then determines what effect, if any, the fire has had on the target. Based on this determination, the observer may request any of the following actions:

a. Termination of fire, either because the effect has been sufficient or because no further effect can be obtained.

b. Continuation of fire on the same point to achieve additional effect.

c. Shifting of fire, if a shift will make the fire more effective or if the target has moved.

Note. If either action in *b* or *c* above is taken, the observer may request that the number of pieces, type of ammunition, distribution, or method of fire (MF) be changed. Upon completion of a mission, the observer reports the effect which he has observed.

149. Battalion Observation Posts

Each field artillery battalion establishes its own observation posts to supplement the OP's of the observers with the frontline units. Because observation is so important, artillery units will usually be required by the division artillery commander (or comparable commander) to install OP's at points which provide overlapping coverage of the entire front. This type of observation is integrated with the observation provided by the forward observers with frontline units. This action will decrease the possibility of undetected surprise moves by the enemy. It will also increase the information which contributes to the development of full fire power against the enemy. Battalion OP's are, as time permits, located by survey methods (TM 6–200). When two or more OP's are so located, they form a base and may be used for survey location of targets by intersection. The controlling (more accurately located) OP is called O1 regardless of location, and the auxiliary OP or OP's are called O2, O3, etc.

150. Air Observation Posts

Fixed wing and/or rotary wing aircraft, with pilot and observer, are used for battlefield observation, to adjust fire, and for surveillance of fire for effect. See chapter 14 for details.

CHAPTER 8
PREPARATORY OPERATIONS

151. General

The observer's preparatory operations contribute to the speed and accuracy with which he locates targets and reports information to the FDC. The preparatory phase begins before the occupation of the OP. At that time the observer checks his equipment, reports for briefing to the designated artillery and infantry (tank) personnel, and briefs the members of his observer party. Once in position, the observer concludes the preparatory phase as rapidly as possible. Each member of the observer party concurrently performs a predesignated duty. Any of the following actions which could not be completed before occupying position are completed at this time:

a. Check communications.

b. Orient the map with ground features, including plotting at least one point (preferably several) whose location and direction can be determined.

c. Augment map data by marking on the map the observer's location and any other information that will aid in locating points of activity or interest. Security information should not be placed on maps.

d. Prepare an observed fire fan.

e. Prepare fire requests for points of probable activity.

f. Make the initial report to the FDC, which includes observer's location, targets, and other information. (Immediate fire requests may have been processed before this initial report.)

152. Orienting in Direction and Location of Position

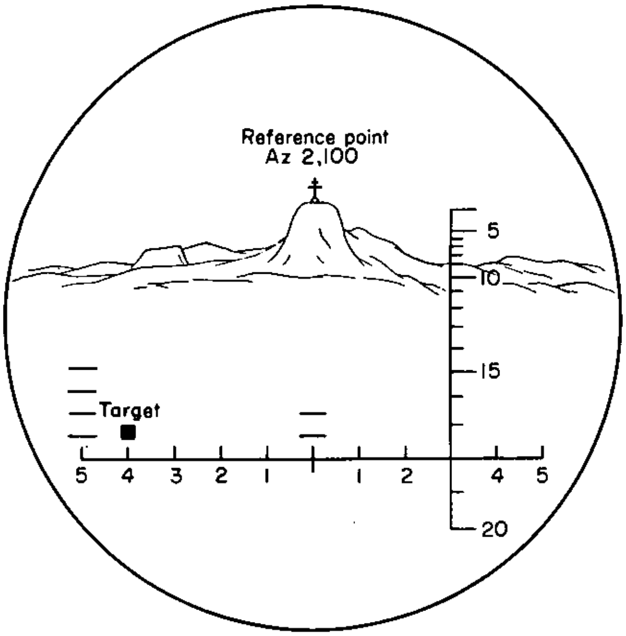
a. The observer must orient himself in direction. If possible he should locate his position so that he can specify grid direction to various points in the target area. Further, he should, if possible, identify at least one point (preferably several) which can be plotted on the FDC maps (charts). This gives the observer and the FDC common references for locating points and facilitates the observer reporting additional locations which can be plotted on FDC charts. Normally, the observer has an opportunity to familiarize himself with the terrain through map and ground reconnaissance. Therefore he usually finds it easy to determine his location.

b. Grid azimuth may be determined initially by measuring with a properly declinated magnetic instrument or by measuring it from a map with a protractor. Thereafter, when referring to the observer, the common term "azimuth" is used and means grid azimuth. Once the azimuth to one point has been determined, a number of reference points should be selected and the azimuth to each carefully measured and recorded.

c. After a number of reference point azimuths have been recorded, the observer can determine the azimuth to any other point in the target area by measuring, with the horizontal mil scale in his binoculars, the angle from a reference point to the desired point. In figure 64, the target is 40 mils left of the reference point. Azimuth to the target is 2,060 mils (2,100—40).

d. Besides his own location, the observer determines the location of, and the azimuth to, outstanding natural and manmade features. The more thoroughly the observer orients himself, i. e., appreciates the ground conformation in relation to the map, the better will be his ability to accurately locate critical portions of the battlefield when he requests artillery fire. It is not necessary for the observer to determine the locations of the weapons which may fire his missions. The FDC is equipped with a target grid device, which graphically converts corrections sent by the observer (in relation to the observer-target (OT) line) to corrections for the weapons (in relation to the gun-target (GT) line) (figs. 121 and 123).

e. Sometimes circumstances render extremely difficult or even impossible the observer's estab-



Verticol scale on right of lens is not used by the FO in determining data for his fire request. It is used primarily by the Infantry for siting automatic weapons.

Figure 64. Use of reference point azimuth and binocular scales to determine azimuth to target.

lishing his location or target locations. Examples of such circumstances are—

(1) Adverse conditions of visibility (fog, rain, or darkness).

(2) Lack of reliable maps.

(3) Operations in deceptive terrain (desert, plains, mountains, or snow flats).

(4) Rapid movement through unfamiliar terrain which tends to confuse the observer.

f. An observer and the FDC personnel can

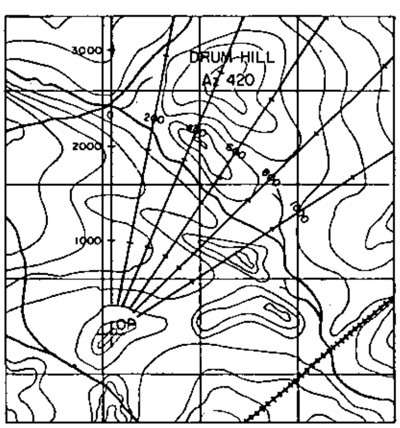


Figure 65. Map augmented to show lines of direction and distances from the observer position.

locate a point in common by firing, when other means of target location are inadequate. The observer requests a round be fired into the center of the target area (center of sector). This request usually specifies a type of ammunition that is easily identified on impact, such as white phosphorus smoke shell. The FDC personnel then prepare the data which will place a round in the center of the sector at a safe distance from friendly troops and commands one weapon to fire. If the observer fails to see this round, the FDC personnel prepare new data which will move the next round to a different but equally safe point of impact or, by employing time fuze, will raise the burst into the air. This procedure is continued until the observer positively identifies the round. He then orders a shift from the point of impact (burst) of the identified round to a target or object which is permanent or semipermanent in nature, such as a tree, crossroads, barn, ruins of a building, etc. Once this point has been located by adjustment of fire and has been plotted on the FDC charts, the observer may use it as a reference point from which shifts to subsequent targets may be made.

153. Auxiliary Map Data

a. When the observer has completed his initial orientation, he begins a systematic augmentation of map data. This augmentation consists principally of recording information on his map and preparing a terrain sketch. As time permits, a visibility diagram is also prepared.

b. The map is augmented with lines of direction radiating from the observer's position at convenient angular intervals. These lines are intersected with arcs of distance by using the observer's position as the center (fig. 65). The observer then marks points of importance which were not included on the map when printed. He also marks (emphasizes) any points which he might frequently need, such as reference points, registration points, concentrations, and likely points of enemy activity. Each of the foregoing actions will increase the efficiency and accuracy of the observer reports.

c. The observed fire (OF) fan (fig. 66) is a fan-shaped protractor constructed of transparent material, covering a 1,600-mil sector. This fan is divided by radial lines 50 mils apart. Arcs representing distance (scale of 1:25,000) from the OP are printed on the fan in increments of 500 yards from 1,000 to 4,000 yards and at 5,000 yards.

(1) To use the OF fan, the observer orients it on his map with the vertex on his OP location in such a manner that the fan is approximately centered on the zone of observation and one of the radial lines is parallel to a grid line or other line of known direction. The fan is then taped or tacked to the map. The line of known direction is labeled with its correct azimuth. The other radial lines are then labeled with their azimuths. If desired, only the 100-mil azimuth lines are labeled.

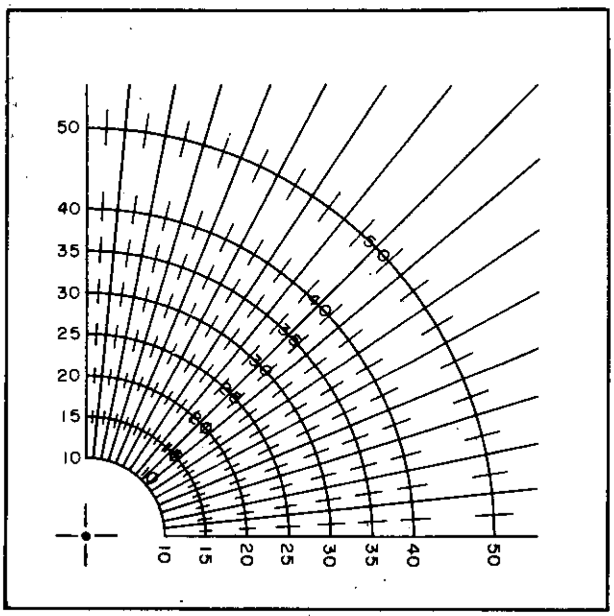


Figure 66. The observed fire fan.

(2) Accurate polar plot data, or coordinates, for a target are required for fire for effect without adjustment, or for the initial round of an adjustment. To get this data, the observer measures the target azimuth with a compass or other instrument or measures and applies the deviation from a known azimuth. Estimating the observer-target distance, the observer locates the target on the map somewhere along the ray representing the azimuth to the target. By comparing the terrain with the map contours along the ray, the observer can select a point and refine the accuracy of the location to obtain normally excellent azimuth and distance or coordinates of the target.

d. Another device which the observer uses to assist in the location of targets is the terrain sketch (fig. 67). This is a panoramic representation of the terrain, sketched by the observer. The sketch shows reference points, registration points, concentrations, and points of probable activity. The terrain sketch is also a rapid means of orienting relief personnel.

e. When available, photographs of the area of observation should be marked, showing pertinent points and lines of direction, and used in conjunction with the terrain sketch. Copies of the photograph and/or the terrain sketch may be required for reference at the FDC.

f. The visibility diagram is a sketch of the area of observation, drawn to map scale, showing those portions which cannot be observed from a given OP. This diagram may be prepared by

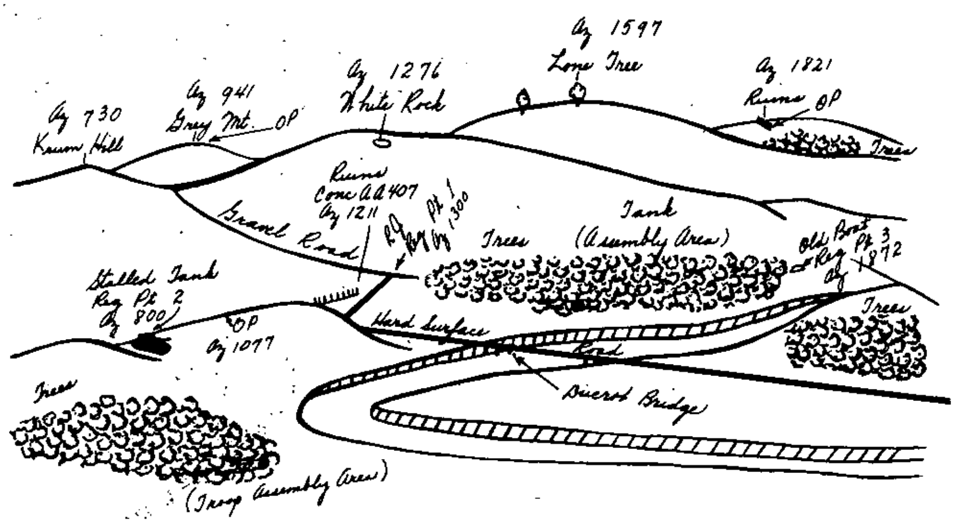


Figure 67. Terrain sketch.

observer personnel or by FDC personnel if the position of the OP is plotted on FDC maps.

(1) When the observer prepares the visibility diagram, a copy on overlay paper is sent to the FDC. The diagram is prepared by constructing profiles of the terrain along radial lines emanating from the OP (FM 21-26). Except in very symmetrical terrain, each adjacent pair of rays should form an angle no greater than 100 mils. When the profile along each ray is completed, straight lines are drawn from the observer's position to each point of high ground in the field of observation. These rays represent lines of vision; all ground areas between a peak point of tangency and the intersection of ray with the ground are blind spots (fig. 68). These blind spots are projected to the base of the diagram and transferred to the appropriate line of direction on the observer's map or on a piece of overlay paper. Related points are connected and blind areas are shaded (fig. 69).

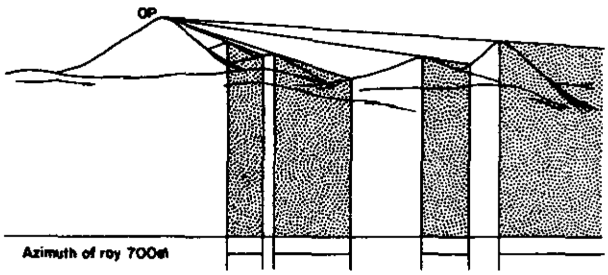


Figure 68. Use of profile to show blind spots (shaded areas).

(2) Use of visibility diagrams will reduce the chance of observer error in reporting target locations. If the target is plotted in an area which is not visible, the location data are obviously in error. The diagram aids the S2 in evaluating target area coverage and in determining the best locations for additional observation posts.

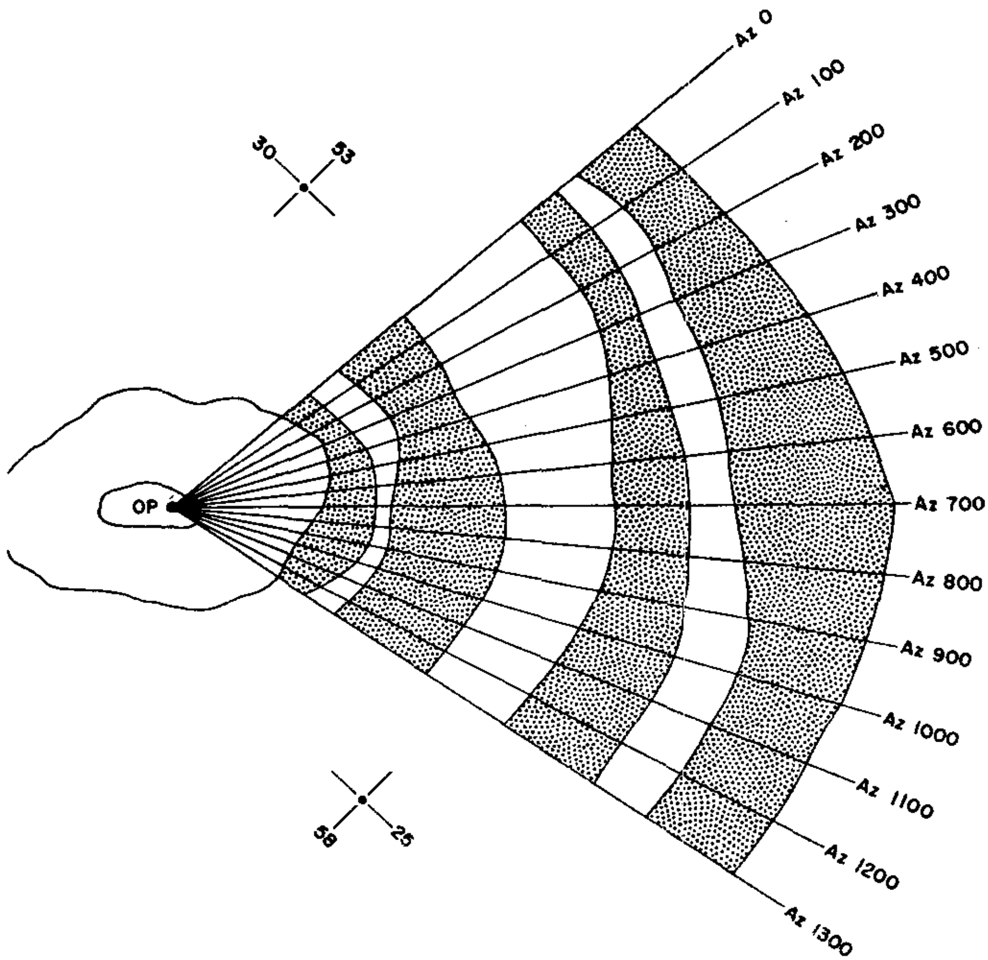


Figure 69. Construction of visibility diagram using direction rays.

CHAPTER 9
LOCATION OF TARGETS

154. General

In locating targets and determining 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. To obtain this initial accuracy, data are used from all previous firing in the area as well as maps, photographs, diagrams, or panoramic sketches of the area. The preparatory operations discussed in chapter 8 are desirable and necessary; however, failure to complete them on occupation of an OP will not preclude the observer calling for fire as soon as targets are observed. The firing phase often begins before the preparatory phase is completed. The firing may be *precision fire*, which places fire on a specific point, or *area fire*, which covers a given area with fire. With either type of fire, the observer processes the mission through the FDC by using a standard sequence and procedure. The sequence is as follows:

a. Target location.
b. Preparation and submission of a fire request.
c. Adjustment of fire if necessary.
d. Surveillance of fire for effect.

155. Target Location

a. *Methods*. An observer employs two methods of stating the location of targets so that FDC personnel may plot them on their charts. These methods are—

(1) Coordinates (par. 156).
(2) Reference to point of known location (par. 157).

b. *Accuracies and Announcement of Data*. All data for target locations in initial and subsequent fire requests are determined to an accuracy consistent with the equipment used for their determination. However, since a graphical solution of data for the weapons is used at the FDC, the observer will normally round off and announce his data as follows:

Azimuth to nearest 10 mils; e. g., AZ 1870.
Deviation to nearest 10 yards; e. g., RIGHT (R) 220.
Vertical change to nearest 5 yards; e. g., UP 25.
Range to nearest 100 yards; e. g., ADD 200.
Coordinates to nearest 10 yards; e.g., 64453774.

c. *Determination of Distance*. 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.

(1) *Estimation of distance*. Estimation of distance is facilitated by establishing a *yardstick* on the ground in the target area. This yardstick can be established by firing 2 rounds from the same piece 400 yards apart in range. The observer can also establish a known distance in the target area by determining from his map or photograph the distance between two points, which he can identify positively both on the map and on the ground. The approximate distance from the observer to a sound source (bursting shell, weapon firing, etc.) can be estimated by timing sound. (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 can be timed by a watch or by counting from the time a burst or flash appears until the sound is heard by the observer. For example, the observer counts "one one thousand, two one thousand," etc., to determine the approximate time in seconds. The time in seconds is multiplied by 400 to obtain the approximate distance in yards.

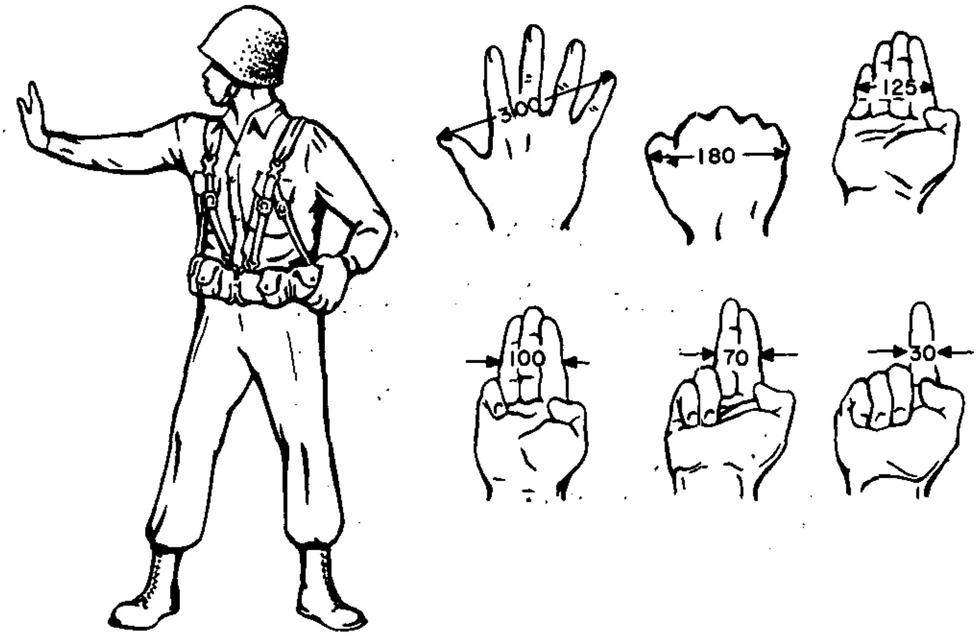


Figure 70. Examples of measuring angles with the hand.

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 4 seconds; therefore, the burst was approximately 1,600 yards (400 x 4) from his position.

(2) *Computation of distance.* The observer can compute distances between points by using angles measured with angle-measuring instruments, such as field glasses, aiming circle, or BC scope, and applying formulas explained in *d* through *f* below. When instruments are not available, angles are measured (fig. 70) by using the hand, fingers, or a ruler held at a known distance from the eye. The specific angle subtended by each is determined by the individual before he goes into the field, recorded, and memorized for rapid use.

d. Mil Relation Formula. Estimates of lateral distances are made easier through the use of the mil relation formula. This formula is based on the assumption that a width of 1 yard (meter) will subtend an angle of 1 mil at a distance of 1,000 yards (meters). The formula is expressed as $\not{m} = \frac{W}{R}$ (fig. 71), where $\not{m}$ is the angular measurement in mils between two points, R is the range (distance) in thousands of yards to the known point, and W is the width in yards between the points from which the angle $\not{m}$ was measured. (This formula should not be used if the angle $\not{m}$ is 600 mils or greater.)

Example (fig. 72): Using binoculars, an observer measures an angle of 300 mils right from a point of known location to a target. The distance to this known point is 2,400 yards. To determine how far to the right the target is, substitute known values in the formula $\not{m} = \frac{W}{R}$, or $300 = \frac{W}{2.4}$; therefore, $W = 300 \times 2.4 = 720$ yards. (The mil relation is also used in the same manner to compute vertical distances or shifts.)

e. Computation of Lateral Shifts Using Sine Factors. When the angle $\not{m}$ (horizontal angle between two points, vertex at the OP) is 600 mils or greater, the accuracy of the mil relation breaks

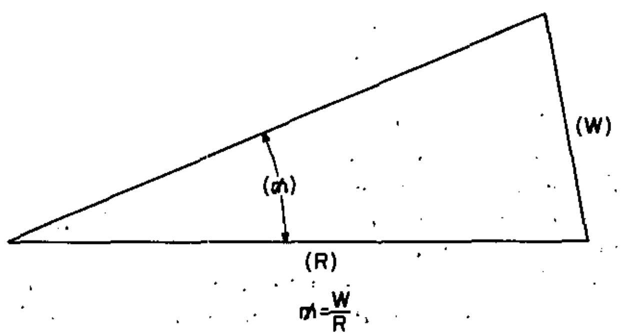


Figure 71. The mil relation.

down. In such a situation, a trigonometric function is used to determine lateral distances instead of the mil relation. Trigonometry (trig) is a study of triangles. A trigonometric function is merely the ratio between two sides of a right triangle. One of these trigonometric functions is the sine (sin). The sine of an angle $A = \frac{\text{side opposite angle A}}{\text{hypotenuse}}$ (fig. 73). The formula for use of the sine factor is $F=\frac{W}{D}$, where F is the factor corresponding to the angle ₥ (value taken to nearest 100 mils), D is the distance to the reference point (hypotenuse), the W is the width of the side opposite the angle ₥. Note that D, or distance, is not reduced to units of thousands of yards when sine factors are used. The sine factors are—

Angle in mils	*Sine factor*
100	0. 1
200	0. 2
300	0. 3
400	0. 4
500	0. 5
600	0. 6
700	0. 6
800	0. 7
900	0. 8
1,000	0. 8
1,100	0. 9
1,200	0. 9
1,300	1. 0
1,400	1. 0
1,500	1. 0
1,600	1. 0

Example: Using binoculars, the observer measures the angle from the reference point to a target to be 920 mils right. The distance from the observer to the reference point is estimated or known to be 2,500 yards. Using these data, the observer must determine how far the target is to the right of the reference point and estimate the distance change to the target. To compute the lateral shift (W), the angle (₥) is rounded off to 900 mils (the nearest 100 mils). The sine factor for 900 mils (0.8) and the range to the reference point (2,500) are substituted into the formula $F=\frac{W}{D}$, giving $0.8=\frac{W}{2{,}500}$ or $W=0.8\times2{,}500=$ 2,000 yards. The lateral shift is right 2,000 yards (fig. 74).

f. Computation of Distance Shifts Using Sine Factors. When the angle at the OP is 600 mils or greater, the sine factors will also be used to compute the distance OP to point X on the OT

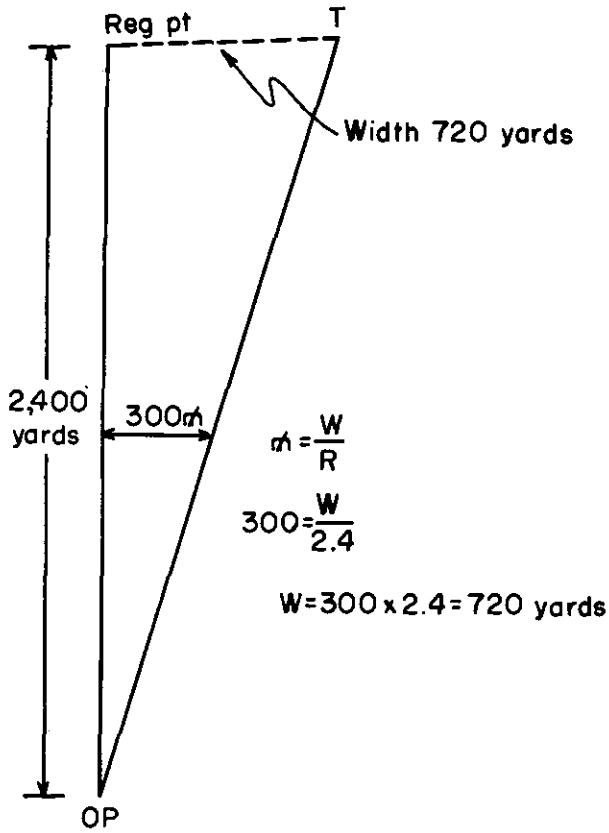


Figure 72. Computation of lateral shift.

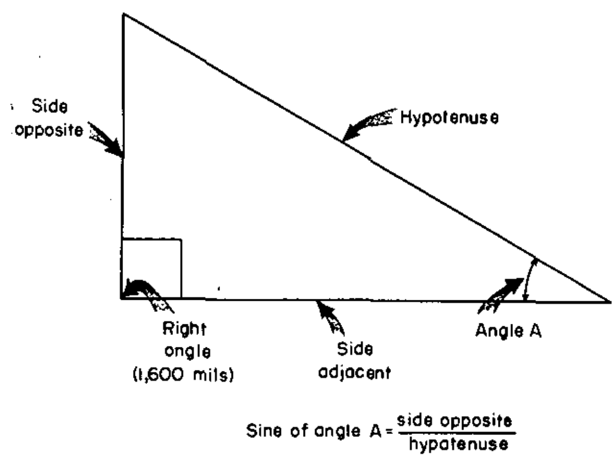


Figure 73. Sine function.

line (fig. 75), by using the sine factor of the horizontal angle between point X and OP (vertex at the reference point), to aid in estimating the distance shift to the target.

Example: The angle at the reference point is used as ₥ and is 1,600 mils minus the angle at the OP, since the angle at point X must be a right angle. (The sum of the angles of a triangle equal 3,200 mils.) In this case, ₥ is 700

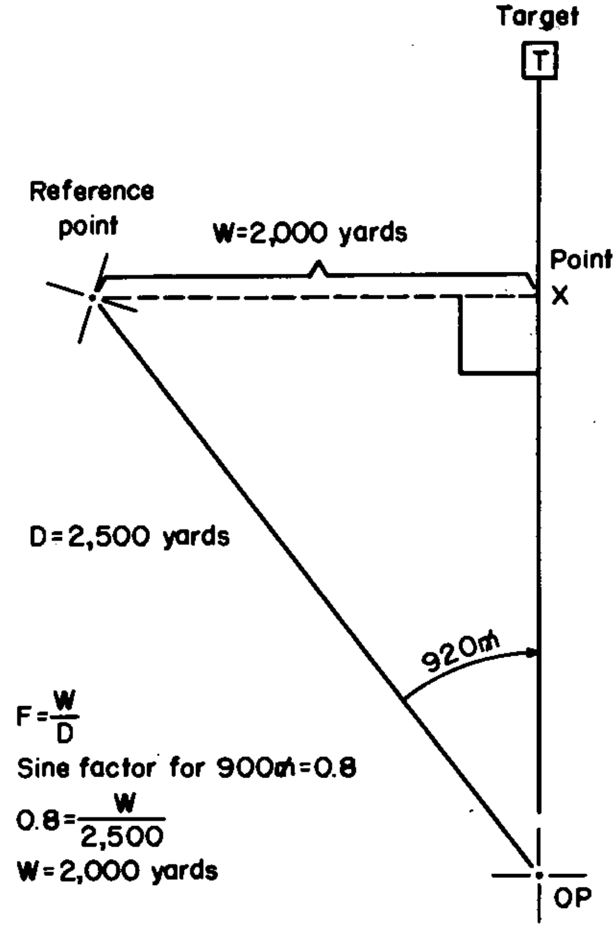


Figure 74. Computation of lateral shift using sine factor.

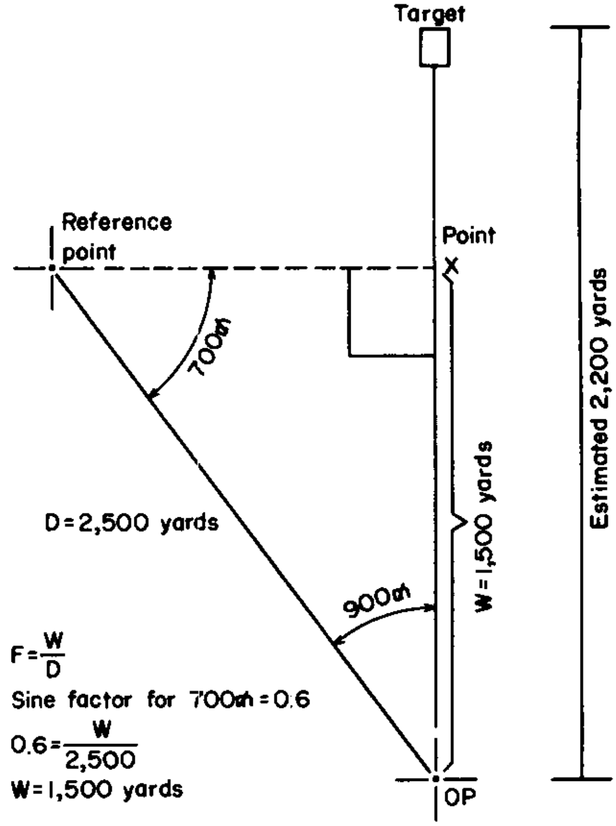


Figure 75. Computation of distance shift using sine factor.

mils (1,600−900=700). The sine factor for 700 mils is 0.6. Substituting in the formula $F=\frac{W}{D}$, $0.6=\frac{W}{2{,}500}$ or $W=0.6\times 2{,}500=1{,}500$ yards. The observer estimates the distance to the target to be 2,200 yards. Having computed the distance to point X, the observer can find the difference and use it as a distance shift. In this case, 2,200−1,500=+700 and the distance shift would be announced as ADD 700.

156. Target Location by Coordinates

a. By using auxiliary map data, determining accurate coordinates of a target is greatly simplified. When the observer sees a target whose location cannot be plotted by rapid inspection, his first step is to determine the target azimuth. He determines the azimuth by using any of the methods described in paragraph 152.

b. Having the measured or estimated azimuth and his location, the observer refers to the corresponding line of direction on the map (or observed fire fan). He selects the point on this line which best describes the target location. He may locate this point by comparing map features with ground features or by estimating the distance from his position to the target. In figure 76, the observer has measured an azimuth of 680 mils to a target whose location is on a small hill an estimated 3,000 yards from the observer's location. He has pinpointed the target on the map by plotting a distance equivalent to approximately 3,000 yards along a ray corresponding to azimuth 680 mils on the observed fire fan. A study of the contour lines aids the observer to estimate more accurately the range.

c. After locating the target on the map, the observer marks the location and determines the coordinates with a coordinate scale or by estimation. When properly used, the coordinate scale enables the observer to measure both easting (E) and northing (N) coordinates with one placement of the scale. To measure the coordinates of a target, the coordinates of the lower left-hand corner of the grid square containing the target are determined first. Starting at this grid intersection, slide the coordinate scale to the right,

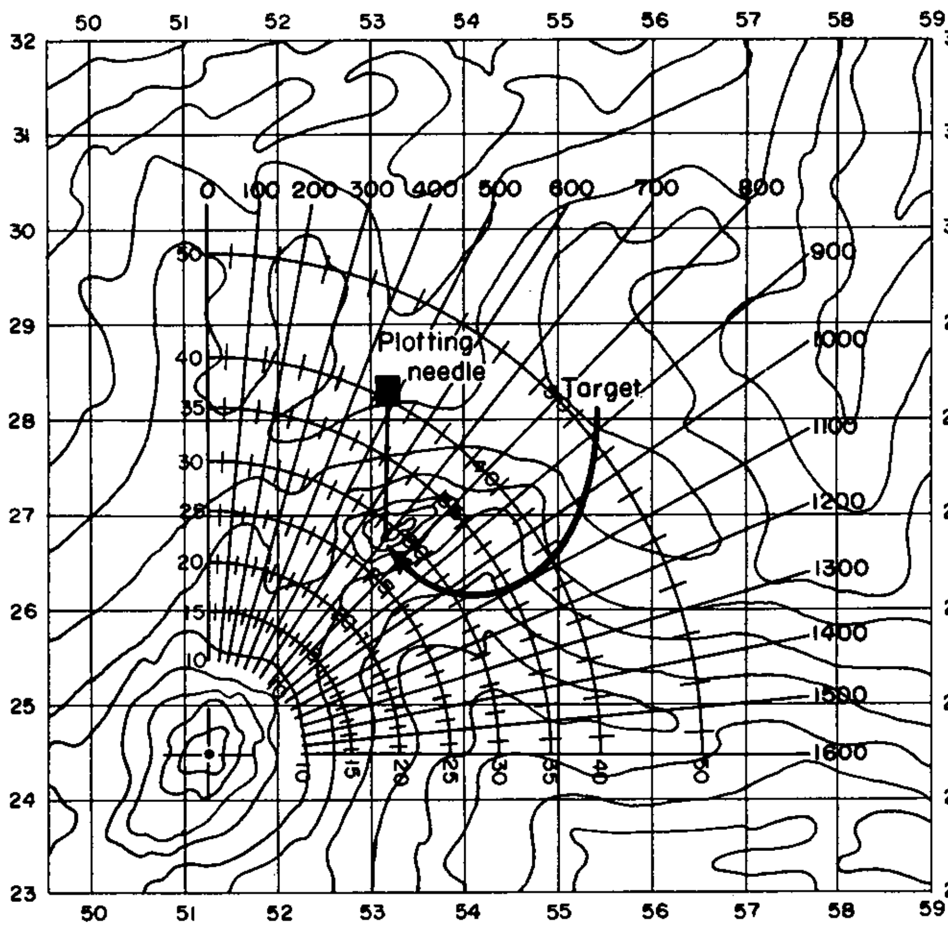


Figure 76. Use of OF fan to assist in reading coordinates.

keeping the horizontal scale in coincidence with the easting grid line, until the target is reached by the vertical scale. Read the distance east and the distance north from the scales (fig. 77). These readings are then added to the coordinates of the grid square to obtain the coordinates of the target; i. e., 53152675.

d. Coordinates may also be determined by relating the target location to the location of one of several ground features marked on the map. This system should be used with extreme care, especially in deceptive terrain, unless the location is such as to preclude error (road junction, building, bridge, etc.). A rapid check of the accuracy of coordinates can be made by use of contour lines on the map. A target whose plotted altitude shows marked disagreement with the actual ground conformation should be replotted.

157. Target Location by Reference to a Known Point

The target location by reference to a known point method may be utilized with either of two types of known points—the observer's position (polar plot data) or any point or object which can be readily located on both map and ground (reference point data may be a marking volley, plotted concentration, or other point of known location).

a. Polar Plot. The observer's location must be plotted on the charts at the FDC if the polar plot method is to be used. The principal advantage of the polar plot method is the rapidity with which the observer can determine the target location. If the azimuth is correct, the first round(s) fired should fall on or close to the line which passes through the OP and the target (OT line). Subsequent shifts are then easier to determine. As in the coordinate method, the observer measures or computes the azimuth and estimates the distance to the target. In figure 78, the location of the target would be reported to the FDC as AZIMUTH 1000, DISTANCE 1400. The vertical shift, if any, is computed by using the mil relation. A vertical shift would then be included as follows: *AZIMUTH 1000,* UP (DOWN) (SO MUCH), *DISTANCE 1400.*

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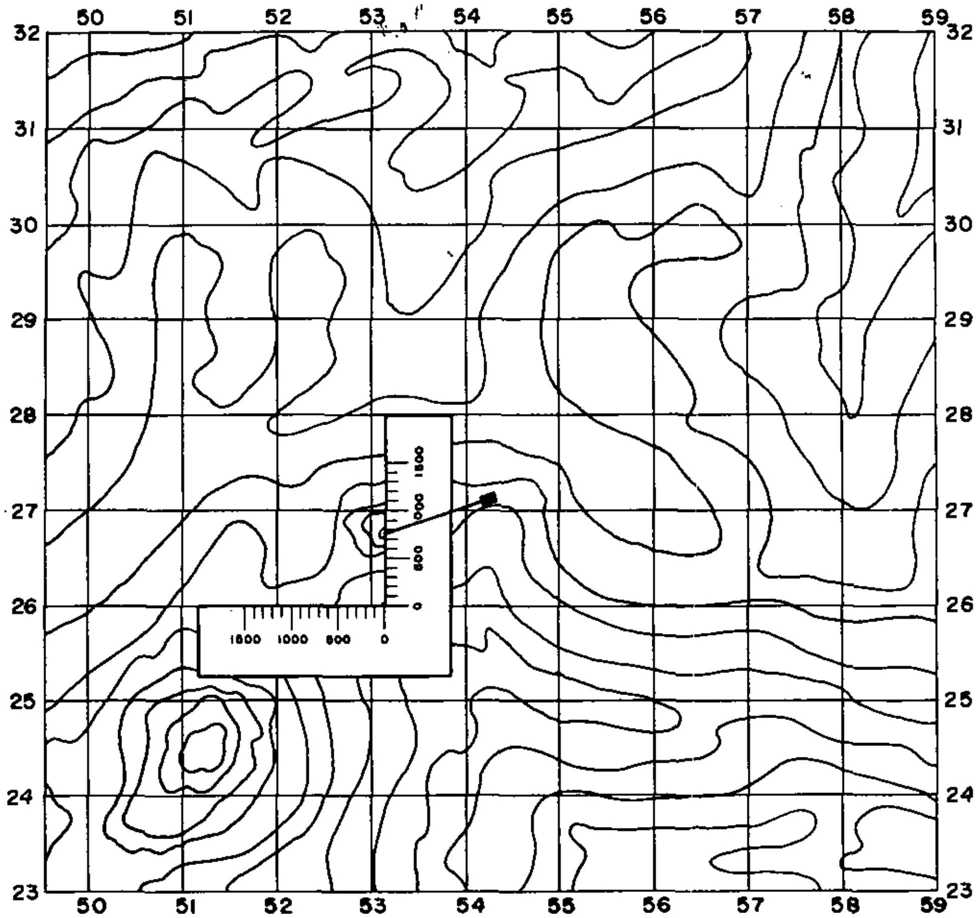

Figure 77. Use of coordinate scale.

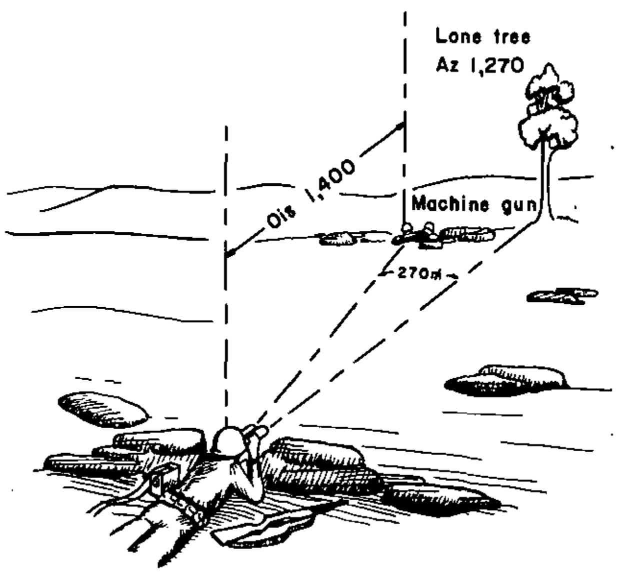

Figure 78. Polar plot.

b. Reference Point. For the reference point method, FDC personnel plot on their charts a number of points whose ground locations are obvious to the observer. Some of these points may be plotted prior to firing, and other points may be plotted later. Either the observer or the FDO may select points for use as reference points, but both observer and FDC personnel must know the location and designation of such points. If a target appears in the vicinity of one of the reference points, the observer may find it convenient to indicate the location of the target with relation to the reference point. To do this, he proceeds to determine the grid azimuth from his position to the target and then computes the lateral shift and the shift in distance from the reference point to the target. Lateral shift is computed by using either the mil relation formula or the sine factor formula, or it may be estimated if the shift is obvious. Shift in distance is determined by comparing the observer-reference point distance to the observer-target distance, when angular deviation is less than 600 mils. If angular deviation is 600 mils or greater, the shift is computed by using the sine factor method. The vertical distance be-

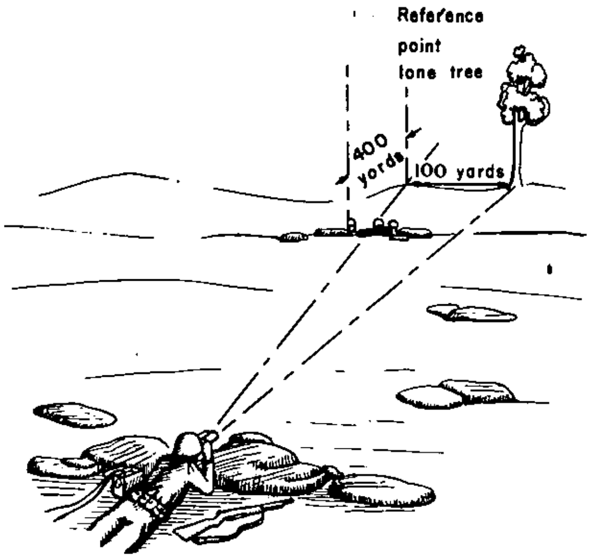

Figure 79. Shift from reference point.

tween reference point and target, if any, must be computed by using the mil relation.

Example (fig. 79): The observer measures a grid azimuth of 1,000 mils to a target. He computes the lateral shift to be 100 yards left from a lone tree previously designated as a reference point and the distance to be 400 yards less than the reference point distance. To the FDC he announces FROM LONE TREE, AZIMUTH 1000, LEFT 100, DROP 400.

c. Vertical Shift.

(1) In the polar plot method, a vertical shift must be made if there is a difference in altitude between the observer's location and the target. The observer, using a BC scope, aiming circle, or M2 compass for accurate measurement or binoculars for an approximation, measures the vertical angle to the target. This vertical angle is measured from the horizontal plane through the observer's location to the target. Substituting this measured vertical angle and the estimated distance to the target, for $\cancel{m}$ and R, respectively, in the mil relation formula, the observer computes the vertical shift.

Example: The measured vertical angle locates the target at 20 mils above the OP. Estimated distance to target from the OP is 2,000 yards. Using the mil relation, $20=\frac{W}{2.0}$, $W=40$ yards. The vertical shift is announced as UP 40.

(2) In the reference point method, a vertical shift must be made if there is a difference in altitude between the reference point and the target. The observer measures the vertical angle to the reference point. Knowing the distance from his OP to the reference point and using the mil relation, the observer determines the vertical interval or the amount in yards that the reference point is above or below his OP. He then computes the vertical interval between his OP and the target. By comparing the reference point vertical interval to the target vertical interval, he determines the vertical change (up or down) from reference point to target.

Example (fig. 80): The observer measures a vertical angle of minus 10 mils between the OP and a target at a distance of 2,500 yards. The distance and the vertical angle from the OP to the reference point are 1,500 yards and minus 20 mils, respectively. In the formula $\cancel{m}=\frac{W}{R}$, let W represent the vertical interval, $\cancel{m}$ represent the measured angle

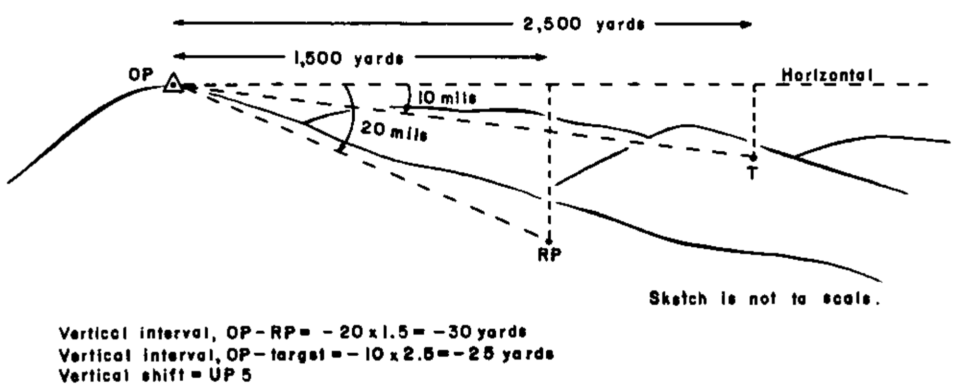

Figure 80. Determination of difference in height between reference point and target.

in mils, and R represent the distance to the target (reference point) in thousands of yards. Therefore, $-10=\frac{W}{2.5}$; $W=-10 \times 2.5=-25$ yards vertical interval between OP and target. By using the same procedure, vertical interval between OP and reference point is -30 yards $\left(-20=\frac{W}{1.5};\ W=-30\right)$. A comparison of results shows the target to be 5 yards above the reference point. Thus, the vertical shift would be announced as UP 5.

d. Prearranged Data. For possible future firing, certain points, known as concentrations, are recorded on the FDC charts. Each point is assigned a concentration number. When a concentration is plotted on the FDC charts, its number and location are furnished to the observer. An observer may request FDC personnel to plot a concentration when he feels that it may be used for future reference. If a target appears at a point near a plotted concentration, the observer may indicate the location of the target by a shift from the concentration. If a target appears at the point of the plotted concentration, the observer requests fire by specifying the concentration number.

e. Marking Volley. The observer may request a marking volley from which he can shift fire to a target. Some examples are—

MARK REGISTRATION POINT.

MARK CENTER OF SECTOR. (The observer may add UP (SO MUCH), FUZE TIME, to obtain a high air burst which he can identify.)

CHAPTER 10

FIRE REQUESTS

158. Elements and Sequence of Fire Request

a. When an observer desires to fire on a target, he transmits a fire request. The fire request is a concise message prepared by the observer containing the information needed at the FDC for the preparation of fire commands. The fire request contains 11 elements arranged in a predetermined sequence. When any of these elements are not pertinent, they may be omitted.

b. The following is a list of the elements and the sequence in which they are transmitted.

(1) Identification of observer.
(2) Warning.
(3) Reference point or target coordinates.
(4) Azimuth (observer to target).
(5) Location of target by shift (omitted for coordinates).
(6) Nature of target.
(7) Classification of fire.
(8) Type of adjustment.
(9) Type of projectile.
(10) Fuze action.
(11) Control.

159. Identification of Observer

The element identifying the observer consists of appropriate call signs or codes necessary to establish contact between the observer and the unit from which he is requesting fire. For example, the observer transmits STALLION 15 (call sign of the FDC being contacted) THIS IS STALLION 48 (observer's call sign).

160. Warning

The warning element is the notice sent by the observer to achieve communications priority and to alert the FDC personnel to process a fire mission. It is announced as FIRE MISSION.

161. Azimuth and Location of Target

Azimuth and location of target are announced in the sequence that will permit their being applied most readily by the FDC.

a. When the target location is given in the form of *coordinates*, azimuth is announced after the coordinates; for example, COORDINATES 385624, AZIMUTH 1260.

b. When the target location is given by a *shift from a known point*, azimuth is announced immediately after designation of the point from which the shift is being made; for example, FROM CONCENTRATION AA413, AZIMUTH 2450, RIGHT 250, DOWN 20, ADD 500.

c. When a target location is given by *polar coordinates*, azimuth is announced as the first element of target location; for example, AZIMUTH 1870, DOWN 20, DISTANCE 1600.

162. Nature of Target

The element indicating the nature of the target includes a description of the installation, personnel, equipment, or activity which is observed. This description should be brief but sufficiently informative to enable the FDO to determine the relative importance of the target and the best manner of attack. The observer should state the approximate number of personnel or units of materiel comprising the target; e. g., 50 INFANTRY AND 3 TANKS IN THE OPEN. He should give a clear description of the target, the shape of which is significant; e. g., 60 INFANTRY DIGGING IN ALONG RIDGE LINE. He should indicate the approximate size of a target that covers a large area; e. g., TRUCK PARK IN WOODS, 300 BY 300. Size of the target is omitted in the case of precision registration.

163. Classification of Fire

Fires are classified as either *close* (within 600 yds of friendly troops) or *deep* (beyond 600 yds of friendly troops) according to the proximity of the target to friendly troops. Use of the classification of fire element is optional when adjusting ground artillery fire but mandatory in the adjustment of naval gunfire. (For naval gunfire procedures, see app VII.) This element may be required by a unit commander when other provisions, such as *no-fire* lines, do not guarantee safety of the friendly troops.

164. Type of Adjustment

a. In adjustment, two types of fire may be employed—area or precision. When a precision adjustment is desired, the observer specifies either registration or destruction, depending on the reason for firing. In all other circumstances, i. e., area missions, this element is omitted. If no specific type of adjustment is designated, area fire will be used.

b. Two choices of trajectory for the adjustment may be available—low-angle or high-angle. When low-angle fire is desired, the observer omits this element; this omission specifies low-angle fire. When high-angle fire is desired and the FDO does not have the information necessary to determine that fact, the observer requests HIGH ANGLE. When computations at the FDC show high-angle fire to be necessary, the FDO will notify the observer that high-angle fire will be used.

c. The observer has two methods of fire available—*salvo* or *volley*. If no method is specified, volley fire will be used. Salvo fire is desirable in adjustment or fire for effect (FFE) under certain conditions such as—

(1) When wind conditions cause one burst to be obscured by another, the observer may request SALVO RIGHT (LEFT) (depending on the location of the battery in relation to the OT line or depending on the direction of the wind) in order that the near round will burst after the far round. If the observer does not know the location of the battery in relation to the OT line, he requests SALVO FIRE and uses the numerical sequence of fire for identification of individual pieces.

(2) When one piece is firing out of sheaf, in which case salvo fire may be used to determine the piece which is firing in error.

d. A normal sheaf is usually fired on an area target in FFE. When another type of sheaf is desired, the observer announces the type of sheaf desired; e. g., CONVERGED SHEAF.

e. The observer may indicate the volume of FFE desired; e. g., REQUEST BATTALION.

165. Type of Projectile

a. The observer omits the element indicating type of projectile when he desires shell HE. Unless the observer specifies a projectile by type (WP, smoke, illuminating), the FDO will direct the use of shell HE.

b. The observer may request one type of projectile initially, e. g., WP, and subsequently request another type of projectile, e. g., HE, to complete the fire mission.

c. When the observer requests SHELL SMOKE, the FDO will direct the use of shell HE initially in adjustment and shell smoke for completion of adjustment and in effect.

d. When the observer wants a combination of projectiles in effect, he must so state in this element of the initial fire request; e. g., SHELL HE AND WP IN EFFECT.

166. Fuze Action

a. The observer omits the element indicating fuze action when he desires fuze quick (FzQ) or when he has no choice in the type of fuze to be used. For example, if he requests either HC smoke shell or illuminating shell, the element indicating fuze action would be omitted since these shells are always fuzed with a time fuze.

b. Unless the observer designates a specific fuze, the FDO will direct the use of an applicable fuze.

c. When the observer wants VT fuze in FFE, he requests FUZE VT. The FDO will direct the use of fuze quick in adjustment and VT in effect. If, in an exceptional case, the observer wants fuze VT during adjustment, he must so specify by requesting FUZE VT IN ADJUSTMENT.

d. When the observer wants a combination of fuzes in effect, he must so state in this element of the initial fire request. For example, FUZE VT AND QUICK IN EFFECT.

e. For information on requesting a change in fuze during a fire mission, see paragraph 195.

167. Control

The control element indicates the control which the observer will exercise over the time of delivery of fire and whether an adjustment is to be made or fire is to be delivered without an adjustment. Method of control is announced by the observer by use of one or more of the terms in *a* through *d* below.

a. Will Adjust. Will adjust indicates that an adjustment is necessary, that the observer can see and adjust the fire, and that the firing unit may begin firing when ready.

b. Fire for Effect. When the location of the target is sufficiently accurate to preclude adjustment, the observer announces FIRE FOR EFFECT. This type of fire has appreciable surprise value and is preferable. FFE indicates that the observer is ready to observe and that the firing unit may fire for effect when ready. When the observer requests fire for effect, the FDO may decide, from knowledge not available to the observer, e. g., when corrections are not current, that an adjustment is necessary and will so inform the observer.

c. At My Command. At my command indicates that the observer desires to control the time of delivery of fire. The observer announces AT MY COMMAND immediately preceding the announcement of *a* or *b* above; i. e., AT MY COMMAND, WILL ADJUST, or AT MY COMMAND, FIRE FOR EFFECT. When the pieces are ready to fire, the FDC personnel announce BATTERY (BATTALION) IS READY to the observer, after which the observer announces FIRE when he desires the pieces to fire. This method of control remains in effect throughout the mission unless the observer transmits FIRE WHEN READY, which cancels AT MY COMMAND.

d. Cannot Observe. Cannot observe indicates that the observer will be unable to adjust the fire; however, he has reason to believe that a target exists at the given location and that it is of sufficient importance to justify firing on it without adjustment.

168. Correction of Errors

a. If the observer makes an error in announcing an element of the fire request, or a part thereof, and recognizes the error immediately, he announces CORRECTION, followed by that element in its correct form. For example, the observer has transmitted STALLION 15, THIS IS STALLION 48, FIRE MISSION, FROM REGISTRATION POINT 2, AZIMUTH 4680. Immediately upon announcing AZIMUTH 4680, the observer realizes that he should have transmitted AZIMUTH 5680. In this instance, he announces CORRECTION, AZIMUTH 5680, and then continues to announce the remainder of the fire request.

b. If the observer has transmitted all elements of his fire request and finds that he has made an error in one of the elements or that FDC personnel have repeated back incorrectly one of the elements; he sends CORRECTION, followed by only the corrected element which was in error. The remaining elements of the fire request need not be retransmitted. For example, the observer has transmitted STALLION 15, THIS IS STALLION 48, FIRE MISSION, FROM REGISTRATION POINT 2, AZIMUTH 5680, LEFT 200, ADD 400, 25 INFANTRY IN OPEN, FUZE DELAY, WILL ADJUST. He desires to change LEFT 200 to RIGHT 200. To correct his error, he sends CORRECTION, RIGHT 200, ADD 400 (RIGHT 200, ADD 400 is one element).

c. If any element of the fire request has been omitted erroneously, the observer sends that element to the FDC as a separate transmission. He does this without repeating the entire fire request. For example, the observer has transmitted STALLION 15, THIS IS STALLION 48, FIRE MISSION, FROM REGISTRATION POINT 2, AZIMUTH 5680, RIGHT 200, ADD 200, COMPANY OF INFANTRY IN OPEN, WILL ADJUST. He desires to include fuze delay which he omitted initially. To correct his error he sends CORRECTION, FUZE DELAY.

d. If at any time the observer discovers that data have been transmitted which, when fired, will endanger friendly elements, he immediately transmits CEASE FIRING. This command must always be followed by an explanation. For example, after the observer has transmitted data to bring fire on a road junction, a friendly patrol moves into view near it. The observer immediately transmits CEASE FIRING, FRIENDLY PATROL IN AREA.

169. Examples of Initial Fire Requests

Table V gives examples of initial fire requests together with explanations of what the observer can expect from each sample request.

Table V. The Fire Request

Fire request			Examples				
Element	When omitted	When announced	1. Precision registration using surveyed chart	2. Area mission using polar plot	3. Destruction mission using reference point shift	4. Area mission using prearranged data	5. Area mission firing high-angle fire
a. Identification of observer	Never	Always	THUNDER 15, THIS IS THUNDER 48.	STALLION 15, THIS IS STALLION 48.	COMPOUND 15, THIS IS COMPOUND 48.	KANVAROD 15, THIS IS KANVAROD 48.	RAMROD 15, THIS IS RAMROD 48.
b. Warning	Never	Always	FIRE MISSION	FIRE MISSION	FIRE MISSION	FIRE MISSION	FIRE MISSION.
c. Location of target *d*. Azimuth *e*. Location of target by shift	Never	Always	REGISTRATION POINT 2, AZIMUTH 4710.	AZIMUTH 5260, DOWN 30, DISTANCE 3200.	FROM REGISTRATION POINT 1, AZIMUTH 2640, RIGHT 500, UP 25, DROP 800.	CONCENTRATION AB 302, AZIMUTH 5040.	COORDINATES 762184. AZIMUTH 4750.
f. Nature of target	In precision registration	When other than precision registration is desired.	Omitted	20 INFANTRY IN THE OPEN.	BUNKER	5 TANKS AND COMPANY OF INFANTRY IN THE OPEN.	MACHINE GUN FIRING.
g. Classification of fire	When target is deep	Optional when target is close.	Omitted	Omitted	Omitted	Omitted	CLOSE 500.
h. Type of adjustment:							
(1) Type of fire	Area of fire	Precision	REGISTRATION	Omitted	DESTRUCTION	Omitted	Omitted.
(2) Trajectory	Low-angle fire	High-angle fire	Omitted	Omitted	Omitted	Omitted	HIGH ANGLE
(3) Method of fire	(*a*) In precision fire. (*b*) When 2 piece volleys are desired. (*c*) In FFE mission.	When any method other than two piece volleys is desired in area fire.	Omitted	SALVO LEFT	Omitted	Omitted	Omitted.
(4) Distribution	(*a*) When normal sheaf is desired. (*b*) In precision fire.	When firing other than normal sheaf in area fire.	Omitted	Omitted	Omitted	Omitted	CONVERGED SHEAF.
(5) Volume FFE	When applicable	When applicable	Omitted	Omitted	Omitted	REQUEST BATTALION.	Omitted.
i. Type of projectile	When shell HE is desired	When other than shell HE is desired.	Omitted	Omitted	Omitted	SHELL HE AND WP.	Omitted.
j. Fuze action	(1) When Fuze Q is desired. (2) When HC smoke or illuminating shell is requested.	When any fuze other than Fuze Q is desired for shell HE.	Omitted	FUZE TIME	Omitted	Omitted	FUZE VT.
k. Control	Never	Always	WILL ADJUST	WILL ADJUST	WILL ADJUST	FIRE FOR EFFECT.	WILL ADJUST.
IMMEDIATE RESULTS OF INITIAL FIRE REQUEST			(Observer will get 1-piece, low-angle, precision, shell HE, fuze Q.)	(Observer will get 2-piece salvos from the left, low-angle, regular sheaf, shell HE, fuze Ti.)	(Observer will get 1-piece, low-angle, precision, shell HE, fuze Q.)	(Observer will get area fire, low-angle, normal sheaf, shell HE and WP, fuze Q, bn FFE.)	(Observer will get area fire, high-angle, 2-piece volleys, converged sheaf, shell HE, fuze Q in adjustment, fuze VT in effect.)

CHAPTER 11

ADJUSTMENT PROCEDURE BY GROUND OBSERVER

Section I. GENERAL

170. Adjusting Point

Those targets which cannot be attacked with sufficient accuracy to place effective fire on the target with the first round(s) fired require adjustment. Adjustment is a system of trial firing to determine the firing data necessary to deliver effective fire on a selected point. The selected point is called the adjusting point and may be the target, a portion of the target, or some well-defined point in the target area (fig. 81)

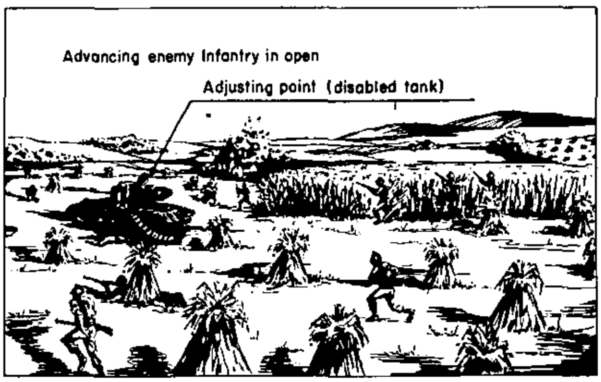

Figure 81. Adjusting point in area fire.

171. When to Adjust

When the observer cannot locate the target with reasonable accuracy, he will normally conduct an adjustment. Lack of accuracy in the location may be the result of poor visibility, deceptive terrain, poor maps, or difficulty on the part of the observer in pinpointing the target. The decision to adjust rests with the observer. If, in his opinion, fire for effect can be delivered on the basis of target location, and surprise is desired, he will request FIRE FOR EFFECT in his initial fire request. If, in his opinion, fire for effect cannot be delivered on the basis of target location, he will signify the need for adjustment by including WILL ADJUST in his fire request. If a current registration of the pieces has not been accomplished, adjustment may be directed by the FDO regardless of the accuracy of the target location.

172. Use of Bracket

A bracket is the distance between two rounds fired on opposite extremes of a target. Brackets may be established for range, direction, or height of burst. The normal procedure for adjustment is the establishment of a bracket for range along the observer's line of vision (OT line) (fig. 82). Direction and height of burst, however, are normally corrected by the observer without resorting to a bracket.

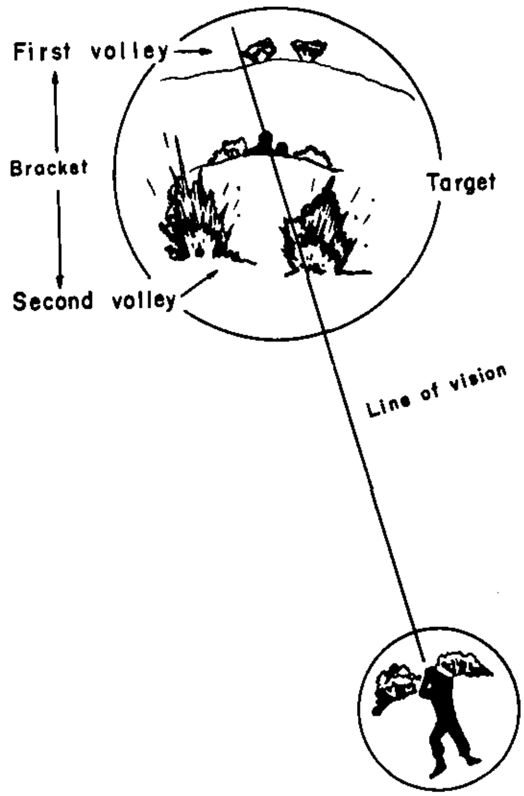

Figure 82. Establishing a bracket for range.

173. Number of Pieces During Adjustment

The number of pieces used for an adjustment depends on the type of mission being fired. If the mission is a precision mission, one piece is used. If the mission is an area mission, two pieces are normally used by light, medium, and heavy artillery and one piece by very heavy artillery. The number of pieces to be used during adjustment will be determined at the FDC. If the observer desires a specific number of pieces, he must specify the number desired; e. g., BATTERY SALVO. During training, when ammunition is in short supply or when an experienced observer has a thorough knowledge of the target area, one piece only may be used by prearrangement with the FDC.

174. Appearance of Bursts

The observer must be able to identify the type of shell and fuze used from the appearance of the burst. Descriptions of types of shells and fuzes with which an observer will normally be concerned are given in *a* through *f* below. These types are applicable to all artillery weapons; however, size of the bursts will vary in accordance with the caliber of the weapon (fig. 83).

a. Shell HE, Air Burst, Fuze Time, or Fuze VT. A fuze time or fuze VT air burst is characterized by a flash, sharp explosion, and puff of black smoke which becomes elongated along the trajectory (fig. 83 ①). The effect of fragments on the terrain may be seen below the burst, if the burst is not too high and soil conditions are favorable.

b. Shell HE, Fuze Delay, Ricochet. A ricochet burst is a low air burst which is characterized by a flash, sharp explosion, and ball of smoke (usually black) (fig. 83 ②). Dirt is kicked up by the shell fragments from the side and base spray. Burst appearance will vary with the nature and condition of the soil and the attitude of the projectile as it bursts. The characteristic flash, black smoke, and sharp explosion of an air burst are indications of an effective ricochet burst while a dirt-colored smoke cloud and muffled explosion are indications of graze or mine action. Facility in distinguishing between ricochet and graze bursts is gained by practical experience in observing fire.

c. Shell HE, Fuze Quick. A burst resulting from a fuze quick detonation is characterized by black smoke, discolored by dirt, which spreads both upward and laterally (fig. 83 ③). If the impact occurs on a rock or other hard surface, a flash may also appear. Fuze quick fired into a wooded area will sometimes result in air bursts, caused by the projectile striking the trees and detonating before reaching the ground.

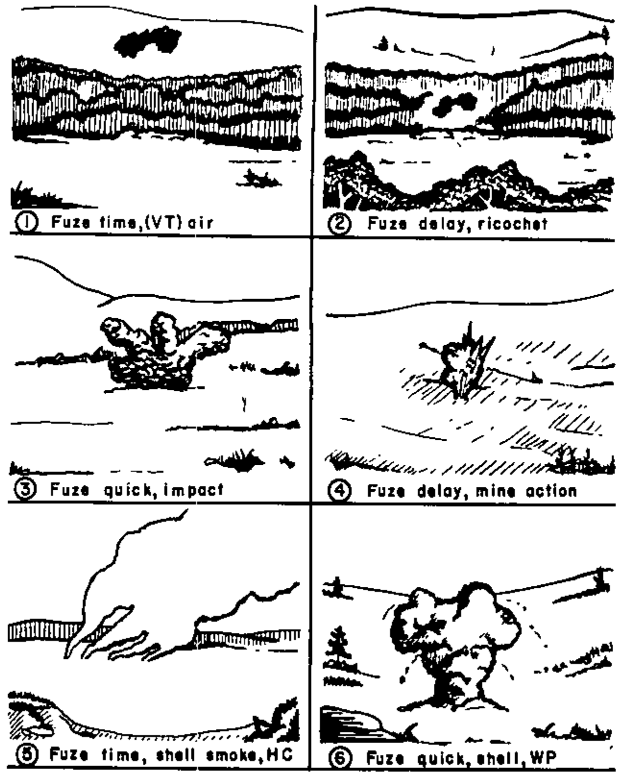

Figure 83. Appearance of bursts.

d. Shell HE, Fuze Delay. Mine Action. A mine action burst is characterized by the eruption of a vertical column of dirt, often with clods of earth, and produces very little smoke (fig. 83 ④). The explosion is muffled.

e. HC and Colored Smoke, Fuze Time. Functioning of an HC or colored smoke shell with fuze time is characterized by a small burst in the air, produced by the expelling charge, which ejects the smoke canisters from the base of the shell (fig. 83 ⑤). These canisters fall to the ground and emit their smoke in thin streams. These smoke streams travel an appreciable distance and then billow out.

f. Shell WP, Fuze Quick. A fuze quick WP shell burst is characterized by a fountain of brilliant white smoke and burning phosphorus (fig. 83 ⑥). Small particles of phosphorus are spread upward and outward as a pillar of smoke forms and rises.

175. Effects of HE Projectile

The effect obtained with an HE projectile depends on the fuze action (fig. 84).

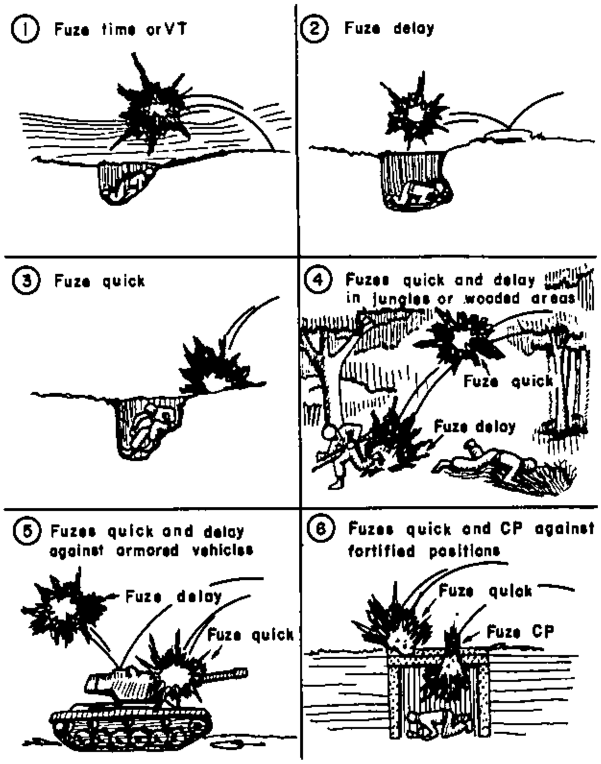

Figure 84. Effects of HE bursts.

a. Fuze VT. VT fuze is a radio-activated fuze which bursts the projectile automatically at a predetermined height above the earth's surface. Therefore, a height of burst adjustment is not required. During the adjustment phase, fuze quick is normally employed because greater speed can be obtained and sensings can be facilitated. Fuze VT is suitable for use against—

(1) Personnel in the open.
(2) Personnel in entrenchments.
(3) Area type targets where neutralization is desired.

b. Fuze Time. Time fuze bursts the projectile on operation of a preset time mechanism or on impact. Thus, height of burst is controlled by the observer. Since the observer must adjust the height of burst, use of this fuze will be more time-consuming than fuze VT. However, with fuze time the observer may obtain any height of burst desired. Fuze time is very ineffective in high-angle fire, because of the large height of burst probable error involved in long times of flight. Fuze time is suitable for use against the same types of targets as those which fuze VT is used for within the limits imposed by the vertical probable error of the fuze.

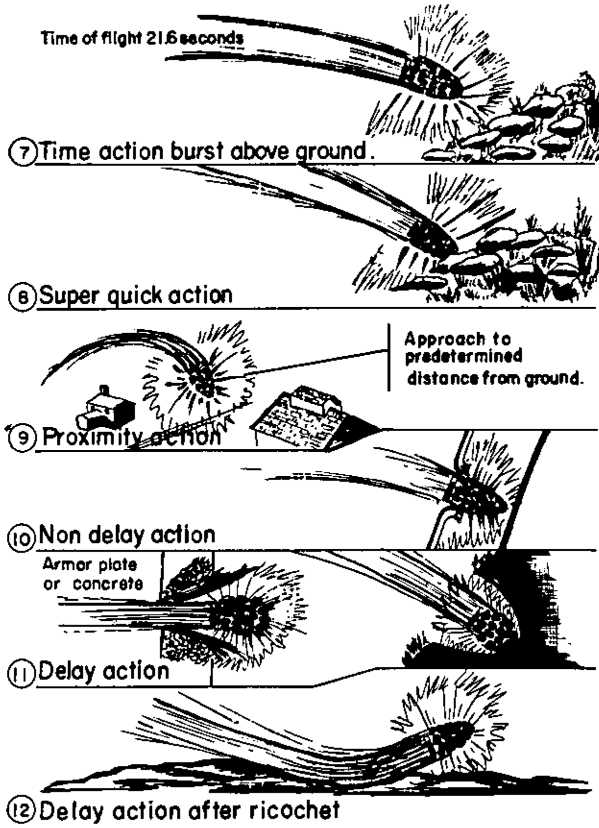

Figure 84.—Continued.

c. Fuze Delay. When delay action of the fuze is used, the projectile has time after impact and before detonation (fuze M51A5, delay element is 0.05 second) either to penetrate and produce mine action or to ricochet and produce a low air burst. This fuze is used with shell HE for destruction missions which require penetration and for ricochet fire.

(1) Factors which determine whether a shell will ricochet are angle of impact; shape, weight, and terminal velocity of projectile; length of delay of fuze; and condition of surface of ground, including composition of soil.
(2) When the angle of impact is small, the projectile tends to ricochet. As the angle of impact increases, the projectile first penetrates and then tends to rise. When the angle of impact is large, the projectile continues downward until it stops or detonates. When penetration occurs, a crater is produced. However, if penetration is very great, the burst may produce a camouflet; that is, a hole underground, the surface of the

ground remaining unbroken. Whether a camouflet or a crater is produced depends on the depth of burst, type of soil, and force of detonation.

(3) When penetration occurs and the shell is in the earth at the instant of detonation, fragmentation effect above the ground is very small. Penetration into a bunker or dugout will produce casualties by blast effect and fragmentation. Penetration into a masonry structure which has been shattered by armor-piercing (AP) projectiles will tend to blow the shattered portions apart. Penetration into a structure built of logs, sandbags, or similar materials results in the blowing apart of constituent units; effectiveness depends on the amount of high-explosive filler. Use of concrete-piercing (CP) fuze increases depth of penetration and the angle at which penetration may be obtained against reinforced concrete or heavy masonry targets.

(4) Effect of ricochet bursts is similar to that of air bursts obtained with time or VT fuzes and may be used against the same type of targets. Factors which determine whether a projectile will ricochet cannot be evaluated for the particular point of impact until the burst is sensed. Hence, ricochet fire *must be observed,* and another type of fire must be used if ricochets cannot be expected from at least 50 percent of the rounds fired in FFE.

d. Fuze Superquick. Superquick (quick) fuze action bursts the projectile immediately on impact. Ease of spotting a fuze quick burst, together with the fact that no height of burst adjustment is necessary, makes possible a most rapid adjustment with fuze quick. Fuze quick is suitable for use against—

(1) Personnel in the open (very effective in high-angle fire).

(2) Personnel in sparsely wooded terrain where tree bursts give the effect of a low air burst.

(3) Materiel when penetration is not required.

(4) Armored vehicles when firing heavy artillery (concussion).

e. Combined Fuze Action in FFE. When the target is such that more than one type of fuze action will add to the effectiveness of fire for effect, for example as shown in figure 84④ through ⑥, the observer will include the fuzes desired in the intitial or a subsequent fire request.

176. Sensings

Determination by the observer of the location of a burst or group of bursts with respect to the adjusting point as observed along the OT line is called a sensing. Sensings are made for *height of burst, range, and deviation.* Except as noted in *d* below, bursts must be observed to be sensed. Sensings must be based on what the observer sees at the instant the burst occurs, not on what he remembers. Normally, sensings are made instantaneously except when delayed to take advantage of drifting smoke or dust.

a. The observer must make definite sensings promptly during adjustment and should be required to announce these sensings during his early training. As an observer gains experience, sensings must be made but need not be announced. Range *sensings* are made as OVER, SHORT, DOUBTFUL, RANGE CORRECT, or TARGET. Deviation and height of burst sensings are made in mils.

b. In precision fire, the observer announces sensings rather than corrections during fire for effect. When FFE is being conducted with impact fuze, the observer announces range sensings and deviation sensings in that sequence. During a time registration, the observer announces only height of burst sensings, since an impact registration previously conducted has determined the necessary range and deflection corrections.

c. A positive range sensing by the ground observer of a burst not on the OT line is called a terrain sensing. Such a sensing is based on the observer's knowledge of the terrain in association with his observation of the burst, drifting smoke, or burst shadow. Even the experienced observer must exercise caution and good judgment in making terrain sensings. When sensings are made on drifting smoke or on shadows, direction of the wind or position of the sun *must* be considered.

d. Under certain conditions the observer may be able to make a sensing, although he is unable to observe the burst. For example, if the observer heard the burst and the only possible place where the burst could occur and not be visible to the observer was in a ravine beyond the adjusting point, then the burst could be properly sensed as being beyond the adjusting point.

177. Corrections

The observer causes the mean point of impact or burst to be placed on, or sufficiently close to, the target by making appropriate adjustment corrections during the adjustment phase prior to fire for effect. From his sensings, the observer determines deviation, height of burst, and range corrections in yards. He announces these corrections in that sequence as commands to bring the bursts onto the OT line, to obtain the desired height of burst (time fire), and to establish the appropriate bracket of the adjusting point along the OT line.

178. Fire for Effect

a. Fire delivered after an adjustment which has caused the mean point of impact or bursts to be within the desired distance of the target or adjusting point is called *fire for effect.* The type and amount of fire delivered depends on the effect sought. It may consist of a limited number of rounds fired by one piece, as in a precision registration, or, in the case of area fire, it may consist of a devastating volume of fire delivered by one or more batteries or battalions.

b. When an adjustment is not required and surprise fire is desired, *fire for effect* is requested in the initial fire request.

Section II. ADJUSTMENT OF DEVIATION

179. Deviation Sensings

a. Deviation is the perpendicular distance from the burst center to the OT line, and a deviation sensing is the determination of the angular amount and direction of the deviation. During conduct of fire, the observer measures in mils the angular amount each burst or group of bursts appears off the OT line. When a single round is fired, the measurement is taken from the center of the burst. When a salvo or volley is fired, the measurement is taken from the center of the group of bursts (fig. 85).

b. A burst, or the center of a group of bursts, may be on the OT line or it may be right or left of the OT line. Possible deviation sensings during adjustment are LINE or (SO MUCH) RIGHT (LEFT). For example, the observer sees a burst which he measures to be 20 mils to the right of the OT line. His deviation sensing in this instance would be 20 RIGHT.

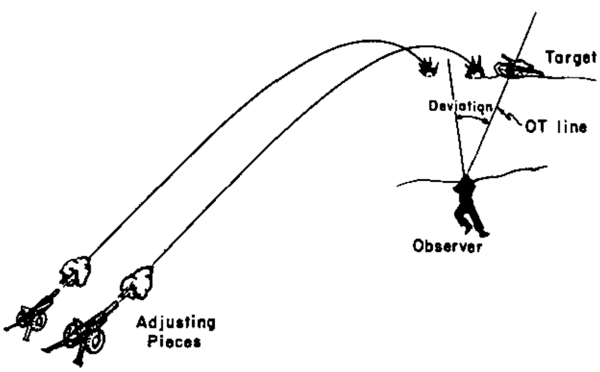

Figure 85. Deviation.

c. During fire for effect in precision fire, the observer normally announces the deviation sensing of a burst off the OT line as simply RIGHT or LEFT without announcing the amount of deviation. However, when the deviation is large or the amount of deviation may assist the FDO in expediting the mission, the observer announces the deviation in yards. Deviation sensing for a burst on the OT line is announced as LINE.

180. Deviation Corrections

a. General. A deviation correction is the distance in yards required to move a subsequent burst, or the center of a subsequent group of bursts, right or left to place it on the OT line. The observer computes and announces deviation corrections to the nearest 10 yards. It is of particular importance that subsequent bursts be brought to the line as quickly as possible in a precision registration to facilitate FDC sensings during the adjustment.

b. The OT Factor. The number expressing observer-to-target distance in thousands of yards is called the OT factor. The OT factor is carried out to 1 decimal place. An OT factor of 3.7 represents an OT distance of 3,700 (3,651 to 3,749) yards. OT distance can be measured on a map or estimated.

c. Computation of Deviation Correction. The observer uses the mil relation to compute a deviation correction. He multiplies the observed deviation in mils (deviation sensing) by the OT factor to obtain the required correction in yards. This amount is rounded off to the nearest 10 yards. The correction is given in the direction opposite the sensing. Deviation correction is announced in yards as LEFT (RIGHT) (SO MUCH). The following are examples of computation of deviation corrections:

OT distance	*OT factor*	*Sensing*	*Deviation correction*
4,000 yds	4	40R	LEFT 160
3,400 yds	3.4	50L	RIGHT 170
2,500 yds	2.5	100L	RIGHT 250
1,500 yds	1.5	20R	LEFT 30

d. Rounding Off OT Factor and Measured Deviation. It is not always practicable to use the full OT factor and the exact measured deviation in computing each deviation correction. The observer strives to make the most accurate corrections possible; however, time limitations and the nature and size of the target often require that these figures be rounded off in computing a correction.

e. Correcting Erroneous OT Factor. During the adjustment, the observer may find that his initial estimate of the OT distance was in error. In such a case, he must adjust his OT factor in accordance with new indications of the OT distance. For example, the observer's initial estimate of OT distance was 2,200 yards:

(1) If, after the first volley, he added 800 yards and then 400 yards more to obtain an OVER, it is apparent that the OT distance is between 3,000 and 3,400 yards; the OT factor should be increased accordingly to 3.2.

(2) If, after the first volley, he measured a deviation of 100 mils right, sent a correction of LEFT 220, and measured a deviation of 30 mils right on the second volley, the OT factor should be increased to 3.1 $\left(\frac{W}{\not{m}}=R=\frac{220}{70}=3.1\right)$. However, if the angle T is large (*f* below), care must be exercised to distinguish range dispersion from deviation.

f. Effect of Large Angle T. The angle T is the angle at the target formed between the OT line and the gun-target (GT) line (fig. 86). When the angle T is large (500 mils or greater), range dispersion appears to the observer as deviations from the OT line, making line shots difficult to obtain. The observer therefore must take advantage of accurate terrain sensings whenever possible. An observer must learn to judge whether or not small deviations from the line

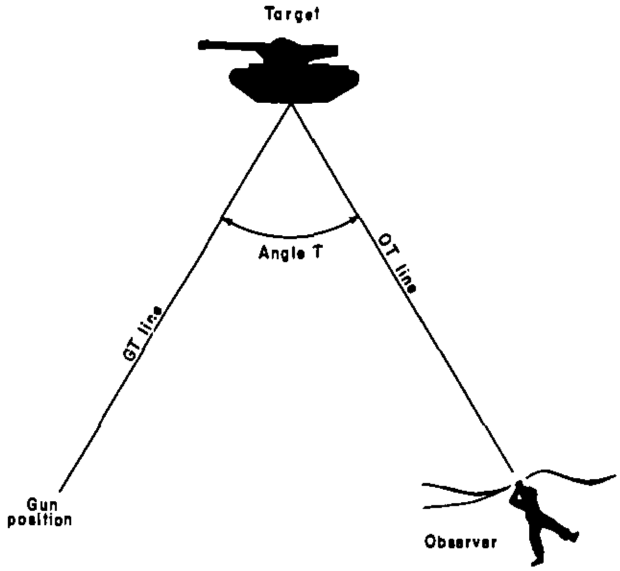

Figure 86. Angle T.

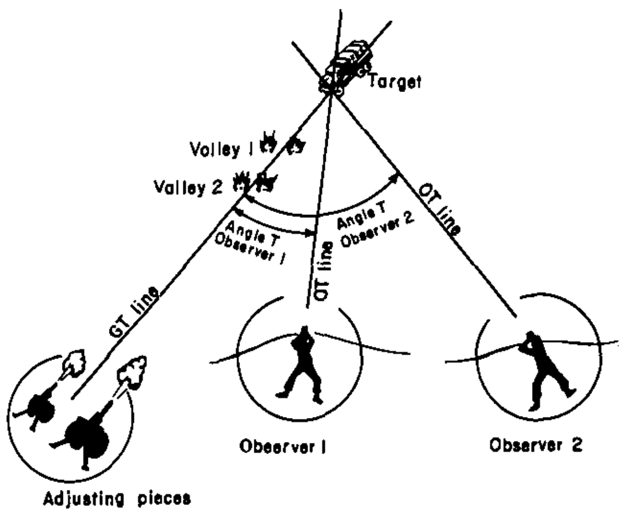

Figure 87. The effect of angle T when viewing range dispersion.

are due to range dispersion. In figure 87, the two volleys shown were fired at the same elevation and deflection. The difference in location of the bursts is due to range dispersion along the GT line. As viewed by observer 1, from whose location the angle T is relatively small, there appears to be little difference in the amount of deviation correction needed to bring these volleys to the OT line. However, as viewed by observer 2, volley 2 appears to be twice as far off the OT line as volley 1. To assist the observer in judging range dispersion, the FDC personnel will announce to the observer the size of the angle T to the nearest 100 mils when the angle T is 500 mils or greater, because at this size angle T it becomes difficult to distinguish range dispersion from deviation. For example, when an observer finds that a deviation correction results in the next volley bursting on the opposite side of the OT line at a sufficient deviation to make the sensing for range difficult, the observer should systematically reduce the size of subsequent deviation corrections until deviations become small enough to ignore. A guide is to use one-half the indicated correction (compute the correction in the usual manner, and then apply only half of it). The cause of this deviation may be range dispersion, irregular terrain, unrefined OT factor, errors of personnel or materiel, or a combination of all these factors.

g. Firing Close to Friendly Troops. The observer must exercise caution in making deviation corrections in the direction of friendly elements close to the target.

Section III. ADJUSTMENT OF HEIGHT OF BURST

181. General

In firing time fuze in area fire, the observer must adjust the height of burst. During adjustment, the observer makes a sensing of height of burst in mils and then computes and announces a correction to the nearest 5 yards as UP (DOWN) (SO MUCH) to raise or lower the subsequent burst to the desired height. Computations are made by using the mil relation in the same manner as for deviation shift. A good height of burst for adjustment is that height in the air which provides distinct sensings. The proper height of burst for fire for effect is 20 yards (fig. 88).

Figure 88. Effective height of burst (approx 20 yds).

182. Height of Burst Sensings

Height of burst is sensed when fuze time or fuze delay is being fired for ricochet fire. When fuze VT is fired, only malfunctions and graze bursts are reported. Sensings for height of burst are as follows:

a. Air. A burst in the air is sensed AIR; a burst in the air below target level is sensed AIR BELOW.

b. Graze. An impact burst is sensed GRAZE; an impact burst above target level is sensed DOUBTFUL.

c. Mixed. A salvo or volley resulting in an equal number of air and graze bursts is sensed MIXED.

d. Mixed Air. A salvo or volley resulting in both air and graze bursts is sensed MIXED AIR when a preponderance of air bursts is obtained.

e. Mixed Graze. A salvo or volley resulting in both air and graze bursts is sensed MIXED GRAZE when a preponderance of graze bursts is obtained.

183. Height of Burst Corrections During Area Missions

a. To determine the height of a burst, the observer multiplies the vertical angle in mils between the ground and center of burst by the OT factor (mil relation). For example, if the observed vertical angle is 20 mils and the OT distance is 3,000 yards, the height of the center of burst is 60 yards (20×3). To bring the next burst(s) down to a height of 20 yards, the observer announces DOWN 40 ($60 - 20$).

b. When the initial volley results in all grazes, a correction of UP 40 is given. When the initial volley results in mixed or mixed graze (50% or more graze bursts), 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 all airs, the mean height of burst of the volley (in yards) is computed as in *a* above and the correction announced. In figure 89, the correction for height of burst would be DOWN 20.

c. When air bursts have been obtained during adjustment and a subsequent volley resulted in all grazes, a correction of UP 20 is given. Since a height of burst bracket has been previously

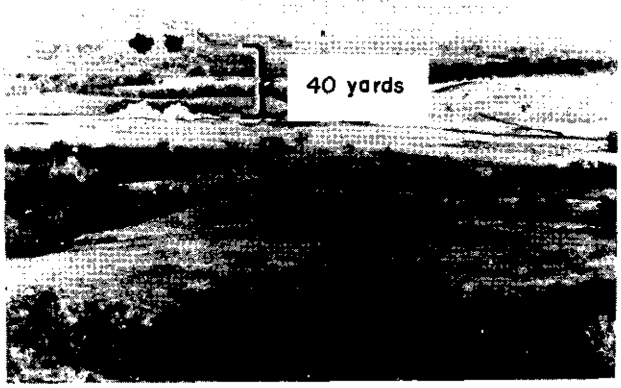

Figure 89. Adjusting height of burst.

established, it is not desirable to make a correction of UP 40.

d. Fire for effect is started only after a correct height of burst is assured, regardless of the existing distance (range) bracket. Therefore, *fire for effect is never commenced when the last volley observed resulted in all graze bursts.*

e. When firing at targets located on steep slopes or on extremely irregular ground, the observer must exercise caution in adjusting the height of burst. Air bursts below the level of the target must be corrected for height of burst; e. g., in figure 90 ①, the air bursts are sensed as AIR BELOW, SHORT and must be raised 30 yards to reach the height of the target plus an additional 20 yards for proper height of burst, resulting in a correction for height of burst of UP 50. Graze burst above the level of the target is not corrected for height of burst; e. g., in figure 90 ②, the graze bursts are sensed as DOUBTFUL, OVER and only a range correction is made, since, after the FDC personnel correct range and fuze setting, the new height of burst cannot be predicted.

f. When rounds cannot be sensed by the effect pattern on the ground because of heavy foliage, snow, or wet ground, adjustment is made with a

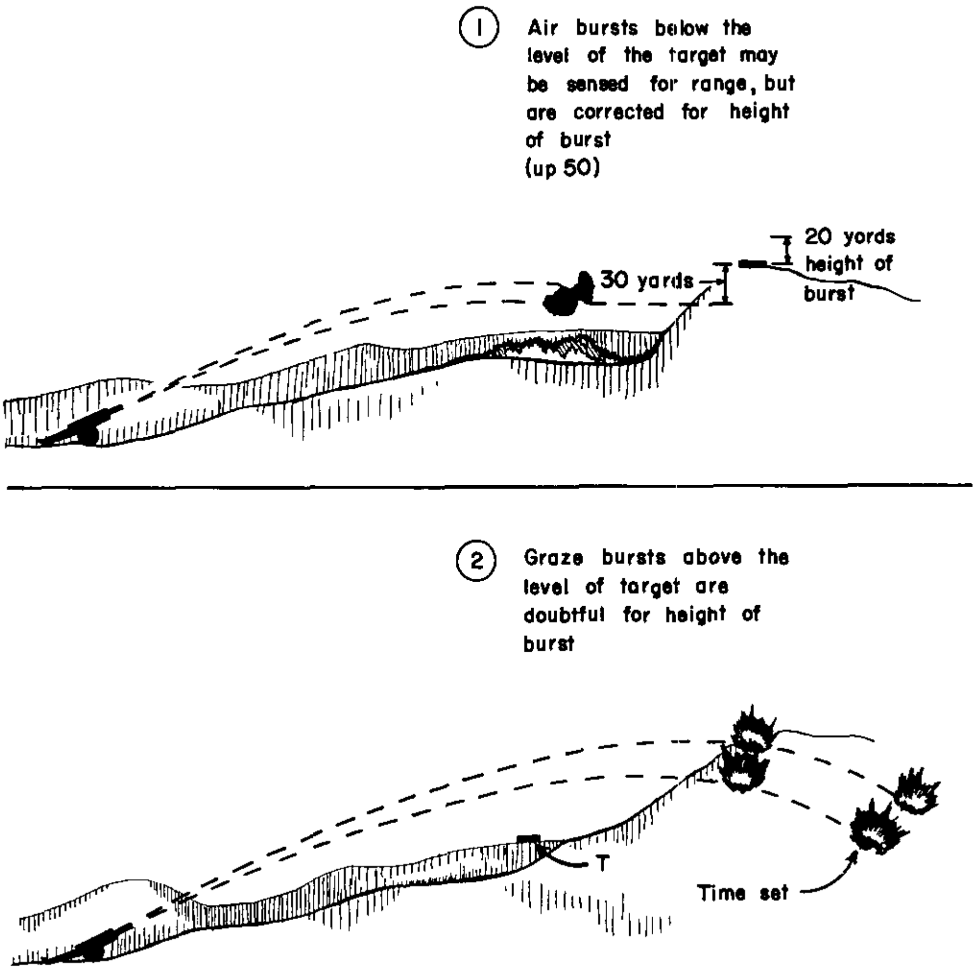

Figure 90. Sensing height of burst when firing on steep slope.

very low height of burst (0 to 10 yds). Adjustment is not conducted with a mean height of burst lower than zero (half airs, half grazes).

g. When fuze delay is employed for ricochet action, no adjustment of height of burst is possible. The observer notes the number of air and graze bursts in each volley. If the two volleys which established the bracket to be split to enter fire for effect contained 50 percent or more air bursts, fire for effect is commenced using fuze delay; if more than 50 percent of the bursts were sensed graze, the observer requests either FUZE VT or FUZE QUICK, whichever is more appropriate.

h. No adjustment of height of burst is possible with fuze VT. Burst height is controlled by the mechanism inside the fuze. The mechanism functions at varying heights for different caliber projectiles. The time of functioning is also influenced by the angle of fall of the projectile; the greater the angle of fall, the lower the height of burst (fig. 91).

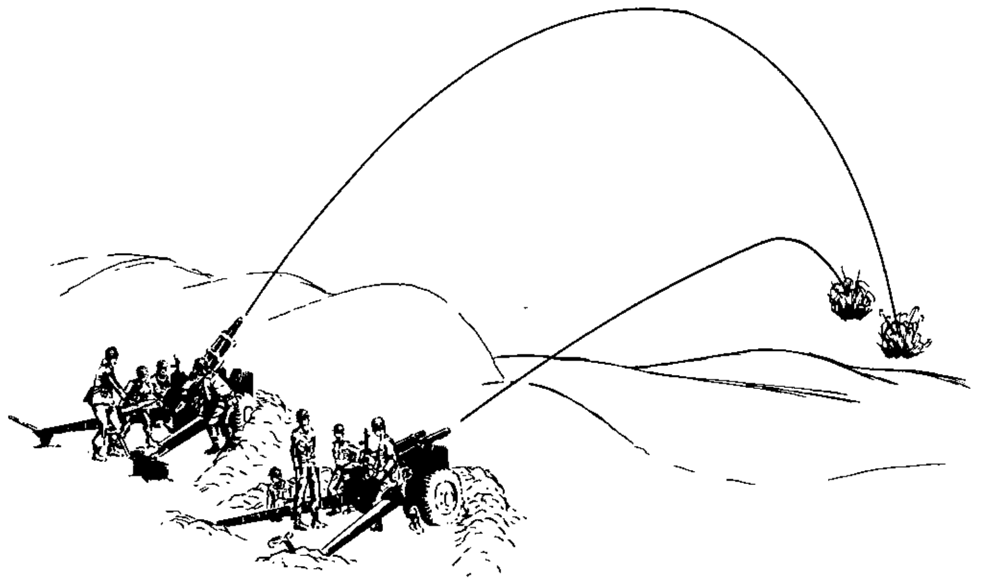

Figure 91. Effect of angle of fall on VT fuze.

Section IV. ADJUSTMENT OF RANGE

184. General

The observer makes an adjustment of range by using the *bracketing* method of adjustment. From sensing of bursts, the observer determines proper range corrections to establish successively smaller range brackets around the adjusting point until the bracket required for entering fire for effect has been established. A fire for effect bracket may be defined as that bracket which, when split, will insure a reasonably high degree of lethal effect on the target.

185. Range Sensings

a. General. Positive range sensings are required to obtain a correct range adjustment. The observer makes a positive range sensing before announcing a range correction. An impact burst on the OT line normally gives a positive range sensing. Figure 92 is intended as a guide in which areas for the various sensings are approximated; the exact size and shape of each area depends on the configuration of the terrain.

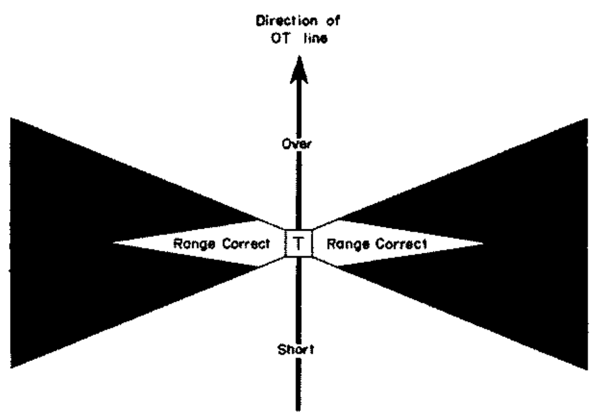

Figure 92. Range sensings.

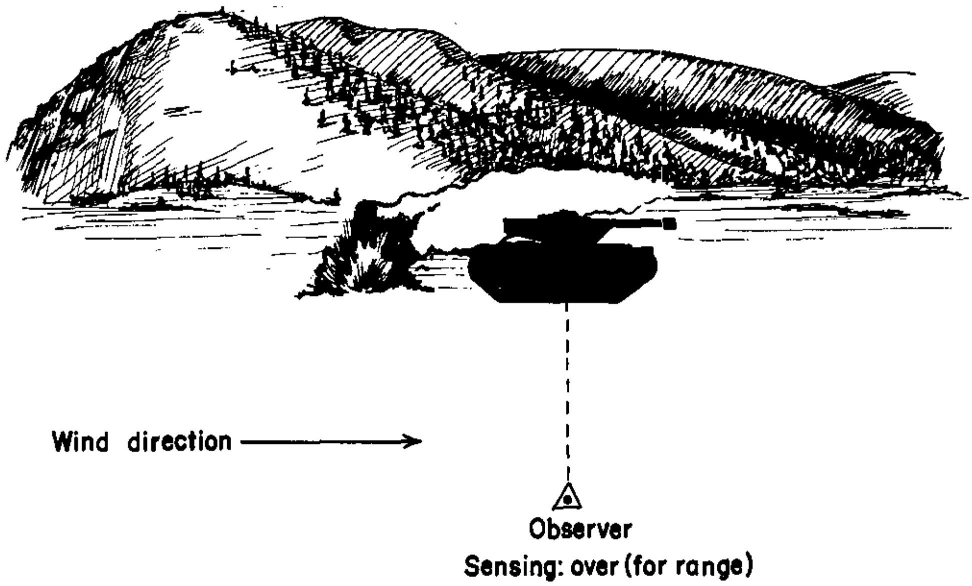

Figure 93. Terrain sensing using drift of smoke.

b. Terms. The terms in (1) through (7) below are used in making range sensings.

(1) *Over.* Bursts which occur beyond the adjusting point are sensed OVER. If a line shot is not obtained, terrain sensing or smoke sensing is appropriate. For example, an impact burst occurs to the left of the OT line near the adjusting point, the wind is blowing across the observer's front from left to right, and smoke from the burst drifts directly behind the adjusting point. In this case, the burst is sensed as OVER for for range (fig. 93). Care must be exercised by the observer in taking a sensing on drifting smoke, since inaccurate determination of wind direction in the target area can result in a false sensing.

(2) *Short.* Bursts which occur between the adjusting point and the observer are sensed SHORT. There is one exception; if a fuze time graze burst occurs close to the target, it is sensed DOUBTFUL because a correction in height of burst only may cause the next burst to occur beyond the target (fig. 94). A terrain sensing is appropriate in the following example: an air burst is observed off the OT line, the sun is behind the observer, and the shadow of the air burst falls on a terrain feature known to be short of the adjusting point. In this case, the burst is sensed as SHORT (fig. 95).

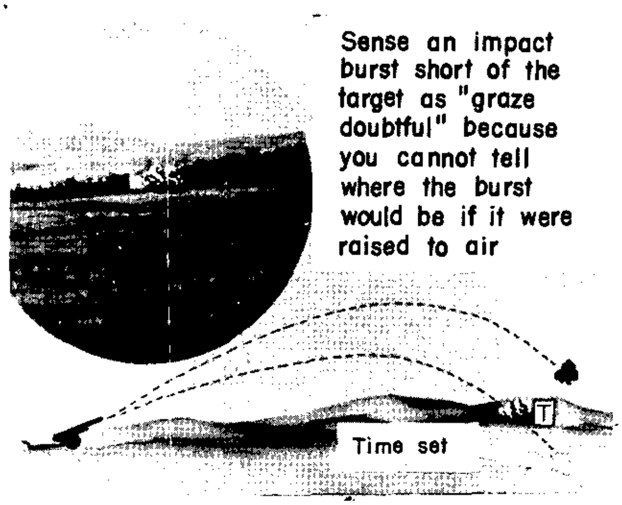

Figure 94. Error in site causing a round to land short of the target in time area fire. With proper site, burst would be over.

(3) *Target.* Bursts which hit the adjusting point are sensed TARGET. This sensing is used in precision fire only.

(4) *Range correct.* A burst which is at the proper range, or a volley or salvo resulting in an equal number of overs and shorts, is sensed RANGE CORRECT (not used in precision fire for effect).

(5) *Doubtful.* A burst which can be sensed for fuze action and/or deviation but which cannot be definitely sensed as

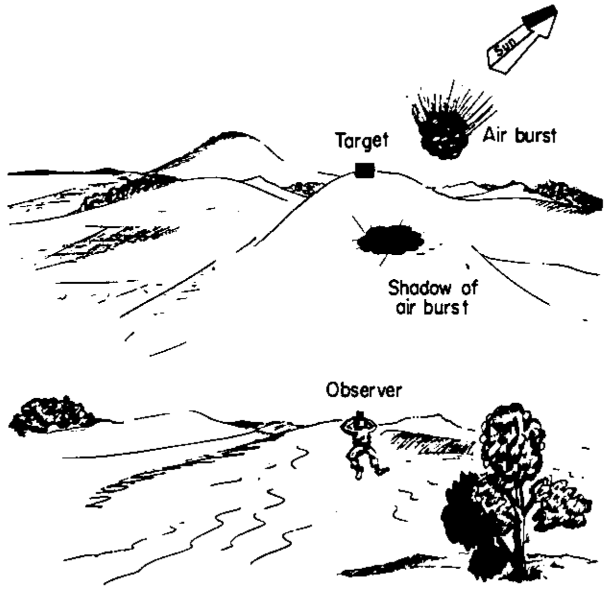

Figure 95. Terrain sensing (short) using shadow of air burst.

OVER, SHORT, TARGET, or RANGE CORRECT is sensed DOUBTFUL.

(6) *Lost.* A burst whose location cannot be determined is sensed LOST. Because refiring the same data will normally result in another lost round, a bold change in direction or range, or both, is requested. Bursts which are sensed as LOST should be so reported to the FDC; e. g., LOST, ADD 400 or LOST, RIGHT 200, ADD 400.

(7) *Lost, over (short).* A burst which is not observed but is known to be definitely beyond or short of the adjusting point may be properly sensed as LOST, OVER or LOST, SHORT (par. 176*d*).

186. Bracketing

a. In conducting fire on a target, the observer establishes a proper bracket or makes a definite sensing of *range correct* before entering fire for effect. After the first positive range sensing of either OVER or SHORT has been obtained, the first range correction should be large enough to bracket the target. If the first range sensing is SHORT, the second should be OVER and vice versa to prevent wasting ammunition and time. The amount of first range correction is based on the accuracy of the location of the target by the observer and the observer's estimation of the distance change along the OT line necessary to bracket the target. After this initial bracket has been established, the observer announces a range correction which will result in having the next burst split this bracket. This burst, together with one of the initial bracketing bursts, establishes a new and smaller bracket. The observer splits this new bracket and successive brackets in a similar manner until a proper bracket is established for entering fire for effect. This proper bracket is normally 100 yards; when the observer splits this bracket, he is justified in calling for fire for effect. However, under certain conditions, notably in heavy (except 8-in. how.) and very heavy artillery when probable errors are large, an observer is justified in calling for fire for effect when a 200-yard bracket is split. When these occasions arise, the FDC personnel will notify the observer that fire for effect should be initiated.

b. Usually the observer should make range corrections in *even* multiples of 100-yard increments (200, 400, 800, etc.). By following this rule, the observer will facilitate his adjustment and will never establish a bracket of odd-numbered values, i. e., 300 or 500, which, when split, will result in awkward values for subsequent range changes. An obvious exception to this rule occurs when the observer splits a 100-yard bracket, in which case he makes a correction in the proper direction of 50 yards.

c. The observer must use his knowledge of the terrain into which he is firing, his general experience, knowledge from previous firing, and his own judgment to determine the size of his initial range change. For example, for one situation, an initial change of 800 yards may be required; for another situation, 400 yards may be adequate. After the initial range bracket has been established, it is still essential that the observer use his own judgment in determining the amount of the range change required to further reduce the size of the bracket rather than blindly following the rule of splitting the bracket. For example, an observer sees a volley which he senses as SHORT and announces a range change of ADD 1200. This next volley is sensed OVER but much closer to the target than the initial volley. The observer's next range change should be DROP 400.

d. When the observer requests an adjustment on a target close to friendly elements, the necessary precautions are taken at the FDC to have the initial burst occur at a safe distance from friendly elements. Thereafter, the observer makes range corrections toward friendly elements in increments which he considers safe. He does not

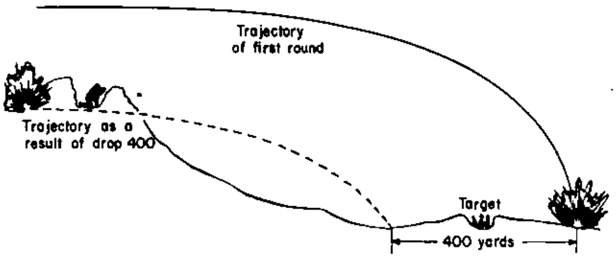

Figure 96. Need for creeping when close to friendly troops.

necessarily attempt to bracket the target with any successive corrections. As his corrections bring the bursts closer to the target, positive range sensings can be made easily. Small, safe shifts may result in a greater expenditure of ammunition and time than normal bracketing methods but may be necessary to insure safety (fig. 96). An adjustment made in this manner is referred to as *creeping*.

Section V. SUBSEQUENT FIRE REQUESTS

187. General

After the initial burst(s) appears, the observer transmits subsequent fire requests until the fire mission is completed. These requests include appropriate changes in elements previously transmitted and the necessary corrections for deviation, height of burst, and range. A subsequent fire request *always* includes a correction for range or a statement that no correction in range is desired. Any other element listed in *a* through *j* below, to which a change or correction is *not* desired, is omitted. The elements (listed in order announced) of subsequent fire requests are as follows:

a. OT azimuth.
b. Deviation.
c. Height of burst.
d. Trajectory.
e. Method of fire.
f. Distribution.
g. Shell.
h. Fuze.
i. Range.
j. Control.

188. Change in OT Azimuth

A change in OT azimuth is given when it deviates from the announced azimuth by more than 100 mils. For example, an observer has begun an adjustment on several self-propelled guns, using a tree at azimuth 5,620 as the adjusting point. During the adjustment, the self-propelled guns move to a new position an appreciable distance from the original adjusting point. The observer selects a new adjusting point in the vicinity of the target and measures the azimuth to the point as 5,840. The first element of his next adjustment correction is AZIMUTH 5840.

189. Correction for Deviation

The observer determines and transmits deviation corrections to the nearest 10 yards as RIGHT (LEFT) (SO MUCH).

190. Correction for Height of Burst

The observer determines height of burst and transmits corrections to the nearest 5 yards as UP (DOWN) (SO MUCH).

191. Change in Trajectory

The observer requests a change in the trajectory during a low-angle adjustment when it becomes apparent that high-angle fire will be necessary or, during a high-angle adjustment, when it becomes apparent that high-angle fire is no longer required. For example, the observer is making an adjustment on a moving self-propelled gun. During adjustment, the target moves into a deep gully for cover. The observer knows from previous firing in the area that high-angle fire will be necessary to bring effective fire into the gully, so he requests HIGH ANGLE. Conversely, an observer is making a high-angle adjustment on a column of vehicles halted along a street in a town constructed of tall buildings. During adjustment, the vehicles move out toward the edge of town. As soon as he notices that the vehicles are emerging from town, the observer should request LOW ANGLE to expedite the firing.

192. Change in Method of Fire

If a change in method of fire is desired during an adjustment, the observer announces the change. For example, to change from 2-piece volleys to two pieces firing in order from left to right the observer requests SALVO LEFT. This change may be requested by the observer to take advantage of drifting smoke to facilitate sensings or to clarify sensings when one round is obscuring another.

193. Change in Distribution

Since the FDO normally directs the firing of normal (parallel) sheaf in area fire adjustment, the observer seldom has reason to request a change in distribution during the adjustment phase. However, anytime the distribution is obviously in error or should be changed to facilitate the adjustment, the observer reports this fact to the FDC. The FDC personnel will then determine necessary corrections or cause the errors to be corrected. In order to bring more effective fire to bear on the target, the observer may request a change in distribution on entering fire for effect or after the first volley in fire for effect. For example, CONVERGED SHEAF is requested to bring all the fire to bear on a point target. If the shape of the target is such that a normal sheaf will not give the desired effect, the observer describes the shape of the target to the FDC so that appropriate corrections may be applied.

194. Change in Type of Shell

When the observer desires to change the type of shell, he announces the desired change. For example, the observer might be unable to identify the first round of shell HE in adjustment, in which case he might request SHELL WP to locate the burst.

195. Change in Fuze

When the observer desires to change the fuze or fuze action, he announces the desired change. For example, assume the observer is adjusting with fuze delay to obtain ricochet bursts. If no ricochet action results, the observer would request a different fuze; i. e., FUZE VT or FUZE QUICK (if no VT is available) prior to entering fire for effect.

196. Correction for Range

The observer always announces a range correction, or repeat range, as part of his subsequent fire request.

a. Add. The term "add" is used by the observer to move subsequent bursts away from the observer along or parallel to the OT line. Figure 97 shows an example of when to add. If a volley falls short of the target, the observer estimates the distance along the OT line needed to establish a bracket and commands ADD (SO MUCH).

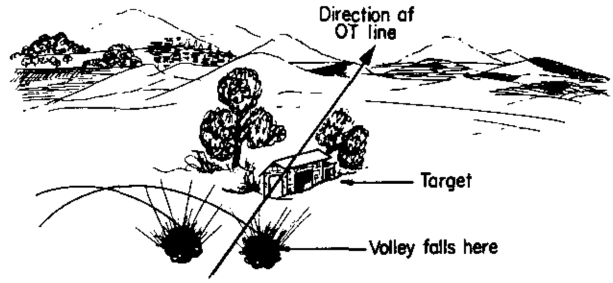

Figure 97. When to add.

b. Drop. The term "drop" is used by the observer to move subsequent bursts toward the observer along or parallel to the OT line. Figure 98 shows example of when to drop. If a volley falls beyond the target, the observer estimates the distance along the OT line needed to establish a bracket and commands DROP (SO MUCH).

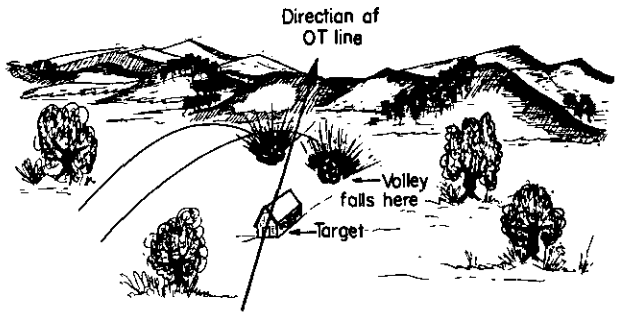

Figure 98. When to drop.

c. Repeat Range. The term "repeat range" is used by the observer when he does not desire a change in range. Figure 99 shows an example of

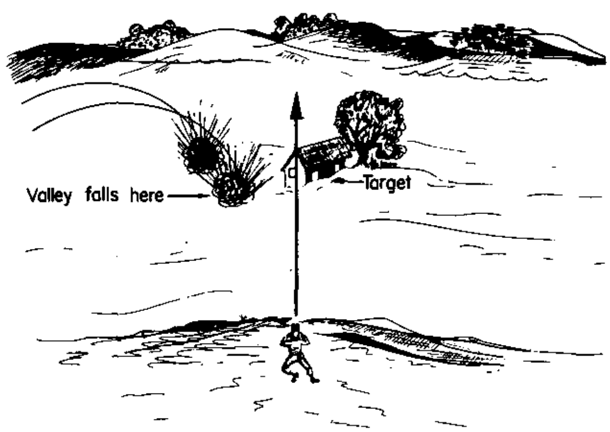

Figure 99. When to repeat range.

when to repeat range. If a volley is sensed as DOUBTFUL for range, the observer commands a shift for deviation, followed by the command REPEAT RANGE.

197. Change in Control

When the observer desires to change the method of control, he announces the desired change. For example, to change the control from AT MY COMMAND, the observer transmits FIRE WHEN READY.

198. Correction of Errors

The observer may discover that he has transmitted erroneous data in a subsequent fire request. He then announces CORRECTION and sends the correct data in an entirely new subsequent fire request. When CORRECTION is transmitted, the *entire* last transmission is cancelled and disregarded. For example, after the observer transmitted RIGHT 200, UP 40, ADD 400, he realized the correction in height of burst should have been DOWN 40. In this case he announces CORRECTION, RIGHT 200, DOWN 40, ADD 400

CHAPTER 12
FIRE FOR EFFECT

Section I. PRECISION FIRE

199. 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 at which FFE is commenced.

a. The observer requests FFE on splitting the appropriate range bracket (usually 100 yds) or on obtaining a target hit.

b. Fire for effect consists of a number of rounds fired either singly or in groups of 2 or 3 by the adjusting piece. FDC personnel inform the observer of the number of rounds that are to be fired in the initial group and in subsequent groups, if a change is to be made in the number of rounds to be fired. The observer normally does not send corrections during precision FFE. Rather, he only announces his sensings of bursts as they occur. However, any burst which in the judgment of the observer is obviously in error or which will materially assist the FDC personnel in expediting the mission must be reported. For example, a round in FFE is observed to be doubtful for range but rapidly computed to be 60 yards left of the target. The observer must transmit a sensing of DOUBTFUL, 60 YARDS LEFT. Since sensings are normally made in mils, the word "YARDS" is used to prevent error and to facilitate operations at the FDC since the OT distance is not usually known at the FDC. Another example is when a burst is observed to be very close to the target. This information combined with the deviation sensing in yards may assist the FDC personnel improving the deflection or in establishing that the deflection is correct; e. g., 20 SHORT, 5 YARDS RIGHT.

200. Precision Registration With Fuze Quick

a. During fire for effect in a precision registration with fuze quick, the observer announces the range and deviation sensing of each burst as he observes it. He announces range sensings as OVER, SHORT, DOUBTFUL, or TARGET and deviation sensings as RIGHT, LEFT, or LINE. These sensings are announced in the order of range, then deviation; e. g., SHORT, LINE.

b. Fire for effect is continued until the FDC personnel notify the observer that the registration is complete.

201. Precision Registration With Time Fuze

a. After a fuze quick registration, a time registration may be initiated from the FDC. The FDC personnel notify the observer to OBSERVE TIME REGISTRATION. A round is fired at the adjusted deflection and elevation determined from the fuze quick registration and with a fuze setting determined at the FDC.

b. The observer normally sends no corrections in a time registration but only announces the height of burst sensing of each burst as AIR or GRAZE. However, if the height of burst of any round of a time registration is in excess of 50 yards, the height of burst will be computed rapidly and reported with the sensing; e. g., AIR, 75 YARDS. If any succeeding round, in the judgment of the observer, is obviously in error for range, deflection, or height of burst, the amount of the error must be determined and reported with the sensing. For example, a round in FFE is observed to be a graze, on line with the target, but estimated to be 100 yards short of the target. The observer transmits GRAZE, 100 YARDS SHORT, LINE. Rounds are fired singly until both an air burst and a graze burst have been obtained, and then rounds are fired in series of 2 or 3. After both air and graze bursts have been obtained, the observer must note, but does not report unless directed (as long as bursts are within the limits stated above), whether air bursts obtained are high (over 20 yards) or low.

c. The firing of time fuze continues until the FDC personnel notify the observer that registration is complete.

d. For an example of a precision registration mission, see chapter 15.

202. Precision Destruction Mission

a. In a precision destruction mission, FDC personnel will direct the use of fuze quick in the initial rounds of fire for effect, as well as in adjustment. This procedure facilitates valid sensings by the observer and expedites determination of an adjusted deflection and quadrant elevation at the FDC. Subsequently, the FDO directs the use of the fuze that will be most effective against the target; e. g., fuze delay, fuze concrete-piercing, etc. If this subsequent fuze is not effective, the observer must request a change to a fuze which, in his opinion, will be more effective.

b. During FFE, the observer announces sensings just as he does in a precision registration with fuze quick.

c. Fire for effect is continued until the observer notifies the FDC that the mission has been accomplished.

Section II. AREA FIRE

203. General

a. In area fire, the observer requests FFE in the initial fire request when his target location is accurate enough to preclude adjustment. When the target location is not accurate enough to permit delivery of surprise FFE without prior adjustment, the location is normally established by adjustment by using the bracketing method.

b. The type and the volume of fire delivered in FFE are determined by the FDO. His decision is based on the observer's description of the target, status of ammunition supply, and other considerations (particularly tactical). If FFE is ineffective or insufficient, necessary corrections are made and additional FFE requested.

c. On completion of FFE, the observer sends END OF MISSION and reports the effect observed. The words CEASE FIRING END OF MISSION may be used. However, since CEASE FIRING is primarily used as an emergency phrase to stop firing after data have been transmitted to the weapons, the observer may end a mission by transmitting only END OF MISSION.

204. Fire for Effect Without Adjustment

When surprise fire is particularly desired or the initial location of the target is accurate enough to preclude adjustment, FFE should be requested immediately. Cases of such accurate location include, but are not limited to, the following:

a. A surveyed location.

b. A recently fired concentration.

c. A small, accurate shift from a recently adjusted registration point or a recently fired concentration.

d. Accurate polar coordinates from a surveyed OP.

e. A prominent feature clearly identifiable both on the ground and on an accurate map.

f. A large area target which will insure first volley effect in the target area.

205. Fire for Effect After Adjustment

a. Deviation. The adjustment of deviation is complete when the mean point of impact or burst is on the OT line. Since, during the adjustment, the observer sends successive deviation corrections to place the bursts on the OT line, it should not be necessary to make a large shift on entering FFE.

b. Height of Burst. When time fuze is being used, FFE is not requested until the height of burst is correct or until a correction can be expected to result in the correct height of burst. FFE is not immediately requested if the last volley observed consisted entirely of graze bursts. The height of burst of such a volley is an indeterminable amount below zero and does not provide the basis for a proper correction. When fuze delay is being used for ricochet fire, its use is continued on entering FFE if at least 50 percent of the bursts which established the final range bracket were air bursts. If more than 50 percent of these bursts were graze bursts, the observer should request fuze VT or fuze quick on entering FFE.

c. Range. The adjustment of range is complete when the observer has obtained bursts at the same range as the adjusting point or target (range correct) or when he has split the appropriate range bracket (usually splits a 100-yd bracket).

206. Distribution

a. Normally, the FDO determines the proper distribution of fire for a target. His decision is based on the observer's description of the target and other available information. Unless the nature and the size of the target require otherwise, artillery fires are delivered at center range, with light and medium artillery using a normal sheaf and heavy artillery using an open sheaf. In certain cases, the FDO may direct the use of a sheaf other than that normally fired. He may also direct a battery or batteries to fire through different elevations for greater coverage.

b. When appropriate, the observer may request the firing of a particular type of sheaf. This request should be announced in the initial fire request when possible. It may be announced later if it becomes apparent that the sheaf normally fired will not provide optimum distribution of fire. In making such a request, the observer announces the type of sheaf desired, such as OPEN SHEAF or CONVERGED SHEAF.

c. When the number of pieces allocated to the mission are not adequate to cover the target effectively with an open sheaf, the observer may make successive shifts in fire for effect to insure coverage of the target.

207. Surveillance of Fire for Effect

The observer carefully observes the results of the FFE and then takes whatever action is necessary to complete the mission.

a. If the fire has been effective and sufficient, the observer announces END OF MISSION and reports the effect observed; for example, 20 CASUALTIES, INFANTRY DISPERSED. If he desires to make a correction to improve the accuracy of the replot of the target but not to fire again, he announces the correction; e. g., LEFT 20, REPEAT RANGE, followed immediately by END OF MISSION.

b. If the fire has been insufficient but accurate, including an effective height of burst, the observer may request REPEAT RANGE, REPEAT FIRE FOR EFFECT to obtain additional fire.

c. If any element of the adjustment (deviation, range, or height of burst) was sufficiently in error, so that the effect sought was not obtained, the observer should correct the element(s) in error and continue the fire for effect; for example, DOWN 10, ADD 50, REPEAT FIRE FOR EFFECT.

d. If ricochet action with fuze delay was indicated and sought but during fire for effect fewer than 50 percent of the bursts were air bursts, the observer requests a change to fuze VT or fuze quick and calls for additional fire, if needed; for example, FUZE VT, REPEAT RANGE, REPEAT FIRE FOR EFFECT.

e. For an example of an area fire mission, see chapter 15.

CHAPTER 13
ADJUSTMENT PROCEDURE FOR SPECIAL SITUATIONS

Section I. CONDUCT OF FIRE WITH CHEMICAL SHELL

208. General

Chemical shell includes smoke shells (base ejection smoke shell and white phosphorus shell) and gas shell (irritant or toxic agents). For detailed uses of gas shells, see FM 3–5.

209. Smoke Shell

a. General. The observer should call for smoke shell in the following situations: to screen enemy observation, to aid in the adjustment of fire (fired to help the observer locate his rounds), as a prearranged signal, and as a marking round for air observation or an air strike. Requests for smoke screens may sometimes be denied, since such missions must be coordinated with higher authority to avoid interference with other operations.

b. Observer Procedure for Screening With Base Ejection Smoke Shell. Adjustment is begun with shell HE (normal observer procedures apply) to avoid obscuring the adjusting point. The observer normally selects an adjusting point well upwind from the target. Wind will then disperse the smoke over the area to be screened. When the approximate adjustment with shell HE has been accomplished, the observer will call for shell smoke to complete the adjustment phase. Height of burst is adjusted with a single piece until proper height and placement of the smoke are obtained. Too low a height of burst will cause the canisters to bury themselves in soft ground or bounce if the ground is hard, while too high a height of burst will cause the canisters to scatter. The observer checks the results achieved by observing the effect of the wind velocity and direction on the smoke. If the desired effect is not obtained, the point of impact must be shifted to a more advantageous position. When the desired placement is obtained, the observer calls for fire for effect to build and maintain the smoke screen. The rate of fire necessary to maintain the screen depends on 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 adjusting the fire should be near the troops whose operations are to be concealed. The screen should be placed on or near enemy positions. Rounds of HE shell (preferably air bursts) or white phosphorous shell fired into the smoke area will prevent enemy troops from leaving shelter to extinguish the smoke canisters. The effect of weather conditions on the development of a smoke screen are shown in figure 100.

c. White Phosphorus Shell. Shell WP is useful for marking, screening, incendiary, and casualty actions. Fuze quick is normally used. Action of the fuze and burster charge breaks the shell and scatters phosphorus particles, which ignite spontaneously on contact with the air. The smoke rises rapidly because of the heat generated by the burning phosphorus. This smoke is desirable for marking purposes and for the buildup of a smoke screen, but, because of the rapid rise of the smoke, WP is not as effective as base ejection smoke for maintaining a smoke screen. If fuze time is used, causing a burst at medium height in the air, the phosphorus particles burn out before reaching the ground. When phosphorus shells are used against frame houses and objects of similar material, some fuzes should be set at delay to effect penetration before bursting and thus increase the incendiary effect of the burning phosphorus particles. Casualties are effected by the small particles of phosphorus adhering to the clothing and skin, causing painful burns.

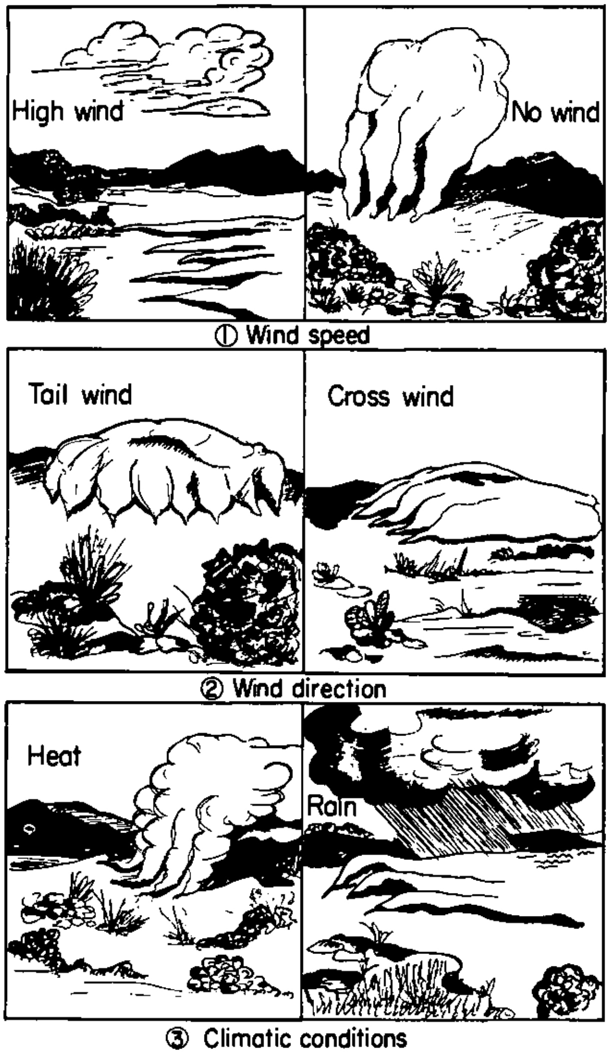

Figure 100. Weather conditions affecting smoke.

d. Colored Smoke. Base ejection smoke shell in colors (white, green, red, and yellow) is used for aiding an observer to locate his rounds, as a prearranged signal, and as marking rounds fired at a predesignated point to guide an air strike to a target.

210. Gas Shell

a. General. Gas shell is fired within restrictions imposed by higher authority. Wind velocity and direction are always carefully considered so that friendly troops are not endangered. Data for firing gas shell should be the most accurate obtainable. To achieve surprise, adjustment is normally conducted with shell HE. Either low air or superquick impact bursts are used with gas shell.

b. Nonpersistent Gas. Surprise and the rapid buildup of an effective concentration are essential elements in the success of an attack with nonpersistent gas. Surprise may be attained not only by adjusting with shell HE but also by means of a transfer of fire or by adjustment on an auxiliary target. An effective concentration is built up by rapid firing.

c. Persistent Gas. Persistent gas is most effective against personnel when it is well distributed on vegetation, materiel, and the ground. To obtain the most effect, a given amount of gas delivered with light weapons is preferable to the same amount delivered by medium or heavy weapons. Dispersion from several smaller projectiles will cause better distribution than dispersion obtained from fewer large projectiles.

Section II. BATTLEFIELD ILLUMINATION

211. General

Battlefield illumination provides friendly forces with sufficient light to assist them in ground operations at night. The artillery observer is concerned primarily with two means of illumination: illumination projectile and searchlight. When properly used, night illumination increases the morale of friendly forces, facilitates operations, and harasses and blinds the enemy. The artillery is charged with the responsibility of providing illumination with illuminating shells and with searchlights; therefore, any artillery observer may be called on to conduct an illumination mission.

212. Conduct of Fire Using Illuminating Shell

a. Uses. Illuminating shell is used for the following purposes:

(1) Illuminating areas of suspected enemy movements.
(2) Night adjustment or surveillance of artillery fire by air or ground observer.
(3) Harassing the enemy in positions or installations.
(4) Furnishing direction to friendly troops for attacks or patrol activities. (Flares must be placed well in advance of friendly troops to avoid illuminating the troops.)

(5) Guiding low level tactical bombers on important targets that are within artillery range.

b. Ammunition. The following comparison gives some of the factors to be considered in the employment of artillery illuminating shells. All data are approximate.

Weapon	*Initial height of burst*	*Initial distance between bursts (spread illumination)*	*Burning time*	*Rounds for continuous illumination*
Howitzer, 105-mm	800 yd	800 yd	60 sec	2 per min
Howitzer and gun, 155-mm	700 yd	1,400 yd	60 sec	2 per min

c. Area To Be Illuminated.

(1) The size of the area which can be illuminated effectively depends on the observing distance, conditions of visibility, and candlepower of the shell used. If the area to be illuminated is large or observing conditions are poor, the firing of only one round of illuminating shell at a time may not be adequate.

(2) When effective illumination of an area can be accomplished by firing one round of illuminating shell at a time, the observer requests ONE GUN, ILLUMINATING, as the type of adjustment and ammunition in his fire request.

(3) When two rounds bursting simultaneously at the same place are desired, the observer requests TWO GUNS, ILLUMINATING.

(4) Two rounds bursting simultaneously with the appropriate spread in range or deflection will provide more light and less shadows than a single flare. When this type of illumination is desired, the observer requests TWO GUNS, RANGE (DEFLECTION) SPREAD, ILLUMINATING. The FDC personnel center the spread over the point indicated by the observer.

(5) Four rounds bursting simultaneously in a diamond pattern of a size depending on the shell used will illuminate a large area with practically no shadows or dark spots. To obtain this pattern, the observer requests FOUR GUNS, ILLUMINATING. The FDC personnel center the diamond pattern usually obtained by firing the center four weapons of a battery, over the point indicated by the observer (fig. 101).

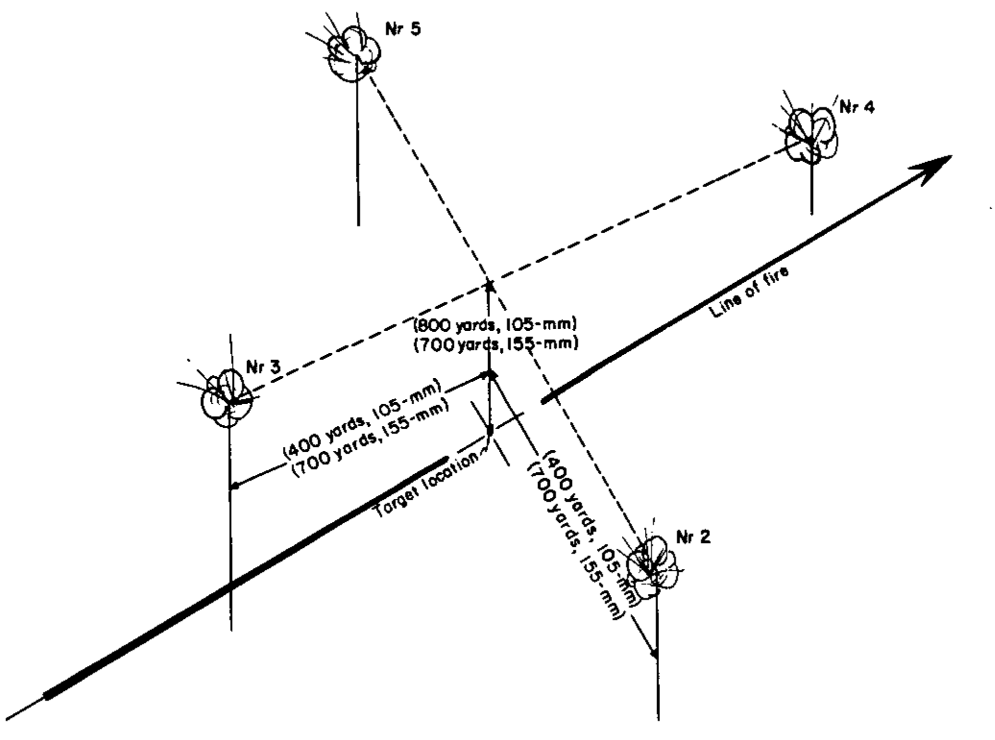

Figure 101. Artillery illuminating shell.

d. *Adjustment.*

(1) Range and direction are adjusted by using standard observed fire procedures, except that adjustment of illumination closer than 200 yards of the target is not justified owing to the size of the area illuminated.

(2) The correct relative position of the flare to the adjusting point depends on the terrain and the wind. Generally, the position of the flare should be to one flank of the adjusting point and at about the same range. In a strong wind, the point of burst will have to occur some distance from the adjusting point because of drift of the flare. If the target is on a forward slope, the flare should be on the flank and at a slightly shorter range. If the adjusting point is a very prominent target, better visibility can be obtained by placing the flare beyond the target to silhouette it.

(3) The proper height of burst is that which will allow the flare to strike the ground just as it stops burning. Changes in height of burst are made in multiples of 50 yards. The variation between flares in the time of burning renders useless any closer adjustment of the height of burst.

(4) When the point of burst is too high, the height of burst change is estimated from the height of where the flare burned out. When the point of burst is too low, the change required is estimated from the length of time (T) in seconds the flare burned on the ground. By multiplying $T \times 10$ (approx rate of descent, 10 yds per sec), the observer can determine the approximate correction required for any illuminating shell.

Example: Flare burned 13 seconds on the ground; $13 \times 10 = 130$; correction is UP 150 (answer rounded off to nearest 50 yds).

(5) Once the observer has adjusted the illuminating shell to the desired location, he should control the rate of fire and number of pieces firing, reducing ammunition expended to the minimum necessary for the required observation.

e. *Ill umination for HE Adjustment.*

(1) If the adjustment of illuminating shell discloses a suitable artillery target, the observer should request CONTINUOUS ILLUMINATION while he adjusts HE fire on the target.

(2) As soon as the observer has located a suitable target for HE fire, he should initiate a normal fire request. If no better means of designating the location of the target is possible, the burst center of the illumination can be used as a reference point. The OT azimuth is announced when it varies by more than 100 mils from the azimuth announced for illumination.

(3) If the observer decides to adjust both the illuminating fire and the HE fire concurrently, he prefaces the requests pertaining to illumination with the word ILLUMINATING and those pertaining to HE with the letters HE; for example, ILLUMINATING, ADD 200, HE, RIGHT 60, ADD 200.

(4) If the HE adjustment is made on an immobile target, such as a disabled tank or a bridge under construction, the observer may be able to conserve illuminating ammunition by coordinating illumination with the adjustment of HE. The observer requests COORDINATED ILLUMINATION instead of continuous illumination and requests control to be BY SHELL, AT MY COMMAND. This indicates that *both* HE and illuminating shell will be fired only at the observer's command. As soon as FDC personnel report that illuminating and HE fires are ready, the observer commands the firing of illuminating shell and then gives the command to fire the HE shells so that the rounds will arrive during the period of maximum illumination of the target. The observer may elect to change the method of control of HE to FIRE WHEN READY while continuing to fire illuminating AT MY COMMAND.

f. *Example Mission.* See chapter 15 for example mission.

213. Conduct of Fire Using Searchlight Illumination

a. The primary use of searchlights by the observer is illumination of areas of suspected enemy movement and night adjustment or surveillance of artillery fire from air or ground OP's. Searchlights are also used to guide friendly elements, mark bomb lines, mark targets for close support air missions, and illuminate objectives in an attack.

b. The number of lights used in any mission will depend on the number available and the situation at that particular time. Normally, when direct illumination is used, a single light will suffice.

c. For the adjustment of the searchlight beam, the observer procedure is similar to that employed in a fire mission. However, the observer makes the adjustment on the *searchlight-target* line in deviation and site. The correction is made in 1 of 2 ways. The observer can move the beam in yards, right/left and up/down, or the observer can move the beam in a number of beam widths. In most cases, the beam-width method is simpler and faster for the observer, since his yardstick is the width of the beam itself. The narrowest beam width (pencil beam) is 22 mils; when fully spread (spread beam), the beam width is 265 mils. Examples of observer corrections are—

(1) RIGHT 100		(1) LEFT TWO BEAMS
	or	
(2) UP 20		(2) DOWN ONE-HALF BEAM

d. The smallest correction in yards which can be made by the observer is 20 yards. For beam widths, the smallest correction is a quarter beam width shift. It is not necessary to give a change in both deviation and elevation each time an adjustment is desired; it is necessary to give only the element to be corrected while the omission of the other element indicates it is to remain the same. If it is desirable to change the degree of beam spread, the terms used are INCREASE BEAM SPREAD (SO MUCH) or REDUCE BEAM SPREAD (SO MUCH). This correction precedes the elevation and deviation corrections.

e. Elements of the illumination request are as follows ((1)–(10) below).

(1) *Identification of observer.* Identification of the observer for an illumination mission is the same as that for a fire mission.

(2) *Warning.* The warning for a searchlight mission is ILLUMINATION MISSION. Since this term is used only for a searchlight mission, it alerts all personnel involved to pass the mission to the searchlight light direction center (LDC). The LDC is normally located at division level. Operators in the communication network must be familiar with this warning signal and the action to be taken.

(3) *Reference point or target coordinates.* The reference point or target coordinates methods of reporting a target location for a fire mission are applicable to a searchlight mission.

(4) *Azimuth* (*observer to target*). The azimuth from the observer to the target is given in an illumination mission for two reasons—first, so that the LDC personnel can select a searchlight for the mission which will best illuminate the target for the specific OP; second, so that the LDC personnel will be able to plot the target location, when an azimuth is required for this purpose.

(5) *Location of target by shift* (*omitted when coordinates are reported*). The observer may indicate the target location by a shift from any point whose chart location is known.

(6) *Nature of target.* Nature of the target is preceded by the word SUSPECTED if identity of the target cannot be made. If the target is identified, the procedure is the same as that for a fire mission. This report will enable the LDC personnel to determine the priority of missions.

(7) *Type of adjustment.* If the type of adjustment is omitted from the observer's request, the observer will receive one light in adjustment. The observer may request two or more lights if he desires.

(8) *Type of illumination.* The observer may have a choice of direct or indirect illumination. Direct illumination requires a clear line of sight between the searchlight and the target area. Visibility into the illuminated area is nearly equivalent to daylight observation if the light source is back of the observer. In a single beam, shining at low angles of elevation, deep shadows are cast by brush and other small objects.. Intersecting beams may be used to eliminate shadows in the immediate target area. Direct illumination eases control; it is, however, more vulnerable to enemy fire than indirect illumination. With direct illumination, there is a possibility of impairing the night vision of friendly forces and of silhouetting friendly troops and installa-

tions. The observer must try to avoid either or both of these situations. If the observer does not specify INDIRECT ILLUMINATION, it will indicate he desires direct illumination. If INDIRECT ILLUMINATION is requested, the observer will receive light which utilizes the scattered or reflected light rays from the main searchlight beams. For an observer looking away from the light source, visibility in the illuminated area at ranges of 5,000 to 7,000 yards from the light source is equivalent to visibility under a quarter moon. The diffused light of indirect illumination reaches into hollows, draws, and tree-lined roads. An observer in an area illuminated by diffused light can detect with the unaided eye a man standing at ranges up to 150 yards. With the aid of field glasses, an observer can detect a man moving at considerably greater ranges. Indirect illumination can be employed for longer periods of time than direct lighting because the light source is less vulnerable to enemy interference. However, indirect illumination does provide sufficient light for limited surveillance. When looking away from the light source, visibility in the illuminated area is approximately three times as great as that when looking toward the light source.

(9) *Degree of beam spread.* Since the searchlight beam can be spread from 22 mils to 265 mils, the beam spread is included in the request so that the observer can illuminate as large an area as possible commensurate with his observing range capability. The degree of beam spread is designated as a fractional part of a fully spread beam in increments of one-eighth spread. If the observer omits this element, the pencil or narrow beam of 22 mils will be used.

(10) *Control.* There are only two methods of control used with searchlights—WILL ADJUST and AT MY COMMAND—FLICK. FLICK is the command used at the searchlight battery to turn on the lights. The observer uses the word FLICK to prevent personnel from misinterpreting fire commands.

f. Some of the terms used in an illumination mission but not common to field artillery are—

(1) Flick—put light in action (corresponds to command FIRE).

(2) Action complete—pointing data have been set on light (corresponds to command ON THE WAY).

(3) Cut—put light out of action.

(4) Hold—light is on target.

g. See chapter 15 for example mission.

Section III. CONDUCT OF ASSAULT FIRE

214. General

a. Assault fire is a special technique of indirect fire. Firing is conducted at short range from a defiladed weapon position to attain pinpoint accuracy against a stationary target. The gun-target range is sufficiently short to make possible successive hits on the same portion of the target. Only one weapon is used on a mission, and the FDC for the mission is normally located at or near the weapon position.

b. Assault fire is used for the destruction of caves, pillboxes, or other fixed fortifications with sufficient vertical dimensions. Assault fire is not designed to attack targets on flat terrain that do not have significant vertical dimensions.

215. Ammunition Used for Assault Fire

a. Projectiles. Shell HE is normally used for assault fire. Deep penetration may be obtained with the 155-mm gun by using armor-piercing (AP) projectiles fired with supercharge against hard surfaces, such as concrete or rock. The crater made by AP projectiles will be small in diameter and will usually require a round of shell HE to be fired every fourth or fifth round to widen the crater and clear away rubble.

b. Fuzes. Concrete-piercing (CP) fuzes are appropriate for destruction of fortifications. Fuze quick or fuze concrete-piercing, nondelay, is used for adjustment and to clear away rubble; fuze concrete-piercing, delay, may be used for FFE to effect penetration. Fuze M51, delay, may be used in FFE if concrete-piercing fuze is not available. Fuse M51 is used to cut through a parapet or earth covering, after which the appropriate fuze CP or fuze M51, delay, is used to effect destruction of the fortification. If excessive ricochets result from the use of concrete-piercing delay fuze, nondelay fuze should be used until enough cratering has been effected to prevent ricochet of the delay fuze.

216. Preparatory Operations

The observer and all personnel concerned with an assault fire mission should prepare detailed plans for the mission. Thorough planning, reconnaissance, and coordination must be completed before the weapon position is occupied. The observer must occupy an observation post as near the target as possible and on or near the gun-target line.

217. Initial Data

Normally, initial data are prepared in advance by use of the best means (usually survey) available to locate the target with respect to the assault weapon position. Therefore, in most cases, a complete initial fire request from the observer is not necessary.

218. Adjustment

a. Adjustment is made by using a modified procedure in which the observer exercises complete control of fire throughout the mission. Corrections in yards are given by the observer for each successive round until the point of impact is on the desired portion of the target. An off-line burst is corrected to bring subsequent bursts to the line through normal adjustment procedure *except* that deviation corrections should be given to the nearest yard. The target is bracketed for range, and the bracket is split successively.

b. When the bursts are very near the target, the observer normally is able to 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 for site rather than range. The point at which the observer begins adjusting site instead of range cannot be prescribed exactly; it depends on the terrain, vertical dimensions of the target, and experience and ability of the observer. As an example, for a target such as a cave entrance on a steep forward slope, after an observer splits a 50-yard range bracket, normally he can adjust site more easily than range. Thereafter the smallest correction appropriate in direction or site is one-half yard.

c. The observer usually will be able to see each round in flight as it travels toward the target. He will make more accurate sensings by noting the position of the round at the instant before the burst than by judging from the burst itself. This will enable the observer to make the small corrections necessary to attain pinpoint accuracy.

219. Fire for Effect

When the point of impact is on the desired portion of the target, the observer does not announce FIRE FOR EFFECT. He continues to send a correction to the FDC for each round fired. All rounds are fired singly or as requested by the observer to permit the desired corrections or changes in ammunition to be made between rounds. The authority to control and to end the mission remains with the observer.

220. Illustrative Missions

See chapter 15 for illustrative missions.

Section IV. CONDUCT OF FIRE USING COMBINED OBSERVATION

221. General

a. Combined observation is that type of observation where two or more observers at different locations are employed to obtain sensings on the same target. For effective conduct of fire using combined observations, the angle of intersection of the OT lines should not be less than 250 mils.

b. Combined observation is used for observing the following types of missions:

(1) High-burst registration.

(2) Center-of-impact registration.

(3) Fire to obtain surprise through use of FFE transfers.

(4) Surveillance of planned fires.

(5) Combined adjustment.

c. Observation posts should, if possible, be established during daylight so that instruments may be oriented and a line materialized on the ground for orientation after dark. The OT azimuth of targets discovered during daylight is recorded by all observers. Targets may be located at night by placing the illuminated cross hairs of an observing instrument on the flash of an enemy weapon. Vertical angle and azimuth are recorded if adjustment is not started at once. As an expedient, direction to a flash may be materialized on the ground by a piece of white tape or two stakes.

222. Equipment

a. To obtain optimum accuracy, each observer should be equipped with an angle-measuring instrument, such as a BC scope or an aiming circle.

b. Initial azimuths to the target can be obtained by the use of a compass. Subsequent deviations from the OT line can be measured with field glasses. However, the use of such equipment in this manner for combined observation is inaccurate. This inaccuracy may preclude the use of this method of adjustment during darkness.

223. High-Burst Registration

a. General. At night, visual adjustment of fire on a ground registration point is impossible without illumination. In desert, jungle, or arctic operations, clearly defined registration points in the target area often are not available. To provide for registrations under these conditions, special procedures have been developed. One such procedure is a high-burst registration using time fuze.

b. Orientation of Observer. In a high-burst registration, the observer's location and that of the desired point of burst are known at the FDC. With these data available, the FDC personnel will furnish the observer with the azimuth and the vertical angle to the expected point of burst. A typical message to the observers from the FDC follows: PREPARE TO OBSERVE HIGH BURST, 01 AZIMUTH 1164, VERTICAL ANGLE +12, MEASURE THE VERTICAL ANGLE, 02 AZIMUTH 718, VERTICAL ANGLE −3, REPORT WHEN READY TO OBSERVE.

c. Conduct of Registration. 01 and 02 orient their instruments on the azimuths and vertical angles given and report when ready to observe. (The observer will, as soon as practicable after orientation of his instrument, set out on a known azimuth a stake which can be equipped with a light for night orientation.) The FDO directs the firing of one orienting round and sends ON THE WAY. The observer will use the orienting round if necessary to reorient the center of the reticle of his instrument on the point of burst. After the orienting round, the observer will not change the orientation of his instrument. Instead, the observed deviation on the reticle is combined with the reading set on the azimuth and micrometer scales to derive the measured azimuth. The same general procedure is used to measure the angle of site. Readings are reported to FDC.

224. Center-of-Impact Registration

Center-of-impact registration is conducted exactly as in paragraph 223, except that an impact fuze is employed instead of fuze time.

225. Combined Observation for Missions Other Than High-Burst or Center-of-Impact Registrations

a. General. When observing at long ranges (exceeding 4,000 yds.) the use of combined observations may result in conservation of ammunition. This is especially important in the case of heavy and very heavy artillery where observing ranges are normally so great that adjustment by normal procedure is extremely difficult and often impossible.

b. OP's Known.

(1) If the OP's are plotted on the FDC charts and the location of the target is known (e. g., target assigned by higher headquarters), orientation is conducted as indicated in paragraph 223*b*. If the target is located by one observer, the other observer is then oriented by FDC personnel.

(2) Targets may be located by one observer by using the methods described in chapter 9. If both OP's are oriented on the same target, location may be accomplished by intersection, performed at FDC, from the OT azimuths.

(3) When fire on a target is desired by the observers, the FDO requires an initial fire request from only one observer. The OT azimuth from the other observer is desirable but not required. The FDO will designate one observer to control the mission.

(4) 01 and 02 orient their instruments and report when ready to observe. After each round(s) is fired, the observers

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report azimuth and vertical angle to the burst(s). Deviations rather than azimuths are reported when directed.

c. OP's Unknown.

(1) If the OP's are not plotted on the FDC charts, but the observers are in communication with each other, it is usually difficult, but possible, for one to so describe the target and surrounding terrain that the other can identify the target. If the observers do not have direct communications, this can be accomplished through the FDC.

(2) Targets may be located by one observer by using the methods described in chapter 9. In FFE transfers from previously fired targets, the observers orient on the previous target. Then they measure and report the mil deviation to the transfer target.

(3) When fire on a target is desired by the observers, the FDO requires an initial fire request from only one observer. The OT azimuth from the other observer is desirable but not required. The FDO will designate one observer to control the mission.

(4) Observer right (OR) and observer left (OL) orient their instruments on the target and report when ready to observe. After each round is fired, the observer measures and reports only the observed deviation in mils of the burst in relation to the target that is being fired on.

Section V. ADJUSTMENT OF HIGH-ANGLE FIRE AND AUXILIARY ADJUSTING POINT

226. General

a. Fire delivered at elevations greater than the elevation for maximum range is called *high-angle fire*. High-angle fire is often required when the weapons fire out of deep defilade, from within cities, or over high terrain features near friendly troops. High-angle fire may also be required when targets are located directly behind hill crests, in jungles, or in deep gullies or ravines and cannot be reached by low-angle fire.

b. Most artillery weapons are capable of firing high-angle fire. Generally, those weapons which have a maximum elevation substantially in excess of 800 mils (approx 45°) have the capability of firing high-angle fire.

227. Determining Requirements for High-Angle Fire

Usually an observer can determine whether high-angle fire is required for any given target; if he cannot determine this, the observer should notify the FDC that high-angle fire may be necessary. In any case, the FDO may decide that high-angle fire is desirable and will notify the observer of its use. By inspecting the map and terrain, the observer usually can determine if a trajectory with a high angle of fall is necessary to deliver fire. Furthermore, previous adjustment of fire in a certain sector by the observer may indicate that high-angle fire is required to attack new targets in that sector.

228. Initial Fire Request

a. When high-angle fire is desired, the observer so indicates in his initial fire request.

b. An *accurate* initial location of the target is desirable because large shifts during adjustment may necessitate a change of charge, since there is little or no overlap in ranges reached by various charges.

c. The long time of flight makes time fire undesirable, since the height of burst probable error is excessive. Furthermore, because of the steep angle of fall, ricochet fire is seldom possible.

d. Quick and VT fuzed projectiles give excellent effect from side spray because of the steep angle of fall. VT fuzes produce a lower height of burst than normally obtained with low-angle fire.

Example: RESERVE 15, THIS IS RESERVE 48, FIRE MISSION, FROM CONCENTRATION AB103, AZIMUTH 670, LEFT 60, UP 25, ADD 200, INFANTRY IN OPEN, HIGH ANGLE, FUZE VT, WILL ADJUST.

229. Adjustment

a. The observer procedure for the adjustment of high-angle fire is the same as that for low-angle fire.

b. The observer must realize that small corrections during adjustment may be unnecessary and time-consuming owing to the increased dispersion experienced during high-angle fire.

c. Since the time of flight is long, in both adjustment and fire for effect, the FDC personnel will give ON THE WAY when the round(s) is fired and SPLASH 5 seconds before the burst occurs. Air observers are given ON THE WAY and both the time of flight and SPLASH.

230. Auxiliary Adjusting Point

a. In area fire, the observer must select a well-defined point on which to adjust. To insure surprise fire, the observer may select some nearby point (auxiliary adjusting point) and adjust on it, and then shift the fire to the area which includes his target.

b. This shift from the auxiliary adjusting point to the target is determined by measuring the deviation shift and range change on the map with a coordinate scale or other suitable device or by using polar plotting technique if a map is not available.

c. There is no advantage to using an auxiliary adjusting point to obtain surprise fire if corrections are current and any one of the following conditions exist.

(1) Accurate target locations can be obtained from a suitable map, photograph, or survey.

(2) Several points have been accurately located by firing or survey (registration points, concentrations, etc.) from which accurate shifts can be made to a target.

CHAPTER 14

THE AIR OBSERVER

Section I. INTRODUCTION

231. General

Observation and adjustment of fires are extended and improved by proper use of organic Army aviation and high-performance aircraft. An air observer is normally employed since it is difficult for a pilot to navigate and observe at the same time. However, the pilot should be well-trained in the adjustment of fire, since such knowledge is invaluable when training new air observes and increases the flexibility in obtaining prompt and accurate fire if an observer is not available.

232. Observation From Army Aircraft

Observation from organic Army aircraft is normally limited to altitudes and locations which will allow the aircraft to avoid enemy ground fire and enemy fighter aircraft.

233. Observation From High-Performance Aircraft

Use of high-performance aircraft provides observation deep into enemy territory beyond the limits of organic Army aircraft. The pilot and observer can fly over enemy territory to sufficient depth to observe and adjust long-range artillery fire. Usually two aircraft are used on a mission—one to adjust the fire, the other to observe for hostile aircraft. Danger from both hostile antiaircraft batteries and hostile planes usually increases as the duration of the flight and the depth into hostile territory increases. For this reason the air observer must minimize the time required for an adjustment.

Section II. PREFLIGHT PREPARATIONS

234. General

The air observer and pilot should be given a preflight briefing by either the unit aviation officer or one of the unit staff officers. Preflight coordination with ground units should cover the method of calling for and executing flak suppression programs and the withholding of friendly aircraft and ground fire against the friendly plane.

235. Preflight Briefing

a. All pilots and observers flying a mission should be briefed on all points pertinent to the mission, including—

(1) Location of battery position areas, registration points, concentrations, target locating reference points, reference lines to be used in making corrections (if GT line is not used), suspected targets, and areas to be searched.

(2) Tactical situation, to include locations of frontlines and no-fire lines and zones of action of supported troops.

(3) Surveillance required, time of mission, type of adjustment to be made, maps and photographs to be used, known enemy antiaircraft defenses, flight instructions, and security restrictions.

(4) Communications details, to include location of ground radios, panel stations, channels to be used, call signs, check-in time(s), and prearranged signals.

b. All important enemy locations, lines, and areas indicated in the briefing are recorded on the appropriate map. Photographs, oblique or vertical, are gridded when possible and marked for direction and locations of critical points, lines, and areas.

236. General

The air observer must transmit an initial fire request in the same sequence as the ground observer. Most target locations are given as military grid references; other target locations are given in terms of a shift from a reference point and a reference line. Since the plane is constantly moving, the observer-target line method is not applicable. Therefore, sensings are based on a given reference line instead of an observer-target line.

237. Determination of a Reference Line

The air observer makes sensings and corrections with respect to a reference line. The reference line and its direction must be known by the FDC personnel of the unit whose fires the observer is adjusting. If possible, the reference line is established prior to flight. There are three reference lines which the observer may select for use in making his adjustment—the gun-target (GT) line, a line of known direction, or a convenient line which the observer selects when in flight and describes in sufficient detail so that the FDC personnel can determine its direction. Since the observer is moving continuously, his reference line on the ground must be easily identified and distinctly visible. In addition, the observer should select a prominent terrain feature or object near the target to facilitate its identification at all times.

a. Gun-Target Line. The observer may select the GT line as his reference line. If the observer knows the location of the weapons, visualization of the GT line is facilitated. If he does not know the location of the weapons, the observer requests that two rounds be fired at different ranges but at the same deflection setting (ranging rounds). By observing the two bursts, the observer determines the direction of the GT line. Once the observer determines the direction of the GT line, he should select terrain features, such as a road, stream, or ridgeline, which will assist him in remembering the GT direction.

b. A Line of Known Direction. The observer may select a line formed by a road, railroad, canal, or any series of objects. Prior to flight the observer selects the line and determines its direction; he informs the appropriate FDC of this line and direction and that he will base his sensings and corrections on this line.

c. A Convenient Reference Line. While in flight, the observer may select a reference line which is convenient and easily identifiable. To use this line, the observer must describe it in detail to the FDC personnel so that its direction may be determined. The FDC personnel confirm the location and direction of the line and then notify the observer to commence using it as his reference line.

238. Location of Targets

When a target is observed, its location can be determined and indicated by military grid reference, by a shift from a known point and a reference line, by a prearranged code, or by cardinal direction.

a. Military Grid Reference. The observer locates the target on his map and transmits the coordinates of the location. When the altitude of a target is not readily apparent to the observer, the FDC personnel must make the necessary computation.

b. Shift From a Known Point and a Reference Line. The observer may indicate the location of a target by announcing a shift from a known point and a reference line. The point must be plotted on the firing chart and must be identifiable on the ground by the observer. This point may be a registration point or any point previously located by survey or by firing. The observer announces the shift from the known point to the target in yards; e. g., FROM REGISTRATION POINT 1, RIGHT 400, ADD 800. If any reference line other than the GT line is used, it must be identified; e. g.. FROM CONCENTRATION AB 406, REFERENCE LINE N–S HIGHWAY, RIGHT 400, ADD 800.

c. Prearranged Code. When the location of a target has been established by the FDC personnel and the observer prior to a flight, a code name or concentration number may be given to it. In this case, the observer need only transmit the preassigned symbol to obtain fire on the target.

d. Cardinal Direction. Cardinal points of the compass may be used for locating targets from a reference point; for example, FROM REGISTRATION POINT 1, EAST 400, NORTH 800.

239. Determination of Distance

The observer can determine distance on the ground by requesting one round at a given range and then add or drop 400 (or more) yards for a second round at the same deflection setting. A range spread of no less than 400 yards will allow accurate visualization of the GT line and minimize the effect of normal range dispersion. By using this method of determining distance, the observer establishes a "yardstick" for estimating subsequent range and deflection corrections.

Section IV. ADJUSTMENT PROCEDURE

240. General

Adjustment and adjustment procedures for the air observer are the same as for the ground observer *except* as noted in paragraph 236.

a. Considerations for the selection of an adjusting point are the same for both air and ground observers. When no maps are available and there has been no previous firing in an area, the observer may request a marking volley to be fired in approximately the center of the zone of observation and at a range sufficient to clear friendly frontlines.

b. Opening fire, sensings and corrections, as described in chapter 11, are the same for the air observer *except* for those sensings and corrections noted in paragraph 241.

c. The air observer can adjust artillery fire in the dark by using daylight procedures. However, artificial illumination may be necessary to make the target area discernible. The illumination may be by searchlight, illuminating shells, or aircraft parachute flares. Aircraft parachute flares are considered the most desirable because of the length of burning time and the illumination produced. When using parachute flares, it is desirable that the flares be released from an aircraft other than the observer's aircraft. The observer may then see into the target area from the side rather than looking down into the area after a flare has been released. Night adjustment missions should be planned during daylight hours. Plans should include a daylight flight over the proposed area of operation for the selection of check points and for general terrain orientation. The aerial observer must consider the different shapes and shadows which will be formed in the target area as a result of the illumination. Orientation may also be a problem, especially on very dark nights. However, effective fire can be placed on the target area by a well-trained observer.

d. The time of flight and a 5-second SPLASH warning are transmitted from the FDC to the observer. Splash time is very important when time of flight is long.

241. Adjustments

a. Adjustment of Deviation. The air observer senses deviation in *yards,* based on the GT line or other prearranged reference line, and corrections are announced in yards.

b. Adjustment of Height of Burst. The air observer is seldom required to adjust height of burst in area missions since differences in height are not readily apparent. The observer may be required to observe time registrations in which case sensings of AIR or GRAZE are transmitted.

c. Adjustment of Range. The air observer senses bursts for range, based on the GT line or other prearranged reference line, and, using the bracket method of adjustment, announces range corrections in yards.

242. Fire for Effect

The air observer calls for fire for effect and announces sensings during fire for effect in the same manner as that described for the ground observer (ch 12).

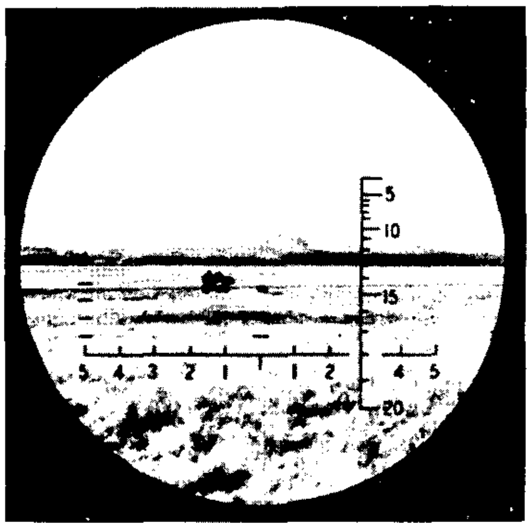
CHAPTER 15
ILLUSTRATIVE EXAMPLES

243. General

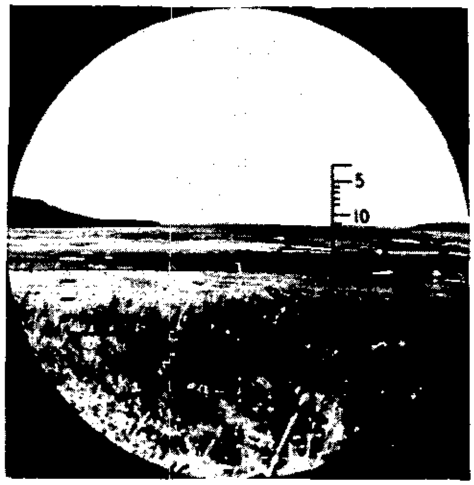
The examples of missions contained in this chapter are typical of those that an observer may be called on to fire. In the examples in paragraphs 244 through 249, the symbols indicate the following: +, a sensing of "over"; –, a sensing of "short", and ?, a sensing of "doubtful."

244. Precision Registration Mission

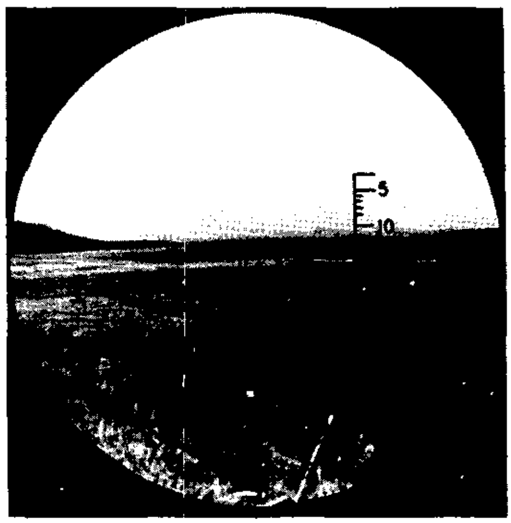
Target, surveyed registration point; mission, registration; materiel, 105-mm howitzer; ammunition, shell HE with superquick fuze.

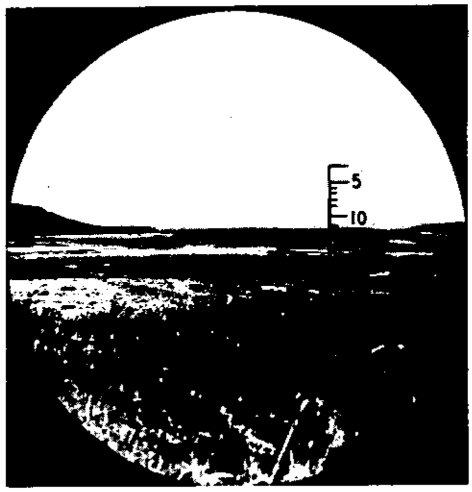
Messages, corrections, and commands	*Results*	*Sensings*	
		Rg	*Dev*
Observer to FDC (fire request): FIRE MISSION, REGISTRATION POINT 1, AZIMUTH 4710, REGISTRATION, WILL ADJUST. The observer will hear the FDO order and receipt for it with a ROGER. FDC to observer: ON THE WAY.		?	15L

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

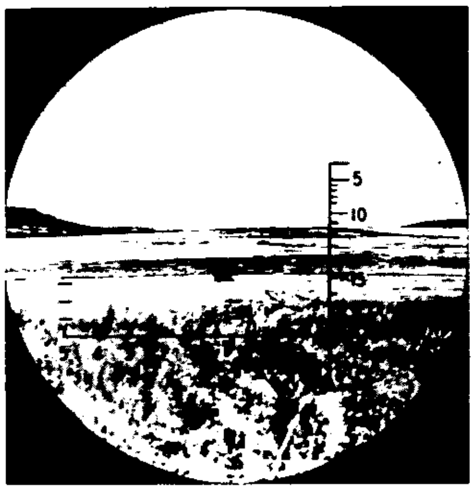
Messages, corrections, and commands	*Results*	*Sensings* Rg	Dev
Observer to FDC: RIGHT 50, REPEAT RANGE. FDC to observer: ON THE WAY.		+	Line

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.

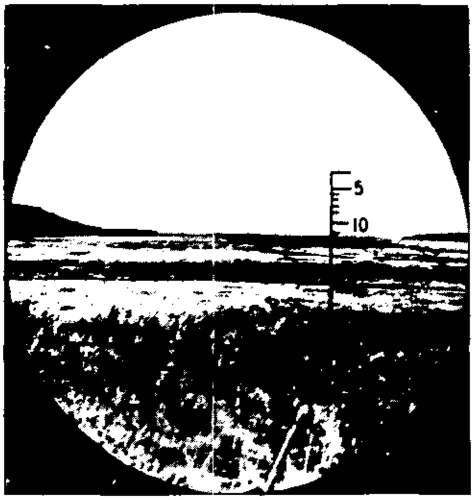
Messages, corrections, and commands	*Results*	*Sensings* Rg	Dev
Observer to FDC: DROP 200. FDC to observer: ON THE WAY.			Line

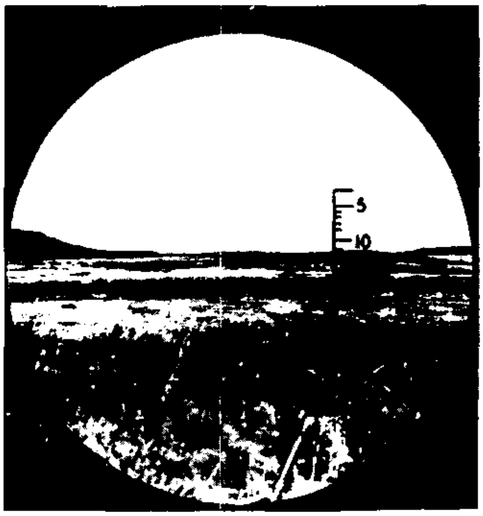
Messages, corrections, and commands	*Results*	*Sensings* *Rg*	*Dev*
Observer to FDC: ADD 100. FDC to observer: ON THE WAY.		+	Line

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).

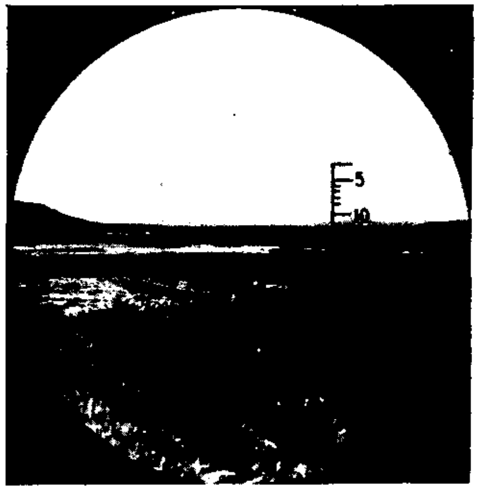
Messages, corrections, and commands	*Results*	*Sensings* *Rg*	*Dev*
Observer to FDC: DROP 50, FIRE FOR EFFECT. FDC to observer: ON THE WAY. Observer to FDC: SHORT, LINE.		−	Line

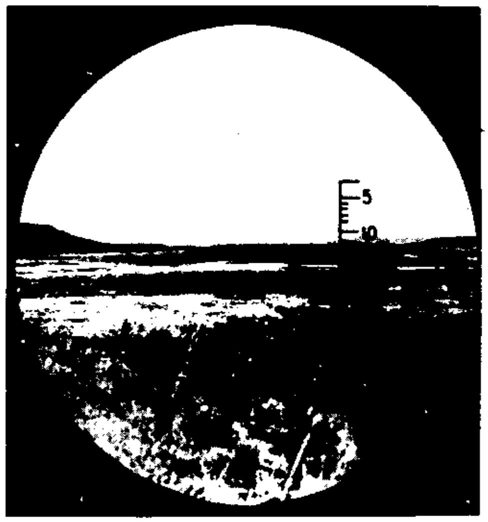
Remarks: No further corrections by the observer are given. FDO assumes control and continues the mission until he has sufficient sensings from which to compute an adjusted elevation. The observer reports only his sensings.

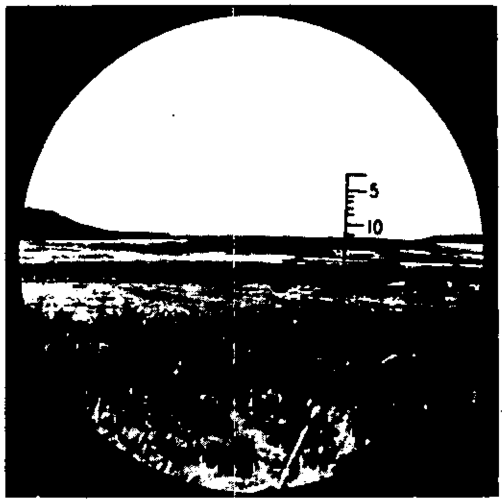
Messages, corrections, and commands	*Results*	*Sensings* Rg	Dev
FDC to observer: ON THE WAY. Observer to FDC: OVER, LINE.		+	Line

Messages, corrections, and commands	*Results*	*Sensings* Rg	Dev
FDC to observer: ON THE WAY. Observer to FDC: DOUBTFUL, LEFT.		?	Left

Remarks: This round appears off the OT line. The observer senses the round as DOUBTFUL, LEFT.

Messages, corrections, and commands	*Results*	*Sensings* *Rg*	*Dev*
FDC to observer: ON THE WAY. Observer to FDC: OVER, LINE.		+	Line

Messages, corrections, and commands	*Results*	*Sensings* *Rg*	*Dev*
FDC to observer: ON THE WAY. Observer to FDC: SHORT, LINE.		—	Line

Messages, corrections, and commands	*Results*	*Sensings* *Rg*	*Dev*
FDC to observer: ON THE WAY. Observer to FDC: DOUBTFUL, RIGHT.	 	?	Right

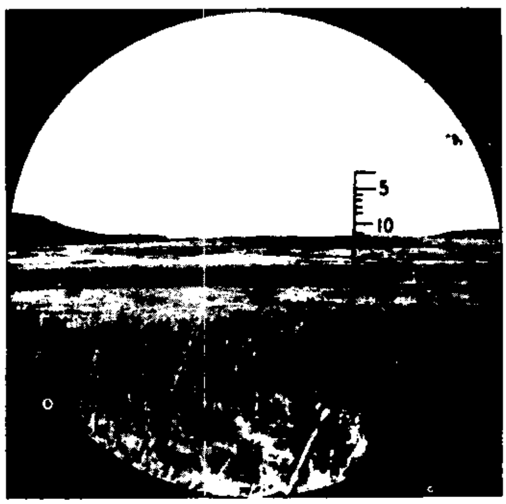
Remarks: FDO has now obtained six usable sensings and therefore notifies the observer that the mission has been accomplished.

Messages, corrections, and commands

FDC to observer:
END OF MISSION.

245. Time Registration Mission

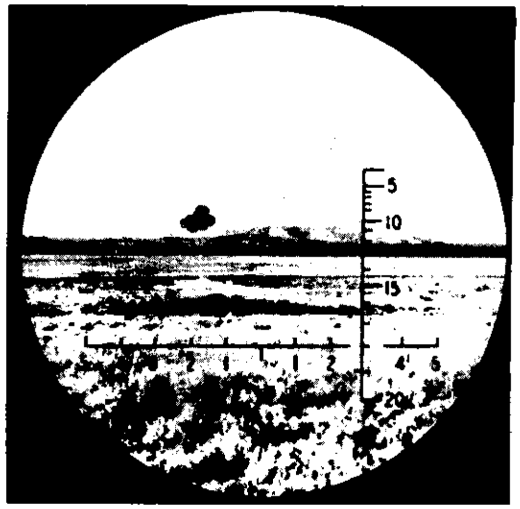
Target registration point; mission, time registration (it is assumed that the observer has just completed a precision registration on the registration point, using time-fuzed shell set on impact); materiel, 105-mm howitzer; ammunition, shell HE, fuze M500.

Messages, corrections, and commands	*Results*	*Sensing*
FDC to observer: OBSERVE TIME REGISTRATION, ON THE WAY. Observer to FDC: GRAZE.	 	G

Messages, corrections, and commands | *Results* | *Sensing*

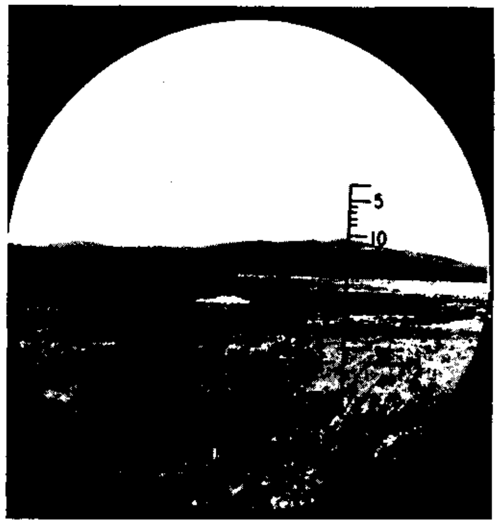
FDC to observer:
ON THE WAY.

Observer to FDC:
AIR.

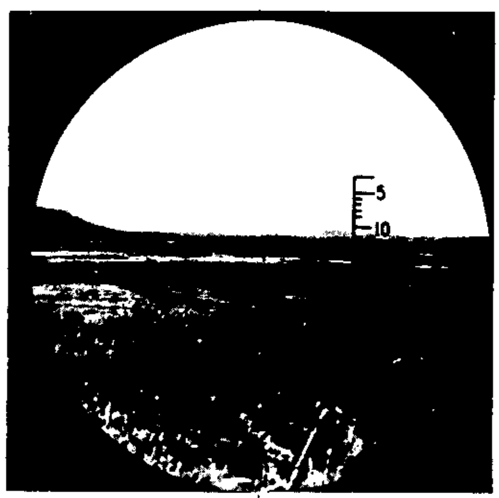


Messages, corrections, and commands | *Results* | *Sensing*

FDC to observer:
3 ROUNDS,
ON THE WAY.

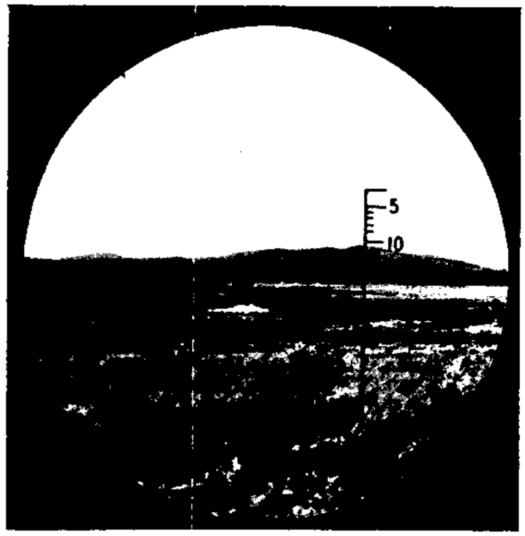


Messages, corrections, and commands | *Results* | *Sensing*



Messages, corrections, and commands | *Results* | *Sensings*

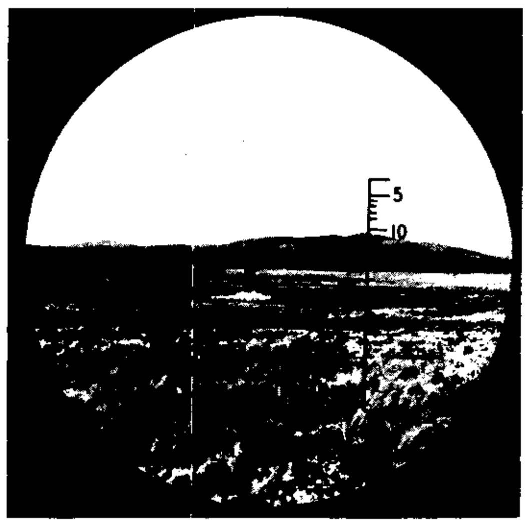
Observer to FDC:
AIR, GRAZE, AIR.



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

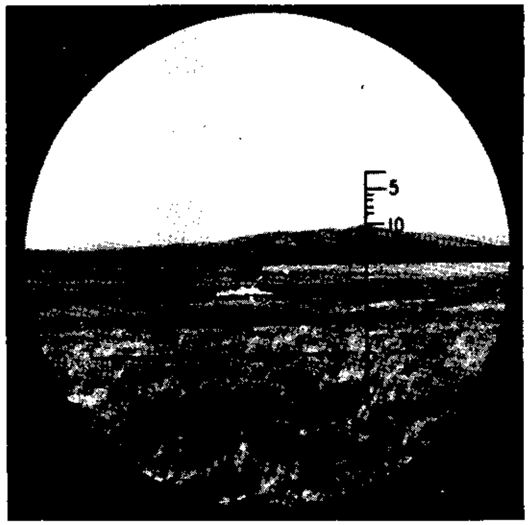
Messages, corrections, and commands | *Results* | *Sensing*

FDC to observer:
ON THE WAY.



A

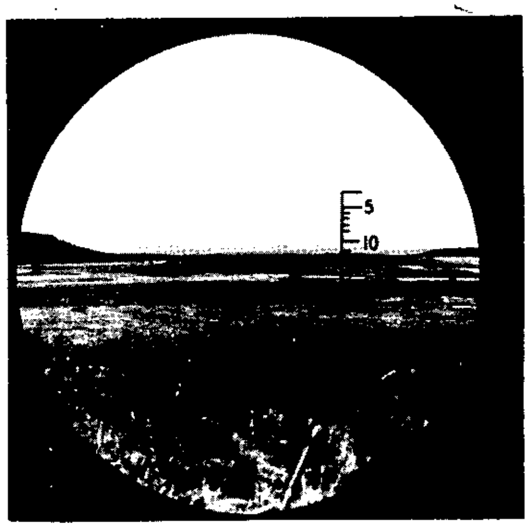
Messages, corrections, and commands | *Results* | *Sensing*



A

Messages, corrections, and commands | *Results* | *Sensing*

Observer to FDC:
AIR, AIR, GRAZE.



G

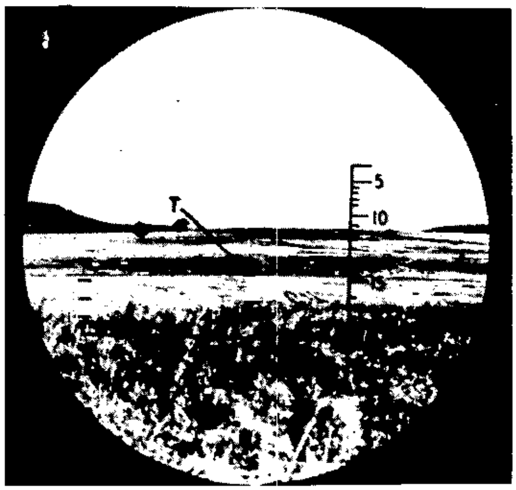
Remarks: The time sensings have been reported to the FDC. Registration is now complete. Observer will be notified.

Messages, corrections, and commands

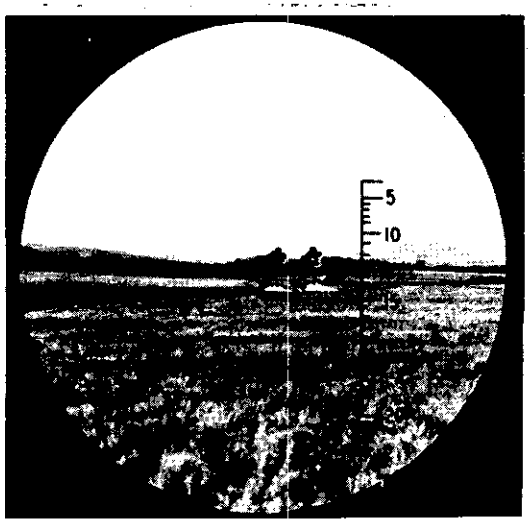
FDC to observer:
END OF MISSION.

246. Area Fire Mission

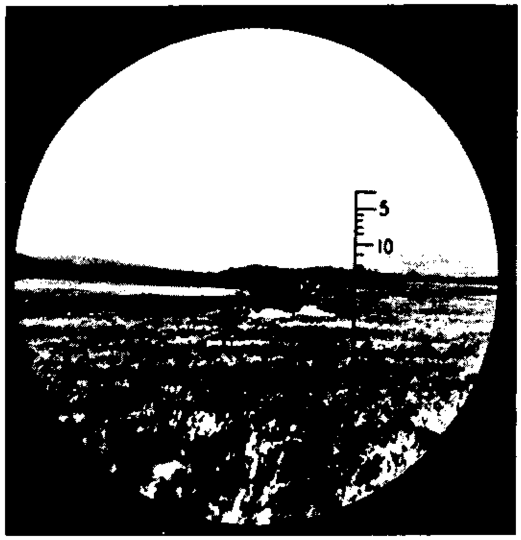
Target, machine guns; mission, neutralization; materiel, 105-mm howitzer; ammunition, shell HE (both M51 and M500 fuzes in battery). Shift from registration point.

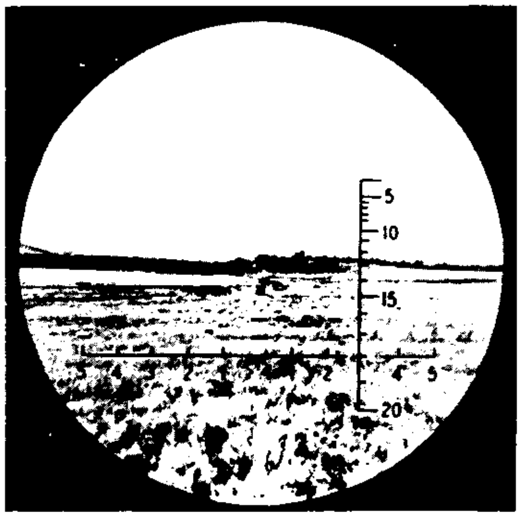
Messages, corrections, and commands	*Results*	*Sensings HB*	*Sensings Rg*	*Sensings Dev*
Observer to FDC (fire request): FIRE MISSION, FROM REGISTRATION POINT 1, AZIMUTH 1880, LEFT 660, DROP 1000, MACHINE GUNS, FUZE TIME, WILL ADJUST.				
The observer will hear the FDO order, noting those elements of interest to him.				
FDC to observer: 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 the OT line. Observed deviation=60 yards (30 x 2.0). No range sensing is obtained. Observed height of burst=30 yards (15 x 2.0).

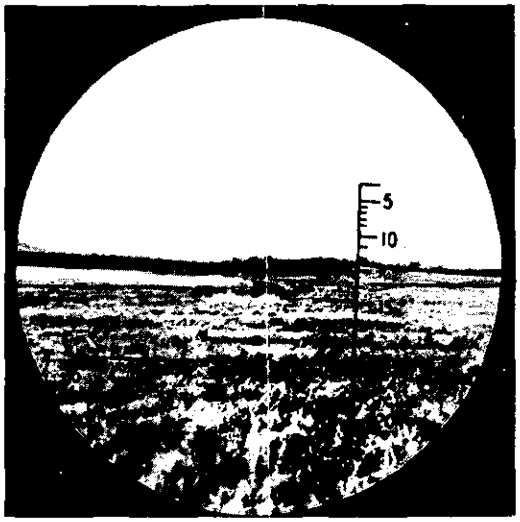
Messages, corrections, and commands	*Results*	*Sensings HB*	*Sensings Rg*	*Sensings Dev*
Observer to FDC: RIGHT 60, DOWN 10, REPEAT RANGE.				
FDC to observer: ON THE WAY.		A	+	10R

Remarks: Deviation of 10 mils is small. The observer elects to ignore it unless it persists inasmuch as he is able to obtain sensings. If a range sensing was not obtainable, this deviation would be corrected to the line.

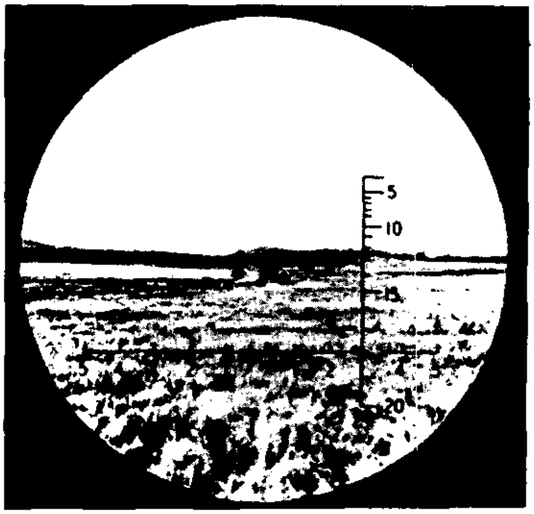
Messages, corrections, and commands	*Results*	*Sensings*		
		HB	*Rg*	*Dev*
Observer to FDC: DROP 400.				
FDC to observer: ON THE WAY.		A	—	10R

Messages, corrections, and commands	*Results*	*Sensings*		
		HB	*Rg*	*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.

Messages, corrections, and commands	*Results*	*Sensings* *HB*	*Rg*	*Dev*
Observer to FDC: LEFT 20, DROP 100.				
FDC to observer: ON THE WAY.		A	—	Line

(Desired height of burst.)

Messages, corrections, and commands	*Results*	*Sensings* *HB*	*Rg*	*Dev*
Observer to FDC: ADD 50, FIRE FOR EFFECT.				
FDC to observer: BRAVO FIRING FOR EFFECT.		Mixed air	Range 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 the FDC.

Messages, corrections, and commands	*Results*	*Sensings* *HB*	*Rg*	*Dev*
Observer to FDC: END OF MISSION, MACHINE GUNS SILENCED.				

247. Illuminating Shell Mission

a. Observer hears a number of heavy vehicles at an azimuth estimated at 5,800. He cannot detect any lights and the entire area is in complete darkness. Judging from sound and map study, the observer estimates the source of the noises to be grid reference 725365. This is about 2,000 yards from his observation post. He sends the following fire request—

RANGER 15, THIS IS RANGER 48,
FIRE MISSION,
COORDINATES 725365,
AZIMUTH 5800,
VEHICLE NOISES—SUSPECTED TANKS,
ONE GUN,
ILLUMINATING,
WILL ADJUST.

b. The first illuminating round bursts about 100 mils left of the suspected area and 150 yards too high. Observer transmits—

RIGHT 200 (OT factor 2),
DOWN 150,
REPEAT RANGE.

c. The second round bursts short near the OT line but too low—the round burns 5 seconds on the ground. Observer requests—

UP 50 (T x 10=50),
ADD 400.

d. The third round bursts at a good height over the suspected area, but haze, along with distance of area from observer, makes visibility poor with only one round of illuminating shell. The observer feels that two rounds will be adequate but desires a lateral spread along a section of road which he is observing to extend the visible area and reduce shadows. Observer requests—

TWO GUNS,
DEFLECTION SPREAD,
REPEAT RANGE.

e. Two rounds burst in a spread over the suspected area, and the observer notices two tanks and a number of infantry moving out to the right at the extreme right edge of the illuminated area. He determines a shift from the center of illumination and transmits the following:

RIGHT 400,
REPEAT RANGE,
CONTINUOUS ILLUMINATION (and immediately after):
FROM ILLUMINATION,
AZIMUTH 6100,
SHELL HE,
REPEAT RANGE,
TWO TANKS AND PLATOON OF INFANTRY,
FUZE QUICK AND VT IN EFFECT,
AT MY COMMAND,
WILL ADJUST.

f. Continuous illumination is begun over the desired point, disclosing two additional tanks and more infantry. FDC reports READY. As soon as the next illuminating shell bursts, observer orders FIRE. He acknowledges FDC's report of ON THE WAY and gives a new description of the target at this time, as FOUR TANKS AND PLATOON OF INFANTRY.

g. Observer adjusts HE during continuous illumination and fire for effect is delivered. The FFE apparently causes several casualties among infantry troops. Observer's order to fire for effect was DROP 50, FIRE FOR EFFECT. He retains control of the time of firing to observe the effect.

h. Tanks and remaining infantry are moving out to the northwest away from the observer. It is necessary to shift illumination, and observer desires to repeat FFE against the target. He orders—

ILLUMINATING,
ADD 400,
HE,
LEFT 50,
REPEAT RANGE,
REPEAT FIRE FOR EFFECT.

i. Tanks and infantry have moved out of observation capabilities of observer so he orders—

END OF MISSION,
TANKS AND INFANTRY DISPERSED TO NORTHWEST,
REQUEST REPLOT.

248. Searchlight Mission

a. Observer hears movement and suspects an attempt is being made to repair a disabled tank which is blocking a road in his sector. Searchlights are available, and a study of the terrain indicated that it is possible to illuminate the tank directly. He sends the following mission:

FORWARD OBSERVER BRAVO,
ILLUMINATION MISSION,

COORDINATES 67184437,
AZIMUTH 780,
SUSPECTED ACTIVITY AROUND DISABLED TANK,
TWO LIGHTS,
WILL ADJUST.

b. Left beam appears below the target, and right beam is two beam widths to the left. He orders NO. 1, RIGHT TWO BEAMS; NO. 2, UP ONE-HALF BEAM.

c. Both beams having been centered on the target, the observer orders HOLD. This command HOLD causes the lights to be held on the target and allows the observer to call for a destruction mission on the tank. After the tank is destroyed, the observer will terminate the mission as indicated below:

END OF MISSION, STALLED TANK DESTROYED.

d. If, in the course of the HE mission, the observer decides it is better to cut off the lights yet wants to hold the position of the lights, he orders HOLD, CUT. To restore light to the target he next orders FLICK.

e. Using these commands, together with his artillery fire AT MY COMMAND, the observer is able to light the target for surveillance or adjustment and hold to a minimum the exposure of friendly light positions.

249. Assault Fire Mission

a. Target, cave in hard rock of hillside. Mission, to seal cave entrance. Materiel, 8-inch howitzer. Gun-target range, 1,500 yards. Observer-target distance, 1,000 yards. The mission has been prearranged in detail and a complete initial fire request is unnecessary. The observer reports when he is ready to observe and the FDC personnel, having carefully prepared all data in advance, sends commands to the howitzer to fire the first round. Fired at such short range with precise initial data, the first round should be close to the target.

Remarks	*Observer corrections*
First round bursts 10*m* right of OT line, doubtful for range.	LEFT 10, REPEAT RANGE.
Second round bursts between observer and target.	ADD 50.
Third round bursts beyond target.	DROP 25.
Fourth round bursts just above upper right corner of cave entrance. (Changes in site instead of range are now appropriate.)	LEFT 1, DOWN 1, REPEAT RANGF.
Fifth round bursts at left edge just below eave entrance.	RIGHT ½, UP ½, REPEAT RANGE.
Sixth round is in cave entrance. Fuze CP delay is now appropriate to penetrate hard rock.	FUZE CONCRETE-PIERCING DELAY, REPEAT RANGE.
Seventh round also bursts in cave entrance. Cave is now almost completely sealed.	REPEAT RANGE.
Eighth round strikes top of cave entrance, completely sealing it with rubble.	END OF MISSION, CAVE ENTRANCE SEALED.

b. Target, concrete pillbox on forward slope of hill. The pillbox has several gun ports from which machine guns are firing; one embrasure faces the observer. Mission, to reduce pillbox. Materiel, 155-mm gun (SP). Gun-target range, 2,000 yards. Observer-target distance, 500 yards. The mission has been prearranged in detail and a complete initial fire request is unnecessary. The observer reports when he is ready to adjust. and the FDC personnel gives commands to the gun to fire the first round.

Remarks	*Observer corrections*
First round bursts 20*m* right of OT line, short on terrain.	LEFT 10, ADD 50.
Second round bursts 8*m* left of OT line, over on terrain.	RIGHT 4, DROP 25.
Third round strikes pillbox 4*m* above center of embrasure. (Changes in site instead of range are now appropriate.)	DOWN 2, FUZE CONCRETE-PIERCING DELAY, REPEAT RANGE.
Fourth round strikes at lower left corner of embrasure.	RIGHT ½, UP 1, REPEAT RANGE.
Fifth round strikes center of embrasure, causing great damage.	REPEAT RANGE.
Sixth round strikes same hole. Rubble now closing embrasure. (Observer requests nondelay fuze to blast away rubbie.)	FUZE CONCRETE-PIERCING NONDELAY, REPEAT RANGE.
Seventh round strikes pile of rubble, blasting most of it away.	FUZE CONCRETE-PIERCING DELAY, REPEAT RANGE.
Eighth round pierces embrasure, enters pillbox, explodes inside. No further activity from pillbox.	END OF MISSION, PILLBOX DESTROYED, RESISTANCE CEASED, APPARENTLY 100 PERCENT CASUALTIES.

PART FOUR
FIRE DIRECTION
CHAPTER 16
FIRE DIRECTION—GENERAL

Section I. INTRODUCTION

250. Definitions

a. Fire Direction. Fire direction is the tactical employment of fire power, the exercise of tactical command of one or more units in the selection of targets, the concentration or distribution of fire, and the allocation of ammunition for each mission. Fire direction also includes the methods and techniques used in fire direction centers to convert fire missions into appropriate fire commands.

b. Fire Direction Center. The fire direction center is an element of a command post. It consists of gunnery and communication personnel and equipment by means of which fire direction and/or fire control is exercised. Fire direction center personnel convert target intelligence, fire missions of higher commanders, and fire requests into appropriate fire commands. They also transmit the commands to the weapon(s). (Division artillery and artillery group headquarters FDC's normally do not produce fire commands. They do not transmit commands directly to the weapons.)

c. Fire Control. Fire control is all operations connected with planning, preparing, and placing fire on a target.

d. Tactical Fire Control. Tactical fire control is the employment of fire power in regard to selecting targets; opening, suspending, or ceasing fire; and classes of fire.

e. Technical Fire Control. Technical fire control is the means used to place accurate fire on the target.

251. Objectives

The methods employed in fire direction must insure—

a. Continuous, accurate, and timely 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.

252. Command

a. Artillery headquarters control the fires of subordinate units. The headquarters may allocate reinforcing artillery fires in order to further the plan of the force commander. Division, group, corps, and army artillery headquarters are concerned primarily with tactical fire direction. (See FM 6–20 for fire direction above battalion.)

b. Fire direction as exercised by an artillery battalion consists of tactical fire direction (FM 6–101) as well as technical fire direction (i. e., converting fire missions from higher headquarters and requests for fire into appropriate fire commands).

c. When a battery is operating independently, fire direction is exercised by the battery commander through his FDC.

d. The battery executive should not be the battery FDO. He should have no duties other than the command of the firing battery. The battery FDO does not assume any of the battery executive's responsibilities for controlling the firing of the weapons or the operations of the firing battery.

253. Observed and Unobserved Fires

a. Fire which can be observed is adjusted to the target. The observer who conducts the fire mission will report the effect on the target upon completion of the mission.

b. When fires cannot be observed, the battalion FDC personnel use known corrections to derive fire commands which will provide the most effective fires possible. When unobserved fires are necessary, the area taken under fire should be increased, to improve the probability that the target is included within the area covered. If possible, registration always should be fired, and appropriate corrections applied to firing data. In the absence of specific corrections for each battalion, the corrections determined by registration of one battalion may be used by other battalions equipped with like weapons. The provisions in (1) through (5) below are prerequisites for unobserved fires when only one battalion registers. Lack of any one of these provisions may seriously reduce the effectiveness of unobserved fires.

(1) The battalions are connected by survey.

(2) The battalions are not widely separated laterally or in depth.

(3) Calibration data for the battalions are known and used.

(4) The same ammunition lot is used by all battalions.

(5) Current met and velocity error corrections are known and applied.

Section II. TARGET LOCATION

254. Sources of Target Locations

A complete description of the target should accompany each report, and a request or order for fire may accompany the report. The agency reporting the target may recommend a method of attack. The report should include the number of batteries or battalions desired in fire for effect, thus indicating the size and importance of the target. To be of maximum value, the report must be transmitted promptly and the target designation must be accurate. Targets for field artillery may be located and reported by—

a. Supported troops.

b. Artillery liaison personnel with those troops.

c. Field artillery ground or air observers.

d. Personnel of the field artillery observation battalion (sound, flash, and radar).

e. Adjacent or higher headquarters (air and ground reconnaissance agencies).

f. Analysis of photographs and knowledge of enemy activities.

g. Interrogation of prisoners of war and civilians.

255. Reported Target Locations

FDC personnel may receive reports from organic observers designating target locations by shift from a known point or by coordinates. In addition they may receive target locations marked on maps or photographs or traced on overlays which match such maps or photographs. The reported location normally is a point at the center of the target. For a barrage, the length and direction of the barrage must be designated. If possible, dimensions should be pointed out on the ground to the observer responsible for adjustment and surveillance of fires used in the barrage.

Section III. FIRING DATA

256. Processing Fire Requests

Targets are reported from numerous sources directly to the battalion and/or battery FDC where they are plotted on firing charts. From this plot, data are prepared and sent to the firing batteries as fire commands. Fire direction centers for headquarters higher than battalion level normally do not determine fire commands.

257. Attack of Targets

When a request for artillery fire on a target is received, the fire direction officer (FDO) must weigh a number of factors in reaching his decision to grant the request. Pertinent points which must be considered are covered in detail in paragraphs 534–542.

258. Execution of Fire Missions

Accuracy, flexibility, and rapidity in the execution of fire missions depend on—

a. Accurately and rapidly preparing firing data from the firing chart and transmitting commands to the firing batteries.

b. Accurately and rapidly verifying firing data.

c. Efficient division of duties.

d. Adherence to a standard technique and procedure.

e. Efficient use of FDC plotting and data determining devices.

f. The functioning of personnel as a team in a specified sequence in order to avoid errors and to save time.

g. Efficient communications, including use of a fire direction center switchboard at battalion.

Section IV. FDC ORGANIZATION

259. General

The organization of a FDC is designed to permit division of duties so that fire missions can be processed rapidly and accurately on a 24-hour basis. Tables of organization and equipment will show the personnel and equipment authorized to accomplish the fire direction function.

260. Principles of Operation

a. Production of Firing Data. Firing data are *normally* processed in the firing battery FDC's and checked in battalion FDC's of all artillery battalions. Firing data will be processed and checked in the battalion FDC when it is impossible to operate the battery FDC's for any reason. In the following circumstances, firing data may be processed and checked in the battalion FDC.

(1) For critical missions, such as those for determination of corrections.

(2) For difficult missions, such as night illumination.

(3) For attack of targets of unusual shape or size.

b. Processing Fire Missions. Accuracy, flexibility, and speed in processing either single or multiple fire missions depend largely on the considerations set forth in paragraph 258 and—

(1) A thorough knowledge of the communication system and procedures by all fire direction personnel.

(2) Establishment of a strict communication standing operating procedure (SOP) and adherence to communication discipline.

261. Fire Direction Officer (FDO)

a. The FDO or the duty FDO, as the representative of the battalion commander, is the officer in charge of the operation of the battalion FDC.

b. The battalion FDO controls the fires through supervision of the battalion FDC. All requests for fire are received, and targets are plotted. The battalion FDO makes the decision to fire. He also prescribes the method of attack and the amount of ammunition to be fired on each target, and issues the fire order.

c. Targets are also plotted at the battery FDC where the observer's fire request and the battalion fire order are converted into commands to the weapons.

d. When a battery is operating independently, the battery FDO performs the duties of the battalion FDO.

e. The duties of the battery FDO should not be assigned to the battery executive; likewise, the battery FDO should not assume the duties of the battery executive. The sole duty of the battery executive during firing is supervision of the firing battery.

262. Chief Computer

The chief computer, normally the senior noncommissioned officer in the battalion FDC, must be proficient in both communication and gunnery procedures.

263. Battery Computer

Each battery FDC has a computer to maintain records and make computations as indicated by the nature of the fire mission.

264. Chart Operators

Chart operators, whether at battalion or battery FDC, have functions in constructing and maintaining firing charts and determining firing data. The combined organization of the battalion and battery FDC's provide for three types of firing charts: *control*, *primary*, and *check chart*. The difference in functions of control, primary, and check chart operators are discussed in chapter 20.

265. Battalion Switchboard Operator-Computer

The battalion employs a switchboard operator-computer to operate the FDC switchboard. He also maintains records, and does computations as directed by the chief computer.

266. Radiotelephone Operators

Radiotelephone operators answer calls and record as required within the battalion and battery FDC.

Section V. GRID SYSTEMS

267. General

a. A military grid is a network of mutually perpendicular grid lines superimposed and forming squares on a map. The grid interval on maps and sheets ordinarily used as firing charts is 1,000 meters. A scale of 1:25,000 is preferable but satisfactory results can be obtained using a scale of 1:50,000. North-south lines are labeled to show distance east of an origin (eastings); east-west lines are labeled to show distances north of the origin (northings).

b. When a specific military grid is used with a specific map projection, the two are referred to as a *grid system*.

c. Map projections and grid systems are explained in detail in TM 6–200.

268. Grid Coordinates

The easting and northing values for a point located on a gridded map or sheet are called *grid coordinates*. In artillery survey, grid coordinates are expressed to the nearest tenth or hundredth of a meter, and, when so expressed, are inclosed in parentheses. The easting value precedes the northing value, and the two are separated by a dash. An example of grid coordinates is (632948.29–937853.45).

269. Grid Reference

a. A military grid reference consists of the grid zone designation, the 100,000-meter square identification, and the rectangular coordinates of the point within the 100,000-meter square, expressed to the desired accuracy. A grid reference is written as a continuous series of letters and numbers without spaces, parentheses, dashes, or decimal points. Examples and explanation of a complete grid reference follows:

18SUT............ designates a location within a 100,000-meter square.
18SUT90.......... designates a location within a 10,000-meter square.
18SUT9109......... designates a location within a 1,000-meter square.
18SUT916091....... designates a location within a 100-meter square.
18SUT91620914..... designates a location within a 10-meter square.
18SUT9162309143... designates a location within a 1-meter square.

b. A military grid reference can be abbreviated by omitting the grid zone designation and, in some instances, by omitting the 100,000-meter square identification. Each commander should specify the manner in which subordinate units will report military grid references. Examples and explanation of an abbreviated grid reference follows:

UT9109.... designates a location within a 1,000-meter square.
916091..... designates a location within a 100-meter square.
91620914... designates a location within a 10-meter square.

c. For use on firing charts, locations may be received as grid coordinates or military grid references depending on the accuracy to which a point has been located. Locations accurate to the nearest tenth or hundredth of a meter can be had using artillery survey. Thus, grid coordinates are normally used. Locations established by map measurement are usually given as military grid references because readings less than 1 meter are virtually impossible to make. Military grid references and grid coordinates are usually referred to as *coordinates*.

Section VI. FIRING CHARTS

270. General

The firing chart is a map, photomap, grid sheet, or a sheet of plain paper on which is shown the relative locations of batteries, registration points, targets, and other details needed in preparing firing data.

271. Map

A map is a graphic representation, drawn to scale, of a portion of the earth's surface and is only as accurate as the ground survey from which it is made. Maps based on accurate ground survey require the least amount of additional survey. These maps provide direction and horizontal and vertical control and can be used as the basis for field artillery survey. If the map is not based on an accurate and adequate ground control, it should be used only to obtain approximate locations and vertical control to supplement a grid sheet firing chart.

272. Photomap

a. A photomap is a reproduction of an aerial photograph or a mosaic on which are added grid lines, marginal information, and place names. 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 inaccurate.

b. Even though the photomap may be 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.

Note. See paragraphs 548 through 572 for further details regarding aerial photographs.

273. Grid Sheet

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

274. Purpose

a. The firing chart is used to determine firing data (piece-target range, deflection, and difference in altitudes) which are used to lay the pieces. The accuracy of a firing chart should be verified by firing at the earliest opportunity, consistent with safety.

b. The effectiveness of artillery fires depends to a large degree on the relative accuracy and completeness of the firing chart. Every effort must be made to supplement the firing chart by vertical and oblique photographs.

275. Types of Firing Charts

There are two types of firing charts used in an FDC—the surveyed firing chart and the observed firing chart.

a. The surveyed firing chart is a chart on which the locations of all key points (battery positions, registration points, OP's) are based on survey (TM 6-200). All plotted points are in correct relation to one another and are tied together by actual map coordinates. When determination of actual map coordinates has not been completed, assumed coordinates may be used initially to tie together the points to be plotted. The procedures pertaining to construction of a surveyed firing chart and determination of firing data therefrom are covered in paragraphs 277 through 306.

b. The observed firing chart is a chart on which all chart locations must be established by firing. Relative locations of the batteries and targets can only be established by the adjustment of fire, hence the name "observed firing chart." Procedures pertaining to determination of firing data as stated in paragraphs 277 through 306 apply to an observed firing chart; however, details pertaining to construction of an observed firing chart are contained in paragraphs 435 through 468.

276. Initial Firing Charts

a. When an artillery unit must occupy position and open fire prior to completion of survey, some type of initial firing chart must be used. This circumstance is normal when the unit is attached to an advanced guard force or in a direct support role during a rapidly moving situation. If a battery is operating independent of battalion control, the initial chart is used until survey becomes available, at which time transfer of chart locations is made to a surveyed chart.

b. When a map is used as the initial chart, FDC procedures are generally the same as those used

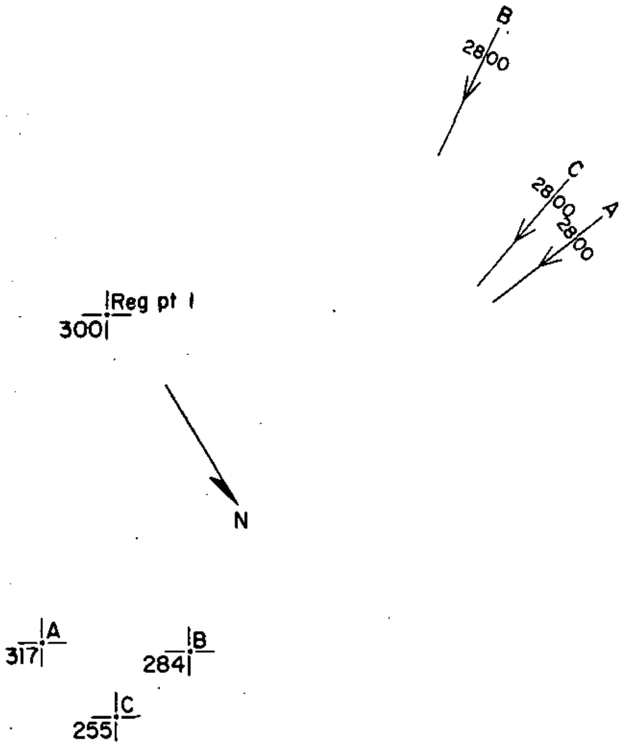


Figure 102. Construction of battalion observed firing chart (plain paper).

with a surveyed chart (pars. 392–434). Inspection is a form of survey; therefore, any chart based on map inspection is in effect a surveyed chart. Likewise, when the coordinates of a battery and target positions have been determined by map inspection and plotted on a grid sheet, procedures used are the same as those used on a surveyed chart. Target location may be given by coordinates, by shifting from any known point identifiable at the FDC, or by polar coordinates (par. 286) when the location of the observer is known at the FDC.

c. If reliable maps of adequate scale are not available and cannot be quickly obtained, an *observed firing chart* built up on a grid sheet is used and the relative locations of the battery and targets are established by the adjustment of fire. Target location is given only by shifting from previously fired targets or from marking rounds.

d. In an emergency, a plain sheet of paper may also be used to construct an initial firing chart. The procedures are the same as those for a grid sheet observed firing chart except that there are no grid lines on the chart. For orientation of the chart, direction may be indicated by drawing a north arrow in any convenient direction (fig. 102).

CHAPTER 17
CHART DATA

Section I. PLOTTING

277. General

Every effort must be made to insure the accuracy of data shown on the firing chart. All firing charts in the battalion should be identical to insure that any chart can be used to mass the fires of the battalion.

278. Plotting Equipment

The construction and use of a firing chart requires the use of special tools. The accuracy obtained with this special equipment depends as much on plotting habits and care of equipment as on the accuracy of the equipment.

a. The 6H Pencil (fig. 103 ①). Any line drawn on the firing chart from which measurements will be made must be drawn with a 6H (hard lead) pencil, sharpened to a wedge point. This procedure is required if the necessary accuracy is to be achieved.

b. The 4H Pencil (fig. 103 ②). The 4H pencil is used for lettering and to accentuate tick marks. It should be sharpened to a conical point.

c. Map Pins (fig. 103 ③). Map pins are short pins used to mark battery, radar, and OP positions. The pins are issued in 2 sizes—1 for use with the range-deflection fan (plastic and aluminum) and a slightly longer pin for use with the GFT fan. Map pins must never be used in the target area portion of the firing chart.

d. Plotting Needles (fig. 103 ④). Plotting needles are long, very fine needles used for plotting. No other type of pin will be used for plotting.

e. Plotting Scale (fig. 104 ①). The plotting scale is used for measuring distances and for plotting and determining coordinates for critical points, such as batteries, radar, OP's, and registration points, which must be located very accurately. The scale should always be used in plotting coordinates determined by survey computations. The

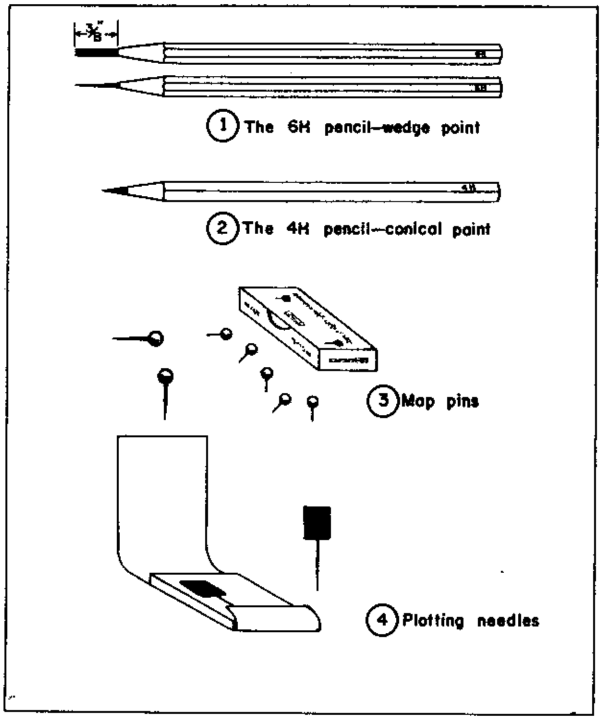


Figure 103. Pencils, pins, and needles.

scale is graduated in meters, yards, and inches. The meter and yard graduations are at 1 : 25,000, 1 : 50,000, and 1 : 62,500 scales. The plotting scale is the most accurate distance-measuring tool issued to FDC and should be used as a standard of accuracy for other distance-measuring equipment.

f. Coordinate Scale (Plastic) (fig. 104 ③). The plastic coordinate scale is a right-angled scale that is used for plotting and determining coordinates of targets other than registration points and coordinates determined by survey computations. This scale is graduated in meters and yards at 1 : 25,000 and 1 : 50,000 scales.

g. Coordinate Scale (Aluminum) (fig. 104②). The aluminum coordinate scale is a square-shaped

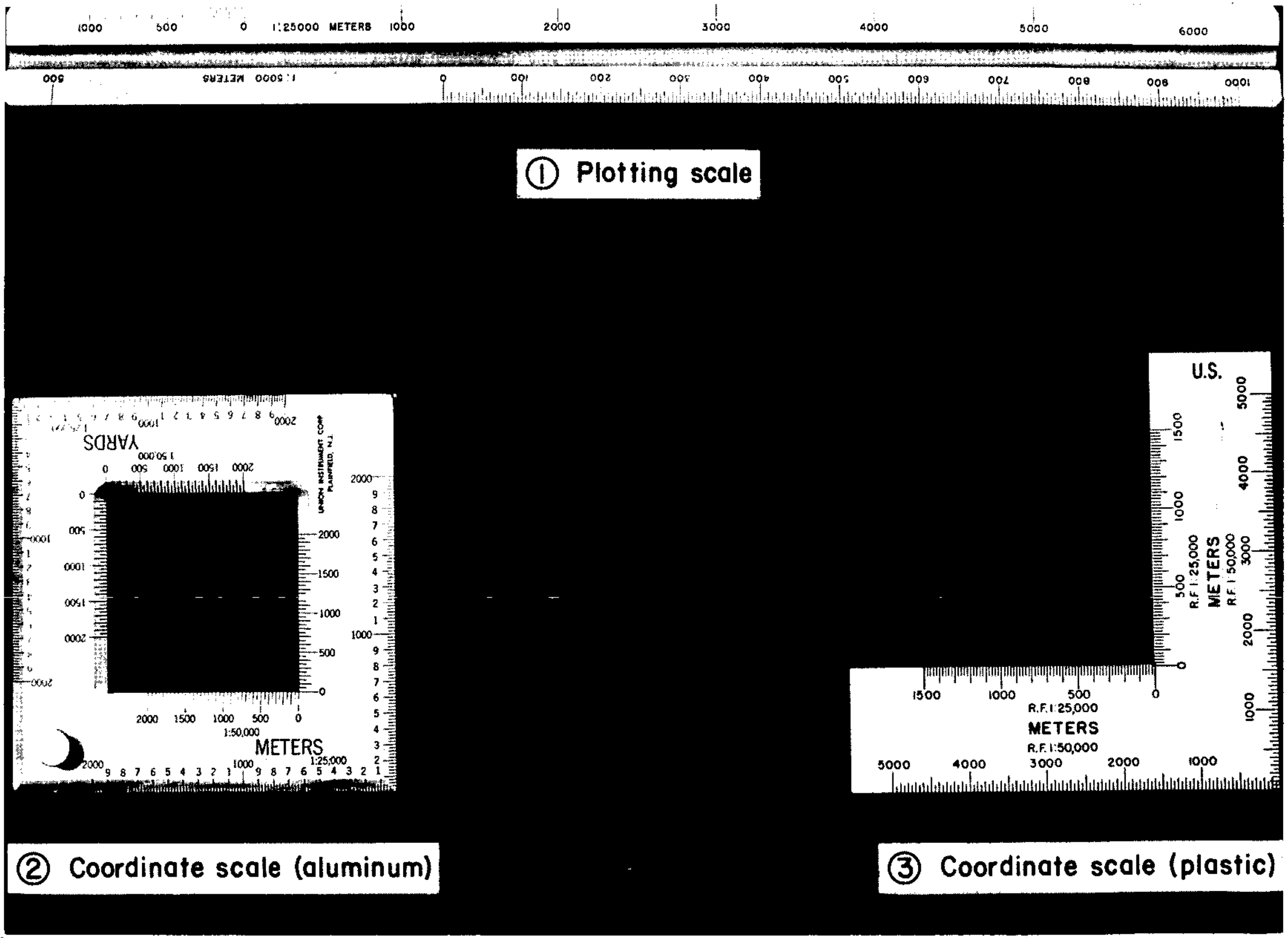


Figure 104. Plotting and coordinate scales.

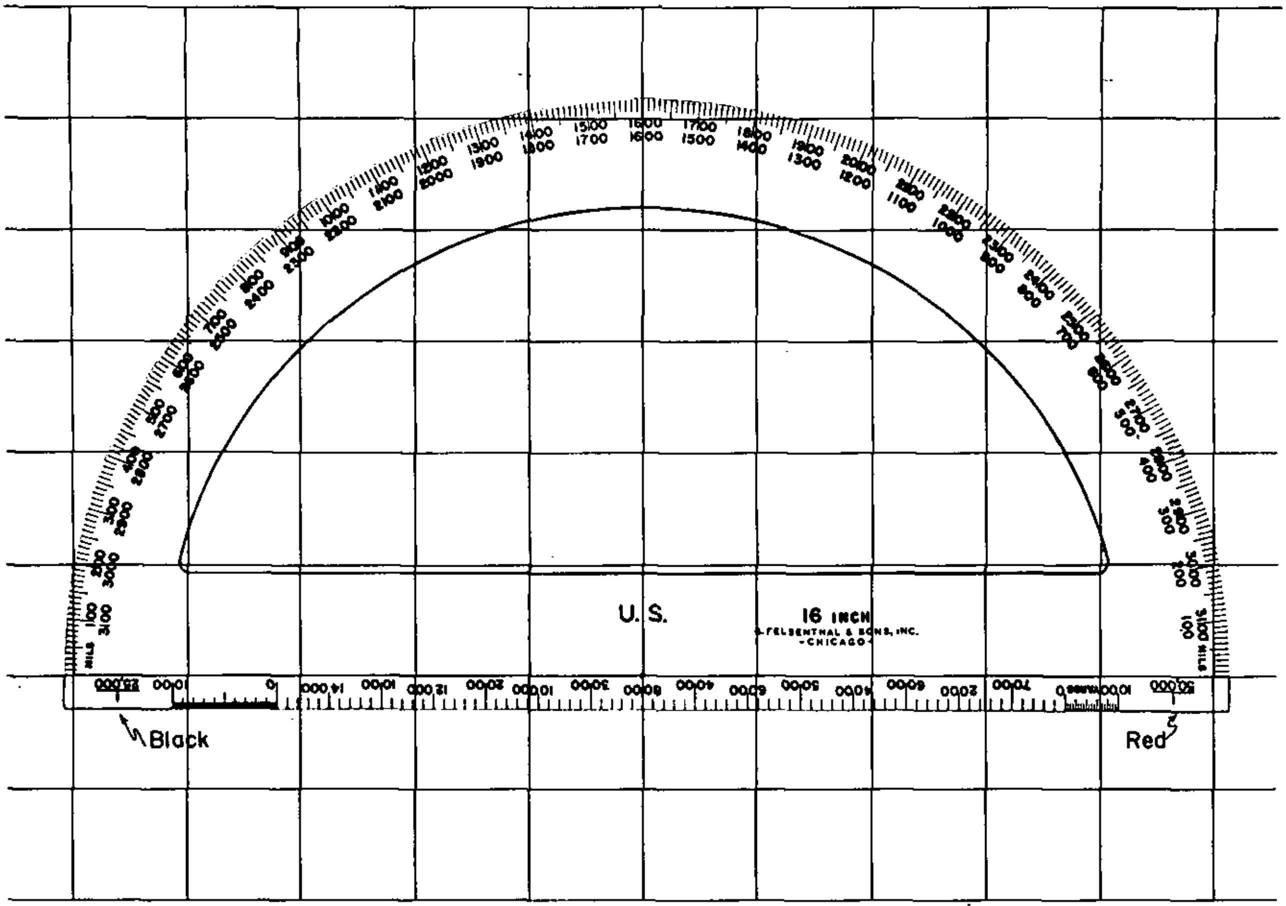


Figure 105. Protractor.

scale that is used for plotting and determining coordinates of targets other than registration points and coordinates determined by survey computations. This scale is graduated in meters and yards at 1:25,000 and 1:50,000 scales. The scale has a projecting knob for ease in handling.

h. Protractor (fig. 105). The protractor is a plastic angle-measuring instrument that is made in the shape of a half circle. The arc in the half circle is graduated in 10-mil increments with each 100-mil graduation numbered in a clockwise and a counterclockwise sequence. The base of the protractor that is used in measuring angles is the hairline connecting the 0- and 3,200-mil graduations. Since the protractor is the most accurate angle-measuring instrument issued to the FDC, it is used as an accuracy standard for other angle-measuring instruments. The straight edge of the protractor is graduated in yards—1:25,000 scale (black) and 1:50,000 scale (red).

i. Graphical Firing Table (GFT) Fan (fig. 106). The GFT fan is a device used for determining firing data and for measuring angles, ranges, and distances. The complete GFT fan consists of the base, necessary ballistic scales, and cursors. The ballistic scales contain the data necessary to plot or measure a *distance in yards* at a scale of 1:25,000; and a graphical representation of firing data appropriate for given ranges. A slot in the left edge of the cursor, called the cursor vertex, allows the left edge of the fan to rest against a plotting needle exactly opposite a hairline on the cursor, so that a precise measurement of deflection or azimuth and range can be made to the chart location of the needle. Above the vertex slot is a small hole and short hairline which are used to facilitate the preparation of fire capability diagrams, safety diagrams, etc. The cursor is transparent and is frosted so that it can be marked with a pencil. Four cursors are furnished with each GFT fan to provide extras in case of loss or damage of a cursor and to provide enough cursors for graphical application of more than one set of corrections. The base bears a scale in meters on the arm; however, the ballistic scale must be removed in order to read the metric scale. The

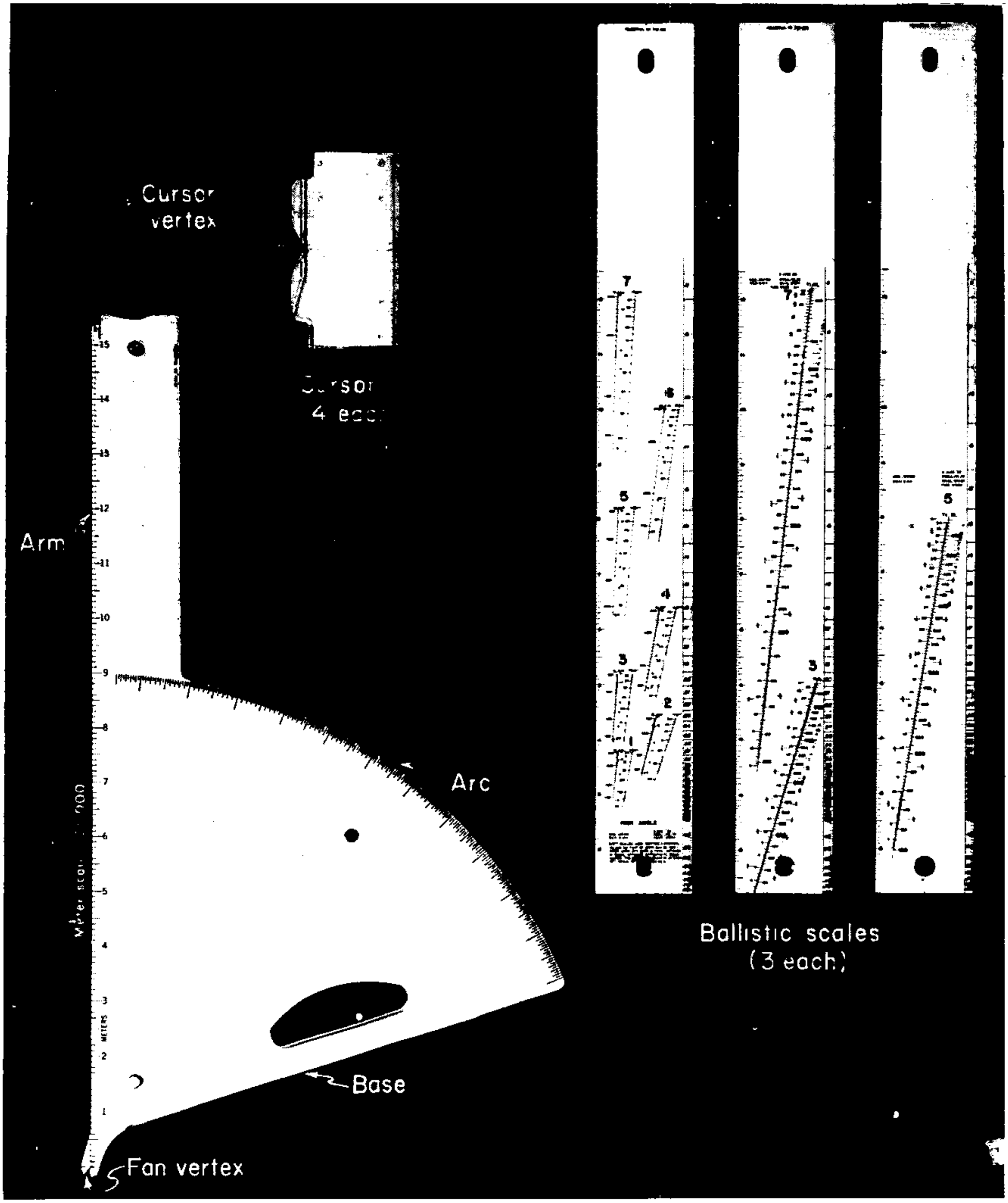


Figure 106. GFT fan.

mil scale on the arc, which is graduated in 5-mil increments with every 100 mils indicated by a long line (for reading deflections and azimuths), covers 1,000 mils. The total angle from the left edge of the arm to the right end of the mil scale on the arc is 1,200 mils. At the top of the range arm of the fan base is a 10-mil graduated scale for use in more accurate displacement of the deflection index. For example, assume the base piece to be laid on the registration point and aiming posts placed out at deflection 2,800. After registration, the adjusted deflection is 2,803. The deflection index can be accurately displaced 3 mils to the right by using the 10-mil graduated scale. The semicircular hole near the bottom of the arc of the fan is provided for ease in handling.

j. Range-Deflection Protractor (Aluminum) (fig. 107 ①). The aluminum range-deflection protrac-

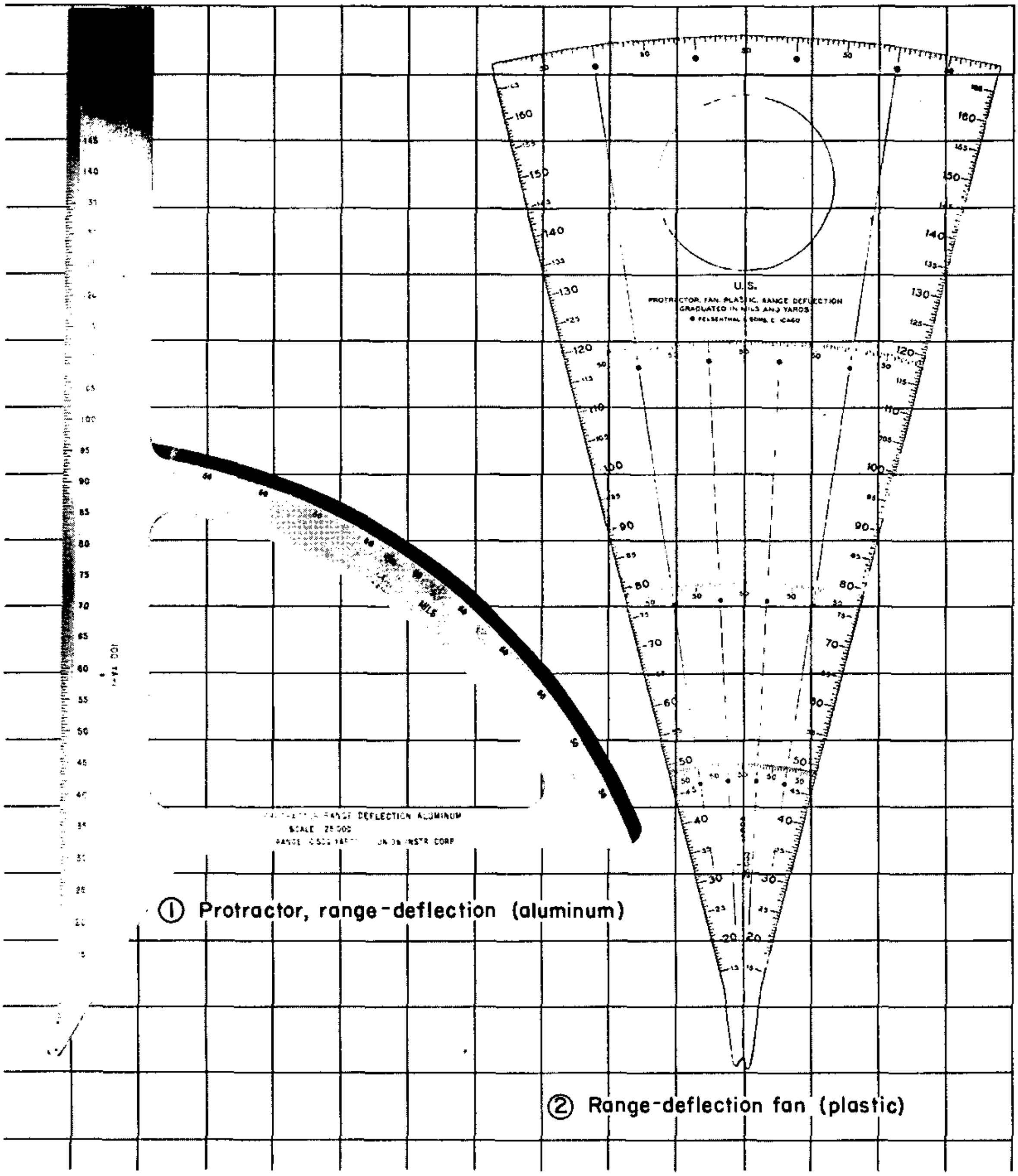


Figure 107. Range-deflection fans.

tor is a device that is used for measuring both angles and distances. It is used to determine deflections and ranges and for plotting targets. The protractor has the appearance of the GFT fan but it has no ballistic scales or cursors. The *left edge* of the fan is graduated in yards (1:25,000 scale), and the arc, graduated in 5-mil increments with each 50 mils indicated by a long line, covers 1,000 mils.

k. Range-Deflection Fan (Plastic) (fig. 107 ②). The plastic range-deflection fan is a device that is used for measuring both angles and distances. There are 3 or more mil scales on the fan, each representing a 500-mil segment of the protractor. The graduations are in 5-mil increments with each 50 mils labeled and each 100 mils indicated by a long line. If more than one scale falls on the chart, greater accuracy is obtained by using the scale farthest from the vertex. On each edge of the fan is a range scale (1:25,000 scale) graduated in yards.

279. Tick Marks

a. Tick marks are symbols used to mark locations of batteries, radars, observation posts, registration points, and concentrations (targets). The tick mark is constructed starting approximately 40 meters from the needle point and extending 150 meters (scale of 1:25,000). The identification of the plotted location is contained in the upper right quadrant of the tick marks, and this identification is indicated by using the appropriate color—Battery A, red; Battery B, black; Battery C, blue; Battery D, orange (when applicable); radar, green; and all other points in black. The altitude of the plotted point is entered in the lower left quadrant in black with a 4H pencil. The type of fuze used in fire for effect is entered in the lower right quadrant. This information is given only for fired concentrations and is entered in black. When a target has been fired on by high-angle fire, block letters HA and charge (optional) will be placed in the upper left quadrant. This quadrant is left blank if low-angle fire is used. Tick marks for targets located by survey are drawn as solid lines in black; those located by adjustment of fire are drawn as solid lines in red (fig. 108).

b. An explanation of the identification placed in the upper right quadrant of the tick marks and used in the preparation of firing charts is as follows:

(1) Battery—letter designation; e. g., A.

(2) Radar—military symbol; e. g.,

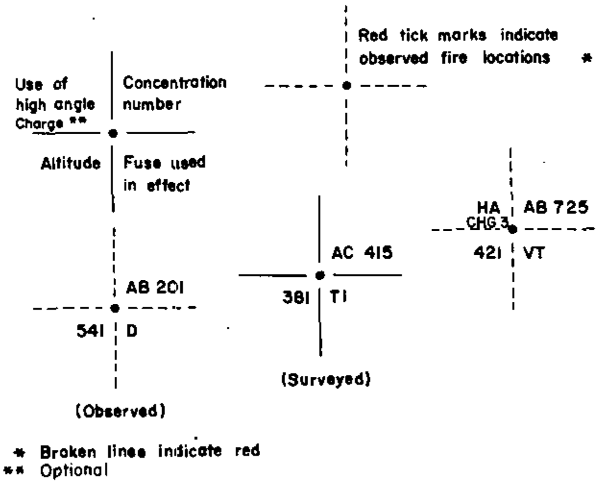


Figure 108. Marking plotted points.

(3) Forward observation post—military symbol plus the call number of the observer; e. g., 48. (If the observer is from another unit, call sign and call number both will be used.)

(4) Battalion observation post—letter designation plus the assigned number; e. g., 02.

(5) Registration points—registration point plus the number assigned; e. g., Reg pt 3.

(6) Concentrations (targets)—assigned concentration number; e. g., AD 415.

280. Plotting a Point From Coordinates Using Plotting Scale

a. A normal grid is defined as a grid that is printed to the exact scale of the plotting scale (fig. 109). To plot a point whose coordinates are 6241938749 on a normal grid, place the 0 of the plotting scale on the north-south line 62 and the 1,000-meter graduation of the subdivided section of the scale on the north-south line 63. Holding the scale about 1 grid square above the approximate location of the point, mark 419 meters with a plotting needle. Place the scale about 1 grid square below the approximate location of the points and repeat the operation. Connect the two plotting needles with a fine, light line by using a 6H pencil. This will be the north-south line passing through the point. In a similar manner, determine the east-west line passing through the point. The intersection of these lines is the desired point, habitually indicated by a tick mark made with a 4H pencil. If the point to be plotted falls exactly on a grid line or very

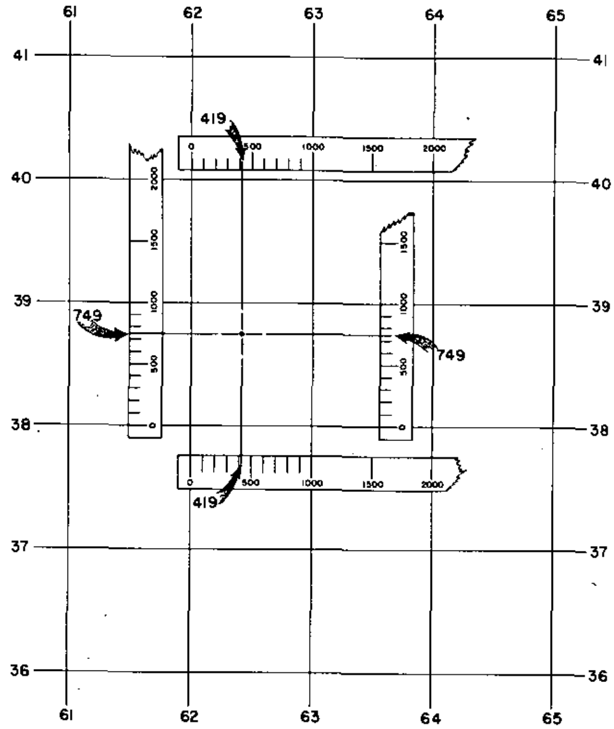


Figure 109. Plotting a point from coordinates on normal grid.

close to it, the tick mark should be plotted at about a 45° angle to the grid line (fig. 110).

b. Grid lines are sometimes closer or more distant than normal owing to poor manufacturing processes or the influence of the atmosphere on the size of the paper. When grid lines are closer than normal, plot the point in the same manner as described in *a* above but incline the scale so that the 0 of the scale is on 1 grid line and the 1,000-meter graduation is on the other grid line. The point will then be plotted in its true relation to

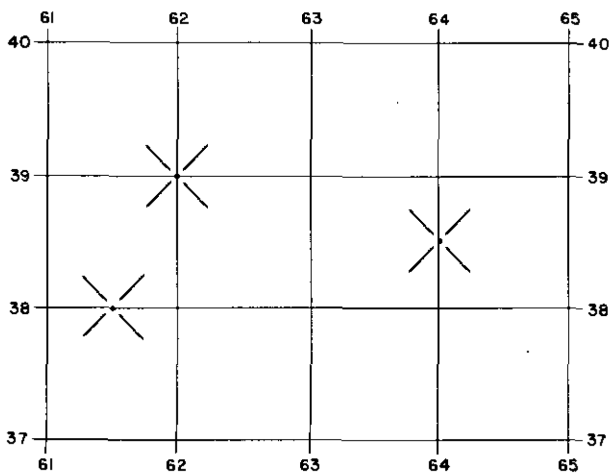


Figure 110. Plotting a point which falls on a grid line.

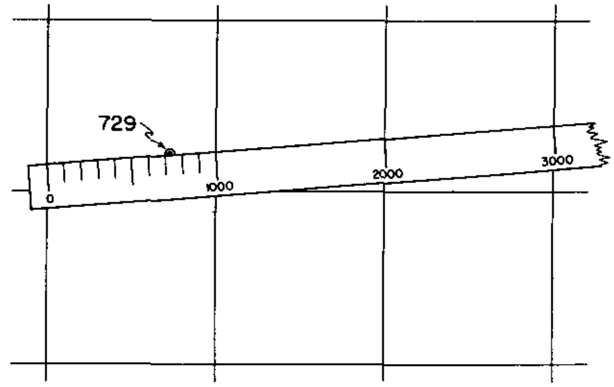


Figure 111. Plotting a point from coordinates when grid lines are closer than normal.

the grid, as the 100-, 10-, and 1-meter digits express the proportional part of the distance between grid lines (fig. 111).

c. If the grid lines are more distant than normal, 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 grid lines is measured as 1,020 meters, the difference from normal is 20 meters. The proportional part of this distance for a 400-meter measurement is 400/1,000 x 20 or 8 meters. The 400-meter measurement then is scaled as 408 meters (fig. 112①).

d. Similar results can be obtained by inclining the plotting scale so that 0 graduation is on 1 grid line and the 2,000-meter graduation is on the next adjacent grid line. The meters to be plotted are multiplied by 2, and that distance is scaled. In figure 112②, in plotting the easting coordinate, the 400-meter measurement would be scaled as 800 on the inclined plotting scale.

281. Measuring Coordinates of a Point Using Plotting Scale

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. The first digit(s) of the easting coordinates is the number appearing at the top or bottom of the north-south line west of the point. The balance of the easting coordinate is the distance of the point east of this north-south line as measured with the scale. For the northing coordinate, the first digit(s) is obtained from the right or left end of the east-west line south of the point and the balance of the northing coordinate is the distance of the point north of this line as measured with

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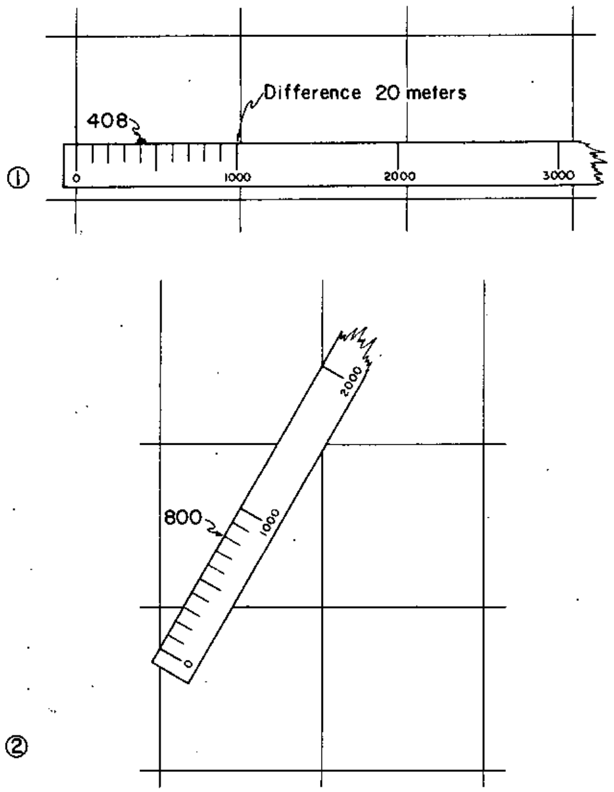


Figure 112. Methods of plotting points from coordinates when grid lines are more distant than normal.

the scale. If the grid is not a normal grid, the measurements are made in the same manner as they are in plotting points.

282. Use of Coordinate Scale

a. When the rapid massing of fires on targets of opportunity is necessary, the plotting may be done with the coordinate scale (fig. 104 ② and ③). To plot, using the coordinate scale, first determine the grid square in which the point will fall. With the horizontal scale in coincidence with the east-west grid line, slide the scale along this line until the distance to be plotted is indicated opposite the north-south grid line. Keeping the scale in this position, read up the vertical scale to the distance to be plotted and mark this point with a plotting needle; accentuate with tick marks as explained in paragraph 279. When plotting with the coordinate scale, always have one arm of the scale on the east-west grid line pointed toward the west and the other arm pointed toward the north. Since the coordinate scale has 1:25,000 and 1:50,000 scales, it is frequently desirable to place tape over the scale not in use to avoid using the wrong scale.

b. To measure the coordinates of a point, determine the coordinates of the lower left-hand corner of the grid square first. Placing the coordinate scale at this grid intersection, slide the coordinate scale to the right, keeping the horizontal scale in coincidence with the easting grid line until the point is reached by the vertical scale. Read the distance east and the distance north from the scales. Combine these readings with the coordinates of the grid square to obtain the coordinates of the point.

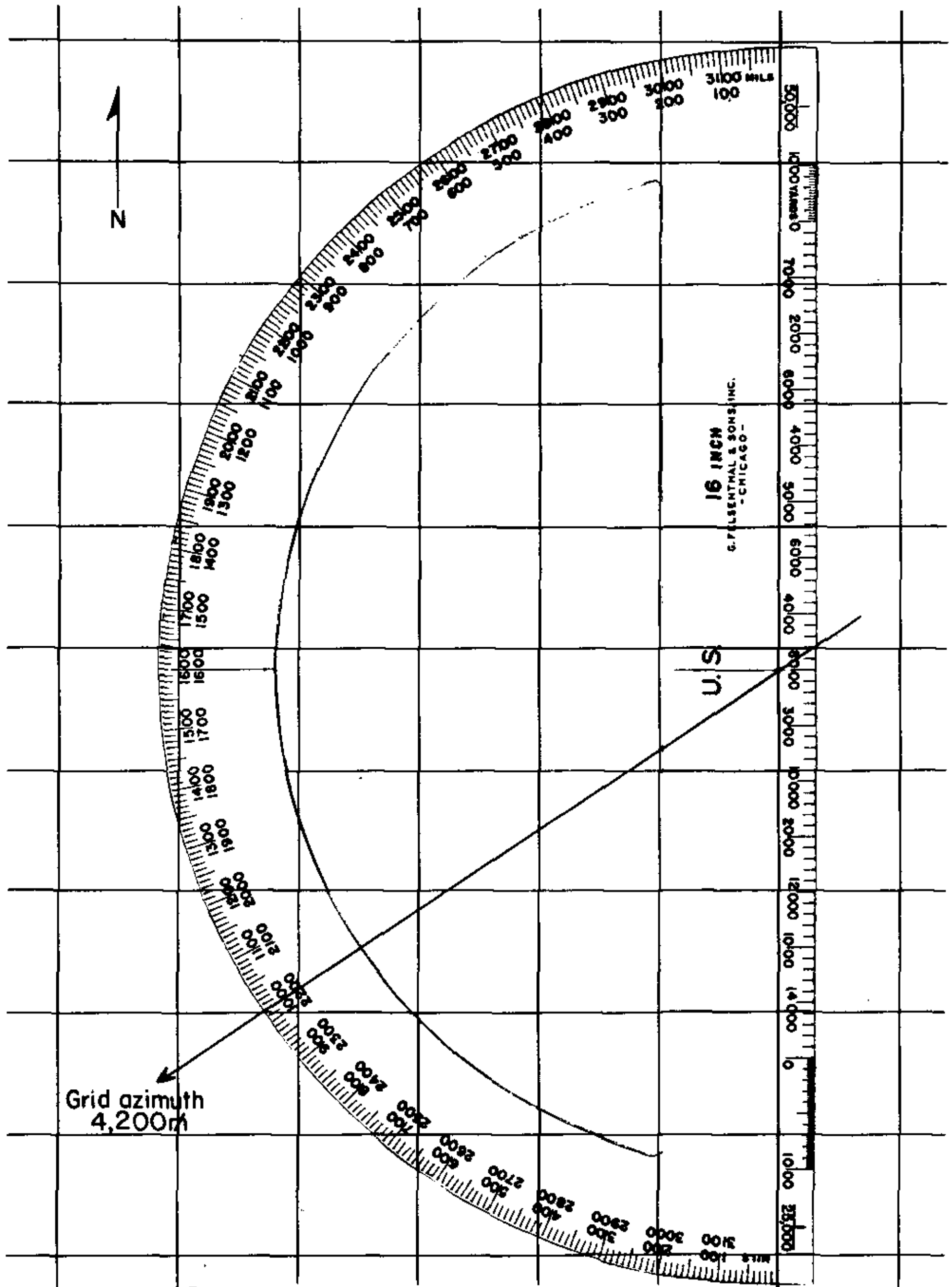
283. Measuring and Plotting an Angle With a Protractor

To accurately measure and plot an angle with a protractor, the center of the protractor must be placed exactly over the vertex of the angle, and the base of the protractor must be placed exactly over one side of the angle. For greater accuracy, measure the angle with both sides of the protractor and take the mean of the reading. For example, first measure with the arc of the protractor to the right of the center and 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.

a. There are two ways of orienting the protractor to measure a grid azimuth. One method is to orient the protractor from a north-south grid line. The grid azimuth of a line can be measured by using the intersection of the line with a north-south grid line as the vertex. The protractor is placed so that the clockwise angle, from the north-south grid line to the given line, is read. If the arc of the protractor is left of the north-south grid line, the azimuth is the value shown on the outer scale of the protractor plus 3,200 mils (fig. 113①). If the arc of the protractor is right of the north-south grid line, the azimuth is read on the outer scale of the protractor.

b. The grid azimuth of a line also may be measured by orienting the protractor from an east-west grid line and using the intersection of the line with the east-west grid line. Place the center of the protractor over the intersection and the 1,600-mil graduation of the protractor on the east-west grid line; the azimuth of the line is determined as in *a* above (fig. 113 ②). If the grid azimuth is greater than 3,200 mils, the proper relation of the measured angle to 3,200 or 6,400 must be determined as in *a* above.

c. To draw a line of given azimuth through a point, the following procedure is used: Place the



① Orienting the protractor from a Northing line

Figure 113. Methods of measuring grid azimuth with a protractor.

center of the protractor exactly over the point and the base of the protractor roughly parallel to either an east-west or a north-south grid line. Rotate the protractor about the point until an east-west grid line (north-south grid line) cuts off the same amount of arc on both ends of the protractor. The base of the protractor now is parallel to the east-west grid line (north-south grid line). A line of given azimuth (or back-azimuth) is drawn by marking the correct azimuth with a plotting needle at the circumference of the protractor and drawing a line through the given point and the marked point. In figure 114, the north-south grid line cuts 160 mils of arc from each end of the protractor. The line drawn has a grid azimuth of 5,630 mils. For plotting, if the baseline of the protractor is

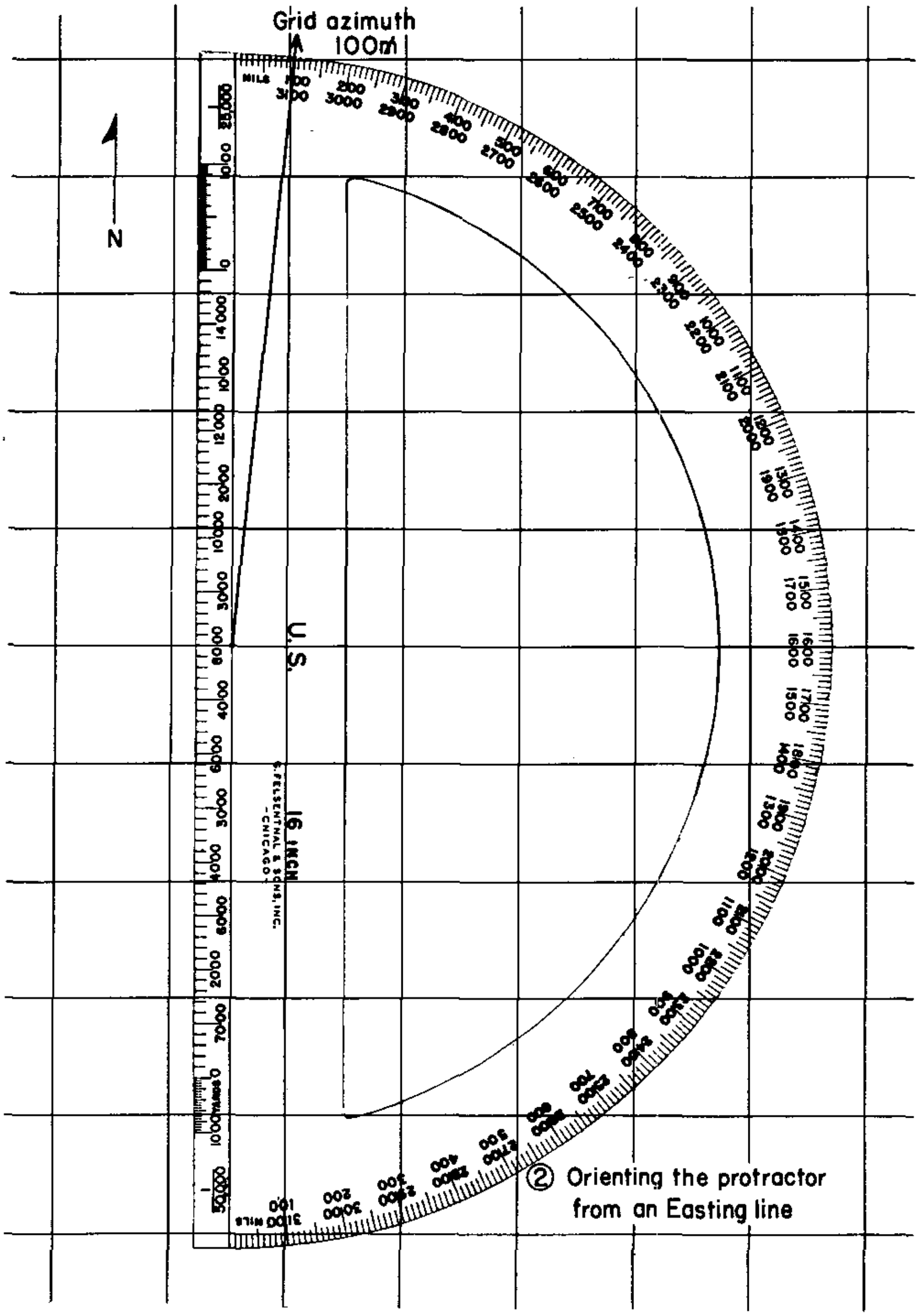


Figure 113—Continued.

always used parallel to the north-south grid line, the correct azimuth of the plotted point is determined as described in *a* above.

284. Measuring and Plotting Distances With Plotting Scale

The most accurate method of determining the distance between two points plotted on a firing chart is with the plotting scale. Care must be taken to use the correct scale on the plotting scale.

a. After the direction of a line has been established on a chart (par. 283), the length of this line may be plotted with the plotting scale.

b. A more accurate method of plotting a definite line for distance and direction is to plot the extremities of the line by using coordinates. At times, the coordinates of the extremities will plot 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 azimuth, determine the differences in the easting and northing coordinates of the 2 points, multiply these differences by the same number, and apply the products to the coordinates of 1 of the original points. The result is the coordinates of a third point which, when plotted, will lie on an extension of the line of the first two points. For example, the coordinates of point A are 6247537694 and the coordinates of point B are 6284337943. It is desired to plot the line AB. The points, when plotted, are too close together to allow a line to be drawn between them satisfactorily. To obtain points that are more

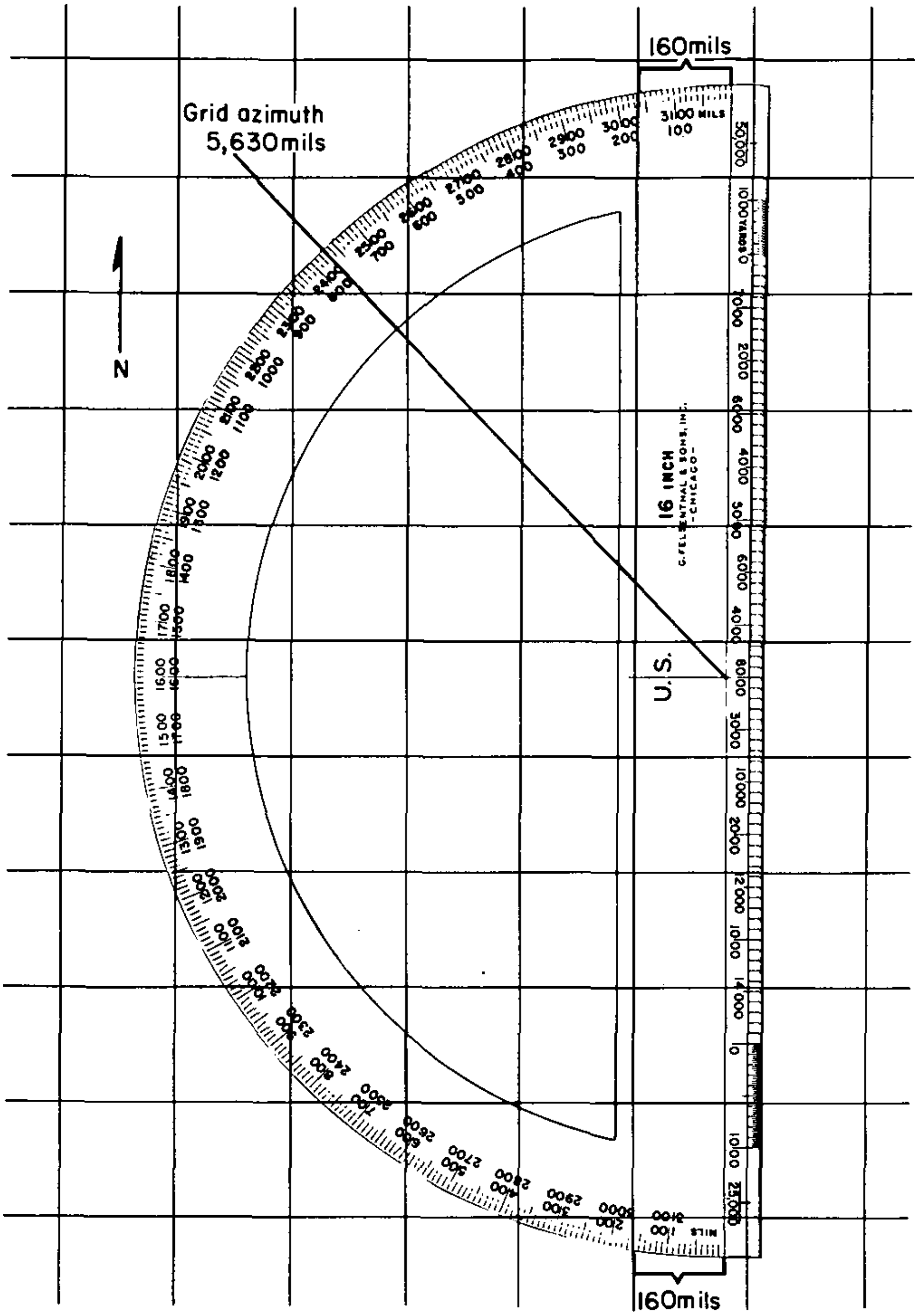


Figure 114. Method of drawing line of a given grid azimuth through a point.

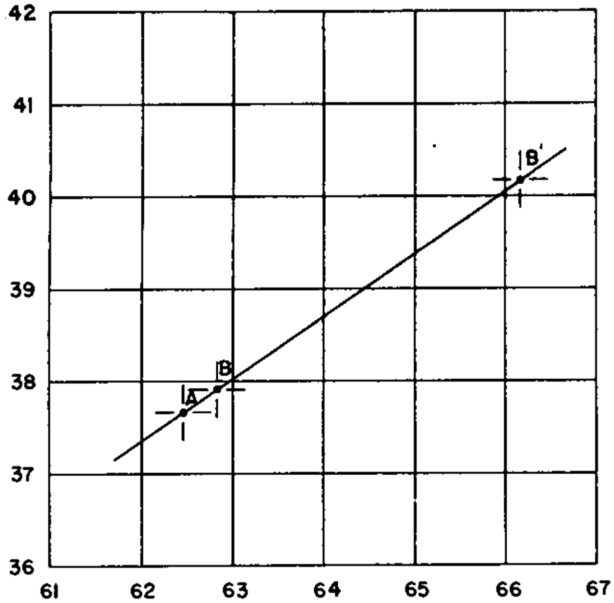


Figure 115. Method of plotting a line by coordinates.

widely separated, the procedure outlined above is followed. For example:

Coordinates point B	62843	37943
Coordinates point A	62475	37694
dE	+368	
dN		+249
Multiply by same number	10	10
	+3680	+2490
Apply to point A	62475	37694
Coordinates point B'	66155	40184

The point B' is plotted, and the line AB' is drawn. Line AB' has the same direction as the line AB (fig. 115).

285. Measuring and Plotting Angles and Distances Using Graphical Firing Table Fan

When several angles and distances are to be plotted or measured, using 1 point and 1 line of direction, the procedure is facilitated by using the graphical firing table fan. The accuracy obtainable in measuring and plotting is not as great as that with a protractor and a plotting scale. However, it is sufficient for such purposes as polar plotting of targets from an OP or radar stations, replotting of targets located by adjustment, and for establishing indexes on the firing chart.

a. All scales of the GFT fan must be checked with scales that are 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 on which the fan is used also should be checked from time to time with the fan; for example, originally the distance between 2 points on the firing chart is measured as 6,620 meters; later, because of expansion of the paper, the distance between the same 2 points is measured as 6,680 meters. 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 easting and northing directions.

b. Angles up to 1,000 mils can be measured conveniently with the GFT fan. This measurement is accomplished by placing the vertex of the fan at the point at which measurement is to be made and rotating the fan between the lines describing the angle, noting the angular value of the rotation indicated on the arc of the fan. It is always desirable to rotate the fan from right to left in measuring an angle. To *measure a distance in yards* between 2 points, place the vertex of the fan at 1 point and the vertex of the cursor at the other point and *read the distance on the ballistic scale* under the hairline. When the *measurement of distance is desired in meters, the ballistic scale and cursor are not used. Distance is read on the meter scale on the arm of the fan* with the ballistic scale removed. For example, three points, A, B, and C, have been plotted on the chart (fig. 116). It is desired to measure the angle at A between lines AB and AC and to measure the distance AC. With the vertex of the fan against the pin in point A and the left edge of the arm against a needle in point B, place a needle in the chart at the last 100-mil graduation at the left end of the arc. Remove the needle in point B and rotate the fan so that the left edge of the arm is placed against a needle in point C. With the arm thus against the needle in point C, read the value of the angle (350 mils) opposite the needle placed along the arc. To measure the distance between A and C in meters, place the fan so that the vertex is against a pin in point A and the left edge of the arm is against a needle in point C. Read the distance on the meter scale opposite the needle as 7,500 meters.

c. The procedure for plotting an angle and a distance is similar to that used for measuring. Assume in the situation shown in figure 116 that

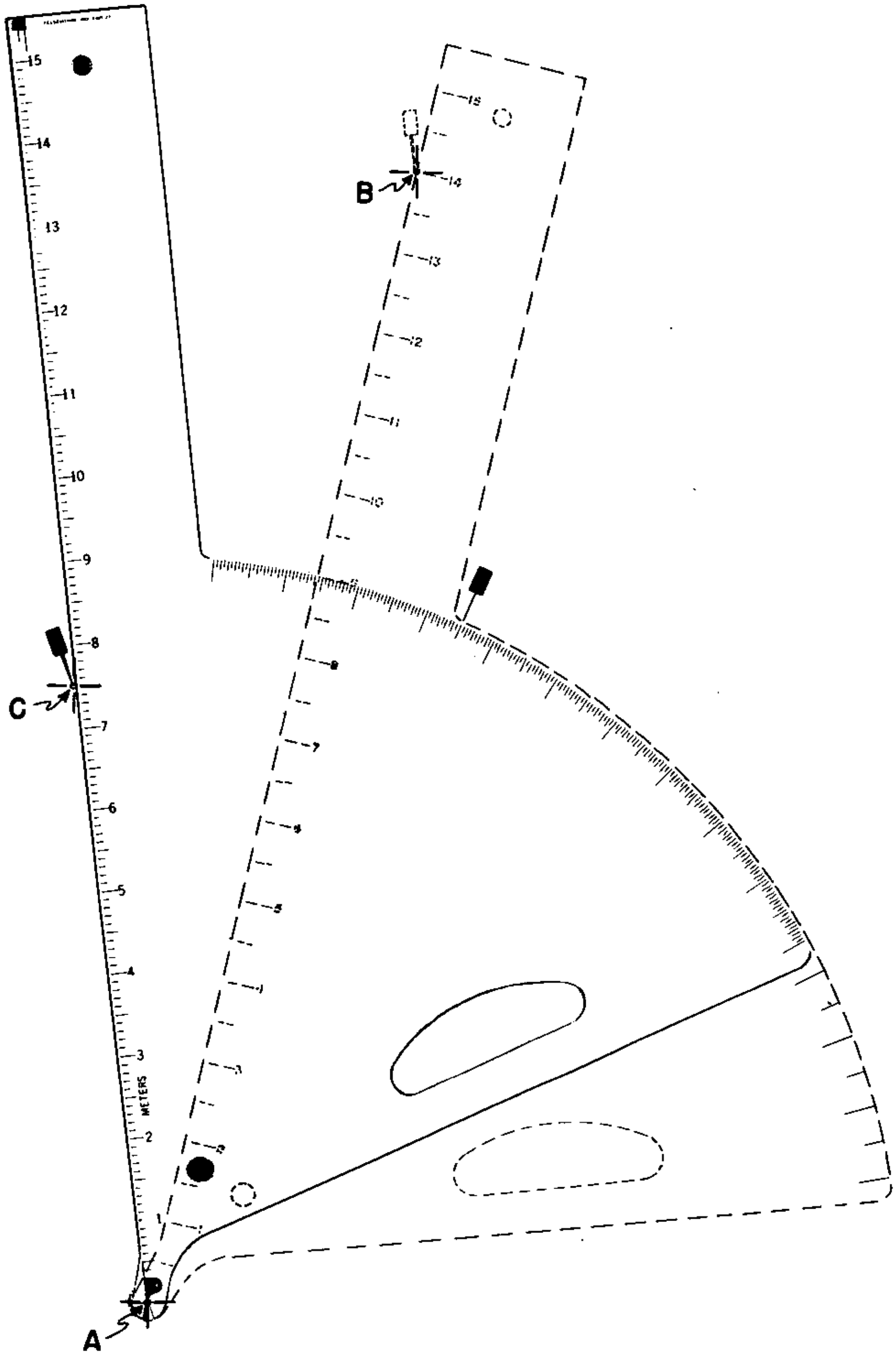


Figure 116. Measuring or plotting an angle and distance with the GFT fan.

only points A and B have been plotted on the chart. It is desired to plot point C 350 mils left of the line AB at a distance equal to 7,500 meters from point A. With the arm of the fan along line AB, place a needle in the chart at the last 100-mil graduation at the left end of the arc. Rotate the fan to the left until an angle of 350 mils has been set off between the needle and the last 100-mil mark at the left edge of the arc. With the fan in this position, place a needle in the chart opposite 7,500 on the meter scale, establishing the location of point C. Assume in the situation above that it is desired to plot point D (not shown) 460 mils *right* of the line AB and a distance equal to 7,500 meters from point A. With the arm along the line AB, place a needle in the chart opposite the last graduation at the right end of the arc. Then rotate the fan to the right until an angle of 460 mils has been set off between the last graduation at the right end of the arc and the needle placed along the arc. Place a needle in the chart opposite 7,500 on the meter scale, thus plotting point D.

286. Polar Coordinates and Polar Plotting

Points may be designated by specifying the distance from a known point along a line of known direction. This method is known as designation by *polar coordinates;* for example (observer's location is known at the FDC), azimuth 2,000, OT range 900. For artillery purposes, the line of known direction is usually grid azimuth and the distance is expressed in yards or meters. In any case, the point of origin, the line of known direction, and the unit of measurement to be used must be mutually prearranged between personnel or agencies concerned. The procedure of plotting a point with polar coordinates is known as *polar plotting*.

287. Preparing Chart With Polar Plot Indexes for GFT Fan

In order to polar plot from radar or OP positions, using the GFT fan, it is necessary to establish indexes on the firing chart at 1,000-mil intervals covering the target area (fig. 117). The procedure in *a* through *f* below will be followed in establishing those indexes.

a. First place the fan so that its vertex is against a pin in the radar or OP position and the left edge of the fan is parallel with a convenient grid line. (This establishes a *reference line* (not drawn) at an azimuth of 1,600, 3,200, 4,800, or 6,400 mils.)

b. Place a needle opposite the last 100-mil graduation at the left end of the arc.

c. Rotate the fan counterclockwise through an angle equal to the difference between the *reference line azimuth* and the next lower 1,000 mils. (This angle will be 200 mils, 400 mils, 600 mils, or 800 mils, depending on the initial orientation of the fan.) At this time, the left edge of the fan is along an azimuth of either 1,000, 3,000, 4,000, or 6,000 mils.

d. Without changing the location of the fan, place a needle opposite the last 100-mil graduation at the right end of the arc. *This needle indicates the location of the index for the particular azimuth of the left edge of the fan.*

Note. When left edge of fan is oriented on the reference line representing azimuth 6400 (0 mils), the last 100 mil graduation at the right end of the arc indicates the location for the 0 index.

e. Next, move the fan so that the left edge of the fan is placed against the needle and draw in the index with a wedge-pointed 6H pencil. The index is a fine line approximately 2 inches long, extending 1 inch beyond and 1 inch short of the mil scale. The index is labeled along the left side of the line, beginning one-eighth inch (50 yards, scale 1:25,000) beyond the mil scale. For radar, the lettering on the indexes is in green. For OP's, the lettering is in black.

f. To establish the index for azimuth 2,000 or 5,000 after the index for 3,000 or 6,000 has been established, place the vertex of the fan against the pin in the radar or OP position and the right 0 graduation on the arc in coincidence with the appropriate index on the chart. Place a needle in the chart against the arc at the last 100-mil graduation at the left end of the arc, marking the point where the index is to be constructed.

288. Preparing Chart When Azimuth to a Known Point Has Been Reported From Radar Measurement

There will be times when the azimuth to a known point, which is located on the firing chart, can be measured by radar. In this case, the procedure in *a* through *d* below will be used to establish azimuth indexes for the radar.

a. With the left edge of the fan against the

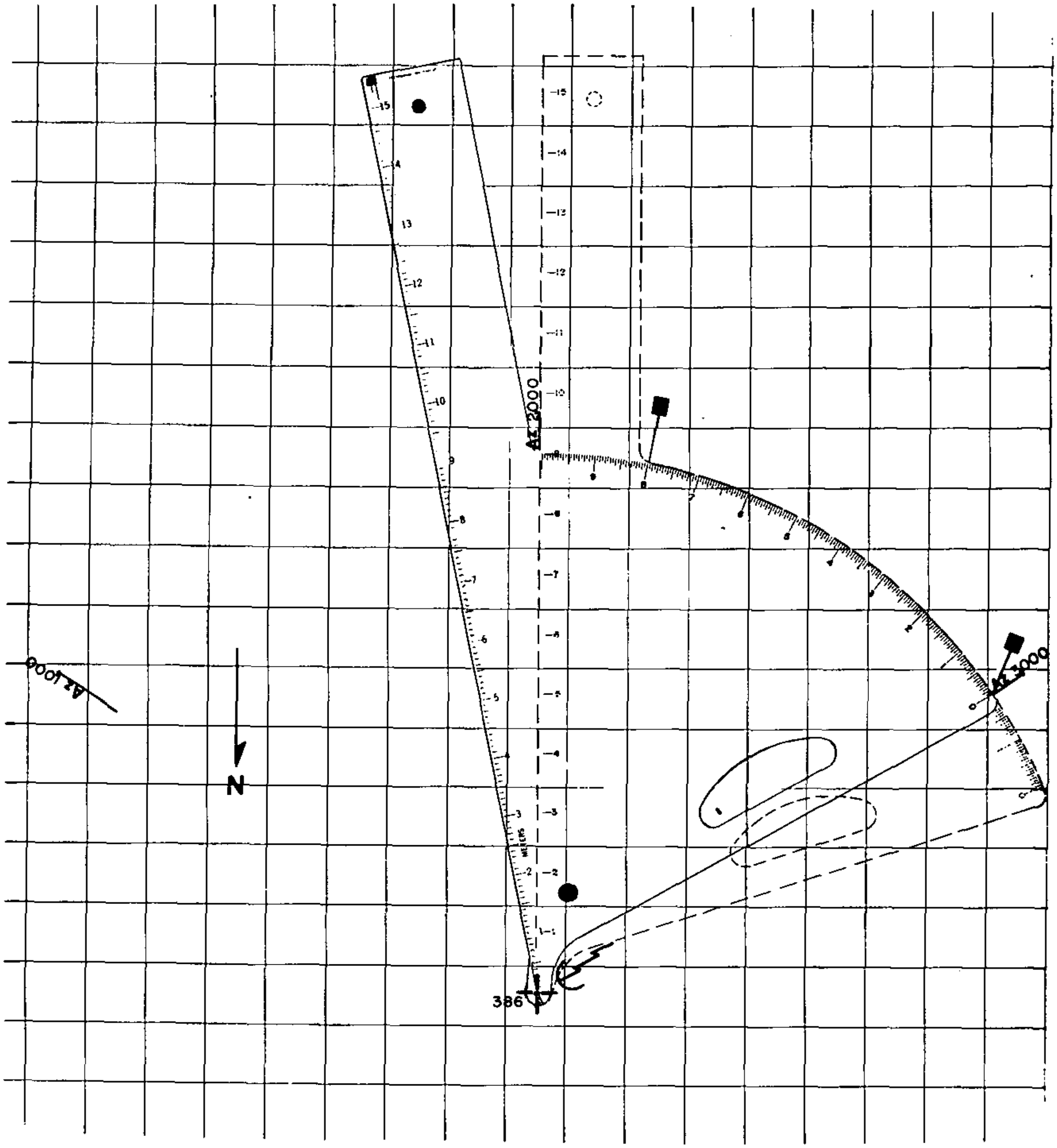


Figure 117. GFT fan and chart prepared for plotting targets located by radar.

needle in the point of known azimuth, place a needle opposite the last 100-mil graduation at the left end of the arc.

b. Rotate the fan counterclockwise through an angle equal to the *difference between* the reported azimuth and the next lower 1,000 mils. At this time, the left edge of the fan is along an even 1,000-mil azimuth as measured from the radar.

c. Place a needle in the chart opposite the last 100-mil graduation at the right end of the arc.

d. Construct the index through that point and mark it as described in paragraph 287e. This procedure minimizes orientation error in the radar.

Example: The azimuth to the registration point has been measured as 2,309 mils by radar and is reported to the FDC. The chart operator places the left edge of the GFT fan against the needle in the registration point and places another needle in the chart opposite the last 100-mil graduation at the left end of the arc. The chart operator then removes the needle from the registration point and rotates the fan counterclockwise through 309 mils. At this time, the left edge of the fan is along a line of azimuth 2,000 mils from the radar. The chart operator places a needle in the chart opposite the last 100-mil graduation at the right end of the arc and then constructs the index through that point and labels it "Az 2,000". Other necessary indexes are constructed at 1,000-mil intervals from this index.

289. Numbering Mil Scale of GFT Fan for Polar Plotting

To facilitate reading angular measurements when polar plotting, the 100-mil graduations of the mil scale of the GFT fan are numbered as follows:

a. Mark a zero at the last graduation at the right end of the arc.

b. Moving from right to left, mark with an appropriate black pencil each succeeding graduation from 1 through 9, leaving the last 100-mil graduation on the left edge unnumbered. This last graduation should not be marked, since values are read from right to left.

290. Plotting a Target Reported by 01

The procedures used for plotting a target reported by 01 are as follows:

a. Place the vertex of the fan against the pin in the 01 (designation of control OP) position with the arc over the proper 01 index. There will be only one 01 index which can be used to polar plot a given target. The index to be used is the one numbered with the multiple of 1,000 that is next lower than the azimuth reported by the observer.

b. Orient the fan over the index so that the azimuth on the index used, added to the angle read from the arc, is equal to the azimuth reported. Care must be exercised to insure that azimuth readings taken from the arc always increase from right to left. This causes the left edge of the arm to be on the reported azimuth from 01.

c. Place a needle in the chart along the left edge of the arm at the computed distance from 01 (fig. 118). For example, it is desired to plot a target at an azimuth of 1,960 mils and a distance of 10,700 meters from 01. Since distance is to be plotted in meters, the GFT fan is used without the ballistic scale and cursor. Place the vertex of the fan against the pin in 01 and the arc over the 01 index labeled "Az 1,000". Then rotate the fan until 960 on the arc is in coincidence with the index marked "Az 1,000". The left edge of the arm is now along azimuth 1,960 from 01. Without moving the fan, place a needle in the chart along the left edge of the arm at a distance equal to 10,700 meters from 01. If it had been desired to plot the distance from 01 in yards, a ballistic scale and cursor would have been used.

291. Measuring and Plotting Using Range-Deflection Protractor (Aluminum)

The procedure for measuring and plotting angles and distances with the aluminum range-deflection protractor is the same as that for the GFT fan.

292. Measuring and Plotting Using Range-Deflection Fan (Plastic)

The procedure for measuring and plotting angles and distances with the plastic range-deflection fan is as follows:

a. Assume that three points, *A*, *B*, and *C*, have been plotted on the chart (fig. 119). It is desired to measure the distance from point *A* to point *C* and the angle between the lines *AB* and *AC*. With the vertex of the fan at point *A* and one side running through point *B*, a fine line is drawn with a 6H pencil along that side of the fan extending short of and beyond the selected mil scale. With the left edge of the fan against a needle in point *C*, the distance *AC* is read opposite the needle (8,100 yards) and the angle is read on the mil scale reading from the left edge to the fine pencil line (240 mils).

b. The procedure for plotting an angle and distance is very similar to that used for measuring an angle and distance. Assume that in the situation above (fig. 119) points *A* and *B* have been plotted on the chart. It is desired to plot point *C* 240 mils left of the line *AB* at a distance equal to 8,100 yards from point *A*. An extension of the line *AB* is made as described in *a* above. The fan, with vertex at point *A*, is moved until the

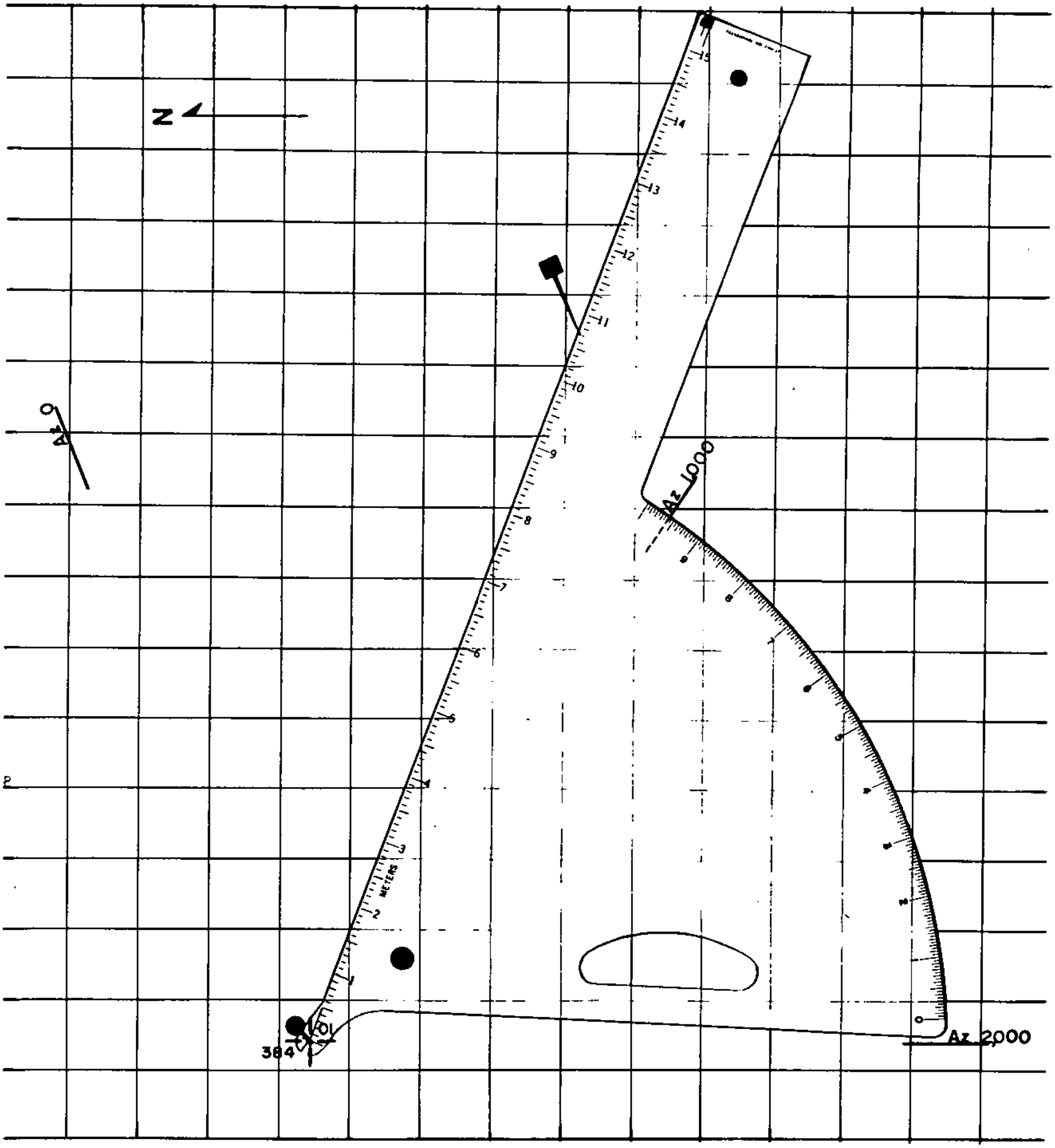


Figure 118. Polar plotting from 01.

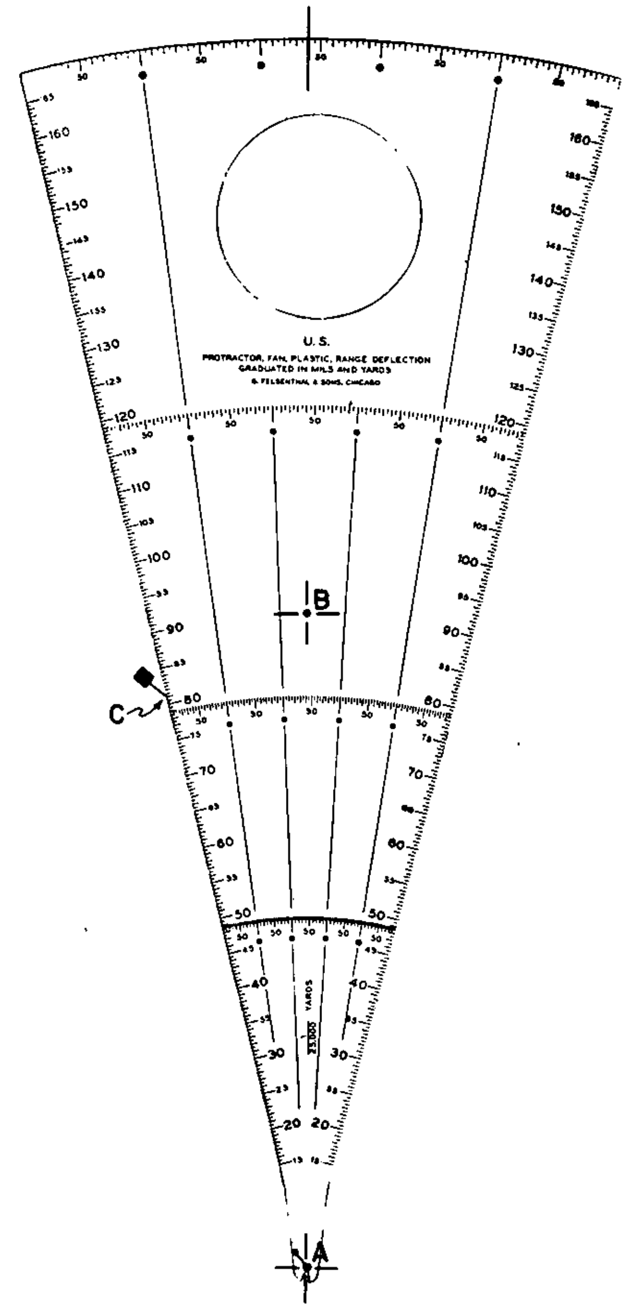


Figure 119. Method of measuring or plotting a distance and an angle with the range-deflection fan (plastic).

extension of line *AB* cuts the fan at 240 mils right of the left edge. With the fan in this position, point *C* is plotted at the left edge of the fan at a distance equal to 8,100 yards.

c. To facilitate plotting many points from one position, such as radar, 01, and 02, locating indexes are constructed on the chart. With the vertex of the fan at the position to be plotted from and the edge of the fan parallel to a grid line, draw an index at a convenient mil scale. After drawing the index, construct reference lines covering the target area in even 500-mil graduations and label them in the appropriate color with proper azimuth (fig. 120). Reference lines are drawn approximately 2 inches in length, extending 1 inch *above* and 1 inch *below* the mil scale to be used.

293. Target Grid (DA Form 6–53)

a. General. The target grid is a device for converting, by plotting, 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. An arrow extends across the grid, with the point of the arrow 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. The scale is graduated in a counterclockwise direction at 10-mil intervals from 0 to 6,400 mils, each 100 mils being labeled. The scale of the target grid must be the same as that of the firing chart. When the target grid is used with a firing chart at a scale of 1:25,000, the smallest graduation of the grid represents a distance of 100 yards or meters (fig. 121).

Note. As used in this manual, there has been no differentiation between yards and meters in the use of the DA Form 6–53 (Target Grid) for observer corrections. For observed fire bracketing procedures the difference between yards and meters is minor and may be ignored.

b. Placing the Target Grid. The center of the grid is placed over any point of orientation in the target area. This point may be the initial plotted location of the target to be adjusted on, a registration point, a met check point, a previously fired concentration, or an arbitrarily selected point such as a grid intersection. The selection of a point other than the target to be plotted should be such that the target 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.

c. Orienting the Target Grid. The chart operator 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 on the chart at zero azimuth, extending 1 inch above and 1 inch below the edge of the target grid, and marked "N" plainly to prevent its being confused with other

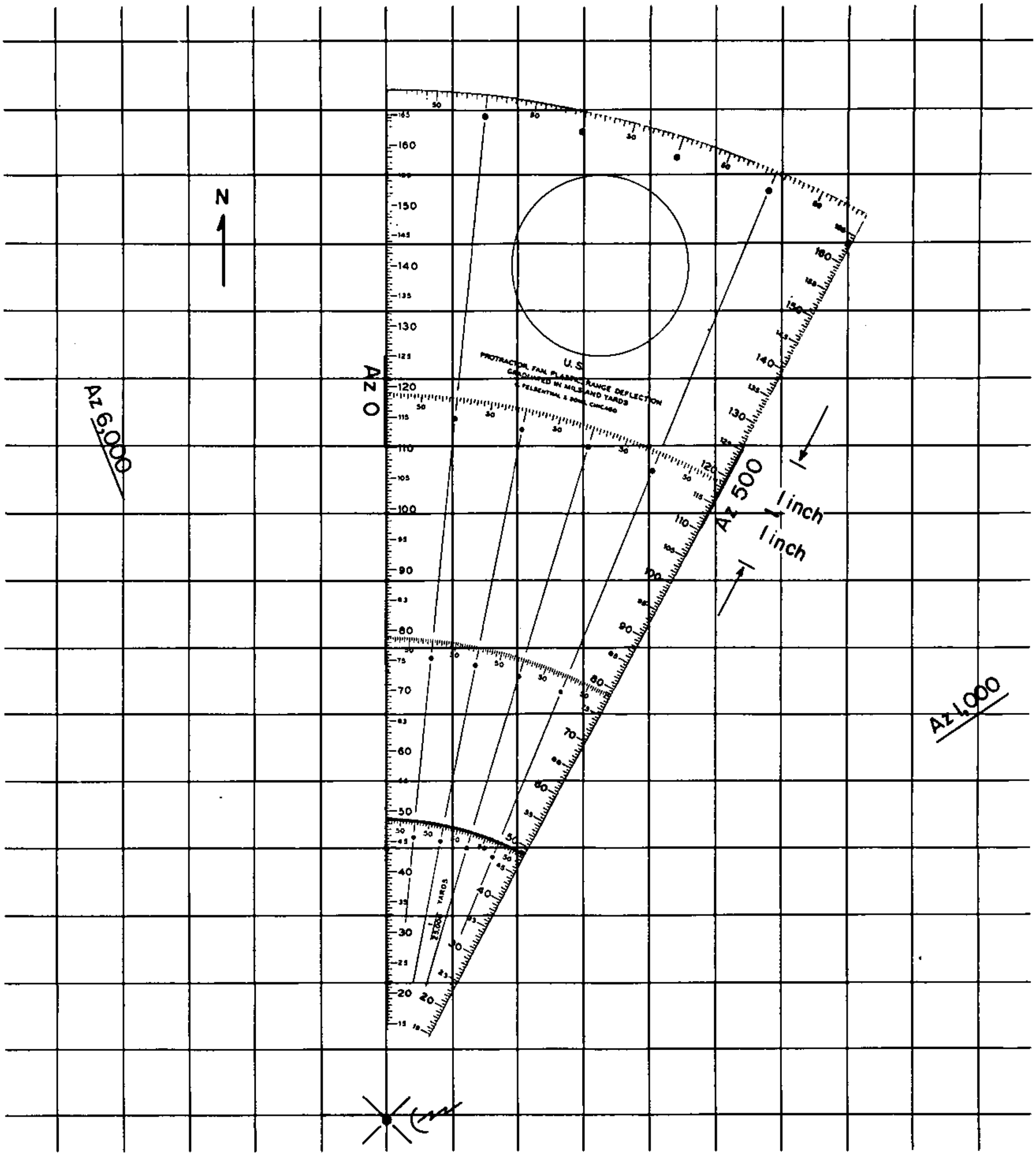


Figure 120. Indexing the chart for radar (plastic fan).

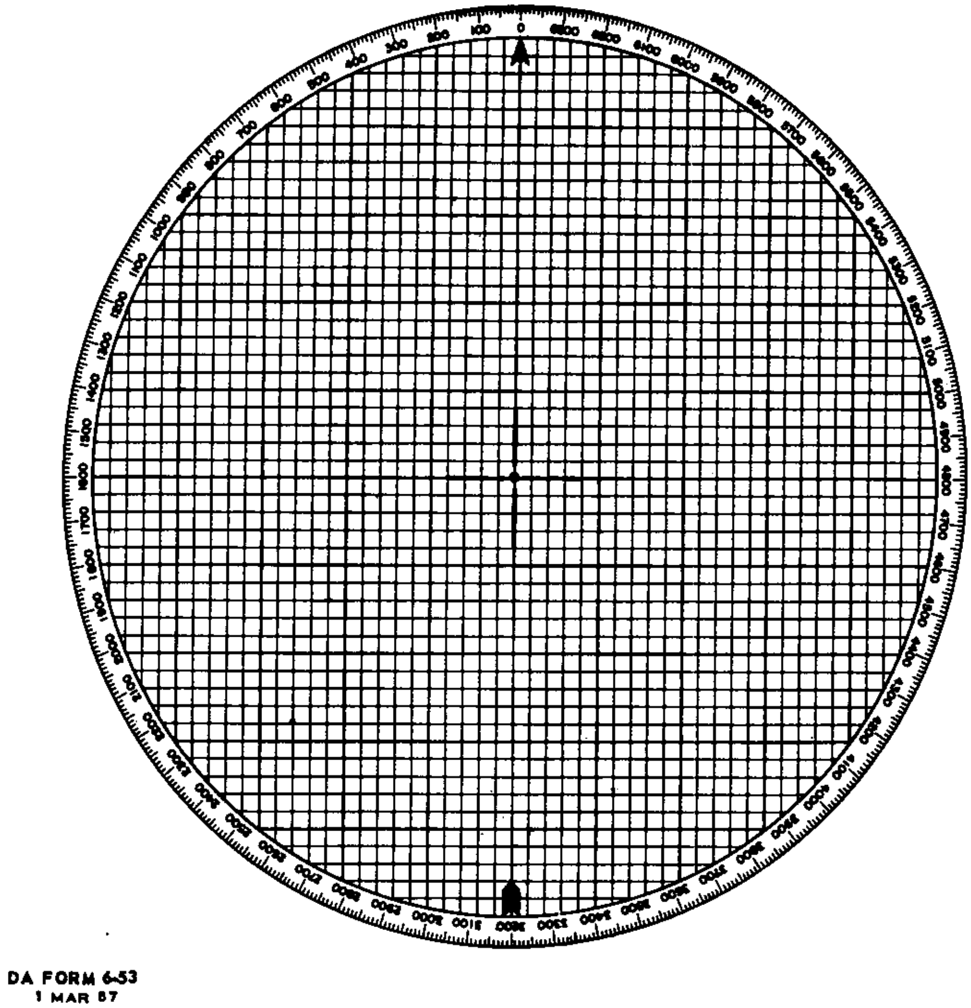


Figure 121. The target grid.

indexes on the chart. Orienting the target grid is accomplished by rotating it until the figure read opposite the aximuth 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. 122).

d. Plotting a Target by Shift From Known Point. The target grid is placed over the chart location of the known point and oriented on the azimuth given by the observer. The target needle is moved right or left of center along a line perpendicular to the arrow and forward or back from the center line along the directional arrow or one of the lines parallel to it. Figure 123 shows the plot of an observer's initial fire request; e. g., FROM REGISTRATION POINT 1, AZIMUTH 4110, RIGHT 600, DROP 1000. In this manner, the observer's target location is plotted in reference to a known point with respect to the OT line.

e. Measuring an Angle. The target grid may be used to measure an angle in instances where a high degree of accuracy is not required. To measure an angle, the center of the target grid is placed over the apex of the angle and the 0 of the azimuth circle is placed to fall on 1 side of the angle to be measured so that the other side of the angle falls to the left. The size of the angle is read at the point on the azimuth circle that is intersected by the side to the left.

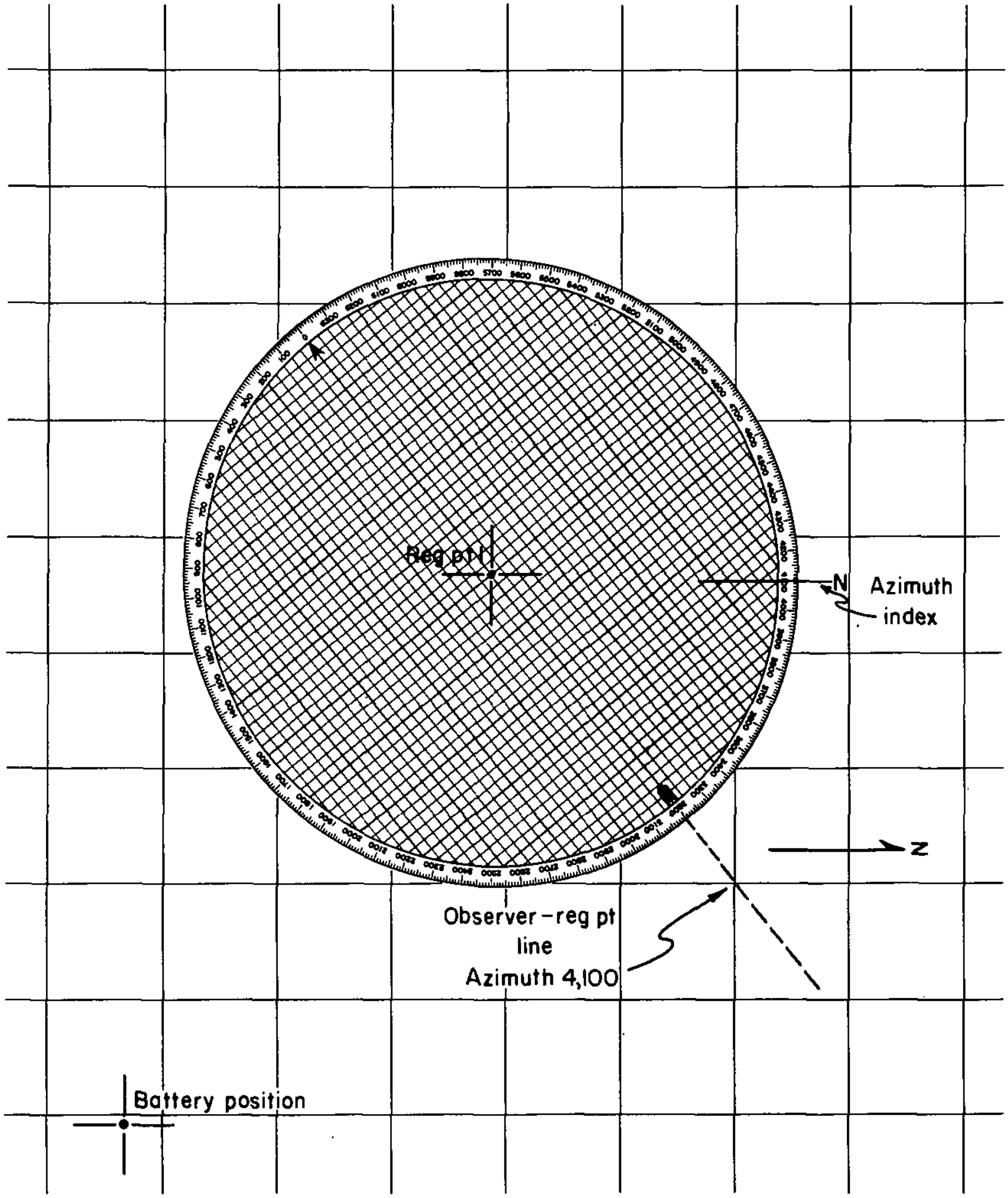


Figure 122. Orienting the target grid.

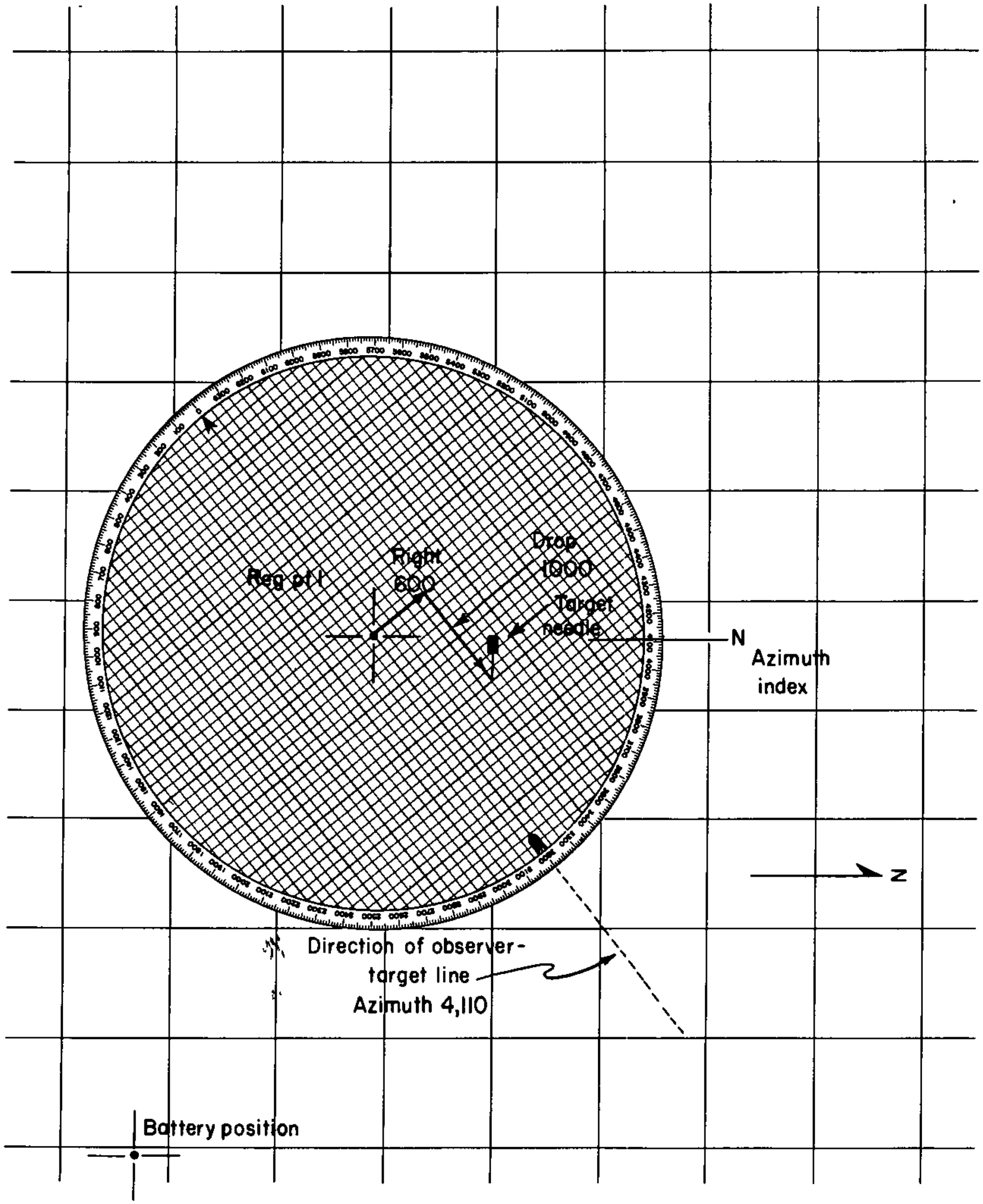


Figure 123. Plotting a target using the target grid and shift from a known point.

294. General

The purpose of a firing chart is to provide a graphic means for determining firing data. When available, the GFT fan is normally used for measuring deflection and computing elevation. However, this fan is not yet available for some weapons. In the latter case, the range-deflection fan and the graphical firing table are used to determine this data. Altitudes are determined by the control chart operator, who must always use a map as a firing chart for this purpose.

295. Preparing GFT Fan for Measuring Deflections

a. The determination of direction in terms of deflection is normally used in preparing chart data. In order to determine deflections, the mil scale on the arc of the GFT fan is prepared as

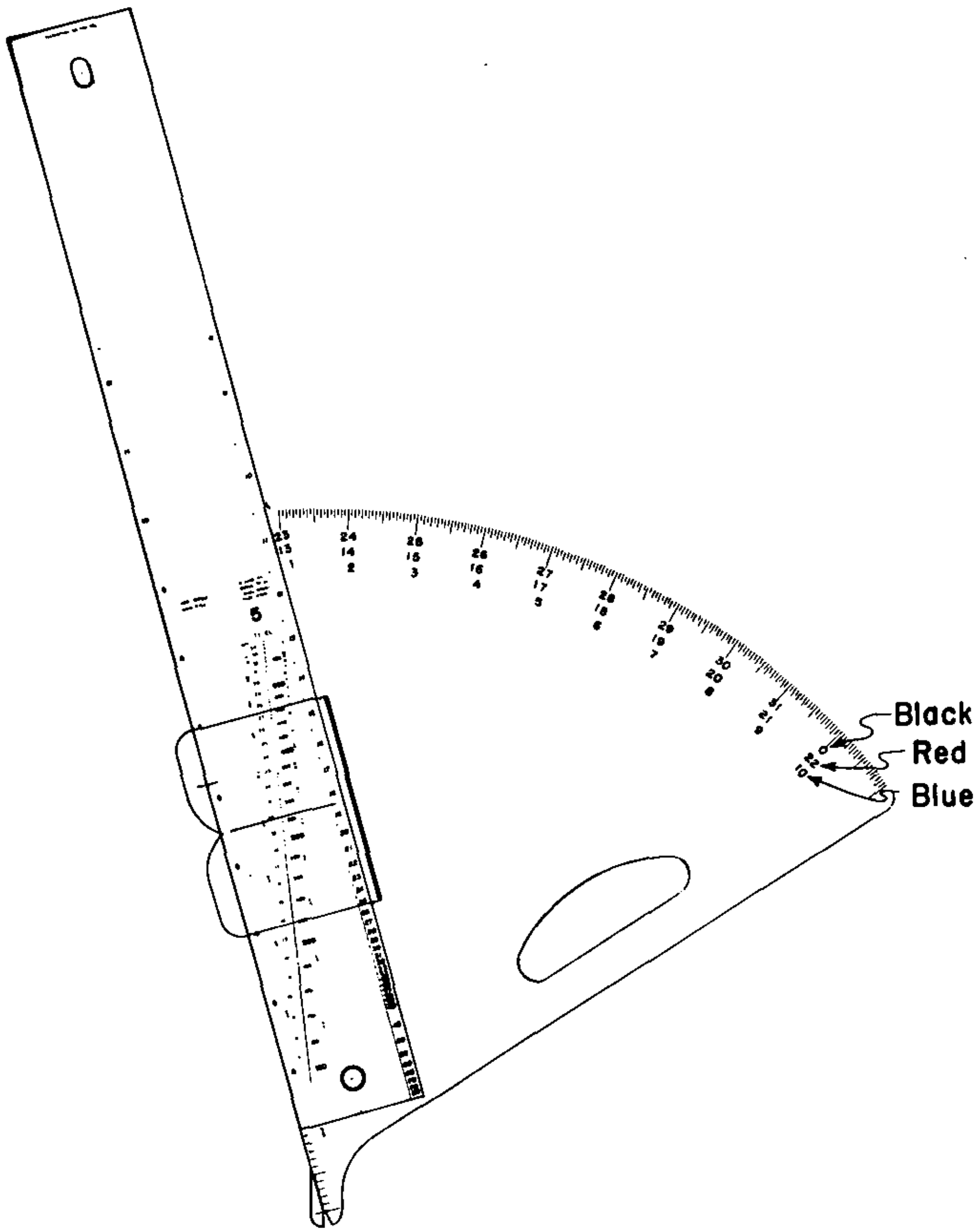


Figure 124. GFT fan prepared for reading deflections (aiming posts emplaced at deflection 2,800).

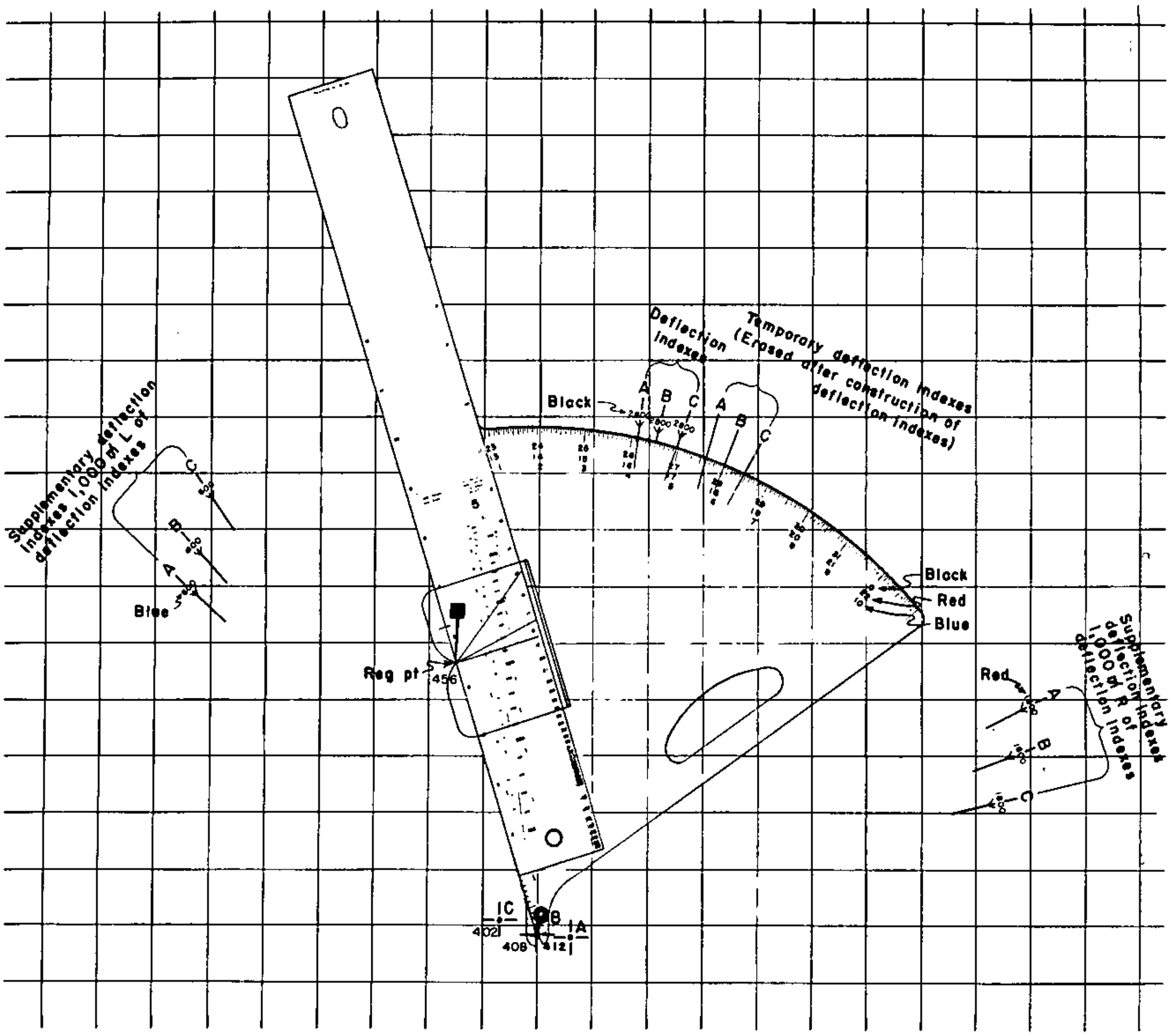


Figure 125. Chart and GFT fan prepared for determination of firing data.

shown in figure 124. The center graduation of the mil scale on the arc is numbered with the deflection at which the aiming posts are placed. Graduations to the right of center increase in 100-mil increments; to the left, they decrease. The last graduation at the right end of the mil scale is not numbered, since values cannot be read beyond the right edge of the scale. The numbers are placed on the fan with an appropriate black pencil. The zeros representing hundreds are omitted. For example, the numbers 2,900, 3,000, and 3,100 are written as 29, 30, and 31. The number 3,200 is written as 0 to avoid reading a deflection greater than 3,200. The numbers 100, 200, and 300 are written as 1, 2, and 3.

b. Scales for use with supplementary indexes are marked on the fan in red and blue as explained in paragraph 299.

296. Preparing Firing Chart

a. Before the firing chart can be used for determining chart data, the battery positions (centers) must be plotted and certain indexes constructed. A color scheme is used for identifying battery locations, pins, and indexes (par. 279, except that a white pin is used for Battery B). When preparing a firing chart to be used with the GFT fan, care must be exercised to plot the battery positions and target area generally to the left of center of the chart. This will permit drawing indexes directly on the chart (fig. 125).

b. The direction of fire on which the battery is initially laid is made known to the FDC, and a line representing the deflection of this direction is marked on the firing chart. This line is called a temporary deflection index.

297. Temporary Deflection Index (GFT Fan)

a. A temporary deflection index is marked on the chart for use in reading deflections before the initial registration has been completed. Since this index is temporary, it will usually be displaced later. All lines and marks are drawn lightly so that they may be erased; no arrowheads are made on the index and no color other than black is used.

b. A temporary deflection index is constructed by placing the vertex of the GFT fan against the pin representing the battery center on the firing chart and the vertex of the cursor against a needle marking the azimuth on which the battery is initially laid (initial direction of fire). A needle is stuck in the chart at the 100-mil graduation at the center of the arc, which has been numbered to represent the referred deflection to the aiming posts. The fan is then moved to place the left edge of the arm against the second needle and a fine line is drawn (6H pencil) on the chart along the range scale, extending 1 inch above and 1 inch below the fan arc.

c. A temporary deflection index is constructed for each battery plotted on the firing chart. The battery designation (A, B, C, etc.) is printed in block letters at the upper end of the index (fig. 125).

298. Deflection Index (GFT Fan)

After the initial registration, a deflection index corresponding to its adjusted deflection is constructed for each battery. This index is used thereafter for reading deflections, and the temporary index is erased. The procedure for constructing the index is as follows:

a. Position the fan so that the vertex of the fan is against the pin in the position of the registering battery and the cursor vertex is resting against the needle in the registration point. Stick a second needle in the chart against the arc at the adjusted deflection on the fan.

b. Place the left edge of the arm against the second needle while the vertex of the fan remains against the pin in the battery position and draw the deflection index on the chart along the left edge of the arm.

c. When properly drawn, the index passes through the center of the hole made by the needle which was placed in the chart against the arc at the adjusted deflection.

d. Draw the index 2 inches long, extending it 1 inch above and 1 inch below the point where the needle was stuck.

e. Draw an arrowhead on the deflection index, pointing towards the mil scale at a point one-eighth inch beyond the mil scale.

f. Immediately above the arrowhead, write the deflection at which the battery has placed its aiming posts. The deflection is written, using a black lead, 4H pencil.

g. Mark the letter designation of the battery at the upper end of the index with colored pencil, using block letters. The appropriate color is used to place the arrowheads and the letter designation on the deflection indexes (fig. 125).

h. The deflection index is not erased and redrawn for corrections based on subsequent registrations unless the corrections on the deflection correction scale (par. 347) exceed the limitations of the gunner's aid (20 mils).

299. Supplementary Deflection Indexes (GFT Fan)

When firing is conducted at deflections beyond the limits of the GFT fan, i. e., over 500 mils right or left of the aiming posts deflection, it is necessary to construct supplementary deflection indexes on the chart and to place a supplementary set of deflections on the arc of the fan for each supplementary index (fig. 125).

a. Supplementary indexes are placed on the chart 1,000 mils right and/or left of the deflection index and drawn in the same manner as the deflection indexes. Supplementary indexes to the right are labeled in *red* with a deflection of 1,000 mils less than that used for the deflection index. The supplementary indexes to the left are labeled in *blue* with a deflection of 1,000 mils greater than that used for the deflection index. The supplementary indexes are erased and redrawn each time that the deflection indexes are changed.

b. When supplementary indexes are used, the fan must have a corresponding set of deflections placed on the arc for each index. The number placed at the center graduation on the arc is the same as that placed on the supplementary index for use therewith, and the color code (red for right set of indexes and blue for the left set of indexes) is followed. A GFT fan that is prepared for 2 sets of supplementary indexes will have 3 rows of numbers on the arc. The top row of numbers, in black, corresponds to the deflection indexes; the second row, in red, corresponds to the right set of supplementary indexes; and the third row, in blue, corresponds to the left set of supplementary indexes (fig. 125).

300. Indexing the Chart Using GFT Fan (Example)

Situation: Battery B, 105-mm howitzer, laid on an azimuth of 5,000 mils (initial direction of fire), aiming posts placed out at deflection 2,800.

a. Using a protractor, measure an azimuth of 5,000 mils from the plotted battery center and place a plotting needle at this azimuth. Then place the vertex of the cursor against this needle with the vertex of the fan against the map pin in the plotted battery center; a second needle is placed opposite the center graduation on the arc of the fan. The left edge of the fan is placed against this second needle, keeping the vertex of the fan against the battery pin. The temporary deflection index, representing a deflection of 2,800 is drawn 1 inch above and 1 inch below the arc of the fan, and a block letter B is placed above this line. With the center graduation on the arc of the fan opposite the temporary index, the left edge of the fan is now along a line of azimuth 5,000 and the temporary deflection index is constructed at a deflection of 2,800. As explained in paragraph 295*a*, the 100-mil graduations of the fan are marked, using an appropriate black pencil and starting with the center graduation as 2,800, which is the deflection at which the battery has placed its aiming posts.

b. Assume that after registration, on a registration point the adjusted deflection is 2,755. A deflection index is constructed by placing the vertex of the cursor against a needle in the registration point and sticking a needle in the firing chart opposite deflection 2,755 on the fan. The left edge of the fan is placed against this needle, keeping the vertex of the fan against the battery pin, and the deflection index is drawn 1 inch above and 1 inch below the arc of the fan. An inverted arrowhead is drawn one-eighth inch above the arc of the fan and the index is labeled 2,800 above the arrowhead. A block letter B is placed above the index to identify this deflection index as the index to be used with Battery B. The arrowhead and identification letter will be in black (black being the code color for Battery B).

c. If supplementary indexes are needed, they will be constructed 1,000 mils right and left of the deflection index and labeled in the appropriate color immediately above the arrowhead (par. 299).

301. Preparing Range-Deflection Protractor (Aluminum) and Chart for Determination of Data

The preparation of the aluminum range-deflection protractor is identical with the preparation of the GFT fan.

302. Preparing Range-Deflection Fan (Plastic) and Chart for Determination of Data

a. Marking the Fan. In order to read deflections directly, the range-deflection fan is prepared as shown in figure 126. Deflections are marked at 100-mil intervals with an appropriate marking pencil. Either edge of the fan represents the deflection at which aiming posts have been set out by the battery. The 100-mil intervals are numbered so that the deflections *increase* from the left edge of the fan to the right and *decrease* from the right edge of the fan to the left. Increasing and decreasing deflections should be marked in different colors; for example, if the edge of the fan represents deflection 2,800, then decreasing figures, such as deflection 2,700, 2,600, etc., are marked in red, while increasing 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 126; 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 needle, the red scale is used. When the side with the black "T" is against the target needle, the black scale is used.

b. Temporary Deflection Index. To construct a temporary deflection index, the vertex of the plastic fan is placed against the pin representing the battery center on the firing chart and either edge of the fan against a needle placed on the azimuth on which the pieces were initially laid. A fine line (6H pencil) 2 inches long is drawn, extending 1 inch above and 1 inch below the appropriate mil scale on the fan. This index is marked in the manner described in paragraph 297.

c. Deflection Index. A deflection index is constructed after the completion of the initial registration. 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 registration point position and the vertex of the

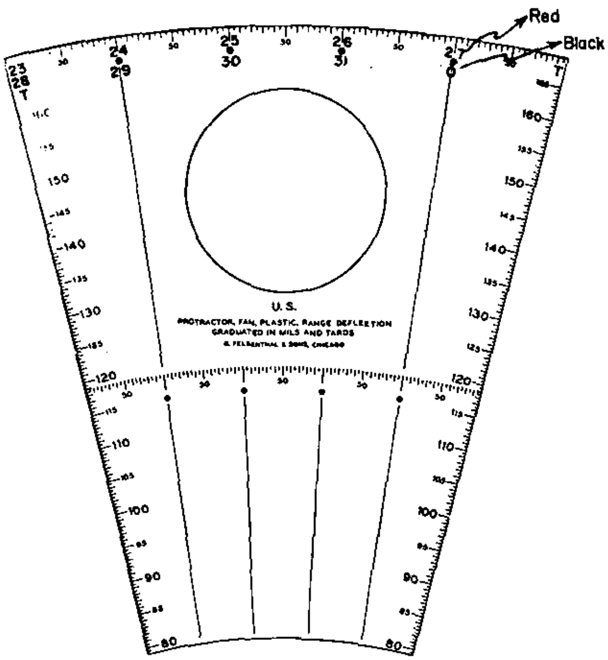


Figure 126. Range-deflection fan marked for reading deflections when referred deflection is 2.800.

fan is at the plotted position of the battery center. This deflection index is marked in the manner described in paragraph 298.

d. Supplementary Indexes (fig. 127). When the target area is very wide, supplementary deflection indexes are placed on the chart at 500 mils right and left of the deflection index. These indexes are drawn, marked, and labeled in the same manner as the deflection index. To avoid confusion, the supplementary indexes should be drawn to intercept a different mil scale on the fan than the deflection index. The fan must also be marked for use with the supplementary indexes. At the mil scale selected, the fan is marked to measure deflections to the right of the right index and to the left of the left index. Deflections for the right index are written in red and a red "T" is placed on the right edge of the fan. Deflections for the left index are written in black and a black "T" is placed on the left edge of the fan. These deflections decrease from right to left in the same manner as the figures for the deflection index.

303. Direction

Measurements and computations for direction are taken to the nearest mil. The deflection is read from the deflection scale of the GFT fan, the range-deflection protractor (aluminum), or the range-deflection fan (plastic). Deflection is measured from the temporary deflection index until a registration has been completed. After registration, the temporary deflection index is erased and the deflection index is constructed and used for measuring all deflections.

304. Angle of Site

The angle of site in mils equals the difference in altitude in yards (meters) between piece and target (vertical interval) divided by the range in thousands of yards (meters). Altitudes are determined from a contour map, by computations from instrument readings, from stereoscopic study of photographs, by interpolation between known altitudes, or by a combination of these methods. Altitudes are taken from a contour map to the nearest 5 feet or nearest yard or meter, depending on the contour interval of the map. Altitudes computed using instruments or interpolation between known altitudes are taken to the nearest yard.

Caution: Values of both vertical interval and range must be expressed in the same unit of measure before angle of site is computed.

Example: Altitude of battery 463 yards. Altitude of target 502 yards. Range from battery to target 5,500 yards.

502 yards = altitude of target
−463 yards = altitude of battery

+39 yards = vertical interval from battery to target
Range 5500/1000 = 5.5
+39 yards VI ÷ 5.5 yards range = 7.09 or +7 mils angle of site

305. Range

Ranges are measured to the nearest 10 yards or meters with the GFT fan (fig. 106) and to the nearest 10 yards with the range-deflection fan (plastic) or the range-deflection protractor (aluminum) (fig. 107). Range in meters is graduated along the arm on the *left edge* of the GFT fan. Range is graduated in yards along the *left edge* of the *ballistic scales* of the GFT fan, along the left edge of the arm of the range-deflection protractor (aluminum), and along both edges of the range-deflection fan (plastic). Range is read directly from any of the fans by placing the vertex against the pin in the battery position and the edge or arm of the fan against the needle representing the target.

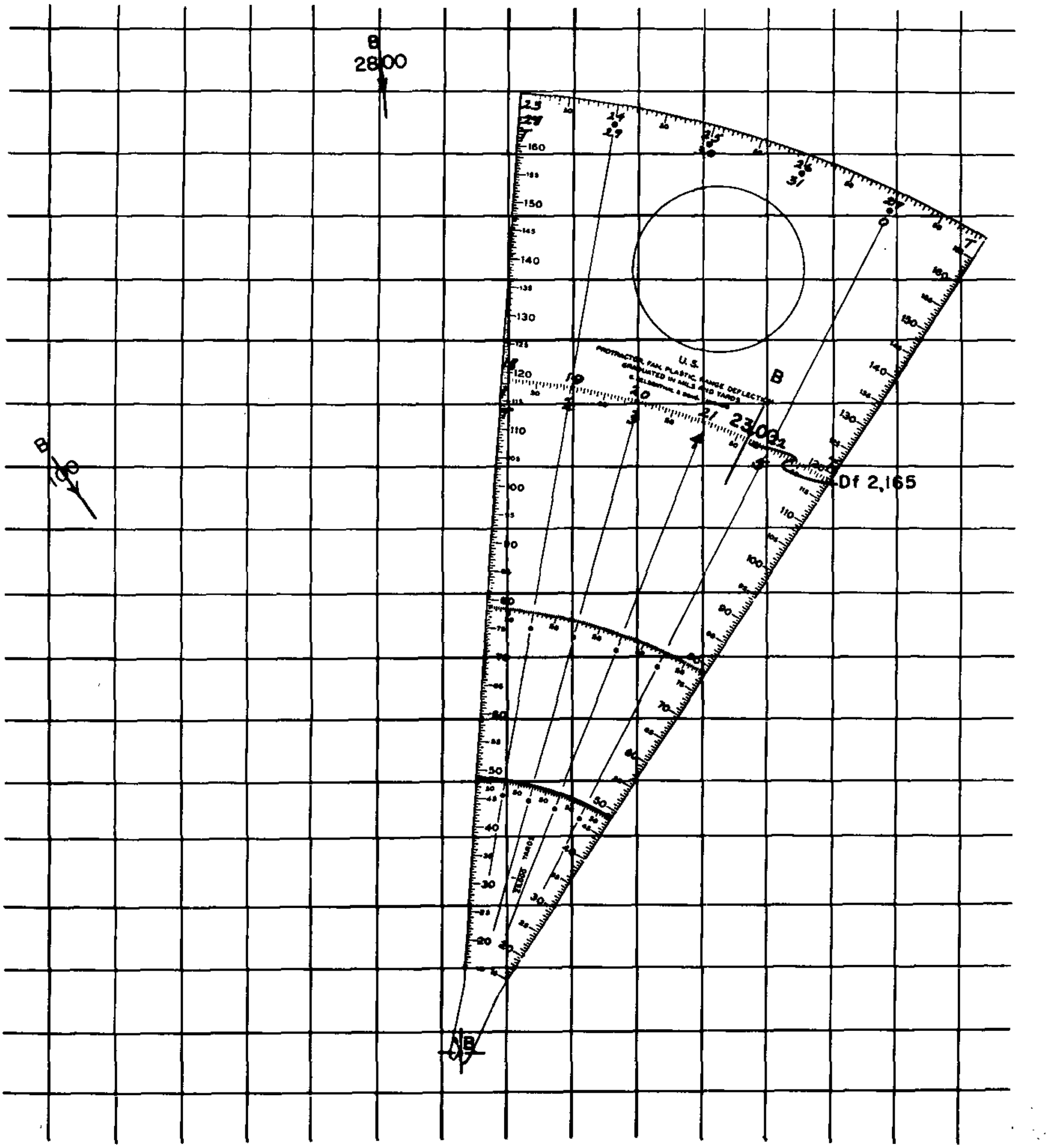


Figure 127. Range-deflection fan marked for supplementary indexes when referred deflection is 2,800.

306. Graphical Tables

The determination of firing data is simplified or augmented by the use of graphical tables. The three tables most commonly used for this purpose are the ballistic scales of the GFT fan, the graphical firing table, and the graphical site table.

a. Ballistic Scales, GFT Fan (fig. 106). Each ballistic scale has one or more ballistic data lines for each charge plotted on the scale. In addition, each scale has a range scale graduated in yards on the left edge and a 100/R scale on the right edge. Data are also presented for drift, fuze setting, elevation, and fork. The scales and cursors are removable from the fan. The cursor slides on the ballistic scale. A hairline on the cursor is provided for use as an index for reading elevation, range, drift, fork, fuze setting, and 100/R factor pertaining to a given charge for a plotted location on the chart. Measurements are taken to the nearest mil. When no corrections are known elevation and other ballistic data corresponding to the chart range are read under the hairline when the vertex of the fan is against the pin in the battery center and the cursor vertex is against the needle in the target location. When corrections have been determined from registration or other sources, they are applied as described in paragraphs 337–391.

b. Ballistic Scales (Metal GFT Fan). Ballistic scales to be issued later with the metal GFT fans will have a gage point on the elevation scale opposite the range corresponding to five-sixths of the maximum range for all charges except the maximum charge. For the maximum charge, this gage point will be located at seven-eighths maximum range. A gage point will also be placed on the fuze setting line opposite the point where the height of burst probable error is 15 yards.

c. Graphical Firing Tables (fig. 128). The graphical firing table is used principally for determining elevations corresponding to ranges as determined by using the aluminum range-deflection protractor or the plastic range-deflection fan. Each table consists of one or more rules and a cursor (indicator), which slides on the rule. A hairline on the cursor is provided for use as an index for reading data on the rule. The range scale is the basic scale on the graphical firing table. All other scales are plotted with reference to the range scale. Above the range scale is a scale printed in red marked "100 YDS." Beneath the range scale are ballistic scales—from top to bottom they are elevation, fork, drift, and fuze setting. On the dividing line between the *ELEV* (el) scale and the *F* scale is a red segment indicating the range limits which normally should be fired with a particular charge. For all charges except the maximum charge, this red line runs from ½ to ⅚ maximum range of the charge. For the maximum charge of a weapon, this red line runs from ½ to ⅞ maximum range of the charge. A red triangle on this line indicates a good range for computing meteorological effects. For ammunition which is fuzed for time fire, the fuze setting at which the probable error in height of burst is 15 yards is indicated by a red triangular gage point extending above the heavy red line which separates the 2 charges. To the left of this point and also extending above the heavy red line is a second red triangular gage point which indicates the range at which the probable error in height of burst for the next *lower* charge is 15 yards. Normally, time fire with a particular charge should not be attempted at ranges exceeding that indicated by the red triangular gage point for that charge. When no corrections are known, elevation and other ballistic data corresponding to chart range are read under the hairline when the hairline has been placed over the determined range. Corrections determined from registration or other sources, are applied as described in paragraphs 337 through 391. For detailed instructions on nomenclature and use of the graphical firing table, see TM 9–525.

d. Graphical Site Table (fig. 129). The determination of site by use of angle of site and the complementary angle of site factor from the firing tables is time-consuming. To facilitate computation, the graphical site table (GST) can be used to determine either angle of site or site. The GST can also be used to determine vertical interval when site or vertical angle and range are known. The GST consists of the base, which contains the D scale (site and vertical interval); a slide, which contains the C scale (range) which can be read in yards or meters; range scales for various charges in yards (meters); yard and meter gage (index) points; and the cursor, which is a clear piece of plastic with a hairline running vertically through the center. The C and D scales are identical to those on any slide rule and are used on the GST for determining angle of site or vertical interval when angle of site is known. For use of the C and D scales, in multiplication

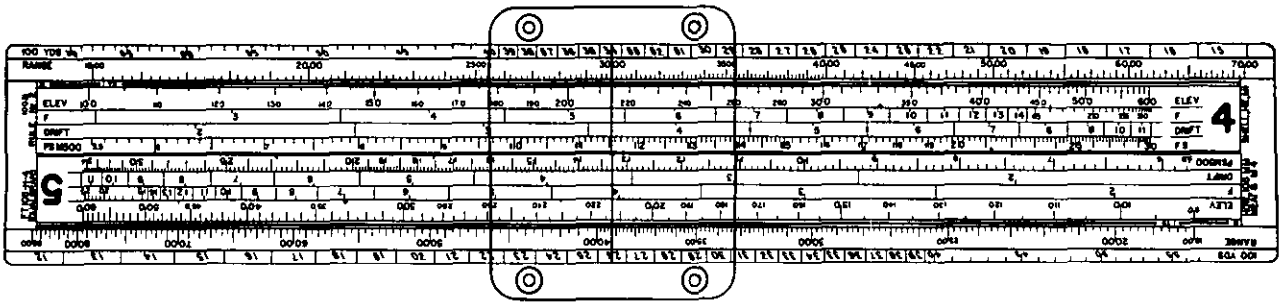


Figure 128. The graphical firing table.

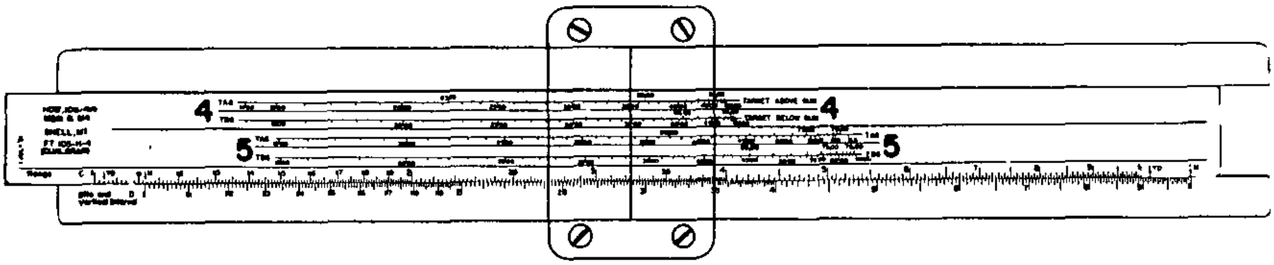


Figure 129. The graphical site table.

and division, refer to TM 6–240. For each charge, there are 2 range scales—1 in red marked "TBG" (target below gun) and the other in black marked "TAG" (target above gun). The scales are so constructed that the complementary angle of site is included. The TAG and TBG range scales differ by small amounts just as the complementary angle of site factor for a minus angle of site differs from the factor for a plus angle of site. These scales are used in computing site or determining vertical interval when site is known. Instructions for using the GST are written on the back of the table.

e. Conversion of Meters to Yards.

(1) The ballistic scales of the GFT fan have no provision for conversion of meters to yards.

(2) The graphical firing table has, at the left end of the red line dividing the range and elevation scales, two gage points labeled "M" and "YD" respectively (fig. 128). These gage points may be used to convert meters to yards as follows:

(*a*) Place hairline over YD gage point.

(*b*) Construct a meter index on the window by drawing a fine line (gageline) over M gage point.

(*c*) When range is known in meters, place the meter index (gageline) over the distance in meters on the range scale.

(*d*) The distance in yards and the corresponding elevation and fuze setting can then be read under the hairline.

(3) The graphical site table has, at the left end of the C (range) scale, yard and meter gage (index) points labeled in red "YD" and "M" respectively (fig. 129). These gage points may be used to convert meters to yards as follows:

(*a*) Place YD gage point opposite the range in *meters* on the D (site and vertical interval) scale.

(*b*) Opposite the M gage point, read the range in *yards*.

(4) If it is desired to convert yards to meters, the GFT and GST may be used by reversing the procedures in (2) and (3) above.

CHAPTER 18
REGISTRATIONS

Section I. GENERAL

307. Introduction

If all conditions of materiel and weather were standard, firing an elevation shown in the firing tables would result in the projectile traveling the distance (range) corresponding to that elevation. Similarly, with the proper deflection set on the weapon (including the drift correction from the firing table), the projectile would burst on the gun-target line. However, standard conditions of materiel and weather will seldom exist simultaneously; thus the projectile will rarely hit the target when fired at a given chart range and deflection. The cumulative error contained in survey, firing chart, materiel, and nonstandard atmospheric conditions is the amount that the projectile bursts over or short, right or left, of the target. The magnitude of the cumulative error can be determined by registration.

308. Types of Registrations

The types of registrations are—

a. Precision Registration. A precision registration is the firing of a group of rounds on a registration point, the location of which is known on the ground and on the firing chart.

b. High-Burst and Center-of-Impact Registrations. A high-burst or a center-of-impact registration is the firing of a group of rounds at a point arbitrarily selected on the chart but which is not necessarily an identifiable object in the target area.

309. Purpose of Registrations

a. Registration is an adjustment of fire on a selected point in the target area to determine data for use in subsequent firing. A registration is accomplished by firing a group of rounds on a selected target or point to determine the center of impact. In order to determine the most probable location of the center of impact in relation to the registration point, it is assumed that the pattern of a small group of rounds fired with a weapon will follow the normal dispersion pattern of all rounds fired with that same weapon.

b. If the location of the center of impact can be determined, corrections in mils can be computed by comparing that CI location with the location of the registration point. The difference is the correction necessary to place the center of impact on the registration point.

c. These corrections can be applied to improve firing data in subsequent firing. However, even after applying corrections determined from a registration, there will be the inherent probable error of dispersion among rounds fired with the same data. Corrections determined from registration data are the most accurate that can be obtained for firing. Therefore, registrations should be conducted or check rounds fired as frequently as possible within ammunition, and other limitations in order to provide current corrections. Determining and applying corrections in subsequent firing is covered in detail in paragraphs 337 through 391.

Section II. PRECISION REGISTRATION

310. General

a. The procedure used in a precision registration is designed to obtain a correct deflection and elevation for a point of known location in the target area (registration point). These correct deflection and elevation comprise the adjusted (adj) data.

(1) The adjusted deflection is the deflection that will cause the trajectory to pass through the registration point.

(2) The adjusted elevation is the elevation that will place the range center of impact on or very close to the registration point.

b. A precision registration is in 2 phases—adjustment phase and fire for effect phase; only 1 piece is employed.

c. DA Form 6–12 (Record of Precision Fire) (fig. 135), is a form for recording the fire mission. During the conduct of the registration, an adjusted deflection and elevation may be computed on the form by a member of the FDC.

d. An adjusted elevation and deflection can be determined only with respect to the GT line. Therefore, all sensings made by the observer with respect to the OT line must be converted to sensings relative to the GT line at the FDC. This conversion depends on the location of the observer with respect to the GT line (right or left) and the size of the angle T (the angle between the OT and GT lines with the vertex at the target). A sensing table to facilitate conversion of observer sensings is shown in figure 132. (The sensing table is printed on the reverse side of DA Form 6–12 (fig. 135).)

311. Determining Elevation Correction

a. If the distance in range between the target and the center of impact can be determined in terms of probable errors, it can be converted to an elevation correction in mils (1 fork being the elevation change in mils required to effect a range change equal to 4 probable errors) (pars. 23–28). The correction is applied to the mean elevation used in firing the center of impact, in order to obtain the adjusted elevation.

b. The following equation is used to determine the elevation change necessary to move the center of impact to the target:

$$\text{Elevation change} = \frac{\text{(difference in number of overs and shorts)}}{2 \times \text{number of rounds fired}} \times \text{fork}$$

For example, 6 rounds are fired under identical conditions and 4 of the rounds fall *short* (—) and 2 fall *over* (+). The elevation change is determined by substituting these known values in the equation given above.

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

Since the preponderance of the rounds are *short*, the elevation must be increased one-sixth of a fork to place the center of impact on the target. The smaller the number of rounds fired, the less precise the correction will be. Four rounds are the minimum number of rounds that can be used. Six rounds generally provide information of sufficient accuracy. Firing 12 or more rounds affords a slight increase in accuracy and permits verification of sensings.

312. Adjustment Phase

During the adjustment phase, the observer sends certain corrections to the FDC until a trial range is established. The trial range is the range for the center of a 100-yard bracket (for exception, see pars. 186 and 516), the range sensed as correct, or a range giving a target hit. It is important that the burst be moved to the OT line as quickly as possible to facilitate FDC deflection sensings during the adjustment. Observer procedures during the adjustment phase of a precision registration are covered in paragraphs 170 through 198.

a. When the observer's correction is ADD or DROP (so much) and does not include a deviation correction, a line shot is presumed at the FDC and a positive deflection sensing for the GT line is made (fig. 130). These deflection sensings are recorded on the record of precision fire form and are used, if practicable, during the fire for effect phase to establish one limit of a deflection bracket.

b. In figure 131 (DA Form 6–12), round three was a line shot, giving the FDC a positive (left as opposed to doubtful) deflection sensing. This

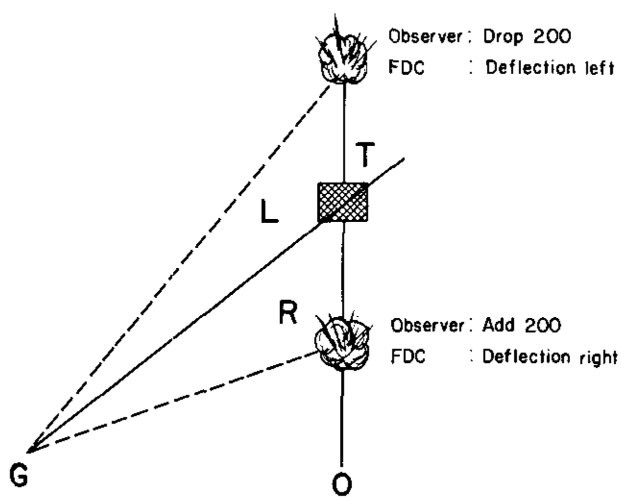
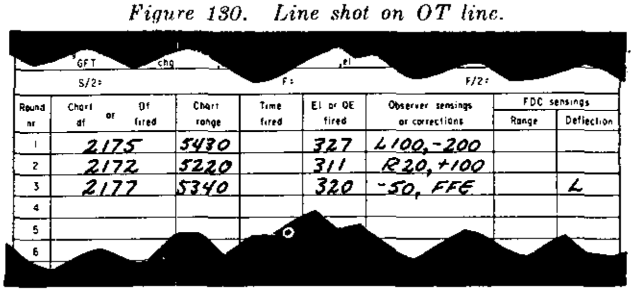


Figure 130. Line shot on OT line.

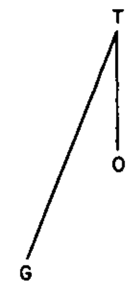


GFT chg el
S/2: F: F/2:

Round nr	Chart df or Df fired	Chart range	Time fired	El or QE fired	Observer sensings or corrections	FDC sensings Range	FDC sensings Deflection
1	2175	5430		327	L100, -200		
2	2172	5220		311	R20, +100		
3	2177	5340		320	-50, FFE		L
4							
5							
6							

Figure 131. FDC sensings for on-the-line burst (guns on the left).

FDC SENSING

Guns on left	Observer Sensing	1-99m̂	100-499m̂	500-799m̂	800-1399m̂	1400-1600m̂	1601-1799m̂	1800-2399m̂	2400-2699m̂	2700-3099m̂	3100-3200m̂
	?R	?R	+R	+?	+?	+?	+?	+?	+?	+L	?L
	?L	?L	-L	-?	-?	-?	-?	-?	-?	-R	?R
	+LN	+L	+L	+L	+L	+L	-L	-L	-L	-L	-L
	+R	+R	+?	+?	+?	+L	+L	?L	-L	-L	-L
	+L	+L	+L	+L	?L	-L	-L	-?	-?	-?	-R
	-LN	-R	-R	-R	-R	-R	+R	+R	+R	+R	+R
	-R	-R	-R	-R	?R	+R	+R	+?	+?	+?	+L
	-L	-L	-?	-?	-?	-R	-R	?R	+R	+R	+R

FDC SENSING

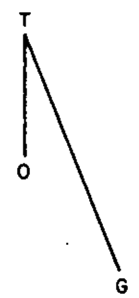
Guns on right	Observer Sensing	1-99m̂	100-499m̂	500-799m̂	800-1399m̂	1400-1600m̂	1601-1799m̂	1800-2399m̂	2400-2699m̂	2700-3099m̂	3100-3200m̂
	?R	?R	-R	-?	-?	-?	-?	-?	-?	-L	?L
	?L	?L	+L	+?	+?	+?	+?	+?	+?	+R	?R
	+LN	+R	+R	+R	+R	+R	-R	-R	-R	-R	-R
	+R	+R	+R	+R	?R	-R	-R	-?	-?	-?	-L
	+L	+L	+?	+?	+?	+R	+R	?R	-R	-R	-R
	-LN	-L	-L	-L	-L	-L	+L	+L	+L	+L	+L
	-R	-R	-?	-?	-?	-L	-L	?L	+L	+L	+L
	-L	-L	-L	-L	?L	+L	+L	+?	+?	+?	+R

Figure 132.[1] *The FDC sensing table.*

sensing is recorded but not used at this time because the chart operator plots the observer correction (DROP 50) and announces the deflection from this plot.

313. Fire for Effect Phase

a. A round bursting on the OT line gives a positive deflection sensing for the GT line, regardless of the size of the angle T. The sensing will be left or right, depending on which side of the OT line the weapon is located. For an angle T less than 1,600 mils, a line shot will give the *same* FDC *range* sensing as that made by the observer. If the angle T is greater than 1,600 mils, a line shot will give an FDC *range* sensing *opposite* to that made by the observer.

b. FDC sensings for off-line shots are dependent on the size of the angle T and the location of the weapon with respect to the observer. Observer sensings converted to sensings for the piece, called FDC sensings, are tabulated in figure 132.

314. Factor *S*

The factor *s* is the deflection shift in mils necessary to keep the burst on the OT line for a change of 100 yards in range along the OT line (fig. 133). The size of the factor *s* depends on the GT range and the size of the angle T.

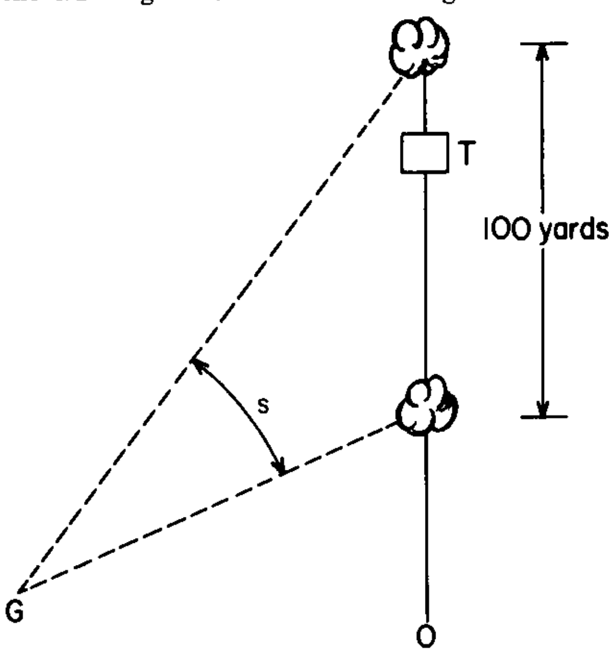


Figure 133. The factor s.

a. When the observer obtains a 100-yard range bracket on the OT line, it is assumed that a 1 *s* deflection bracket also exists.

b. When a 100-yard range bracket is split, the corresponding deflection change, measured by the chart operator, should bring the next burst to within ½ *s* of the adjusting point in deflection. Therefore, if a deflection bracket on the GT line has not been established by the first round in FFE, a shift of ½ *s* (*s*/2) in the appropriate direction will be made after each positive FDC deflection sensing obtained, until the deflection bracket is established.

c. The values of ½ *s* have been tabulated and reproduced (fig. 134), for all likely combinations of range and angle T on the back of DA Form 6–12 (Record of Precision Fire). The approximate value of ½ *s* may be obtained by computation by using the formula $\frac{50 \times \sin T}{R} = \frac{s}{2}$, or an arbitrary ½ *s* value of 4 mils may be used.

½ s TABLE

GT range in yards	Angle T in mils				
	0-99 3100-3200	100-499 2700-3099	500-799 2400-2699	800-1300 1800-2399	1400-1600 1601-1799
2000	2	4	8	16	16
3000	2	4	8	8	16
4000	2	2	4	8	8
5000	2	2	4	8	8
6000	2	2	4	4	8
7000	2	2	4	4	4
8000	2	2	4	4	4
9000	2	2	2	4	4
10000	2	2	2	4	4
11000	2	2	2	4	4
12000	2	2	2	2	4
13000	2	2	2	2	4
14000	2	2	2	2	2
15000	2	2	2	2	2

Figure 134. 1/2 s table.

d. When firing on a surveyed registration point, the value of ½ *s* is determined at the start of the mission; if the registration point location is not accurately known, the value of ½ *s* (and angle T) is determined at the trial range immediately prior to entering FFE.

315. Deflection

Deflection is correct when one of the following conditions has been satisfied.

a. A target hit is obtained.

b. A 2-mil deflection bracket is split (par. 316*e*).

c. Deflection sensings of left and right are obtained from the same deflection setting or from settings 1 mil apart. In the latter instance the last deflection fired is considered the correct deflection.

316. Deflection in FFE Phase

a. Deflection is *not* changed on a sensing of doubtful except as modified in *d* below.

b. If a deflection bracket does not exist and a positive FDC deflection sensing is made, deflection is changed ½ *s* in the appropriate direction until a bracket is obtained.

c. When a bracket is obtained, it is split *or* the deflection is changed ½ *s*, depending on which is the smaller amount.

d. If, after obtaining an adjusted elevation, the deflection is not correct, deflection adjustment is continued. All successive rounds are fired at the adjusted elevation (adjusted quadrant). After two successive deflection sensings of doubtful, the FDO may consider deflection correct or command an arbitrary deflection shift based on information furnished by the observer relating location of the rounds to location of the target. It is anticipated that the arbitrary shift will yield a positive deflection sensing. This procedure is continued until the FDO is satisfied that a proper deflection bracket has been obtained.

e. Although the center of a 2-mil deflection bracket is a deflection correct, the artillery commander is justified in accepting the center of a 4-mil deflection bracket as deflection correct when—

(1) Observed fires only are to be used.

(2) Speed, not refined accuracy, is critical either in combat or in certain phases of Army training tests.

Note. If a 4-mil deflection bracket is split before achieving an adjusted elevation, improvement in the deflection bracket continues until the adjusted elevation (adjusted quadrant) is established or a 2-mil deflection bracket is split.

317. Fork

The fork is the change in elevation necessary to move the center of impact a distance equal to four range probable errors. The correct value to be used (found in the tabular firing tables and on the GFT or GFT fan) is the value which corresponds to the first fire for effect (trial) elevation. The correct value is used in the computation of the adjusted elevation. However, if the correct value of the fork is an odd number and it is necessary to split the fork during the fire for effect phase, the value of the fork will be increased to the next higher even number and then split when used (par 319*c*).

318. Elevation

To determine adjusted elevation, 6 positive range sensings are required (except for a 4-round adjustment); *no rounds fired in adjustment may be considered* except that a target hit in adjustment is considered as the first round in FFE (firing is continued at that elevation until 5 more positive range sensings are obtained). When fire for effect is entered, three rounds are fired at the trial elevation.

a. If the first 3 rounds include both over(s) and short(s), a second group of 3 rounds is fired at the same elevation.

b. If the first group of 3 rounds are all in the same sense, the elevation is changed ½ fork in the appropriate direction and 3 more rounds are fired.

c. If a range sensing of doubtful is obtained, firing is continued at that elevation until the proper number of positive sensings are obtained.

d. In low-angle fire, the elevation change is added to the mean elevation if the preponderance of rounds were short; subtracted, if the preponderance of rounds were over. In high-angle fire, the correction is applied in the opposite direction—the elevation change is added to the mean elevation if the preponderance of rounds were *over;* subtracted, if the preponderance of rounds were *short.*

319. Adjusted Deflection and Elevation

Procedure for determining adjusted deflection and elevation is illustrated by an example mission (155-mm howitzer) (fig. 135).

a. First Round in Fire for Effect.

s/2=4 F=5

Rnd	Df	Chart range	QE	Obsr sensing	FDC sensing
4	2172	5, 280	316	? R	+ ?

Comment: The data for round four was a product of the firing chart. *Since the FDC deflection sensing* (obtained from the sensing table—angle T 500–799 mils, howitzers on the left) *is doubtful, no change in deflection can be made.* Since three rounds must be fired at the trial elevation, the next command will be to repeat the quadrant elevation (QE) fired.

b. Second Round in Fire for Effect.

Rnd	Df	QE	Obsr sensing	FDC sensing
5	(no change)	316	+ L	+ L

Comment: A positive FDC deflection sensing has now been obtained, but a deflection bracket has not been established. Therefore, the deflection is changed ⅛s (4 mils) to the right, seeking a sensing of right, which will establish the bracket. QE remains the same.

c. Third Round in Fire for Effect.

Rnd	Df	QE	Obsr sensing	FDC sensing
6	2, 168	316	? R	+ ?

Comment: Deflection sensing being a doubtful, no change will be made in deflection. Since all three rounds, fired at the same elevation, were overs by FDC sensings, the procedure is to decrease the elevation by ½ fork. (Since a fork of 5 is an odd number, the value is raised to the next higher number, or 6, before it is split.) The object now is to obtain one or more range sensings of short. If mixed sensings had been obtained in the first 3 rounds, no change would be made in the QE for the second 3 rounds.

d. Fourth round in Fire for Effect.

Rnd	Df	QE	Obsr sensing	FDC sensing
7	(no change)	313	– R	– R

Comment: The 4-mil deflection bracket that has been established (left at 2,172, right at 2,168) is split to obtain a deflection of 2,170, and improvement of the deflection bracket continues. (If an odd-numbered deflection bracket should occur owing to the sensing of a line (ln) shot during adjustment, it should be rounded off to the nearest even number *after* splitting.)

e. Fifth Round in Fire for Effect.

Rnd	Df	QE	Obsr sensing	FDC sensing
8	2, 170	313	? R	+ ?

Comment: No change will be made in the fire commands.

f. Sixth Round in Fire for Effect.

Rnd	Df	QE	Obsr sensing	FDC sensing
9	(no change)	313	– Ln	– R

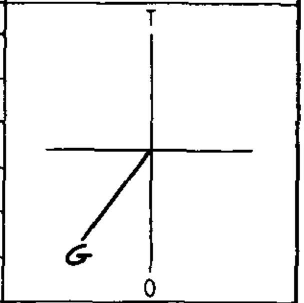
Comment: The 2-mil deflection bracket that has been established (left at 2,172, right at 2,170) is split, resulting in an adjusted deflection of 2,171. The FDC has six positive range sensings and before computing the adjusted elevation gives END OF MISSION to the observer and to the howitzers (unless a time registration is to be conducted at this point).

g. Computing Adjusted Quadrant (Adjusted Elevation). Computation of adjusted quadrant is based on a *minimum* of 6 positive range sensings, and it is assumed that all 6 rounds fired in effect were fired at the mean of the 2 quadrant elevations

RECORD OF PRECISION FIRE

Date and time	Observer	Adjusting point	Battery
103002 July	Ln O2	Reg pt 1	B

Chart data	Initial fire commands
Deflection 2175	Nr 3 Adjust
Range 5430	Sh HE ,Lot X ,Chg 4
Site +15	Fz Q ,MF Nr 3 (1)
Adjusted data	Corr 0 ,Df 2175
Deflection 2171	Si +15
Elevation 299	El 312
Time	QE 327



Angle T 600

GFT setting GFT B chg 4 ,lot X ,rg 5430 ,el 299 ,ti

Deflection correction Right 4

S/2= 4 F: 5 F/2: 3

Round nr	Chart df or Df fired	Chart range	Time fired	El or QE fired	Observer sensings or corrections	FDC sensings Range	FDC sensings Deflection
1	2175	5430		327	L100 -200		
2	2172	5220		311	R20 +100		
3	2177	5340		320	-50, FFE		L
4	2172	5280		316	? R	+	?
5				316	+ L	+	L
6	2168			316	? R	+	?
7				313	- R	—	R
8	2170			313	? R	+	?
9				313	- Ln	—	R
10	2171 (Adj df)						
11					4 overs and 2 shorts		
12					Difference = 2 overs		
13							
14					$\frac{2\times5}{2\times6}=\frac{10}{12}=\frac{5}{6}=.8$ mils		
15							
16				Mean QE =	314.5		
17					-.8		
18				Adj QE =	313.7		
19				Site	-(+15.0)		
20					298.7 = 299 Adj elevation		
21							
22							

DA FORM 1 APR 57 6-12 REPLACES EDITION OF 1 AUG 55

Figure 135. Record of precision fire.

fired. Quadrant elevations fired were 316 and 313; the mean is 314.5. An elevation change, based on the number of overs and shorts, is applied to this mean QE to determine the adjusted QE.

h. Elevation Change Formula. Substituting numerical values in the elevation change formula (the fork is 5; use actual value), the—

$$\text{Elevation change}=\frac{\text{difference in overs and shorts x fork}}{\text{2 x number of rounds fired}}=$$

$$\frac{\text{4 overs}-\text{2 shorts x 5}}{2 \times 6}=\frac{\text{2 (overs) x 5}}{12}=\frac{10}{12}=\frac{5}{6}=0.8 \text{ mil.}$$

The mean quadrant elevation fired was 314.5, and the computed elevation change is 0.8 mil. The elevation change must be subtracted from the mean QE fired because the preponderance of the six rounds in fire for effect was over; i. e.,

Mean QE fired	=314. 5
Computed elevation change	=−0. 8
Adjusted quadrant elevation	=313. 7

i. Determining Adjusted Elevation. To determine the adjusted elevation, the chart site is subtracted algebraically from the adjusted quadrant. In this problem the chart site was +15 mils; therefore, the adjusted elevation is 298.7 (313.7−(+15)) or 299 mils (fig. 135).

j. Using Target Hit. Continuing the example in *a* above, assume that a round fired during the adjustment phase had been a target hit; it is given an FDC sensing of target, indicating both ½ over and ½ short. Thus from the 6 rounds which give positive range sensings, 5 sensings are used. The elevation change formula is used as stated in *h* above.

QE fired	*Obsr sensing*	*FDC range sensing*
320	T	T
320	−Ln	−
320	? R	+
320	−R	−
320	? R	+
320	+L	+

$$\text{Elevation change}=\frac{\text{difference in overs and shorts x fork}}{\text{2 x number of rounds fired}}$$

$$=\frac{\text{(3 overs}-\text{2 shorts) x fork (5)}}{2 \times 6}$$

$$=\frac{1 \times 5}{2 \times 6}=\frac{5}{12}=0.4 \text{ mil}$$

Mean QE fired	=320
Minus elevation change	=—0. 4
Adjusted QE	=319. 6 mils

Section III. TIME REGISTRATION

320. General

a. Just as range and deflection are affected by nonstandard conditions, the mechanical functioning of the time fuze is affected by atmospheric and storage conditions. It is therefore necessary to determine the proper fuze setting which corresponds to a particular elevation. To do this, a fuze setting is sought which will give a "zero height of burst."

b. A zero height of burst is obtained when the mean height of the bursts, all fired with the same deflection, quadrant elevation, and fuze settings, is at ground level.

c. A time fuze functions either at the expiration of the fuze setting or on impact, whichever occurs earlier. Therefore, a 0 height of burst is assumed when a group of at least 6 rounds, fired with the same settings, produces an equal number of air and impact bursts.

321. Procedures

On completing a precision registration and determining the adjusted deflection and adjusted elevation, a time registration may be conducted. Fuze time is ordered for the registering piece. The observer is directed to observe time registration.

a. The fuze setting for the initial round is that setting corresponding to the adjusted elevation, plus or minus any average time correction which might be known from a previous firing. The time corrections (difference between adjusted time and time corresponding to adjusted elevation) from previous registrations should be averaged and applied to the fuze setting corresponding to the adjusted elevation.

Example: 105-mm howitzer, charge 5:

	Adj el	Time corresponding to adj el	Adj time	Time corr
First registration	365	22. 1	21. 6	−. 5
Second registration	356	21. 6	21. 2	−. 4
Average known time correction $(-.5+(-.4)=-.9; -.9/2=-.45)$	----	----		=−. 4
Third registration	374	22. 6	22. 0	−. 6
Average known time correction (new)* $(-.4+(-.6)=-1.0; -1.0/2)$	----	----		=−. 5
Fourth registration:				
Adjusted elevation				=370ɱ
Time corresponding to adj el				=22. 4 sec
Time for initial round $(22.4+(-.5))$				=21. 9 sec

**Note.* In determining a new average time correction, previous average time corrections are averaged with time correction determined from current registration.

b. The adjusted deflection and the adjusted QE (or elevation and site) determined from the impact registration are not changed throughout the time registration.

c. During the time registration, the observer senses fuze action only—air (A) for each air burst and graze (G) for each impact burst (par. 201*b*).

d. After the observer's first sensing, the fuze setting is changed 0.4 second (adding 0.4 second to the time if the first sensing was air; subtracting 0.4 second from the time if it was graze) and the second round is fired. However, if the height of burst of any round of a time registration is in excess of 50 yards, a fuze setting change larger than 0.4 second may be appropriate. If the observer's second sensing is the same as the first, the fuze setting is again changed by 0.4 second in the appropriate direction and a third round is fired. This procedure is continued until a round in the opposite sense is obtained, establishing a time bracket.

e. After a bracket of 0.4 second is obtained, it is split and 3 rounds are fired at the trial time. Trial time is the fuze setting at which fire for effect is commenced after an appropriate bracket has been established. If mixed sensings result (air and graze) from these 3 rounds, 3 more rounds are fired at the same fuze setting.

f. If the first 3 rounds are all in the same sense (all air or all graze), the fuze setting is changed 0.2 second in the appropriate direction and 2 rounds are fired. The round fired at the same fuze setting, which originally established 1 limit of the bracket, is combined with the last 2 rounds fired to give a group of 3. In this situation, all 6 rounds are assumed to have been fired at the mean fuze setting between the 2 groups of 3. For example, 3 rounds fired at fuze setting 12.6 and 3 rounds fired at fuze setting 12.8 are treated as 6 rounds fired at fuze setting 12.7.

g. The adjusted time is the fuze setting for a zero height of burst, and it is computed in the same manner as the adjusted elevation except that 0.4 is used in place of the fork. The formula is—

$$\text{Adjusted time} = \frac{\text{mean time fired} \pm \text{difference in } A \text{ and } G \times 0.4}{2 \times \text{number rounds fired}}$$

h. If a preponderance is obtained, the correction to the mean time derived from the formula will, when rounded off, always equal 0.1 second; therefore, if the preponderance is air, add 0.1 second to the mean time; if the preponderance is graze, subtract 0.1 second from the mean time. If no preponderance is obtained (equal number of air and graze), the mean time is the adjusted time.

i. An example of a time registration, using a 105-mm howitzer, charge 7, adjusted elevation 236, time corresponding to adjusted elevation 19.6, is as follows:

Round number	Deflection fired	Chart range	Time fired	Elevation or QE fired	Observer sensing or correction
FDC to observer: OBSERVE TIME REGISTRATION					
(Previous rounds used in impact registration.)					
12	2, 811	----	19. 6	236	A
13	------	----	20. 0	236	A
14	------	----	20. 4	236	G
Message to observer: OBSERVE THREE ROUNDS					
15	------	----	20. 2	236	A
16	------	----	20. 2	236	A
17	------	----	20. 2	236	A
Message to observer: OBSERVE TWO ROUNDS					
18	------	----	20. 4	236	G
19	------	----	20. 4	236	A

Comment: Initial round, fired at time corresponding to adjusted elevation, was an air; 0.4 second was added to the fuze setting until a time bracket was established (air at setting 20.0 and graze at setting 20.4). The bracket was split and 3 rounds were fired at a fuze setting of 20.2, all resulting in sensings of air. Two more rounds were fired at fuze setting of 20.4 which resulted in the last opposite (graze) sensing, giving a total of 6 rounds. Since the preponderance of the 6 rounds was air, 0.1 second is added to the mean time of 20.3 to arrive at an adjusted time of 20.4 (20.3 plus 0.1 second time correction= 20.4). If sensing for rounds 18 and 19 had been graze, there would have been no preponderance (3 airs at 20.2 and 3 grazes at 20.4) and the adjusted time would have been the same as the mean time; i. e., 20.3.

Section IV. INVALID AND REFINED REGISTRATIONS

322. General

a. An invalid registration may result from—

(1) A missensing by the observer, resulting in a false bracket in either range, deflection, or fuze setting.

(2) Errors at the piece, resulting in a wrong elevation, deflection, or fuze setting.

(3) Errors at the FDC.

b. Whenever a registration does not meet the requirements for validity, it must be continued until valid corrections have been obtained.

323. Invalid Impact Registration

a. A registration is considered valid for elevation if 6 positive sensings obtained in fire for effect include not more than 5 rounds in the same sense (over or short). The registration is invalid if all rounds are in the same sense and must be continued by changing the elevation ½ fork in the proper direction (all rounds over, subtract ½ fork from last elevation fired); firing is continued until 3 more positive range sensings are obtained. If 1 or more sensings in the opposite sense are obtained in this last group of rounds, the adjusted elevation is computed, based on the last 2 groups of rounds which resulted in mixed sensings (fig. 135).

b. If rounds in the opposite sense are not obtained in this last group of three rounds, the last round fired is polar-plotted from the weapons with the deflection and range corresponding to the last elevation fired. The observer is notified that the registration is invalid and to proceed with a new adjustment from the last round fired. The results of the previous FFE are disregarded.

c. A registration which results in a single round in one sense, i. e., 5 overs and 1 short, may be verified before being accepted as correct. The FDO will verify the accuracy of the record of fire and discuss the mission with the observer, particularly in case of an off-line range sensing in the adjustment phase. The firing battery may also be checked. If an error is detected or if a doubt exists, the 5 and 1 registration should be verified. *To verify a 5–1 preponderance*, the elevation is changed ½ fork in the appropriate direction from the last elevation fired and 1 round is fired. If the round is in the same sense as the single or minority round of the 5–1 preponderance, the adjusted elevation computed from the 6 rounds fired is verified (ignore verification round in computation). If the round is in the same sense as the preponderance, two more rounds are fired at the same elevation at which the first verification round was fired. If these two rounds are both in the same sense as the preponderance, the registration is invalid and the FDO proceeds as in *b* above. If any of the rounds fired at the verification elevation are in the minority sense, a new adjusted elevation is computed using the last six rounds fired. An example of verification is as follows:

Rnd	*El*	*Sensing*
1, 2, 3	335	+ + +

Since all rounds are sensed as overs, elevation is dropped ½ fork (fork=8) and 3 more rounds are fired.

Rnd	*El*	*Sensing*
4, 5, 6	331	+ + −

FDO, after checking record of fire, decides to verify the adjusted elevation (330). The elevation is dropped ½ fork from last elevation fired and 1 round is fired.

Rnd	*El*	*Sensing*
7	327	−

Since the round is sensed as short, the adjusted elevation (330) is verified. Assume round 7 is sensed over—

Rnd	*El*	*Sensing*
7	327	+

Two more rounds are fired at the same elevation.

Rnd	*El*	*Sensing*
8, 9	327	+ +

Since all rounds (7, 8, 9) are sensed as overs, the registration is invalid and a new registration must be started.

Assume last two rounds were mixed.

Rnd	*El*	*Sensing*
8, 9	327	− +

A new adjusted elevation is computed using the last six rounds.

Rnd	*El*	*Sensing*
4, 5, 6	331	+ + −
7, 8, 9	327	+ − +

New adjusted elevation is 328.

324. Invalid Time Registrations

a. A time registration which contains only 1 graze burst is considered valid if the air bursts are close to the ground (mean height of burst 20 yards or less). If the mean height of burst is greater than 20 yards (reported by observer), the registration should be continued by firing 3 rounds singly at the apparent adjusted time determined by computation. If a graze burst results from any of these rounds, the computed time is accepted as the *adjusted time* and the mission is terminated.

b. If a graze burst is not obtained, 0.2 second is added to the computed time and 3 more rounds are fired at this fuze setting. If 1 or more grazes are obtained in this last group of 3 rounds, the last 6 rounds fired are used to compute the adjusted time.

c. If graze bursts are not obtained from the last 3 rounds fired, a new time bracket is established by adding 0.4 second to the last time fired; a new FFE is completed, and the adjusted time is computed.

Example: (155-mm how, chg 4, fz M500, el 227)

Rnd No.	*Time*	*Sensing*	*Remarks*
1	14. 1	G	
2	13. 7	A	0.4-second bracket is established.
3, 4, 5	13. 9	A, A, A	
6, 7	14. 1	A, A	Observer reports mean height of airs as 30 yards; continue registration at computed time (mean time 14.0 +0.1 =14.1).
8	14. 1	A	
9	14. 1	G	Computed time is adjusted time.

Example continued: Assume rounds 8 and 9 were sensed as air bursts.

Rnd No.	*Time*	*Sensing*	*Remarks*
8, 9	14. 1	A, A	One more round is fired.
10	14. 1	A	0.2 second must be added to computed time and 3 rounds are fired.
11, 12, 13	14. 3	G, G, A	Adjusted time based on last 6 rounds is 14.3.

d. A time registration must be continued if only one air burst is obtained in FFE. Three rounds are fired singly at the time determined using the adjusted time formula. If an air burst is reported, firing is ceased and the computed time is accepted as the *adjusted time.*

e. If an air burst is not obtained, 0.2 second is subtracted from the computed time and 3 more rounds are fired at this setting. If an air burst is obtained, the last six rounds are used to compute the adjusted time.

f. If an air burst is not obtained from the last group, a new 0.4-second bracket is established and a new registration begun.

Example continued:

Rnd No.	*Time*	*Sensing*	*Remarks*
1	14. 1	A	
2	14. 5	G	.04-second bracket is established.
3, 4, 5	14. 3	G, G, G	
6, 7	14. 1	G, G	Only one air; continue registration at computed time.
8	14. 1	G	
9	14. 1	G	
10	14. 1	A	Computed time is the adjusted time.

Example continued: Assume rounds, 8, 9, and 10 were sensed as graze bursts.

Rnd No.	*Time*	*Sensing*	*Remarks*
8, 9, 10	14. 1	G, G, G	0.2 second must be subtracted from computed time and 3 rounds are fired.
11, 12, 13	13. 9	A, G, A	Adjusted time based on the last 6 rounds is 13.9.

325. Refined Registrations

a. Although rarely used, when immediate transfers of fire requiring extreme accuracy are to be fired, impact and time registrations should be continued until a second group of 6 sensings is obtained for both elevation and time. The proper correction (½ of the indicated correction) is applied in each case. For third series of 6 sensings, apply ⅓ of the indicated corrections; for fourth and subsequent series, apply ¼ of the indicated corrections.

b. Computations of adjusted elevation should be accomplished to the nearest 0.1 mil. Computations of adjusted time should be accomplished to the nearest 0.01 second. In both cases values should be rounded off at the completion of computation.

Section V. CENTER-OF-IMPACT OR HIGH-BURST REGISTRATIONS

326. General

A precision registration is limited since it requires visual observation on a clearly defined, accurately located registration point in the target area. At night, visual adjustment of fire on a registration point is impossible without some type of illumination. In desert, jungle, or arctic operations, clearly defined registration points in the target area are not normally available. To overcome these limitations, two alternate registration procedures may be used. These procedures are known as the center-of-impact registration and the high-burst registration.

327. Advantages

a. The two methods of registration have mutual advantages, as follows:

(1) May be conducted during darkness.

(2) May be used when no identifiable terrain feature is available.

(3) Fewer rounds are required in the adjustment phase of registration. With proper initial data for CI or HB registrations, all rounds may be considered as fire for effect (orienting round(s) not included).

b. The HB registration has a distinct advantage in that a time fuze is employed. This makes possible the determination of all three required corrections (time, deflection, and elevation). Since air bursts are used, it is easier to observe—especially at night—and corrections can be obtained for areas concealed from friendly ground observation.

328. Disadvantages

The two methods of registration also have mutual disadvantages, as follows:

a. Surveyed location of the OP's for graphic intersection or surveyed location of 01 and measured base to 02 for computed intersection are required (TM 6–200).

b. Communication with the two OP's is required.

329. Orientation of Observers

a. The OP's should be established during daylight so that the instruments may be oriented and a line materialized on the ground for orientation after dark. The instruments may be oriented on each other (requiring intervisible OP's) or on a point of known location (a reference point visible to both OP's).

b. Each observer (01–02) of a target area base should be given an azimuth and a vertical angle to the burst to aid his observing the first round of the registration. The azimuths from 01 and 02 to the expected location of the CI or HB are measured on the firing chart; the vertical angles are computed by using the mil relation.

c. The message to observer will include the alert or warning order, orientation data for 01, directive to 01 to measure vertical angle, orientation data for 02, and coordination report for both observers. An example of a complete message is PREPARE TO OBSERVE CENTER OF IMPACT (HIGH BURST): 01 AZIMUTH 1065, VERTICAL ANGLE +10; MEASURE THE VERTICAL ANGLE. 02 AZIMUTH 785, VERTICAL ANGLE +8. REPORT WHEN READY TO OBSERVE. The instruments should be oriented on these data after which each observer reports READY TO OBSERVE.

d. The first round fired (the rounds will be fired singly, controlled at FDC by AT MY COMMAND) normally is used to orient instruments. Succeeding rounds will be observed and the measured azimuth reported by both observers. 01 (02 if directed) also measures and reports the vertical angle.

e. An ON THE WAY is given for each round fired. Observers report for each burst in numerical sequence; for example, 01 AZIMUTH 1059, VERTICAL ANGLE +13; 02 AZIMUTH 792.

f. Sufficient rounds must be fired to obtain an accurate location of six rounds. Any erratic rounds or rounds observed by only one observer are disregarded.

g. Since an inexperienced observer may mistake a graze burst for a low air burst, care must be taken in HB registration to determine a minimum acceptable vertical angle.

h. When the registration point is to be located by higher headquarters (observation battalion) or by radar, the coordinates and height of the burst center are furnished to the FDC conducting the registration.

330. Impact Area

The impact area selected for HB or CI registrations should be in or near the center of an area in which later firing is anticipated. For CI registrations, the area should be clear of trees, buildings, sharp ravines, etc., so that the burst may be easily observed.

331. Preparation of Firing Data—Center of Impact

a. The firing deflection is the measured deflection to the selected registration point.

b. The firing elevation is the elevation corresponding to the range measured to the selected registration point.

c. The site to be fired is computed by using the chart range and the vertical interval (VI). The VI is computed by comparing the altitude of the battery and the altitude of the selected registration point.

332. Computation of Location of Center of Impact

a. The 6 usable azimuths reported by 01 and 02 and the 6 usable vertical angles reported by 01 are averaged to obtain the mean azimuths and the vertical angle. These are used in computing and/or plotting the location and altitude of the center of impact.

b. The 01–CI distance is computed by using the triangle 01–02–CI (TM 6-200).

(1) The length and azimuth of the base (01–02) is determined by computation from coordinates as described in TM 6–200.

(2) The angles at 01 and 02 are determined by comparing the averaged 01 and 02 azimuths to the CI with the azimuth of the base.

c. The coordinates of the CI are either computed and plotted or polar-plotted on the firing chart from 01 data by using average azimuth 01 to CI and the distance 01 to CI.

d. The altitude of the CI is computed by using the altitude of 01, the 01–CI distance, and the tangent of the average vertical angle.

333. Preparation of Firing Data—High Burst

a. Procedure used in a high-burst registration is much the same as that used in a center-of-impact registration. The high burst is fired with fuze time. Enough site must be included to place the burst in the air in view of both observers; however, a high burst should not be fired so high that the angle of site (at the piece) is more than 50 mils. When the angle of site exceeds 50 mils, errors in elevation corrections will result because the complementary angle of site factors listed in the firing tables are not valid for an angle of site deviation of over 50 mils.

b. As with the CI, the deflection to be fired is the measured deflection to the selected registration point.

c. The elevation corresponding to the measured range to the selected registration point is fired.

d. The fuze setting to be fired is the time corresponding to the elevation to be fired, plus or minus any known time corrections.

e. The site to be fired is computed by using the chart range and the vertical interval. The vertical interval is computed by comparing the altitude of the battery and the desired altitude of burst.

334. Computation of Location of HB

If the location of the HB is not furnished by higher headquarters or by radar, a target area base is used to determine the direction and distance to the burst center. The coordinates of the HB are either computed and plotted or polar-plotted in the same manner as for a CI (par. 332*c*)

335. Procedure Example

A 105-mm howitzer battery has occupied position, and preparations are being made to fire a high-burst registration. The following steps in preparation for the registration have been accomplished:

a. The battery position, the location of the selected registration point, and the surveyed location of 01 and 02 have been plotted on the firing chart. Azimuth indexes for 01 and 02 have been constructed.

b. 01 and 02 have been occupied during the daylight hours, and the observer's instruments have been oriented on each other (OP's intervisible). For each OP, a reference stake was emplaced, and the azimuth to one edge of the stake was measured and recorded. Should the orientation of either instrument be disturbed during darkness or periods of poor visibility, the selected edge of the reference stake would then become a supplementary azimuth mark for reorientation of the instrument.

c. The following data have been measured from the firing chart or obtained from survey:

(1) Data for observer orientation:

01 to HB distance = 2,730 yards
01 to HB azimuth = 2,093 mils
01 to 02 distance = 684 yards
01 to 02 azimuth = 505 mils
02 to HB distance = 2,760 yards
02 to HB azimuth = 2,443 mils

Altitude 01 = 719 yards
Altitude 02 = 723 yards

(2) Data jointly used for observer orientation and firing data:

Ground altitude of point selected for high burst (map) = 711 yards
Desired height above ground (FDO) = 40 yards
Desired altitude of burst (711 + 40) = 751 yards

d. Vertical angles for 01 and 02 are determined by using the mil relation.

01 to HB vertical interval (751 − 719) = +32 yards
01 to HB vertical angle (GST: 32/2.73) = +12 mils
02 to HB vertical interval (751 − 723) = +28 yards
02 to HB vertical interval (GST: 28/2.76) = +10 mils

e. The observer orientation is complete when the following information is sent: Message to observers, PREPARE TO OBSERVE HB REGISTRATION. 01 AZIMUTH 2093, VERTICAL ANGLE +12; MEASURE THE VERTICAL ANGLE. 02 AZIMUTH 2443, VERTICAL ANGLE +10. REPORT WHEN READY TO OBSERVE.

f. Firing data for the HB is determined at the FDC from the HB plot on the chart. The following commands are sent to the howitzers: NUMBER 3 ADJUST; SHELL HE; CHARGE 5; FUZE TIME; NUMBER 3 1 ROUND, AMC; CORRECTIONS ZERO, DEFLECTION 2860; SITE 315; TIME 14.7; ELEVATION 238.

g. The first round is normally used for observer orientation. ON THE WAY will be given as each round is fired. If necessary, the observer will use this round to reorient the center of the reticle of his instrument. Thereafter the instrument orientation is not changed since a more accurate measured azimuth is obtained by combining the observed deviation on the reticle with the reading set on the azimuth and micrometer scales. As measurements for each round are completed, observers will report in numerical order.

h. The following information has been reported by the observers:

Rnd No.	*01 azimuth*	*01 vertical angle*	*02 azimuth*
1	Orienting round		
2	2, 093	+11	2, 344
3	2, 099	+15	2, 348
4	~~2130~~	~~+9~~	~~2387~~
5	2, 096	+13	2, 345
6	2, 098	+16	2, 349
7	2, 097	+14	2, 346
8	~~2122~~	~~+5~~	~~lost~~
9	2, 097	+16	2, 343
Total	12, 580	+85	14, 075
Average	2, 097	+14	2, 346

(Rounds No. 4 and 8 were disregarded as erratic.)

Azimuth 01 to 02 = 505 mils; azimuth 02 to 01 = 3,705 mils.
Azimuth 01 to HB = 2,097 mils; vertical angle 01 to HB = +14 mils.
Azimuth 02 to HB = 2,346 mils.
Apex angle = 249 mils (2,346 − 2,097).
Base length = 684 yards.
Interior angle 01 = 1,592 (2,097 − 505).
Interior angle 02 = 1,359 (3,705 − 2,346).

Distance 01 to HB = 684 x $\frac{\sin 1{,}359}{\sin 249}$.

(Using the law of sine, $a = \frac{b \times \sin A}{\sin B}$)

Log 684 = 2. 835056
+Log sin 1,359 = 9. 987729–10

12. 822785–10
−Log sin 249 9. 383865–10

Log dis yd = 3. 438920
01 to HB distance = 2, 747 yards

(The military slide rule may be used as a check on the computed 01 to HB distance. In some cases (distances of less than 2,000 yards), distances determined with the military slide rule are sufficiently accurate for artillery purposes.)

Vertical interval 01 to HB = distance × tan vertical angle.

Log dis yd = 3. 438920
+Log tan 14 mils = 8. 138155–10

Log VI = 11. 577075–10
VI = 37. 8 yards

(The VI may be computed by using the military slide rule.)

i. The HB is polar-plotted by using the 01 azimuth (2,097) and the distance 01 to HB (2,747 yards). The height of burst is determined by applying the computed VI to the known altitude of 01 (719 + 38 = 757 yards altitude of burst). (See TM 6–200 for computation of coordinates if HB is plotted from coordinates.)

j. The calculation procedure is identical for a CI.

336. Checklist for Solution of CI or HB Registrations

a. Plot the coordinates and altitude of the battery position, 01 and 02, and the registration point on the firing chart.

b. Index the chart for 01 and 02.

c. Select the approximate location for the HB or CI to be fired and check the size of the apex angle (should be 250 mils or greater).

d. From this approximate location, determine the firing data to be fired; i. e., deflection, range (elevation), site.

e. Measure and compute orienting data for 01 and 02 (azimuth and vertical angle).

f. Send orienting data to observers at 01 and 02 and instruct observer at 01 to measure the vertical angle.

g. Send commands to the battery to fire CI or HB.

h. Obtain six usable readings from observer at 01 and 02.

i. Compute mean azimuths from 01 and 02 to CI (HB) and compute mean vertical angle from 01 to CI (HB). Determine interior angles of triangle 01–02–CI (HB).

j. Compute coordinates or polar-plot data of CI (HB).

k. Compute altitude of CI (HB). Distance 01 to CI (HB) × tan vertical angle reported by 01 equals amount CI (HB) is above (below) 01. Height 01 + (−) this amount equals altitude of CI (HB).

l. Plot CI (HB) on the firing chart.

m. Determine registration corrections for deflection and elevation by comparing adjusted data (fired) with chart data (plotted location of CI or HB).

CHAPTER 19

DETERMINATION AND APPLICATION OF CORRECTIONS

Section I. INTRODUCTION

337. General

a. The registration corrections are the sum of corrections owing to the effects of weather, materiel, ammunition, and survey and chart errors. Although highly accurate only for a small area surrounding the registration point at the time the registration was fired, these corrections are assumed to be applicable also under conditions set forth in this chapter. It is possible to separate these total corrections into components (owing to weather) and to establish proportional corrections within certain limits. Frequent registrations or the firing of check rounds within ammunition limitations should be encouraged. This will provide current corrections.

b. In addition to registration corrections, it is frequently necessary to determine and apply corrections for—

(1) Differences in the capabilities (shooting strength) of any two like weapons (calibration corrections, pars. 381–385).

(2) The position of weapons with relation to the target (position area corrections, pars. 386–389).

(3) The desired pattern of bursts of a number of weapons (sheaf corrections, pars. 386–389) if other than a normal sheaf is desired.

c. This chapter deals with practical methods of determining and applying corrections for these purposes. In spite of the application of these corrections and extreme care in the service of the piece, there are many factors which cannot be measured accurately. These factors will cause dispersion or variation in the point of impact from round to round under the same firing conditions (pars. 611–637).

338. Principles of Determining and Applying Registration Corrections

a. The magnitude of registration corrections is established by comparing data determined by firing (adjusted data) with the data obtained from the chart (chart data); the difference between the two is the correction.

b. Corrections determined from an initial registration at registration point range are applied graphically to the chart (for deflection) and to the GFT fan or GFT (for elevation and time). In subsequent registrations, the deflection correction at registration point range for the new registration becomes the basis for construction of a new deflection correction scale. This scale then becomes the basis of the FDO announced deflection corrections. Corrections from subsequent registrations are determined for elevation and time and are applied graphically to the GFT fan or GFT.

c. Corrections determined by registration apply only to the charge and ammunition lot used in the registration and are valid only within transfer limits.

339. Transfer Limits

Corrections are assumed to be valid within transfer limits (fig. 136); that is—

a. When the registration point or met check point is within 10,000 yards of the piece, transfer limits extend 1,500 yards over and short and 400 mils right and left of the point.

b. When the registration point or met check point is more than 10,000 yards from the piece, transfer limits extend 2,000 yards over and short and 4,000 yards right and left of the point.

340. Computation of Range Correction and Range *K*

a. A range correction is established by comparing the measured chart range to the registration point with the range corresponding to the adjusted elevation and assuming that the ratio of one to the other remains constant for a given charge and ammunition lot. The range *K* is expressed as plus or minus so many yards per thousand yards. The computation of range *K* as outlined in this paragraph is used only when graphical equipment is not available.

b. The range *K* is determined by dividing the range correction in yards by the chart range in thousands of yards; range *K* expressed as a formula is—Range $K = \frac{\text{range correction}}{\text{range in thousands}}$

Example: (105-mm how, chg 6)

Range corresponding to the adjusted elevation (295)	6, 250 yards
Chart range	6, 080 yards
Range correction	+170 yards

Range $K = \frac{+170}{6.1*} = +27.9$ or $+28$ per thousand yards

**Note.* Chart range is rounded off to the nearest 100 yards.

c. The determination of corrected elevation for a transfer of fire is a reversal of the process used in determining a range *K*. To determine the corrected elevation, multiply the range *K* by the chart range in thousands of yards to obtain the range correction; add the correction algebraically to the chart range; and, from the firing tables, determine the elevation corresponding to the corrected range. In continuation of the example in *b* above, assume that, after registering at a range of 6,080 yards and determining a range *K* of +28 yards per thousand, it was decided to fire at a range of 7,000 yards. Corrections are to be applied.

Total range correction = range (in thousands) x range *K*.
= 7.0 (range 7,000 yards) x +28 yards per thousand = +196 yards.

The elevation to be fired must correspond to the chart range plus range correction (7,000+196= 7,196 yards; el 357.6m̸ (358m̸)).

341. Computation of Time Correction

The time correction is the difference between the firing table time setting corresponding to the adjusted elevation and the adjusted time. For example, assume that a time registration has been conducted and an adjusted time of 19.8 computed; the time corresponding to the adjusted elevation (105-mm how, chg 6, el 295) is 20.5 seconds; the time correction is −0.7 seconds (19.8–20.5).

342. GFT Setting

A GFT setting that is based on registration is a graphic comparison of adjusted data to chart range. In principle it is the same as the range *K*, as determined in paragraph 340*b*. The elements of a GFT setting and the order in which they are always expressed are: unit registering; charge; ammunition lot; chart range (nearest 10 yards); adjusted elevation; and adjusted time. The GFT setting is recorded as shown by the following example:

GFT A: Charge 6, lot Y, range 6,080, elevation 295, time 19.8.

343. GFT Setting—GFT Fan

a. The GFT fan, with the GFT setting applied, aids in determining the corrected elevation and time to any target within transfer limits. The

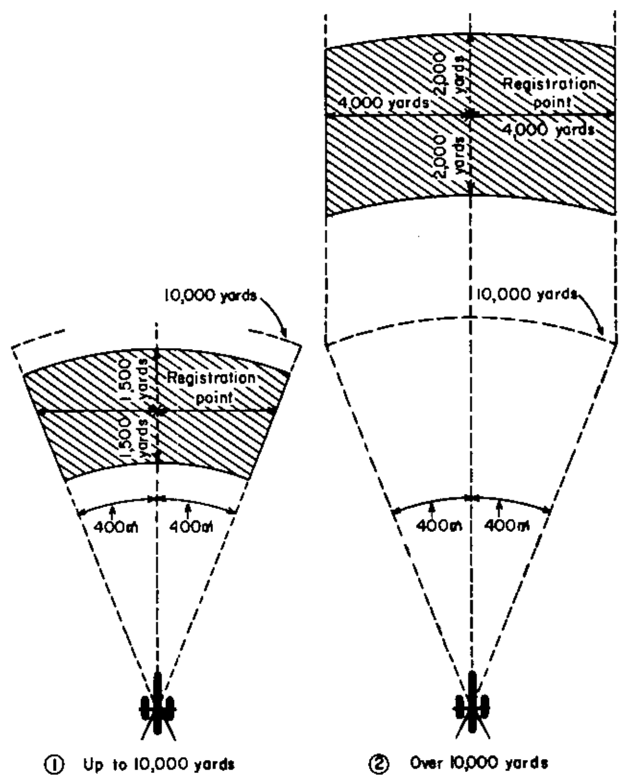


Figure 136. Transfer limits.

Section III. DUTIES OF BATTERY FDC PERSONNEL

402. Battery Fire Direction Officer

Any officer in the battery may be required to act as the battery FDO. When the battery is operating independently, the battery FDO is required to perform those duties of the battalion FDO and control chart operator which would apply under the circumstances. When the battery is under battalion control, the specific duties of the battery FDO are to—

a. Supervise the operation of the battery FDC.

b. Supervise the functioning of battery fire direction wire and radio nets (pars. 431–433).

c. Supervise the construction of battery firing charts (par. 406).

d. Relay commands and other transmissions to the battery executive (pars. 413, 415, and 416*e*).

e. Verify computations performed by the battery FDC personnel.

f. Conduct registrations and other precision missions when directed (pars. 307–336 and 493).

g. Compute special corrections as directed (pars. 381–389).

h. Maintain appropriate records in the battery FDC (par. 422).

i. Submit required reports (unit SOP and higher Hq).

j. Supervise the preparation of data sheets (par. 531).

403. Primary Chart Operator

The primary chart operator and the check chart operator function as a team. Both operators perform identical duties in the construction and maintenance of firing charts and the determination of firing and replot data. The difference between their functions is that the primary chart operator announces data and the check chart operator announces agreement or disagreement with the announced data. Chart operators are required to—

a. Prepare and maintain firing charts (pars. 270–276).

b. Announce range and the 100/R factor to the computer when required (pars. 305 and 306*a*).

c. Determine the following data:

(1) Deflection correction (pars. 375 and 376).

(2) Chart deflection (pars. 294–302).

(3) Site (par. 306*d*).

(4) Fuze setting (when applicable) (pars. 341–345).

(5) Elevation (pars. 342–345).

d. Determine the size of the angle T and announce it when it is 500 mils or greater (par. 411).

e. Determine adjusted coordinates of concentrations to be replotted (par. 420).

f. Replot concentrations (par. 420).

404. Battery Computer

The duties of the battery computer are to—

a. Record fire requests, fire orders, firing data, corrections, and all other data which the FDO directs and maintain necessary records (pars. 407, 409, 410, 413, 415, and 422).

b. Compute and announce total deflection when necessary (i. e., chart deflection plus deflection corrections) (par. 486).

c. Combine the announced site with the 20/R (height of burst over range) factor and compute changes in site during the adjustment of time fire (par. 425).

d. Combine the announced site with the announced elevation to determine quadrant elevation for medium and heavy artillery.

e. Compute met, VE, and special corrections when directed (pars. 359–375, and 381–391).

f. Transmit the executive officer's report to the battalion FDC.

g. Assist in the conduct of registrations and determination of registration corrections (pars. 307–336).

h. Prepare data sheets and maintain a record of all data sheets for prearranged fires sent to the firing battery (par. 531).

405. Radiotelephone Operator

Radiotelephone operators answer calls, record data as required, and perform other duties as indicated in paragraph 401.

406. Charts

a. Battalion FDO Chart. If the battalion FDO desires a separate chart, it is constructed to show the fire capabilities and the locations of firing batteries, front lines, and the no-fire line (FM 6–20). This chart should be a battle map.

b. Control Chart. The control chart is a firing chart (battle map) on which are plotted the locations of the firing batteries, the radar, surveyed OP's, registration points, met check points, barrages, and targets as ordered by the FDO. The control chart operator maintains the control chart. He also keeps a situation overlay on which are posted the no-fire line, friendly locations, and routes of current and scheduled patrols. The control chart operator also maintains fire capabilities and dead space overlays.

c. Primary and Check Charts. The primary and check charts must have identical grids and have plotted on them the locations of the firing batteries, the radar, surveyed OP's, registration points, met check points, barrages, and targets as ordered by the FDO.

d. Adjustment of Charts. The purpose of adjustment of charts is to insure uniformity among the charts within a battalion. Uniformity is achieved by bringing all charts into agreement with one carefully prepared master chart. Charts are adjusted under the supervision of the control chart operator. The adjustment is to resolve errors in plotting, placement of indexes, and GFT settings. Chart adjustment is performed as soon as practicable and during lulls in firing. Fire missions should never be delayed solely to adjust charts. However, the data should be checked to insure that friendly troops are not endangered and that firing data do not contain gross errors. The control chart operator selects a conveniently located grid intersection or critical point and announces its chart location to all chart operators. He designates a check chart operator to determine and announce deflection, time (when appropriate), and elevation for each battery to the selected point. This check chart is established as the master chart for purposes of adjustment of charts. Each chart operator determines the same elements of data for each battery from his chart. Any chart operator whose data do not compare with the master chart data within the prescribed tolerances shown below immediately announces the error to the control chart operator. Appropriate steps are taken to resolve any discrepancy between charts. Minor discrepancies are resolved by adjusting either the deflection indexes and/or the GFT settings to bring all charts (including control chart) into agreement with the master chart. The control chart operator should check as many points in this manner as may be necessary to achieve chart uniformity. Personnel and equipment differences make exact agreement difficult to achieve. Charts are in adjustment when data determined are within the following tolerances:

Deflection	2 mils
Range	20 yards

Fire missions will be processed and fired even though charts have not been adjusted. Time and elevation gagelines, when established, must be brought into coincidence with those of the master check chart.

e. Record of Surveyed Data. For convenience, each chart should have attached to it a sheet of paper on which are tabulated the coordinates and altitude of each firing battery and all critical points plotted on the chart. The azimuth(s) of the orienting line(s) should also be recorded.

407. Recording Initial Fire Request

a. The majority of requests for fire will reach the FDC by telephone or radio. They will be in the form of an initial fire request from an observer. Missions coming to the battalion FDC by wire are answered and recorded by the switchboard operator-computer. Missions received by radio are answered and recorded by a radiotelephone operator. He insures that all members of the FDC are alerted to the mission. The fire request is recorded on DA Form 6–16 (FDC Computer's Record) (fig. 151).

b. All battery computers not actively engaged in another mission record the initial fire request. If the fire request is received directly by a battery FDC over wire, the computer reads back the fire request. If the fire request is received over radio, the radio operator reads back the fire request.

c. When a fire request is received, the warning, FIRE MISSION, is announced in the FDC's. This warning alerts all personnel that a fire request is forthcoming.

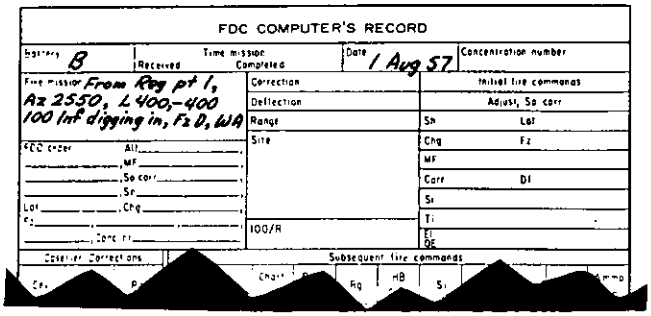


Figure 151. Recording the initial fire request.

408. Plotting the Target Location

All chart operators, including the control chart operator, plot the target location. The plot is based on the method of location used in the initial fire request. When a fire mission is received, each primary and check chart operator, unless otherwise actively engaged in a fire mission, will immediately plot the location of the new target.

409. Battalion Fire Order

a. When a target is plotted, the battalion FDO examines its location relative to the frontline, no-fire line, zones of fire, and registration points. From this examination, and considering the factors listed in chapter 23, he decides whether to fire the mission.

b. If the battalion FDO decides to fire the mission, he issues a fire order which consists of some or all of the elements in (1) through (14) below. Inapplicable elements are omitted, but the sequence indicated is always followed in order to avoid errors and confusion and to save time.

c. The following considerations affect the elements of the fire order:

(1) *Altitude.* The control chart operator normally determines the altitude from his chart and announces it to the FDO. Altitude is always announced in that unit of measure which facilitates computation of site; i. e., if the map is contoured in feet, the altitude is converted to yards or meters by the control chart operator by using the C and D scale on the graphical site table (GST).

(2) *Batteries to fire.* The decision as to which battery or batteries will fire a mission depends on—

(*a*) The number of batteries available to fire.

(*b*) The size of the area to be covered and the accuracy of location.

(*c*) The caliber, type, and number of weapons per battery.

(*d*) Whether or not surprise fire is feasible.

(*e*) The importance of the target.

(*f*) The range to the target.

Element	*When announced*	*Command*
(1) Altitude	Always	ALTITUDE 412 YARDS
(2) Battery(ies) to fire	Always	BATTALION
(3) Adjusting battery	When applicable	BRAVO
(4) Method of fire of adjusting battery	When different from observer's request or standard procedure; i. e., volley fire.	SALVO RIGHT
(5) Basis for corrections	When applicable	USE REGISTRATION POINT 2
(6) Use of special corrections	When applicable	SPECIAL CORRECTIONS, CONVERGED SHEAF
(7) Projectile	When different from observer's request or standard procedure; i. e., shell HE.	SHELL WP
(8) Ammunition lot	When applicable	LOT _____
(9) Charge	Always, except for high-angle fire	CHARGE 5
(10) Fuze	When different from observer's request or standard procedure; i. e., fuze quick.	FUZE DELAY
(11) Number of volleys	Always	5 VOLLEYS
(12) Range spread or zone	When different from observer's request or standard procedure; i. e., center range.	ONE C APART
(13) Time of opening fire	When different from observer's request or standard procedure; i. e., when ready.	AT MY COMMAND
(14) Concentration number	Always	CONCENTRATION ALFA BRAVO 101

(g) The relative locations of batteries to each other and to the target.
(h) Whether the purpose of fire is neutralization, harassment, or interdiction.
(i) The battery with the most recent or best corrections in the zone to be covered.
(j) The ammunition situation.

(3) *Adjusting battery.* For registration or for missions requiring fires of the battalion, it is usually best to use the midrange battery as the adjusting battery.

(4) *Method of fire of adjusting battery.* Unless the observer requests a specific method of fire, e. g., salvo fire, volley fire is used by the adjusting battery.

(5) *Basis for corrections.* If the target is within transfer limits of more than one registration point, the registration point nearest the target will give the greatest accuracy if the corrections are current.

(6) *Use of special corrections.* Special corrections are determined for each piece of a battery. Such corrections are used for barrages, targets very close to friendly troops, targets of unusual shape or dimensions, or when ordered. Special corrections are applied to correct for echelonment (position corrections), difference in altitude, and calibration of the pieces to produce the range and distribution desired.

(7) *Projectile.* The projectile or combination of projectiles selected depends on the mission and the nature of the target. Unless the observer requests a specific type of projectile, shell HE is used.

(8) *Ammunition lot.* In fixed and semifixed ammunition, the ammunition lot number pertains to an assembled projectile-propellant combination. For simplicity, the lot number may be coded as lot X. Alfa, Bravo, and Charlie will not be used to designate lots to avoid confusion in the fire order. In separate-loading ammunition, when a specific projectile-propellant combination is desired, the lot may be coded as lot X–Y with "X" designating projectile lot and "Y" designating propellant lot. Over a period of time, a unit tends to accumulate several lots of ammunition. Many of the lots will consist of small quantities. Large quantity lots are reserved for use on registration and subsequent transfer of fires, and the ammunition lot numbers will be announced or prearranged. Small quantity lots should be used for battery *will adjust* missions only, and lot numbers need not be announced. Battery computers and the chief computer will keep a record of lots available and registration points on which they were used.

(9) *Charge.* The mission, nature of target and terrain, ammunition available, type of fuze to be used, range, and effects sought govern the selection of the charge to be used.

(10) *Fuze.* The mission, nature of target and terrain, fuzes available, range, and effects sought govern the selection of the fuze to be used.

(11) *Number of volleys.* The mission, nature of target, ammunition available, and pertinent orders from higher headquarters govern the number of volleys to be fired.

(12) *Range spread or zone.* The area to be covered, the accuracy of the target location, and the probable error of the weapon should be considered in determining the range spread or zone to be used. Normally, a battalion should not fire with a range spread between batteries greater than 1 C (100 yards), for a greater spread will not give uniform coverage of the target. A spread of less than 100 yards, i. e., ½ C, will serve to thicken the fires.

(13) *Time of opening fire.* The mission, nature of target, and effect desired govern the selection of time of opening fire, such as TIME ON TARGET (TOT), AT MY COMMAND, WHEN READY, or any specific time according to a prearranged schedule.

(14) *Concentration number.* A number is selected for each concentration from the block of numbers assigned to the battalion (FM 6–20) unless a number has been specified by higher headquarters. (Battalion, division artillery, artillery group, corps artillery, or army artillery may assign a number to a concentration.) This number may be preceded by a letter(s) prefix to indicate the unit which

assigned the number. The chief computer will keep a list of the numbers readily available in order to avoid duplication.

410. Announcing and Recording the Fire Order

a. The fire order is announced and repeated, if necessary, to insure that all interested personnel receive it.

b. When radio is being used, the fire order is recorded by a radio operator at the battalion FDC. He repeats it on the radio for the battery FDC's and the observer. When wire communication is used, the switchboard operator-computer records the fire order as the battalion FDO announces it over the conference circuit for the battery FDC's and the observer. Regardless of the communication used and the batteries to fire, *all* battery computers record the fire order, on DA Form 6–16, as shown in figure 152, except when actively engaged in other missions.

c. The method of acknowledging the fire order will depend on the communication means being employed (pars. 431–433).

(1) In an all-wire system, acknowledgment will be made over the conference circuit.

(2) In an all-radio system, each battery will acknowledge in order by sending its call sign followed by ROGER and the proper terminating word.

(3) In a combination wire-radio system, acknowledgment will be made by both means of communication. Batteries will acknowledge over wire, if available, while the FO and/or any installation not having wire will acknowledge by radio.

d. In all cases, the order in which installations reply will be—

(1) The adjusting battery.

(2) Other batteries in order directed by unit SOP.

(3) Observation posts in order directed by unit SOP.

e. In fire for effect missions, unit SOP should indicate a specific battery computer (radio operator) to first acknowledge the fire order.

411. Measuring and Announcing the Angle T

a. As soon as the target grid is oriented, based on the azimuth given in the initial fire request, the adjusting battery primary and check chart operators determine the size of the angle T. They may determine the size by using any available

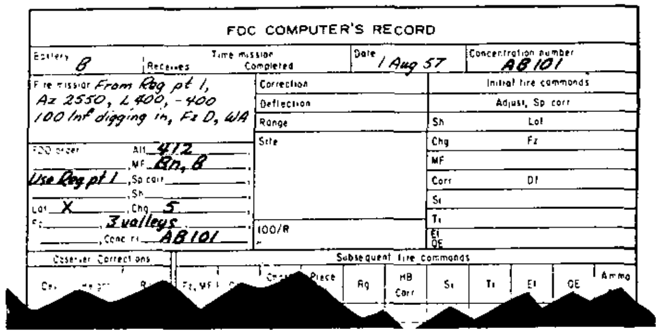

FDC COMPUTER'S RECORD
Battery B | Time mission Received Completed | Date 1 Aug 57 | Concentration number AB101
Fire mission From Reg pt 1, Az 2550, L 400, -400 100 Inf digging in, Fz D, WA
Correction
Deflection
Range
Site
100/R
Initial fire commands
Adjust, Sp corr
Sh Lot
Chg Fz
MF
Corr Df
Si
Ti
El
QE
FDC order: Alt 412, MF Bn, B, Use Reg pt 1, Sp corr, Sh, Lot X, Chg 5, Fz, 3 volleys, Conc nr AB101
Observer Corrections
Subsequent fire commands
Piece | Rg | HB Corr | Si | Ti | El | QE | Ammo

Figure 152. Recording the fire order.

angle-measuring device. They may compute the size of the angle T by comparing the OT azimuth with the GT azimuth. For example, the observer sent AZIMUTH 4850 and the GT azimuth is measured to be 4160.

$$4850 - 4160 = 690 \text{ mils}$$

b. The size of the angle T is announced to the observer when it is 500 mils or greater. It is always given to the nearest 100 mils. The size of the angle T may be requested by the observer at any time.

412. Determining Altitude

a. The control chart operator normally determines the altitude from a contour map and announces it to the FDO. Layer-tinting (FM 21–26) the battle map firing chart used by the control chart operator, or marking it with spot elevations, will aid in determining altitude.

b. When the initial fire request includes a vertical change from a known point, the altitude determined by applying the vertical change to the altitude of the known point is used initially.

413. Determining, Recording, and Transmitting Preliminary Fire Commands

a. Immediately on receiving the fire order, battery computers determine and record all fire commands except those determined from the charts and graphical equipment. For example, by examining the recorded initial fire request and the fire order, the adjusting battery computer determines and records, on DA Form 6–16, the following (fig. 153):

(1) *Battery adjust.* The fire order indicates battalion will fire and Battery B is to adjust.

(2) *Shell HE.* By omission of type of projectile in both the initial fire request

and the fire order, the use of shell HE is implied.

(3) *Lot X.* The fire order indicates use of lot X.

(4) *Charge 5.* The fire order indicates use of charge 5.

(5) *Fuze delay.* The observer requested fuze delay and since no change was ordered in the fire order, the requested fuze is used.

(6) *Center one round.* Volley fire was implied by omission of a method of fire in the observer's request and the fire order. Battery B was designated in the fire order to conduct the adjustment; the computer designates only the center 2 pieces to fire 1 round during the adjustment.

b. The procedure in *a* above is the same for nonadjusting batteries except for the method of fire which must include DO NOT LOAD; i. e., BATTERY 3 ROUNDS, DO NOT LOAD. Transmission of commands to nonadjusting batteries, together with DO NOT LOAD, permits prior preparation of the ammunition and general orientation of the weapons to minimize changes required when the command to fire is received.

c. The battery FDO transmits all fire commands to the battery executive post as soon as they are determined, except that the command for elevation is always transmitted last.

414. Determining and Recording Fire Commands Based on Chart Data (Using Graphical Firing Table Fan)

a. The chart operators determine deflection correction, deflection, site, time, and elevation, based on chart data. The GFT fan is positioned so that the fan vertex is against the appropriate

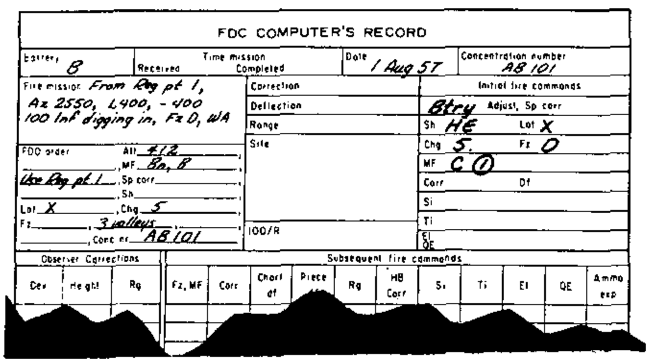

FDC COMPUTER'S RECORD
Battery B
Time mission Received Completed
Date 1 Aug 57
Concentration number AB 101
Fire mission From Reg pt 1, Az 2550, L400, -400 100 Inf digging in, Fz D, WA
Correction
Deflection
Range
Site
100/R
Initial fire commands
Btry Adjust, Sp corr
Sh HE Lot X
Chg 5 Fz D
MF C ①
Corr Df
Si
Ti
El QE
FDO order
Alt 412, MF Bn, B, Use Reg pt 1, Sp corr, Sh, Lot X, Chg 5, Fz, 3 volleys, Conc nr AB 101
Observer Corrections: Dev | Height | Rg
Subsequent fire commands: Fz, MF | Corr | Chart df | Piece | Rg | HB Corr | Si | Ti | El | QE | Ammo exp

Figure 153. Recording the preliminary fire commands.

battery pin with the cursor vertex against the target needle.

b. The deflection correction is applied on the gunner's aid throughout the mission. This correction is determined from the deflection correction scale drawn on the GFT fan at the point on the drift scale intersected by the elevation gageline. If a deflection correction is not available, it is announced as zero. If any subsequent deflection correction, from either registration or met computation, causes a total deflection correction too large (over 20 mils) to be set on the gunner's aid, the deflection index will again be displaced by the amount of the correction at the registration point.

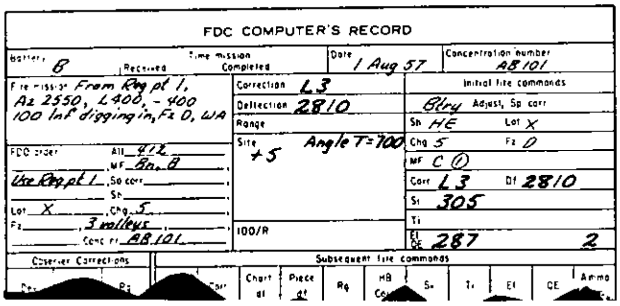
c. The deflection is read from the arc of the GFT fan at the point opposite the deflection index.

d. Site is determined by using the GST. The vertical interval is determined by obtaining the difference between the target altitude and the altitude of the battery. The range is read under the hairline on the cursor of the GFT fan. (Range is determined to the nearest 10 yards.) With these 2 elements, the mil relation is used to approximate the angle of site as less or greater than 50 mils. When the angle of site exceeds 50 mils, both the GST and the complementary angle of site columns in the tabular firing tables are inaccurate. Double interpolation site tables, when available in tabular firing tables, are used to determine site when the angle of site exceeds 50 mils. When double interpolation tables are not available, the site computed by using either the GST or the tabular firing tables must be used.

e. Time is read at the point on the time scale intersected by the time gageline. If a time gageline has not been constructed, the time is read at the point on the time scale intersected by the elevation gageline. If an elevation gageline has not been constructed, time is read at the point on the time scale intersected by the cursor hairline.

f. Elevation is read at the point on the elevation scale intersected by the elevation gageline. If an elevation gageline has not been constructed, elevation is read at the point on the elevation scale intersected by the cursor hairline.

g. Each battery computer records, on DA Form 6–16, these fire commands as they are announced by his primary chart operator (fig. 154). The computer keeps a progressive record of ammunition expenditure in the appropriate column of the FDC Computer's Record (DA Form 6–16).



FDC COMPUTER'S RECORD

Battery B | Time mission Received | Completed | Date 1 Aug 57 | Concentration number AB101

Fire mission From Reg pt 1, Az 2550, L400, -400 100 Inf digging in, Fz 0, WA

Correction L3

Deflection 2810

Range

Site +5 Angle T=700

FDC order: All 412, MF Bn, B, Use Reg pt 1, Sp corr, Sh, Lot X, Chg 5, Fz, 3 volleys, Conc nr AB101

100/R

Initial fire commands: Btry Adjust, Sp corr; Sh HE, Lot X; Chg 5, Fz 0; MF C (1); Corr L3, Df 2810; Si 305; Ti; El QE 287, 2

Observer Corrections: Dev, Rg, Corr

Subsequent fire commands: Chart df, Piece df, Rg, HB Corr, Si, Ti, El, QE, Ammo

Figure 154. Recording fire commands announced by primary chart operator.

415. Determining and Recording Fire Commands Based on Chart Data (Using Plastic Range-Deflection Fan or Aluminum Range-Deflection Protractor)

If the range-deflection fan and the GFT are used instead of the GFT fan, the following procedures are used to determine and record fire commands based on chart data:

a. The chart operators determine deflection correction, deflection, site, time, and elevation, based on chart data. The range-deflection fan is positioned so that the fan vertex is against the appropriate battery pin and the edge of the fan is against the target needle.

b. The deflection correction is applied on the gunner's aid throughout the mission. This correction is determined from the deflection correction scale drawn on the range-deflection fan at the point opposite the target needle. If a deflection correction is not available, it is announced as zero. If any subsequent deflection correction, from either registration or met computation, causes a total deflection correction too large (over 20 mils) to be set on the gunner's aid, the deflection index will again be displaced by the amount of the correction at the registration point.

c. The deflection is read from the arc of the range-deflection fan at the point opposite the deflection index.

d. Site is determined by using the GST. The vertical interval is determined by obtaining the difference between the target altitude and the altitude of the battery. The range is read on the range scale of the range-deflection fan at the point opposite the target needle. (The range is determined to the nearest 10 yards.) With these 2 elements, the mil relation is used to approximate the angle of site as less or greater than 50 mils. When the angle of site exceeds 50 mils, both the GST and the complementary angle of site column in the tabular firing tables are inaccurate. Double interpolation site tables, when available in tabular firing tables, are used to determine site when the angle of site exceeds 50 mils. When double interpolation tables are not available, the site computed by using the GST must be accepted.

e. Time is read at the point on the time scale of the GFT intersected by the time gageline. If a time gageline has not been constructed, the time is read at the point on the time scale intersected by the elevation gageline or, lacking an elevation gageline, time is read at the point on the time scale intersected by the cursor hairline.

f. Elevation is determined by the following steps:

(1) The range is obtained from the range-deflection fan.
(2) The cursor hairline of the GFT is positioned over this range on the range scale.
(3) The elevation is read at the point on the elevation scale intersected by the elevation gageline.
(4) Until an elevation gageline is constructed, elevation is read at the point on the elevation scale intersected by the cursor hairline.

g. Each battery computer records on DA Form 6–16, these fire commands as they are announced by his primary chart operator (fig. 154). The computer keeps a progressive record of ammunition expenditure in the appropriate column of the computer's record.

416. Graphic Check of Firing Data

Accuracy of firing data is assured by making a graphic check of data while it is being determined. Firing data are developed from one chart (primary chart) and checked against data developed from another chart (check chart). The check chart operator indicates agreement with the announced elements by remaining silent until the last element is given, at which time he announces CHECK. Agreement exists for this graphical check if the charts are within the limits of the tolerances shown below:

Deflection correction	1 mil
Deflection	3 mils
Time	0.1 second
Elevation	3 mils
Range	30 yards
Site	1 mil

The check chart operator indicates disagreement with an announced element not within prescribed tolerance by announcing WRONG, followed by the data which he has determined for that element; e. g., WRONG, DEFLECTION 2835. When the check chart operator announces WRONG for any element, all persons concerned immediately take the appropriate steps to resolve the disagreement.

a. When the check charts are at battalion FDC and a WRONG is announced, the battalion FDO requests one or more of the check chart operators to announce his (their) data for the plot in question. Those data must be measured from the pin of the battery whose data are in disagreement. The battalion FDO may require the FDO of the battery in disagreement to resolve the discrepancy by comparing the plot on the primary chart with the battery computer's record of the mission.

b. When the check charts are located at the battery and a WRONG is announced by the check chart operator, the battery FDO compares the plots on the two charts with the computer's record and checks the chart operators' readings to locate the error. Meanwhile, the battalion FDO may direct the control chart operator and/or other chart operators to announce data for the plot in question. When agreement has been reached to his satisfaction, the battalion FDO will announce the correct data followed by CHECK.

c. When the charts primarily concerned cannot readily be brought into agreement and firing resumed, the battalion FDO may designate another chart or another battery to continue the mission.

d. The words CHECK and WRONG are not transmitted to the battery executive. They are announced only between chart operators to indicate agreement or disagreement.

e. The battery FDO transmits fire commands as soon as they are determined. If a WRONG is announced after he has transmitted the elevation, the FDO commands CEASE FIRE, except as noted in *f* below. If a WRONG is announced prior to his transmission of elevation, the FDO sends CORRECTION and then transmits the corrected command.

f. Firing should be continued with the least possible delay. To insure that firing will not needlessly be delayed in every instance that a WRONG is announced, the FDO is given discretion to ignore a WRONG if firing the data transmitted to the weapons will not endanger friendly troops or unnecessarily prolong or complicate the mission. For example, the FDO may exercise this prerogative in the first 2 or 3 volleys in the adjustment phase of firing or when repeated WRONGS from the same check chart would suggest that charts are not accurately adjusted.

g. Tolerances listed may not be possible to attain if firing begins prior to adjustment of charts. In this case, the FDO may ignore a WRONG if friendly troops are not endangered.

417. Procedure During Adjustment

a. The adjusting battery computer (radio operator) announces ON THE WAY as soon as the first volley has been fired by the adjusting pieces. When the observer hears the announcement ON THE WAY, he acknowledges receipt by giving ROGER, WAIT.

b. The nonadjusting chart operators prepare to follow the mission by measuring the data from the adjusting battery pin. When a nonadjusting battery uses the same GFT setting as that used by the adjusting battery, the chart operators of that battery plot each correction sent by the observer. They check the plot against the deflection and elevation announced by the adjusting primary chart operator. Nonadjusting chart operators usually do not announce WRONG in the event of disagreement with the adjusting primary chart operator's announced data; instead they adjust the plot to bring it into agreement with the adjusting primary and check charts. If the check chart operator announces WRONG and the FDO ignores the WRONG, the nonadjusting chart operators adjust their plots to agree with the adjusting primary chart.

c. When each battery has a separate GFT setting, each chart operator marks the extra cursors issued with each GFT fan with GFT settings for other batteries. For those units equipped with the GFT and the range-deflection fan, care must be exercised to insure that elevations are read opposite the gageline which designates the GFT setting of the adjusting battery. Thus, when a nonadjusting battery chart operator is following the adjustment from the adjusting battery pin, care must be exercised that he uses the elevation gageline of the adjusting battery.

d. On receiving the observer's subsequent corrections, each primary and check chart operator plots the corrections. Assume that the observer sends LEFT 20, ADD 200. On the DA Form 6–53 (Target Grid), the chart operator moves the target needle to a point equivalent to 20 yards left of its last location (interpolating visually within the 100-yard square) and up from that point 2 squares (200 yards) and sticks the needle in the chart. The deflection and elevation are then determined to this corrected location. The primary chart operator announces the new deflection and elevation, and the check chart operator announces CHECK if these data are within prescribed tolerances.

e. All battery computers record the observer's subsequent corrections and the announced deflection and elevation (fig. 155).

f. The adjustment proceeds in this manner until the observer transmits FIRE FOR EFFECT.

418. Procedure to Correct a Misorientation of Target Grid

If the observer sends an azimuth which is in error, the resulting error in orientation of the Target Grid (DA Form 6–53) should be corrected when it is large enough to cause the observer difficulty in adjusting.

a. In figure 156, the observer's first correction is ADD 400. The chart operator moves the target needle to a point equivalent to 400 yards up the OT line, and a round is fired with the data obtained.

b. The observer's next correction of RIGHT 200, REPEAT RANGE indicates that the reported azimuth is in error. The chart operator moves the target needle to a point equivalent to 200 yards right of its last location and marks the position of the constructed line shot on the firing chart.

c. While a round is being fired with these data, the chart operator draws a line on the chart connecting the constructed line shot with the previous line shot. The target grid is rotated until the

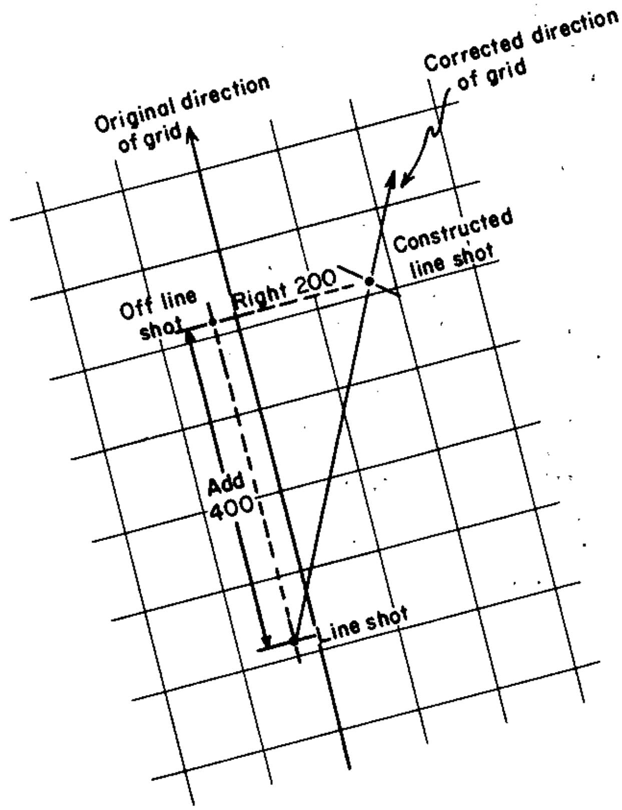
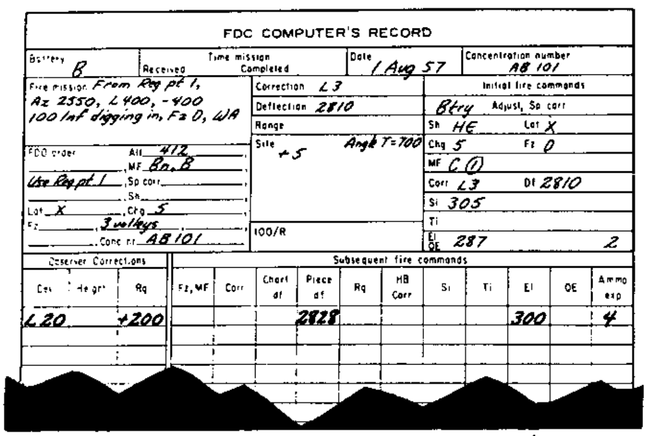


Figure 156. Correcting a misorientation of the target grid.



FDC COMPUTER'S RECORD

Battery B | Time mission Received Completed | Date 1 Aug 57 | Concentration number AB 101

Fire mission From Reg pt 1, Az 2550, L 400, -400 100 Inf digging in, Fz 0, WA

Correction L 3 | Deflection 2810 | Range | Site +5 Angle T=700 | 100/R

FDO order: All 412, MF Bn, B, Use Reg pt 1, Sp corr, Sh, Lot X, Chg 5, Fz, 3 volleys, Conc nr AB 101

Initial fire commands: Btry Adjust, Sp corr; Sh HE; Lot X; Chg 5; Fz Q; MF C (1); Corr L 3; Df 2810; Si 305; Ti; El/QE 287 2

Observer Corrections: Dev	Height	Rg	Subsequent fire commands: Fz, MF	Corr	Chart df	Piece df	Rg	HB Corr	Si	Ti	El	QE	Ammo exp
L 20		+200				2828					300		4

Figure 155. Recording subsequent corrections and commands.

arrow on the grid is parallel to this line. The grid now is oriented correctly. When the next observer correction is received, the target needle is moved from the chart location of the last round fired.

d. When the reorienting procedure results in changing the original azimuth by 200 or more mils, a bracket determined by the observer prior to reorientation must be verified, unless urgency of fire is more important than accuracy or density. Sensings of over and short are correct but the depth of the bracket may be larger than the observer's corrections indicate.

419. Procedure During Fire for Effect

a. The FDC may direct, or a higher headquarters may command, that fire for effect be fired with a specific range spread between batteries or that zone fire be used. The range spread or zone used depends on the size of the area to be covered. When a range spread is directed, it is normally expressed in terms of the C (100 yards); i. e., 1 C apart or ½ C apart. The FDO must include in the fire order the command for the amount of the range spread. The batteries to fire at the various ranges will be designated by unit standing operating procedure. For example, Battery A fires the far limit, Battery B fires the center range, and Battery C fires the short limit. Site is computed in the normal manner. When zone fire is used, it is included in the fire order and expressed in terms of mils and elevations; for example, ZONE 3 MILS, 5 ELEVATIONS. Omission of the number of elevations indicates that three elevations are to be fired. The use of zone fire requires no modification of normal procedures except for its insertion in the proper sequence in the fire commands.

b. A typical transmission from an observer who desires to enter FIRE FOR EFFECT would be RIGHT 10, ADD 50, FIRE FOR EFFECT. Each chart operator plots this correction. The nonadjusting chart operators measure data from their own battery pins, exercising care to use the proper elevation gagelines. They proceed to determine and check firing data for their batteries.

c. All battery FDO's must change the method of fire to BATTERY 3 ROUNDS as determined from the fire order. Each battery computer records this method of fire and the data announced by his primary chart operator.

d. Each battery fires for effect as soon as it is ready regardless of any other battery firing in effect, except when delayed fire for effect is desired. Delayed fire for effect may be used to advantage for any target consisting of personnel who must return to complete a specific job. Also, it may be used for firing on an adjusting point where a target must appear; for example, engineer construction, such as bridges or crossroads frequently used by vehicles or personnel. Time on target procedures (par. 428) can be used in these situations.

e. When the first volley is on the way, the firing battery reports FIRING FOR EFFECT to the FDC. This message is transmitted to the observer, who sends ROGER, OVER. When the last battery to fire has reported ROUNDS COMPLETE, a message is transmitted from the battalion FDC to the observer as BATTALION ROUNDS COMPLETE and he acknowledges with ROGER, WAIT.

f. When the observer sends END OF MISSION (EM), it is acknowledged and recorded at the battalion FDC. The mission is ended by sending ROGER, OUT.

g. The battery computers record the observer's surveillance and complete the ammunition record at the bottom of the FDC Computer's Record (DA Form 6–16) (fig. 157).

420. Replotting Targets

Only those targets requested for replot by the observer or directed by the FDO will be replotted. Replot data consist of the coordinates, altitude, fuze, and concentration number. The deflection and range indicated by the final location of the target needle is used to determine the coordinates for replot of the target. The fuze, initial altitude, and concentration number are obtained from the FDC Computer's Record (DA Form 6–16). Replot data must be determined and verified. Fire for effect chart data, particularly altitude (site), are sometimes not precise. Within the battalion, fire for effect firing data will, if used again, usually cause effective fire to fall on the target. However, for target locations to be sent outside the battalion, the target replot coordinates and altitude must indicate the actual ground location as near as possible.

a. When data for replot are announced by the adjusting battery primary chart operator, they are checked by the check chart operator and recorded by the computer. Determination of replot data is started by the adjusting chart operator. He announces the coordinates of the final location of the plotting needle. He also announces the altitude, fuze, and concentration number for the target to be replotted. The control chart operator plots the announced coordinates on a battle map and determines the map altitude (except for missions fired with fuze time (par. 425*d*)). When the control chart is not available, the target altitude is determined from the battery FDO's battle map. The altitude determined is announced to the primary chart operator. Using this altitude and the FFE chart range to the target, the primary and check chart operators compute a new site and elevation. If this site agrees within 1 mil of the site fired, the initial replot data is verified. If this site differs by more than 1 mil from the site fired, a new replot range is determined. The new range is determined by placing the elevation gageline at the new computed elevation and reading the range under the cursor hairline. The concentration is replotted by the primary and check chart operator by using the deflection fired and the new range determined. The coordinates to this plot are announced to the control chart operator. He plots these coordinates and determines the altitude to the plot. This altitude

FDC COMPUTER'S RECORD

Battery	Time mission	Date	Concentration number
B	Received Completed	1 Aug 57	AB 101

Fire mission From Reg pt 1, Az 2550, L400, −400 100 Inf digging in, Fz D, WA

FDO order · Use Reg pt 1, Alt 412, MF Bn, B, Sp corr ___, Sh ___, Lot X, Chg 5, Fz ___, 3 volleys, ___, Conc nr AB 101

Correction L3

Deflection 2810

Range

Site +5   Angle T = 700

100/R

Initial fire commands

Btry	Adjust, Sp corr
Sh HE	Lot X
Chg. 5	Fz D
MF C (1)	
Corr L3	Df 2810
Si 305	
Ti	
El / QE 287	2

Observer Corrections			Subsequent fire commands										
Dev	Height	Rg	Fz, MF	Corr	Chart df	Piece df	Rg	HB Corr.	Si	Ti	El	QE	Ammo exp
L 20		+200				2828					300		4
		−100				2824					291		6
R 10		+50	FFE	Btry (3)		2828					295		24

EM Est 20 casualties; remainder withdrawing

Data for replot

Coordinates	Altitude	Fuze	Concentration number

Ammunition

Type	Fz M51	Fz M500	Fz VT	Sh HE	Sh WP			
Total	420	320	102	916	22			
Received	—	99	—	—	—			
On hand	420	419	102	916	22			
Expended	24	—	—	24	—			
Remaining	396	419	102	892	22			

DA FORM 1 APR 57 6-16   REPLACES EDITION OF 1 MAR 55

Figure 157. Recording of observer's surveillance and completion of ammunition record.

is announced to the primary and check chart operator, and a new site is computed. The process of determining coordinates and altitude is repeated until two successive site computations agree within 1 mil. Then the last site computed is used in determining the corrected data for replot. Transmission of data for determination of replot is as follows:

Primary chart operator:	DATA FOR REPLOT, COORD 59983694, ALT 402, FZ Q, CONC AD 403
Control chart operator:	CORRECTION, REPLOT ALT 387, CONC AD 403
Primary chart operator:	CORRECTION, REPLOT COORD 60033689, CONC AD 403
Control chart operator:	CORRECTION, REPLOT ALT 380, CONC AD 403
Primary chart operator:	CORRECTED DATA FOR REPLOT, COORD 60053687, ALT 380, FZ Q, CONC AD 403

Note. When the check chart operator does not agree with the primary chart operator, transmission of computed site may be required.

b. The complete report of replot data, after verification, is announced during lulls in firing to the battalion FDC by the adjusting battery computer (radio operator). The chief computer insures that the replot data are given to all nonadjusting chart operators; control chart operators, if necessary; and the observer.

c. Tick marks for the plot are drawn in red to indicate that the location of the target was determined by firing and not by survey. The concentration number, altitude, fuze (optional), and charge (optional) are indicated in black.

421. Report of Firing to Battalion S2

The chief computer will report all missions fired to the battalion S2 as soon after the end of the mission as possible. For example: "Battalion fired 3 volleys on 100 infantry digging in at 60053687, estimate 20 casualties, remainder withdrawing."

422. Records

a. The battery computers will maintain a temporary file of FDC Computer's Record (DA Form 6–16) for possible future reference.

b. A blackboard or sheet of acetate may be used for posting current GFT settings and registration and met data. It may also be used for posting any other information of immediate use to the fire direction personnel. A record of registration and met data as well as VE's developed with specific ammunition lots should be kept for reference.

c. The battalion chief computer and/or battery computers should maintain a temporary file of records of precision fire.

d. The battery computer maintains a temporary file of data sheets for all prearranged fires sent to the battery.

423. Registration

Normally, the battalion FDO supervises registrations; however, registrations may be conducted by the battery FDO as directed by battalion. To insure uniform application of corrections, the FDO who conducts the registration immediately transmits the corrections to the other FDC's. However, the corrections are not applied until so directed by the battalion FDO. All computers maintain a record of current GFT settings and deflection corrections for all batteries.

424. Surprise Missions or Unobserved Fire Missions

The procedure for surprise missions or unobserved fire missions is the same as that used with the initial and fire for effect phases of adjustment missions. Unit SOP should indicate the battery computer to first acknowledge the fire order.

425. Procedure Using Time Fuze

A burst height of approximately 20 yards produces the greatest lethality from time fuzed projectiles. This height of burst is a mean height suitable for light, medium, heavy, and very heavy artillery and will produce effective results without an excessive number of graze or high air bursts owing to the vertical probable error. When a fuze with a time setting is being used and a command prefaced by DNL is received at the firing battery, the fuze setter is set at the time announced but the fuze is not cut until a command to fire the round has been received. This procedure will preclude the setting of the fuze more than once if a different time setting is required when the final time is announced.

a. When time fuze is ordered, an angle of site based on a vertical interval of 20 yards and the GT range must be computed and added to the site determined for the ground location. Determination of this angle of site is simplified by using the scale, termed 100/R scale, on the right edge of the ballistic plate of the GFT fan or the 100-yard scale of the GFT. These figures are a function of range and indicate the number of mils required to move the burst 100 yards in height or deflection. Since only 20 yards height of burst is desired in time fire, only 0.2 or ⅕ of the figure obtained from the 100/R scale is required. For example, when the 105-mm howitzer, charge 5, range 6,000 yards, is used, the 100/R factor is 17 mils. One-fifth, or 0.2, of 17 is 3.4 mils. Thus, 3 mils would be added to the site to achieve a 20-yard height of burst in this instance. Complementary angle of site for the increased vertical interval of 20 yards is insignificant and is ignored.

b. The battery computer computes the angle of site for height of burst based on the 100/R factor given by his primary chart operator, who announces this, when appropriate, as the first element of firing data. For example, 100 OVER R 17, CORRECTIONS L3, DEFLECTION 2810, SITE PLUS 5, TIME 22.2, ELEVATION 365. The battery computer combines the determined angle of site for height of burst with the announced site which becomes the site command to the guns (i. e., site announced is plus 5, angle of site for height of burst is 3 mils, thus site commanded is 308).

c. When a subsequent vertical correction is given by an observer, the battery computer uses the announced 100/R factor and determines a new site command. For example, the observer gives UP 20. The 100/R factor of 17 is multiplied by 0.2, with a result of 3.4 mils. This amount is added to the previous site of 308, resulting in a site of 311.

d. To replot a target in a fuze time mission, the site derived from firing, minus the 20/R computed at the fire for effect range, is accepted as correct and the altitude determined from this site and the fire for effect range is the altitude assigned to the target. If the sites determined from firing vary repeatedly from the sites determined from the map by 2 or more mils, the need for a new time registration may be indicated. The FDO's decision to invalidate the time registration must be based on the accuracy of the altitude determined from the map, the actual height of burst in fire for effect, and the type of terrain at the target.

426. Procedure Using VT Fuze

a. When VT fuze is used, as with time fuze, an additional angle of site, 20/R, must be added to the site determined for the ground location. Application of this additional angle of site compensates for the foreshortened range that would result from the fuze functioning on a trajectory determined for a ground impact location (fig. 158). The height of burst obtained with VT fuzes varies in different types of terrain, resulting in a varying range effect. If an unsatisfactory range results, the 20/R factor will be changed accordingly. In high-angle fire there is no need to compensate for the shortened range, since the descending branch of the trajectory is nearly vertical.

b. The height of burst correction added to the site is determined in the same manner as described in paragraph 425*a*.

c. When VT fuze is to be used in fire for effect, adjustment is made with fuze quick in order to facilitate sensings. To expedite delivery of fire for effect, the fire commands to the adjusting battery will state, as a part of the method of fire, the number of VT fuzed rounds to be used in fire for effect. Typical fire commands for an adjusting battery would be BATTERY ADJUST, SHELL HE, LOT _____, CHARGE 5, FUZE QUICK, CENTER 1 ROUND, BATTERY 3 ROUNDS, VT IN EFFECT, CORRECTIONS L3, DEFLECTION 2756, SITE 302, ELEVATION 250.

d. The adjusting battery primary chart operator announces the 100/R factor to his battery computer as the first element of his initial command; i. e., 100 OVER R 15, CORRECTIONS _____, DF _____, SITE _____. The battery computer computes the height of burst correction and applies it as a part of site on entering fire for effect. Nonadjusting battery computers will determine the height of burst correction and apply it to site in the initial commands, which are sent together with DO NOT LOAD as a part of the method of fire.

e. When VT fuzes are used, time, normally corresponding to the time of flight to the target, is set on the fuze time ring. This fuze setting, however, is announced as a whole number. If the fuze setting corresponding to the elevation is not a whole number, the next higher whole number is announced. For example, if the fuze setting (time of flight) corresponding to the elevation is 24.2 seconds, the fuze setting announced would be 25.0 seconds. Since fuze quick is used in adjustment, the fire command for time is announced with fire for effect data for the adjusting battery; however, the time command is announced in initial commands for nonadjusting batteries. If the observer reports that VT fuzes are bursting

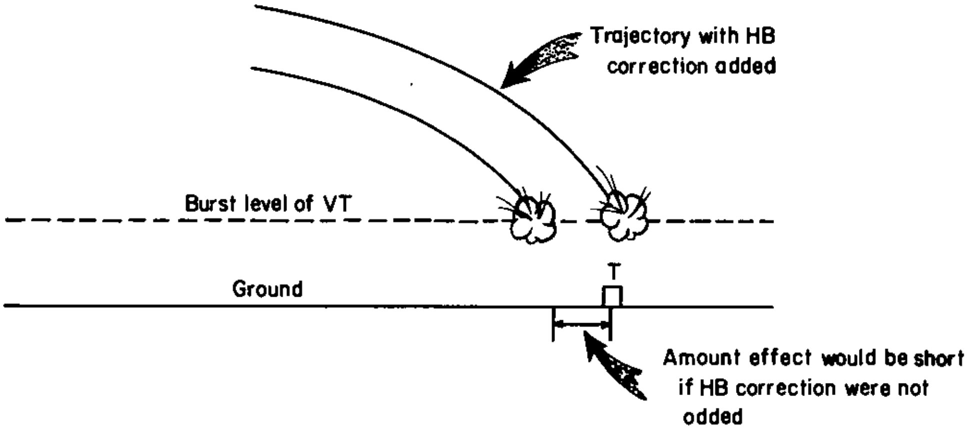


Figure 158. Result of HB correction to VT fuze effect.

on impact, the fuze setting will be decreased 1 second.

f. If the FDO decides to fire VT fuzes on the 0 setting line, he orders FUZE VT, TIME ZERO and the fire command for time is TIME ZERO. If the FDO decides to fire fuzes T226E2 (M513E2) or T227E2 (M514E2) with a fuze setting of point detonating (PD), he orders FUZE VT, QUICK and the fire command for fuze would be FUZE VT, QUICK. The time command is omitted from the fire commands.

g. Replot of targets attacked with VT fuze is accomplished as described in paragraph 420 after the height of burst correction has been subtracted from the site.

427. Procedure for Missions by Air Observer

a. Since the air observer has no fixed location, the azimuth is omitted from the initial fire request. To plot a target location as a shift from a registration point, the chart operator centers the target grid over the registration point and rotates it until the 0–3200 line is in coincidence with the gun-target line of the center battery. The target grid may also be oriented with respect to a reference line, such as a railroad. In this case, the grid is centered over a predesignated point and oriented along or parallel to the reference line.

b. Subsequent corrections are plotted with respect to the gun-target line of the adjusting battery or the reference line. If subsequent deviation corrections are large and there is evidence that the target grid is misoriented, the target grid should be reoriented.

428. Procedure for Time on Target Missions

a. Time on target (TOT) is a special technique of firing the pieces of several units timed 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 by giving the time of day that fire is to be delivered. For example, the order may state TIME ON TARGET IS 0915 HOURS--------TIME NOW IS 0906. Time on target may also be ordered as TIME ON TARGET IS (SO MANY) MINUTES FROM--------NOW! Generally, 10 minutes in the foregoing orders will give all units sufficient time to allow for coordination and time of flight.

b. The target is plotted and firing data and fire commands are determined as usual except for the method of fire. The battalion FDO will include AT MY COMMAND in his order for time on target missions. Each battery FDO coordinates the time of loading so that the rounds do not remain in the bores longer than 30 seconds prior to firing. The fire commands initially transmitted to the firing battery will include DO NOT LOAD when appropriate, which is changed to AT MY COMMAND, TOT (SO MANY) MINUTES FROM--------NOW, at the appropriate time. The time a battery will fire is determined by subtracting the time of flight from the time designated in the time on target order.

c. To coordinate the firing of all batteries, the battalion FDO starts a time count at the appropriate time, counting by seconds approximately 10 seconds before the battery with the longest time of flight must fire. Each battery FDO gives the command FIRE for his battery when the battalion FDO announces the time in his counting which corresponds to the time of flight for his hattery plus 2 seconds. This 2 seconds is added to the time of flight in order to allow for the time lag between the announced count and the actual firing of the pieces.

d. For example, the following message has been received from a division artillery fire direction center:

> THIS IS (CALL SIGN), FIRE MISSION, FIRE 2 VOLLEYS,
> SHELL HE, FUZE VT, COORDINATES 6454231420, ALTITUDE 420 YARDS,
> CENTER RANGE,
> CONCENTRATION AF 101,
> TOT, TOT WILL BE 8 MINUTES FROM --------NOW.

The battalion FDO starts his stop watch at the command NOW and begins his count for the battery FDO's by saying when appropriate, "Time on target is six zero seconds from NOW-------- five zero seconds from--------NOW--------four zero seconds from--------NOW--------three zero seconds from--------NOW--------28, 27, 26," etc., until all batteries have fired. The FDO of a battery which has a time of flight of 18 seconds for this target would command FIRE at the announced count of 20.

429. Multiple Fire Missions

a. Three fire missions can be processed in the battalion FDC simultaneously. All fire requests received at the FDC are acknowledged and recorded. When a battalion fire mission is in process and another mission is received, the switchboard operator-computer records the mission and the control chart operator plots the mission in order for the battalion FDO to examine it and reach a decision to fire. Since only 3 fire missions, i. e., 1 per battery, can be conveniently processed concurrently, the battalion FDO must make a decision when 2 or more requests are in the FDC. The FDO may stop firing a mission in order to attack a more important target; he may take the mission and notify the observer that there will be a delay; he may assign missions to individual battery FDC's if the targets are suitable for attack by a battery; he may call on attached, reinforcing, or adjacent battalions; he may request fire through higher headquarters; or he may decide the target is not sufficiently important to be attacked but will treat the request only as intelligence information and so inform the observer.

b. If a battalion *will adjust* mission is in process and a fire request is received which requires the use of only 1 battery, the battalion FDO may assign the new mission to 1 of the nonadjusting batteries at once. The FDO would order the selected battery SUSPEND ON CONCENTRATION AB 205, FIRE MISSION. The fire request, already recorded in the battalion FDC, would be repeated to the selected battery. A fire order for the mission would be announced. END OF MISSION, followed by the new fire commands would be announced by the battery FDO to the battery executive. If the battery should complete this mission before the mission on concentration AB 205 is in fire for effect status, the battalion FDO might order this battery to RESUME ON CONCENTRATION AB 205. He would have the adjusting battery check chart operator announce a polar plot (deflection and elevation or range) for the present target needle location of concentration AB 205.

c. When additional fire is required, a request is submitted to higher headquarters (FM 6–20).

430. Procedure Using Special Corrections

a. When the use of special corrections, i. e., position corrections and/or calibration corrections, is indicated in the fire order, the battery computer normally computes these corrections. The battery computer must always, therefore, obtain and maintain a record of calibration corrections and distribution of pieces.

b. If both deflection correction and a special correction (i. e., sheaf correction or piece displacement correction) apply they will be combined by the battery computer. The combined correction will normally differ for each piece. They are announced as CORRECTIONS ZERO, DEFLECTION (SO MUCH), NO. 1 LEFT 3, NO. 2 LEFT 5, etc. (CORRECTIONS ZERO indicates that a common correction for the entire battery is not applicable.) In this case, the individual corrections will then be applied on the gunner's aid.

c. For the 105-mm howitzer, position corrections for range and/or height and calibration corrections for range will be announced and applied as site corrections; e. g., SITE 304, NO. 1 UP 2, NO. 2 ZERO, NO. 3 DOWN 1, etc. For weapons which do not have a site scale, position corrections for range and/or height and calibration corrections for range will be determined as elevation (quadrant) corrections. A separate elevation will be computed and announced for each piece; e. g., ELEVATION NO. 1–308, NO. 2–310, NO. 3–307, etc.

d. Time corrections for position and calibration corrections will be combined and announced for each piece; e. g., TIME 18.2, NO. 1 PLUS .1, NO. 2 ZERO, NO. 3 MINUS .2, etc.

Note. If special corrections have not been ordered, calibration corrections within the battery are ignored if all piece velocities are within 5 foot-seconds of the base piece velocity. If any individual piece velocities vary by more than 5 foot-seconds from the base piece, the battery will apply a correction for the piece on all missions without orders from the battalion FDC. In this case, the FDO will give position and sheaf corrections only to this piece when special corrections are ordered.

Section V. COMMUNICATIONS

431. General

a. To provide the communications necessary for fire direction, separate radio and wire systems are installed. These systems parallel each other so far as possible. Thus an alternate means of communication is provided if either system fails. The radio and wire systems described can readily be adapted to units regardless of caliber or mission. *All* FDC personnel should be trained in both communication and gunnery techniques. Neither wire nor radio is considered the primary means of communication. The presence of both types of communication permits a selection of the best means to meet any situation. All personnel will be trained to use radiotelephone procedure to transmit firing data and fire commands at all times, except within the firing battery. For fire direction purposes, a single call sign will be used to identify the battalion installations regardless of the transmission means employed. For detailed instructions pertaining to wire and radio communications, see FM 6–101 and FM 24–5.

b. The short-phase repeat-back method of transmissions described in Joint Army-Navy-Air Force Publication (JANAP) 164 may be modified for greater speed when stable communication permits. The initial fire request may be sent as a single transmission and read back in that manner. The FDO's fire order may be sent as a single transmission and acknowledged by the adjusting computer with a ROGER rather than a read back.

c. Maximum use will be made of fire direction personnel to set up the communications within each FDC. For example, wire personnel will normally lay wire to a terminal near the FDC. FDC personnel are responsible for the communications from the terminal to and throughout the FDC. Radio operators will remote the radios and extend the speaker lines. The switchboard operator-computer will conduct the normal wire checks for those lines terminating in the switchboard. Check chart operators will insure that checks are made on the alternate lines to the batteries as required.

432. Radio

a. Owing to crowding of the frequency spectrum only two channels are usually available for fire direction. Normally, all air and ground observers, liaison officers with supported battalions, a base set at the battalion FDC, and a radio at each battery FDC will operate in the primary fire direction net. A base set at the battalion FDC and a radio at each battery FDC operate in the secondary fire direction net. The secondary net is used for transmission of firing data by nonadjusting batteries when the battalion is employed on a single mission. When multiple missions must be fired, the FDO will direct appropriate sets to be shifted to the secondary channel. A third channel, alternate fire direction net, is highly desirable in the direct support battalion. When a channel is not available for an alternate fire direction net, a less desirable solution is to use the command net. The alternate fire direction net is used for retransmission by the liaison officer from the observer to the FDC. It is also used to aid the handling of three missions at one time. When retransmission can be used to extend the range of forward observer sets, the liaison officer will direct the FO concerned to switch to the alternate fire direction net. Retransmission may be completed on either the primary or the secondary fire direction net as indicated by the FDO. For retransmission purposes, no base set is required for the alternate channel. A type fire direction radio system is shown in figure 159. The battalion command net, frequency-modulated (FM), normally used for command functions, is not shown.

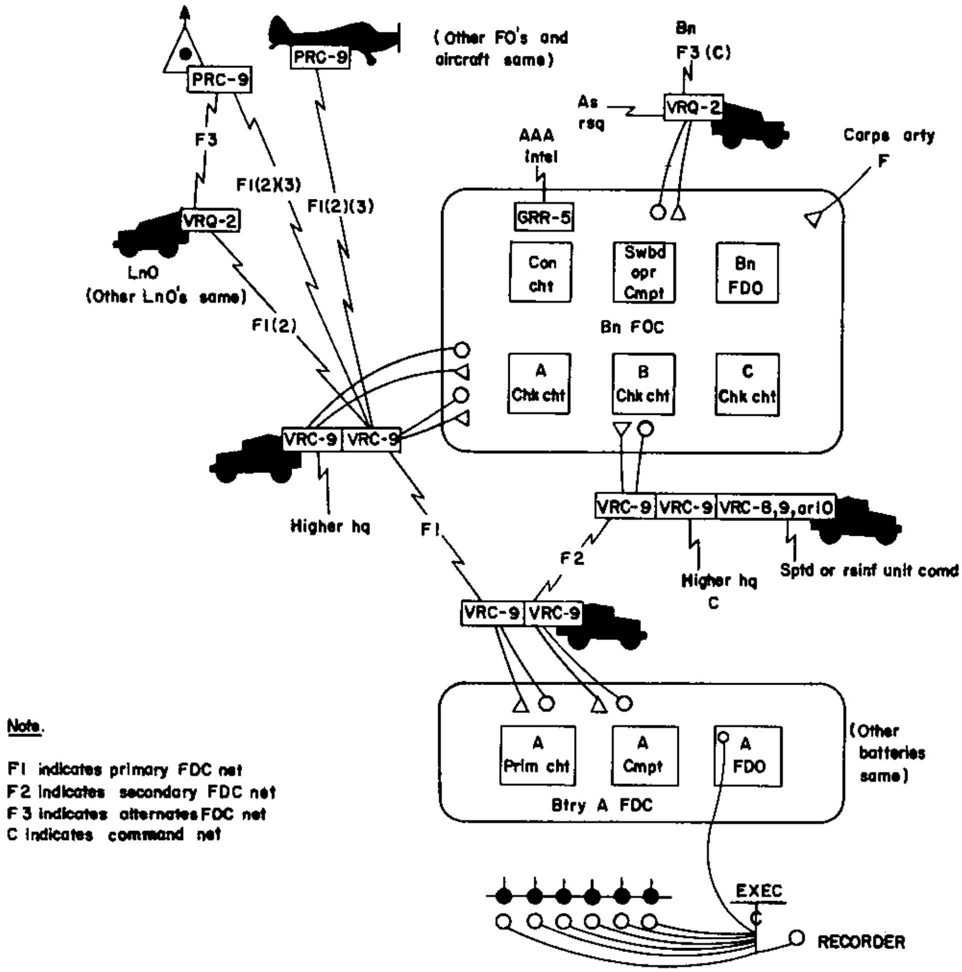


Figure 159. Type battalion radio communication system for conduct of fire.

b. All base sets are remoted into the FDC to permit normal transmission after removal of vehicles from the area. In addition, speaker lines are extended. This extension is accomplished by attaching the male and female ends of a 10-pin audio connector to opposite ends of a length of field wire of sufficient length to link the radio set location and the FDC. Appropriate ends are connected to the speaker and the audio outlet on the set (fig. 160).

c. To handle external radio communication requirements, the battalion FDC has radios operating in higher headquarters and supported or reinforced unit nets, as required.

d. When a radio set AN/VRQ–2 is used in lieu of two radio sets, AN/VRC–9, each receiver-transmitter of the AN/VRQ–2 is remoted separately. The audio circuits must be separated to prevent crosstalk on the speakers. This authorized procedure is explained in TM 11–287. Without this separation, both signals would be received on both speakers.

433. Wire

The extent of the wire system installed depends on the length of time a position is occupied.

a. If a battalion position is occupied for a short period of time, lack of time may preclude developing the wire system beyond installing the fire direction lines to the battery FDC's. In this case, radio will carry traffic to liaison officers and forward observers.

b. If a battalion position is occupied for a sufficient length of time, a complete wire system is installed. The installation of wire is started on completion of reconnaissance. The system is progressively expanded and improved with time of occupancy. Wire circuits parallel the radio circuits. Thus the traffic on radio facilities is reduced. The wire system is expanded and im-

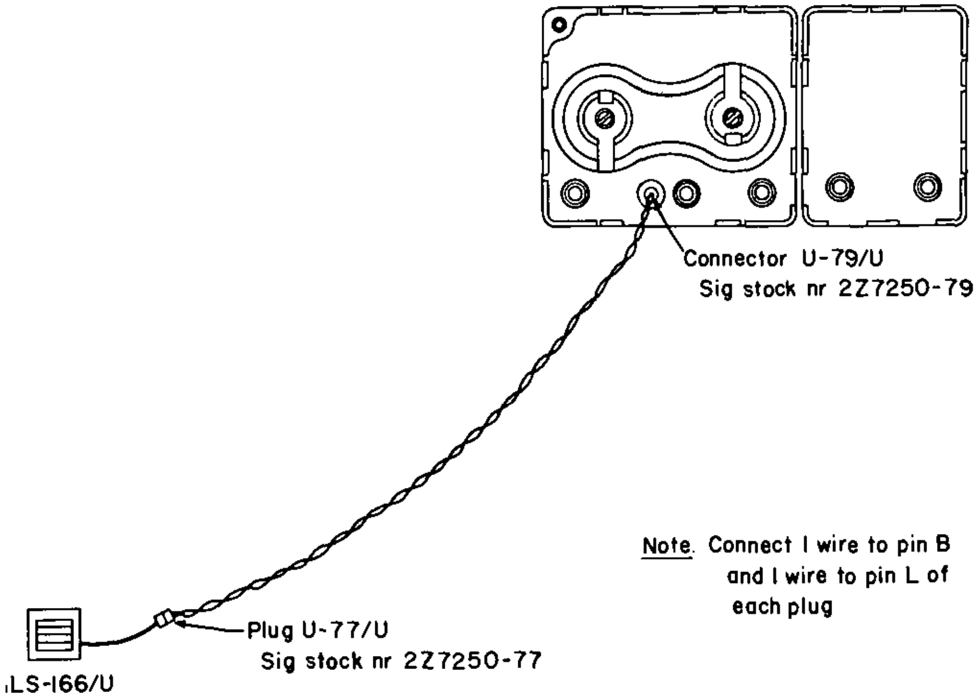


Figure 160. Method of extending speaker lines.

proved by installing additional locals, lateral circuits, and duplicate circuits until the wire net fulfills the communication requirements of the tactical situation. The wire system is installed in three phases, all or any of which may occur at the same time (FM 6–101). A type wire system for fire direction is shown in figure 161.

c. A switchboard is established in the battalion FDC. Lines to battery FDC's are terminated in individual remote control units. These remote control units, as well as those shown in the battalion FDC in figure 162, are used in lieu of telephones to permit the use of the authorized head and chest set groups with 10-pin audio connector. When telephones which have a 10-pin audio connector are issued, they may be substituted for these remote control units. The battalion FDC switchboard is operated by the switchboard operator-computer. The operator's pack on the FDC switchboard is replaced with five line packs. The 17 packs thus made available are utilized for the following circuits:

(1) Battery A.
(2) Battery B.
(3) Battery C.
(4) FDO.
(5) Liaison officer 1.
(6) Liaison officer 2.
(7) Liaison officer 3.
(8) Liaison officer 4.
(9) Switchboard operator-computer.
(10) Control chart operator.
(11) Chief computer.
(12) S3.
(13) S2.
(14) Command switchboard.
(15) Command switchboard.
(16) Higher headquarters FDC.
(17) Countermortar radar section.

d. Alternate circuits from the firing batteries, when established, will terminate in individual telephones at the chart operator positions.

e. On each incoming circuit from the firing battery FDC, a double-pole single-throw (DPST) switch is inserted at the position of each check chart operator. The purpose of this switch is to permit a chart operator to cut himself out of a conference circuit to check data with his primary chart operator, without action by the switchboard operator-computer. Care must be exercised to insure that each switch is installed on the circuit *between* the FDC switchboard and the check chart operator. The correct method of inserting the DPST switch is shown in figure 163.

f. At each battery position, the circuit from the battalion FDC is connected to the remote control unit of the primary chart operator. The

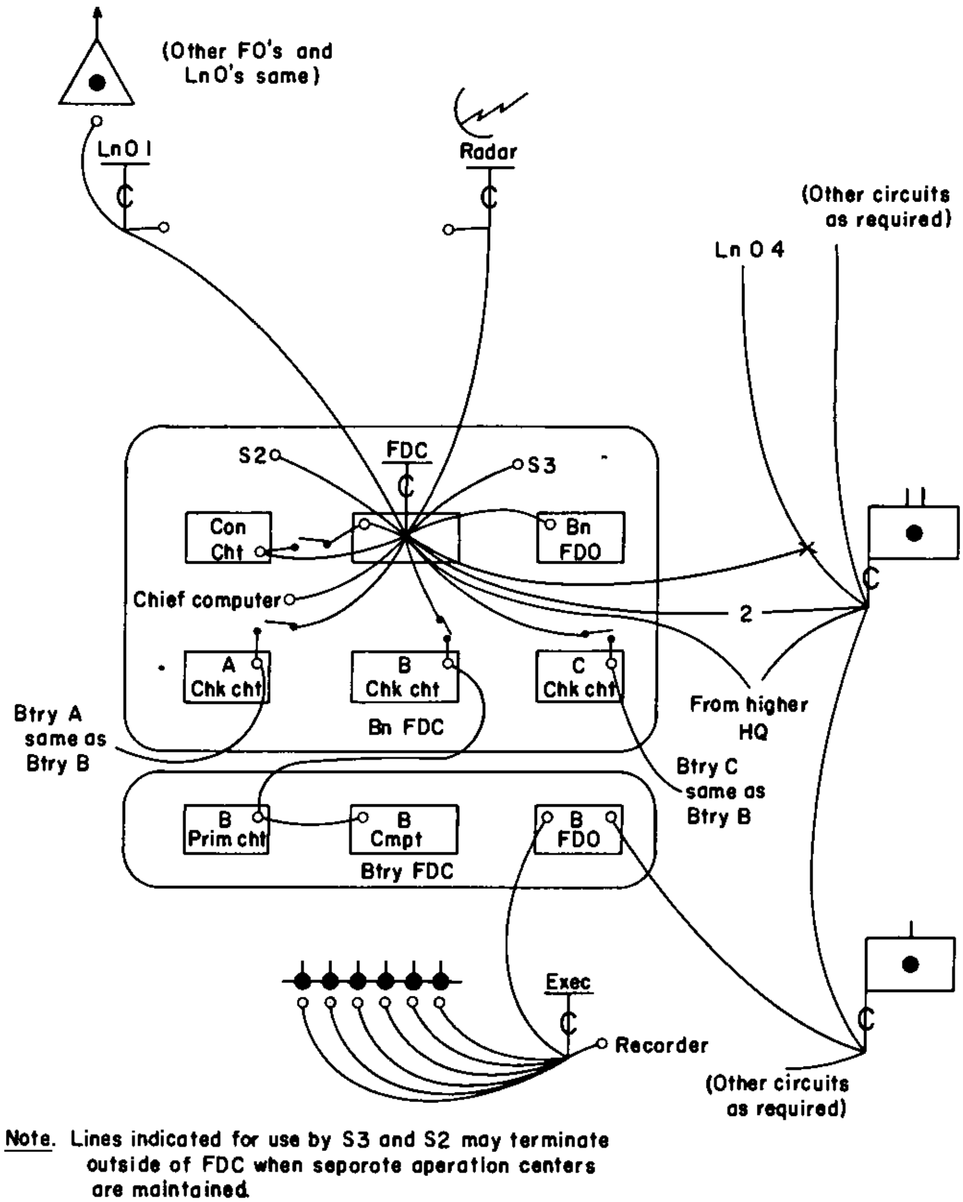


Figure 161. Type battalion wire communication system for conduct of fire.

circuit is extended to the computer's remote control unit.

g. The DPST switch at the control chart operator's position allows the operator to connect into all calls answered by the switchboard operator-computer. It also provides an independent facility to follow a mission when the switchboard operator-computer is processing incoming calls (fig. 162). In the case of multiple missions, the use of his cord and jack provides a facility to handle or monitor multiple missions.

h. The FDC lines from the batteries are normally interconnected at the battalion FDC switchboard. This provides a standing conference circuit for processing battalion missions (fig. 164). This conference connection is maintained at all times in the battalion FDC switchboard. However, it may be disconnected for handling fire missions other than battalion missions. For example, if two missions are processed at the same time, the conference call may be split into two parts (fig. 165). In this example, Batteries B and C remain interconnected on one conference circuit, while Battery A fires alone on the other.

i. The communication plan for the firing battery normally provides for a line from the battery FDO through a connecting and switching kit MX–155/GT at the executive's post to a telephone at

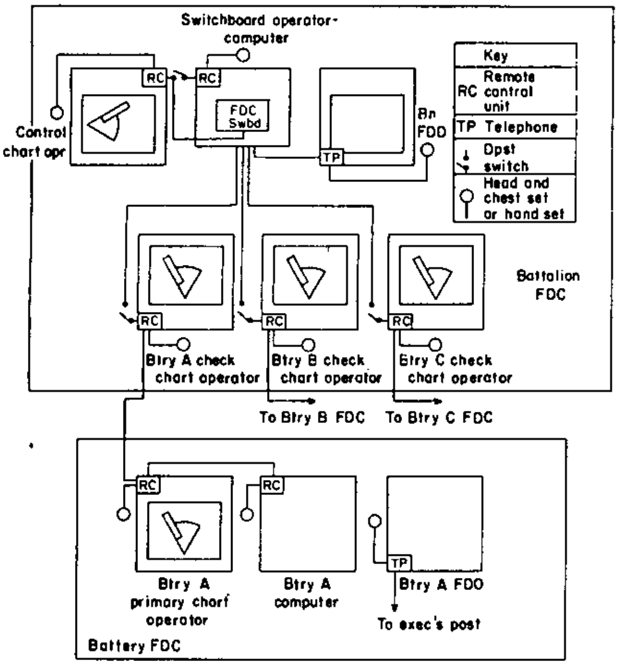


Figure 162. Schematic arrangement of battalion and battery FDC's (check charts at battalion).

each piece. The battery recorder at the executive post will record and repeat back fire commands. The executive or his representative will insure that all pieces receive the correct fire commands. Each chief of section is responsible for connecting his section line into the MX–155/GT. The battery FDC personnel will connect the FDO line to the MX–155/GT.

j. During displacement, normal procedures are followed in the installation of the wire net. Every effort should be made to install the circuits between the battalion FDC switchboard and the battery FDC before or as soon as possible after the position is occupied. Aggressive and timely reconnaissance and detailed prior planning are required for this practice. This practice will reduce traffic on the radio circuits. The battalion FDC maintains control over the fires of the batteries during the displacement, regardless of how it is accomplished, except when a battery is operating independently.

434. Sample Missions

The sample fire missions in *a* through *c* below are given in the sequence which normally occurs when a battalion has displaced and must rely at first on radio communications only. Succeeding missions may be fired in a normal development of communication nets ending in a basic FDC wire net throughout the battalion. Check chart operators are located at battalion FDC. In these missions, the battalion call name is BANNER. The following numbers are used as call signs within the battalion:

Bn FDC	15
Btry A FDC	22
Btry B FDC	42
Btry C FDC	62
Btry A check chart	20
Btry B check chart	40
Btry C check chart	60
Btry A observers	27, 28, 29
Btry B observers	47, 48, 49
Btry C observers	67, 68, 69

a. Mission No. 1. An example of a will adjust mission when fuze VT in effect and radio communication only is used:

Observer: (using primary channel)	BANNER 15, THIS IS BANNER 48, FIRE MISSION, OVER
Radio operator on primary channel:	BANNER 48, THIS IS BANNER 15, SEND YOUR MISSION, OVER

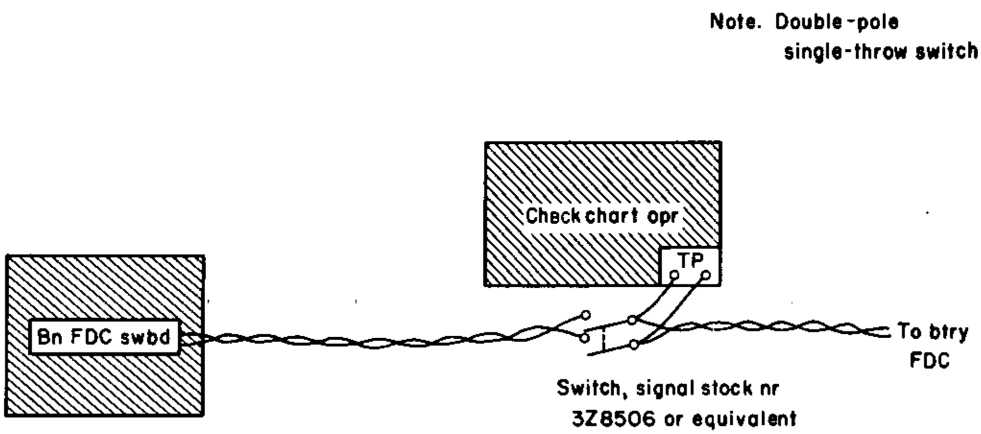


Figure 163. Method of inserting DPST switch.

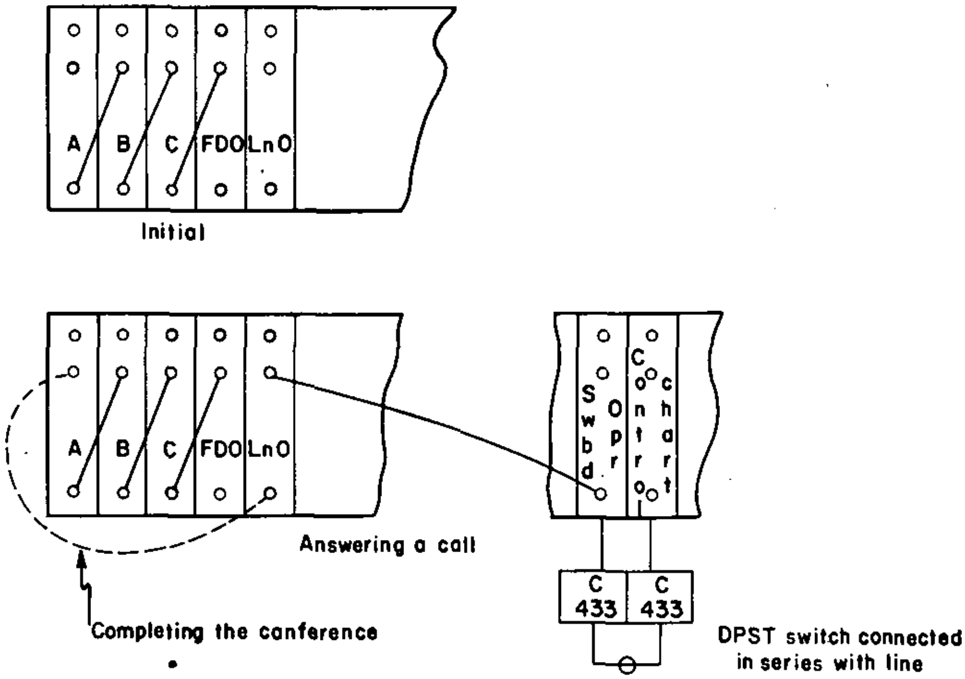


Figure 164. Conference connection.

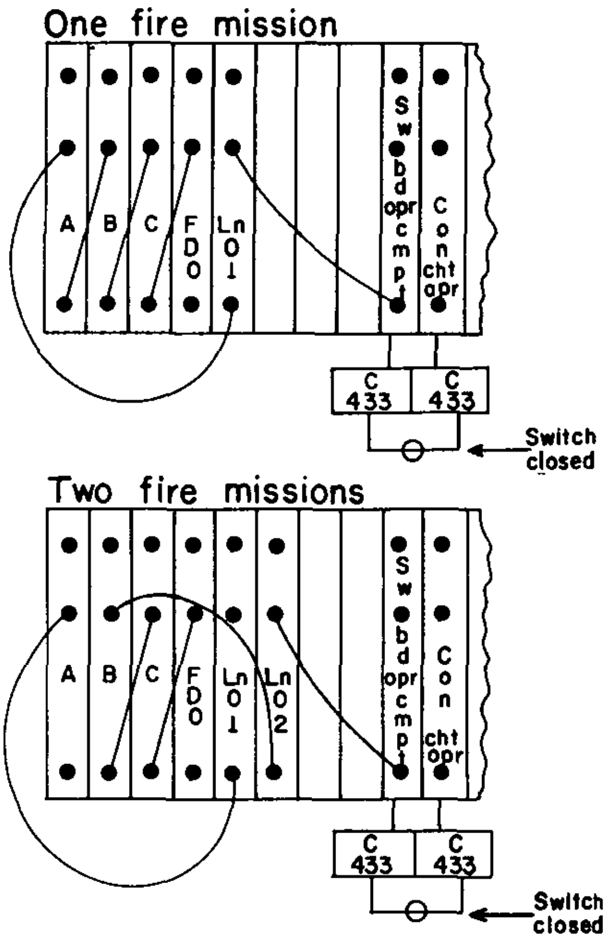


Figure 165. Two simultaneous conference connections.

Observer:	48, COORD 432234, AZ 800, MACHINE GUNS, FZ VT, WA, OVER
(All computers and radio operators on primary channel record fire request.)	
Radio operator on primary channel:	15, COORD 432234, AZ 800, MACHINE GUNS, FZ VT, WA, WAIT------
Control chart operator: (to bn FDO)	ALTITUDE 406
Bn FDO: (recorded and relayed by radio operator on primary channel)	15, ALTITUDE 406, BN, BRAVO, CHG 5, 4 VOLLEYS, CONC AB 406, OVER
Btry B radio operator:	42, ROGER, OVER
Nonadjusting btry radio operators:	22 (62), ROGER, OVER
Observer:	48, ROGER, OVER

Note. The nonadjusting batteries in a predesignated order use the alternate channel to announce and check data, if it is not being used to process another mission. If the alternate channel is being used, nonadjusting batteries use the primary channel after transmissions by the adjusting battery.

Btry B FDO: (to exec)	BA, SH HE, CHG 5, FZ Q, CEN 1 RND, BTRY 4 RND, VT IN EFFECT
Btry B primary chart operator: (recorded by btry computer and relayed by the radio operator)	42, 100/R 22, CORRECTION ZERO, DF 2965, SITE PLUS 3, EL 253, OVER

Btry B check chart operator: (relayed by radio operator on the primary channel)	40, CHECK
Btry B computer:	SITE 303
Btry B FDO: (to exec)	CORRECTION ZERO, DF 2965, SITE 303, EL 253

Note. The FDO does not wait before sending data to the exec post. FDO sends each element as soon as it is available, except that elevation is always the last element transmitted.

Btry B recorder: (reads back)	CORRECTION ZERO, DF 2965, SITE 303, EL 253
Btry B exec: (to pieces)	FIRE
Btry B radio operator:	42, ON THE WAY, OVER
Observer:	48, ROGER, WAIT—48, R200, ADD 400, OVER
Btry B radio operator:	42, R200, ADD 400, WAIT—
Btry B primary chart operator: (recorded by computer and relayed by radio operator)	42, DF 3018, EL 279, OVER
Btry B check chart operator: (relayed by radio operator on the primary channel)	40, CHECK
Btry B FDO: (to exec)	DF 3018, EL 279
Btry B recorder: (reads back)	DF 3018, EL 279
Btry B exec: (to pieces)	FIRE
Btry B radio operator:	42, ON THE WAY, OVER
Observer:	48, ROGER, WAIT------48, L100, DROP 200, OVER
Btry B radio operator:	42, L100, DROP 200, WAIT------
Btry B primary chart operator: (relayed by radio operator)	42, DF 2992, EL 266, OVER
Btry B check chart operator: (relayed by radio operator on the primary channel)	40, CHECK
Btry B FDO: (to exec)	DF 2992, EL 266
Btry B recorder: (reads back)	DF 2992, EL 266
Btry B exec: (to pieces)	FIRE
Btry B radio operator:	42, ON THE WAY, OVER
Observer:	48, ROGER, WAIT------48, R50, ADD 100, OVER
Btry B radio operator:	42, R50, ADD 100, WAIT------
Btry B primary chart operator: (relayed by radio operator)	42, DF 3007, EL 272, OVER
Btry B check chart operator: (relayed by radio operator on primary channel)	40, CHECK
Btry B FDO:	DF 3007, EL 272
Btry B recorder: (reads back)	DF 3007, EL 272
Btry B exec: (to pieces)	FIRE
Btry B radio operator:	42, ON THE WAY, OVER
Observer:	48, ROGER, WAIT------48, ADD 50, FFE, OVER
Btry B radio operator:	42, ADD 50, FFE, WAIT----
Btry B FDO: (to exec)	FZ VT, BTRY 4 RND
Btry B primary chart operator: (recorded by computer and relayed by radio operator)	42, DF 3015, TI 17.0, EL 274, OVER
Btry B check chart operator: (relayed by radio operator on primary channel)	40, CHECK

Note. Battery B computer uses the previously announced 100/R and multiplies it by the HB/R factor (0.2). The product is the height of burst correction and is added to the site previously commanded. This computation is checked by the FDO.

Btry B computer:	SITE 307
Btry B FDO: (to exec)	DF 3015, SITE 307, TI 17.0, EL 274
Btry B recorder: (reads back)	DF 3015, SITE 307, TI 17.0. EL 274
Btry B exec: (to pieces)	FIRE
Btry B radio operator:	42, FIRING FOR EFFECT, OVER
Observer:	48, ROGER, OVER
Nonadjusting btry radio operators:	22 (62), FIRING FOR EFFECT, OVER

Note. Each battery fires for effect when it is ready.

Btry B exec: (to FDC)	ROUNDS COMPLETE
Btry B FDO: (aloud)	ROUNDS COMPLETE
Btry B radio operator:	42, ROUNDS COMPLETE, OVER
Nonadjusting btry radio operators:	22 (62), ROUNDS COMPLETE, OVER
Chief computer: (relayed by radio operator on primary channel)	15, BATTALION ROUNDS COMPLETE, OVER
Observer:	48, ROGER, WAIT------48, END OF MISSION, MACHINE GUNS SILENCED, OVER
Chief computer: (relayed by radio operator on primary channel)	15, ROGER, OUT

b. Mission No. 2. An example of an adjustment mission when fuze time is used and observer is using radio; wire is used between the battalion FDC and the batteries—a conference circuit is set up on the switchboard interconnecting the batteries.

Observer: (on primary channel)	BANNER 15, THIS IS BANNER 48, FIRE MISSION, OVER
All check chart operators: (to their batteries)	FIRE MISSION

Note. All check chart operators normally leave switches open when their batteries are not firing. They now close their switches, bringing their batteries into the established conference circuit.

Radio operator on primary channel:	BANNER 48, THIS IS BANNER 15, SEND YOUR MISSION, OVER
Observer:	48, FROM REG PT 1, AZ 800, DOWN 20, ADD 800, MACHINE GUNS, FZ TI, WA, OVER

Note. Switchboard operator-computer and radio operator record. Radio operator repeats back the fire request.

Control chart operator: (to bn FDO)	ALTITUDE 406
Bn FDO: (into conference circuit relayed by radio operator to the observer)	15, ALTITUDE 406, BN, BRAVO, CHG 5, 4 VOLLEYS, CONC AB 407, OVER
Btry B computer: (by wire)	42, ROGER, OVER
Nonadjusting btry computers: (by wire)	22 (62), ROGER, OVER
Observer:	48, ROGER, OVER

Note. The nonadjusting battery check chart operators switch themselves and their battery FDC's out of the conference circuit to develop and check data for their own batteries.

Btry B FDO: (to exec)	BA, SH HE, CHG 5, FZ TI, CEN 1 RND
Btry B primary chart operator:	42, 100/R 23, CORRECTION L2, DF 2965, SITE PLUS 3, TI 15.7, EL 253, OVER
Btry B check chart operator:	40, CHECK
Btry B computer:	SITE 308

Note. The computer uses the 100/R for the initial range and computes the necessary site change, which he enters on the computer's record, together with the other firing data announced by the primary chart operator.

Btry B FDO: (to exec)	CORRECTION L2, DF 2965, SITE 308, TI 15.7, EL 253
Btry B recorder: (reads back)	CORRECTION L2, DF 2965, SITE 308, TI 15.7, EL 253
Btry B exec: (to pieces)	FIRE
Btry B radio operator:	42, ON THE WAY, OVER
Observer:	48, ROGER, WAIT______48, R200, UP 40, ADD 400, OVER
Btry B radio operator: (while computer records)	42, R200, UP 40, ADD 400, WAIT______
Btry B primary chart operator:	42, DF 3018, TI 17.2, EL 279, OVER
Btry B check chart operator:	40, CHECK
Btry B computer:	SITE 317

Note. The FDO takes the data as determined and immediately announces them in the proper sequence. The FDO checks the computer's computation of site.

Btry B FDO: (to exec)	DF 3018, SITE 317, TI 17.2, EL 279
Btry B recorder: (reads back)	DF 3018, SITE 317, TI 17.2, EL 279
Btry B exec: (to pieces)	FIRE
Btry B radio operator:	42, ON THE WAY, OVER
Observer:	48, ROGER, WAIT______48, L100, DOWN 20, DROP 200, OVER
Btry B radio operator:	42, L100, DOWN 20, DROP 200, WAIT______
Btry B computer:	SITE 312
Btry B primary chart operator:	42, DF 2992, TI 16.4, EL 266, OVER
Btry B check chart operator:	40, CHECK
Btry B FDO: (to exec)	DF 2992, SITE 312, TI 16.4, EL 266
Btry B recorder: (reads back)	DF 2992, SITE 312, TI 16.4, EL 266
Btry B exec: (to pieces)	FIRE
Btry B radio operator:	42, ON THE WAY, OVER
Observer:	48, ROGER, WAIT______48, R50, ADD 100, OVER
Btry B radio operator:	42, R50, ADD 100, WAIT____
Btry B primary chart operator:	42, DF 3007, TI 16.8, EL 272, OVER
Btry B check chart operator:	40, CHECK
Btry B FDO: (to exec)	DF 3007, TI 16.8, EL 272
Btry B recorder: (reads back)	DF 3007, TI 16.8, EL 272
Btry B exec: (to pieces)	FIRE
Btry B radio operator:	42, ON THE WAY, OVER
Observer:	48, ROGER, WAIT______ 48, ADD 50, FFE, OVER
Btry B radio operator:	42, ADD 50, FFE, WAIT____
All btry FDO's: (to exec)	BTRY 4 ROUNDS
Btry B primary chart operator:	42, DF 3015, TI 16.9, EL 274, OVER
Btry B check chart operator:	40, CHECK

Note. At this time, the nonadjusting battery check chart operators switch out of the conference circuit to develop and check fire for effect data for their own batteries. Each battery fires for effect when it is ready.

Btry B FDO: (to exec)	DF 3015, TI 16.9, EL 274
Btry B recorder: (reads back)	DF 3015, TI 16.9, EL 274
Btry B exec: (to pieces)	FIRE
Btry B radio operator and computer:	42, FIRING FOR EFFECT, OVER
Observer:	48, ROGER, OVER

Note. At this time, the nonadjusting battery check chart operators, having checked data produced by their battery FDC's, switch back into the battalion conference circuit.

Nonadjusting btry computers:	22 (62), FIRING FOR EFFECT, OVER
Btry B FDO: (aloud)	ROUNDS COMPLETE
Btry B computer:	42, ROUNDS COMPLETE, OVER
Nonadjusting btry computers:	22 (62), ROUNDS COMPLETE, OVER
Chief computer: (relayed by radio operator on primary channel)	15, BATTALION ROUNDS COMPLETE, OVER

Observer:	48, ROGER, WAIT______ 48, END OF MISSION, MACHINE GUNS SILENCED, OVER
Radio operator on primary channel: (relayed on wire net by switchboard operator-computer)	15, ROGER, OUT

c. Mission No. 3. An example of a will adjust mission when all wire communication is used. A 105-mm howitzer battalion and a common GFT setting are used in executing this mission.

Switchboard operator-computer: (answering call)	THIS IS BANNER 15, OVER
Observer:	BANNER 15, THIS IS BANNER 48, FIRE MISSION, OVER

Note. The switchboard operator arranges the switchboard so that the battalion FDO, the operator, the observer, the control chart operator, and all check chart operators are in conference circuit (fig. 164).

Switchboard operator-computer: (aloud)	FIRE MISSION
All check chart operators: (to their batteries)	20 (40) (60), FIRE MISSION, OVER

Note. All check chart operators now close their switches to get into the established conference circuit.

Switchboard operator-computer:	15, SEND YOUR MISSION, OVER
Observer:	48, FROM REG PT 2, AZ 3200, R400, UP 20, ADD 800, 4 ACTIVE ARTY PIECES, FZ D, WA, OVER
Switchboard operator-computer:	15, FROM REG PT 2, AZ 3200, R400, UP 20, ADD 800, 4 ACTIVE ARTY PIECES, FZ D, WA, WAIT______
Control chart operator: (to bn FDO)	ALTITUDE 400
Bn FDO:	ALTITUDE 400, BN, BRAVO, USE REG PT 2, LOT Y, CHG 5, 3 VOLLEYS, CONC AB 201, OVER
Btry B computer:	42, ROGER, OVER
Nonadjusting btry computers: (record and receipt for fire order)	22 (62), ROGER, OVER
Observer:	48, ROGER, OVER

Note. Nonadjusting battery check chart operators switch themselves and their battery FDC's out of conference circuit. As soon as determinable from elements of the fire request and the battalion fire order, battery FDO's begin transmission of commands.

Btry B FDO: (to exec)	BA, SH HE, LOT Y, CHG 5, FZ D, CEN 1 RND
Btry B primary chart operator: (to his FDO, computer, and check chart operator)	42, CORRECTION R4, DF 1964, SITE PLUS 8, EL 324, OVER
Btry B computer:	SITE 308
Btry B FDO: (to exec)	CORRECTION R4, DF 1964, SITE 308, EL 324
Btry B recorder: (reads back)	CORRECTION R4, DF 1964, SITE 308, EL 324

Note. Each element is sent by the FDO immediately as it is determined. The deflection correction is set on the gunner's aid of each piece.

Btry B check chart operator:	40, CHECK
Btry B exec: (to pieces)	FIRE
Nonadjusting btry FDO's: (to exec)	BA, SH HE, LOT Y, CHG 5, FZ D, BTRY 3 RND, DNL
Nonadjusting btry primary chart operators: (to their FDO's, check chart operators, and computers)	22 (62), CORRECTION____, DF____, SITE____, EL____, OVER
Nonadjusting btry check chart operators:	20 (60), CHECK

Note. After nonadjusting battery check chart operators announce CHECK, they switch into the battalion conference circuit and follow the adjustment on the battalion conference circuit.

Btry B computer:	42, ON THE WAY, OVER
Observer:	48, ROGER, WAIT______ 48, L100, ADD 400, OVER
Btry B computer:	42, L100, ADD 400, WAIT______
Btry B primary chart operator:	42, DF 1996
Btry B FDO: (to exec)	DF 1996
Btry B check chart operator:	40, WRONG, DF 1985, OVER
Btry B primary chart operator:	42, WRONG, DF 1985, OVER

Note. All personnel concerned take whatever steps are necessary to resolve the discrepancy and determine the correct data. Both battalion and battery FDO's make all necessary independent checks, to locate errors in plotting or reading on their respective charts, and communicate with each other as required to resolve the discrepancy and come to agreement on the correct data.

Btry B primary chart operator: (having discovered that he had plotted the target needle left 200 rather than left 100. FDO has confirmed this)	42, CORRECTION, DF 1986, EL 362, OVER
Btry B FDO: (to exec)	CORRECTION, DF 1986, EL 362
Btry B recorder: (reads back)	CORRECTION, DF 1986, EL 362

Btry B check chart operator: (primary and check chart operator's data now check within prescribed tolerances)	40, CHECK
Btry B exec: (to pieces)	FIRE
Btry B computer:	42, ON THE WAY, OVER
Observer:	48, ROGER, WAIT------48, DROP 50, FFE, OVER
Btry B computer:	42, DROP 50, FFE, WAIT ------
All btry FDO's: (to exec)	BTRY 3 RND
Btry B primary chart operator:	42, DF 1950, EL 357, OVER
Btry B FDO: (to exec)	DF 1950, EL 357
Btry B recorder: (reads back)	DF 1950, EL 357
Btry B check chart operator:	40, CHECK

Note. Nonadjusting battery check chart operators switch out of conference circuit.

Btry B exec: (to pieces)	FIRE
Nonadjusting btry primary chart operators:	DF_____, EL_____, OVER
Nonadjusting btry FDO's: (to exec)	DF_____, EL_____
Nonadjusting btry recorders: (read back)	DF_____, EL_____
Nonadjusting btry check chart operators:	20 (60), CHECK

Note. Each nonadjusting battery check chart operator now closes his switch so that the battery computer can announce over the battalion conference circuit when his battery is firing for effect.

Btry B computer:	42, FIRING FOR EFFECT, OVER
Observer:	48, ROGER, OVER
Btry B exec: (to FDC)	ROUNDS COMPLETE
Btry B computer:	42, ROUNDS COMPLETE, OVER
Nonadjusting btry computers:	22 (62), ROUNDS COMPLETE, OVER
Switchboard operator-computer:	15, BATTALION ROUNDS COMPLETE, OVER
Observer:	48, ROGER, WAIT------48, END OF MISSION, 10 CASUALTIES, ARTY PIECES SILENCED, OVER
Switchboard operaror-computer:	15, ROGER, OUT

Note. All battery computers report ammunition expenditure and receive replot information as applicable. When artillery pieces can be observed, initial neutralization may be followed by a destruction mission to destroy materiel (par. 547).

CHAPTER 21

OBSERVED FIRING CHARTS

Section I. INTRODUCTION

435. General

Immediate delivery of supporting fire must not be delayed by an incomplete survey or lack of suitable maps for a firing chart. When such conditions exist, an *observed firing chart* is constructed. An observed firing chart is normally a grid sheet, on which the relative locations of the battery position(s) and targets are established by the adjustment of fire.

436. Construction of Chart

a. On a battery observed firing chart, the battery center is assigned arbitrary coordinates and altitude; e. g., coordinates 20004000, altitude 400 yards. The grid sheet is appropriately numbered according to the general direction of fire, and a deflection index is constructed at the azimuth on which the battery was laid. The relative locations of the battery and target can now be established by the adjustment of fire (fig. 166). To fire the initial round, the FDO must select an azimuth to the center of the observer's sector and a range that will be positively safe for friendly forces. To assist the observer in picking up the first round, WP, colored smoke or a high air burst may be fired. FDC procedures during adjustment are the same as those for a surveyed firing chart.

b. On a battalion observed firing chart, a registration point is assigned arbitrary coordinates and altitude. The grid sheet is appropriately numbered. The battery locations are backplotted from the registration point based on battery adjustments thereon (par. 439).

c. In determining data to plot the chart location of targets fired with percussion fuze, every effort must be made to determine, or reasonably approximate, the site. Weather and VE corrections must be applied. Assuming that site is zero and failing to correct for weather and VE will result in the poorest type of observed firing chart. Frequently, site can be obtained from a small-scale map used in conjunction with the chart. Also, site can be computed by using the mil relation. For computation purposes, vertical angles can be measured with a battery commander's telescope or aiming circle and distances can be estimated. When site cannot be accurately determined, even a rough approximation will improve data for plot.

(1) If site and weather corrections cannot be obtained, targets are polar-plotted on the chart from the battery position(s). The direction corresponding to the adjusted deflection, a range corresponding

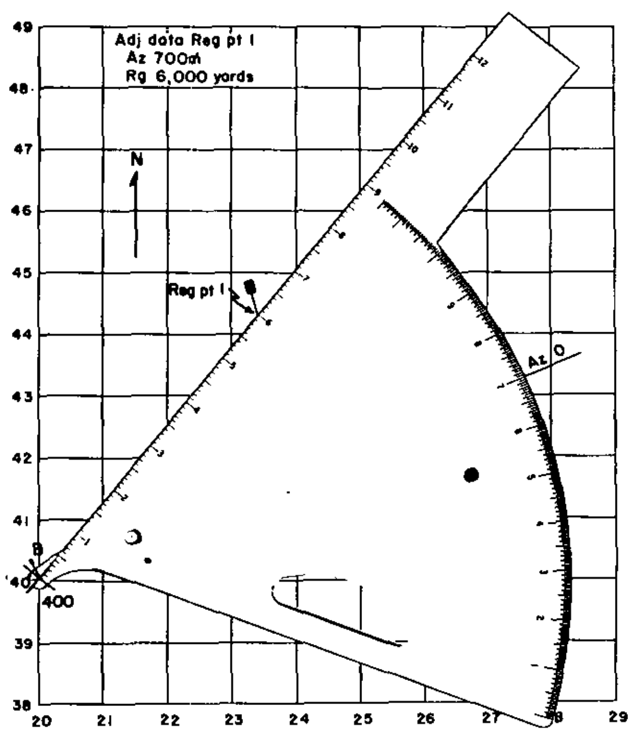


Figure 166. Polar-plotting registration point and/or targets on an observed firing chart.

to the adjusted quadrant elevation, and the adjusting battery altitude are used for the polar-plot.

(2) When site is used, targets are plotted at a range corresponding to the adjusted elevation. The target altitudes are determined by applying the vertical intervals algebraically to the altitude of the adjusting battery.

d. Adjustment of time fuzed shell permits derivation of the site. Thus the error that results from assuming that site is zero (*c* above) is reduced. Site is computed by comparing the elevation corresponding to the adjusted time (less any time correction) with the adjusted quadrant elevation. The difference is the site. Targets fired with time fuzed shells are replotted in the same manner as those fired with percussion fuzed shells except that plot range corresponds to the adjusted time instead of the adjusted elevation. The relative altitude of a target is determined by computing the vertical interval and applying it to the assumed altitude of the adjusting battery. (The plot range and the derived site are used to compute the vertical interval.)

e. As long as weather, materiel, and ammunition remain constant, any previously fired concentration may be refired by using the previously determined adjusted data. As conditions change, subsequent fires will not be accurate unless corrections for the effect of the change are determined and applied.

(1) The method of determining plot ranges in *c* and *d* above ignores the effect of nonstandard conditions. If the met and/or VE range effect are known or can be estimated, based on an experience range correction, a GFT setting (pars. 343 and 344) should be established for the range to the approximate center of the sector. This GFT setting strips out any known range or time correction. It is used to determine the range corresponding to the adjusted elevation.

(2) To measure subsequent ballistic changes, registrations are conducted as required, by using different ammunition lots, fuzes, and charges; and a deflection-correction scale is constructed with zero correction at registration point range. The deflection and range at which the registration point is first plotted in relation to the battery center become chart data.

Note. Unless a battery is operating independently, the battalion observed firing chart normally will be constructed after the first registration (pars. 438–449). Corrections for other types of ammunition or to compensate for weather changes determined by later registrations are determined by comparing chart data with adjusted data.

(3) A correction for a GFT setting cannot be obtained from an initial registration. Therefore, it is not possible to improve on plot of targets replotted prior to a registration other than for difference in drift. It is not necessary to replot for this 1- or 2-mil drift variation. If known corrections were included in the GFT setting used for registration and were not stripped from data for replot for targets replotted prior to registration, it will be necessary to again replot those targets.

437. Fire Direction Procedures

a. FDC procedures used with an observed firing chart are generally the same as FDC procedures used with a surveyed firing chart. The target grid may be oriented over any convenient point in the target area which will allow plotting of the observer's corrections. Centering the target grid on a north-south grid line will eliminate the need for drawing an azimuth index.

b. A deflection index is constructed for each battery. The index corresponds to the adjusted deflection after a registration (fig. 167).

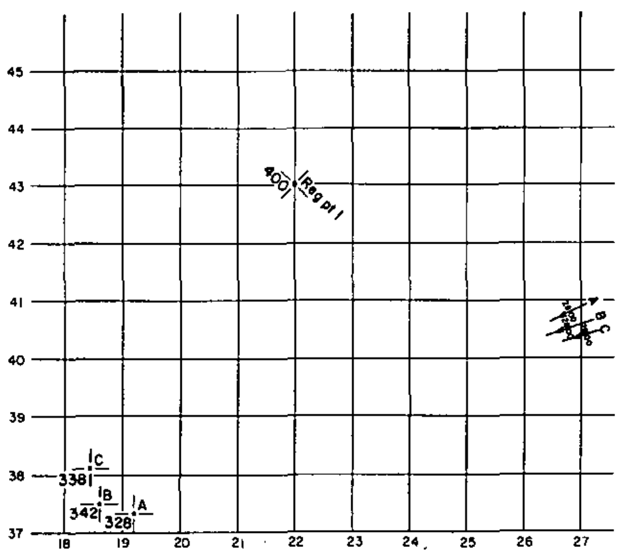


Figure 167. Observed firing chart with three batteries plotted.

c. A deflection correction scale is constructed for use with all observed firing charts in the same manner as for a surveyed firing chart (pars. 348 and 349). The use of deflection correction in replotting target locations compensates for changes in drift and will facilitate transferring from an observed firing chart to a surveyed firing chart.

Section II. BATTALION OBSERVED FIRING CHARTS—PERCUSSION PLOT

438. General

a. The battalion observed firing chart is based on the concept that points located relative to a common point are located relative to each other. Accordingly, after each firing battery has registered on a common point, its relative location to that point is polar-plotted on the battalion chart by using the distance and direction determined from the registration (fig. 168). Thereafter, the fires of all batteries of the battalion may be massed on any target located by the adjustment of fire of any one of the firing batteries; however, transfer to a surveyed firing chart should be accomplished as soon as possible.

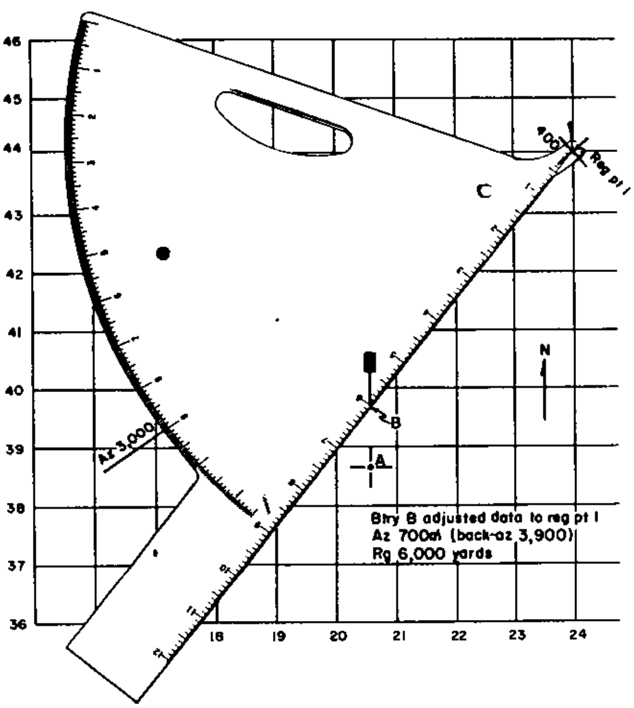


Figure 168. Polar-plotting batteries on a battalion observed firing chart.

b. To aid in deriving site, time fuze should be used in the registration. However, when height of burst probable error is excessive (par. 31) or time fuze is not available, fire may be massed by using an observed firing chart based on an impact registration.

439. Construction of Percussion Observed Firing Chart

The procedure for constructing a battalion percussion observed firing chart is as follows:

a. All batteries are registered on a common registration point. The point should be located, if possible, in the center of the sector of fire.

b. Arbitrary coordinates (a grid intersection is preferred) and altitude are assigned to the selected registration point.

c. The grid sheet on which the registration point is plotted should be numbered appropriately for the general direction of fire. Coordinates are assigned to the registration point.

d. The adjusted firing data, including orienting angle when possible, are determined by each battery. The data are reported to the battalion FDC.

e. Each battery center is plotted in relation to the common registration point at the battalion FDC. Direction and distances as determined from the report of adjusted data are used.

440. Determination of Direction for Polar Plotting

a. The direction of fire as determined from registration is included in the report of adjusted data from the firing batteries. This direction is derived either by measuring the adjusted azimuth or by computing the adjusted azimuth by using the measured adjusted orienting angle and the azimuth of the orienting line(s). Of the two methods, computation by using the orienting line is the more accurate. The battalion FDC personnel convert the reported adjusted azimuth to a back-azimuth. They locate the batteries for direction by polar plotting from the registration point.

b. When an orienting line has not been established, the adjusted azimuth must be measured on completion of the registration. This is the least desirable method of determining direction in that 3 different aiming circles are used in 3 different locations. An example of data for plotting direction is shown below:

Btry	Adj az	Az for polar plot (back-az)
A	1, 965	5, 165
B	1, 830	5, 030
C	1, 685	4, 885

c. When an orienting line has been established, the orienting angle for each battery is measured after registration. The azimuth of fire is computed from the azimuth of the orienting line. (Az of OL—orienting angle=az of fire.) An example of determining data for plot is shown below:

Element	Battery A	Battery B	Battery C
Azimuth of OL	1, 790	1, 430	1, 230
Adj orienting angle	1, 736	1, 240	918
Firing az (az OL—adj orienting angle)	54	190	312
Az for polar plotting (back-az)	3, 254	3, 390	3, 512

d. In the absence of surveyed data for direction, the azimuth of the OL('s) may be established by using the magnetic needle of a properly declinated aiming circle. The azimuth must be determined with 1 and *only 1* aiming circle. If the orienting line is not common to all batteries, the azimuth determined by the one instrument must be carried by directional traverse to all OL's. Thus, the error introduced by one magnetic needle will be common to all batteries.

e. If the firing azimuth is computed from the orienting line and the orienting angle (measured after registration), the adjusted azimuth is measured and used as a check on the computed azimuth. Also, the difference between the adjusted and the initial deflection can be applied to the initial azimuth and orienting angle as a check on the measured azimuth and orienting angle.

441. Determination of Range and Altitude for Polar Plotting

a. When sites to the registration point are unknown or cannot be approximated, each battery is polar-plotted from the registration point. The back-azimuth of the direction of fire and a range corresponding to the adjusted quadrant elevation (adj QE) are used in polar-plotting. Since sites are unknown (assumed to be zero), the same altitude which is arbitrarily assigned to the registration point is also assigned to each battery. An example of determining range and altitude for a 105-mm howitzer, charge 5, sites unknown, is shown below:

Battery	Adj QE	Range for polar plotting*	Altitude**
A	283	4,960 yards	400 yards
B	267	4,730 yards	400 yards
C	297	5,140 yards	400 yards

*Range corresponds to adjusted quadrant elevation.
**Same altitude as registration point.

b. The ranges determined in the example in *a* above include an error equal to the sites involved, nonstandard conditions, and velocity error of pieces. Battalion fires cannot be massed satisfactorily, except in the immediate vicinity of the registration point, unless there is little or no difference in altitude between the batteries. The chart may be improved by assuming the site to be zero for the center battery and estimating the difference in altitude between the center battery and each of the flank batteries to determine relative sites.

c. Observed firing chart accuracy can be greatly improved if altitudes or relative altitudes can be determined (par. 444*c*). If altitudes can be determined, range for plot is determined as follows:

(1) The altitudes of the battery and registration point are determined.
(2) From these altitudes the vertical intervals (VI) are determined.
(3) The range corresponding to adjusted QE is determined.
(4) Site is computed by using range corresponding to adjusted QE and VI.
(5) Adjusted elevation (QE—site) is determined.
(6) Range corresponding to adjusted elevation is determined.
(7) By using range corresponding to adjusted elevation, site is recomputed and new adjusted elevation is determined.
(8) If site computed in (7) above agrees within 1 mil with site computed in (4) above, the battery is plotted at the range corresponding to the last adjusted elevation.
(9) If the 2 sites disagree by more than 1 mil, successive approximation is continued until the last 2 sites computed agree within 1 mil; the battery is then plotted at the range corresponding to the last computed adjusted elevation.

d. An example of determining range for a 105-mm howitzer, charge 5, altitude known, is shown below (alt reg pt 1, 472 yards):

Element	*Battery* *A*	*B*	*C*
Altitude in yards (small-scale map)	400	414	410
Vertical interval in yards	+72	+58	+62
Adjusted QE	283	267	297
Range corresponding to adjusted QE	4, 960	4, 730	5, 150
First apparent site (GST: VI/Rg corresponding to adjusted QE)	+16	+14	+14
First apparent adjusted elevation (QE-apparent site)	267	253	283
Range corresponding to apparent adjusted elevation	4, 740	4, 530	4, 960
Second apparent site (GST: VI/Rg corresponding to apparent elevation)*	+17	+14	+14
Adjusted elevation**	266	253	283
Range plotted	4, 720	4, 530	4, 960

*Agrees within 1 mil of last apparent site and is used as the corrected site.
**Adjusted elevation corresponds to quadrant elevation minus corrected site.

442. Application of Known Corrections

a. The observed firing chart can be improved in situations in which the met and/or VE range effect are known (or can be estimated, based on an experience range correction) by establishing a GFT setting to obtain the range corresponding to the adjusted elevation (or quadrant elevation if sites are unknown). An example of determining a GFT setting for a 105-mm howitzer battery, charge 5, firing at a range of 5,000 yards, is shown below (met and VE are known):

Elevation for range 5,000 yards	=286 mils
Met range effects (elevation 286)	= −300 yards
VE range effects	= −100 yards
Range plus range effects (5000+(−400))	=4600 yards
GFT____: Charge 5, lot____, rg 4,600, el 286	

b. Plot ranges for batteries are determined after the GFT setting is placed on the cursor of the fan (window of the GFT). The elevation gage-line is placed over the adjusted elevation and the plot range is read under the hairline.

Section III. BATTALION OBSERVED FIRING CHART—TIME PLOT

443. General

The major source of errors in an observed firing chart established with percussion fuze is the inclusion of a false site. False site introduces an error which may be very large. Such an error may prevent satisfactory massing of fires when the batteries are widely separated in range and altitude. The use of a time plot observed firing chart minimizes errors due to false site. It also provides more accurate and effective delivery of time fire. It is limited only by availability and range limitations of the time fuze. When setting up a time plot observed firing chart, care in selecting the charge will greatly reduce height of burst dispersion errors. Thus the accuracy of the chart (par. 438) is further increased. The nearer the actual site can be determined, the nearer the observed firing chart approaches the accuracy of the surveyed chart.

444. Construction of Time Plot Observed Firing Chart, Site Unknown

A time plot observed firing chart, site unknown, is constructed in the same manner as a percussion plot observed firing chart (par. 439) except for the determination of range for polar plotting the battery positions and the determination of altitude.

a. The batteries are back-plotted from the registration point for direction. Deflection indexes are drawn as on any other observed firing chart.

b. The range for polar plotting battery positions corresponds to adjusted time (except when large angles of site are involved (par. 448)) less any known time correction.

c. Since site can be derived from a time registration, the relative altitude of each battery can be established in relation to the registration point.

(1) Site is determined by comparing the elevation corresponding to the adjusted time (less known time corrections) with the adjusted quadrant elevation. The difference is the derived site.

(2) The relative altitude of each battery is determined by computing the vertical intervals, based on the derived registration point ranges (*b* above) and the derived sites, and applying these to the assumed altitudes of the registration point.

d. For example, the batteries of a 105-mm howitzer battalion are registered on a registration point with time fuzed shell, *charge 5*, and FDO's report the following adjusted data: (Deflection data have been omitted for simplicity.)

Btry	Adj ti	Adj QE
A	17.0	289
B	17.6	295
C	16.3	278

(1) Determination of plot data:

Btry	Range for polar plotting corresponds to adj ti	Adj el corresponds to adj ti*	Site (QE–El)	Alt**
A	4,850	275	+14	439
B	4,990	285	+10	456
C	4,680	264	+14	441

* Time correction is not known.
** Altitude of registration point: 500 yards.

(2) In computing the altitude of a battery, if the site is plus, the battery is below the registration point; if site is minus, the battery is above the registration point.

445. Application of Known Corrections

In constructing a time plot observed firing chart, failure to apply known time or range corrections will result in false battery locations and will limit accuracy in massing fire. Time and range corrections are absorbed in a false site. When average or specific time corrections are not known, they are assumed to be zero. Range corrections, when not known, may be estimated, based on weapon VE and existing weather conditions. Known corrections must be stripped from the adjusted data before site is derived. Use of a GFT setting will, in effect, strip out known time and range corrections included in the adjusted data.

a. An example of determining a GFT setting for an observed firing chart based on weather and knowledge of velocity errors for a 105-mm howitzer, charge 4, firing at an estimated range to registration point of 4,000 yards, is shown below:

Elevation for range 4,000	=302 mils
Met range effects (elevation 302)	= −400 yards
VE range effects	= −100 yards
Range plus range effects (4,000+(−500))	=3,500 yards
Time corresponding to elevation 302	=16.1 seconds

GFT_____: Chg 4, lot_____, rg 3,500, el 302, ti 16.1

b. Plot ranges and adjusted elevations for batteries are determined after the GFT setting is placed on the cursor of the GFT fan (GFT). The time gageline (corresponds to elevation gageline when no time correction is known) is placed over the adjusted time and the plot range is read under the hairline and the adjusted elevation under the elevation gageline.

c. If an average time correction is known, the time gageline is constructed over the corrected time; i. e., time corresponding to the corrected elevation plus the time correction. In the example in *a* above with a time correction of +0.2 second, GFT time gageline would be constructed at time 16.3 (16.1+0.2). Plot ranges and adjusted elevations are then determined as indicated in *b* above.

446. Construction of Time Plot Observed Firing Chart—Site Known

a. Although an approximate site can be derived through the use of time fire, a time plot observed firing chart is greatly improved if the site to the registration point for one or all batteries can be determined. If at all possible, the site for each battery to the registration point should be determined or at least approximated. Approximate sites may be determined from a small-scale map, by computation with instruments, or by firing an executive's high burst (par. 447).

b. When site is known, the chart is constructed the same as when sites are unknown except for the determination of altitudes of the batteries. The procedure for determining altitude of each battery is as follows:

(1) The adjusted elevation for the battery(ies) whose site is known is determined by subtracting the known site from the adjusted quadrant elevation and the GFT setting(s) is determined. Registration point range corresponds to the adjusted time (less any known time correction).

(2) If no time correction is known, the hairline will be the range gageline and also the time gageline since range is determined from the adjusted time.

(3) The relative altitude of each battery is determined by computing the vertical intervals, based on the derived registration point range and the known sites, and applying these to the assumed altitude of the registration point.

(4) If the site for only one battery is known, the adjusted data of that battery are used to establish a common GFT setting. To determine the *relative site* for the other two batteries (using the common

GFT setting), the hairline is moved to the adjusted time for the battery concerned. The elevation is read under the elevation gageline. This elevation is subtracted from the adjusted quadrant elevation. The remainder is the derived site for the battery concerned. The relative altitude of each battery is then determined as in (3) above.

c. An example of determining GFT settings when sites are known for all batteries:

(1) Situation: All 3 batteries of a 105-mm howitzer battalion have been registered on a registration point at an altitude of 500 yards. Charge 5 and fuze time and southeast direction of fire were used. Azimuth of OL: 4,072.

Adjusted data include—

Btry	*Orienting angle*	*QE*	*Time*	*Site**
A	1, 599	316	18. 5	+5
B	1, 735	291	17. 4	0
C	1, 815	289	16. 6	+11

*Sites determined from small-scale map.

(2) Determination of plot data (solution):

Btry	*Azimuth* Plotted*	*Range*	*Adj el*	*Alt*
A	5, 673	5, 200	311	477
B	5, 537	4, 950	291	500
C	5, 457	4, 760	278	453

*Azimuth plotted is azimuth of OL minus orienting angle plus 3,200.

(3) Since sites are known for all three batteries, each battery of the battalion will have a different GFT setting.

GFT A: Chg 5, lot_____, rg 5,200*, el 311, ti 18.5

GFT B: Chg 5, lot_____, rg 4,950*, el 291, ti 17.4

GFT C: Chg 5, lot_____, rg 4,760*, el 278, ti 16.6

*With hairline placed over ad usted time, range is read under hairline.

d. An example of determining a GFT setting when site is known for one battery.

(1) Situation: All 3 batteries of a 105-mm howitzer battalion have been registered on the registration point (altitude 500 yards) with charge 5 and fuze time, and the following adjusted data have been reported (deflection data omitted for simplicity):

Btry	*Adj ti*	*Adj QE*
A	12. 5	221
B	13. 4	230
C	12. 9	228

Site for Battery B to registration point has been determined by executive's high burst to be −5 mils.

(2) Determination of plot data (solution):

Btry	*Range*	*Adj el*	*Site*	*Alt*
A	3, 710	218	+3	490
B	3, 950	235 (230−(−5))	−5	519
C	3, 820	226	+2	493

(3) Since site is known for only one battery (Battery B) each battery of the battalion will have the same GFT setting; i. e., GFT_____: Chg 5, lot_____, rg 3,950, el 235, ti 13.4. Site for Batteries A and C for plot data was derived by using the common GFT setting (par. 446*b*(4)). The adjusted elevations for Batteries A and C are based on their respective adjusted times and the common GFT setting determined by Battery B.

447. Determination of Site by Firing (Executive's High Burst)

If the angle of site is unknown, after a precision impact and time registration, it may be determined by firing a modified high-burst registration. Such a registration will establish the elevation-fuze setting relationship (time correction). The relative altitude of the high burst is established by measuring the vertical angle (angle of site) from the battery to the mean burst center. The executive officer measures the vertical angle with an aiming circle or a BC telescope.

a. A modified high-burst registration to establish a time correction is conducted as follows:

(1) After the time registration, 1 (or more) battery(ies) is ordered to fire a 3-round executive's high burst over the registration point. The command is OBSERVE HIGH BURST, MEASURE ANGLE OF SITE, 3 ROUNDS, ADJUSTED DEFLECTION (so much), ADJUSTED TIME (so much), ADJUSTED QUADRANT ELEVATION (so much).

(2) The battery executive increases the quadrant elevation by the site necessary to place the bursts above the intervening mask. (This insures that the bursts can be observed from the battery position.) He fires the rounds ordered at the adjusted deflection and adjusted fuze setting but with the increased quadrant elevation. He observes the bursts with either an aiming circle or BC telescope set up in the vicinity (preferably directly to the rear) of the registering piece. Then he reports to the FDC the

average observed vertical angle (angle of site) to the center of the bursts. He also reports the quadrant elevation at which the rounds were fired.

(3) At the FDC, the quadrant elevation at which the high burst was fired minus the average measured angle of site to the center of the bursts is compared with the adjusted quadrant elevation to the registration point. The result is the unknown angle of site. The site to the registration point is found by adding the complementary site and the derived angle of site. Complementary site is found by multiplying the derived angle of site by the complementary angle of site factor for the range to the registration point.

b. For example, a 105-mm howitzer was registered on a point with charge 5. Adjusted data for the registration point included adjusted time (fz M500), 16.0 seconds and adjusted QE, 260 mils. The report from the executive following the high burst was OBSERVED ANGLE OF SITE, +30; QE FIRED, 280. Determination of registration point site and adjusted elevation is as follows:

Range corresponding to adjusted time 16.0.	=4,600 yards
Comp site factor, range 4,600	=+.08 mil
QE fired for HB	=280 mils
Minus measured angle of site HB	=−(+30) mils
Elevation to HB+comp site to HB*	=250 mils
Adjusted QE to registration point	=260 mils
Minus elevation+comp site to HB (reg pt).**	=250 mils
Angle of site to registration point	=+10 mils
Plus comp site (+.08 x 10)	=+1 mil
Site to registration point	=+11 mils
Adjusted elevation to registration point (260−11).	=249 mils

*From the basic formula QE=elevation+angle of site+comp site. Transposition will derive the formula *QE−angle of site=elevation+comp site.*

**Since the same fuze setting (adjusted time 16.0) applies to both the registration point and the high burst and the *fuze setting is a function of elevation plus comp site*, the sum elevation plus comp site for the high burst must be equal to the sum—elevation plus comp site to the registration point.

448. Determination of Range for Polar Plotting With Large Angles of Site

a. Frequently, in constructing a time plot observed firing chart, it may be necessary to register on a point which will yield a large derived angle of site and consequently a large complementary angle of site. Since fuze setting corresponds to elevation plus comp site, the range derived from the adjusted time will be in error proportionate to the required time correction (par. 391). This correction to fuze setting may be ignored as long as the comp site does not exceed 2 mils; however when the computed comp site exceeds 2 mils, the adjusted time must be corrected prior to determining plot ranges.

Example: 105-mm howitzer, charge 5, adjusted time 17.9, adjusted QE 332. Range for plot and relative altitude of battery (alt reg pt 500 yards) is determined as follows:

Elevation (+comp site) corresponding to time (17.9).	=290.8 mils
Angle of site (QE−(elevation+comp site)) (332−290.8).	=+41.2 mils
Comp site (+41.2 x 0.1 (comp site factor)).	=+4.1 mils
Site (+41.2+4.1)	=+45.3 mils
Adjusted elevation (QE 332−site 45.3).	=286.7 mils
Time corresponding to elevation 286.7.	=17.6 seconds
Comp site time correction (17.9 (adjusted time)−17.6).	=+0.3 second
Adjusted time—comp site time correction (17.9−(+0.3)).	=17.6 seconds
Range to back-plot battery location (range corresponding to time 17.6)	=5,000 yards
Vertical interval (GST: 5.0 x 41.2)	=202 yards
Relative altitude battery (500−202)	=298 yards

b. To avoid interpolation required with tabular firing tables in the example in *a* above, graphical firing tables may be used to determine the required elevation to the nearest mil, time to the nearest 0.1 second, and range to the nearest 10 yards. The hairline is used to determine all elements unless corrections from previous firings are known.

Section IV. OBSERVED FIRING CHART FOR MORE THAN ONE BATTALION

449. General

Massing of fires of more than one battalion by using an observed firing chart is possible provided common control can be established. To achieve common control, aiming circles must be uniformly declinated. A common registration point with coordinates and altitude assigned must be designated for all battalions. Also, one battery of each battalion must be registered on the common registration point. The area in which fires can be accurately massed is smaller than the area represented by the observed firing chart for one battalion. The comparatively large distance between battalions will introduce errors which increase as the distance from the common registration point to the target increases. Relative altitudes of the common registration point and battalion position areas must be known if several widespread battalions are to mass their fires accurately.

450. Construction of Observed Firing Chart for More Than One Battalion (Plotting)

Higher headquarters is responsible for selecting the registration point, assigning arbitrary coordinates and altitude, and coordinating registration. Registration may be coordinated by assigning times for conducting registrations or by requiring one battalion to register a battery of each battalion involved. Within a battalion, massing is improved if the center battery is selected to register. Each battalion observed firing chart is constructed as follows (fig. 169).

a. The adjusting battery is polar-plotted from the common registration point designated by higher headquarters. The back-azimuth of the

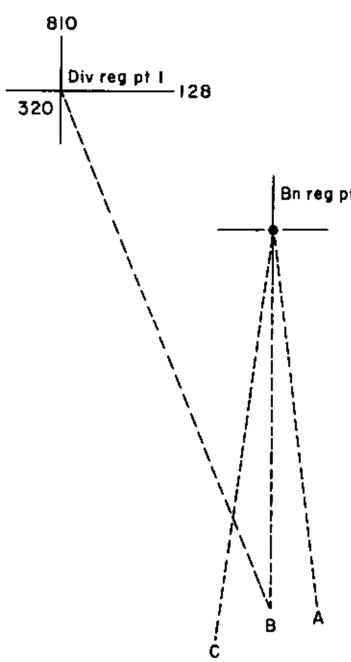


Figure 169. Observed firing chart built by registration on a division artillery registration point.

adjusted azimuth and distance derived from the adjusted data (pars. 438–449) are used in polar plotting.

b. The battalion registration point is polar-plotted from the adjusting battery position. The azimuth and distance to the battalion registration point that was determined previously from registration are used in polar plotting.

c. Other batteries, deflection indexes, and previously fired targets are replotted by using previously determined data.

d. If the battalion registration point and the common registration point are not within transfer limits or if different charges are used, then separate GFT settings and separate deflection correction scales will be established.

451. Construction of Observed Firing Chart for More Than One Battalion (Tracing Paper Method)

An alternate but less accurate method of constructing an observed firing chart for more than one battalion is the *tracing paper method.* This chart is constructed as follows:

a. The common registration point from the adjusting battery position is plotted on the battalion chart. The altitude is computed.

b. An overlay of the battalion chart is made. The overlay must include the battalion registration point, batteries, common registration point, and all concentrations.

c. The common registration point is plotted on the chart for more than one battalion.

d. A ray is drawn on the chart from the common registration point through the estimated location of the registering battery. The ray is drawn in the direction of the back-azimuth of the adjusted azimuth of fire.

e. The overlay is oriented so that the common registration point is over its chart location and the registering battery is over the ray previously drawn.

f. The location of batteries, battalion registration point, and concentrations are pinpricked through the overlay onto the chart.

g. All altitudes are reconciled with the altitude assigned to the common registration point.

h. Deflection indexes are constructed on the chart for more than one battalion. The indexes are based on adjusted data for the battalion chart.

Section V. OBSERVED FIRING CHART WITH INCOMPLETE SURVEY

452. General

A target area survey or position area survey may sometimes be used in conjunction with the observed firing chart until the surveyed firing chart is available. In either case, that part of the chart established by firing must be plotted to the same scale as that part obtained by survey. Any range corrections which can be eliminated from the ranges determined by firing will improve the accuracy of the range plotted on the observed firing chart.

453. Target Area Survey

The 01 may be back-plotted (polar-plotted) on the observed firing chart from the registration point; the direction is the back-azimuth of the measured azimuth of 01 to the registration point; the distance is computed by using the 01–02 base. The relative altitude of 01 is computed by using the measured angle of site, 01 to the registration point, and the computed distance.

454. Position Area Survey

a. In some situations, time and ammunition can be saved by eliminating the registration of two batteries and substituting a position area survey. The procedure is as follows:

(1) A common orienting line (OL) is established for the battalion, if possible; otherwise, an OL is established for each battery.

(2) Starting from any convenient point, a traverse is run to locate all battery positions horizontally and vertically and to determine direction of all orienting lines.

(3) The battery positions, altitudes, and OL's are plotted on tracing paper to the same scale as that for the chart to be used. This overlay, including the measured grid azimuth of the OL's, constitutes the position area survey as delivered to the FDC.

(4) One battery is registered on the registration point; from the adjusted data, the observed firing chart is started by plotting the registration point and registering the battery.

(5) Using the measured orienting angle of the registering battery, the direction of fire line of the battery is drawn on the overlay of the position area survey.

(6) The battery center plotted on the overlay is placed over the registering battery center of the firing chart. The overlay is rotated until the direction of fire line on the chart and the overlay coincide. The locations of the nonregistering batteries are pinpricked. Those locations are labeled with proper altitudes in relation to registering battery.

(7) The coordinates of the nonregistering batteries are measured. Using these coordinates and those of the registration point, the direction of fire of the nonregistering batteries is computed. For each battery, the azimuth of the battery OL minus the determined direction of fire equals the orienting angle for laying the battery.

b. As an alternate method to that in *a* above the registering battery and registration point are plotted as for a battery observed firing chart; i. e., coordinates are assumed for the battery and the registration point is polar-plotted. In this case, the nonadjusting batteries are plotted on the firing chart in relation to the adjusting battery by coordinates determined by survey. The assumed cordinates and altitude of the adjusting battery are used to establish survey control. Direction for laying the nonregistering batteries is determined as in *a*(7) above.

c. Typical situations which might necessitate the use of an observed firing chart based on registration of one battery and a position area survey are—

(1) When lack of time and/or ammunition precludes registering all three batteries.

(2) When the battalion displaces by echelon, data can be ready for the remaining batteries when they arrive at the new position.

(3) When displacement of the battalion is to be made after dark, a single howitzer can be brought up and registered during daylight. Data can be ready for the entire battalion when it arrives.

(4) When alternate positions have been occupied and firing must begin without registration from those positions.

(5) When fire from positions to be occupied is not permitted before a certain hour but massing is required immediately after that time and a single registration may be performed from an alternate position. Data can then be prepared for the battery positions after connecting them to the registration position with a position area survey.

Section VI. RADAR FIRING CHARTS

455. General

In conjunction with radar observed high-burst registrations, there are three techniques that can be used in constructing a firing chart, as follows:

a. Observed firing chart improved by radar (time plot).

b. Radar chart—no maps or survey.

c. Radar chart, registering piece located (minimum survey for GFT setting).

456. Time Plot Observed Firing Chart Improved by Radar

In many cases the observed firing chart will be constructed before the radar is ready to observe. In such cases, when radar is available, an observed firing chart improved by radar will replace the initial observed firing chart. The radar can supply data for accurate GFT setting and deflection correction from a 6-round high-burst registration fired by 1 of the batteries. The observed firing chart improved by radar is the most accurate type of observed firing chart that can be constructed (approaches survey accuracy).

457. Advantages of Radar Improved Chart

The radar improved chart has the following advantages over a time plot observed firing chart:

a. An accurate time correction is obtained from which the site is derived. The quadrant elevation can be correctly divided into elevation and site; thus, errors in site are not left in the elevation to be plotted as range.

b. The GFT setting, based on a true radar range, will allow the observed firing chart to be plotted to a relatively true scale.

c. The directions in which the batteries are plotted from the registration point are more accurate by the amount of deflection correction determined from the radar observed high-burst registration.

d. The accuracy of a radar improved chart will allow effective use of an 01–02 base. 01 may be back-plotted on the chart by using its measured azimuth and range to the registration point.

458. Construction of Radar Improved Chart

A radar improved observed firing chart is constructed as follows:

a. All firing batteries are registered on a common registration point to obtain an adjusted orienting angle or azimuth, adjusted quadrant, and adjusted time.

b. A high-burst registration (pars. 307–336), observed by radar, is fired by a battery which has been located relative to the radar location by survey. The point selected for the high burst should be visible to the radar, be as close as possible to the registration point, and if possible have a site of less than 50 mils. If time does not permit survey from the battery position to the radar, a registering piece may be temporarily located close to the radar for firing the high burst.

c. The location of the high burst and the location of the registering piece, both in relation to the radar, are established. By computation or plotting, the location of the high burst in relation to the registering piece is obtained and the range, site, and azimuth are determined.

d. A GFT setting and deflection correction are determined from the high-burst registration and used in plotting the batteries. The range for the GFT setting is the measured chart range from the battery to the high burst. Location of the high burst is determined from radar data. The elevation is the adjusted quadrant less the computed site. The time fired is the adjusted time.

e. Transfer from observed firing chart to the radar improved chart is accomplished as follows:

(1) The registration point is used as the initial plot in the usual manner and is plotted at arbitrary coordinates and altitude.

(2) Each battery is back-plotted from the registration point. The range and site are derived from the adjusted quadrant and adjusted time by using the GFT setting determined from the high-burst registration. With the time gageline over the adjusted time, range is read

under the hairline and elevation is read under the elevation gageline.

(3) The vertical interval for each battery, in relation to the registration point, is determined by using the derived site and plotted range.

(4) The azimuth on which to plot each battery is the back-azimuth of the adjusted azimuth or firing azimuth determined from the registration. The adjusted or firing azimuth is modified by the deflection correction determined from the high-burst registration. This azimuth is most accurately determined by using orienting lines. The deflection correction determined from the high burst is stripped from the registration point azimuth to determine replot azimuth.

(5) The deflection indexes are constructed in the usual manner.

(6) The radar antenna is plotted in relation to the battery to which it is connected by survey (azimuth, distance, and difference in altitude). Radar azimuth indexes are added (par. 462).

f. For example, a 105-mm howitzer battalion has occupied position and all batteries have been registered with charge 5, lot X, on a common registration point (assigned altitude 400 yards). Adjusted data are as shown below:

Btry	*Adj az*	*Adj orienting angle**	*Df*	*QE*	*Ti*
A	6, 046	1, 795	2, 751	313	18. 8
B	6, 134	1, 707	2, 766	309	18. 4
C	6, 229	1, 612	2, 771	304	18. 0

*Azimuth of common OL is 1,441 mils.

(1) An observed firing chart is constructed and radar is polar-plotted from Battery B with which it had been connected by survey (distance 360 yards, azimuth 423 mils, vertical angle +16 mils).

(2) A high-burst registration was fired by Battery B in the vicinity of the common registration point with the following data: Chg 5, lot X, df 2,766, si 322 (60 yards above reg pt), ti 18.4, el 300.

(3) The high burst is polar-plotted from radar and located on the chart, based on the data obtained by radar to the high burst (rg 4,770 yd, az 6074 mils, vertical angle +17 mils).

(4) GFT setting is determined as follows:

Height of HB in relation to radar (GST: 4,770×(+17))	=+80 yards
Height of radar in relation to Btry B (GST: 360×(+16))	=+6 yards
Height of HB in relation to Btry B (+80+6)	=+86 yards
Chart rg, Btry B to HB (measured)	=5,040 yards
Site, Btry B to HB (GST, chg 5: +86/5040)	=+19 mils
Adj el (QE 322−si+19)	=303 mils

GFT B: Chg 5, lot X, rg 5,040, el 303, ti 18.4.

(5) Deflection correction is determined as follows:

Chart df, Btry B to HB (measured)	=2,781 mils
Adj df (fired)	=2,766 mils
Deflection correction (2,766−2,781)	=R15 mils

(6) The following replot data are computed by using the GFT setting (4) above, deflection correction (5) above, and the adjusted data from the common registration point: (The batteries are replotted from the common registration point, resulting in an OF chart improved by radar.)

Element	Battery A	Battery B	Battery C
Az for polar plotting (back-az)*	2, 831	2, 919	3, 014
Range (corresponds to adj ti)	5, 140	5, 040	4, 950
Adj time	18. 8	18. 4	18. 0
Adj QE	313	309	304
El**	310	303	296
Derived site	+3	+6	+8
Vertical interval (GST)	+14	+27	+35
Altitude***	386	373	365

*Back-az of adj az minus deflection correction; e. g., Btry A 6,046−R15−3,200=2,831.
**Elevation under elevation gageline; GFT setting when time gageline is on adjusted time.
***Alt reg pt (400) minus GST computed vertical interval.

(7) A deflection correction scale is constructed, based on the established GFT setting (par. 348 and 349), and deflection indexes are constructed for each battery, based on the adjusted deflection from the HB registration.

(8) Radar is now replotted in relation to Battery B on the OF chart by using survey data. Altitude of radar becomes 379 yards (new alt Battery B, 373 yards + 6 yards).

459. Radar Chart

Without radar there is no easy and practical method by which a battalion can occupy positions during darkness without maps or prior survey and be prepared to mass effective fires at daylight. However, when radar is available, an observed firing chart can be constructed which will permit the battalion to mass fire effectively if one battery has adjusted on a target. This observed firing chart is called the *radar chart*.

460. Construction of Radar Chart

The radar chart is not as accurate as an observed firing chart improved by radar. Its construction is based on the firing of a high-burst registration by each battery. Procedures for construction of the radar chart are as follows:

a. The radar is oriented by using the aiming circle and plotted on the firing chart at assumed coordinates and altitude.

b. Batteries are laid by azimuth on the approximate azimuth to the center of the sector.

c. A high-burst registration, observed by radar, is fired from the base piece of each battery at a safe range and fuze setting.

d. Range, azimuth, and elevation (angle of site) to each of the three high bursts are determined by radar.

e. Each high burst is polar-plotted on the firing chart with respect to the radar.

f. The altitude of each high burst is determined by using the radar range and elevation.

g. Each battery is back-plotted on the chart from its high-burst location.

(1) Each high burst represents the registration point of the battery which fired it.

(2) The battery is polar-plotted from its high-burst location on the back-azimuth of the azimuth at which the high burst was fired.

(3) The range at which the battery is plotted is the range corresponding to the time setting at which the high burst was fired.

h. The altitude of the battery is equal to the altitude of its high burst minus the vertical interval between the battery and the high burst. The vertical interval is determined by multiplying the site fired by the range at which the battery is plotted.

i. The deflection index is constructed for each battery in the usual manner.

461. Evaluation of Radar Chart

The radar chart is fundamentally a time plot-observed firing chart, sites unknown, with the exception that each battery has its own registration point. The accuracy of the radar chart is slightly less than that of the time plot-observed firing chart, sites unknown.

a. To obtain the greatest accuracy and to attain usable battalion transfer limits, the three high-burst registrations should be fired as close to the same point as possible.

b. Without survey, pointing data for the radar to each of the HB's cannot be accurately determined. For this reason, it will generally be necessary to move the antenna in azimuth and elevation after the first round is fired in order to observe succeeding rounds through the orienting telescope. Therefore, each registration will usually require 7 to 8 rounds.

c. The radar chart can be used to mass fires on targets reported by radar and on targets which have been adjusted on by one battery.

462. Radar Chart, Registering Piece Located

If the relative location of the radar and the registering piece can be established either by survey or by moving the registering piece to the radar, the accuracy of the radar chart can be substantially improved, since a GFT setting and deflection correction can be established.

a. When one battery position is located in relation to radar after a radar chart without survey or maps has been constructed (par. 460), a GFT setting and deflection correction can be derived from the registration of that battery. When a registering piece is moved to the radar position, another high-burst registration must be fired to establish a GFT setting and deflection correction.

b. When radar is located relative to one battery prior to initial registration, the high-burst registration of this battery is used to establish the GFT setting and deflection correction.

c. The GFT setting and deflection correction in *a* and *b* above are established and applied in back-plotting each battery from its respective high-burst location in the same manner as for an observed firing chart improved by radar (par. 458). However, the chart thus established is not as accurate as the observed firing chart improved by radar, since the high bursts are not at a common point.

Section VII. TRANSFER FROM OBSERVED FIRING CHART TO SURVEYED CHART

463. General

As soon as the surveyed firing chart is available, it should replace the observed firing chart. The observed firing chart is retained until all concentrations are transferred to the surveyed firing chart. The transfer of information is made as soon as possible.

464. GFT Settings and Deflection Index

a. The determination of GFT settings and construction of the deflection index for the surveyed firing chart is accomplished in the same manner as if the surveyed firing chart had been on hand at the time the registrations were fired. The adjusted elevation is determined by subtracting the site, as computed from the surveyed firing chart, from the adjusted quadrant elevation. The range is measured on the surveyed firing chart. The time gageline is drawn over the adjusted time for each registration. When all three batteries have registered on the observed firing chart, each may have a different GFT setting.

b. The deflection correction scale to be used with the surveyed chart is based on the surveyed chart GFT setting with a deflection correction of zero at registration point range (pars. 348 and 349).

465. Transfer From Observed Firing Chart to Surveyed Firing Chart, Percussion Fuze

a. The procedure for transfer of targets from the observed to the surveyed firing chart is the same as that for replotting observed targets on the surveyed firing chart (par. 420). Data for replot of a target are obtained from the adjusted data for that target.

(1) The target is plotted by using the chart deflection as determined from the observed firing chart.

(2) Information indicating the altitude of the target, such as a map or observer's UP and DOWN corrections, is used to separate the adjusted quadrant into the components of site and elevation.

(3) The surveyed firing chart GFT setting is used to derive the range from the adjusted elevation.

b. The GFT setting must be appropriate to the surveyed firing chart at the time of adjustment on the targets. When more than one registration has been made, the elevation used in establishing the GFT setting is selected from the registration which most nearly coincides with the time of firing on the targets.

466. Transfer From Observed Firing Chart to Surveyed Firing Chart, Time Fuze

Targets fired with time fuze are transferred from the observed firing chart to the surveyed firing chart in the same manner as those fired with percussion fuze, except for the following:

a. The relationship between range, adjusted time, and adjusted elevation is fixed by the surveyed firing chart GFT setting.

b. The adjusted time is used to derive the range and adjusted elevation.

c. The adjusted elevation is subtracted from the quadrant elevation to determine the site.

467. Transfer to Surveyed Firing Chart, Computer Records Available

When the computer records are available, targets are replotted on the surveyed firing chart by polar plotting at deflections, ranges, and altitudes as described in *a* through *d* below:

a. Deflection. The same deflection used to replot the target on the observed firing chart is used to replot that target on the surveyed firing chart. This deflection is the "chart" deflection on the FDC Computer's Record (DA Form 6–16). Using this deflection may introduce an error owing to the difference in deflection correction scales of the 2 charts, but the error would seldom exceed 1 mil.

b. Range. Range is determined with the GFT setting for the surveyed firing chart (par. 465*b*). For missions fired with percussion fuze, range is determined by placing the elevation gageline over the adjusted elevation and reading the range under the hairline. For missions fired with time fuze, the time gageline is placed over the adjusted time setting and the range is read under the hairline.

c. Site and Elevation (Percussion Fuze).

(1) The altitude of the target is determined from a map, if one is available, or from the observer's request. For example, the observer requested FROM REGISTRATION POINT, RIGHT 350, UP

20, ADD 400. The target is 20 yards above the registration point.

(2) The site is determined by successive approximation (par. 441). Site is based on the vertical interval (difference in altitude of battery and target) and fire for effect range.

(3) The final adjusted elevation is used to determine the final plot range.

d. Site and Elevation (Time Fuze).

(1) If accurate sites were known for the observed firing chart GFT settings, then the sites and elevations will not change when applied to the surveyed firing chart.

(2) If accurate sites were not known for the observed firing chart GFT setting, then the time correction will not remain the same in the surveyed firing chart GFT setting. The adjusted elevation must be obtained for each target. It is obtained by placing the surveyed GFT setting time gageline over the adjusted time and reading the elevation under the elevation gageline. The derived site is the algebraic difference between the elevation and the adjusted quadrant elevation.

e. Example of Target Replotted on a Surveyed Firing Chart. Personnel from a 105-mm howitzer battalion have completed survey and are transferring targets from an observed firing chart (percussion fuze) to a surveyed firing chart. Surveyed firing chart GFT: *Chg 5, lot X, rg 5,400, el 310.* Concentration BC 401 is to be replotted on the surveyed firing chart. (No map available.)

Adjusted data				*Replot data (computer's record)*		
Fz	*Df*	*Si*	*El*	*FFE rg*	*Fz*	*Observer's site corr*
Q	2, 616	314	340	5, 700	Q	Up 70

Altitude of btry	=420 yards
Altitude of reg pt (survey)	=438 yards
Altitude of conc (438+70)	=508 yards
Apparent site of conc (GST−88(508−420)/5700)	=+18 mils
QE fired (site(+14)+el 340)	=354 mils
Apparent adj el (354−(+18))	=336 mils
Apparent rg for replot (GFT)	=5,730 yards
Site (GST: 88/5730)	=+18 mils*
Range for replot (el 336)	=5, 730 yards

*Agrees with apparent site within 1 mil.

468. Transfer to Surveyed Firing Chart, Computer Records Not Available

When the computer records are not available, targets are replotted on the surveyed firing chart by polar plotting at deflection, range, and altitude determined as described in *a* through *c* below:

a. Deflection. The deflection for replot of a target is measured directly from the observed firing chart. It is used without change in transferring to the surveyed firing chart, since the deflection correction for the surveyed firing chart will not differ from that for the observed firing chart by more than 1 mil.

b. Range. The range is measured from the observed firing chart. The elevation that was fired is determined by using the observed firing chart GFT setting. The range for replotting the target on the surveyed firing chart is determined by using this elevation as in paragraph 467.

c. Site. Site is determined as described in paragraphs 466 and 467.

CHAPTER 22

FDC PROCEDURES FOR SPECIAL SITUATIONS

Section I. CHEMICAL SHELL

469. General

Chemical agents may be used to kill, injure, or harass personnel; to deny observation or use of an area; or to burn materiel. This section is concerned only with the employment of chemical agents through the use of chemical shells. Chemical shell includes smoke shell (white phosphorous shell and base-ejection smoke shell) and gas shell (irritant or toxic agents).

470. Smoke Shell

a. Purpose. Smoke shell is fired for the purpose of—

(1) Screening enemy observation.*

(2) Producing casualties (WP and FS).

(3) Damaging enemy installations and materiel by burning (WP).

(4) Sending prearranged signals; e. g., to friendly patrols.

(5) Marking targets and bomb lines for aerial bombing.

(6) Assisting the observer to locate his rounds.

b. Ammunition.

(1) *White phosphorous (WP).* Shell, WP, is a bursting-type of smoke shell which produces smoke, incendiary effect, and casualty effect. Against most targets, superquick fuze action is preferable. The action of the fuze and burster charge breaks the shell and scatters the phosphorous particles above ground. Since WP smoke rises, or pillars, it is not suited for maintaining a smoke screen; however, it is excellent for the initial buildup of a smoke screen.

(2) *Smoke, FS.* Shell, smoke, FS, is a bursting-type of smoke shell that contains a liquid which forms white smoke when exposed to air. Although FS is less dense than WP, it is a better screening agent since it does not rise as much. The smoke irritates the skin slightly, and the liquid splashed on the skin produces severe acid burns, thus producing some casualties. Smoke shell FS is normally fired with fuze quick.

(3) *Smoke, HC.* HC is base-ejected and produces white smoke that is used primarily for screening; shell, smoke, HC, is normally fired with time fuze. Smoke, HC, is the most effective screening agent but produces no casualty effect. HC readily absorbs and retains moisture; therefore its employment is made more effective by rain or mist.

(4) *Colored smoke.* Colored smoke is base-ejected and is normally used for prearranged signals and as an aid to the observer in identifying his rounds. Colored smoke shell is normally fired with time fuze. Except for the color of the smoke, colored smoke (red, violet, green, or yellow) is similar to HC smoke (white).

471. FDC Procedures for Adjustment of Smoke Shell

If fire for effect is to be conducted with smoke shell, the adjustment is conducted with shell HE to avoid obscuring the impact area.

a. The WP and FS projectiles are heavier than shell HE; therefore a correction for weight of projectile should be computed and applied in changing from shell HE to shell WP or FS. For

*The use of smoke for screening must be coordinated with higher authority, owing to the danger of changes in wind causing smoke to drift into an area where it is not desired.

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example, 105-mm howitzer, firing charge 5 (for simplicity a GFT setting has been omitted):

Chart range to target (FFE)	=5,040 yards
Elevation corresponding to range 5,040 (GFT).	=289 mils
Weight of projectile—HE	=2 square
Weight of projectile—WP	=5 square
Difference in weight of projectile	=+3 square
Variation of 1 square (FT 105-H-4, el 289).	=−36 yards
Total effect (+3x(−36))	=−108 yards
Range at which to fire WP (5,040 +108).	=5,148 yards
Elevation to fire WP for range 5,150 (HE GFT).	=297 mils

Note. Since weight of projectile is the only element of change, the additional accuracy that would be obtained by establishing a new GFT setting (par. 342) for smoke shell is negligible and may be ignored.

b. When WP or FS smoke shell is to be used for screening, the HE adjustment is followed by a smoke adjustment with a single piece to insure that the desired smoke screen will be in the proper place.

c. When base-ejection smoke shell is to be used for screening, the initial HE adjustment is continued with 1 piece firing smoke shell until the proper height of burst (approximately 100 yards), as well as proper location, has been obtained. The lowest possible charge is used to reduce the terminal velocity of the shell to prevent scattering of the smoke cannisters. Base-ejection smoke shell is fired with a fuze setting of *2 seconds less* than the fuze setting for a zero height of burst for HE shell; therefore, it is unnecessary for the computer to include the 20/R factor in his site. The height of burst is changed by increasing or decreasing the site.

472. Building and Maintaining a Smoke Screen

a. To form an adequate smoke screen quickly, two rounds per point of impact should be fired as rapidly as possible. The smoke screen is then maintained by firing at the minimum rate necessary. The minimum rate is governed largely by the velocity of the wind. A guide to the proper rate of fire for 105-mm and 155-mm howitzers is as follows:

	Fire per point of impact	
Wind velocity	*105-mm howitzer*	*155-mm howitzer*
3 MPH	1 rnd every 60 seconds.	1 rnd every 120 seconds.
10 MPH	1 rnd every 40 seconds.	1 rnd every 80 seconds.
15 MPH	1 rnd every 30 seconds.	1 rnd every 60 seconds.

Note. The above rates must be modified based on what the observer sees on the ground.

b. Depending on the wind speed and direction and the size of the front to be screened, the spacing of the points of fall may be as great as 400 yards or as small as 30 yards. These data must be based on the observer's requests and will be changed as necessary to correct for changes in weather and the tactical situation.

473. Gas Shell

Gas shell is fired only when ordered by headquarters that has the authority to direct its employment. Met data are especially important and *must* always be considered in the computation of firing data, because the effect of wind direction and velocity on the gas might endanger friendly elements. If possible, gas shell missions should be fire for effect missions. Where surprise FFE is not possible, HE shell is used for adjustment and corrections for weight of projectile (par. 471) are applied before firing the gas shell. Surprise can be obtained by using an auxiliary adjusting point. Use of nonpersistent and persistent gases is covered briefly in paragraph 210 and, in more detail, in FM 3–5.

Section II. ILLUMINATING SHELL

474. General

a. Illuminating shell may be used for any of the following specific purposes and in any other situation where illumination is needed:

(1) Illuminating areas of suspected enemy movement, attack, or counterattack.
(2) Surveillance of fires at night.
(3) Night adjustment of artillery fire by ground or air observer.
(4) Harassing enemy positions and installations.
(5) Furnishing direction to infantry for attacks or patrols. (Flares must be placed well in advance of friendly troops to avoid illuminating them.)

b. Some of the factors to be considered in the employment of artillery illuminating shells are listed below (all data are approximate).

Weapon	Projectiles	Initial height of burst	Initial distance between bursts	Burning time	Rounds for continuous illumination*
Howitzer, 105-mm	M314A1	800 yd	800 yd	60 sec	2 per min.
Howitzer and gun, 155-mm	M118A1 and M118A1B1	700 yd	1,400 yd	60 sec	2 per min.

*Strong wind may necessitate a faster rate of fire.
Note. For earlier types of projectiles (M314 and M118 (M118B1)), reduce initial distance between bursts one-half.

475. Adjustment of Illumination

a. The bursting (ejection) point of illuminating shell normally must be adjusted to obtain effective illumination. Adjusting illumination closer than 200 yards of the target is not justified because of the size of the area lighted. Availability of illuminating shell and the judgment of the observer will govern the number of weapons employed in the adjustment.

b. After illumination is adjusted over a point of known range, transfers may be made to other points. However, the effect of the wind on the flare may influence normal transfer limits. The flare drift is not affected appreciably by a change in range. Therefore, range and deflection corrections determined from the adjustment are applied without change (flat corrections) in later firings.

c. The size of the area effectively lighted depends on the observing distance. A 155-mm illuminating shell bursting at optimum height will effectively illuminate an area about 2,000 yards in diameter for an observer at medium distances (3,000 yards or less). Two rounds bursting at the same time above a common point produce a better lighted area. Two rounds should be used for observing under adverse conditions due to haze, smoke, dust, or long observing range. The observer obtains this type of illumination by requesting TWO GUNS. Two rounds fired at the same deflection but set to burst at the same time with optimum distance between adjacent bursts in range or fired at the same range with deflection spread equal to optimum distance between bursts will give better observation than a single flare. They will also 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. Two rounds fired with a range or deflection spread will permit much better observation of the terrain than two single rounds fired at the same point. In searching an area, enough rounds, properly placed to cover the area, should be fired at the same time. Firing 4 rounds at one time, forming a diamond (diagonals of the diamond being equal to the optimum distance between bursts for the caliber concerned), will light an area more than 2,000 yards square with minimum shadows (fig. 101). To obtain this type of illumination, the observer commands: FOUR GUNS, ILLUMINATING. When the observer calls for a range or deflection spread or a diamond pattern, the center of the pattern is centered over the area indicated by the observer.

476. FDC Procedure

The initial target location and subsequent corrections are plotted in the normal manner, and the chart data are determined as for an HE mission except as follows:

a. When an illuminating shell is being fired, all charges for 105-mm and 155-mm howitzers may be used; however, the lowest possible charge should be used in order to reduce the possibility of ripping the parachute on ejection from the projectile. When a 155-mm gun is being fired, only normal charge may be used.

b. Fuze setting and elevation for a proper height of burst at a given range under standard conditions are determined from the appropriate firing table (a GFT has not been accepted as standard).

(1) *105-mm howitzer.* FT 105–H–4 gives fuze setting and elevation for a graze burst. Since an initial height of burst of 800 yards is considered proper, it is necessary to change the fuze setting and elevation for a desired range by applying the data from *Change in Elevation* and *Fuze Setting for 100 yd Increase in Altitude* columns.

Example: 105-mm howitzer, charge 5, fuze M501, range 4,000 yards. Change for 100-yard height of burst—fuze setting, 0.15 seconds; elevation, 27.8 mils.

	Fuze setting	*Elevation*
Graze burst	15.8 seconds	272.3 mils
Change for 800-yard height of burst:		
Fuze setting (8×.15)	1.2 seconds	
Elevation (8×27.8)		222.4 mils
800-yard height of burst.	17.0 seconds	494.7 or 495 mils

(2) *155-mm howitzer or 155-mm gun.* FT 155–Q–2 (change 9) and FT 155–S–2 (change 11) give fuze settings and elevations for a 700-yard height of burst. Since an initial height of burst of 700 yards is considered proper for 155-mm weapons, the fuze setting and elevation for a desired range are taken directly from the table.

Example: 155-mm gun, charge N, fuze M501, range 7,500 yards:

	Fuze setting	*Elevation*
700-yard height of burst.	18.3 seconds	269 mils

c. The observer's correction for height or burst, made in multiples of 50 yards, is converted to a site correction, which is applied to the elevation as determined in *b* above. The observer's correction is converted by using the *Change in Elevation* column of the firing table.

(1) *105-mm howitzer.* The *Change in Elevation* column, FT 105–H–4, gives data for a change of 100 yards in altitude. Half the change shown is applied for each 50 yards of observer correction.

Example: Charge 5, range 4,000 yards:

Initial elevation fired = 495 mils
Observer's correction—UP 50, REPEAT RANGE
Change in elevation for 100-yard increase in altitude = 27.8 mils
Change in elevation for 50-yard increase in altitude $= \frac{27.8}{2} = 13.9$ mils
Elevation to be fired (495 + 13.9) = 508.9 or 509 mils.

(2) *155-mm howitzer or 155-mm gun.* The *Change in Elevation* column, FT 155–Q–2, C–9 (155-mm howitzer), and FT 155–S–2, C–11 (155-mm gun), gives data for changes of 50 *feet* in altitude. This value must be multiplied by 3 to obtain the change in elevation for a 50-*yard* change in altitude.

Example: 155-mm howitzer, charge 5, range 4,000:

Initial elevation fired = 367 mils
Observer's correction—UP 50, REPEAT RANGE
Change in elevation for 50-*foot* change in height of burst = 4 mils
Change in elevation for 50-*yard* change in height of burst (4×3) = 12 mils
Elevation to be fired (367 + 12) = 379 mils.

d. If 2-gun illumination is requested, rounds are fired simultaneously from 2 weapons, with the same time setting and at the same deflection and elevation.

e. If 2-gun illumination with a range or deflection spread is requested by the observer, the center of the area is plotted and the necessary changes to deflection or elevation are determined and applied.

(1) A normal deflection spread is 800 yards for a 105-mm howitzer and 1,400 yards for a 155-mm gun or howitzer. Chart deflections are modified to move the bursts right and left in the appropriate amounts (400 yards or 700 yards, respectively) of the plotted location. This change may be computed by using the mil relation or 100/R scale of HE graphical equipment.

Example: 155-mm howitzer, charge 6. range 5,000 yards:

Observer requests—TWO GUN, DEFLECTION SPREAD
Deflection to center of area (chart) = 2,513 mils
Deflection change for 700-yard shift (700/5) = 140 mils
Deflection to be fired by right piece (2,513 − 140) = 2,373 mils
Deflection to be fired by left piece (2,513 + 140) = 2,653 mils.

(2) When a range spread is requested, elevations are determined to move the right burst (400 yards, 105-mm howitzer; 700 yards, 155-mm gun or howitzer) short of, and the left burst an equal distance over, the chart range to the center of the area.

Example: 155-mm howitzer, charge 6, range 5,000 yards:

Observer requests—TWO GUN, RANGE SPREAD
Range to center of area (chart) = 5,000 yards.
Elevation to be fired by right piece (range 5,000 − 700 = 4,300) = 311 mils
Elevation to be fired by left piece (range 5,000 + 700 = 5,700) = 339 mils.

f. When 4 guns are requested, the 4 interior pieces of the battery will fire as follows: The center 2 pieces fire a range spread at the deflection to the center of the area; the other 2 pieces fire a deflection spread at the range to the center of the area (fig. 101).

Example: 155-mm howitzer, charge 6, range 5,000 yards:

Observer requests—FOUR GUNS
Deflection to center of area (chart) = 2,513 mils
Range to center of area (chart) = 5,000 yards

Piece	*Deflection*	*Elevation*
No. 2 (right piece of deflection spread)	2, 373	320
No. 3 (short piece of range spread)	2, 513	311
No. 4 (long piece of range spread)	2, 513	339
No. 5 (left piece of deflection spread)	2, 653	320

g. The data given for proper height of burst, time of burning, and distance between bursts of adjacent volleys vary from one projectile lot to another owing to variations in the illuminant. In addition, the length and conditions of storage cause data for a given lot, at time of firing, to vary from data for that lot determined at the time of manufacture. Thus, large variations from the desired height of burst can be expected unless a correction for each lot is determined by adjustment and used when that lot is being fired. To prevent waste of ammunition, corps or division artillery should coordinate adjustment of various lots. If higher headquarters does not provide the proper height of burst for an ammunition lot, the firing unit FDC personnel must record the corrections from all adjustments and use the best height of burst data available to start future adjustments. There may still be large variations in required height of burst owing to changes in rate of fall and changes in burning time, which are due to effects of temperature, humidity, and wind velocity.

477. Night Adjustment of Artillery

When an adjustment mission is to be fired during darkness with the aid of illuminating shell, the observer indicates in his initial illumination fire request the nature or suspected nature of the target; for example—

FIRE MISSION,
COORDINATES 62347185 (to indicate the desired point of burst of the illumination),
AZIMUTH 3750,
SUSPECTED TANKS AND INFANTRY ASSEMBLING,
TWO GUNS,
ILLUMINATING,
WILL ADJUST.

a. The FDO designates the battery to adjust and fire the illuminating shell, the battery to adjust HE on the target, and the battery or batteries to fire in effect. Separate fire orders are given for illumination and HE (or other).

b. The observer adjusts the illuminating shell to the desired location. When the adjustment has been completed satisfactorily, he requests CONTINUOUS ILLUMINATION. The observer may give the target location with respect to the burst center of the illumination and begin the adjustment of HE shell; for example—

CONTINUOUS ILLUMINATION,
FROM ILLUMINATION,
AZIMUTH 3630.
LEFT 100,
SHELL HE,
DROP 200,
TWO TANKS AND PLATOON OF INFANTRY,
WILL ADJUST.

The target azimuth is announced when it differs by more than 100 mils from the initial azimuth. The observer may specify the length of time for the illumination to continue.

c. When continuous illumination is requested, changes in data are made for firing illuminating shell only when called for by the observer. The piece(s) used to fire the illuminating shell isfired at the rate of 1 round every 30 seconds unless the observer requests a faster or slower rate of fire.

d. The HE adjusting piece(s) is fired at the deflection and range indicated by the observer's corrections. When flat corrections are applied to the illuminating shell chart data, the observer's HE shell correction can be plotted from the last illuminating shell chart location. When flat corrections are not applied to the illuminating shell chart data, any known flat corrections must be stripped from the illuminating shell firing data. The resulting data are polar-plotted on the firing chart. The observer's correction is plotted in relation to this chart location. Failure to strip flat corrections from illuminating shell data prior to plotting HE shell correction may result in lost rounds and wasted ammunition. A change in observer's target azimuth will require target grid reorientation. After chart location for initial HE round has been determined, normal FDC procedures are followed.

e. When the piece firing the illuminating shell is from a battery other than the one firing HE, the illumination is adjusted and then initial data are sent to the battery that is firing HE. If the target is located with sufficient accuracy, initial data may be sent to both batteries at the same time.

f. If, during the adjustment, the observer desires to move the illumination and the HE, he prefaces the illumination command with ILLUMINATING and the HE command with HE; for example, ILLUMINATING, ADD 100; HE, RIGHT 60, ADD 200.

g. To conserve illuminating ammunition, the firing of illuminating shell may be coordinated with the adjustment of HE. In that case, the observer will request COORDINATED ILLUMINATION and change the method of control to BY SHELL, AT MY COMMAND. At this command, the FDO will have data determined for both illuminating shell and HE shell. Each piece will be loaded with the type of shell designated for that piece. The FDO will inform the observer that HE IS READY and ILLUMINATION IS READY. The observer will control the firing of the illumination and the HE so that the HE will arrive during the period of maximum illumination of the target. The FDO may direct the use of coordinated illumination; however, unless the ammunition supply rate is critical, the observer should be allowed to make the decision as to the type of illumination required.

Section III. PROPAGANDA SHELL

478. General

Artillery may be used to saturate an area with psychological warfare leaflets. Pinpoint accuracy is not required for these missions. As a guide, 25 rounds (105-mm howitzer) may be used to saturate an area 500 x 500 yards. Each 105-mm shell holds about 500 leaflets, size 4 x 6¾ inches. The order to fire a propaganda mission will normally originate at corps artillery or higher headquarters. The order will prescribe the area to be covered and the amount of ammunition to be expended. The ammunition will be prepared by Ordnance personnel and issued through an ammunition supply point.

479. Ammunition

A base-ejection type of projectile is used to deliver propaganda leaflets. To date, there is no standard projectile but an HC smoke projectile, with booster and filler removed, is generally used. For example, shell, semifixed, smoke, HC, BE, M84, dualgran (w/o booster), with fuze MTSQ, M501, for 105-mm howitzers, may be used. The smoke canisters are removed, and the cavity is filled with leaflets. The shell weight, when filled with leaflets, will be determined and specified by the unit which prepares the ammunition.

480. FDC Procedures

Data are determined as in an HE mission with the following exceptions:

a. Site. The height of burst will depend on the effect of wind velocity and direction on the ejected leaflets. As a rule, the first round of the adjustment should be fired at a site which will give a 100-yard height of burst.

b. Fuze Setting. Since no firing tables are available for this type of shell, fuze setting must be computed from HE tabular firing tables.

Example: Elevation 348, chart range 5,800, charge 5, fuze M501 (105-mm howitzer):

Weight of shell HE, M1 (FT 105–H–4).	=33.0 pounds
Weight (as determined by Ordnance) of shell M84, with leaflets.	=26.4 pounds
Difference in weight	=6.6 pounds
Variation from standard per square (FT 105–H–4).	=.6 pounds
Difference in weight from standard (6.6/.6).	= −11 squares
Effect for variation of 1 square (elevation 348).	= −39 yards
Total effect (−39 x (−11))	= +429 yards
Effective range at which to fire leaflets (5,800−429).	=5371 yards
Fuze setting corresponding to range 5,370.	=19.2 seconds

c. Elevation. The elevation used is that which corresponds to effective range as determined in *b* above.

d. GFT. The existing HE GFT setting will be utilized to improve the degree of accuracy.

Note. Since pinpoint accuracy is not required for firing a propaganda shell, a special propaganda shell GFT setting was not determined in the example in *b* above (pars. 343 and 344).

Section IV. ASSAULT FIRE

481. General

Assault fire is a special technique of indirect fire. The FDC personnel, as part of the assault fire team (par. 111, 112, and 214–220), should make certain preparations prior to the occupation of position. Firing charts should be plotted and initial firing data computed. Also, deflection shift and quadrant change cards should be prepared. The advance planning and preparations should result in excellent initial data and a resulting short adjustment phase.

482. FDC Procedures

a. To obtain the necessary accuracy, an FDC is employed for each emplaced weapon. Normal observed fire and FDC procedures are used during the adjustment phase. The maximum charge which will clear the intervening crests is used to effect maximum muzzle velocity and penetration. The tabular firing table must be used. The minimum range on GFT's for the higher charges precludes their use.

b. Weapons used in assault fire should be of the largest calibers practical in the situation and should be emplaced within approximately 3,000 yards of the target (par. 111). Axial observation should be used if possible. After bursts are brought close to the target (within 25 yards), the observer makes corrections for site rather than for range to place the burst directly on the target, retaining control of the mission and reporting corrections for each round until the target is destroyed. Observer corrections are given initially to the nearest yard and finally to the nearest ½ yard. If, during the mission, the observer changes from fuze delay to fuze concrete piercing (CP), an FDC correction of UP 1 YARD is made to compensate for the ballistic difference between the fuzes.

c. After the data are measured for the first round in fire for effect, the use of the firing chart is discontinued. During the remainder of the mission, data for commands (deflection and quadrant) are computed to place the burst directly on the target by a two-man team consisting of a deflection computer and a quadrant computer.

(1) As an aid in computing required deflection changes, the deflection computer prepares, prior to the start of the mission, a deflection shift card (fig. 170) for the chart range to the target. This card is prepared by using the C and D scales and Yd index of any GST or military slide rule. The range to the target is set on the C scale opposite the observer's correction on the D scale and the deflection shift in mils is read opposite the Yd index. The deflection shift in mils is rounded off to the nearest whole mil for observer corrections greater than 2 yards and to the nearest ¼ mil for observer corrections of 2 yards or less. A deflection board (fig. 57) is used by the battery to set off ¼-mil units of deflection (par. 112). To determine a new deflection to include the observer's corrections, the required deflection shift is applied to the previous deflection by use of the LARS rule (left, add; right, subtract).

Deflection shift card Observer's deflection correction (in yards)	Chart range 1,500 yards deflection shift (in mils)
½	¼
1	¾
2	1¼
3	2
4	3
5	3
6	4
7	5
8	5
9	6
10	7

Figure 170. Deflection shift card.

Example: Chart range 1,500 yards:

Previous df fired	*Observer's correction (yd)*	*Df shift from card (mils)*	*New df command*
2610	R7	R5	2605
2605	L4	L3	2608
2608	L2	L1, 1/4	2609, L1/4
2609, L1/4	R1	R3/4	2609, R1/2
2609, R1/2	L1/2	L1/4	2609, R1/4

(2) As an aid in computing the required quadrant change (to the nearest 1/10 mil), the quadrant computer prepares in advance a quadrant change card (fig. 171) for the chart range to the target.

This card is prepared in the same manner as the deflection shift card. The quadrant change in mils is rounded off to the nearest whole mil for observer corrections greater than 2 yards and to the nearest 1/10 mil for observer correction of 2 yards or less. The gunner's quadrant is used throughout the mission. To determine a new quadrant to include the observer's correction, the required quadrant change is applied in the appropriate direction to the previous quadrant fired.

Example: Chart range 1,500 yards:

Previous QE fired	*Observer's corrections (yd)*	*QE change from card (m)*	*New QE command*
30.0	UP 4	+3	33. 0
33.0	DOWN 2	−1. 4	31. 6
31.6	UP ½	+0. 3	31. 9

Quadrant change card	Chart range 1,500 yards
Observer's site correction (in yards)	Quadrant change (in mils)
½	0.3
1	0.7
2	1.4
3	2
4	3
5	3
6	4
7	5
8	5
9	6
10	7

Figure 171. Quadrant change card.

Section V. HIGH-ANGLE FIRE

483. General

a. Fire delivered at elevations greater than the elevation for maximum range is called high-angle fire. Most howitzers are capable of firing effectively at elevations in excess of the elevation corresponding to maximum range. High-velocity weapons, such as guns, normally are not used for high-angle fire. Their high maximum ordinate may produce unpredictable results. High-angle fire may be required when firing into or out of deep defilade, such as that found in jungle, mountainous terrain, sharply eroded terrain, or cities. Also, it may be required when firing over high terrain features near friendly troops. This type of fire may be requested by the observer or ordered by the FDO, based on the terrain around the target. It may be ordered by the FDO because of the terrain in the position area. The principles of observed and unobserved fires applicable to normal trajectories apply in general to high-angle fire. However, in high-angle fire, an increase in elevation decreases the range and a decrease in elevation increases the range to the point of impact.

b. High-angle fire involves extremely high maximum ordinates and correspondingly long times of flight. Small changes in range cause relatively large changes in maximum ordinate and time of flight. To assist an observer in identifying his rounds, the FDC personnel will notify the observer ON THE WAY and may give the time of flight. Time of flight must always be given to an air observer. The warning SPLASH will be given 5 seconds prior to impact of the shell(s).

c. Fire commands for high-angle fire must include the command HIGH ANGLE to alert the gun crews that a high-angle mission is to be fired. This command follows the ammunition lot number. All other commands for a precision mission and for the adjusting battery for an area mission are the same as for low-angle fire. Commands for the nonadjusting batteries include only partial elements of information; i. e., the charge, which may change during the adjustment, and the elements of quadrant elevation, which cannot be used until the piece is to be loaded, are omitted until fire for effect. For example—

Adjusting battery	*Nonadjusting battery*
BATTERY ADJUST	BATTERY ADJUST
SHELL HE	SHELL HE
LOT ———	LOT ———
HIGH-ANGLE, CHARGE 4	HIGH ANGLE (charge is omitted)
FUZE Q	FUZE Q
CENTER 1 ROUND	BATTERY 4 ROUNDS
CORRECTIONS ZERO	CORRECTIONS ZERO
DEFLECTION 2992	DEFLECTION 2847
SITE 297	WAIT (Further commands are not given until FFE.)
ELEVATION 956	

484. Charge

In selecting the charge to be used, the adjusting battery chart operator (computer), supervised by the FDO, selects the charge which is least likely to result in a need for changing charges due to subsequent range corrections from the observer. Depending on the weapon used, there is some degree of overlap in ranges covered by various charges. If there appears to be no choice between two charges, the lower charge is selected to reduce time of flight and tube wear. However, during an adjustment it may be necessary to change from one charge to another unless the observer's initial target location is accurate.

485. Fuze

The most effective fragmentation of an air burst occurs in a plane approximately at right angles to the line of fall. This fragmentation is practically parallel to the ground with high-angle fire. Consequently, if time fuze were fired, a very slight error in height of burst may raise the fragmentation so high as to cause total loss of effect. Owing to the large height-of-burst error, time fuze is not feasible with high-angle fire. The steep angle of fall eliminates the possibility of ricochet fire. Fuze quick or fuze VT normally is used.

a. Fuze quick is very effective when used in high-angle fire against personnel in the open because the projectile is almost vertical at the instant of detonation. Since the side spray of the burst contains most of the shell fragments, the effect is a spray in all directions out from the point of impact, approximately parallel to and very close to the ground.

b. The maximum lethality against personnel in the open is attained from the HE projectile by using fuze VT. This combination has the advantages of the lateral spray effect obtained with fuze quick and the effectiveness of a very low air burst.

c. Because the side spray is horizontal rather than vertical as with low-angle fire, high-angle fire can be expected to be less effective against personnel in trenches or foxholes, regardless of the fuze used.

486. Deflection

Chart deflection is measured by using the current low-angle deflection index, except when only high-angle fire will be fired. In this case, a deflection index will be constructed after the first high-angle registration.

a. 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 (fig. 172).

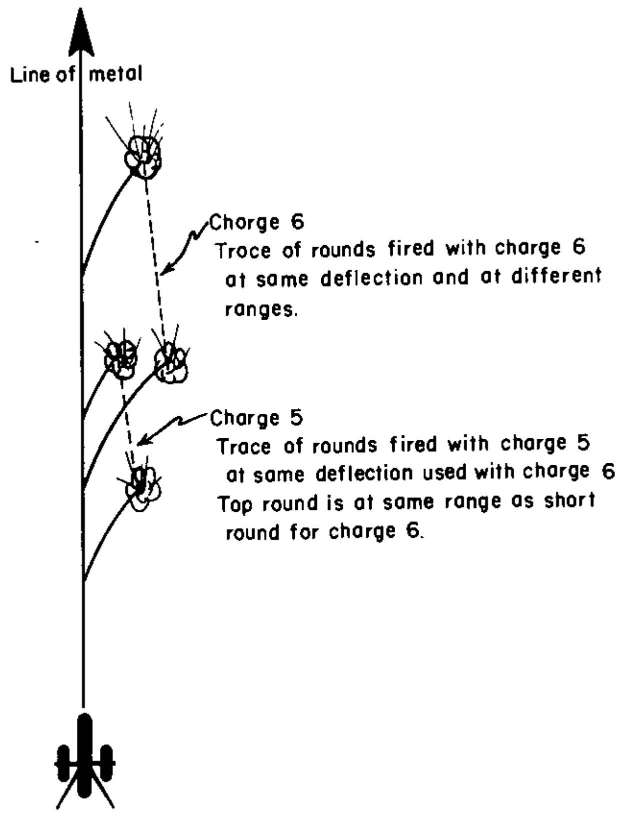


Figure 172. Drift effect in high-angle fire.

b. Drift changes too rapidly to permit use of a deflection correction scale as used in low-angle fire. Because drift changes an appreciable amount for relatively small range changes, a correction to compensate for drift, which is determined at the elevation to be fired, is included in each deflection to be fired. Since drift in present standard artillery is to the right, the correction is to the left and therefore is always added to the chart deflection.

Example: 105-mm howitzer, charge 4, high angle:

Range	*Elevation*	*Chart deflection*	*Drift*	*Piece deflection*
5,500	1,076	2,800	R41	2,841

c. When a registration is conducted, total deflection corrections are determined by comparing chart and adjusted deflection; i. e., total correction equals known corrections plus unknown corrections. The correction that is known for any adjusted elevation is drift; therefore, total corrections equal drift corrections plus unknown corrections; or, unknown corrections equal total corrections (registration) minus drift corrections. In high-angle fire, these unknown corrections become the deflection correction used for the charge. They correspond to the deflection correction scale used in low-angle fire.

Example: 105-mm howitzer, charge 3, high angle:

Chart range to registration point---	=4,500 yards
Chart deflection to registration point-	=2,918 mils
Adjusted elevation---------------	=1,045 mils
Adjusted deflection---------------	=2,970 mils
Total deflection correction (includes drift) (2,970−2,918=+52).	=L52 mils
Drift corresponding to adjusted elevation.	=R37 mils
Drift correction------------------	=L37 mils
Deflection correction (charge 3) (total deflection correction L52 minus drift correction L37).	=L15 mils

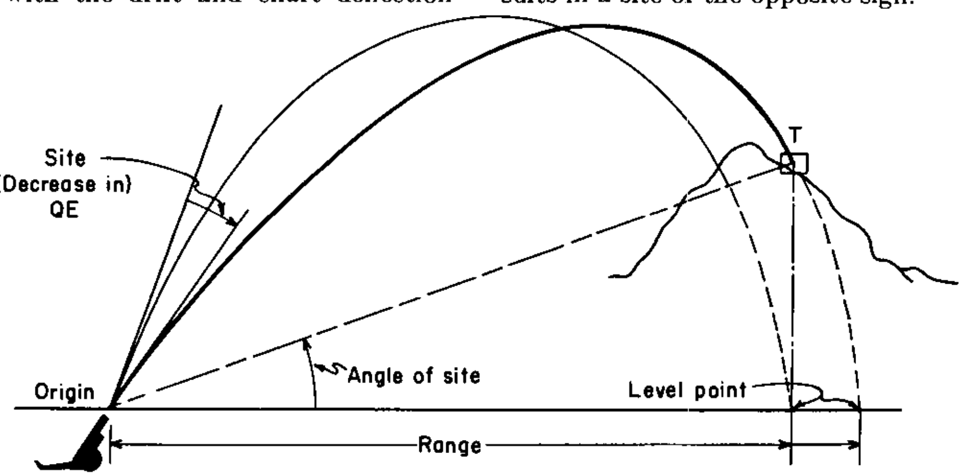
d. If a registration has not been conducted and met or experience factors are unknown, a deflection correction of zero will be used. When a registration(s) has been conducted, the deflection correction for that charge, or for the charge nearest the charge to be fired, will be used. The deflection correction is normally used in observed fire missions with equipment prepared as described in paragraphs 348 and 349. The method of handling deflection correction in high-angle fire differs from the method for low-angle fire in that the deflection correction is not placed on the gunner's aid. Instead, the deflection correction is combined with the drift and chart deflection and the total is announced to the pieces as deflection. For consistency, deflection correction of zero is announced in the normal sequence in the fire command.

487. Site

a. For observed fires, site, which has a relatively small effect because of the large angle of fall, normally can be ignored if the angle of site is no larger than plus or minus 30 mils. However, site must always be considered in registrations or transfers of fire. Whether or not site is to be included is decided by the FDO and announced in the fire order. Omission in the fire order of the command INCLUDE SITE means that site is to be ignored. Regardless of whether or not site is included in fire commands, the height of burst over range factor (20/R), used with fuze VT in low-angle fire, is not used in high-angle fire because the descending branch of the trajectory is nearly vertical.

b. No GST is provided with which *sites* for high-angle fire may be computed; therefore, the C and D scales of any GST can be used to compute the *angle* of site. An increase in angle of site requires a decrease in quadrant elevation (fig. 173) because the complementary angle of site is greater than one and always has a sign opposite that of the angle of site. If the angle of site is plus, the comp site is minus; if the angle of site is minus, the comp site is plus. The comp site factor is a function of elevation and not of range.

c. When tabular firing tables are used to compute site, complementary angle of site is added algebraically to the angle of site and always results in a site of the opposite sign.



Note. Range at level point corresponding to smaller QE is longer than range corresponding to larger QE.

Figure 173. Effect of plus angle of site on trajectory.

Example: 105-mm howitzer, charge 4, using tabular tables (FT 105-H-4):

Chart range	=5,580 yards
Elevation corresponding to chart range.	=1,063.2 mils
Altitude of battery	=400 yards
Altitude of target	=443 yards
Vertical interval	=+43 yards
Angle of site (C and D scales, GST: 7.8).	=+8 mils
Comp site factor (col 16, FT 105-H-4) corresponding to elevation 1,063.2 (1,060.0).	=−1.47 mils
Comp site (+8 x (−1.47) = −11.8)	=−12 mils
Site = angle of site + comp site (+8+(−12)).	=−4 mils
Quadrant elevation = elevation + site (1,063.2+(−4) = 1,059.2).	=1,059 mils

d. To simplify the determination of site when high-angle fire is being used, a special site scale has been included on high-angle graphical equipment. On the GFT fan, a site scale is located to the right of the elevation scale; on the GFT, a site scale is located just below the elevation scale. The site scale is constructed in units of 10 mils to avoid printing decimals and to facilitate reading the scale. This scale is referred to as the 10-mil site scale. The readings obtained from this scale give the *site* for 10 mils *angle of site* at the elevation and charge that is being used. The site for any point is determined by multiplying the figure read from this scale by the angle of site to that point in units of ten. The 10-mil site scale was constructed by including the average of the plus comp site factor and the minus comp site factor found in the tabular firing tables. Hence, the site derived from the 10-mil site scale will be slightly less accurate than the value computed from the tabular tables. The 10-mil site reading will always be opposite in sign to the angle of site since it includes comp site.

Example: 105-mm howitzer, charge 4, using GFT:

Chart range	=5,580 yards
Elevation corresponding to chart range	=1,063 mils
Altitude of battery	=400 yards
Altitude of target	=443 yards
Vertical interval	=+43 yards
Angle of site (C and D scale, GST: 7.8)	=+8 mils
Site for +10 mils (ballistic scale)	=−4.3 mils
Site for +8 mils (+0.8 × (−4.3) = −3.4)	=−3 mils
Quadrant elevation (1,063 + (−3.0))	=1,060 mils

488. Precision Registration, High-Angle Fire

a. During the adjustment phase of a high-angle fire precision registration, standard FDC procedures are followed (par. 312), except that drift is combined with chart deflection for each round.

b. During the fire for effect phase (fig. 174), the same procedures are followed as in a low-angle fire registration except that when the the first 3 positive sensings from rounds fired at the trial elevation are *over* in range, the trial elevation will be *increased* by ½ fork; when the first 3 positive sensings are *short* in range, the trial elevation will be *decreased* by ½ fork.

(1) When the elevation is changed by ½ fork, the change in drift for the new elevation is negligible and may be ignored.

(2) In computing the apparent adjusted elevation, if the preponderance is *over*, the change in elevation will be *added* to the mean elevation; if the preponderance is *short*, the change in elevation will be *subtracted* from the mean elevation.

c. Site must be stripped from the adjusted quadrant elevation to determine the adjusted elevation. The correct site can only be derived by successive approximations since comp site is a function of elevation and not of chart range.

Example: Determination of adjusted elevation by successive approximations, 105-mm howitzer, charge 3:

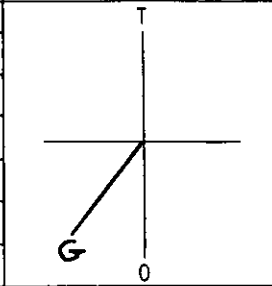
Chart range	=4,490 yards
Angle of site (from chart data)	=+48 mils
Adjusted elevation	=1,015 mils
Site fired	=−19 mils
Adjusted quadrant elevation	=996 mils
First apparent 10-mil site factor (corresponds to elevation 1,015)	=−6.1 mils
First apparent site (+4.8×(−6.1) = −29.3)	=−29 mils
First appartent adjusted elevation = quadrant elevation − site (996−(−29))	=1,025 mils
Second apparent 10-mil site factor (corresponds to elevation 1,025)	=−5.7 mils
Second apparent site (+4.8×(−5.7) = −27.4)	=−27 mils
Second apparent adjusted elevation (996−(−27))	=1,023 mils
Third apparent 10-mil site factor (corresponds to elevation 1,023)	=−5.8 mils
Third apparent site (+4.8×(−5.8) = −27.8)	=−28 mils
Adjusted elevation (996−(−28))	=1,024 mils

Adjusted elevation is established when the site computed agrees within 1 mil of the previous computed site.

RECORD OF PRECISION FIRE

Date and time	Observer	Adjusting point	Battery
1 Aug 57	O1	Reg pt 2	B

Chart data		Initial fire commands
Deflection	2952	Nr 3, Adjust
Range	4590	Sh HE, HA, Lot X, Chg 3
Angle of Site	+8	Fz Q, MF Nr 3 ⓘ
Adjusted data		Corr O, Df 2991
Deflection	2984	Si 300
Elevation	1081	El 1060
Time		QE



Angle T 840

GFT setting GFT 8 chg 3, lot XX, rg 4590, el 1081, ti

Deflection correction Right 10

S/2 = 8 F = 20 F/2 = 10

Round nr	Chart df or Df fired	Chart range	Time fired	El or QE fired	Observer sensings or corrections	FDC sensings Range	FDC sensings Deflection
1	2952 + L39 2991	4590		1060	L30 -200		
2	2920 + L44 2964	4420		1090	+100		R
3	2940 + L42 2982	4490		1078	+50, FFE		R
4	2948 + L41 2989	4530		1070	+R	+	?
5	2989			1070	+Ln	+	L
6	2985			1070	+Ln	+	L
7	2983			1080	-Ln	−	R
8	2984			1080	-R	?	R
9				1080	+R	+	
10				1080	-L	−	
11	El change $\frac{4-2}{2\times6}$ ×	20=3.3			Drift corresponding to adj el		= R42
12	Mean el (1075) +3.3	= 1078.3			Adj df		= 2984
13	Adj el	= 1078			Chart df		= 2952
14	Site fired	= 0			Total df corr		= L32
15	Adj QE	= 1078			Less drift corr		= L42
16	10 mil site factor	= -4.0			Df corr		= R10
17	1st Apparent site (-4.0x0.8=3.2) = -3						
18	1st Apparent adj el (1078-(-3)) = 1081						
19	10 mil site factor	= -3.9					
20	2d Apparent site (-3.9x0.8=-3.12)=3						
21	Adj el	= 1081					
22							

DA FORM 1 APR 57 6-12 REPLACES EDITION OF 1 AUG 56

Figure 174. Record of Precision Fire (DA Form 6–12).

d. GFT settings are established in the same manner as for low-angle fire. For the example in *c* above, the GFT setting is—GFT B: Charge 3, lot X, range 4,490, elevation 1,024.

489. Preparation of Graphical Equipment

Graphical equipment is prepared for high-angle fire in the same way it is for low-angle fire missions, except that deflection corrections are recorded on the GFT and the range-deflection fan. Deflection corrections for different charges are determined from registration for each charge to be used. They are recorded in the following manner (*a–c* below):

a. Aluminum GFT Fan. The tabular firing table value of drift is printed on the ballistics scales of the aluminum GFT fan. The deflection correction for each charge determined from a precision registration, or from met data, will be written on the ballistic scale. The data will be written to the right or left of the charge scale to which the particular deflection correction applies (fig. 175①).

b. Plastic GFT Fan. High-angle ballistic scales for the plastic GFT fan either do not have drift values printed on the scale or have only the drift value printed corresponding to the short limit of each charge. If no high-angle registration data are available, drift values must be entered for each charge by using the value of drift from the tabular firing table or, when applicable, the one printed drift value. If registration data are available, a deflection correction is determined in the normal manner. The deflection correction is combined with drift, and the *combination* entered opposite the appropriate graduation (fig. 175②).

c. Range-Deflection Fan. To record the deflection correction for high-angle fire, the maximum and minimum range limits for each charge are marked on the interior part of the range-deflection fan so as not to interfere with any deflection correction scales for low-angle fire which may be on the edge of the fan. The deflection correction for each charge is entered on the fan within the range limits of the charge (fig. 175③).

490. Data for Replot

a. Data for replot is computed when the ajustment on a target is completed. This is accomplished in order that the battalion may mass its fires on a target when only one battery has adjusted and the correct location may be established for plotting the target on the firing chart.

b. Regardless of whether or not site is included during the adjustment, the correct site must be stripped from the adjusted quadrant elevation to obtain the adjusted elevation. The range at which the target is plotted is determined from the adjusted elevation. During the adjustment, the 10-mil site factor may change considerably and will result in a different effective site at the end of the adjustment than that used in the initial commands. This error must be corrected if the target is to be plotted at its correct range.

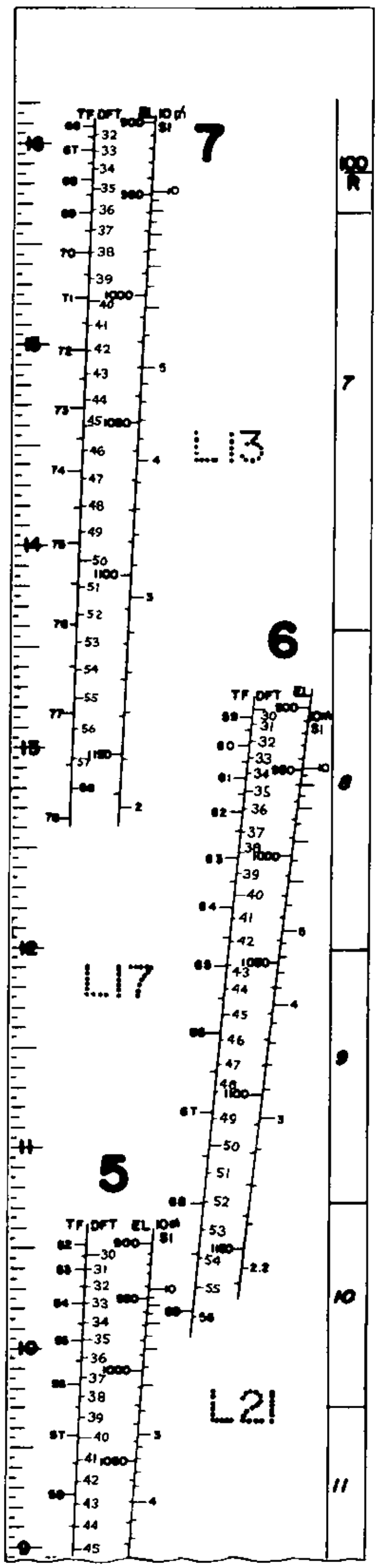
Example: 105-mm howitzer, GFT setting (from prior registration), GFT B: Charge 3, lot X, range 4,500, elevation 1,090:

Angle of site	=+20 mils
Adjusted quadrant elevation	=970 mils
10-mil site factor corresponding to elevation 970.	=−8.6 mils
First apparent site (+2.0 x (−8.6)= −17.2).	=−17 mils
First apparent adjusted elevation (970−(−17)).	=987 mils
10-mil site factor corresponding to elevation 987.	=−7.6 mils
Second apparent site (+2.0 x (−7.6)=−15.2).	=−15 mils
Second apparent adjusted elevation (970−(−15)).	=985 mils
10-mil site factor corresponding to elevation 985.	=−7.7 mils
Correct site (+2.0 x (−7.7)= −15.4). (This site agrees within 1 mil of the last computed site.)	=−15 mils
Correct adjusted elevation (970−(−15)).	=985 mils
Range corresponding to elevation 985 (use GFT setting) used in plotting target.	=5,000 yards

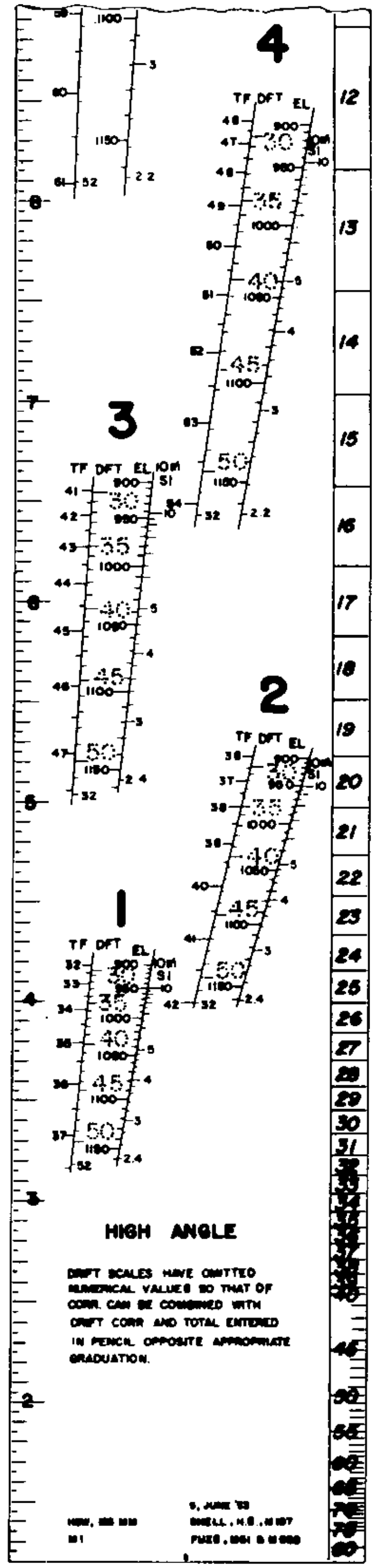
c. After the correct adjusted elevation has been determined as described in *b* above, the deflection correction for the charge and the drift correction (total correction) are subtracted from the adjusted deflection. If no deflection correction for the charge has been determined, the deflection for replot will be obtained by stripping only the drift correction from the adjusted deflection. The result is the deflection for plotting the target.

Example: 105-mm howitzer, charge 3:

Adjusted deflection	=2,645 mils
Adjusted elevation	=1,120 mils
Drift correction corresponding to adjusted elevation.	=L49 mils
Deflection correction for charge 3	=L15 mils
Total deflection correction (L49+L15).	=L64 mils
Replot deflection (2,645−L64)	=2,581 mils

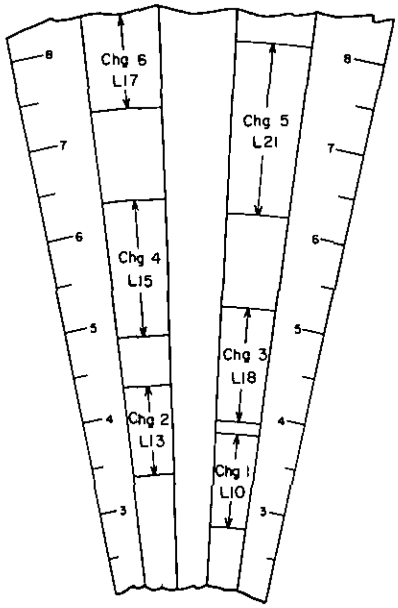


① Aluminum GFT fan



② Plastic GFT fan

Figure 175. Deflection corrections, high-angle.



③ Range-deflection fan

Figure 175—Continued.

d. If the firing chart is a contour map or if a large range change has been made since the angle of site was originally computed, based on the altitude of the target furnished by the observer or by estimate, the angle of site is recomputed for the replotted location of the target. If the recomputed angle of site differs 1 mil or more from the angle of site originally announced, a new adjusted elevation and a corrected range for replotting the target must be obtained. The process is repeated until the correct angle of site (one that changes less than 1 mil) and adjusted elevation are determined. Data for replot are reported using the same procedures as for low-angle fire except that the type of fire and charge used is included. For example, coordinates ———, altitude ———, fuze ———, *high-angle, charge* ———, concentration ———.

491. Transfers

The high maximum ordinates and long times of flight encountered in high-angle fire make massing or transfer of fire less reliable than with low-angle fire. Successful transfers of fire within a charge under stable weather conditions are practicable. The small area of range covered by each charge prevents establishment of definite transfer limits. Consequently, every effort should be made to obtain observation and to adjust each battery to fire on each target. During the adjustment of 1 battery, the 10-mil site factor may change considerably. This change will result in a different site at the end of the adjustment than that used in the initial commands. If the battalion is to mass on the target, this error in site must be corrected by replotting the target (based on the data for replot) before the chart data are determined for nonadjusting batteries.

492. Duties of Fire Direction Personnel

The duties of fire direction personnel in high-angle fire are the same as in low-angle fire except for minor modifications as stated in *a* through *d* below.

a. The FDO must include in the fire order the command HIGH ANGLE instead of the charge and whether to include site (par. 487).

(1) When adjustment is required prior to massing the battalion and only one battery is to adjust, the battery that is centrally located should normally be designated as the adjusting battery to eliminate large differences in range.

(2) For area missions for more than one battery, all batteries should fire at center range, since dispersion in range will usually result from the effects of weather and the probable use of different charges by each battery.

Example: High-angle fire order:

ALTITUDE 406, BN, BRAVO, HIGH ANGLE, INCLUDE SITE, FUZE VT, 2 VOLLEYS, CONCENTRATION AB 404.

b. The chart operator when using the GFT fan—

(1) Selects and announces the charge to be fired (par. 484).

(2) Announces drift corrections, in addition to deflection, and deflection corrections (deflection correction and drift corrections are combined on the plastic GFT fan) (par. 486).

(3) Determines angle of site and then site (par. 487).

c. The chart operator when using the range-deflection fan—

(1) Does not operate the GFT as in low-angle fire.

(2) Announces CORRECTIONS ALL CHARGES, ZERO if there has been no

registration with high-angle fire. When there has been one or more registrations, deflection correction is not announced until requested for a specific charge by the computer.

(3) Determines and announces angle of site instead of site as in low-angle fire.

d. The computer—

(1) Operates the GFT for the chart operator (when range-deflection fan is used).

(2) Determines drift and computes site if using a GFT.

(3) Combines the announced deflection with the announced and/or determined corrections and announces the piece deflection.

(4) Requests corrections when not announced by the chart operator.

Section VI. DESTRUCTION MISSIONS

493. General

a. The destruction of a target requires one or more target hits. If the target is strongly constructed (concrete, stone, earth and logs, etc.), target hits by light artillery have little effect. Therefore, most destruction missions will be fired by medium, heavy, or very heavy artillery. The 8-inch howitzer is an excellent weapon for this purpose, because of its accuracy and destructive power.

b. To destroy a point target, such as a disabled tank, bridge, or pillbox, the general procedures for precision fire as described in paragraphs 310 through 319 are employed. In a destruction mission, however, the object is to destroy the target; therefore, the mission is terminated by the observer instead of by the FDO, when destruction has been accomplished.

494. FDC Procedure

a. The adjusted deflection and quadrant elevation are determined in the same manner as in a normal precision registration. The adjusted quadrant elevation is computed and used to the nearest 1/10 mil.

b. If the target has not been destroyed prior to computing the first adjusted quadrant elevation, firing is continued at the adjusted quadrant elevation (nearest 1/10 mil), to obtain a second group of 6 positive range sensings, and a new adjusted quadrant elevation is computed. In computing the second adjusted quadrant elevation, one-half the indicated correction is applied. If a third group of sensings is required, one-third the correction is applied; for the fourth and succeeding groups, one-fourth the correction is applied.

Example: Fork=6:

No. of rounds fired	*QE fired*	*Range sensings*	*Remarks*
3	317	+ + +	Drop ½ fork (3)
3	314	− + −	El change $=\frac{4-2}{2\times 6}\times 6=-1$
			First adj QE=315.5+(−1)=314.5
6	314. 5	− − −	
		+ − +	El change $=\frac{\frac{4-2}{2\times 6}}{2}\times 6=+.5$
			Second adj QE=314.5+.5=315.0
6	315. 0	+ + +	
		+ + −	El change $=\frac{\frac{5-1}{2\times 6}}{3}\times 6=-.7$
			Third adj QE=315.0+(−.7)=314.3
6	314. 3	+ T +	
		− − −	El change $=\frac{\frac{3-2}{2\times 6}}{4}\times 6=+.1$
			Fourth adj QE=314.3+.1=314.4

Section VII. BARRAGES

495. General

A *barrage* is a prearranged barrier of fire. It is designed to protect friendly troops and installations by impeding enemy movements across defensive lines or areas. The normal ground use of a barrage is to establish prearranged close-in defensive fires which include coordinated employment of other artillery fires, mine fields, obstacles, final protective machine gun fire, and mortar barrages. Each battery is assigned only one barrage. It is normally laid on that barrage when not firing other missions. The barrage may be fired on prearranged signal or on call from the supported unit. The firing of a barrage may be repeated on call as often as necessary. When possible, the data for the barrage should be verified or corrected by the firing of check rounds.

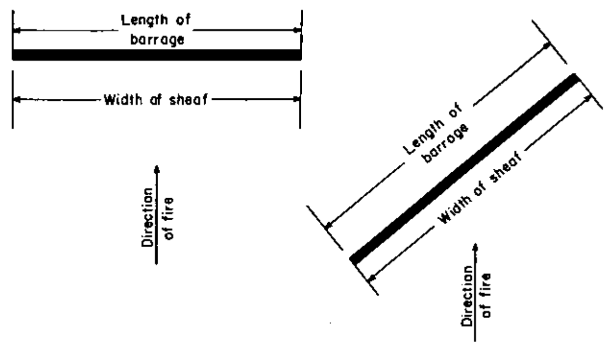


Figure 176. Barrage.

496. Characteristics of Barrages

The firing of a battery barrage, either individually or coordinated with other batteries, is based on the following (*a–c* below):

a. Width of Barrage (fig. 176). The width or the length of the barrage, which can be covered by a single battery without shifting its fire, should not exceed the width of an open sheaf as shown in table I. When necessary, the length of tbe barrage may be increased by agreement between the commanders of the artillery and the supported unit. However, the effectiveness of fire will be decreased.

b. Preparation of Data. The barrage may be at any angle to the direction of fire. Special corrections normally are used to place each burst in the proper position (pars. 381–389). Map data for a barrage are taken from the center point of the barrage line. The angle between the barrage and the direction of fire is used to secure a plot of the barrage on the device (M10 plotting board) that is used to compute individual corrections for each piece (par. 387). Firing data are determined by using normal procedures except for—

(1) *Distribution.* A barrage is fired by using a special sheaf.

(2) *Method of fire.* Fire is continuous fire 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. This may be done by the battery as a whole by employing shifting fire. 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. Shifting fire is accomplished by laying the battery (pieces) first on one part and then on other parts of the barrage to be covered. Continuous fire by piece is delivered alternately on each part of the target.

Section VIII. OFF-SCALE CHARTS

497. General

An off-scale chart is any map, grid sheet, or photograph from which chart data are to be measured and whose scale differs from that of the plotting equipment to be used in making measurements. For determination of scale, see TM 6–200.

498. Limitations

a. When the target grid is used, the observer's shift, range change, and subsequent corrections must be converted to the scale of the firing chart before they can be plotted, thus slowing the processing of a mission. Conversion of corrections is accomplished by setting up the following proportion:

$$\frac{\text{Scale of target grid}}{\text{scale of chart}}=\frac{\text{shift to be plotted}}{\text{observer shift}}$$

Use of the military slide rule or the C and D scales on the GST will facilitate a rapid solution.

Example: Scale of chart=1:20,000; scale of target grid=1:25,000; observer shift=500 yards:

$$\frac{1:25{,}000}{1:20{,}000}=\frac{\text{shift to be plotted}}{500} \text{ or } \frac{20{,}000}{25{,}000}=\frac{X}{500}$$

Shift to be plotted=400 yards.

b. It is preferable to use the off-scale map or photograph in conjunction with an on-scale grid sheet firing chart. The information contained on the map or photograph can be utilized by restituting from the photograph or map to the grid sheet.

499. FDC Procedures

a. When it is necessary to use an off-scale chart, the measured chart ranges must be converted to true ranges. The GFT fan and GFT can be set up to facilitate such conversion by using additional gageline(s) as indicated in (1) through (3) below:

(1) *GFT fan.* The gageline for the GFT fan is constructed by placing the hairline over the chart range and drawing a gageline through the elevation corresponding to the true range. This gageline may be labeled "True Range". For example, the true distance between 2 points is 5,280 yards whereas the chart distance is 4,800. With the hairline over range 4,800, a gageline is drawn from the vertex of the cursor through the elevation corresponding to range 5,280. Thus, with the vertex of the GFT fan at the chart location of the target, chart range is read under the hairline, and true range is read from the range scale *opposite* the elevation which is under the gageline. Elevation and time are read from the ballistic scale under the gageline.

(2) *GFT.* The gageline for the GFT is constructed by placing the hairline over the the chart range and drawing a gageline at the true range. This gageline may be labeled "True Range."

Example: The true distance between 2 points is 5,280 yards whereas the chart range is 4,800. With the hairline over 4,800, draw a gageline at 5,280. By moving the hairline to the announced chart range, the true range, elevation, and time can be read under the gageline. If the difference is such that, with the hairline over the chart range, the true range does not appear under the window, 2 gagelines must be drawn—1 representing chart range and the other, true range.

(3) *GFT settings.* Elevation and time gageline(s) are constructed and labeled in the normal manner.

Example: 155-mm howitzer, charge 4:

Chart range to registration point	=4,550 units
True range to registration point	=5,000 yards
Adjusted elevation	=305 mils

(*a*) *GFT fan.* With the hairline over the chart range of 4,550, an elevation gageline is drawn from the cursor vertex through elevation 305.

(*b*) *GFT.* With the hairline over the chart range of 4,550, an elevation gageline is drawn at elevation 305.

b. The deflection correction scale for an off-scale chart is constructed in relation to chart units, but it is based on transfer limits for true range. For example, by using the GFT setting established in *a* (3) above, the deflection correction scale would be as indicated below. The center of the scale is 5,000 yards or 4,550 chart units. The upper limit is 5,900 chart units (6,500 ground), and the lower limit is 3,200 chart units (3,500 ground).

3.2		(3.8) 3.9		4.5	(4.6)	5.0		5.4		5.8		5.9
	R2		R1		0		L1		L2		L3	

Section IX. COMBINED ADJUSTMENT

500. General

Combined adjustment is the conduct of fire by 2 or more observers. The observers should be located so that their observing lines intersect at an angle of 250 mils or more. This is a special type of adjustment in which the observers sense the deviation in mils. These sensings are converted into fire commands at the FDC. The amount and direction of the error of each round is determined from the combined information received from the observers. 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 for accurate surveillance of scheduled missions; and for surprise fire. The most serious limitation is the difficulty of coordination between the observers, in regard to communication, target designation, and sensing of the correct round. Center-of-impact and high-burst registrations are forms of combined observation and are explained in chapters 13, 18, and 19.

501. Target Designation and Conduct of Fire

a. For conduct of fire with combined adjustment, a minimum of two observation posts, the *location* of which need not be known, must be established. The angle of intersection between lines of sight from the 2 observation posts must be 250 mils or greater; however, for more accurate results, the angle of intersection should be at least 500 mils. If the observation posts are to be occupied at night, the instruments should be set up and oriented during the day or the instrument position and line of orientation must be staked out during the day.

b. Targets or adjusting points may be designated by one observer, or by the FDO, to the other observers by giving coordinates, by giving a description of the target and surrounding terrain, or by designating the target by reference to nearby objects. When observer locations are known, target designations may be given by instrument reading and vertical angle from a designated reference point or by polar coordinates.

c. When combined observation is to be used, the observer who initiates a mission makes the fire request, coordinates the target location, and ends the fire mission. When direct communication is not available between observers, coordination must be accomplished through the FDC. When a mission originates from the FDC, one observer is directed to control the mission. When possible, the OT azimuth will be reported by all observers. This information will help the FDC personnel in determining firing data.

d. If observation posts have been plotted on the firing chart and azimuths have been established, observers will report either azimuths or deviations as directed. The location of each burst center is plotted by intersection. Errors are determined and appropriate changes in data are made. FFE is started when a target hit or burst near the target is obtained. When corrections are current, time and ammunition can be saved by surprise FFE; when corrections are not current, surprise may be achieved through the use of an auxiliary adjusting point.

e. If observation posts are not plotted on the firing charts and azimuths have not been established, the observers report deviations in mils from the target. Fire is conducted at the FDC by using graph paper on which the observers' mil sensings are plotted and appropriate changes in data are made. Both precision and area missions can be fired by using this method. Area fire with surprise effect can be placed on any target that can be identified by both observers. Procedures used during the adjustment phase are covered in paragraph 502; FFE phase, paragraphs 503 and 504.

502. FDC Procedure During Adjustment, Observer Location Unknown

Fire direction procedure during the adjustment phase of firing with combined adjustment and observers' locations unknown is the same for both area and precision missions. The procedure is as follows (*a–e* below):

a. Only one gun is used during the adjustment.

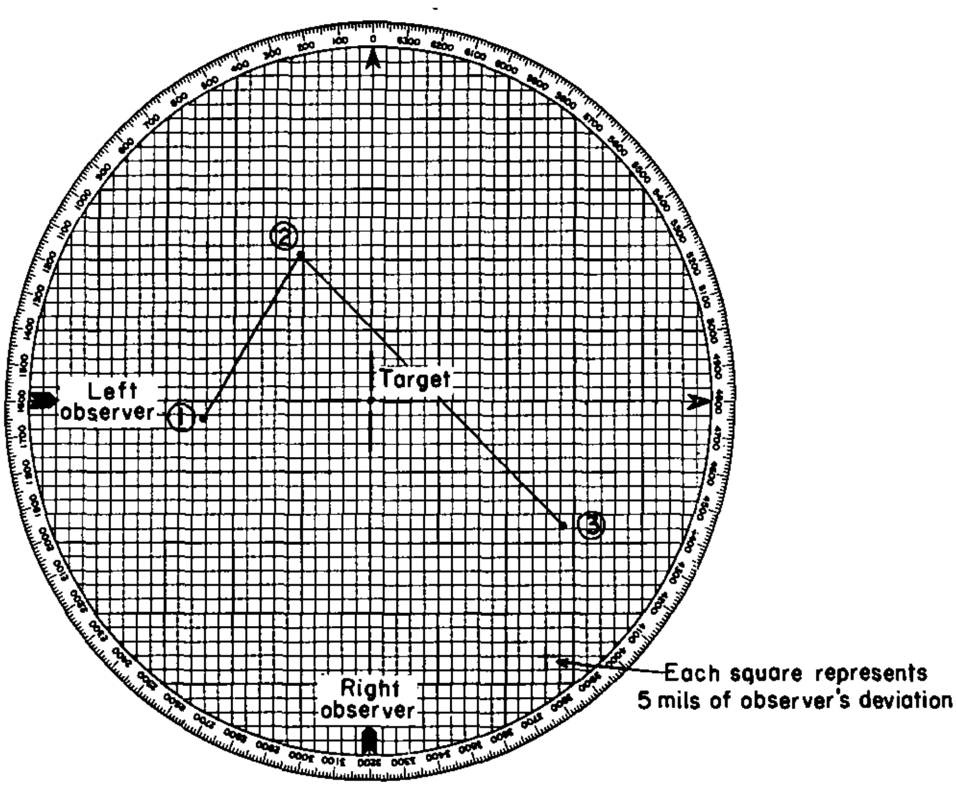
b. Any fuze may be used; however, use of fuze delay may result in lost rounds or erroneous sensings.

c. The target is plotted on the firing chart and initial data is prepared and announced to the crew of the weapon selected for the adjustment.

d. Subsequent elevation and deflection changes are determined by graphic means. Each round is plotted on graph paper (target grid may be used), based on the observers' sensings. The target is arbitrarily plotted at the approximate center of the graph paper. Although the locations of the OP's are unknown, it is arbitrarily assumed that the angle of intersection at the target is 1,600 mils. This assumption does not alter the relationship between the plots of rounds and the target. The left observer's OT line is assumed to be along the horizontal axis through the target, and the right observer's OT line is assumed to be along the vertical axis through the target. Each graduation of the graph paper is assigned the minimum mil value that will allow all rounds fired to be plotted on one sheet of paper.

e. Having an OP on each side of the GT line will produce the most accurate results. However, FFE will still be effective if the GT line is not between 2 OP's, provided that brackets established during adjustment do not exceed 400 yards.

Example: Combined adjustment, 155-mm gun, charge normal, fuze quick: From the chart plot (range 10,840), round 1 is fired at deflection 2,430 and elevation 240. The right observer reports 62 MILS LEFT, and the left observer reports 6 MILS RIGHT, which is plotted on the graph paper (fig. 177, burst ①). A shift large enough (in even multiples of 20 mils corresponding to approximately 400 yards) to bracket the target is made in elevation without changing the deflection. Estimation of size of shift required may be based



	Firing data		Observer deviations	
Burst nr	Deflection	Elevation	Right observer	Left observer
①	2,430	240	62L	6R
②	2,430	260	26L	53L
③	2,390	260	71R	44R

Figure 177. Plotting combined adjustment.

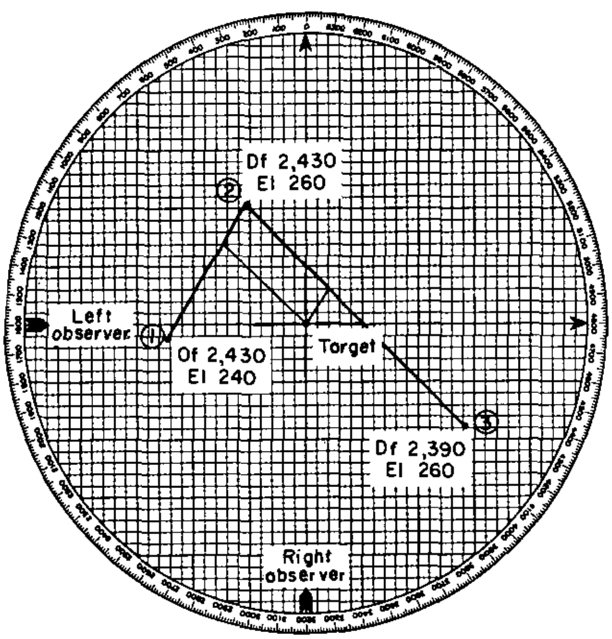


Figure 178. Combined adjustment parallelogram.

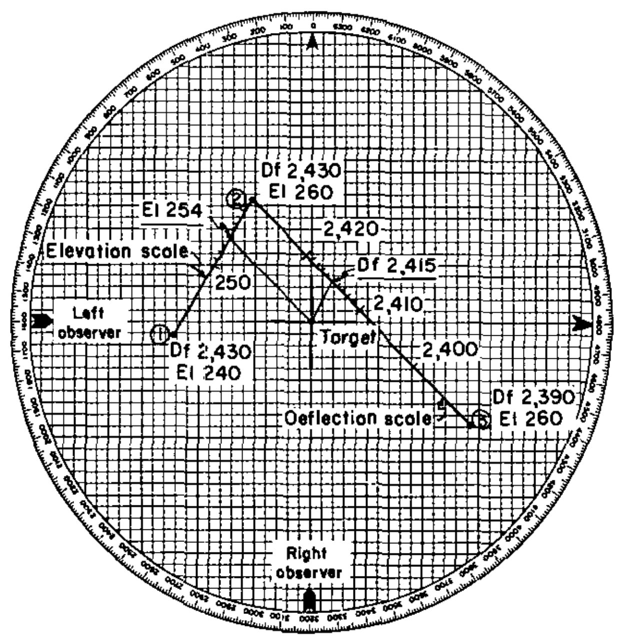
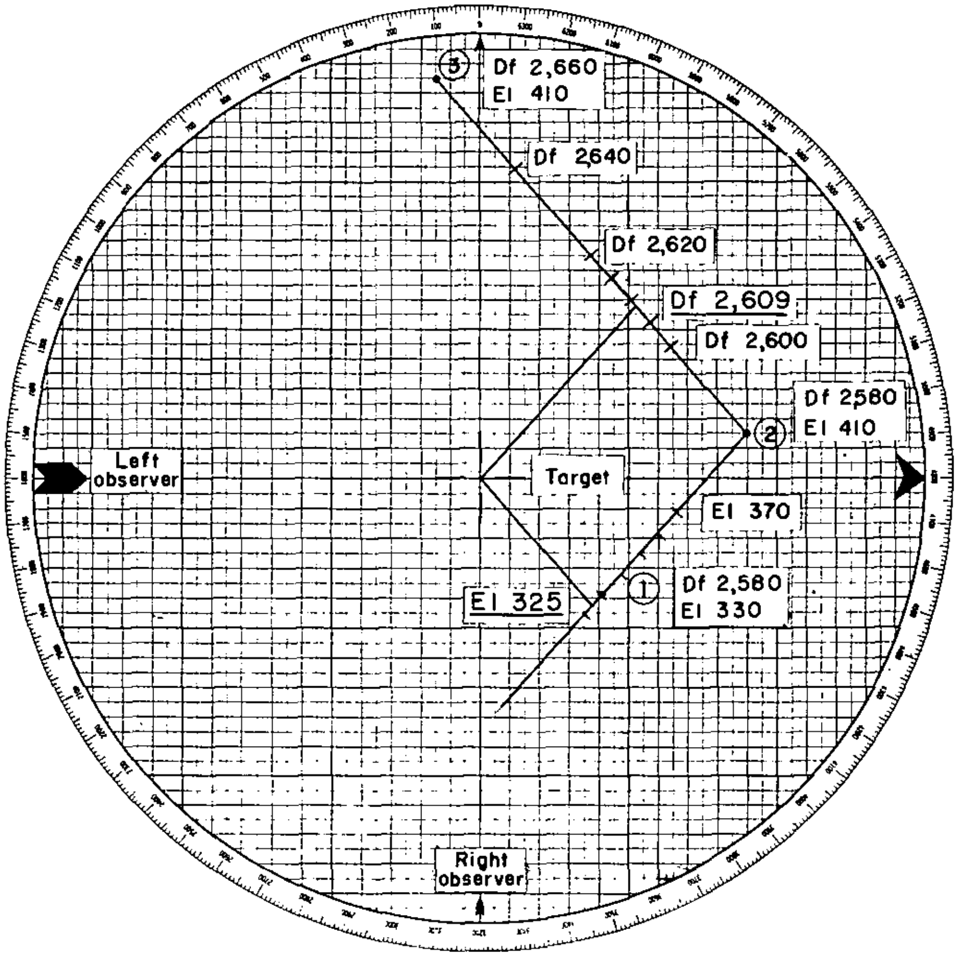


Figure 179. Determination of deflection and elevation by combined adjustment.



Burst Nr	Firing data Deflection	Elevation	Observer deviation Right observer	Left observer
①	2,580	330	41 R	39 R
②	2,580	410	90R	15L
③	2,660	410	15L	135L
FFE	2,609	325		

Figure 180. Combined adjustment without a bracket.

on the FDO's knowledge of the terrain and the situation. For equivalent accuracy, rough terrain requires a smaller bracket than flat terrain, since no round-to-round site change is made. Round 2 is fired at deflection 2,430 and elevation 260. The right observer reports 26 MILS LEFT, and the left observer reports 53 MILS LEFT, which is plotted. The two plotted burst locations (fig. 177, bursts ① and ②) define a line representing an elevation change of 20 mils and an elevation bracket. The GT line is approximately the same as the line representing the elevation change. A shift large enough to bracket the target in deflection (in even multiples of 20 mils corresponding to approximately 400 yards) is now made with no change in elevation. Round 3 is fired at deflection 2390 and elevation 260. The right observer reports 71 MILS RIGHT, and the left observer reports 44 MILS RIGHT, which is plotted. The last 2 plotted burst locations (fig. 177, bursts ② and ③) define a line representing a deflection change of 40 mils and a deflection bracket. As soon as round 3 is plotted, a parallelogram is constructed. It is made by drawing lines through the target, parallel to the elevation and deflection lines (fig. 178). To determine the trial range for registration or the data for FFE in an area mission, the deflection and elevation lines are divided into as many equal parts as they represent mils of deflection and elevation. The deflection (2,415) and elevation (254) for FFE are read where the sides of the parallelogram intersect the deflection and elevation lines (fig. 179).

Note. If a range bracket is not obtained with round 2, an additional round, based on plotted location of bursts 1 and 2, may be fired to obtain a range bracket prior to changing the deflection. The same procedure may be followed if a deflection bracket is not obtained from the first deflection change. However, if the target is not bracketed, for either range or deflection, but the bursts plot near the target, they may be used. Figure 180 illustrates the procedures used to extend the elevation scale to permit extrapolation of the elevation to be used in FFE. If a deflection bracket is not obtained, the deflection scale is extended in the same manner.

503. Fire for Effect, Registration

a. If either observer's azimuth to the target is known, that observer can be utilized to send sensings in FFE as in a precision registration with one observer (par. 313). The observer selected to conduct the FFE is notified that normal precision registration FFE procedure is required.

b. If observers' azimuths have not been determined, deviations in mils must be reported by each observer until FFE is completed. At the FDC, each round is plotted on the graph and positive elevation and deflection sensings are obtained by considering each plot in relation to the sides of the parallelogram which were drawn through the target. The line drawn parallel to the deflection scale separates *overs* from *shorts*, and the line drawn parallel to the elevation scale separates *rights* from *lefts*. For convenience, the line parallel to the deflection line may be divided into a deflection scale.

Example: Figure 181 shows round 4 as plotted from the observers' reported deviations. The plot is *short* of the line dividing overs and shorts and approximately 2 mils *left* of the line dividing

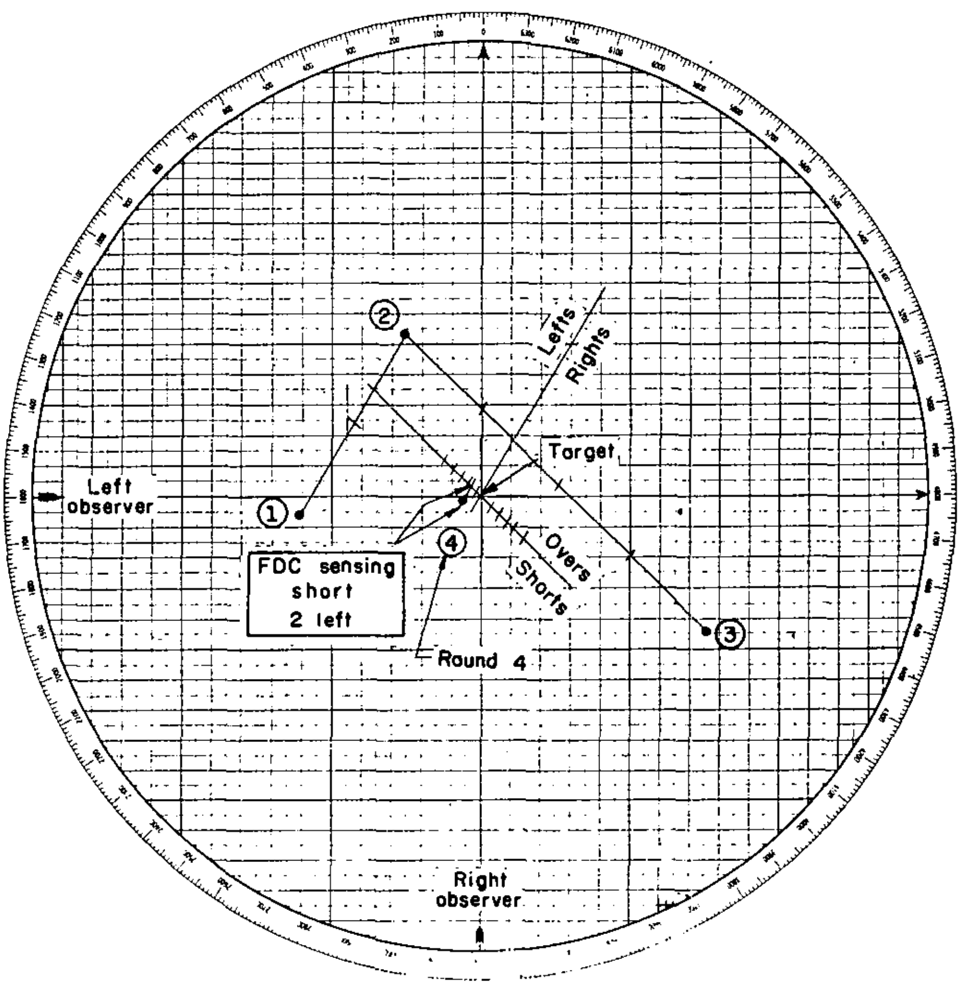


Figure 181. FDC sensing of first round in FFE for registration by combined adjustment.

lefts from rights. Therefore, the FDC sensing is SHORT, 2 LEFT.

(1) Elevation is corrected and adjusted elevation is determined as in a precision registration employing one observer.

(2) To determine adjusted deflection, a deflection bracket is established and split as in a precision registration employing one observer. The deflection bracket is established by firing the second round in FFE at a deflection determined by applying twice the amount of the measured FDC deviation in the appropriate direction to the deflection for the first round. For example, in figure 181, round 4 was fired at deflection 2,415 and the FDC sensing was 2 LEFT. Round 5 will be fired at deflection 2,411 (2,415+ right 4).

504. Fire for Effect, Area Missions

a. The adjusting battery may bring area targets under FFE at the deflection and elevation determined from the graph after the three rounds which establish the deflection and range brackets are plotted.

b. For area targets requiring the massed fires of more than one battery, the target location must be polar-plotted on the firing chart. The FFE deflection and elevation determined for the adjusting battery are used in polar plotting.

505. Fire for Effect Transfers

FFE transfers within 500 yards of a target adjusted on may be fired by using the scales determined from the adjustment. FFE transfers in excess of 500 yards may be made after a check round has been fired. To determine data for the transfer, the observers report the number of mils

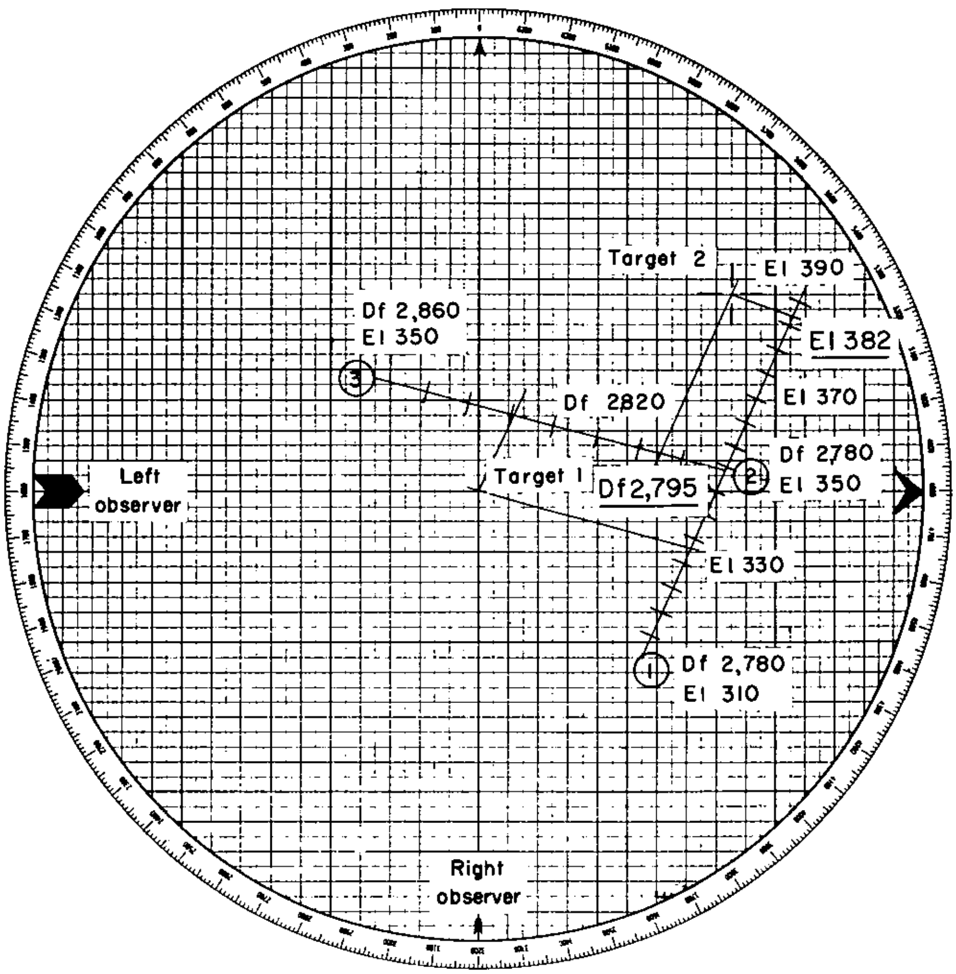


Figure 182. Combined adjustment, FFE transfer.

deviation from the target adjusted on to the new target. These deviations are plotted and the parallelogram is constructed through this target so as to intersect the deflection and elevation scales or their extensions.

Example: Target 1 has been adjusted on and scales have been determined as shown in figure 182. The right observer reports TARGET 2 IS 84 MILS RIGHT; the left observer reports TARGET 2 IS 64 MILS LEFT. Target 2 is plotted and data determined to be deflection 2,795, elevation 382.

Section X. SOUND, FLASH, AND RADAR OBSERVATIONS

506. General

Sound, flash, and radar observation agencies are used by field artillery to locate targets, adjust fire, and obtain battlefield intelligence. These agencies can locate targets at distances and under conditions which preclude standard visual observation. Observation battalions contain sound, flash, and radar elements. Such battalions are normally assigned to corps artillery headquarters. However, observation batteries when operating independently may be attached to division or lower headquarters. The information and assistance of the observation battalion are available to the firing battalion by coordination through division or corps artillery or the observation battalion. Countermortar radar is organic to divisional light artillery battalions. The techniques employed by sound, flash, and radar units are covered in FM 6–120.

507. Target Designation

a. Targets located by sound, flash, or radar are reported by coordinates and altitude if survey and reliable maps are available. Sound and radar platoons must determine altitudes of targets from maps; however, flash platoons can always determine relative altitudes. In the absence of survey, the observation battalion can report targets in relation to a reference point, previous concentration, or registration point which has been located relative to both the firing battalion and the locating agency (FM 6–120).

b. The location of a target or registration point can be given to the observation battalion as coordinates, if survey or maps are available; as an orienting azimuth, if directional control is available; or in relation to a known point. The target or point must be described to facilitate location.

508. Coordination for Area Missions

a. Targets, located by the observation battalion, which are to be fired upon without adjustment are assigned to the firing battalion by the controlling headquarters. The observation battalion may conduct surveillance of fire for effect. In that case, results on the target are reported to the controlling headquarters.

b. If the observation battalion is to adjust fire, direct communication should be established between the battalion to fire and the locating agency (e. g., flash platoon). Direct communication is normally established on existing nets. Standard target grid procedure is used at the FDC for the mission.

c. Targets which are not normally of primary concern to the controlling headquarters (e. g., mortar locations, in the case of corps artillery) can be reported directly to the firing battalion by the observation battalion. This system is established by coordination between the firing battalion and the observation battalion. Targets so reported are also reported to the controlling headquarters.

509. Conducting Registration and Calibration

a. Sound, flash, and radar units can register artillery (FM 6–120). Registration by sound ranging is the least accurate of these three methods. It should be used only when registration by any other means is impossible. The coordinates and altitude of the registration point (point selected for CI or HB) should be determined by the firing battalion in conjunction with the observation battalion.

b. If the registration is to be a CI or HB, the number of rounds fired is determined at the FDC; however, the observation battalion may request one or more rounds fired AT MY COMMAND in order to orient the observers. (They may be requested to assure positive identification in the case of sound ranging or radar.) A specific interval between rounds may also be requested. Additional rounds may also be required in the case of lost or erratic rounds. The most current corrections should be applied by FDC personnel to CI or HB firing data to facilitate sensing the first round by the observing unit. The location of the CI or HB is computed by the observation battalion and reported to the firing battalion. In the case of a precision registration, normal FDC procedures are followed.

c. The flash platoon of an observation battalion can provide mean burst location for comparative calibration (pars. 638–655).

d. Registration and calibration missions are secondary to the observation battalion's primary mission of locating targets. Such missions must be coordinated to prevent interference with the primary mission.

510. Sound Ranging

a. Sound ranging is used to locate hostile artillery and to adjust fire. Sound locations and adjustments are not affected by poor visibility; however, high winds make the use of sound equipment more difficult.

b. Sound ranging involves the use of OP's manned by observation battalion personnel who can also conduct visual adjustment of fire. However, when adjusting fire, these observers cannot effectively perform their primary mission of locating hostile artillery by sound ranging.

511. Flash Ronging

Flash ranging is the most accurate means of locating targets; however, the efficiency of the flash OP's is limited by poor visibility and adverse terrain. Flash ranging equipment is used to—

a. Locate hostile artillery.
b. Adjust and register friendly artillery.
c. Collect battlefield information.
d. Perform comparative calibration of artillery.

512. Radar Ranging

a. Field artillery radar is used to—

(1) Locate hostile artillery and mortars.
(2) Adjust and register friendly artillery.
(3) Perform battlefield surveillance.

Note. The same radar position cannot be used effectively for both locating hostile weapons and battlefield surveillance. Radar ranging is not affected by conditions of poor visibility or darkness. However, mountainous terrain makes both selection of radar positions and location of targets more difficult. Adjustment of fire by radar is difficult and time-consuming. It should be used only when no other means is available.

b. Radar can be used to register friendly artillery and improve the observed firing chart (pars. 455–462).

513. FDC Procedures for Targets Located by Sound, Flash, or Radar

a. Depending on the accuracy of location, type of target, and time available, targets located by sound, flash, or radar may be attacked with or without adjustment.

b. When targets are to be attacked without adjustment, FDC procedures are the same as those used for any FFE target received from higher headquarters.

(1) Radar and sound ranging surveillance will include only the distance the center of impact of FFE landed from the target and will not contain any observed results. Flash ranging surveillance may be more detailed than that expected from the forward observer.

(2) Sound ranging platoons may request one round to be fired after the FFE to plot the location of the effect, because many rounds bursting at the same time make sound tapes difficult to read.

c. When sound, flash, or radar is used to conduct the adjustment of fire on a target, the FDC will receive a standard fire request and standard corrections; procedures are the same as those used in a normal adjustment by a forward observer except that—

(1) Time of flight is given to the adjusting agency (e. g., sound platoon) prior to commencing fire. ON THE WAY and SPLASH are always given for each round.

(2) All adjustments are conducted with one weapon.

(3) Flash adjustment may contain refined corrections which would not be encountered in an observer adjustment (e. g., RIGHT 110, ADD 550), because each burst is accurately located.

(4) Sound-on-sound adjustments (FM 6–120) must be conducted with fuze quick.

(5) Radar personnel may request the range and azimuth to the target to assist in orienting the antenna for picking up the rounds.

(6) Adjustments by sound, flash, or radar will be slower than adjustments by one observer, owing to the necessity of plotting each round prior to determining corrections.

Section XI. HEAVY AND VERY HEAVY ARTILLERY FIRE DIRECTION PROCEDURE

514. General

a. The mission of heavy and very heavy artillery is to provide general artillery support and/or reinforcing fire to units of a division, corps, or field army.

b. The procedures set forth in part FOUR generally apply to all heavy and very heavy field artillery. Specific differences are covered in this section. For information on 280-mm gun gunnery techniques, see appendix IV.

c. Observation for long-range adjustments is difficult to obtain. With the exception of organic air observation, heavy and very heavy artillery battalions normally rely on other units or higher headquarters for observation. 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 requires coordinated observation by two or more observers.

d. Heavy and very heavy artillery must be used with prudence. Ammunition is difficult to obtain and transport. Wear of the tubes is great.

e. General organization and characteristics of heavy and very heavy artillery battalions are presented in table VI.

515. Firing Chart

a. The deliberate method of employment of heavy and very heavy artillery normally permits adequate survey to be accomplished before firing; therefore, the surveyed firing chart is used habitually. General procedures are the same as for light and medium artillery. When the tactical situation requires well-dispersed positions, it may be necessary to plot—

(1) The location of each piece (this is normal with very heavy artillery).

(2) The platoon center of each platoon.

b. When each piece, or the platoon center, is plotted on the firing chart, the standard battery color system is employed together with the number of the piece, or platoon, for the tick mark and deflection indexes.

516. Registration

The present techniques for the handling of a precision registration by the FDC apply in general to all artillery, regardless of caliber. The exceptions to this rule are when the value of the fork is 150 yards or greater or 50 yards or less.

a. Fork is 150 Yards or Greater. When the value of the fork is 150 yards or greater, regardless of the type of mission (area or precision), the rounds fired as a result of ADD (DROP) 50, FFE, may be wasted, since dispersion may cause them to hit in the same place. In such cases, the FDO should notify the observer with the initial ON THE WAY to begin FFE when a 200-yard bracket is split. The value of the fork in yards is determined in the following manner:

Example: 155-mm gun, supercharge, range 22,000 yards:

Fork = four range probable errors
Range probable error (FT 155–S–2, p 64, col 7) = 54 yards
Fork (4 x 54) = 216 yards

Table VI. Organization and Characteristics

Weapon	Pieces per btry	Max range	Charges	Avg tube life* (Full charge rnds)	Avg loss of MV during tube life
155-mm gun	4	25,715 yd	Normal and super	1,800	90 to 120 f/s
8-inch how	4	18,510 yd	1 to 5 green bag; 5 to 7 white bag	6,000	(**)
240-mm how	2	25,255 yd	1 to 4	2,000	50 to 70 f/s
8-inch gun	2	35,490 yd	Green bag: reduced and normal; white bag: normal and super.	700	224 to 296 f/s
280-mm gun	2	31,200 yd	1 to 4	400	Unknown

* Used as a guide, not basis for condemnation.
** Unknown, but very small. There is negligible loss in muzzle velocity in 2,000 full charge rounds.

b. Fork is 50 Yards or Less. When the value of the fork is 50 yards or less, normal techniques are followed in area missions; for precision missions, the initial 3 rounds fired at the trial elevation as a result of ADD (DROP) 50, FFE, may be wasted, since a change of 50 yards may move the point of impact more than ½ fork from the target. Instead of ordering DROP (ADD) 50, FFE (based on the observer's correction), the FDO will order DROP (ADD) 50, 1 ROUND. Based on the sensing of this round, the FDO will continue the adjustment by moving one fork in the appropriate direction until a bracket is established. The FDO will then split the one-fork bracket and order FFE. The value of the fork in yards is determined in the same manner as in *a* above.

Example: 8-inch howitzer, charge 7:

s/2=2 F=2 Guns on right Angle T=720㎖

Round No.	Df fired	Chart range	El or QE fired	Observer sensings or corrections	FDC sensings Rg	FDC sensings Df
*	*	*	*	*		
5	2, 652	12, 600	326	+50 FFE	----	L
6	2, 650	12, 670	329	−R	—	?
7			331	?L	+	?
8			330	−LN	—	L
9	2, 648		330	−LN	—	L
10	2, 646		330	−LN	—	L
11	2, 644		331	+LN	+	R
12	2, 645		331	−LN	—	----

Adj QE=331.
Adj df=2,645.

(1) FFE is not begun until a 1-fork bracket is established (round 7).

(2) The 1-fork bracket is split and the first group of 3 rounds (rounds 8, 9, 10) is fired.

(3) Since the first 3 rounds in FFE were in the same sense, 2 additional rounds are fired at the appropriate end of the 1-fork bracket. Since these 2 rounds are fired at the same elevation as round 7, round 7 is used as the sixth round in FFE.

(4) Adjusted elevation is computed by using the six rounds considered in FFE.

517. Destruction Mission

a. If a point target, such as a bunker, a pillbox, or a disabled tank is to be destroyed, the same general precision procedures are used. Prior to attacking a point target, the FDO should compute the single shot hit probability (SSHP). With this, he should enter the assurance graph for the estimated required hits at the desired level of assurance. From the graph he can read the probable number of rounds required. Computing the SSHP and the use of assurance graphs are discussed in chapter 27. The probable number of rounds required and the available supply rate may determine if the mission should be fired.

b. The normal procedures for a destruction mission apply to heavy and very heavy artillery.

c. During a prolonged mission, there is a possibility that the center of impact may move owing to a change in weather or ammunition. A change in the center of impact is indicated when, during the FFE phase, the observer sensings are all in the same sense (six shorts (overs)). In this event, a new bracket is established by moving ½ fork in the appropriate direction and firing 1 round to establish a new bracket. If the round is in an opposite sense, the elevation fired is considered as the trial elevation and two more rounds are fired. If all three rounds are in the same sense, the bracket is split and FFE is continued. If the 3 rounds are sensed as mixed, an additional group of 3 rounds is fired and a new adjusted elevation is computed. For fire direction purposes, the refinement of FFE is started anew.

518. Fire Capabilities

Fire capabilities charts are constructed for heavy artillery in the same manner as for light artillery (par. 532). Very heavy artillery weapons are normally located on the firing chart by individual piece, and the fire capabilities are determined for each piece.

519. Calibration

Calibration of heavy and very heavy artillery is essential. The velocity error of each *piece* must be determined. Redistribution of weapons and the subsequent computation and application of calibration corrections are performed in the same manner as for light and medium artillery. However, erosion is relatively rapid in high-velocity guns. There is a correspondingly greater loss in muzzle velocity for a given number of rounds fired. Therefore, unless the same number of rounds are fired by all weapons of a battery, calibration data must be altered periodically. It is, therefore, necessary to maintain an accurate record of calibration data and subsequent firing. The corrections determined from subsequent firing are applied to the calibration data. The VE of the piece(s) may be checked when regular fire missions are being fired if firing with accurate survey data and surveillance of fire is executed. The record of firing is maintained in the Weapon Record Book (DA Forms 9–13 and 9–13–1). A complete record of calibration data is recorded at battery and battalion FDC.

520. Wear Tables

Wear tables provide an approximation of the loss in muzzle velocity. The data are based on the number of full service rounds fired. Alteration of calibration data by using wear tables is not a substitute for calibration. However, wear tables will indicate the need for corrections between calibrations.

521. Special Correction

a. Calibration Corrections. As a general rule, calibration corrections should be applied to all missions when the VE differs from standard or from the reference piece by more than 3 f/s. To facilitate application of calibration corrections, a calibration correction data card similar to that shown in paragraph 385, or as shown below, may be used.

Example: Calibration correction data card, 155-mm gun, supercharge:

QE	No. 1141 (VE+1 f/s)	No. 110 (VE+61 f/s)	No. 2026 (VE+66 f/s)	No. 2025 (VE+75 f/s)
143	143	136	135	134
144	144	137	136	135
145	145	137	137	136
---------	---------	---------	---------	---------
---------	---------	---------	---------	---------
---------	---------	---------	---------	---------
357	357	337	335	332

b. Position Corrections. Heavy artillery batteries normally are emplaced in well-dispersed positions. This requires that displacement corrections (width and depth) be made for most fires. With very heavy artillery batteries, it is normal to compute separate data for each piece of the battery. With 155-mm gun and 8-inch howitzer batteries, a base piece for each platoon may be designated and data computed for it.

c. Computation and Application of Special Corrections. Special corrections for heavy and very heavy artillery are computed and applied in the same manner as for light and medium artillery, as discussed in chapter 19. There will be times when it will not be practical to compute corrections because time will not be available; also, when accurate location of target is doubtful or harassing missions are being fired. In these cases, the battery with the smallest VE differences should be selected to fire.

522. Application of Met Corrections

a. The most accurate and reliable means of determining corrections are from a current registration. The corrections so determined compensate for the combined effect of all nonstandard conditions. When a current registration is impossible, the best available data can be determined by applying met plus VE corrections. Met corrections are determined by solving an appropriate met message (normally type 4). With heavy and very heavy artillery, the effects of rotation of the earth must be considered in computing met corrections (pars. 359–367).

(1) With heavy artillery, it is normal to compute corrections to a met check point. Transfers are made to targets within transfer limits of this point (par. 366).

(2) With very heavy artillery and when greater accuracy is required with heavy artillery, met and VE corrections are computed for the specific target to be attacked. A GFT setting is established for that specific target. Target data may be computed by using the following formula instead of establishing a special GFT setting:

$$\text{Corrections} = -\frac{(\text{standard range})}{(\text{standard range} + \text{effects})} \times \text{effects}$$

This formula is used only with tabular firing tables which list effects instead of corrections. The formula must be qualified according to the conditions stated in paragraph 371*c*.

b. Because of the pronounced air density effect, the FDO must consider the use of the latest met corrections on all rounds fired in conjunction with corrections for velocity error.

Example: 155-mm gun, supercharge, elevation 340 (range 18,500 yards), FT 155–S–2:

Air density standard value	=	100 percent
Current air density (met)	=	96. 9 percent
Air density variation from standard.	=	−3. 1 percent
Air density unit effect	=	−104 yards

Total air density effect	
(−3.1 × (−104) = +322.4)	= +322 yards
Other met effects	= +99 yards
Total met effects	= +421 yards
VE piece No 1	= +46 f/s
Yd/f/s elevation 340	= +7. 8 yards
VE effect (+46 f/s × 7.8 yards = +358.8 yards)	= +359 yards
Total effect met +VE	= +780 yards

It is obvious from the above example that regardless of how accurately the observer locates the target, the first rounds fired will be in error approximately 780 yards, unless corrections are made based on the latest and most complete data.

523. Application of Calibration Corrections Outside of Transfer Limits

a. The VE determined by calibration for a specific ammunition lot is assumed to be valid for any ranges, including those outside of normal transfer limits. The possibility of a VE remaining constant for a charge depends on the type and magnitude of nonvelocity elements absorbed into it. For example, a 2 percent error in density absorbed into a VE at elevation 191 (14,000 yards) (155-mm gun, supercharge) results in a 22.5 f/s error in the VE $\frac{(2 \times 72 \text{ (col 19)})}{(6.4 \text{ (col 16)})}$. This erroneous VE applied at elevation 403 (20,000 yards) results in 43 yards error, even assuming the same 2 percent error in density (2 × 115 (col. 19)) − (8.3 (col. 16) × 22.5). If the 2 percent error in density does not repeat itself (is zero), then the missed distance would be 187 yards (8.3 × 22.5). The example in density is used because of its relation in changes in the ballistic coefficient from ammunition lot to lot.

b. The procedure to compute corrections outside transfer limits is discussed in paragraphs 368 through 376.

524. Miscellaneous FDC Procedures for Heavy Weapons

a. Except for the very heavy artillery, where each piece is plotted on the chart, deflection is handled the same as for light artillery. Each piece or platoon may have a separate deflection index.

b. Heavy and very heavy weapons are not equipped with an independent site scale; therefore, site must be added to elevation and a QE announced to the pieces. Normal computer records (DA Forms 6–16 and 6–16–1) are kept in the battery FDC.

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 very heavy artillery units. For complete information on the computation of data from coordinates, see TM 6–200.

Section XII. DEAD SPACE

525. General

Dead space is the area within the maximum range of a weapon which cannot be covered by fire from a particular position because of intervening obstacles, the nature of the ground, characteristics of the trajectory, and the mechanical limitation of elevating and depressing the tube. These areas can be determined only with an accurate contour map. Trajectories for all charges, low- and high-angle fire, must be considered in computation of dead space.

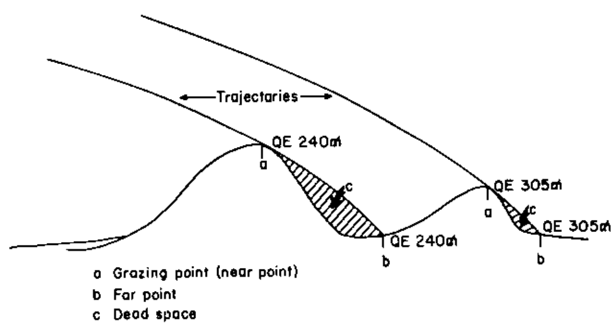


Figure 183. Dead space profile.

526. Limits

The near limit for any dead space area is the grazing point of the trajectory; i. e., the point where the trajectory initially intersects the ground (fig. 183). The far limit is the first point of impact beyond the near limit or grazing point. Additional limits, particularly at very short ranges, may be imposed by the characteristics of the fuze fired. These additional limits are often undeterminable owing to varying factors of the position, weapon, and ammunition. Some examples of possible additional limits due to fuze characteristics are—

a. VT fuzes require a minimum arming time range, short of which they will not function.

b. Time fuzes are restricted to the minimum and maximum effective functioning times.

c. Delay fuze is not normally considered in the computation of dead space owing to the possibilities of ricochets.

527. Determination of Dead Space

Dead space may be determined by a quadrant elevation ray method. The dead space for one ray is determined, and the process is repeated for such additional rays as necessary to clearly indicate the extent of the dead spaces.

a. The procedure for each charge and type of fire is as follows:

(1) A ray is drawn on a map overlay from the plotted position of the piece through the desired point of the intervening terrain feature. By inspection, the highest point of the mask considered is determined. The quadrant elevations of this point and other points on this ray that are 50 to 100 yards beyond the initial point tested are determined. The point requiring the greatest quadrant elevation marks the beginning of the dead space and is known as the grazing point.

(2) The point of impact, or far limit of dead space, is determined by finding a point beyond the mask which required 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 the quadrant elevation is less than that for the grazing point, the point is in dead space; if it is greater than that for the grazing point, the point is beyond dead space. By repeating the process, the point of impact can be determined to any desired degree of accuracy.

(3) When friendly elements occupy the terrain that is being considered, quadrant elevation must be increased by safety factors of 2 forks and 5 yards at piece mask range (pars. 76–83).

Note. Computations must also be made without safety factors for true dead space.

(4) Additional dead space areas along the ray are determined in the same manner as in (1) and (2) above.

b. Except in very symmetrical terrain, each adjacent ray should form an angle of no greater than 100 mils. In extremely hilly terrain, it may be necessary to determine dead space at 50-mil or smaller increments. The smaller the increments, the more accurately the diagram will reflect true dead space. Dead space for additional rays is determined in the same manner as in *a* above.

528. Dead Space Chart

a. The area of dead space is outlined on a chart or map by connecting points of determined quadrant elevation, corresponding to the same hill mask, on adjacent rays. Areas between the connecting lines are shaded or labeled as dead space. The shaded, or labeled, area is the dead space area which cannot be reached by fire with the particular weapon, charge, and type of trajectory.

b. Dead space charts which are forwarded to higher headquarters, unless directed otherwise, need show only dead space areas for low-angle and high-angle fires without regard to charge. Dead space charts for battalion FDC should be improved as time permits. Improved charts should show charge capabilities as well as dead space areas for low-angle and high-angle fires.

Section XIII. MISCELLANEOUS

529. Proximity (VT) Fuze, General

a. The effectiveness of artillery projectiles has been greatly increased by the development of the VT fuze. The VT fuze gives air bursts up to the maximum ranges of the weapons. However, the VT fuze does not replace the standard time fuzes. VT fuzes supplement standard time fuzes at longer ranges and in high-angle fire.

b. In combat, no special precaution to assure safety of aircraft is required when using the terrestrial type of VT fuze. However, VT or other type of fuzed projectiles will not be fired into the immediate vicinity of a target that is under attack by friendly aircraft. The sensitivity of the terrestrial type of VT fuze is such that impulses must be received from the target for an appreciable period of time before the fuze will function. Hazard to aircraft is comparatively small when the terrestrial type of VT fuze is used; however, to avoid danger during training from normal or early burst, aircraft should not approach the trajectory or target area closer than 350 yards for a 105-mm or smaller shell nor closer than 700 yards for a larger shell.

c. Normal fire direction procedures are applicable when VT fuzes are used. However, the required vertical clearance for the safety of friendly troops may be a deciding factor in the choice of the charge to be used.

530. Registration With VT Fuze

a. Normally, registration is not conducted with VT fuze. It is not necessary if an impact registration has been made with an ammunition lot cavitized for VT fuzes. If the registration was not conducted with a shell cavitized for VT fuze, a registration with cavitized shell and impact fuze is conducted.

b. If a precision or center-of-impact registration must be conducted with a type of VT fuze which cannot be set for impact bursts (e. g., T226B1), normal procedures are used. However, the correction for height of burst (20/R) must be stripped from the apparent adjusted elevation. The result is the adjusted elevation which would be obtained with an impact fuze.

531. Fire Planning and Data Sheets

a. Fire Plans. The extent and type of fire planning required for an artillery battalion depends on the type of mission assigned; i. e., direct support, reinforcing, or general support. Fire planning is continuous from the time a mission is received until it is completed. Artillery battalion fire planning is based mainly on close and continuous support to the supported unit. Coordination and cooperation between the supporting and supported unit are essential to effective fire planning. The fire plans are submitted to the next higher artillery headquarters for consolidation, addition of fires, coordination, and approval. A schedule of fires based on the approved fire plan is sent to the batteries for execution at the prearranged times. If firing data are determined by the battery FDC personnel for these scheduled fires, data are entered on data sheets (DA Form 6–14) to insure prompt execution of fire. For a detailed discussion and examples of fire planning, see FM 6–20 and FM 6–101.

b. Data Sheet. The chart and firing data for prearranged fires normally are predetermined and entered on data sheets (DA Form 6–14) to facilitate maintaining firing data with current corrections applied. Since fires from data sheets are fire for effect missions, the latest corrections must be constantly applied to the chart data to maintain correct fire commands. The battery data sheet (DA Form 6–14) is usually prepared at the battery fire direction center; and, if time permits, the data from the battery data sheet are converted to individual piece data and entered on section data sheets (DA Form 6–13) (par. 119).

c. Battery Data Sheet. A sample Firing Battery Data Sheet (DA Form 6–14) is shown in figure 184 and is self-explanatory except for the following:

(1) The times entered indicate when firing is started and lifted.

(2) Time of flight is normally omitted. When time of flight is significant, as it is for final fires on positions about to be assaulted by infantry, TOT's, high-angle fire, or fires at extreme ranges, this factor is entered and is used at the battery to modify the listed time of firing.

(3) Column for angle of site and composite is used for site when GST is used to determine site.

(4) Columns for special corrections and zone fire are used only when applicable.

(5) The remarks column contains any special instructions, such as ammunition lot number.

(6) When new corrections are obtained, the old commands are lined out, instead of erased, and the change is entered.

532. Fire Capabilities Chart

The fire capability chart of the battalion shows the area that can be reached by the combined capabilities of the batteries of the battalion with on-carriage traverse or, if directed, additional limits. The area that can be reached by three-fourths of the pieces in deflection and range is the fire capability of the battery. The fire capabilities chart of the battalion, as reported to higher artillery headquarters, may be the area which can be reached by each battery or the combined coverage of all the batteries. The chart is used in conjunction with the dead space chart (par. 528) for determining areas not covered by units and for selecting units to fire on targets. For detailed information and illustrations of the fire capabilities chart, see FM 6–101.

FIRING BATTERY DATA SHEET

Battery C | Coordinates 5736038478 | Altitude of battery 397 | Time 2000 | Date 1 Aug 57 | Page number 1

Conc nr	Coordinates	Chart data: Time From	Time To	Time of flight (sec)	Deflection Corr	Deflection Chart df	Range / El	Alt / Diff alt / Ht of burst	~~Angle of~~ site / ~~Comp site~~	Fire commands: Sp corr / Sh / Lot	Chg / Fz / MF	Corr (Individual sheaf correction)	Df (Individual sheaf correction)	Si (Indiv corr)	Ti (Indiv corr)	Zone	El or QE	Remarks
BA 103	53395 39542	~~H-30~~ 0530	~~H-28~~ 0532		~~L3~~ L1	~~2470~~ 2477	4490 ~~265~~ 270	401 +4 20/R=	+1 +5	HE QX	5 Ti B6	~~L3~~ L1	~~2470~~ 2477	306	~~16.4~~ 16.6		~~265~~ 270	
BA 101	53843 37558	~~H-26~~ 0534	~~H-23~~ 0537		~~L3~~ O	~~2997~~ 3003	3970 ~~219~~ 223	410 +13	+4	HE QY	5 D B4	~~L3~~ O	~~2997~~ 3003	304			~~219~~ 223	
BA 104 200 Yard Zone	50631 36525	~~H-21~~ 0539	~~H-29~~ 0541		~~L10~~ L4	~~3024~~ 3031	7660 ~~293~~ 300	437 +40 20/R=	+6 +3	HE QY	7 VT B2	~~L10~~ L4	~~3024~~ 3031	309		3 ~~m~~	~~293~~ 300	Fire 5 elevations
BA 102	52440 37802	~~H-17~~ 0543		20	~~L5~~ L2	~~2875~~ 2882	5440 ~~340~~ 347	380 -17 20/R=	-4 +4	HE QX	5 Ti B5	~~L5~~ L2	~~2875~~ 2882	300	~~20.7~~ 21.0		~~340~~ 347	TOT a+ ~~H-17~~ 0543
BA 105	52647 38863	~~H-14~~ 0546	~~H-12~~ 0548		~~L4~~ L1	~~2654~~ 2661	5170 ~~303~~ 309	392 -5	-1	HE QX	5 Q B3	~~L4~~ L1	~~2654~~ 2661	299			~~303~~ 309	

DA FORM 6-14, 1 APR 57 — REPLACES EDITION OF 1 FEB 55

Figure 184. Firing battery data sheet.

533. FDC Common Errors and Malpractices

a. The formation of proper habits in training and the use of independent checks are the means of eliminating the common errors and malpractices that occur in the fire direction center.

b. Common errors and malpractices in plotting are—

(1) Using 1:50,000 scale instead of 1:25,000 scale of the coordinate square.

(2) Using meter scale instead of the yard scale or vice versa.

(3) 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.

(4) Plotting the coordinates from the wrong grid line in the wrong direction, when the firing chart is so placed that north is toward the plotter.

(5) Putting the center of the protractor over the wrong point.

(6) Reading azimuths 1,600 or 3,200 mils in error.

c. Common errors and malpractices pertaining to the GFT fan or the range-deflection fan (protractor) and the GFT are—

(1) Failing to calibrate fans (protractor) periodically by comparing with a master fan or with a boxwood scale for range.

(2) Failing to properly seat the cursor on its ballistic scale or against the target needle (GFT fan).

(3) Reading wrong elevation or time gageline when more than one line is placed on a cursor (window).

(4) Failing to seat the vertex of the fan (protractor) firmly against the pin in the battery position when firing data are being determined, or against the pin in an OP or radar position when polar plotting is being performed.

(5) Reading the data from a position other than directly above the index and scale, thus introducing parallax errors.

(6) Reading deflections from the temporary deflection index rather than from the deflection index or reading deflections from the deflection index of the wrong battery.

(7) Misreading of deflection; for example, 2,620 for 2,580, 2,610 for 2,660, etc.

(8) Reading deflection from the wrong deflection scale; for example, red numbers for blue numbers.

(9) Using the ballistic scale for the wrong charge.

(10) Using drift figure instead of the F (fork) figure or vice versa.

d. Common errors and malpractices with the target grid are—

(1) Miscounting in increments of 100 yards (meters) in plotting shifts on the grid.

(2) Failing to orient the target grid properly by using the azimuth scale, which is graduated in a *counterclockwise* direction

(3) Failing to label or construct the azimuth index correctly. This error is especially common when direction of fire is other than north.

(4) Reversing observer's target location; for example, plotting FROM REGISTRATION POINT, RIGHT 500 as 500 yards left (or over, or short) of the registration point.

e. Common errors and malpractices in fire direction procedures are—

(1) Using improper procedure in conduct of registration.

(2) Failing to correctly compute adjusted quadrant, elevation, or time.

(3) Using improper procedure in preparation of observed firing chart; for example, using azimuths instead of orienting angles when available to compute direction for polar plotting battery positions.

(4) Reading the site opposite the yard index point instead of meter index point on the GST or vice versa.

(5) Failing to use survey GFT setting in transferring targets from observed firing chart to surveyed firing chart.

(6) Failing to strip, or stripping incorrectly, drift correction from adjusted deflection in determining the deflection correction for high-angle fire.

(7) Failing to use, or using incorrectly, VE in determination of data.

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CHAPTER 23
TARGET ANALYSIS AND ATTACK

Section I. FACTORS INFLUENCING ATTACK OF TARGETS

534. General

The commander or his designated gunnery officer must consider certain factors when deciding to attack a target or when planning fires. Conformity to the scheme of maneuver of the supported troops and evaluation of the enemy are factors of primary concern. For information on these factors, see FM's 6–20 and 6–101. Other factors which are normally known and must be considered in making a decision to fire are discussed in paragraphs 535 through 542.

535. Nature of Target

The method of attacking a target depends largely on the nature and size of the target. It also depends on the ammunition available and the results desired. The nature of the target includes type, mobility, cover, and importance. It is considered carefully, to determine the proper type of projectile, fuze, caliber of weapon, and necessary ammunition expenditure. The nature of the target is also a guiding factor in determining the type of adjustment and the speed of attack. A target consisting of personnel in the open is most effectively neutralized by area fire by using air or impact bursts. However, if the personnel are dug in, air bursts are essential. Impact bursts are largely ineffective against entrenched targets. A target consisting of both personnel and equipment is normally attacked by area fire by using air or impact bursts to neutralize the area. Any remaining materiel not destroyed is attacked by precision fire for destruction. Armored or fortified targets must be destroyed by precision fire or direct fire by using projectiles and fuzes appropriate for penetration. The highest practicable charge should be used to increase penetration and decrease dispersion. If the target is inflammable, shell WP should be mixed with shell HE—WP to start the fire and the HE to cause fragmentation which will increase the burning area.

536. 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. Fire concentrated on a target which is to be damaged physically to such an extent that it is rendered useless.

b. Neutralization Fire. Fire of great intensity on a target that is used to cause severe losses; to prevent movement or action; to cause limited destruction of materiel; and, in general, to destroy the combat efficiency of the enemy.

c. Harassing Fire. Fire of less intensity than neutralization fire, designed to inflict losses or, by the threat of losses, to disturb enemy troops; to curtail movement; and, in general, to lower morale.

d. Interdiction Fire. Fire, usually of less intensity than neutralization fire, laid down on lines of communication to disrupt or intermittently deny their use to the enemy.

537. Registration and Survey Control

a. Effective transfers are accomplished best when data from survey, registration, and met changes are available. When survey and registration data are not available or are inadequate, targets should be attacked with observed fires, since, in this case, unobserved fires are usually ineffective.

b. Whether or not a fire mission is to be observed depends on the visibility, the availability of observers, the availability of survey and current corrections, and the type of target. If possible, all missions should be observed to determine the results of FFE. The fact that all missions should be observed does not mean all missions should be adjusted. Accurate FFE without adjustment is more effective against targets which contain personnel or mobile equipment. All destruction missions and missions fired at moving targets must be observed and FFE adjusted to the target. In destruction missions, short observing distances allow greater accuracy.

538. Area To Be Attacked

a. The size of 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 or suspected to be. This information is obtained from observers' reports, photographic interpretation, utilization of all other intelligence agencies, and/or experience in similar situations. The size of the area to be attacked is an important factor to be considered in selection of units to fire.

b. Great care must be exercised in firing on area targets close to supported troops. Battalions that are chosen to cover the area should be selected on the basis of most current corrections. The size of the probable error should be considered for those units covering the near limit if safety of friendly troops is involved. When possible, direct support or reinforcing units should be selected.

c. Normally, a battalion should not fire with a range spread greater than 1 C (100 yards), since a greater spread will not give uniform coverage of the target. The probable error at the range to the target, lethality, and effect desired should be considered in the choice of range spread to be used.

539. Maximum Rate of Fire

a. The greatest demoralization and effect result when surprise fire is delivered with maximum density. Surprise fire is best achieved with all units firing so that all projectiles will burst simultaneously (time-on-target method). Because the maximum rates of fire are limited (*b* below), density is best secured by massing the fires of several batteries or battalions. However, this massing will result in a waste of ammunition when the area covered is larger than the target. Furthermore, effective massed fires cannot be sustained without large ammunition expenditure. These factors may dictate the use of fewer units even when more batteries or battalions are available.

b. The maximum rates of fire shown in table VII cannot be exceeded without danger of barrel heat igniting the propelling charge or damaging the tube. To maintain these rates, it is important that the pieces be rested or cooled from previous firing. The lowest charge possible should be used during periods of prolonged firing, since heating is more pronounced with the higher charges.

Table VII. Maximum Rate of Fire

Rounds per piece (maximum)

Charge and weapon	First 10 minutes	First 30 minutes	Prolonged fire per hour
75-mm howitzer:			
4	48	90	150
3	51	96	160
2	57	108	180
1	60	114	190
105-mm howitzer M2A1:			
7, 6	40	80	120
5, 4	42	85	125
3, 2, 1	45	90	135
155-mm howitzer M1			
M3 green bag:			
5, 4	30	45	60
3, 2	32	48	60
1	34	50	60
M4A1 white bag:			
7, 6, 5, 4	30	45	60
3	32	48	60
155-mm gun M1 and M1A1			
Normal and super	10	18	30
8-inch howitzer M2			
M1 propelling charge:			
5, 4	10	18	30
3, 2	12	20	32
1	14	22	34
M2 propelling charge:			
7, 6, 5	10	18	30
8-inch gun M1:			
Normal and super	6	12	20
Reduced	8	16	28
240-mm howitzer:			
4	6	12	20
3	8	14	24
2	10	16	28
1	12	20	32
280-mm gun T131:			
4	5	12	20
3	6	14	22
2	7	20	35
1	8	24	45
Charge and weapon	**First 3 minutes**	**First 20 minutes**	**Prolonged fire per hour**
4.2-inch mortar:			
41 increments	48	100	60

540. Amount and Type of Ammunition

a. The amount of ammunition available is an important consideration in the attack of targets. The available supply rate of rounds per weapon per day will not be exceeded except by authority of higher headquarters. When the available supply rate is low, for example, 10 to 30 rounds per weapon per day for a 105-mm howitzer, missions should be limited to those which contribute the most to the mission of supported troops. These missions should normally be observed fire missions. When the available supply rate is high, missions fired include the type of missions above, missions which may affect planned or future operations, and some missions which require massing of fires without adjustment. Quantities from 100 to 300 rounds per weapon per day may be required for offensive operations or for defensive operations when a strong hostile offensive is encountered.

b. The selection of a charge with which to attack a target depends on the range, terrain, and type of ammunition. To insure that the target can be reached, the maximum range of the charge selected for an adjustment should be at least ⅓ greater than the range to the target when data are obtained by approximate methods and ⅛ greater than the range to the target when data are obtained by precise methods. If possible, a charge giving an elevation to the target of between approximately 240 and 460 mils should be selected for howitzers. For flat trajectory weapons, there is a greater overlap in charges and no specific rule can be applied.

c. The type of ammunition selected to attack a target depends on the nature of the target and the characteristics of the ammunition available for the weapon to be used (pars. 32–37).

d. Effect of shell HE with various fuzes:

(1) Since the effective fragmentation of impact HE shell is greatest if it lands on hard ground at a large angle of impact, the lowest charge that can be used without excessive dispersion will give the greatest effective fragmentation (fig. 185). When the projectile passes through foliage, the detonation may occur in the trees and the effectiveness may be either improved (air burst) or lost, depending on the density of the foliage.

(2) The three types of fuzes that are used with shell HE to obtain air bursts are proximity (VT), time, and delay fired for ricochet. They are listed in order of effectiveness.

(*a*) *Fuze VT.* Fuze VT detonates automatically on approach to a terrestrial object. Therefore it can be used to obtain air bursts (fig. 186) without the necessity of adjusting height of burst. If the VT element fails to function, fuze quick action occurs on impact. (An exception is the M96 and M97 series fuzes which have no fuze quick element.) The height of burst of fuze VT varies with the slope of fall and with the terrain in the target area. If the terrain surrounding the target area is wet or marshy, the height of burst will be increased. Light foliage has little effect on VT fuze, whereas heavy foliage will increase the height of burst by about the height of the foliage. However, if the slope of fall is steep, most bursts will occur below the treetops. Since it is not limited by range and because the height of burst probable error is smaller, VT fuze supplements time fuze for targets which are at long ranges, which require high-angle fire, or which must be attacked at night. The greater the slope of fall, the closer the burst will be to the ground. In firing close to friendly troops, the lowest practicable charge

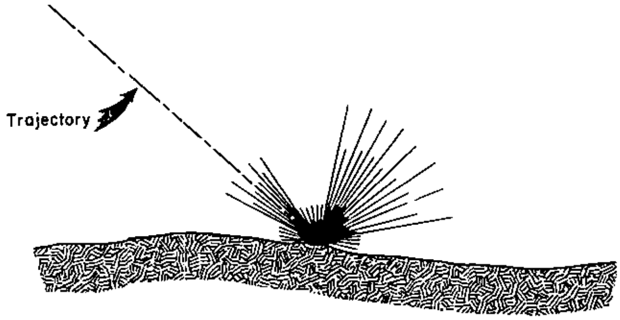


Figure 185. Effect of impact burst with fuze quick.

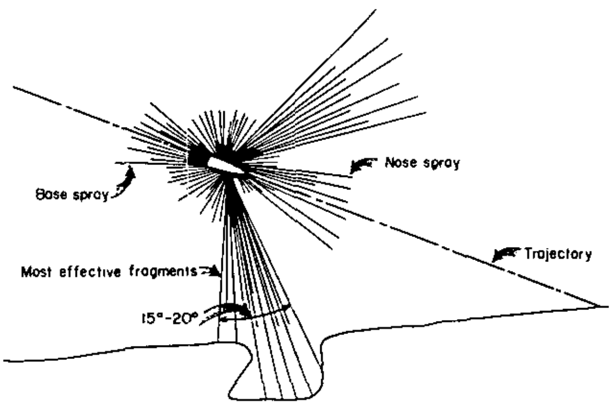


Figure 186. Effect of air burst with VT or time fuze.

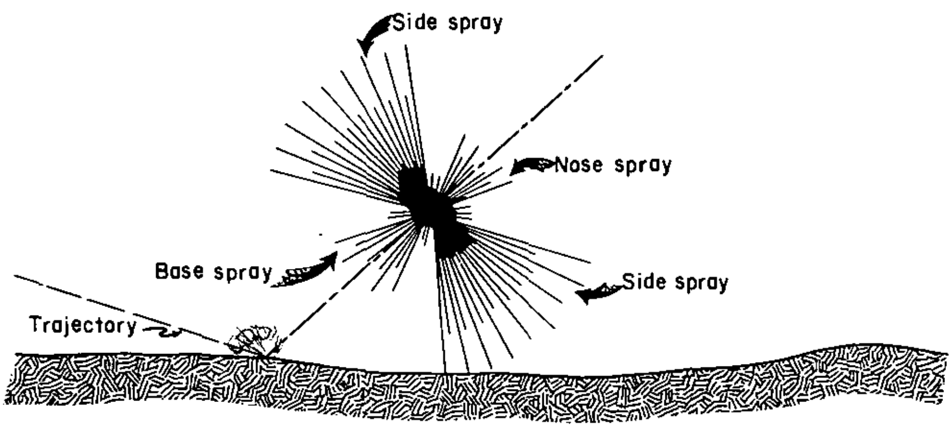


Figure 187. Effect of air bursts with fuze delay (ricochet).

should be used to obtain a steep slope of fall. It should also be used to minimize the danger to forward elements due to occasional premature bursts. The necessary vertical clearance of friendly elements should always be considered.

(*b*) *Fuze time.* Air bursts may be obtained by the use of fuze time with shell HE (fig. 186). The height of burst is determined by the quadrant elevation, charge, and time setting. If the time element fails to function with fuze time, fuze quick action occurs on impact. With fuze time, the height of burst can be adjusted, although, because of dispersion, all bursts will not be at the desired height. The highest practicable charge should be used with fuze time to minimize the height of burst probable error. Ranges and times at which the height of burst probable error for fuzes M500A1 and M501A1 becomes excessive (over 15 yds.) are given below for various weapons.

Weapon	*Range (yds.)*	*Time setting*
75-mm howitzer	6, 500	*22. 8
105-mm howitzer	8, 300	25. 9
155-mm howitzer	5, 000	10. 4
155-mm gun	11, 300	19. 6
8-inch howitzer	7, 500	15. 8
8-inch gun	15, 000	*23. 1
240-mm howitzer	14, 500	29. 0
280-mm gun	13, 000	*21. 0

*Values not marked with an asterisk were determined by field tests and may not agree with the tabular firing tables.

(*c*) *Fuze delay.* Fuze delay may be used to obtain air bursts by ricochet. It is sometimes desirable to mix fuze quick and fuze delay to obtain a combination of air and impact bursts. If the angle of impact is small and the surface it strikes is firm, the shell will ricochet before detonating and produce air bursts (fig. 187). Because of the uncertainty of ricochet action, fuze delay should not be fired in this manner without observation. Ricochet fire is less effective against entrenched personnel than other air bursts because the amount and direction of the ricochet are unpredictable. The highest practicable charge should be used to obtain ricochet bursts with fuze delay. If the angle of impact is too great, the shell will penetrate before detonating, producing mine action (fig. 188). Fuze delay can be used to destroy earth and log fortifications and is effective against some masonry and concrete. When fuze delay is used for penetration, there is little fragmentation but

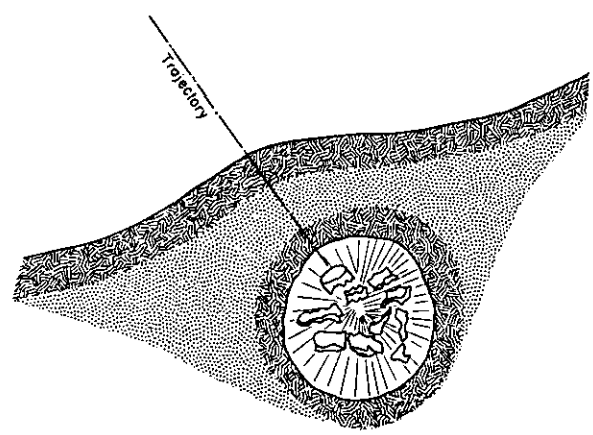


Figure 188. Mine action, fuze delay.

casualties are produced by blast effect. Fuze delay should not normally be used against heavy armor.

(3) Greater penetration against masonry or concrete can be secured with shell HE by using a concrete-piercing fuze (CP). Fuze CP may be set on either *nondelay* or *delay*, with delay giving the greater penetration. Shell AP or HEAT can be used against reinforced concrete or heavy masonry. Shell HE with fuze quick is used at intervals to clear away rubble and blow apart shattered fragments. The effectiveness of various calibers of weapons against concrete is shown in table VIII.

e. Ammunition for attacking armored targets:

(1) The types of projectiles available for attacking armored targets or targets constructed of heavy stone or reinforced concrete are—

(*a*) *HEAT*. High explosive antitank projectiles are available for 75-mm and 105-mm howitzers. The projectile contains a shaped charge. It is propelled by a fixed propelling charge.

Table VIII. Effect on Concrete

Weapon and projectile (maximum charge)	Thickness* of concrete perforated by single round (face normal to line of impact) (ft.)			Number of rounds, falling in circle of given diameter** necessary to perforate various thicknesses* of concrete at given ranges			
	Range (yds.)			Thickness (ft.)	Range (yds.)		
	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***			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***		4. 9	4. 4	3	1	1	1
				5	1	2	3
				7	2	3	5

*Thickness perforated is based on 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.

**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

***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.

(b) *AP*. Armor-piercing projectiles are available for 155-mm guns. The projectile is solid except for a small bursting charge. Penetration is effected by the speed, weight, and shape of the projectile. AP projectiles should be fired by using the highest practicable charge to obtain maximum penetration.

(2) HEAT and AP projectiles are effective against armor (homogeneous plate) as shown below:

Weapon and projectile	Thickness of armor perforated by single round (line of impact perpendicular to surface of armor) (inches). Range (yds.)		
	500	1,000	1,500
75-mm howitzer M1A1, M2, HEAT, M66	3⅝	3⅝	3⅝
105-mm howitzer M2A1, M4, HEAT, M67	4	4	4
155-mm gun M2, AP, M112 (2,745 f/s)	7. 6	7. 5	7. 2

(3) HEAT and AP ammunition is relatively ineffective against personnel in the open because of the small amount of fragmentation. Bursts from both types are difficult to observe, and fire with either type is more effective at short ranges. HEAT and AP are normally fired by direct laying; however, when adjustment of indirect fire is necessary, it is conducted with shell HE until FFE is commenced.

(4) The 155-mm howitzer and larger weapons using shell HE with fuze quick are effective against armor because of the size and explosive power of the shell, and they may be used when armor-piercing type of ammunition is not available.

f. Use of chemical and illuminating shell: The effective attack of targets under the varying conditions of battle can frequently be assisted by chemical or illuminating shell. The use and the method of delivering these shells are described in chapter 13 and chapter 22. For detailed information on any of the shells or fuzes mentioned in this section, see TM 9–1901.

541. Considerations in Selection of Units to Fire

a. The unit selected for a mission must be of the proper size and caliber to cover the target area quickly, effectively, and economically. Most targets are of such size as to allow a wide choice in the selection of the number of batteries or battalions to be used. If the unit selected to fire cannot mass its fire in an area as small as the target area, ammunition will be wasted. Conversely, if a unit can cover only a 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. Although certain limitations are indicated on large targets, the decision of whether to have many units firing a few volleys or a few units firing many volleys is often a critical one.

b. Many overlapping factors affect the selection of units and the number of volleys to fire on a target. Some of these factors which vary with each specific situation are—

(1) *Availability of artillery*. When the number of artillery fire units present is small, more targets must be assigned per artillery unit than if a greater number of artillery units were present.

(2) *Size of area to be covered*. The size of the area to be covered and the effective width and depth of an open sheaf govern the method of firing. By shifting fire laterally, a battery may cover wider areas and by using zone fire or fire at successive ranges may cover deeper areas. When the area covered by the target is too large to be covered by a single concentration by a battery, it must be attacked in parts. If a battery is available for each part and fire from that battery is deemed sufficiently dense, the entire area may be attacked at one time. Otherwise, the parts are attacked successively by the battalion with shifting fire or zone fire. 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. If the area is too large to be covered by a single concentration by a battalion, it is attacked in parts. If a battalion is available for each part, the entire area may be covered at one time. Otherwise, the parts

are attacked successively or additional fire support is requested.

(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 will limit the use of certain weapons. (Accuracy is indicated by the probable error in the firing tables.) If suitable calibers are not available in sufficient quantity for a specific mission, more ammunition must be expended per unit.

(4) *Surprise.* Against many targets, a few volleys from many pieces are preferable to many volleys from a few pieces. To secure maximum surprise, the method of attack must be varied constantly.

(5) *Accuracy of target location.* Certain important targets which are not accurately located may justify the fire of several units to insure coverage.

(6) *Critical targets.* The emergency nature of certain targets may justify the use of all available artillery fire, without regard to economy of ammunition. Enemy counterattack formations is an example of such targets.

(7) *Dispersion.* Coverage at long ranges is less dense and, hence, 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 fires.* These may require the use of small units for a long period of time. Thus, the bulk of the artillery available is free for other missions.

(9) *Registration.* Applying recent registration data will increase accuracy and effectiveness. Thus, a corresponding reduction in ammunition expenditure is achieved.

(10) *Vulnerability of targets.* Some targets should be attacked rapidly with massed fire to insure immediate effect. Such targets would be truck parks or large numbers of personnel in the open.

(11) *Effect on enemy personnel.* A demoralizing effect can be achieved by smothering a hostile position with fire. Smothering is achieved by firing from several directions with different calibers and varied types of fuzes and projectiles.

542. 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 needed from defiladed positions. It may also be needed 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 used for destruction missions when possible. Heavy-caliber howitzers are normally used for greater accuracy and blast action in destruction missions at long range.

Section II. LETHALITY AND METHODS OF ATTACK

543. General

The deadliness, or lethality, of an artillery projectile varies according to many factors. Such factors are type, size, fragmentation, fuzing, attitude when bursting, and height of burst. The size of the target, dispersal of personnel in the target area, and the degree and type of cover are other considerations. Many of these factors can be neither accurately determined nor thoroughly evaluated. However, the expected lethality of a projectile or a group of projectiles can be determined theoretically. This knowledge can be applied in deciding how to attack a target. A complete presentation of all considerations is beyond the scope of this manual. The material herein is limited to a general discussion of those principles of lethality useful in planning the attack of targets with area fire. For information on factors which apply to attack of targets with destruction fire, see chapter 27.

544. Effects Patterns

a. The effect of an impact burst depends on the caliber and fragmentation of the shell and the direction, density, size, and velocity of the fragments. The effective fragmentation of impact bursts is increased as the angle of impact increases. It is greatest when the surface at the point of impact is hard. The relative effectiveness of various calibers, with fuze quick, is indicated below:

Caliber	*Fragmentation area*		
	Approximate size of area covered effectively by impact burst (yds.)		Approximate radius of large fragment effect (yds.)
	Depth	Width	
75-mm howitzer	15	20	140
105-mm howitzer	20	30	190
155-mm howitzer	30	50	390
155-mm gun	30	50	390
8-inch howitzer	30	80	520
8-inch gun	30	80	520
240-mm howitzer	40	100	680
280-mm gun	65	60	740
4.2-inch mortar	15	50	170

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 (fig. 189).

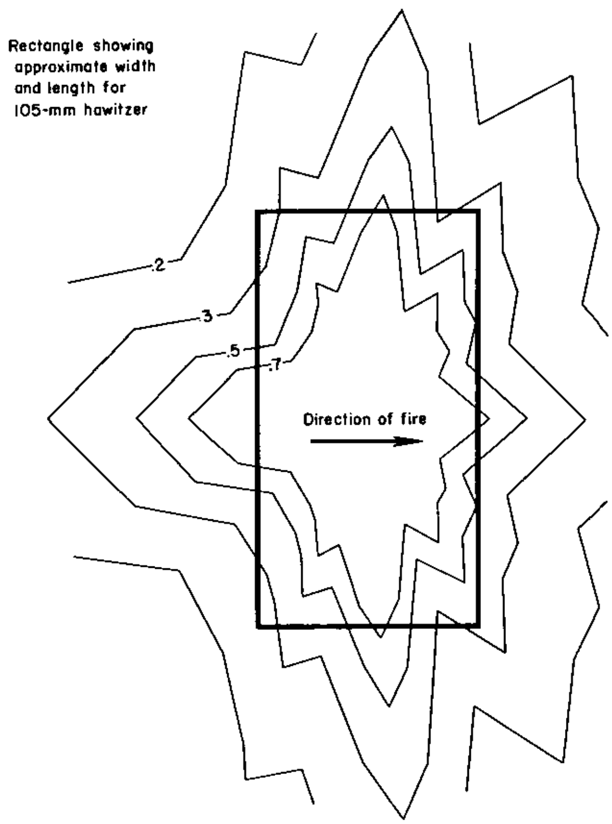


Figure 189. Projectile effects pattern (fuze quick).

b. The 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; and direction of travel of fragments. The direction of travel of the fragments is governed by the angle of fall, the terminal velocity of the projectile, and the initial velocity of the fragments due to detonation. The pattern formed on the ground by an air burst of any artillery shell, regardless of caliber except in high-angle fire, roughly resembles the appearance of a butterfly and is called a *projectile (butterfly) effects pattern* (fig. 190). Most of the fragments

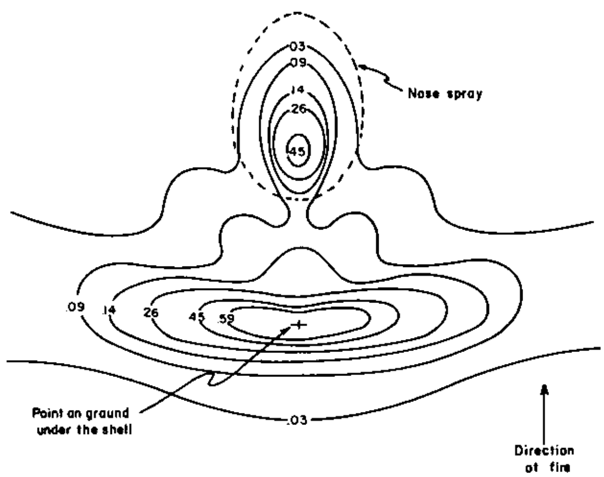


Figure 190. Projectile (butterfly) effects pattern (fuze VT).

are impelled to the ground directly under the shell and laterally to both sides. A number of fragments are impelled forward of the point under the shell to form a second distinctive area of high lethality termed *nose spray*. The probable errors of each weapon can be combined with the probability of the target receiving a fragment from the exploding shell to determine the casualty probability factor. The probability of a casualty at any point in the target area can be computed. From these computations, casualty probability contour lines are constructed. In figures 189 and 190, the figure appearing on a contour line of the pattern represents the probability of a man being a casualty if he were standing on that contour line. Within the area bounded by the contour line, the probability that a man would be a casualty is *at least* as great as if he were on the contour line.

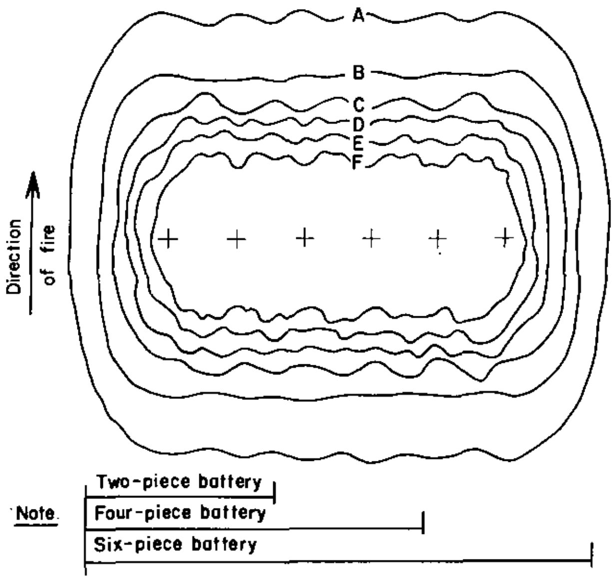


Figure 191. Effects pattern for a one-battery volley.

c. The effects pattern for a one-battery volley of HE shell is shown in figure 191. The casualty probability contours in this figure and subsequent figures in this section are based on an open sheaf with corrections applied, fuze VT, and two-thirds maximum range for charge. Personnel are prone and uniformly dispersed in the target area, and zero degree cover is available. Table IX is an approximate interpretation of the effects pattern for each of the weapons listed and may be used as a guide in attacking targets with area fire.

d. The effects pattern for a one-battalion volley is shown in figure 192. In addition to the conditions existing in *b* above, the direction of fire of the center battery is perpendicular to the target; the direction of fire of the flank batteries is 100 mils left and right, respectively; all batteries are

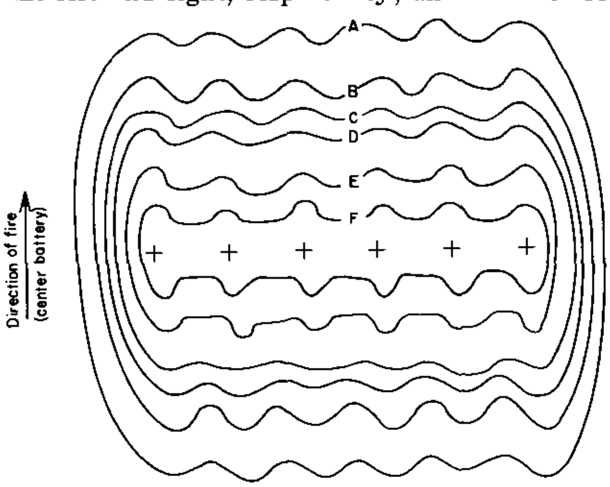
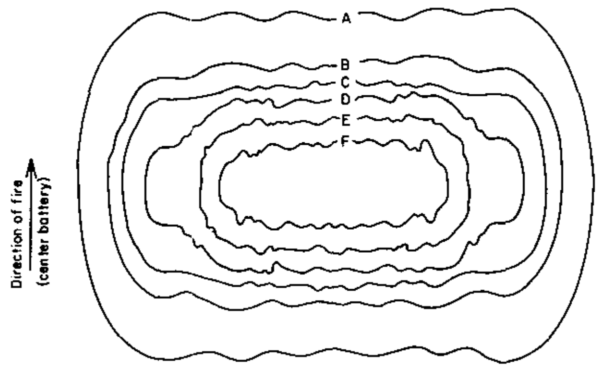


Figure 192. Effects pattern for a one-battalion volley.

at the same range. For interpretation of figure 192, see table X. Although only a linear sheaf is shown, the values for the total area and the percent of casualties would not differ materially for other sheaves if the same distance between adjacent bursts is used.

e. The effects pattern for more than 1 battalion (about 600 yds between battalions) firing 1 volley is shown in figure 193. The size of the area covered, the density of fire, and the casualty probability are greater than those that are obtained for the same amount of ammunition for one battalion (fig. 194). Several battalions used on a target will cover a larger area than a single bat-



Contour	Casualty probability factor	Total area (sq yd)	Approximate Depth (yd)	Approximate Width (yd)	Percent expected casualties within contour
A	.003	86900	230	380	10.1
B	.030	52700	155	335	15.9
C	060	39800	150	310	19.6
D	.115	28200	100	280	24.0
E	.200	16500	85	195	30.3
F	.300	8700	50	170	35.1

Figure 193. Effects pattern for division artillery, one volley (fuze VT).

talion regardless of how carefully corrections are applied. Areas effectively covered by more than one battalion may be estimated by evaluating the actual firing conditions existing for each battalion. For example, assume that the same situation exists as indicated for table X and that there is a lateral distance of about 600 yards between battalions. One 155-mm howitzer battalion and one 105-mm howitzer battalion should effectively cover an area of about 400 yards wide by 250 yards deep.

Note. These figures are about the same as for the size indicated by the .003 casualty probability factor for the 155-mm howitzer battalion (table X). The area covered by the 105-mm howitzer battalion, including dispersion, would be contained within the area covered by the 155-mm howitzer battalion. Corrections for both battalions are

Table IX. Area Covered and Percentage of Casualties for a One-Battery Volley

(Personnel prone, zero degree cover, flat terrain, VT fuze, dispersion included)

Weapon	Area bounded by (fig. 191)	Casualty probability factor*	Total area (sq yd)	Approximate**		Expected casualty percentage***
				Depth (yd)	Width (yd)	
75-mm howitzer:						
Number of pieces, 4; distance between bursts, 20 yards.	A	0. 001	30, 100	320	95	0. 7
	B	. 005	14, 500	170	85	1. 2
	C	. 010	8, 800	120	75	1. 4
	D	. 015	3, 600	--------	--------	1. 8
	E	--------	--------	--------	--------	--------
	F	--------	--------	--------	--------	--------
105-mm howitzer:						
Number of pieces, 6; distance between bursts, 30 yards.	A	. 001	36, 200	170	210	1. 8
	B	. 005	26, 600	130	200	2. 4
	C	. 010	20, 700	110	190	2. 8
	D	. 020	14, 300	80	180	3. 4
	E	. 030	10, 000	60	170	3. 8
	F	. 040	4, 200	30	160	4. 3
155-mm howitzer:						
Number of pieces, 6; distance between bursts, 50 yards.	A	. 001	88, 800	260	340	1. 9
	B	. 005	62, 100	195	320	2. 6
	C	. 010	50, 400	165	305	3. 0
	D	. 020	35, 900	120	295	3. 7
	E	. 030	24, 500	90	280	4. 2
	F	. 040	11, 300	--------	--------	5. 1
155-mm gun:						
Number of pieces, 4; distance between bursts, 50 yards.	A	. 001	41, 800	170	250	2. 9
	B	. 005	32, 800	145	230	3. 7
	C	. 010	25, 700	115	220	4. 5
	D	. 020	19, 900	95	210	5. 3
	E	. 040	12, 900	65	195	6. 6
	F	. 060	8, 200	45	180	7. 5
8-inch howitzer:						
Number of pieces, 4; distance between bursts, 80 yards.	A	. 001	53, 100	140	380	5. 2
	B	. 005	40, 800	115	355	6. 7
	C	. 010	35, 400	105	340	7. 6
	D	. 020	29, 100	90	330	8. 9
	E	. 030	25, 300	80	320	9. 8
	F	. 040	22, 500	70	310	10. 6
8-inch gun:						
Number of pieces, 2; distance between bursts, 80 yards.	A	. 001	84, 690	445	190	1. 3
	B	. 005	53, 910	325	165	1. 9
	C	. 010	37, 070	245	150	2. 4
	D	. 020	19, 960	--------	--------	3. 2
	E	. 030	9, 960	--------	--------	3. 9
	F	. 040	4, 290	--------	--------	4. 4
240-mm howitzer:						
Number of pieces, 2; distance between bursts, 100 yards.	A	. 001	83, 550	340	245	1. 6
	B	. 005	56, 900	260	220	2. 3
	C	. 010	43, 000	215	200	2. 8
	D	. 020	26, 400	--------	--------	3. 6
	E	. 030	17, 000	--------	--------	4. 2
	F	. 040	6, 100	--------	--------	5. 4
280-mm gun:						
Number of pieces, 2; distance between bursts, 60 yards.	A	. 001	65, 900	300	220	3. 1
	B	. 005	36, 800	215	170	3. 2
	C	. 010	28, 900	195	150	3. 9
	D	. 020	21, 500	160	135	4. 7
	E	. 030	16, 300	130	125	5. 4
	F	. 050	9, 000	85	105	6. 6
4.2-inch mortar:						
Number of mortars, 6; distance between bursts, 50 yards.	A	. 001	180, 800	390	460	1. 0
	B	. 005	99, 300	255	390	1. 6
	C	. 010	70, 900	210	340	2. 0
	D	. 015	47, 700	160	300	2. 3
	E	. 020	37, 100	130	285	2. 5

*Probability of a casualty on that line; within the area bounded by the line, the probability is at least as great as if the individual were on the line.

**Data have been omitted where total area covered consists of divided areas of casualty probability.

***Average for total inclosed area.

Note.—Statistics are approximate and will vary for different charges and terrain. They may be used as a guide in attack of targets.

Table X. Area Covered and Percentage of Casualties for a One-Battalion Volley

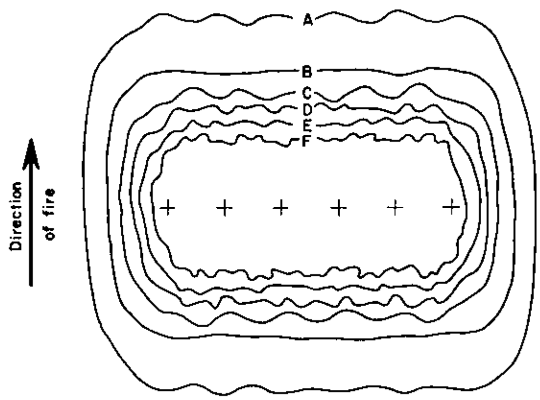
(Personnel prone, zero degree cover, flat terrain, VT fuze, dispersion included)

Weapon	Area bounded by (fig. 192)	Casualty probability factor	Total area (sq yd)	Approximate		Expected casualty percentage
				Depth (yd)	Width (yd)	
75-mm howitzer:	A	0. 003	30, 700	190	160	1. 5
Number of pieces, 12; distance between bursts, 20 yards.	B	. 006	21, 700	160	135	1. 9
	C	. 009	18, 400	150	120	2. 1
	D	. 015	11, 800	125	95	2. 6
	E	. 024	6, 600	90	75	3. 1
	F	. 033	2, 400	60	40	3. 6
105-mm howitzer:	A	. 003	42, 080	175	240	4. 2
Number of pieces, 18; distance between bursts, 30 yards.	B	. 015	27, 860	130	215	5. 9
	C	. 030	21, 220	105	200	7. 0
	D	. 044	17, 380	90	190	7. 8
	E	. 062	13, 800	75	180	8. 4
	F	. 076	8, 680	50	170	9. 3
155-mm howitzer:	A	. 003	87, 300	230	380	5. 8
Number of pieces, 18; distance between bursts, 50 yards.	B	. 015	61, 700	175	350	7. 8
	C	. 030	51, 100	155	330	8. 9
	D	. 059	35, 400	115	310	10. 9
	E	. 087	26, 300	90	295	12. 1
	F	. 118	16, 900	60	280	13. 2
155-mm gun:	A	. 003	100, 200	310	325	3. 5
Number of pieces, 12; distance between bursts, 50 yards.	B	. 015	59, 800	220	275	5. 2
	C	. 030	43, 400	180	240	6. 3
	D	. 047	31, 900	145	220	7. 2
	E	. 062	21, 400	110	190	8. 0
8-inch howitzer:	A	. 003	56, 200	150	370	11. 9
Number of pieces, 12; distance between bursts, 80 yards.	B	. 015	44, 100	125	350	14. 9
	C	. 030	37, 400	110	340	17. 1
	D	. 059	30, 100	90	325	20. 2
	E	. 087	25, 300	80	315	22. 6
	F	. 115	21, 000	70	310	25. 2
8-inch gun:	A	. 003	130, 900	415	315	2. 2
Number of pieces, 6; distance between bursts, 80 yards.	B	. 015	65, 800	285	230	3. 4
	C	. 030	37, 400	200	185	4. 9
	D	. 039	30, 800	185	165	5. 2
	E	. 047	16, 900	140	120	5. 9
	F	. 060	8, 000	100	80	6. 6
240-mm howitzer:	A	. 003	108, 600	350	310	3. 9
Number of pieces, 6; distance between bursts, 100 yards.	B	. 015	69, 000	265	260	5. 6
	C	. 030	49, 300	215	230	6. 9
	D	. 044	38, 000	180	210	7. 9
	E	. 059	29, 100	150	190	8. 6
	F	. 087	13, 000	80	160	10. 1
280-mm gun:	A	. 003	66, 500	310	215	5. 4
Number of pieces, 6; distance between bursts, 60 yards.	B	. 015	39, 500	215	185	8. 6
	C	. 030	30, 900	190	165	10. 3
	D	. 059	21, 900	150	145	12. 7
	E	. 087	16, 300	125	130	14. 6
	F	. 143	8, 600	85	100	17. 5
4.2-inch mortar:	A	. 003	110, 900	280	400	2. 2
Number of mortars, 18; distance between bursts, 50 yards.	B	. 009	76, 700	210	370	2. 9
	C	. 015	66, 500	195	340	3. 2
	D	. 021	48, 900	150	330	4. 0
	E	. 033	40, 000	130	305	4. 3
	F	. 039	33, 000	115	290	4. 4

Note. Statistics are approximate and will vary for different charges and terrain. They may be used as a guide in attack of targets.

assumed to be current. Aiming error (CI missed distance) will increase the size of the area covered proportionate to the amount of the error; however, the density of coverage will decrease. For an approximation, the size of the area covered by more than 1 battalion of the same caliber will equal the size covered by 1 battalion plus 4 probable errors in range and deflection.

f. The effects pattern for more than 1 volley is generally the same as for 1 volley. However, the area covered is slightly larger owing to dispersion and there is an increase in the casualty probability (fig. 194). Casualty probability does not increase as much as when more than one battalion is firing the same amount of ammunition, since surprise effect cannot be obtained after the first volley.



Contour	Casualty probability factor	Total area (sq yd)	Approximate Depth (yd)	Approximate Width (yd)	Percent expected casualties within contour
A	.008	42090	175	240	11.1
B	.041	28040	125	220	15.4
C	.080	21530	110	200	18.2
D	.118	17430	90	190	20.2
E	.155	13810	75	180	21.9
F	.194	10490	65	165	23.4

Figure 194. Effects pattern for 1 battalion, 4 volleys (fuze VT).

545. Comparison of Time and VT Fuzes and Number of Volleys

a. Certain principles of lethality can be readily evaluated by comparing results obtained with two different fuzes and varying numbers of volleys. In the situation in (1) through (5) below, the assumptions remain the same for all calibers. Only the charge and range and resulting probable errors change. For example—

(1) The target size is 200 yards wide and 100 yards deep, approximately the area occupied by a platoon of infantry in the defense.

(2) The direction of fire is perpendicular to the target width.

(3) Personnel are prone, uniformly dispersed throughout the target area, and provide an average target size of 2 square feet.

(4) Batteries are firing at center range with a sheaf fitted to the target; i. e., 200 yards minus the sum of the width of 1 burst and 2 deflection probable errors.

(5) The degree of cover for the first volley is 0°, for the second and third 10°, and for the fourth and fifth 30° (30° of cover offers protection from fragments the path of which form an angle of 30° or less with a plane tangent to the surface of the earth).

b. The percent of casualties calculated for various calibers and ranges are as shown below:

Unit	Charge	Range	Volleys	Cumulative percent of casualties: Fuze VT	Cumulative percent of casualties: Fuze time
75-mm how bn	3	4, 600	1	1. 8	1. 4
			2	3. 1	1. 9
			3	4. 3	2. 4
			4	4. 9	2. 7
			5	5. 5	2. 9
105-mm how bn	5	5, 600	1	8. 0	6. 9
			2	13. 4	9. 9
			3	18. 4	12. 8
			4	20. 8	14. 3
			5	23. 1	15. 6
155-mm how bn	5	7, 200	1	19. 0	11. 3
			2	30. 4	17. 1
			3	40. 2	22. 4
			4	44. 5	25. 0
			5	48. 6	27. 5
155-mm gun bn	Super	17, 100	1	10. 3	3. 8
			2	18. 0	6. 2
			3	25. 0	8. 4
			4	28. 3	9. 6
			5	31. 5	10. 7
8-inch how bn	5	8, 700	1	26. 4	17. 6
			2	41. 5	23. 9
			3	53. 4	29. 7
			4	58. 4	32. 4
			5	62. 9	35. 0
8-inch gun bn	Super	23, 700	1	5. 5	3. 5
			2	9. 4	5. 0
			3	13. 1	6. 3
			4	15. 0	6. 9
			5	16. 7	7. 7
240-mm how bn	3	14, 400	1	10. 2	8. 6
			2	16. 8	13. 1
			3	23. 0	17. 5
			4	25. 9	19. 7
			5	28. 6	21. 7

Unit	Charge	Range	Vol-leys	Cumulative percent of casualties	
				Fuze VT	Fuze time
280-mm gun bn	3	16, 200	1	11. 3	4. 2
			2	19. 7	6. 8
			3	27. 2	9. 2
			4	30. 7	10. 4
			5	34. 1	11. 6
4.2-inch mortar battalion	20	2, 600	1	9. 1	7. 2
			2	14. 9	8. 7
			3	20. 2	10. 2
			4	22. 7	11. 0
			5	25. 2	11. 7

c. The casualty percentages in *b* above indicate a diminishing increase as more volleys are fired. The personnel being attacked are presumed to be caught by surprise with the first volley but thereafter seek and obtain an increasing degree of cover. If no cover were available and the terrain in the target area were perfectly flat, the percent of casualties caused by 5 volleys would be almost 5 times that caused by 1 volley. Hence, the nature of the terrain in the target area should be accurately known in selecting the number of volleys and evaluating the casualty probabilities; for example, if the terrain furnished 10° cover, then the effect for the first volley would be approximately the increase shown between the first and second volley.

d. The percent of casualties obtained with fuze VT exceeds that when fuze time is used and fired under identical conditions. This is due to the larger probable error of the time fuze. Therefore, if a choice of fuze is available, fuze VT is preferable to fuze time for attacking personnel. If fuze quick had been used, for the 105-mm howitzer battalion, the casualty percentages for the first volley would have been approximately 30 percent of those listed for fuze VT; for the 155-mm howitzer battalion, approximately 20 percent. As the degree of cover increases, fuze quick becomes less effective.

e. The situation given in *a* above assumes personnel to be prone and in flat terrain. If the personnel were standing, the percent of casualties for the first volley would be approximately double the value shown.

f. As the target size increases from the assumed size of 200 yards wide by 100 yards deep, the percent of casualties would decrease sharply and directly with the target size. Conversely, the percent of casualties increases as the target becomes smaller in size. For example, with the VT fuze for the 105-mm howitzer battalion, if the target area is a square 200 yards on a side (½ C range spread), the percent of casualties is then 5.0 percent for 1 volley and 8.2 percent for 2 volleys. If the target area is a square 100 yards on a side (converged sheaf), the percent of casualties is 13.8 percent for 1 volley and 25.8 percent for 2 volleys.

g. The percent of casualties varies only slightly with the magnitude of the range and deflection probable errors.

h. The use of range spread will increase the area covered and will decrease the percent of casualties obtained. A comparison of the effects obtained by using range spreads is shown in figures 195 and 196. For interpretation of figures 195 and 196, see table XI.

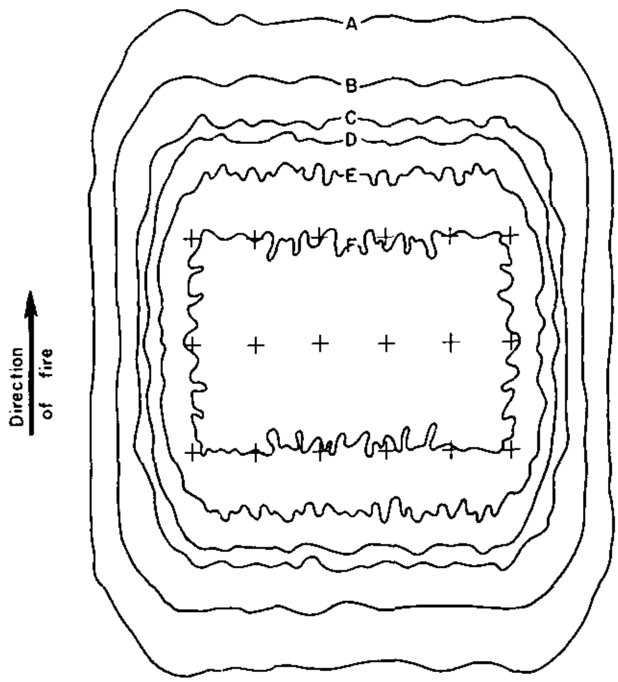


Figure 195. Effects pattern for 1-battalion volley (½ C range spread, fuze VT).

546. Applying Concepts of Lethality

It is impossible to construct effects patterns for every possible combination of ammunition expenditure, pattern of bursts, target dimensions, etc. Effects patterns can only be determined from involved computations and basic ballistic factors. However, to understand the probable effects of fire and to develop a knowledge to be

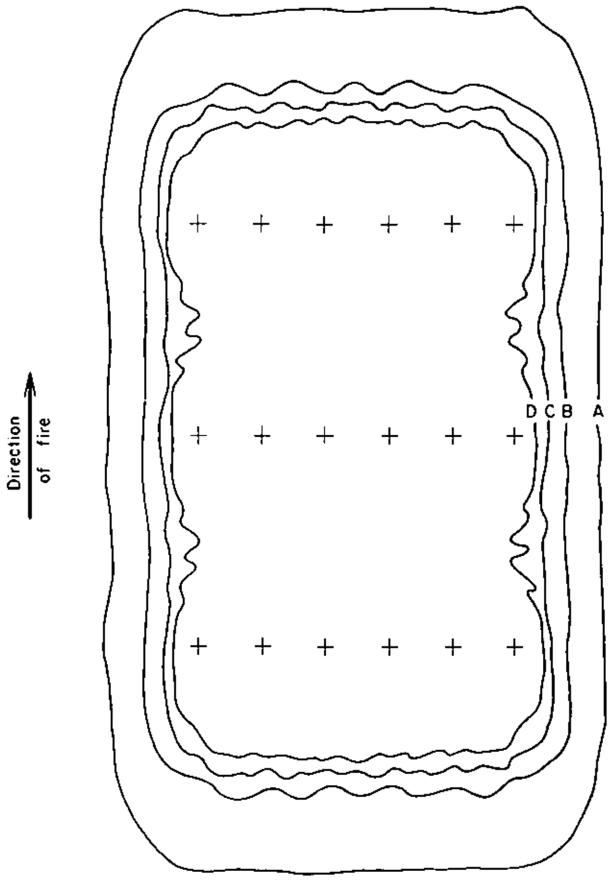


Figure 196. Effects pattern for 1-battalion volley (1 C range spread, fuze VT).

applied in reaching decisions as to methods of attacking targets, the limited material in this section should be analyzed.

a. For example, consider a target of personnel in the open. It can be determined from paragraph 545 that a 155-mm howitzer battalion firing 2 volleys with fuze VT (30.4 percent casualties) would be more effective on such a target than a 105-mm howitzer battalion firing 5 volleys with fuze VT (23.1 percent causalties). Likewise, a target covering an area of 400 yards wide by 200 yards deep cannot be attacked successfully with a 105-mm howitzer battalion (240 × 175 yds.) (table X) without employing shifting fire. However, it could be attacked in its entirety with a 155-mm howitzer battalion (380 x 230 yds.) A comparison of the data listed in table X and the data listed in paragraph 545 clearly shows the advantages of modifying battery sheaves to correspond to the size of the target. For example, table X (VT fuze) lists 10.9 percent expected casualties for area D (the first area that would include the target) for the 155-mm howitzer. However, paragraph 545 lists 19.0 percent expected casualties for the first volley of VT fuze. In this case, an increase of 8.1 percent in expected casualties is obtained by using a fitted sheaf instead of an open sheaf. Consider a target the width of which is less than the front covered effectively by an open sheaf. The most effective fire can be obtained on such a target by using width of sheaf

Table XI. Area Covered and Percentage of Casualties for a 105-mm Howitzer Battalion Firing One Volley with a Range Spread

[Personnel prone, zero degree cover, flat terrain, VT fuze, dispersion included]

	Area bounded by (figs. 195 and 196)	Casualty probability factor	Total area (sq yd)	Approximate		Expected casualty percentage
				Depth (yd)	Width (yd)	
½ C range spread:						
Distance between bursts, 30 yards; range 5,600, charge 5	A	0. 001	67, 000	280	240	2. 6
	B	. 005	49, 600	230	215	3. 4
	C	. 015	37, 600	190	200	4. 1
	D	. 020	33, 600	180	190	4. 4
	E	. 030	26, 400	150	175	4. 9
	F	. 050	14, 600	95	155	5. 8
1 C range spread:						
Distance between bursts, 30 yards; range 5,600, charge 5	A	. 001	90, 780	385	235	1. 9
	B	. 010	62, 030	310	200	2. 5
	C	. 015	54, 710	295	185	2. 7
	D	. 021	47, 770	275	175	2. 9

Note. Statistics are approximate and will vary for different charges and terrain.

corresponding to the width of target minus the sum of the width of 1 burst and 2 deflection probable errors. For example, consider a target that is 150 yards wide and at a range of 8,000 yards. To fire on such a target with a 155-mm howitzer battery, using charge 6, width of sheaf and distance between bursts for the most effective fire are 96 yards and 19 yards, respectively. Width of sheaf and distance between bursts are determined as follows:

Effective width of burst	=50 yards
Deflection probable error, range 8,000, charge 6	=2 yards
Width of sheaf (150 − (50+2+2))	=96 yards
Distance between bursts (96/5 intervals)	=19 yards

b. For more information on lethality, see TM 9–1907 (C).

547. Typical Targets and Methods of Attack

a. Enemy materiel, fortifications, and personnel in sufficient numbers to justify ammunition expenditure are generally artillery targets, except—

(1) *Mine fields*. HE shell is ineffective for clearing mine fields. The mines are detonated only by direct hits. Artillery fire fails to clear the mine fields and makes it harder to locate and remove the mines by hand. It also makes it harder to move equipment across the field.

(2) *Barbed wire*. The employment of artillery to breach wire requires extravagant use of ammunition.

b. Table XII lists typical targets and suggests methods of attacking them.

Table XII. Typical Targets and Suggested Methods of Attack

Type of target	Type of adjustment	Weapon	Shell	Fuze	Type of fire	Remarks
Armored vehicles (rendezvous).	Observed. Unobserved.	All (pref 155-mm or larger)	HE, HEAT, AP	VT, ti, Q	Neutralization. Destruction. Assault.	([1]), ([2]), ([3]).
Armored vehicles (moving).	Observed	All (pref 155-mm or larger)	HE, WP, HEAT, AP.	VT, ti, Q	Neutralization. Destruction. Assault.	Shell HE to force tanks to "button up." Fire of sufficient intensity may demoralize and break up attack. WP may blind vehicle drivers, but it may also obscure adjustment.[2]
Boats	Observed	All	HE	VT, ti, Q	Neutralization. Direct.	Air bursts against personnel manning boats. Destruction by direct fire.
Bridges	Observed. Unobserved.	All (pref 155-mm or larger)	HE	Q, CP, delay	Destruction. Harassing. Interdiction.	Direction of fire preferably (pref) with long axis of bridge. Destruction of permanent bridges is accomplished best by knocking out bridge support. Fuze quick for wooden or pontoon bridges.
Buildings (frame)	Observed. Unobserved.	All	HE, WP	Q	Neutralization	([4]).
Buildings (masonry)	Observed. Unobserved.	All (pref 155-mm or larger)	HE	CP, delay, Q	Destruction. Neutralization of large areas.	Several weapons can be converged on one building. In destroying masonry buildings, the fact that rubble aids defensive fighting and delays friendly mobile elements must be considered.[5]
Fortifications (armor)	Observed	All	HEAT, AP, HE (large calibers).	Q	Destruction. Assault. Direct.	Fire should be adjusted at apertures of steel turrets and pillboxes.[5] Use highest practicable charge.
Fortifications (concrete)	Observed	All (pref 155-mm or larger)	HE	CP, delay, Q	Destruction. Assault. Direct.	Use highest practical charge.[5]
Fortifications (earth, logs, etc.).	Observed	All (pref 155-mm or larger)	HE	Delay, Q	Destruction. Assault. Direct.	Use highest practical charge.[5]
Personnel (in open)	Observed. Unobserved.	All	HE	VT, ti, delay (ricochet), Q.	Neutralization. Harassing.	TOT missions are most effective. Fuze quick should be fired at lowest practical charge (steep angle of fall gives better fragmentation). Intermittent fire is better than continuous fire.[1]
Personnel (dug in)	Observed	All	HE, WP	VT, ti, delay (ricochet).	Neutralization. Harassing.	Air bursts are necessary. Surprise not necessary. WP is useful in driving personnel out of holes and into open.
Personnel (in dugouts or caves).	Observed	All (pref 155-mm or larger)	HE	Delay, Q	Destruction. Assault. Direct.	([5]).
Personnel (under light cover).	Observed. Unobserved.	All	HE	Q, VT, ti, delay (ricochet).	Neutralization	([4]).
Roads and railroads	Observed	All (pref 155-mm or larger)	HE	Delay, CP	Destruction	Attack critical points: defiles, fills, crossings, culverts, bridges, and narrow portions. Direction of fire should coincide with direction of road.
	Unobserved	All	HE	VT, ti, Q	Harassing. Interdiction.	
Supply installations	Observed. Unobserved.	All	HE, WP	Q, VT, ti	Neutralization. Destruction.	([1]), ([4]).
Vehicles (rendezvous)	Observed. Unobserved.	All	HE, WP	Q, VT, ti	Neutralization. Destruction.	([1]), ([3]), ([4]).
Vehicles (moving)	Observed	All	HE, WP	Q, VT, ti	Neutralization. Destruction.	([3]), ([4]), ([6]).
Weapons (fortified)	Observed	All (pref 155-mm or larger)	HE	Q, CP, delay	Destruction. Neutralization.	Air bursts are desirable if weapon is firing. After weapon is silenced, it is attacked for destruction. Choice of fuze is determined by type of fortification. See fortifications.
Weapons (in open)	Observed. Unobserved.	All	HE, WP	VT, ti, delay (ricochet).	Neutralization. Destruction.	([1]), ([3]), ([4]).

[1] Area is neutralized with shell HE (air bursts if practical). Surprise is essential to produce casualties.
[2] Materiel remaining in area should be attacked for destruction by using appropriate shell and fuze.
[3] Shell AP or HEAT may be used in fire for effect provided that ranges and observing distances are short enough to permit sensing rounds.
[4] Shell WP should be combined with HE when the target contains inflammable material and the smoke will not obscure adjustment.
[5] Shell HE with fuze quick is fired at intervals to clear away camouflage, earth cover, and rubble.
[6] The first objective in firing on moving vehicles is to stop the movement. For this purpose a deep bracket is established so that the target will not move out of the initial bracket during adjustment. Speed of adjustment is essential. If possible, the column should be stopped at a point where vehicles cannot change their route and where one stalled vehicle will cause others to stop. Vehicles moving on a road can be attacked by adjusting on a point on the road and then timing the rounds fired so that they arrive at that point when a vehicle is passing it. If available, a battalion or several battalions may fire at different points on the road simultaneously.

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CHAPTER 24
AERIAL PHOTOGRAPHS

Section I. INTRODUCTION

548. General

This chapter provides the information required by field artillery units to plan for, request, and use aerial photographs. Other manuals containing pertinent information on this subject will be referred to by number. Only that aspect of aerial photographs directly related to artillery gunnery and not adequately covered elsewhere will be covered in detail.

549. Planning

Some of the factors involved in a unit's plan for aerial photographs are as follows:

a. Use. The purpose for which aerial photographs are required (par. 551) must be determined. This purpose will govern the type of photographs (FM 21–26) and scale desired. It will also govern the number of prints required.

b. Area To Be Covered. The area in which the unit requires photographic coverage must be determined.

c. Terrain Features. The presence of prominent terrain features for control points in the area to be photographed must be considered.

d. Survey. The possible need for expansion of existing survey for additional ground control must be considered.

550. Requesting Aerial Photographs

Requests for aerial photographs are normally routed through organic intelligence channels (FM 11–40).

551. Use of Aerial Photographs

The uses of aerial photographs by field artillery are—

a. Target Acquisition. A study of aerial photographs can disclose recent enemy construction, digging, movement (tracks and trails), and other activity not discernible to other available agencies of observation. Targets can be identified on aerial photographs by their size and shape and by shadows and tones. They can be transposed to maps and firing charts by techniques explained in this chapter.

b. Reconnaissance. Aerial photographs can provide recent information on the condition of roads, bridges, streams and other terrain features, and manmade objects. This information is an aid to map and visual reconnaissance.

c. Firing Charts. Vertical photographs (photomaps or mosaics) may be used as firing charts. When a map or grid sheet is used as a firing chart aerial photographs are used to supplement the chart by providing additional horizontal locations.

552. Determining Scale of Vertical Photographs

a. Determination of scale of vertical photographs is presented in FM 21–26 and TM 30–245.

b. Marginal data tabulated on photographs are presented in TM 30–245.

553. Converting Photographic and True Measurements

a. Setting Relationship on Military Slide Rule. Photographic measurements may be converted to true distances (and true to photographic) by use of a military slide rule. This is done by setting the photo distance (a number of units obtained with any convenient plotting scale) on the C scale of the slide rule directly over the true ground distance (yards or meters) on the D scale. Once this setting has been established, any photographic measurements obtained with the same plotting scale from the photograph can then be converted to true ground distance by moving the hairline to the photographic measurement on the C scale and reading under the hairline on the D scale the true ground distance.

b. Example. The true ground distance between 2 points identified on a photograph has been determined to be 1,500 yards. By using a plotting scale, the distance between the 2 points on the photograph is measured as 1,800 units. This photo distance (1,800) on the C scale is set over the true ground distance (1,500) on the D scale. Now to convert a photographic measurement of 2,100 units to true ground distance, 2,100 is located on the C scale and the true ground distance (1,750) appears directly below it on the D scale (fig. 197).

c. Computing Relationship With Arithmetic. Photographic measurements may be converted to true distance (and true to photographic) by use of the following equation:

$$\frac{\text{photo distance (units)}}{\text{true ground distance (yards or meters)}} = \frac{\text{photographic measurement (units)}}{\text{X (yards or meters)}}$$

For example, the measured distance between 2 points on the ground is 1,500 yards; the scaled distance between the same 2 points on the photograph is 1,800 units. To convert a photographic measurement of 2,100 units to true ground distance, the following equation is used:

$$\frac{1{,}800}{1{,}500} = \frac{2{,}100}{x}$$

$$x = \frac{2{,}100 \times 1{,}500}{1{,}800} = 1{,}750 \text{ yards true ground distance.}$$

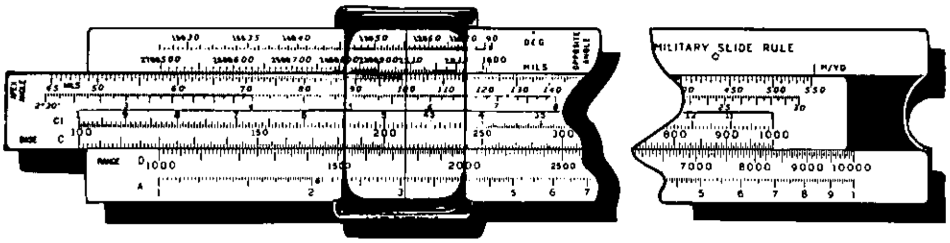


Figure 197. Method of using military slide rule for conversion of photographic measurements to true ground distances.

Section II. DISTORTION IN AERIAL PHOTOGRAPHS

554. General

An aerial photograph of absolutely level ground taken by a camera with its axis truly vertical would result in a picture in which the relative location of points on the picture would be the same as on the ground or a map (fig. 198). However, the vertical photograph is subject to distortion of detail. This is due mainly to tilt of the camera and to relief of the terrain photographed.

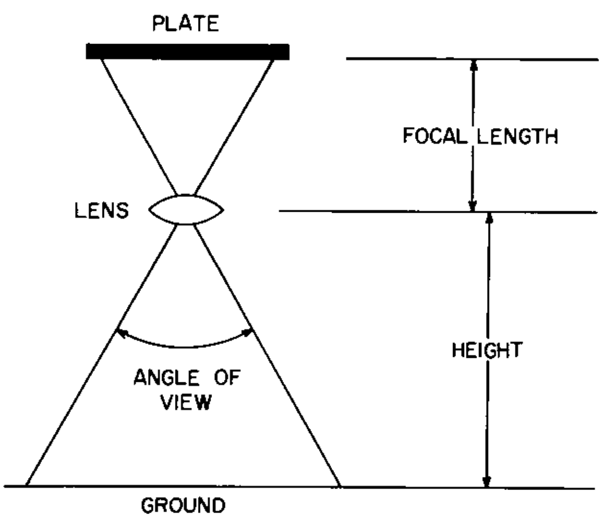


Figure 198. Photographic-ground relationship of a true vertical photograph.

555. Tilt

If the camera is not level at the instant the photograph is taken, the scale of the photograph will not be uniform. This lack of uniformity is the result of tilt. In figure 199, it is evident that a horizontal line of a certain length appearing on a photograph near X will appear longer than a line of the same length appearing on the same photograph near Y, since X is nearer the camera than Y. When the tilt is small, as in the case of a carefully taken photograph, the resulting errors are negligible for artillery work. In a series of overlapping photographs taken on a single flight, exccessive tilt of the camera in taking one of the photographs is apparent if the center of that photograph is materially out of place with reference to the line of centers established by other photographs. If tilt is great enough to distort a vertical photograph, that photograph cannot be used for restitution of points onto a firing chart.

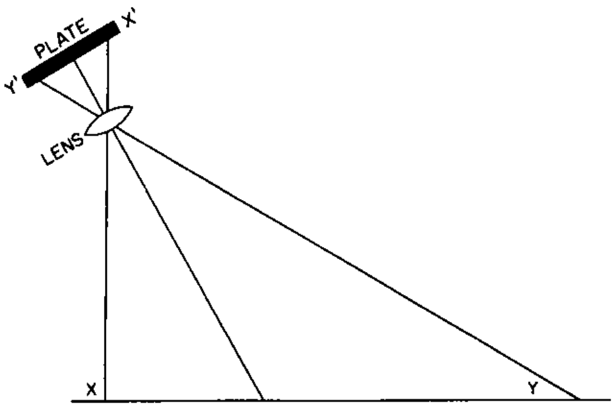


Figure 199. Effect of tilt.

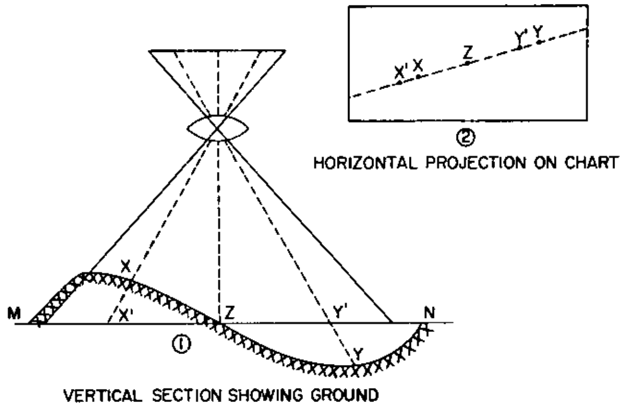


Figure 200. Displacement due to relief of ground.

Photographs taken with excessive tilt are not normally sent to using units, but if an artillery unit does receive such a photograph, a corrected print with the effect of tilt removed should be requested. Artillery units are not equipped to remove the effect of tilt from photographs. Tilt is presented in more detail in TM 5–230.

556. Relief

a. General. The second important source of error in vertical photographs is relief. A point at a higher altitude than the datum plane appears farther from the photo center than it should. Considering figure 200 as any vertical section through the axis of the lens, Z will be recorded in its true position, the center of the photograph, regardless of its altitude. With reference to a horizontal datum plane (MN), an object (X) at a greater altitude will record as being farther from the photo center than it actually is (X′); an object at a lower altitude will appear closer (Y will record as Y′). These displacements are radial from or toward the plumb point (point directly beneath the camera lens at the instant the photograph is taken—also referred to as nadir, ground). If the tilt is small, the plumb point and the center of the photograph 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 the photo center (Z) and the vertical interval between the object and the horizontal datum plane. Note that directions of the radial lines, ZX and ZY, are not changed by the displacements of X and Y. The relief distortion of any particular point varies inversely as the altitude of the airplane varies.

b. Effect of Relief Displacement on Direction and Scale. The effect of relief is the displacement of images radially from or toward the center of the photograph. Considering figure 201, the points X and Y are on the higher ground and the point Z is on lower ground than the center of the photograph (W). In the figure, X, Y, and Z represent the true locations of these points, whereas X′, Y′, and Z′ represent the photographic locations. The lines X′Z′ and X′Y′ are not true direction lines, whereas WX′, WY′, and WZ′ are true and Y′Z′ is approximately true. Therefore, the directions of lines passing through or near the center of an average vertical photograph are substantially true. However, lines passing well away from the center and adjoining points of different altitudes whose images lie in the outer field of the photograph may show excessive errors when relief is considerable. If the altitude from which the photograph was taken is known, the error may be corrected by a replot of the points to the same datum plane.

c. Determination of Relief Correction (fig. 202). The amount of distortion, due to relief, can be found by solving the following proportion:

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

d is the displacement correction in yards (photo distance) radially toward (from) the center of the photograph.

h is the height in feet of ground above (below) the horizontal datum plane.

D is the distance in yards (photo distance) from the center of the photograph to the point to be corrected. (*D* may be measured with 1:25,000 or other convenient scale; the resulting value of *d* will be in the same units as *D*.)

H is the height in feet of the camera lens above the horizontal datum plane. Usually, the

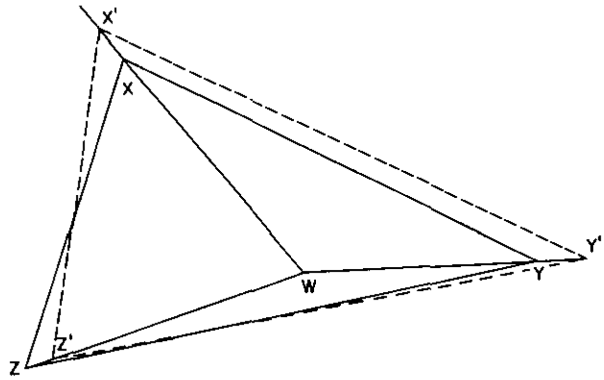


Figure 201. Effect of relief displacement in direction and scale.

altitude of the center of the target area is assigned arbitrarily as the horizontal datum plane and used as the basis for distortion corrections.

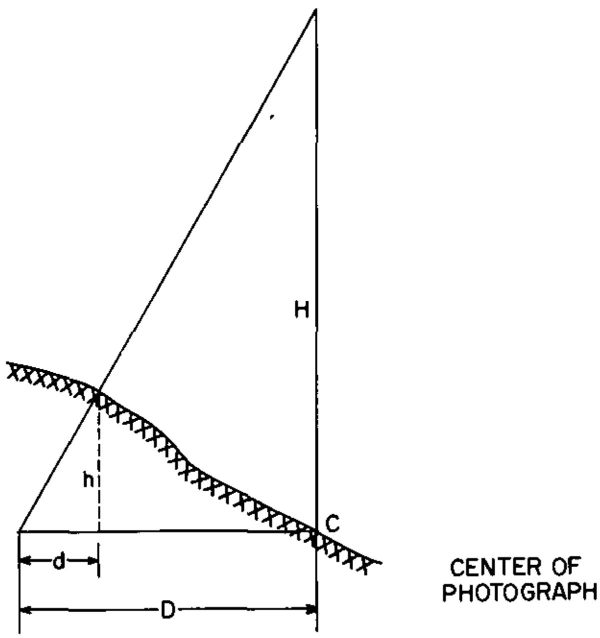


Figure 202. Determination of relief correction.

d. Example of Correction for Relief Distortion (fig. 203). An aerial photograph taken at an altitude of 28,000 feet above sea level is to be used to determine the relative location of points on the firing chart. By survey, point X has been determined to be 180 feet above the registration point. The selected datum plane, based on the approximate altitude of the registration point, is 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 X to the center of the photograph is scaled as 4,000 yards. Point X will be plotted 29 yards $\left(\frac{d}{4{,}000}=\frac{180}{25{,}000}=28.8\right)$ along a radial line toward the center of the photograph from its photographic location.

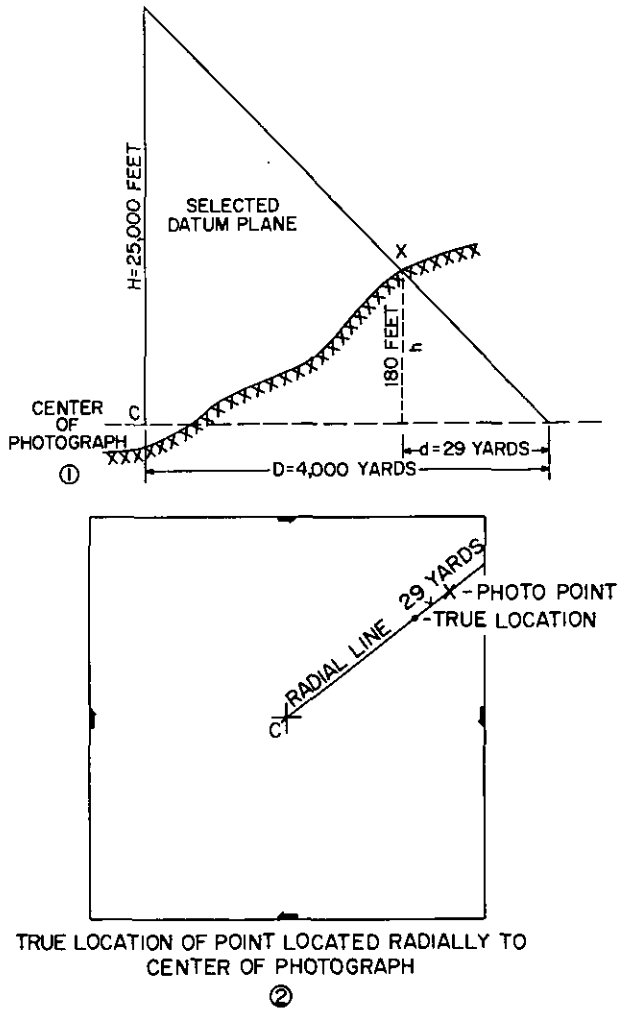


Figure 203. Example of correction for relief distortion.

Section III. RESTITUTION

557. General

a. Restitution is the process of transferring points from one aerial photograph or chart to another.

b. One of the most accurate methods of restitution is the radial line method, which requires the use of overlapping photographs.

c. There are four methods of restitution which involve the use of single vertical photographs only. These methods are listed in order of increasing accuracy as follows:

(1) Tracing paper resection.
(2) Proportional dividers.
(3) Polar plot.
(4) Alternate polar plot.

558. Radial Line Method

For practical purposes, the combined effects of relief and tilt in photographs taken with a camera slightly tilted is assumed to cause displacements along radial lines passing through the centers of the photographs. This assumption is used in the radial line method of restitution to determine accurately the map position of a point appearing in the overlap of two aerial photographs taken at different camera positions. This is one method of restitution that will correct for both tilt and relief. The method fails if the tilt is greater than 3°. It also fails if the point sought falls on or near the line joining the centers of the two photographs, because this makes it difficult to obtain a good angle of intersection. To restitute a target (T) (fig. 204) which appears on two overlapping vertical photographs, the following procedure is used:

a. Mark the photo center of each photograph. The photo center is the geometric center of the photograph and is determined by the intersection of lines through the corners of the photograph or through the fiducial marks along the edges of the photograph (fig. 204 ①).

b. 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 photograph and widely distributed. Draw radial lines or rays from the center (C) of each photograph to the photographic locations of the control points (XYZ) (fig. 204②).

c. Place tracing paper over the firing chart and prick the chart locations of the control points on the tracing paper (fig. 204③).

d. Place the prepared tracing paper over one photograph so that the rays on the photograph pass through the corresponding control points on the tracing paper.

e. Draw a ray on the tracing paper from the center of photograph 1 to the point to be restituted (T) (fig. 204④).

f. Repeat steps in *d* and *e* above on photograph 2 using the same tracing paper (fig. 204⑤). Intersection of the rays gives the tracing paper location of the point to be restituted.

g. Orient the tracing paper over the chart (control point over control point) and prick through the intersection of lines, thus transferring the point to the chart (fig. 204⑥).

559. Tracing Paper Resection

a. Points within a limited area appearing on a vertical photograph may be plotted roughly

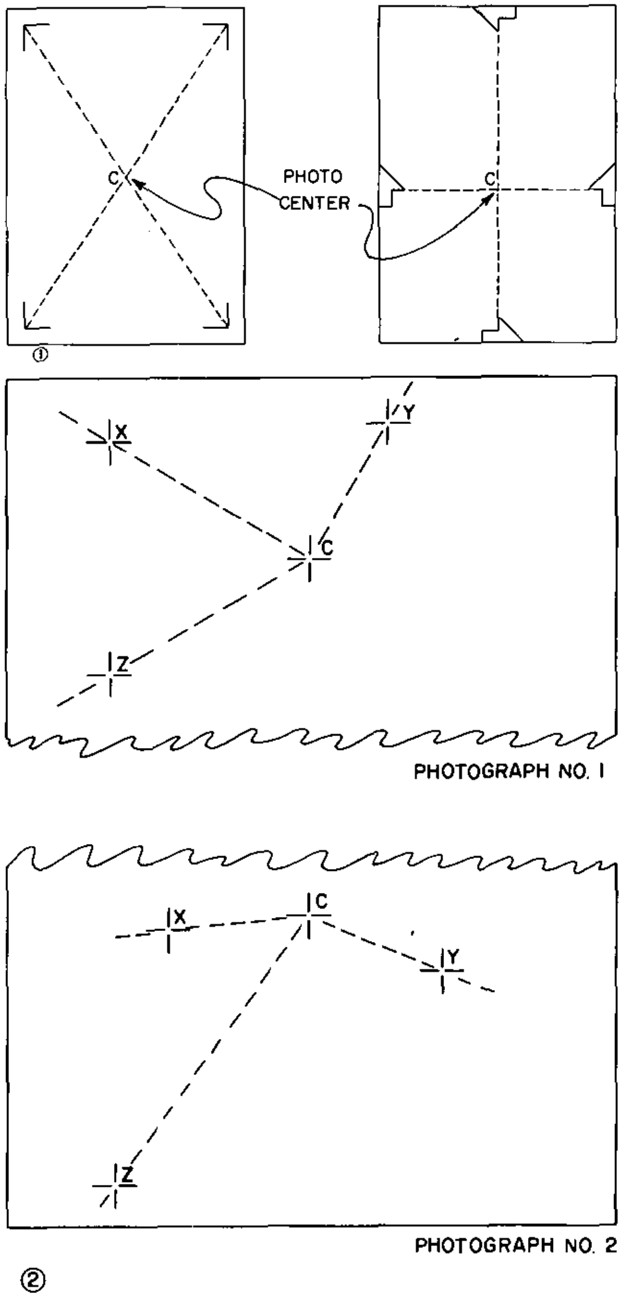


Figure 204. Radial line restitution.

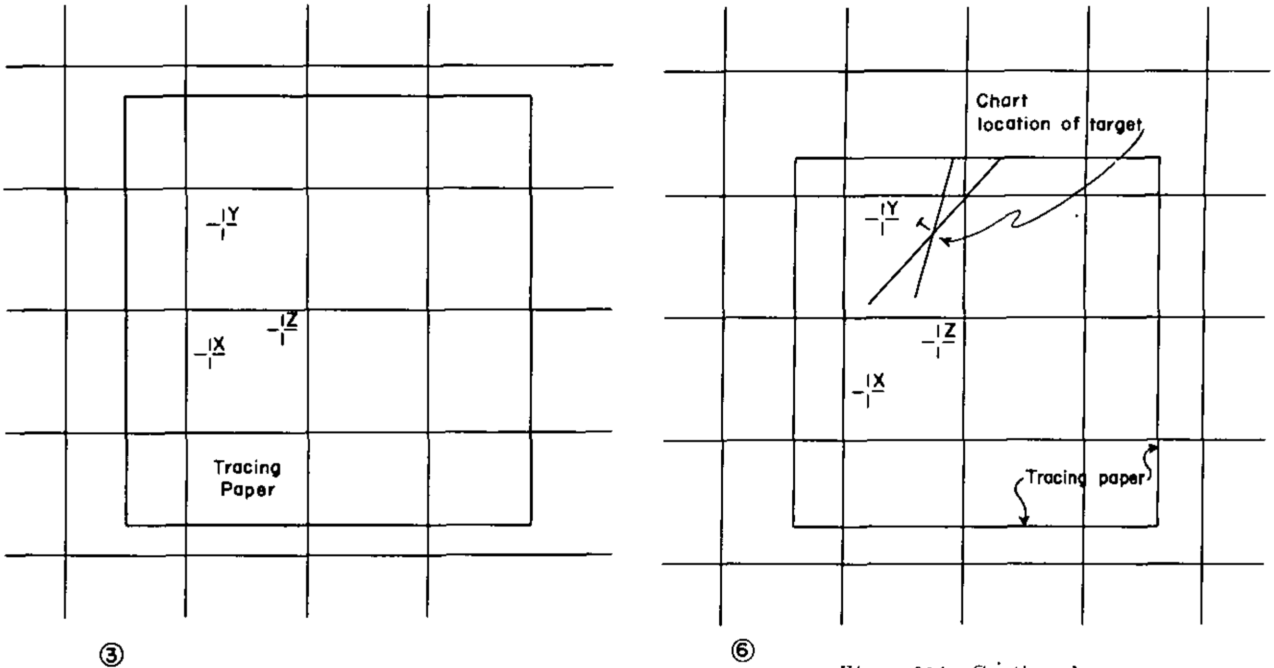


Figure 204—Continued.

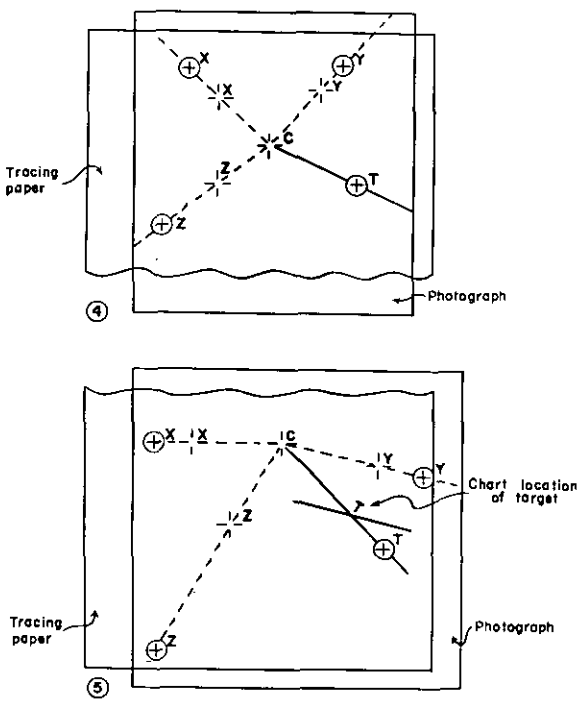


Figure 204—Continued.

on a map or firing chart by the use of tracing paper resection.

b. To locate a point (P) (fig. 205), identify on the photograph at least 3 points (preferably 5) that appear on the map or firing chart. Mark on a sheet of tracing paper the photographed position of these points and the point to be located. This is accomplished best by tacking the photograph over the tracing paper and pricking a pin through each point. On the tracing

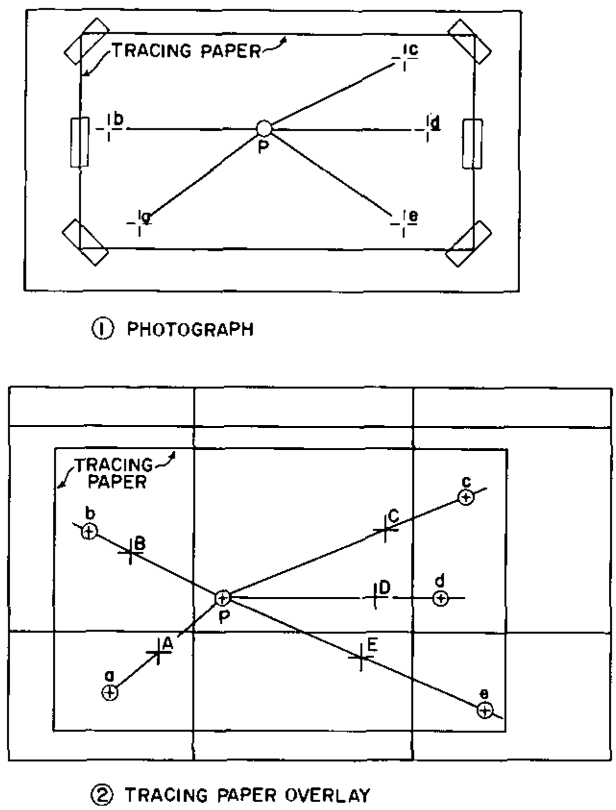


Figure 205. Tracing paper resection.

paper, draw rays from the point (P) to each of the known points, such as a, b, c, d, and e. Place the tracing paper on the map or chart so that the ray to each of the known points passes through the map or chart location of the corresponding point. The point (P), represented by the intersection of the rays, is then in its relative position to the known points and its position may be pricked onto the map.

c. This method is subject to errors of tilt and relief. The error of location can sometimes be reduced by selecting more than the minimum of three known points.

560. Proportional Dividers

The most rapid method of restitution is by use of proportional dividers (fig. 206). 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. Once the pivot of the dividers is set to the proper photograph-chart ratio, all points on any particular photograph may be restituted to the chart without disturbing the adjustment of the pivot. With the pivot at a fixed setting, distances are taken off the photograph with one end of the proportional dividers and laid off on the chart with the other end. These photo distances are subject to errors of tilt and relief. To restitute points from photograph to chart, proceed as follows:

a. Select restitution points which appear both on the photograph and the chart. In figure 206, 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 photograph end of the dividers match the 2 restitution points on the photograph, the points on the chart end of the dividers will match the 2 restitution points on the chart.

c. Using the photograph ends 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 in the direction of the point to be located.

d. Repeat the procedure for the second restitution point. The location of the point on the chart is at the intersection of the two arcs drawn.

Figure 206. Proportional dividers.

If a third restitution point is available, another arc is drawn to give a check on the location determined from the first two.

561. Polar Plot

A more accurate method of restitution than tracing paper resection or proportional dividers is the polar plot method which may be used when only a single vertical photograph 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. As illustrated in figure 207, the procedure is as follows:

a. Two or more well-separated points (A and B), whose chart locations are known, are identified on the photograph and a line is drawn between these two points on both the photograph and the chart. To reduce errors of relief and tilt, these points should be at about the same altitude, and the lines established should pass close to the center of the photograph.

b. The line on the photograph is extended to enable shifts and distances to be measured from either of the points with an angle-measuring device (protractor, range-deflection fan, or GFT fan).

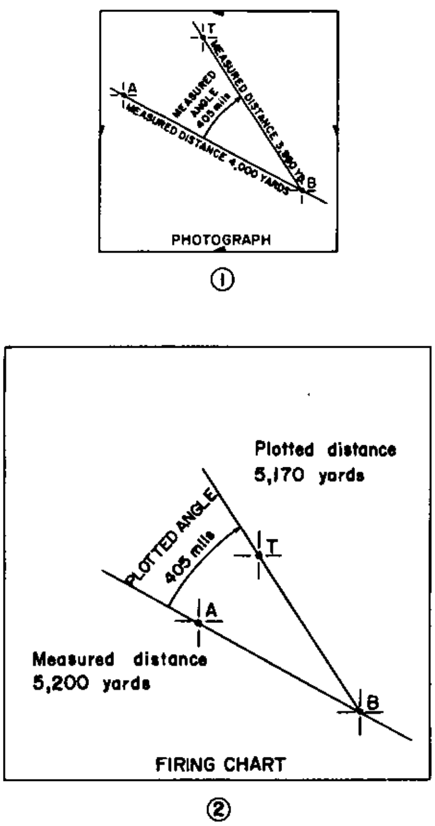


Figure 207. Polar plot restitution.

c. The difference in scale between the photograph and chart is compensated for by measuring the photo and chart distances and by setting up a relation between the two on a slide rule (par. 553). In the example shown in figure 207, photo distance (4,000) is placed on the C scale over chart distance (5,200) on the D scale.

d. To restitute a point (T) from the photograph to the chart, the angular shift from the known line and the distance are measured from whichever known point will give the smallest angle and the largest distance. In this case the measurement is made from point B, and the results are an angular shift of 405 mils right of line BA and a photo distance of 3,980 yards.

e. The photo distance is converted to chart distance by use of the relationship set up on the slide rule. By moving the hairline to the photo distance of 3,980 yards on the C scale, the chart distance of 5,170 yards is read directly below it on the D scale.

f. The desired point T is plotted on the chart by using the measured shift of 405 mils right of line BA and the chart distance of 5,170 yards from point B.

562. Alternate Polar Plot

A refinement of the polar plot method of restitution is called the alternate polar plot method. This method partially eliminates errors due to distortion by using only radial lines from the photo center as bases for polar plotting. The procedure for the alternate polar plot method is as follows:

a. At least three points whose chart locations are known are identified on the photograph and the photo center is determined and marked. Radial lines are drawn on the photograph from the photo center C to the three known points (XYZ) (fig. 208 ①).

b. An overlay is made from the photograph showing the photo center, and the radial lines are drawn from the center through the three points (XYZ) (fig. 208 ②).

c. The overlay is then placed over the chart and moved until the three rays pass through the control points on the chart. When the overlay is in this position, the photo center is then transferred to the chart by pricking through the overlay (fig. 208 ③).

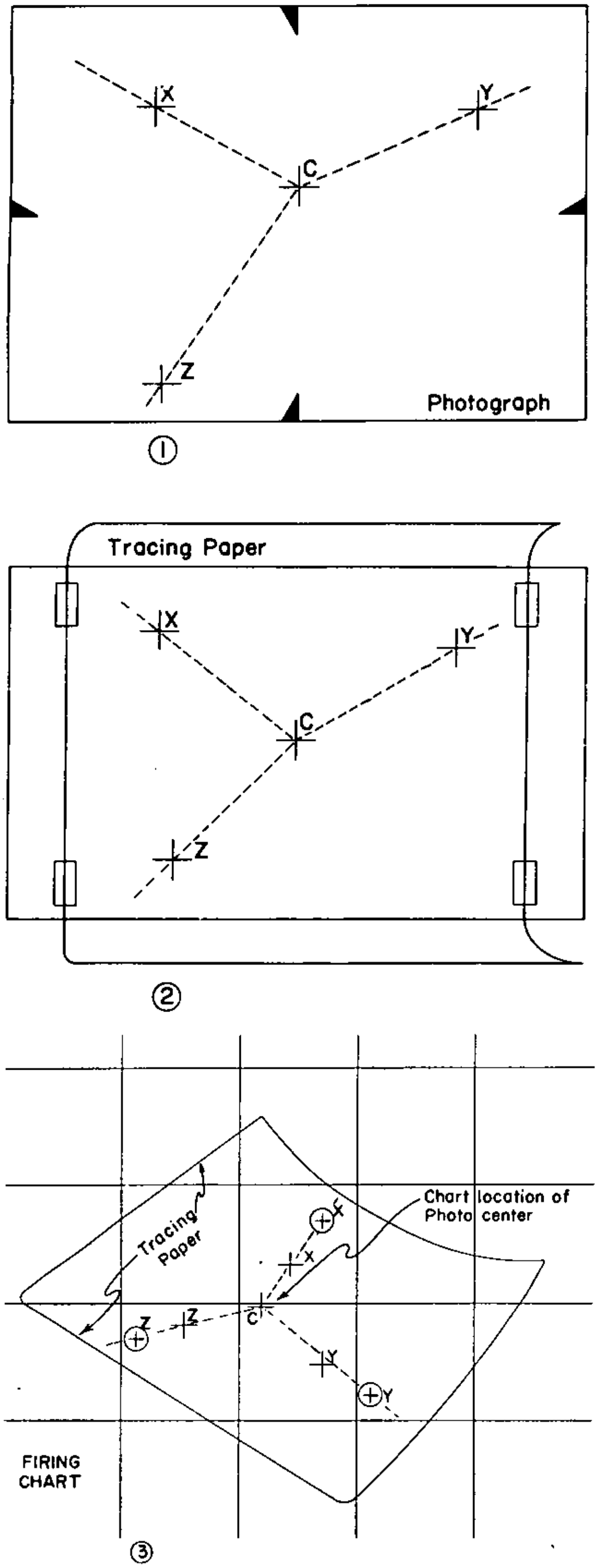


Figure 208. Alternate polar plot restitution.

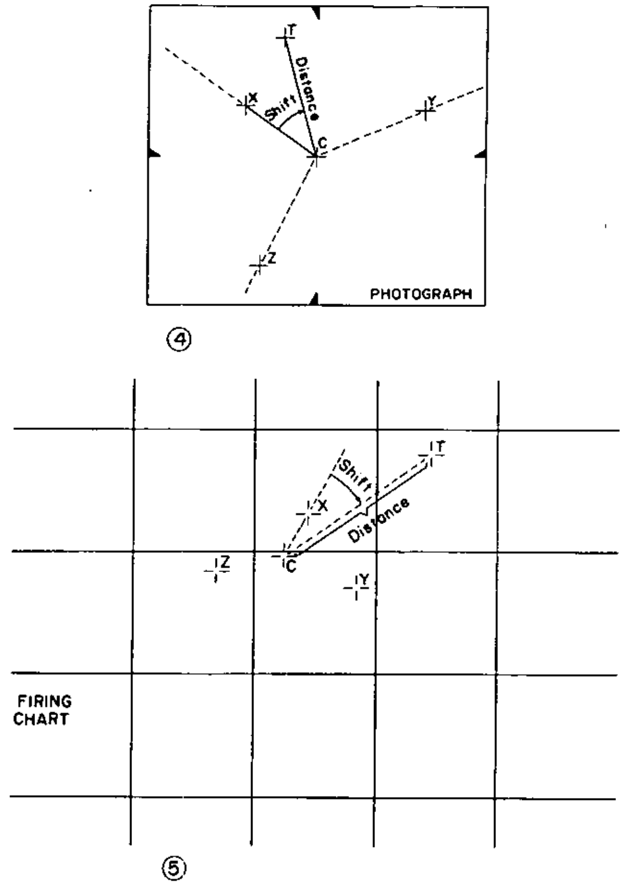


Figure 208—Continued.

d. When the photo center has been located on the chart, the procedure for transferring points is the same as that in the polar plot method, except that all measurements on the photograph and all plotting on the chart are performed with the vertex of the angle-measuring device at the photo center (fig. 208 ④ and ⑤).

563. Vertical Control

Normal methods of restitution do not include adequate means of determining vertical control. Use of a stereoscope may aid in determination of relative heights. High obliques, when gridded, can be used to supplement vertical control. If a map is available and points can be identified on both map and photograph, vertical control is relatively simple. A pantograph (TM 5–230) can be used, if available, to transcribe contour lines from a map to a vertical photograph. Survey can also be used to establish vertical control provided points are on terrain which is accessible, or visible, to the survey party.

Section IV. OBLIQUE PHOTOGRAPHS

564. General

Oblique photographs are those taken with the axis of the camera intentionally tilted from the vertical position. Obliques which show the horizon are high obliques, and those which do not show the horizon are low obliques.

565. Characteristics

The primary characteristics of oblique photographs are as follows:

a. Obliques may be taken from either air or ground observation posts.

b. A special camera is not necessary for taking obliques.

c. Relief is more readily recognizable on an oblique than on a vertical photograph.

d. Obliques are limited by their size and perspective to a useful depth of about 10,000 yards.

566. Uses

Obliques are used for the following purposes:

a. Reconnaissance. Use of obliques to supplement visual reconnaissance enables a commander to more nearly see the terrain as it appears to an observer in a frontline position.

b. Briefing. Obliques are used to brief ground and air observers and to designate objectives, phase lines, boundaries between units, zones of fire, zones of observation, and observation posts.

c. Terrain Sketches. Observers can use obliques as terrain sketches (par. 153). When a copy is available to the FDC, it facilitates the exchange of battlefield information and enables the FDO and S2 to see the terrain as the observer sees it.

567. Mil-Gridded Oblique Photographs

a. Mil-gridded obliques (fig. 209) are made by the Air Force by contact printing the negative

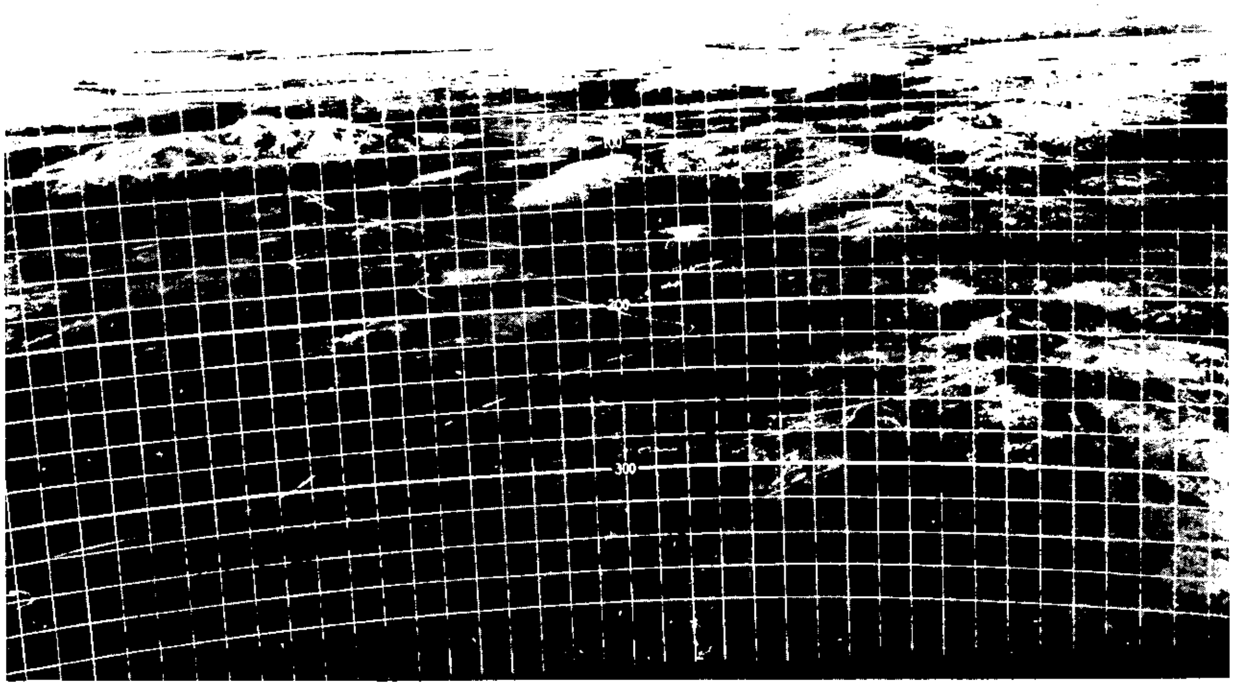


Figure 209. Mil-gridded oblique photograph.

through a transparent mil-grid. Mil-gridded obliques are used in conjunction with firing charts to determine the horizontal and vertical locations of points (fig. 210). Horizontal locations of points obtained from gridded obliques are not as accurate as those obtained from vertical photographs. 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 firing charts for the purpose of determining altitudes.

b. The following terms are used in conjunction with mil-gridded obliques:

(1) *Plumb point*—the point on the ground vertically beneath the perspective center of the camera lens.

(2) *Center line*—the map projection of the vertical plane that contains the axis of the camera at the instant the photograph was taken. On the photograph, 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.

568. Horizontal Locations

a. Orientation of Photographs. Oblique photographs are oriented 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 can be used to determine the chart locations of plumb points. The chart locations of three or more ground control points appearing on each photograph are necessary. These chart locations may be determined by survey or may be taken from a map or vertical photograph. 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 an angle-measuring device. 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

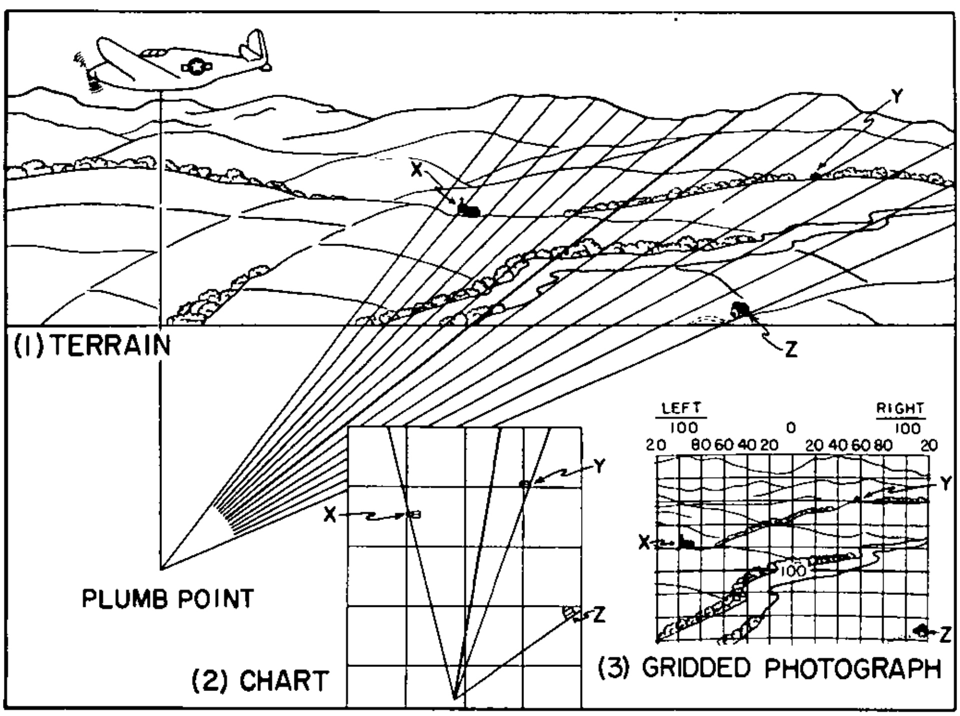


Figure 210. Mil-gridded oblique used in conjunction with firing chart.

plumb point is pricked through to the chart.

(2) *Location of center lines.* With the tracing paper in the same position as in (1) above, any convenient point on the center line is pricked through to the chart.

Note. Each plumb point and center line must be labeled with its photograph number; center lines are marked with identifying arrows.

b. Transposition of Points From Obliques to Charts.

(1) *Point designation.* Oblique references include a photograph number and horizontal and vertical angles; for example, "Photo 58, L156042." The photograph number designates the photograph 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 0 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: The following message has been received from an observer: PHOTO 59, R 210118, INFANTRY PLATOON WITH HEAVY WEAPONS, REQUEST BATTALION, FIRE FOR EFFECT. Fire direction personnel identified the same point on photograph 60 as L060 and on photograph 61 as L305. The target would be plotted as in figure 211.

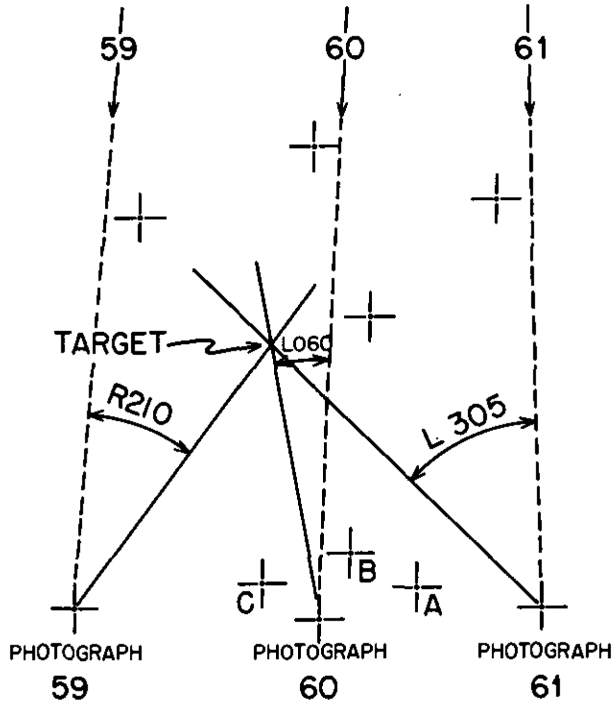


Figure 211. Location of a target on the firing chart.

569. Determination of Altitudes

When mil-gridded obliques are used in conjunction with maps having suitable vertical control, map altitudes are used. If maps are not available, the following method can be used to determine the altitude of a target. The altitude of the camera is computed and then the vertical interval between the camera and the target is subtracted from the altitude of the camera.

a. Altitude of the Camera. One point which can be identified on the photograph and of which the chart location and altitude are known is required to determine the altitude of the camera. The vertical interval between the selected point and the camera is determined by using the mil relation. This interval plus the known altitude of the point is the altitude of the camera. For example, a house whose altitude has been established by survey appears at a vertical angle of 100 mils on photograph 59. Its distance on the firing chart from the plumb point of photograph 59 is 3,500 yards. Figure 212 shows the relations that exist.

Vertical interval (3.5 × (+100))____	=	+350 yards
Altitude of house (survey)_________	=	300 yards
Altitude of camera (350+300)_____	=	650 yards

b. Altitude of the Target. The altitude of a target cannot be determined from a mil-gridded oblique photograph until the altitude of the camera has been determined. When this altitude has been established, the altitude of any target is determined by subtracting the vertical interval between the target and the camera from the altitude of the camera. For example, a target is

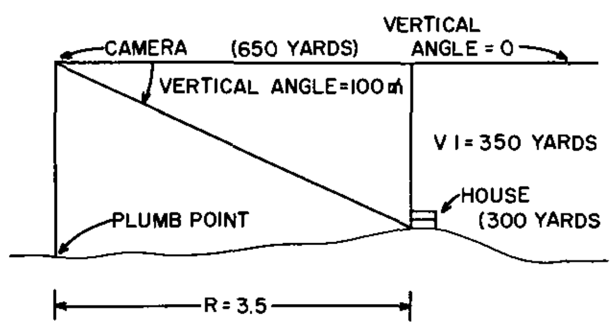


Figure 212. Determination of the altitude of the camera.

reported by oblique reference as PHOTO 59, R210118. Chart distance, after plotting, from the plumb point is 3,200 yards.

Altitude of camera (*a* above)	=	650 yards
Vertical interval (3.2 × (−118))	=	−378 yards
Altitude of target (650−378)	=	272 yards

570. Corrections for Misplaced Mil Grid

A grid may be placed inaccurately because of errors in technique or because haze or terrain features 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. To compute these corrections, an effective camera altitude and a line of zero correction must be established.

a. Effective Camera Altitude. To establish an effective camera altitude and correct for a misplaced grid, three ground control points are required. The points must appear on the photograph and have known chart locations and altitudes. In figure 213, 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 same camera altitude is obtained from all three points, the grid is placed properly and no corrections are required. If a different camera altitude is obtained from each point, the middle altitude of the three is used as the *effective camera altitude*. In figure 213, the 3 altitudes computed are 650 yards, 638 yards, and 666 yards by 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.

b. 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

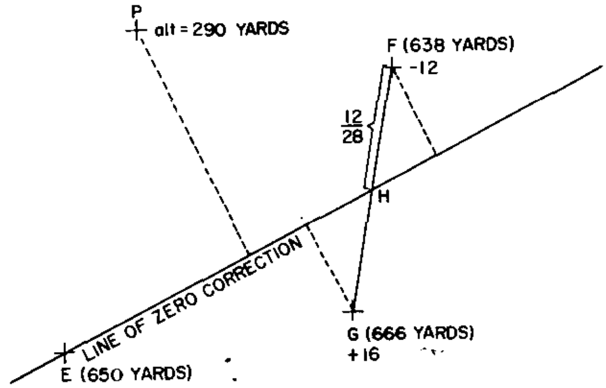


Figure 213. Correcting the altitude when the grid is placed inaccurately.

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*.

571. Altitude Corrections

The correction applicable to the altitude of any point not on the line of zero correction is proportionate 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) used in establishing the line of zero correction (fig. 213). The altitude correction per 1,000 yards is equal to the total altitude correction (28 yds.) divided by the sum of the perpendicular distances (in thousands of yds.) from the points (F and G) to the line of zero correction.

Example:

(1) Point F is 520 yards, and point G is 700 yards from the line of zero correction. The sum of these distances is 1,220 yards. The altitude correction is 28 ÷1,220 or 23 yards per 1,000 yards. On the F side of the line of zero correction, the correction to the altitude determined by 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.

(2) 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 per-

pendicular distance of 2,260 yards from the line. The correction would be $-23 \times 2.3 = -53$ (52.9) yards. The corrected altitude of the point P, then, is $343 - 53 = 290$ yards.

572. 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 photograph. This is done as follows:

a. Determine the true camera altitude by applying the proportion in paragraph 571 to the plumb point. The correction computed for the plumb point is applied to the effective camera altitude to determine the true camera altitude.

b. Determine the true vertical angles for each of the three ground points (E, F, and G) used in determining the corrections for a misplaced grid. 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.

c. Determine the vertical angle correction at each ground control point by comparing the true vertical angle (computed in *b* above) with the vertical angle measured on the oblique photograph. 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. 214).

d. 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.

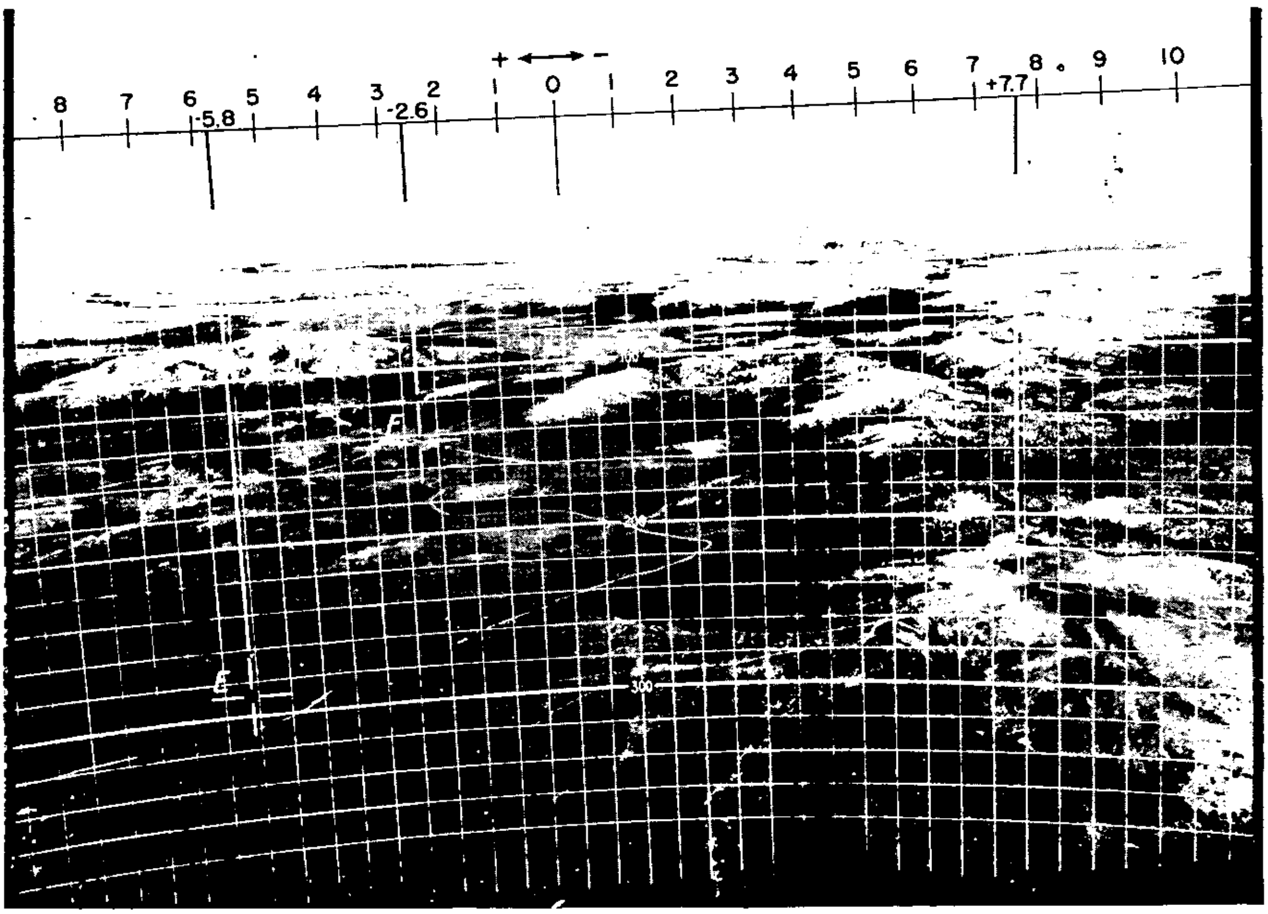


Figure 214. Vertical angle correction scale.

PART FIVE

BASIC BALLISTICS

CHAPTER 25

INTERIOR BALLISTICS

Section I. PROPELLANTS AND MUZZLE VELOCITY

573. Introduction

Interior ballistics is the science which deals with the factors affecting the motion of projectiles before they leave the muzzle of the piece. The total effect of all interior ballistic factors determines the velocity with which the projectile leaves the muzzle. This velocity is called the muzzle velocity and is expressed in feet per second. Actual measurements of the muzzle velocity of a series of rounds, corrected for extraneous factors, depict the performance of a certain weapon-ammunition combination. The result of these measurements can be compared with standard velocities in order to obtain the variation from standard. Application of corrections to compensate for nonstandard muzzle velocity is one of the most important elements in preparation of accurate firing data.

574. Nature of Propellants and Projectile Movement

a. A propellant is a low-order explosive which burns rather than detonates. In artillery weapons using separate-loading ammunition, the propellant is burned in a chamher defined by the weapon powder chamber and the base of the projectile; in weapons using fixed and semifixed ammunition, the propellant is burned in a chamber defined by the shell case and the base of the projectile. When the gases generated by the burning propellant develop pressure sufficient to overcome initial bore resistance, the projectile starts its forward motion.

b. The gas pressure builds up quickly to a peak and gradually subsides shortly after the start of projectile movement. The peak pressure together with the travel of the projectile in the bore (pressure-travel curve) determines the speed at which the projectile leaves the tube.

c. A few general rules ((1)–(5) below) will assist in understanding how various factors affect velocity performance of a weapon-ammunition combination.

(1) An increase in the rate of burning of a propellant increases resultant gas pressure.

(2) An increase in the size of the powder chamber without a corresponding increase in the amount of propellant decreases gas pressure.

(3) Gas escaping around the projectile while in the tube decreases pressure.

(4) An increase in bore resistance to projectile movement before peak pressure further increases pressure.

(5) An increase in bore resistance at any time has a dragging effect on the projectile and decreases velocity. Temporary variations in bore resistance are caused by extraneous deposits in tubes and on projectiles and by differences in heat between the inner and outer tube surfaces.

575. Standard Muzzle Velocity

a. Appropriate firing tables give the standard value of muzzle velocity for each charge of a particular weapon. These standard values are based on an assumed standard tube. The standard values are points of departure, not absolute standards, since they cannot be reproduced at a given instance; that is, a specific weapon-ammunition combination cannot be selected with the knowledge that it will result in a standard muzzle velocity when fired.

b. Charge velocities are established indirectly by the military characteristics of a weapon. Weapons capable of high-angle fire (mortars and howitzers) require a greater choice in numher of charges for firing than do weapons capahle of low-angle fire only (guns). This greater choice is needed in order to achieve range overlap between charges in high-angle fire and the desired range-trajectory combination in low-angle fire. Other factors considered are the maximum range specified for the weapon and the maximum elevation and charge (with resulting maximum pressure) which the weapon can accommodate.

c. Manufacturing specifications for ammunition include the required velocity performance within certain tolerances. The ammunition lots are subjected to firing tests which include measuring the performance of the lots tested against the concurrent performance of a control or reference lot. Both the control lot and the lot being tested are fired through the same tube, assuming that whatever the characteristics of that tube, the performance of both lots is influenced identically. The foregoing assumptions, although accurate enough for firing tests, are not entirely correct and allow a certain amount of error in propellant assessment procedures. (Assessment procedures include correcting charge weights for the tested lot so as to match the velocity developed by the control lot during the test.) Therefore, a wide variation in the performance of ammunition under field conditions can be expected even though all practical measures of quality control are taken. Also, if a weapon develops a muzzle velocity 10 f/s faster (or 10 f/s slower) than another weapon with the same charge lot, it will not necessarily do the same with any other charge of any other lot. However, weapon-ammunition performance is not so unstable as to deny any attempts at predicting future performance based on past results.

Section II. FACTORS CAUSING NONSTANDARD MUZZLE VELOCITY

576. General

In gunnery technique, nonstandard velocity is expressed as a variation (plus or minus so many feet per second) from an accepted standard. Round-to-round corrections for dispersion cannot be made. However, precautions can be taken to assure that normal dispersion as reflected in muzzle velocity performance is not exceeded. In the discussion in paragraphs 577 through 592, each factor is treated as a single entity assuming no influence from related factors.

577. Velocity Trends

All rounds of a series that are fired from the same weapon using the same ammunition lot will not develop the same muzzle velocity; however, the magnitude above or below the average velocity (velocity dispersion) should not be relatively greater or smaller for the first or any other round. Under most conditions of the tube, the velocity of the first one or more rounds follows a somewhat regular pattern, as though it were being effected by factors other than chance alone. This phenomenon is called a velocity trend. The magnitude and extent (number of rounds) of velocity trends vary considerably with the weapon, charge, tube condition at round 1, and firing preceding round 1. Hence, velocity trends do not always lend themselves to prediction of finite corrections to firing data in a given instance and may result in false corrections to firing data. Characteristic velocity trends for some weapons, however, can be detected. A comparison of velocity trends for a 105-mm howitzer when a series of rounds is fired starting with an oily tube, a tube cleaned with rags only, and a tube cleaned with soap and water is shown in figure 215. As a general rule, the magnitude and duration of velocity trends can be minimized when firing is started with a tube which is clean and completely free of oil.

578. Ammunition Lots

Each lot of ammunition has its own mean performance level when related to a common tube. Although the round-to-round probable error within each lot is about the same, the mean velocity developed by one lot may be much higher or lower than another lot. With separate-loading ammunition, both the propellant and the projectile lots must be identified. Variations in projectile manufacture, e. g., the diameter and hardness of the rotating band, affect muzzle velocity. (Projectile variations have a much more apparent effect on exterior ballistics.) Therefore, lots must be segregated whenever possible. The result of mixing lots, whether of necessity or by accident, is increased dispersion within a series of rounds and increased missed distances of the centers of impact.

579. Tolerances in New Weapons

New weapons will not necessarily develop the same muzzle velocity. In a new tube, the pre-

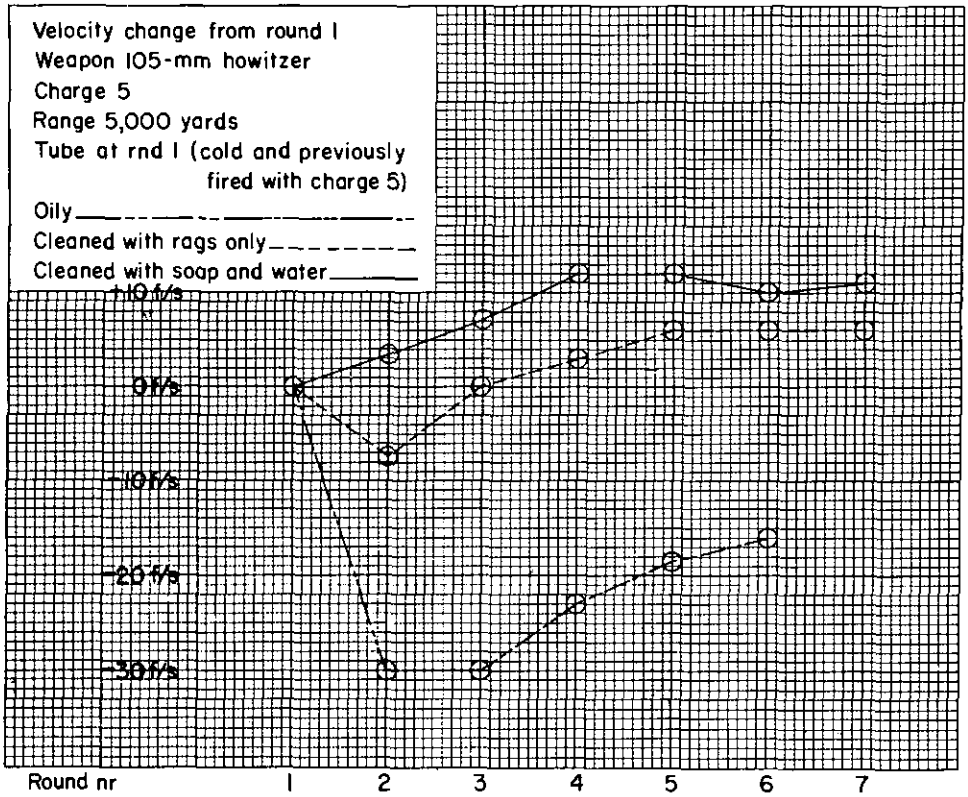


Figure 215. Velocity trends.

dominant factors are variations in the powder chamber and the interior dimensions of the bore. If a battalion armed with new weapons fired all of them with a common lot of ammunition, a velocity spread of 12 f/s between weapons with highest and lowest muzzle velocity would not be unusual. Since these conditions exist, weapons must be calibrated even though they are new.

580. Wear of Tube

Continued firing of a weapon wears away portions of the bore by the action of heated gases, chemical action, and movement of the projectile itself. These erosive actions are more pronounced when higher charges are being fired. Increased tube wear tends to decrease muzzle velocity by allowing the projecile to be seated farther forward in the tube thereby allowing more room for expanding gases, by allowing the expanding gases to escape past the rotating band, and by decreasing resistance to initial projectile movement which lessens pressure buildup. Although normal wear cannot be prevented, it can be minimized by careful selection of the charge and proper cleaning of both weapon and ammunition. Calibration data must be kept current, since losses in velocity do not uniformly follow an increase in measured wear.

581. Nonuniform Ramming

Although a weak ram would decrease the volume of the powder chamber and thereby increase the push given the projectile (the pressure of a gas varies inversely with the volume), this is only a partial effect. Improper seating of the projectile, as a result of weak ramming, allows some of the expanding gases to escape without doing any work and a lower velocity results. The combined effect of escaping gases and a smaller powder chamber is hard to predict; therefore, hard uniform ramming is required for all rounds. When fixed and semifixed ammunition are being fired, the principles of varying volume of powder chambers and escape of gases still apply, especially in worn tubes. Since the obturation of the cartridge case serves as the gas check to the rear in fixed and semifixed ammunition, proper handling and seating of the case is important in reducing escape of gases.

582. Rotating Bands

Ideal rotating bands allow proper seating, provide obturation, and create proper resistance to initial projectile movement to allow uniform pressure buildup. They also provide a minimum dragging effect on the projectile once motion has started. Dirt or burrs on the rotating band cause improper seating which increases tube wear and contributes to velocity dispersion. If excessively worn, the lands may not sufficiently engrave the rotating bands to impart proper spin to the projectile. Insufficient spin reduces projectile stability in flight and can result in dangerously short, erratic rounds. When erratic rounds occur or excessive tube wear is noted, ordnance ballistic and technical service teams should be called upon to determine the serviceability of each tube by wear measurements and other checks. These teams can provide this and other services, such as help in calibration.

583. Powder Temperature (Propellant Temperature)

Any combustible material burns more rapidly when it is heated prior to ignition. When a propellant burns more rapidly, the resultant pressure on the projectile is greater and muzzle velocity is increased. The firing tables show the magnitude of this change in a table titled "Change in Velocity Due to Change in Temperature of Powder." Appropriate corrections to firing data can be computed from that table; however, such corrections are accurate only as they reflect the actual powder temperature. The temperature of propellants in sealed packing cases remains fairly uniform, though not necessarily standard (70° F.). Once the propellant is unpacked, its temperature tends to approach the prevailing air temperature. The time and type of exposure to weather result in powder temperature variations between rounds as well as mean powder temperature variations between weapon sections. It is not practical to measure powder temperature and apply corrections for each round fired by every weapon. Positive action must be taken to maintain uniform powder temperatures; failure to do so results in erratic firing. Also, the effect of a sudden change in powder temperature can invalidate even the most recent registration correction.

a. Ready ammunition should be kept off the ground; should be protected from dirt, moisture, and the direct rays of the sun; and should have an air space between the ammunition and protective covering. (This procedure allows propellants to approach atmospheric temperature at a uniform rate.)

b. Rounds should be unpacked sufficiently in advance so that it is never necessary, in the same mission, to mix freshly unpacked ammunition with ammunition which has been opened for some time.

c. Rounds should be fired in the same order as they are unpacked.

d. Powder temperatures of ready ammunition should be taken at random and should be checked periodically (approximately every 30 minutes). The rounds so checked should not be removed from the rest of the ammunition but should be measured in place to get a true mean. The thermometer should penetrate the charge that is being used and must not touch any metal.

584. Moisture Content of Powder

Although modern propellants contain additive chemicals which tend to prevent change in moisture content, handling and storage can cause moisture changes which will affect the velocity performance of the ammunition. Since changes in moisture content cannot be measured or corrected for, ammunition must be provided maximum protection from the elements.

585. Position of Bagged Propellant in Chamber

In fixed and semifixed ammunition, the propellant has a relatively fixed position with respect to the chamber—the chamber being, in effect, the cartridge case. The position of separate-loading propellants, however, is dependent on the cannoneer who inserts the charge. The farther forward in the chamber the propellant is placed, the slower the rate of burning and the lower the subsequent velocity. In order to assure uniform positioning and thus to obtain uniform propellant performance, the base of the powder bag should be flush against the mushroom head at the instant of firing. Associated with the positioning of the bag in the chamber are variations in the diameters of the bags. An increase in the bag diameter for the same amount of powder tends to increase the rate of burning and the resultant velocity. Loose tie straps or wrappings have the effect of increasing bag diameter from the original diameter; therefore, cannoneers should check wrappings for tightness even when the full charge is being used.

586. Weight of Projectile

The weight of like projectiles varies within certain weight zones. The appropriate weight zone is stenciled on the projectile. Some projectiles are not grouped in weight zones but are marked with the weight in pounds (e. g., SH HE, T122 for 280-mm gun). A heavier than standard projectile is harder to push throughout the length of the tube and a decreased velocity results, whereas a lighter projectile has the opposite effect. (Weight of projectile is also a factor in exterior ballistics.)

587. Coppering

When projectile velocity in the bore is high enough, sufficient friction is developed to remove the outside surface of the rotating band. The removed metal is deposited as a thin film of copper in the bore. This condition is known as coppering. It is more pronounced in high velocity weapons and charges. The amount of copper deposited varies with the velocity. Firing with lower charges will reduce coppering. Coppering causes erratic velocity performance by varying the resistance of the bore to projectile movement. The removal of excessive copper is an ordnance function.

588. Powder Residues

Residues from the burned powder and certain chemical agents mixed with the expanding gases are deposited on the bore surface in a manner similar to coppering. Unless the tube is properly cleaned and cared for, these residues aggravate subsequent tube wear by causing pitting and augmented abrasive action of the projectile. Cleaning the tube before missions should be avoided when optimum accuracy is desired, such as for unobserved fires.

589. Tube Conditioning

The heat of the tube has a direct bearing on the developed velocity. For example, a cold tube offers different resistance to projectile movement than a warm tube. A cold tube is less susceptible to coppering even at high velocities. The results of the warming up process can appear as a trend of increasing or decreasing velocities depending on the weapon, charge, oiliness of the tube, and the degree of coppering.

a. Ammunition is tested in tubes which have been thoroughly conditioned to a desired velocity level by firing several warmup rounds. Tubes which are not conditioned will not allow propellants to perform as they did when tested. Also, the round-to-round variation is much greater during the conditioning period.

b. The fire for effect and corresponding registration corrections may or may not be determined at the velocity level to be experienced later when transfers are made. For a specific projectile lot, transfers fired with velocity levels higher than the velocity levels at the time that corrections were determined will result in bursts beyond the target. Conversely, transfers fired with lower velocity levels will result in bursts short of the target.

c. If the velocity for a certain weapon-ammunition combination is at its true level only after sustained fire at a specified rate of fire, either increases in the rate of fire or lulls in firing can upset this true level. A change of charge can have a noticeable effect on velocity level. For example, if a 105-mm howitzer is conditioned (brought to the true velocity level) with charge 7 (MV 1550), it will be slightly overconditioned for charge 4 (MV 875). Also, if firing is performed immediately with the lower charge, a tendency toward higher than normal velocities will be experienced on the first 1 or 2 rounds. Going from a lower to higher charge also introduces the possibility that the first 1 or 2 rounds will have a lower than normal velocity. It is doubtful whether or not the firing with the lowest charge only can truly condition a tube to normal operating velocity levels since the warming up process is so slow at low velocities. For example, for the 105-mm howitzer, firing started with charge 3 has resulted in an average variation from standard velocity of 10 to 15 f/s below charge 3 performance which was preceded by the firing with charge 7. The tactical situation seldom allows the firing of conditioning rounds. However, the lack of conditioning is a factor that the FDO's must consider in attacking targets without adjustment or in firing close to friendly troops. Likewise, if optimum accuracy is desired, possible velocity trends should be considered in center-of-impact and high-burst registrations and in calibration firing.

d. In general, tube conditioning involves two different effects. One effect is that of heating the tube until the temperature differential from inner to outer surface is stabilized at the rate of fire and charge to be used. The other effect is that of bringing the bore resistance from coppering and powder residues to a similar stabilized condition at the rate of fire and charge to be used. The first few rounds show the greatest difference from the intended level. However, these are the very rounds that determine the accuracy of fire for effect missions. It is not possible at the present time to include corrections for these trends in firing data. It may never prove feasible to include such corrections for most weapons because of the many variations between the conditioned and the unconditioned tube.

e. In calibration shoots involving more than one charge, the higher charge is fired first, since conditioning occurs with fewer rounds if rounds are fired at the highest velocity. Two to four rounds should be sufficient when the highest charge is fired; however, the observed results are the only valid criteria. Calibrations conducted with the lower charges of the 105-mm, 155-mm, and 8-inch howitzers without prior conditioning with higher charges will require relatively more rounds to reach a conditioned tube status. Low charge trends have extended over 20 rounds.

f. If conditioning has been accomplished with 1 charge and a change to another charge is required, at least 1 extra conditioning round should be fired with the new charge.

g. Guns are more sensitive to changes in the rate of fire than howitzers. This is especially true of the 155-mm gun. The accuracy of intensive preparation fires is adversely affected by rapid firing followed by intermittent lulls of varying length.

h. The previous conditioning of any weapon is affected by lulls in firing of more than 10 minutes. If the lull is no longer than 1 hour, normally 1 round brings weapons to the previous velocity level. If the tubes are cleaned during relatively short lulls, erratic velocities may be experienced for the first few rounds after cleaning. If the cleaning is accomplished during long lulls, the normal velocity trends previously described may be expected.

i. Oil or moisture in the tube or on the rotating band tends to increase velocity of the particular round by causing a better initial gas seal and reducing projectile friction on the bore surface. The oily tube condition usually exists concurrent with the cold tube condition. Hence the high velocities induced by oil combining with the erratic velocities characteristic of a cold tube complicate normal velocity trends. When these factors are coupled with coppering and powder residues, it is hard to predict corrections for velocity trends and compensating corrections are uncertain. Moisture on the projectile normally affects only that particular round. As a general rule, firing with a cold dry tube is preferable to firing with a cold oily tube, and projectiles should be dry regardless of tube conditions. Figure 215 illustrates velocity trends measured under the conditions stated. This graph is not to be construed as the basis for determining corrections to firing data. It is merely an example of observed results which most nearly portray the weapon and condition specified after repeated observations.

590. Determination of Muzzle Velocity

The accuracy of artillery fires could be improved if actual muzzle velocities developed by each tube at time of firing were known. Obtaining such data is not feasible at the present time. Therefore, knowledge of past performance of a weapon-ammunition combination must be relied on for the data needed. In other words, velocity performance is determined when possible and future performance is predicted on this basis. Methods used to determine comparative and absolute velocity performance of a group of weapons are discussed in paragraphs 638 through 655. Aspects of calibration are discussed in detail in exterior ballistics (pars. 593–610). The velocity level of each weapon must be determined at every opportunity.

591. Charge-to-Charge Propellant Performance

One of the major problems in gunnery is how to extend best the data developed from firing one charge to all other charges. From the viewpoint of developed muzzle velocities only, there is no basis in available data to state that charge-to-charge performance follows a convenient arithmetic ratio. Since propellants are manufactured to result in standard performance within any given charge, a variation from standard in one charge does not fix a similar or proportional variation in another charge. The velocity level for a charge of a particular lot can be determined only by firing. Once the velocity level is determined, its relative level (with respect to other charges of that lot similarly determined) remains fairly stable. The velocity level developed at a given time by a certain charge is influenced by the state of the tube conditioning. This is particularly noticeable in the lower charges.

592. Steps To Eliminate Certain Extraneous Velocity Factors

Interior ballistics specifically concerns the motion of the projectile while it is in the tube of the weapon. The total effect of all interior ballistic factors is expressed in the resultant muzzle velocity. Corrections cannot be made for normal round-to-round variations in velocity. However, positive steps can be taken to eliminate certain extraneous factors which magnify and distort normal variations. These steps include—

a. Segregation of ammunition by lots.

b. Uniform ramming of projectiles and positioning of powder bags.

c. Maintenance of uniform powder temperature.

d. General care and cleanliness of ammunition.

e. Recognizing velocity trends and the causes and effects of velocity trends on resultant accuracy of fires, such as—

(1) False calibration data.

(2) Inaccurate registration corrections especially from center-of-impact and high-burst techniques.

(3) Inaccurate transfer fires despite complete accuracy of all firing data.

(4) Short rounds when firing close to front-line troops.

f. Proper cleaning.

g. Care in selecting charge to reduce tube wear.

h. Requesting the services of available ordnance ballistic and technical service teams.

i. Utilizing data from all firing as a constant check on the validity of current calibration data.

CHAPTER 26
EXTERIOR BALLISTICS

Section I. THE TRAJECTORY IN A VACUUM

593. Introduction

a. Exterior ballistics is the science which deals with the factors affecting the motion of a projectile after it has left the muzzle of a piece; at that instant, the projectile has had imparted to it the total effect of interior ballistics in terms of developed muzzle velocity. Were it not for gravity and the atmosphere, the projectile would continue indefinitely at this constant velocity along a prolongation of the tube.

b. Gravity causes the projectile to return to the surface of the earth. In a vacuum, the path the projectile would follow during its flight is fairly simple to trace. All projectiles, regardless of size, shape, or weight, would have the same shaped path and achieve the same range for a given muzzle velocity and tube elevation. In the atmosphere, however, this path, or trajectory (par. 22), becomes a very complex curve. The reason for this is twofold. First, projectiles of different size or weight respond differently to identical atmospheric conditions. Second, all projectiles are subjected to an ever-changing atmosphere. Hence, a given elevation and muzzle velocity can result in a wide variety of trajectories, depending on the combined properties of both the projectile and the atmosphere.

c. The various elements of the trajectory have been described in chapter 2. It is the purpose of this chapter to picture the trajectory first in a vacuum and second in the atmosphere. The latter will include a discussion of both the projectile and the atmosphere and the interrelation of the two.

594. Velocity Components

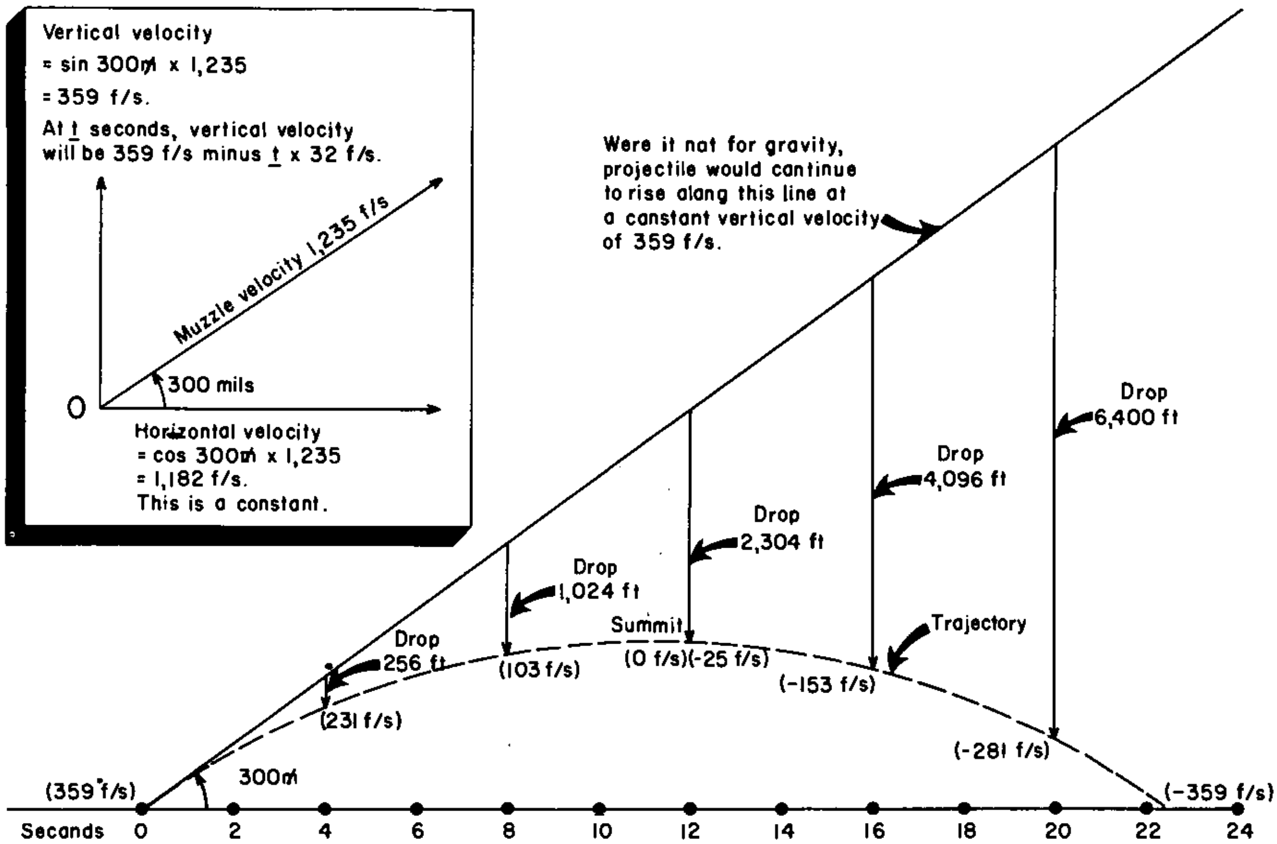
In a vacuum, the factors which must be known to construct a firing table would be the quadrant angle of departure, the muzzle velocity, and gravity. The initial velocity imparted to a projectile consists of two components—a horizontal (range) velocity and a vertical velocity.

595. Horizontal and Vertical Velocity Components

a. The relative magnitudes of horizontal and vertical velocity components vary with the angle of elevation. For example, if the elevation were zero, the initial velocity imparted to the projectile would be all horizontal; it would have no vertical component. If the elevation were 1,600 mils, disregarding the effect of rotation of the earth, the initial velocity would be all vertical; it would have no horizontal component.

b. A projectile in flight will fall to the earth because of gravity. Because of gravity, the height of the projectile at any instant is less than it would be if no such force were acting on it. The vertical velocity decreases from the initial velocity to 0 on the ascending branch of the trajectory and increases from 0 back to the initial velocity on the descending branch. Zero vertical velocity occurs at the trajectory summit and for every vertical velocity value upward on the ascending branch there is an equal vertical velocity value downward equidistant from the summit on the descending branch to and including origin and level point. Since there is no resistance to the forward motion of the projectile in a vacuum, the horizontal velocity component is a constant. This is because of the uniform acceleration of gravity (32 f/s per second) affecting vertical velocity and projectile drop and the constant horizontal velocity component. The trajectory in a vacuum is shown in figure 216.

c. The foregoing (*a* and *b* above) has viewed the trajectory only from the side. If the trajectory in a vacuum were viewed from above, it would not veer away from a line connecting the origin and the level point. Drift would not occur in a vacuum.



Horizontal velocity is a constant from origin to level point; hence the projectile will travel 394 yards in the horizontal plane during each second.

Vertical velocity decelerates from 359 f/s to 0 f/s on ascending branch and accellerates from 0 f/s to 359 f/s on decending branch both at a rate of 32 f/s per second. Brackets denote vertical velocities.

Figure 216. Trajectory in a vacuum.

Section II. THE TRAJECTORY IN THE ATMOSPHERE

596. General

The resistance of the air to a projectile depends on the air movement, density, and temperature. As a point of departure for computing firing tables, an assumed density and temperature structure and condition of no wind are used. The air structure so derived is called "the standard atmosphere."

597. Characteristics of Trajectory in Standard Atmosphere

The most apparent difference between the trajectory in a vacuum and the trajectory in standard atmosphere is the reduction of the range (fig. 217). This is mainly because in the atmosphere the horizontal velocity component is no longer a constant but is continually decreased by the retarding effect of the air. The vertical velocity component is likewise affected by air resistance. The trajectory in standard atmosphere has the following characteristic differences from the trajectory in a vacuum.

a. The velocity at the level point is less than the velocity of origin.

b. The mean horizontal velocity of the projectile beyond the summit is less than the mean velocity before the summit; therefore, the projectile travels a shorter horizontal distance. Hence, the descending branch is shorter than the ascending branch. The angle of fall is greater than the angle of elevation. Also, since the mean vertical velocity is less beyond the summit than before it, the time of descent is greater than the time of ascent.

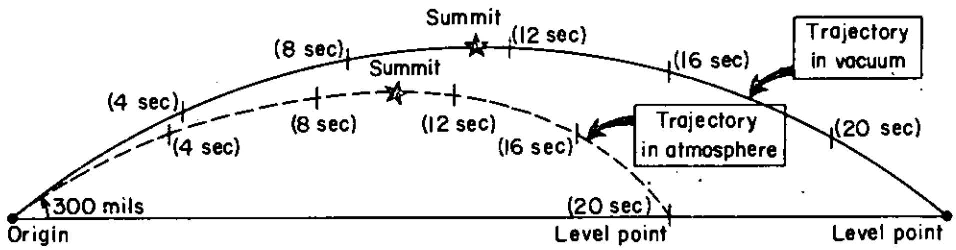
c. The spin (rotational motion) initially imparted to the projectile causes it to respond differently because of air resistance.

A trajectory in standard atmosphere, as opposed to one in a vacuum, will be at a shorter range and at a lower height after any specific time of flight.

This is because——

(1) Horizontal velocity is no longer a constant but decelerates with each succeeding time interval.

(2) Vertical velocity is affected not only by gravity but also by the additional slowing down from the atmosphere.



Note.

(1) The summit in a vacuum is midway between the origin and the level point; in the atmosphere, it is nearer the level point.

(2) The angle of fall, in a vacuum, is equal to the angle of elevation; in the atmosphere, it is greater.

Figure 217. Trajectory in standard atmosphere.

Section III. RELATION OF AIR RESISTANCE AND PROJECTILE EFFICIENCY TO STANDARD RANGE

598. General

This section pertains only to those factors which establish the standard range and elevation relations.

a. The standard range is the range opposite a given elevation in the firing tables—it is regarded as measured along the surface of a sphere concentric with the earth and passing through the muzzle of a weapon. For practical purposes, standard range is the horizontal range from origin to level point.

b. The attained range is the range which is actually developed as a result of firing with a certain elevation of the tube. If actual firing conditions duplicate the ballistic properties and meteorological conditions on which the firing table is based, the attained range and standard range will be equal.

c. The corrected range is that range which corresponds to the elevation that must be fired to reach the target.

599. Drag

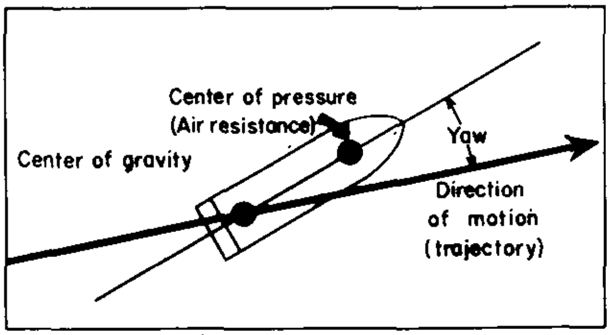
Air resistance affects the flight of the projectile both in range and direction. The component of air resistance in the direction opposite to that of the forward motion of the projectile is called drag. Because of drag, both the horizontal and vertical components of velocity are less at any given time of flight than they would be if drag were zero, as in a vacuum. This decrease in velocity varies directly in magnitude with drag and inversely with the mass of the projectile. This means, in terms of attained range, the greater the drag, the shorter the range; and the heavier the projectile, the longer the range—all other factors being equal. Several factors considered in the computation of drag are—

a. Air Density. The drag of a given projectile is proportional to the density of the air through which it passes. For example, an increase in air density by a given percentage increases the drag by the same percentage. Since the actual air density at a particular place, time, and altitude varies widely, the standard trajectories reflected in the firing tables are computed with a fixed relation between density and altitude. The standard density assumed for sea level is 0.07513 pound per cubic foot.

b. Velocity. The faster a projectile moves, the more the air resists its motion. Examination of a set of firing tables shows that for a constant elevation, the effect of 1 percent air density (hence 1 percent drag) increases with an increase of charge; that is, muzzle velocity. The drag is approximately proportional to the square of the velocity except in the vicinity of the velocity of sound. There the drag increases more rapidly on account of the increase in pressure behind the sound wave.

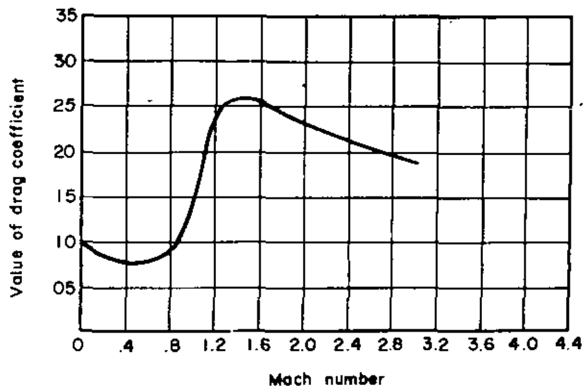
c. Diameter. Two projectiles of identical shape but different size will not experience the same drag. For example, a large projectile will offer a large area for the air to act upon; hence its drag will be increased by this factor. The drag of projectiles of the same shape is assumed to be proportional to the square of the diameter.

d. Drag Coefficient. The drag coefficient combines several ballistic properties of typical projectiles. These properties include yaw (the angle between the direction of motion of the projectile and the axis of the projectile, fig. 218) and the ratio of the velocity of the projectile to the speed of sound (fig. 219). Drag coefficients which have been computed for many typical projectile types greatly simplify the work of ballisticians. When a projectile varies slightly in shape from one of these typical projectile types, its approximate drag coefficient can be found by computing a form factor and by multiplying the drag coefficient of the typical projectile type by this single *form factor.* This computation is done by ballisticians.



(Air resistance is least when center of pressure is on the trajectory; that is, zero yaw)

Figure 218. Yaw of projectile in flight.



1. Mach number = $\frac{\text{velocity of projectile}}{\text{speed of sound}}$
2. The speed of sound is faster in warmer air; hence an increase (decrease) in air temperature decreases (increases) the mach number.
3. A change in the mach number can change the value of the drag coefficient either upward or downward, depending on the mach number at which the change occurs.
4. An increase (decrease) in the value of the drag coefficient decreases (increases) the developed range.

Figure 219. Effect of velocity (mach number) on drag coefficient of projectile type I.

600. Ballistic Coefficient

a. The ballistic coefficient of a projectile is a measure of its relative efficiency in overcoming air resistance as compared with the efficiency of the typical projectile to which it is most nearly related. An increase in the ballistic coefficient reduces the effect of drag and consequently increases the range. The reverse is true for a decrease in ballistic coefficient. The ballistic coefficient can be increased by increasing the ratio of the weight of the projectile to the square of its diameter. It can also be increased by improving the shape of the projectile.

b. Present gunnery techniques recognize the importance of precise muzzle velocity data and that corrections must be made for nonstandard velocities. It is equally important to recognize that errors are introduced in firing projectiles of nonstandard ballistic coefficients. In the past, the effect of nonstandard ballistic coefficients has been treated as a velocity error. However it is not, in fact, a velocity error.

Section IV. FIRING TABLES

601. General

a. Firing tables are based on actual firings of the weapon and its ammunition under, or correlated to, a set of conditions accepted as standard. These standards are points of departure used to compensate for variables in the weapon-weather-ammunition combination that are known to exist at a given instant and location. There is no standard wind, density, or temperature in the atmosphere itself. The atmospheric standards accepted in U. S. firing tables reflect the mean annual condition of a country, like France, situated in the North Temperate Zone. Since firing tables are based on assumed standards, they are most accurate for conditions near these standards; large variations from standard or combinations of large variations may cause errors or inaccuracies.

b. The main purpose of a firing table is to provide the data required to bring effective fire on a target under any set of conditions. To obtain data for firing tables, firings are conducted with the weapon at various quadrant elevations. Computed trajectories, based on the equations of motion, are compared with the data obtained in the firings. The computed trajectories must then be adjusted to what actually occurred and the data tabulated. Data for elevations not fired are found by interpolation. This final data appears in the firing tables as range and elevation. It is the most exact of all data in the firing tables. However, it should be clearly understood that it defines the performance of a projectile of known properties under conditions of standard muzzle velocity and weather and a motionless earth.

c. The principal elements measured in such firings include angle of elevation, angle of departure (which, when compared with the former, gives the vertical jump), muzzle velocity, attained range, drift, and concurrent atmospheric conditions.

602. Differential Effects or Corrections

a. In firing tables similar to FT 105–H–4 and FT 8–J–2, differentials are described as *Range effect of an increase of . . .*, followed by the appropriate unit value in yards. It is assumed that the range effect of a similar decrease is identical but with the sign changed. Also, it is assumed that the only nonstandard condition in existence is the one in question. Actually, the range effects for increasing and decreasing variations from standard are not equal in magnitude; the assumption that they are equal is a compromise of accuracy for simplicity and reduced bulk of the firing table, which results in one type of *second-order error.* (A second-order error may be defined in the broad sense as any error in computed firing data which stems from not actually solving the equations of motion for a specific trajectory and the existing conditions. Firing tables afford a simple and rapid *approximation* of this absolute solution.) For example, in arriving at the value listed in the firing table under an increase of 1 f/s in muzzle velocity, the following procedures are followed:

(1) At a selected range, the true effect of both plus and minus 50 f/s per second are computed.

(2) The two values are then averaged and the result divided by 50 to reduce it to a unit effect at the selected range.

A similar procedure is followed for wind (at ±50 MPH), temperature (at 0° and 118°, compared with 59° as standard), and density (at 90 percent and 110 percent of standard). Hence, the values listed are not precise for either the increasing or decreasing variation; nor are they true unit effects because the large variations used as a basis for computations are not exactly linear in nature; that is, the effect of 1 f/s is not exactly 1/50 of 50 f/s. However, use of the large variations initially makes the tables more accurate over a wider range of variables. The error introduced by using a common absolute value for increasing and decreasing variations is considerably larger and has resulted in a requirement for a general revision of field artillery firing tables which will incorporate separate tables for the increasing and decreasing variations.

b. As stated in *a* above, each effect is computed on the assumption that all other conditions are standard. Actually, any given effect will differ slightly from that computed if one or more of the other conditions are nonstandard. The amount of difference depends on the effect of the other nonstandard conditions. The effect of one nonstandard condition on the effect of another nonstandard condition is known as an *interaction effect.* It is another specific type of second-order error which results from simplified firing tables. The error introduced by interaction can be reduced by using an electronic or mechanical computer. Graphical met equipment can be designed for use in a locality where certain combinations of extreme nonstandard conditions are known to prevail for an extended period of time. For example, low air temperature and low muzzle velocity often occur together.

c. In firing tables similar to FT 280–B–1, differentials are described in separate tables. Those tables are *Correction in Mils for an Increase of . . . .* and *Correction in Mils for a Decrease of . . . .* This type of firing table represents the most accurate table produced for the field artillery. Also, the format used in the tables permits computing corrections to time of flight as separate and distinct from corrections to elevation, since the two do not follow in the same ratio. The format also permits entries into the tables in terms of both range and height factors which more accurately describe the trajectory being considered than range alone. This discussion, however, is mainly concerned with the significance of the unit corrections to elevation. For example, in arriving at the values listed under an increase of 1 f/s in muzzle velocity, the following procedures are used for a specific height above gun:

(1) At a given range (R) and elevation ($\emptyset$), the expected range (R_1) for the single nonstandard condition of +50 f/s is computed.

(2) The elevation ($\emptyset_1$) for this expected range is subtracted from the original elevation ($\emptyset$) to arrive at the *total elevation correction* at R_1 and the appropriate height above guns.

Example (FT 280–B–1, charge 4, height above guns 0):

The effects at 23,868 yards for +50 f/s have been computed to be +632 yards. The expected range for the single nonstandard condition of +50 f/s when the standard elevation for 23,868 yards is fired is 24,500 yards.

Elevation for 23,868 yards______=	386.8 mils
Elevation for 24,500 yards______=	406.7 mils
Difference______________=	−19.9 mils

This means that in order to hit a target at a range of 24,500 yards with the single nonstandard condition of +50 f/s, a *correction* of −19.9 mils must be applied to the standard elevation for 24,500 (elevation 406.7). Dividing the −19.9 mils by 50 f/s results in a unit correction in mils at range 24,500 yards of −.398 mils ($-19.9 \div 50 = -.398$). The unit corrections displayed in the firing tables are for convenient increments of range.

d. Effects and corrections, whether in yards or mils, are not of equal magnitude at the same range. This problem does not arise in dealing directly in terms of corrections as in the FT 280–B–1. However, in firing tables similar to FT 105–H–4, the transition from effects to corrections requires a specific procedure, since computations are in terms of effects initially. The standard elevation for which computations are made must be matched to the expected range that elevation will attain. The relationship between effects and corrections at a given range can be expressed as follows:

$$\text{Corrections} = -\frac{\text{standard range}}{(\text{standard range} + \text{effects})} \times \text{effects}$$

$$\text{Corrected range} = \frac{\text{standard range}}{(\text{standard range} + \text{effects})} \times \text{standard range}$$

For example, it is desired to produce corrected firing data for a target at range 10,000 yards (charge 7, FT 105–H–4). The total effects of nonstandard conditions are computed to be −1,000 yards. This means that the standard elevation for range 10,000 (elevation 439.8) will attain only 9,000 yards. This should be reflected in a GFT setting of charge 7, range 9,000, elevation 440. In order to attain a range of 10,000 yards, it is necessary to fire elevation 537.6, which corresponds to a range of 11,110 yards. Hence, whereas the total effects computed at 10,000 yards are −1,000 yards, the total corrections to attain 10,000 yards are +1,110 yards. This can be computed as follows:

$$\text{Correction} = -\frac{10{,}000}{10{,}000 + (-1{,}000)} \times (-1{,}000) = -\frac{10{,}000}{9{,}000} \times (-1{,}000) = +1{,}110$$

or

$$\text{Corrected range} = \frac{10{,}000}{10{,}000 + (-1{,}000)} \times 10{,}000 = \frac{10{,}000}{9{,}000} \times 10{,}000 = 11{,}110$$

e. Firing tables of the 280-mm gun format are a great improvement over previous types. However, the expression of unit corrections in *mils* may introduce another error, in addition to the interaction effects previously described, in computing data for smaller caliber weapons. The error occurs because of the constantly changing value of the amount of range change caused by a 1-mil change in elevation. This factor changes more rapidly for projectiles of lower ballistic coefficient. When corrections are expressed in yards, the corrected range is actually computed. The corresponding elevation can be taken directly from the firing tables. When corrections are expressed in mils, however, it is assumed that each mil of correction will result in equal increments of range change. This is not true, since each additional mil of elevation changes the trajectory slightly and the corresponding yards per mil factor. This possible source of error will be resolved before revised firing tables are published.

603. Extracting Data From Firing Tables

a. The effect of a nonstandard condition is most nearly related to the time the projectile is exposed to that condition. In the 280-mm gun firing tables, this factor is resolved by more accurately presenting the trajectory in terms of both range and height. In the present firing tables for the 105-mm howitzer, this feature can be almost duplicated by entering the tables for differential effects at the range nearest to quadrant elevation fired minus site. This procedure is particularly necessary in computing velocity errors (pars. 337–391).

b. In computing corrections to the QE to be fired, slightly more accurate data can be obtained by a second computation at the first apparent corrected elevation (range). (This procedure is called successive approximation.) However, the improvement is marginal. It is not warranted unless the corrections exceed 20 per cent of the desired range. Electronic computers have been designed to accomplish this successive approximation.

c. In revised firing tables, the line number of the met message will be expressed to the nearest tenth of a line. The weather that affects a projectile as related to the met message is described by the maximum ordinate it achieves. This maximum ordinate is most nearly defined by the QE fired. The procedure for determining the line number to the nearest tenth from the QE fired is described in chapters 19 and 28.

Section V. EFFECT OF NONSTANDARD CONDITIONS

604. General

a. Deviations from the standard conditions used in constructing a firing table, if not corrected for in computing firing data, will cause the projectile to impact or burst at some point other than the desired point. The gunnery problem is essentially in two phases. The first is to determine the desired standard range, deflection, and time of flight. The second is to determine a corrected range, deflection, and time of flight which will compensate for current nonstandard conditions.

b. Corrections for nonstandard conditions are made to improve accuracy. The accuracy of artillery fires depends on the accuracy and completeness of the data available, computational procedures used, and care in laying the pieces. Accuracy should not be confused with precision. Precision is related to tightness of the dispersion pattern without regard to its proximity to a desired point. Accuracy is related specifically to a desired point.

605. Range Effects

a. *Vertical jump* is the angle formed by the lines of elevation and departure. The shock of firing causes a momentary vertical and rotational movement of the tube prior to the ejection of the projectile. It has the effect of a small change in elevation. The effect of jump depends mainly on the eccentricity of the center of gravity of the recoiling parts with respect to the axis of the bore. In modern weapons jump is usually small. The application of jump corrections, even when listed in the firing tables, would do little to improve accuracy, since the magnitude of round-to-round variations often exceeds the small mean corrections for jump listed. For this reason, jump is not considered separately in the gunnery problem; it is a minor contributing factor to range dispersion.

b. *Droop* is the algebraic sum of barrel curvature, untrueness of the breech quadrant seats, and untrueness in assembling the tube to the breech. Its magnitude is defined as the difference between the elevation measured at the muzzle and the elevation measured on the breech quadrant seats. Firing tables are constructed based on measurements at the muzzle. For example, if droop for a certain weapon is −3 mils and an elevation of 360 is set in the normal manner, the tube elevation is only 357 mils; if it is desired to fire a true 360 mils elevation, a setting of 363 would be necessary. At present, droop is treated separately only for 280-mm gun techniques. In other weapons it is absorbed into the computed velocity error, although in reality it is an elevation error.

c. *Muzzle velocity* is the speed of the projectile at the time it is projected from the muzzle; the greater the velocity of a given projectile, the greater the attained range. The unit factor for muzzle velocity in the firing tables often becomes the catchall for many nonvelocity elements in the computation of VE's. When this occurs, accuracy is adversely affected in subsequent application.

d. Weight of projectiles affects muzzle velocity. Two opposing factors affect the flight of a projectile of nonstandard weight. A heavier projectile is more efficient in overcoming air resistance; however, because it is more difficult to push through the tube, its muzzle velocity is lower. An increase in projectile efficiency increases range, but a decrease in muzzle velocity decreases range. Firing tables combine these two opposing factors into a single effect. The change in muzzle velocity predominates at short times of flight; the change in projectile efficiency predominates at long times of flight. Hence, for a heavier than standard projectile, the effect is minus at the shorter times of flight and plus at the longer times of flight. The reverse is true for a lighter than standard projectile.

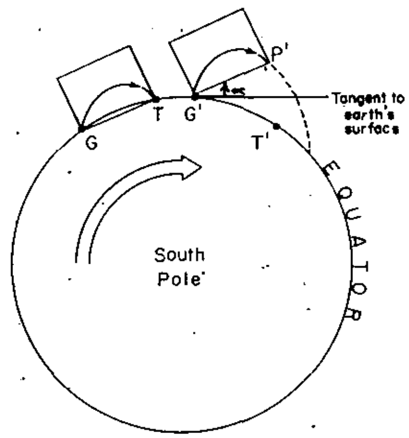
e. Range wind is that component of the ballistic wind blowing in the plane of fire. The plane of fire is a vertical plane that contains the line of elevation. In effect, it changes the relationship between the velocity of the projectile and the velocity of the air near the projectile. If the air is moving with the projectile (rear wind), it offers less resistance to the projectile and a longer range results; headwind has the opposite effect. Winds defined in met messages are weighted averages or ballistic winds.

f. The effects of nonstandard *air temperature* may appear inconsistent and puzzling at first. This is because an increase (decrease) in airtemperature increases (decreases) the velocity of sound which in turn decreases (increases) the mach number (previously defined as projectile velocity divided by the velocity of sound in air). Drag also is related to mach number; however, this relationship changes abruptly in the vicinity of mach 1 when projectile velocity equals the velocity of sound. See figure 219 for a chart of this changing relationship. Note that a decrease in mach number (increase in temperature) will at times lead to an increase in drag and at other times lead to a decrease in drag, depending on the terminal velocity at the range being considered. Temperatures reflected in the met message are average or ballistic temperatures.

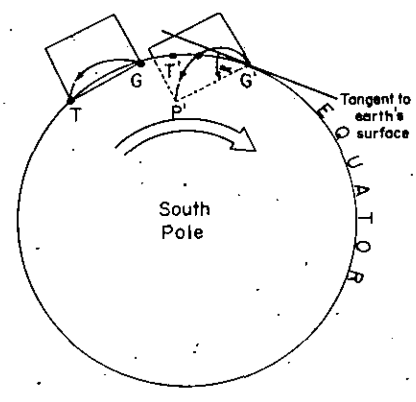
g. Air density effects have been previously discussed as directly related to the drag coefficient, with the more dense air offering greater resistance and vice versa.

h. Rotation of the earth is treated as a nonstandard condition for simplicity. It involves such factors as direction of fire, angle of departure and velocity of projectile, and relative positions of weapon and target with respect to the geographic location (longitude and latitude). These effects are combined in convenient tabular form in firing tables. These tables are all that are needed to compensate for rotation of the earth in the gunnery problem. However, some background theory to rotational effects may assist in a better understanding of ballistics in general.

(1) Owing to rotation of the earth, a point on the Equator has an eastward linear velocity of approximately 1,500 f/s. This linear velocity decreases to zero at either pole. Consider a weapon on the Equator firing due east at a target (fig. 220 ①). During the time of flight of the projectile, the weapon and target will travel from G to G′ and T to T′, respectively, along the circumference of the earth. The projectile, however, travels in a vertical plane the base of



① Rotational effects on range firing eastward



② Rotational effects on range firing westward

Figure 220. Rotational effects.

which is parallel to the original plane of departure established at the time of firing; that is, it is pivotal to the circumference of the earth at the gun but not at the target. At the end of a given time of flight, the projectile will be at P′ when the target is at T′. Hence, the projectile will continue along an extended trajectory and land farther east or, in this instance, beyond the target. Figure 220 ② depicts firing westward. The normal trajectory of the projectile is interrupted. Again, it falls to the east of the target but in this instance east is short. The effect in each example is as if the QE fired were in error by the angle α, which is the angle formed by the base line G′ P′ and a tangent to the earth at G′. Firing eastward α is plus (range over); firing westward, α is minus (range short).

(2) Suppose that a projectile is fired straight up (elevation 1,600 mils) as shown in figure 221. Both the projectile and weapon will have the same eastward velocity imparted to them owing to rotation of the earth; hence, during the time of flight, both will travel the same arc distance. The projectile will travel the mean arc PP′, which is on a circle of greater radius than that of the arc GG′ which is traveled by the weapon. The direction of gravity is always towards the center of the earth. Since the projectile is moving eastward, owing to rotation of the earth, the force of gravity acts so as to pull it back to the west; that is, opposite to the direction of rotation. The projectile appears to lag behind (west of) the weapon. This gravitational effect is at a maximum at an elevation of 90° and is always opposite to the effect described in (1) above. It eventually predominates over the preceding effect at an elevation of 60°. The former effect is at a maximum at 30° elevation. An examination of rotation effects tables, firing due east, for example, shows a plus range effect at the lowest range, gradually increasing, then decreasing, and finally changing in sign to a minus. In firing due west, all signs are reversed.

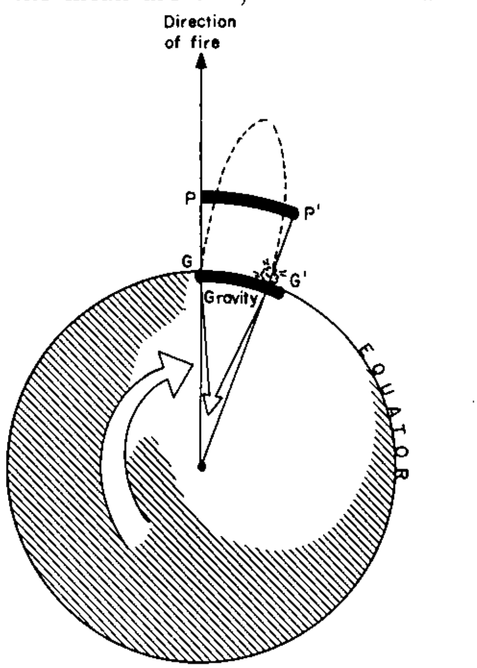


Figure 221. Projectile lag due to rotation of the earth.

(3) A third consideration is the curvature effect. Curvature effect exists because of the use of a map range which assumes the surface of the earth to be flat while the actual range is measured on a sphere. The GT range is computed for a plane tangent to the surface of the earth at the weapon. When the projectile reaches this range, it is still above the curved surface of the earth and will continue to drop, resulting in a slightly longer true range than desired. This effect is of little significance except at very long ranges. It is disregarded when using firing tables, since firing table ranges include curvature effect.

(4) A final rotational effect is described as the latitudinal effect. When the weapon and target are at different latitudes, the eastward rotational velocity imparted to the projectile and the target is different, being faster for the point nearest the Equator. For example, if the weapon is nearest the Equator (fig. 222 ①), the nearer projectile will travel faster and therefore farther to the east than the target (the effect left or right depends on the hemisphere). When the weapon and target are at the same latitude (fig. 222 ②), the projectile will also be deflected

away from the target. This is because the projectile tends to travel in the plane of the great circle containing the weapon and target at the time of firing. Owing to rotation of the earth, this great circle plane is continuously changing with respect to its original position. As viewed from above, it would appear that the great circle containing the weapon and target was turning with respect to the great circle followed by the projectile. An additional latitudinal effect is pictured in figure 222 ③. When the latitude is other than the Equator, the projectile is pulled out of its original vertical plane by the force of gravity which operates from the center of the earth and not on a perpendicular to the axis of the earth.

i. The *ballistic coefficient* of a projectile relates its efficiency to that of an assumed standard projectile in overcoming air resistance. For ease in computations all projectile types are classified into certain standard groups. Each projectile, however, has its own efficiency level. Each projectile lot has its own average efficiency level; that is, ballistic coefficient. In order to establish firing tables, it is necessary to select and fire one specific projectile lot. Based on the performance of this lot, standard ranges are determined. The ballistic coefficient of this particular projectile lot becomes the firing table standard. However, other projectile lots of this type will not have the same ballistic coefficient as the one reflected in the firing tables. If one of the other lots is more efficient, that is, has a higher ballistic coefficient than the firing table standard, it will develop more range when fired. The reverse is true for a less efficient projectile lot. Present gunnery procedures recognize variations in propellant performance as an element of muzzle velocity, which is true. However, the procedures used also unite variations in ballistic coefficient as an element of muzzle velocity, which is not true. It is difficult to produce accurate firing data for the entire zone of the weapon; the yards per foot per second factor is adapted only to muzzle velocity elements. However, a change in the ballistic coefficient would require recomputation of the entire firing table; hence, a more convenient means of expressing ballistic coefficient change must be derived if it is to be separated from muzzle velocity in a usable gunnery procedure. This means may be obtained by relating ballistic coefficient change (BCC) to percent of air density. The formula expressing retardation

$$\left(\text{retardation} = \frac{\text{drag coefficient} \times \text{velocity}^2 \times \text{air density}}{\text{ballistic coefficient}}\right)$$

can be solved in terms of ballistic coefficient

$$\left(\text{ballistic coefficient} = \frac{\text{drag coefficient} \times \text{velocity}^2 \times \text{air density}}{\text{retardation}}\right).$$

This formula relates a change in ballistic coefficient directly to an equal change in percent of air density. A change in the ballistic coefficient then is directly related to some equal change in percent of air density. For example, a more efficient projectile than standard (higher ballistic coefficient) gains range at the same rate as though it were moving through air of some decreased percent density. A less efficient projectile than standard (lower ballistic coefficient) loses range at the same rate as though it were moving through air of some increased percent density. The above formula also points out the fallacy of relating the ballistic coefficient change directly to velocity. The techniques for treating the ballistic coefficient change as an equal change in percent air density, with its adaptability to the gunnery problem, are not finalized for field use. However, the basic principle will remain unchanged. It is included as a contributing source of error.

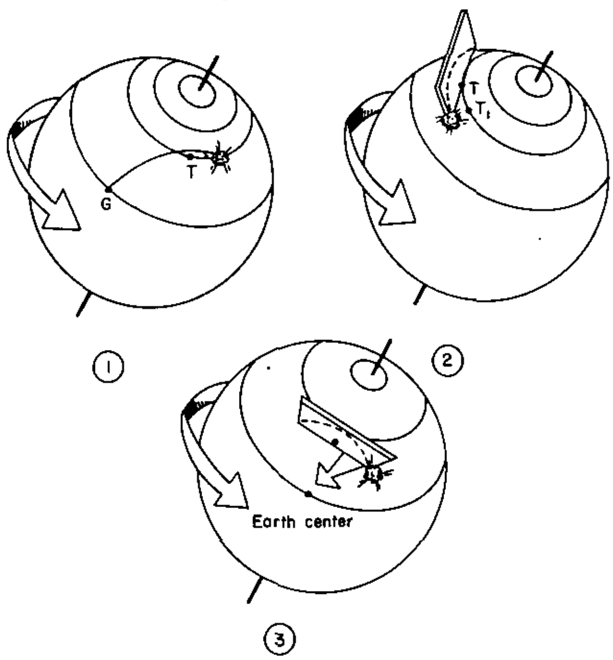


Figure 222. Latitudinal effects.

606. Deflection Effects

a. *Lateral jump* is caused by a slight lateral and rotational movement of the tube at the instant of firing. It has the effect of a small error in deflection. The effect is ignored since it is hard to determine accurately for each specific situation.

b. *Drift* is defined as the departure of the projectile from standard direction because of the combined action of air resistance, projectile spin, and gravity. In order to fully understand the forces that cause drift, it is necessary to understand the angle of yaw, which is that angle between the direction of motion of the projectile and the axis of the projectile. The direction of this angle is constantly changing in a spinning projectile—right, down, left, and up. This initial yaw is at a maximum near the muzzle and gradually subsides as the projectile stabilizes. The atmosphere offers greater resistance to a yawing projectile and it is fundamental in design principles that yaw be kept to a minimum and be quickly damped out in flight. At the summit, where the descending branch of the trajectory begins, summital yaw is introduced and the effect on the projectile is to keep the nose pointed slightly towards the direction of the spin. Therefore, since artillery shells have a clockwise spin, they drift to the right in the descending branch of the trajectory. The magnitude of drift (expressed as lateral distance on the ground) depends on the time of flight and rotational speed of the projectile and the curvature of the trajectory.

c. The *lateral wind* is that component of the ballistic wind blowing across the direction of fire. Lateral wind tends to carry the projectile with it and causes a deviation from the direction of fire. However, the lateral deviation of the projectile is not as great as the movement of the air causing it. Wind component tables simplify the reduction of a ballistic wind into its two components with respect to the direction of fire.

d. The effects on deflection from the rotation of the earth have been previously described in paragraph 605*h*(4) and figure 220.

607. Time of Flight

a. Those nonstandard conditions which affect range also affect time of flight, but tbe corrections do not follow in exactly the same ratio. To this must be added the fact that the fuze settings on current time fuzes, while approximating time of flight, are not interchangeable with time of flight.

b. In the improved firing table format of the 280-mm gun, corrections to time of flight are computed separately from corrections to elevation. This allows a more accurate solution for corrected time of flight from which the final conversion to fuze setting is made. In firing tables similar to FT 105–H–4 fuze setting is treated as a function of elevation; whereas, fuze setting is a function of time of flight.

Section VI. SUMMARY

608. General

a. The ballistic problem stems from the fact that basic (standard) firing data for the weapon-target relation presupposes certain conditions of the weapon-weather-ammunition combination and a motionless earth. The fact that these conditions do not exist concurrently with the firing of the weapon necessitates the computation of corrected data which will attain the range, height, and direction determined in solving the geometric problem.

b. Exterior ballistics deals with those conditions which affect the projectile while in flight; that is, which modify the path of the projectile.

c. A knowledge of the form of a trajectory in a vacuum is an aid in understanding the effect of the forces exerted by the atmosphere in resisting projectiles of different ballistic properties and efficiency (e. g., velocity, shape, size, and weight).

d. Firing tables are constructed by using an accepted standard atmosphere, a motionless earth, and specific ballistic properties of the ammunition. These tables are a point of departure for computing corrections to standard firing data. The computational procedures used in the field must be compatible with the presentation of data in the firing tables.

609. Firing Tables

a. The main purpose of a firing table is to provide the data required to bring effective fire on a target under any set of conditions. The most accurate firing table would be a huge compilation of data for every weapon-target relationship and every combination of conditions of the weapon, weather, and ammunition. The simplest firing table would be a straight range-elevation relationship. Firing tables, therefore, are a compromise between simplicity and accuracy.

b. Firing tables of the 280-mm gun format are more accurate than those of the 105-mm howitzer format. These improvements stem in part from—

(1) The two-dimensional approach. Data are listed for both range and height, thereby more nearly approaching the trajectory in question.

(2) Separate tables for both increasing and decreasing variations from standard.

(3) Unit values for nonstandard conditions expressed as corrections.

(4) Separate tables for corrections to elevation and time of flight.

c. In using firing tables of the 105-mm howitzer format, the most accurate data are obtained by—

(1) Entering the table for unit effects at the range corresponding to QE fired minus site in computing VE's.

(2) Employing successive approximation techniques in computing corrected range (elevation) by hand. However, this is warranted only when the first computation indicates a large correction.

(3) Matching a standard elevation with the expected range in met + VE techniques (GFT setting) or by using the formula

$$\text{corrections} = \frac{-(\text{standard range})}{(\text{standard range} + \text{effects})} \times$$

effects in hand computations.

d. More accurate solutions to the ballistic phase of the gunnery problem are being sought in the development of new firing tables, graphical computers, and electronic and mechanical computers. The graphical equipment will probably be the first available for use in the field.

610. Determination of Nonstandard Conditions

a. Firing tables define standard conditions of the weapon-weather-ammunition combination. In computing corrected data, the unit in the field depends on measurements made at the battery and the data in the met message. Also, the unit depends on past experience of the weapon-ammunition combination as expressed in the *old VE.* The data from these sources make up the unit's knowledge of existing nonstandard conditions.

b. Data from met messages can be improved by—

(1) Line interpolation to the nearest tenth from the QE under certain conditions (par. 362).

(2) Time interpolation of met messages when VE's are being computed.

c. The VE is highly susceptible to error in that it often contains nonvelocity elements. The unit factor in the firing tables for velocity applies only to muzzle velocity variations. When a nonvelocity element is related to it, errors in application result. Muzzle velocity measured by a chronograph is the only true expression of this nonstandard condition. Such measurement is not subject to errors in survey and met data or the limitations of firing tables. Nor is it subject to tube droop or the effect of a projectile which is either more or less efficient in overcoming air resistance than the one used in constructing the firing table. These latter two elements can be isolated.

(1) Tube droop can be measured and treated as an error in elevation.

(2) The ballistic coefficient of the nonstandard projectile can be determined and treated as an equal change in the air density structure.

d. With respect to the other elements, *survey* can be checked, errors in *met data* tend to average out, and improved techniques and equipment will reduce the limitations of present *firing tables.*

CHAPTER 27
PROBABILITY AND DISPERSION

Section I. GENERAL

611. Introduction

a. Two of the prime requisites of artillery are accuracy and precision; that is, the ability to place fire on the designated target.

b. The term *accuracy* refers to the proximity of the center of impact to a given point. To achieve accuracy, the geometric arrangement of weapon and target and the existing conditions of the weapon-weather-ammunition combination must be known. Also, the means to translate this knowledge into accurate firing data and the means to lay the weapon accordingly must be available. The term accuracy can be used with respect to 1 round or several rounds from 1 weapon or several weapons.

c. The term *precision* refers to the proximity of the bursts of two or more rounds to one another when fired from the same weapon with the same settings in as short a time interval as possible. Actually, two or more rounds fired as indicated will seldom, if ever, burst at exactly the same point. For that to occur, absolute uniformity of propellants, projectiles, weapons, performance of personnel, and atmosphere from round to round is required.

d. Precision is concerned only with the grouping of the bursts of individual rounds about the mean location (e. g., center of impact) of the bursts of all rounds fired in the same series; whereas, accuracy is concerned with the location of center of impact itself or of the location of the burst of an individual round with respect *to a target*.

e. Precision is the reciprocal of dispersion; that is, those factors which prevent precision cause dispersion. Dispersion results even though every precaution is taken to assure round-to-round uniformity. Since most artillery targets cover a somewhat indefinite area rather than a precise point, dispersion is in many respects an aid; e. g., it improves distribution of fire on the target area. Dispersion must be understood to understand the capabilities and limitations inherent in artillery fires.

612. Employment of Concepts

Applying probability to real problems has been simplified by the preparation of tables, charts, nomographs, and the like. These permit a simple solution to otherwise difficult problems.

Section II. DISPERSION

613. Types of Dispersion

The term dispersion, in respect to artillery fire, refers specifically to the pattern of bursts attained by a single weapon when every effort is made to fire all rounds under like conditions. However, the term, in lethality studies, is sometimes used to describe the burst pattern of the rounds from several weapons firing as a unit. The term should not be used to describe missed distances from a desired target. Although dispersion is a contributing factor to accuracy, there are also many other factors to consider. For convenience, three separate types of dispersion to be considered are—

a. Dispersion in range—that which occurs along the line of fire.

b. Dispersion in deflection—that which occurs perpendicular to the line of fire.

c. Dispersion in height of air bursts—that vertical dispersion above (below) the horizontal plane passing through the origin and the level point.

614. Causes of Range Dispersion

a. In experimental firing, such as for constructing firing tables, great care is taken to assure round-to-round uniformity in laying, ammunition, loading, etc. The range dispersion which results is due to minor changes from round to round in the following elements:

(1) Muzzle velocity.
(2) Jump.
(3) Initial yaw.
(4) Projectile efficiency.
(5) Meteorological conditions.

b. The causes in *a* above arise in turn from assorted other causes. For example, meteorological condition is a broad term covering range wind, air density, and air temperature. The other elements can be broken down in a like manner into component causes; however, the precise amount each cause contributes to dispersion is not known. The combined effects of the causes result in dispersion patterns which can be reproduced in later firings conducted in a like manner. Firings conducted under field conditions result in patterns of similar shape. However, the dispersion will be somewhat larger than that shown in the firing tables because rigidly controlled conditions are not possible in the field. For example, impact dispersion patterns are assumed to be on a smooth horizontal plane. Irregularities in the impact area distort normal dispersion. Also, dispersion patterns on forward or reverse slopes, respectively, shorten or lengthen normal dispersion. It is mathematically possible to compute slope dispersion patterns by using angle of slope and angle of fall. However, the degree of accuracy to which the angle of slope is normally determined does not warrant such computations.

615. Causes of Deflection Dispersion

Deflection dispersion is caused mainly by lateral jump and the lateral component of wind. As with range dispersion, a small increase in deflection dispersion can be expected in field firings as compared with firing table values.

616. Causes of Height of Burst Dispersion

Height of burst dispersion is due, first, to the same factors which cause range dispersion, since there is a direct geometric correlation between range dispersion and height dispersion; and, second, to those factors causing dispersion in fuze action. Likewise, when time-fuzed rounds are being fired, dispersion along a trajectory owing to variation in fuze action has a corresponding effect on range dispersion as well as on height dispersion.

617. Statistical Interpretation of Dispersion

Dispersion may be studied by statistical techniques. If a certain number of rounds are fired from a single piece under identical conditions, the bursts will occur in a more or less irregular pattern owing to dispersion. The mean (average) point of burst (range, deflection, and height) may be determined by measuring the range, deflection, and height of *each* burst; finding the sums of these values; and dividing the sums by the number of rounds fired. If a large number of rounds are fired, the bursts form a pattern termed *normal distribution*.

Section III. USE OF DISPERSION LADDER AND PROBABILITY TABLES

618. General

The normal probability curve is used to represent magnitudes and relative frequencies of a large number of measurements.

a. Of the *numerical* values representing the observed outcome of an event, the mean value has the greatest probability. Since the magnitudes of errors are measured from the mean, then the mean value itself has a 0 error and it follows that an error of 0 has a greater probability than any other particular error (for a normal symmetric distribution).

b. Small errors occur more frequently (have a greater probability) than large errors; conversely, large errors seldom occur and have a much smaller probability.

c. Plus and minus errors of the same magnitude occur with the same frequency and so have equal probabilities.

619. Zones

The use of zones (fig. 223) facilitates a comprehension of problems involving probability. A zone extends from the limit of plus errors of a given magnitude to the limit of minus errors of the same magnitude. The length of a zone is twice the magnitude of the limiting error and the zone itself is symmetrical with respect to the

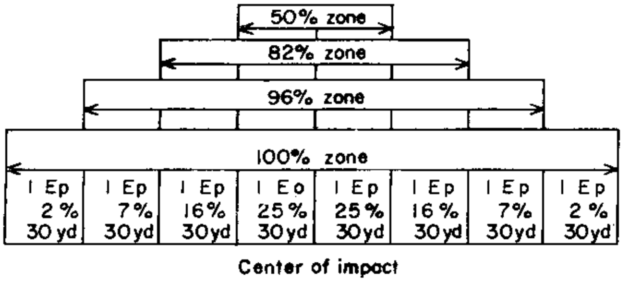


Figure 223. Probability zones and the dispersion ladder for a probable error of 30 yards.

center. Zones are designated by the probability of the occurrence of an event within that zone. For example, if in a large group of rounds the shortest round bursts −120 yards from the mean and the longest round bursts +120 yards from the mean, then the 100-percent zone is from −120 to +120 yards. Continuing the above example, if 50 percent of the rounds fell between −30 yards from the mean and +30 yards from the mean, then the 50-percent zone would be from −30 to +30 yards. The 50-percent zone is called the probable zone, since rounds will fall in it as often as they do not. The probable error is the limit of error of the 50-percent zone without regard to sign. In the above example, the probable error is 30 yards. The graduations on the dispersion ladder can be expressed in terms of probable errors (e_p) or units of measurement as shown below. (The 100-percent zone is actually nearer 99 percent, but, by convention, 8 e_p's are taken to be equal to the 100-percent zone or, in this case, 240 yards.)

620. Application of Probable Errors

a. The advantage of expressing normal distribution of bursts in terms of e_p's lies in the fact that the distribution of e_p's about the mean is the same regardless of the magnitude of the e_p itself. Firing tables list e_p's for range, deflection, and height of burst for specific weapons (and fuze type in the case of height of burst) at each interval of range. It is possible then to reduce given distances to equivalent weapon e_p's and solve problems by using a common set of probability tables or the percentile dispersion ladder.

b. For example, assume that a 105-mm howitzer and a 155-mm howitzer each have attained a center of impact range of 8,300 yards by using charge 6. What is the probability for each weapon that the next round fired will fall within ±50 yards of this center of impact?

Solution:

Weapon	*Range e_p at 8,300 (charge 6)*	*Equivalent of 50 yd in e_p's*	*Percent of rounds falling within equivalent e_p*
105-mm how---	20	50/20=2.5	2(25%+16%+3.5%)=89%
155-mm how---	25	50/25=2	2(25%+16%)=82%

89 percent of the 105-mm howitzer and 82 percent of the 155-mm howitzer rounds would be expected to fall within ±50 yards. Note that the 105-mm howitzer has 44.5-percent probability of rounds landing either within 50 yards over or within 50 yards short. Similarly, the 155-mm howitzer has a 41-percent probability. As a general rule, in computing the probability of a round landing within an error of certain magnitude, reduce the specified error to equivalent e_p's, add the successive percentages associated with this number of e_p's in 1 direction along the dispersion ladder, and multiply the sum by 2.

621. Probability Tables (Table XIII)

Once a random deviation of specified magnitude has been reduced to an equivalent number of e_p's (either range, deflection, or height of burst) at the range and for the weapon in question, the mechanics of computing probability are reduced to a routine procedure. This latter phase can be simplified by the use of probability tables.

a. The entire area under the normal probability curve is unity or 100 percent. Hence, any particular portion of the area represents a certain percentage of the events. It is the ratio of any particular portion of the area to the total area which represents a probability; that is, the probability that the event in question will occur within the interval over which the particular area stands. For example, consider that portion of the total area which stands over the interval from the mean to a distance of 1 probable error on 1 side of the mean. This is 25 percent of the total area under the curve. Hence, numbers in the body of the table are areas under the normal probability curve. The arguments are distances, expressed in *probable errors.* In the first vertical column are distances expressed in probable errors to the nearest tenth; horizontally across the top of the table is the breakdown in hundredths of probable errors. Entry into the table is similar to entry into a table of logarithms. The total area under the probability curve is taken as one. Note that the maximum area defined in the body of the table is .5000 or 50 percent or

½. Therefore, the numbers in the body of the table actually give the probability that the event in question will occur within various probable errors from the mean and on *one side only of the mean.* These tables differ from probability tables found in most firing tables in this respect. The latter depicts the probability associated with *both* sides of the mean; hence, for a given argument the probability given is twice as large in such tables. Interpolation in the tables is an unnecessary refinement. A complete set of probability tables for *one side* of the mean is shown below:

Table XIII. Normal Probability Tables, Areas of the Normal Probability Curve

[*t* is expressed in probable errors]

t	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0027	0.0054	0.0081	0.0108	0.0135	0.0162	0.0189	0.0216	0.0243
0.1	.0269	.0296	.0323	.0350	.0377	.0404	.0431	.0457	.0484	.0511
0.2	.0538	.0565	.0591	.0618	.0645	.0672	.0699	.0725	.0752	.0778
0.3	.0804	.0830	.0856	.0882	.0908	.0934	.0960	.0986	.1012	.1038
0.4	.1064	.1089	.1115	.1140	.1166	.1191	.1217	.1242	.1268	.1293
0.5	.1319	.1344	.1370	.1395	.1421	.1446	.1472	.1497	.1522	.1547
0.6	.1572	.1597	.1622	.1647	.1671	.1695	.1719	.1743	.1767	.1791
0.7	.1815	.1839	.1863	.1887	.1911	.1935	.1959	.1983	.2007	.2031
0.8	.2054	.2077	.2100	.2123	.2146	.2169	.2192	.2214	.2236	.2258
0.9	.2280	.2302	.2324	.2346	.2368	.2390	.2412	.2434	.2456	.2478
1.0	.2500	.2521	.2542	.2563	.2584	.2605	.2626	.2647	.2668	.2689
1.1	.2709	.2730	.2750	.2770	.2790	.2810	.2830	.2850	.2869	.2889
1.2	.2908	.2927	.2946	.2965	.2984	.3003	.3022	.3041	.3060	.3078
1.3	.3097	.3115	.3133	.3151	.3169	.3187	.3205	.3223	.3240	.3258
1.4	.3275	.3292	.3309	.3326	.3343	.3360	.3377	.3393	.3410	.3426
1.5	.3442	.3458	.3474	.3490	.3506	.3521	.3537	.3552	.3567	.3582
1.6	.3597	.3612	.3627	.3642	.3657	.3671	.3686	.3700	.3714	.3728
1.7	.3742	.3756	.3770	.3784	.3798	.3811	.3825	.3838	.3851	.3864
1.8	.3877	.3890	.3903	.3915	.3928	.3940	.3952	.3964	.3976	.3988
1.9	.4000	.4012	.4024	.4035	.4047	.4058	.4069	.4080	.4091	.4102
2.0	.4113	.4124	.4135	.4146	.4156	.4167	.4177	.4187	.4197	.4207
2.1	.4217	.4227	.4237	.4246	.4256	.4265	.4274	.4283	.4292	.4301
2.2	.4310	.4319	.4328	.4336	.4345	.4353	.4361	.4369	.4377	.4385
2.3	.4393	.4401	.4409	.4417	.4425	.4433	.4441	.4448	.4456	.4463
2.4	.4470	.4477	.4484	.4491	.4498	.4505	.4512	.4519	.4526	.4533
2.5	.4540	.4547	.4553	.4560	.4566	.4572	.4578	.4584	.4590	.4596
2.6	.4602	.4608	.4614	.4620	.4625	.4630	.4636	.4641	.4646	.4651
2.7	.4657	.4662	.4667	.4672	.4677	.4682	.4687	.4692	.4697	.4701
2.8	.4705	.4710	.4714	.4718	.4722	.4727	.4731	.4735	.4739	.4743
2.9	.4748	.4752	.4756	.4760	.4764	.4768	.4772	.4776	.4780	.4783
3.0	.4787	.4790	.4793	.4796	.4800	.4803	.4806	.4809	.4812	.4815
3.1	.4818	.4821	.4824	.4827	.4830	.4833	.4836	.4839	.4842	.4845
3.2	.4848	.4851	.4853	.4855	.4857	.4859	.4862	.4864	.4866	.4868
3.3	.4870	.4873	.4875	.4877	.4879	.4881	.4883	.4885	.4886	.4888
3.4	.4890	.4892	.4893	.4895	.4897	.4899	.4901	.4902	.4904	.4906
3.5	.4908	.4909	.4911	.4913	.4915	.4916	.4917	.4919	.4921	.4922
3.6	.4923	.4924	.4926	.4927	.4928	.4929	.4931	.4933	.4934	.4935
3.7	.4936	.4938	.4939	.4940	.4941	.4942	.4944	.4945	.4946	.4947
3.8	.4948	.4949	.4950	.4951	.4952	.4953	.4953	.4954	.4955	.4956
3.9	.4957	.4958	.4959	.4960	.4960	.4961	.4962	.4963	.4964	.4965
4.0	.4965	.4966	.4967	.4967	.4968	.4969	.4969	.4970	.4971	.4972
4.1	.4972	.4973	.4973	.4974	.4974	.4975	.4975	.4976	.4976	.4977
4.2	.4978	.4978	.4979	.4979	.4980	.4980	.4980	.4981	.4981	.4981
4.3	.4982	.4982	.4982	.4983	.4983	.4983	.4983	.4984	.4984	.4985
4.4	.4985	.4985	.4986	.4986	.4986	.4987	.4987	.4987	.4988	.4988
4.5	.4988	.4989	.4989	.4989	.4989	.4990	.4990	.4990	.4990	.4991
4.6	.4991	.4991	.4991	.4991	.4992	.4992	.4992	.4992	.4992	.4992
4.7	.4993	.4993	.4993	.4993	.4993	.4993	.4994	.4994	.4994	.4994
4.8	.4994	.4994	.4994	.4995	.4995	.4995	.4995	.4995	.4995	.4995

Table XIII. Normal Probability Tables, Areas of the Normal Probability Curve—Continued

[*t* is expressed in probable errors]

t	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
4.9	0.4995	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996
5.0	.4996	.4996	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4997
5.1	.4997	.4997	.4997	.4997	.4998	.4998	.4998	.4998	.4998	.4998
5.2	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998
5.3	.4998	.4998	.4998	.4998	.4998	.4998	.4999	.4999	.4999	.4999
5.4	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
5.5	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
5.6	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
5.7	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
5.8	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000
5.9	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000

b. The example in paragraph 620*b* can be solved by use of the probability tables as follows:

Weapon	*Equivalent e_p's*	*From table*	*Probability*
105-mm how	2.5	.4540×2	90.80%
155-mm how	2.0	.4113×2	82.26%

These answers differ slightly from those obtained by using the dispersion ladder. This is because probability tables are to an accuracy of 4 decimal places in hundredths of probable errors whereas the dispersion ladder is to an accuracy of only 2 decimal places in whole probable errors. Probability tables provide the more accurate answer.

c. In some problems, the probability is required for only 1 side of the mean in which case the multiplication by 2 is omitted. (If firing table probability tables were used, division by 2 would be required.) For example, to determine the probability that a burst will be closer to the ground than 100 yards when the mean height is 350 yards above the ground and the height probable error (e_{ph}) is 75 yards, the following procedure is used:

Specified error (yards)=350−100=250 (that is, 250 yards below the mean is 100 yards above the ground)

Error in e_{ph}=250/75=3.33

From probability table XIII, 3.33 corresponds to .4877 which is the probability that the burst will be between the mean and 100 yards above the ground. Since the total probability for a burst being below the mean is .5000, then the probability of a burst being less than 100 yards above the ground, that is, more than 250 yards below the mean, is: .5000−.4877=.0123=1.23%

By extension, the probability that the burst will occur at either less than 100 yards above the ground (250 below the mean) or more than 600 yards above the ground (250 above mean) is 1.23%+1.23%=2.46% (equivalent to 2.46 chances in 100). Any combination of limiting heights above ground can be similarly solved. The maximum and minimum limits specified need not reduce to the same error from the mean as in the foregoing example. Each is solved independently and the probabilities are added.

d. It is emphasized that the probibility table gives the probability of *not* exceeding a certain error; it does not give the probability of making a certain error.

622. The Dispersion Rectangle

a. If the range and direction dispersion ladders are superimposed the result is a dispersion rectangle. Figure 224 is such a dispersion rectangle in which each small rectangle is bounded by 1 probable error in range and 1 probable error in deflection.

b. The percentage number inside each small rectangle in figure 224 lists the probability of one round landing in that rectangle. This number is obtained by multiplying the range probability by the deflection probability applicable to that rectangle. For example, consider one of the rectangles that is assigned a value of 1.12%; .16×.07=.0112 or 1.12%.

c. Note again the use of the convention that 8 probable errors equal the 100-percent zone. Actually, the probability of a round landing in an area bounded by 8 range probable errors and 8 deflection probable errors is 98.6049 percent from the probability tables (2(.4965)×2(.4965)=(.993)(.993)=.986049).

2%	.04	.14	.32	.50	.50	.32	.14	.04
7%	.14	0.49	1.12	1.75	1.75	1.12	0.49	.14
16%	.32	1.12	2.56	4.00	4.00	2.56	1.12	.32
25%	.50	1.75	4.00	6.25	6.25	4.00	1.75	.50
25%	.50	1.75	4.00	6.25	6.25	4.00	1.75	.50
16%	.32	1.12	2.56	4.00	4.00	2.56	1.12	.32
7%	.14	0.49	1.12	1.75	1.75	1.12	0.49	.14
2%	.04	.14	.32	.50	.50	.32	.14	.04
	2%	7%	16%	25%	25%	16%	7%	2%

Direction of fire

Figure 224. Dispersion rectangle.

623. Most Probable Position of Center of Impact

So far only the probability of an outcome of a future event has been considered. This is not always the problem, however. For example, the observer's sensings in the fire for effect phase of a precision registration are the *outcome* of the rounds fired, but they do not in themselves define the relative locations of center of impact and target which yielded these sensings. The problem is to find the *most probable relative location*.

a. There are simple methods of determining the most probable location of the target with respect to the center of impact. These methods are based on, first, the fact that positive range sensings used are of two outcomes only—either over or short; and, second, the assumption that the small number of rounds observed follows normal distribution exactly.

b. For example, if 5 shorts and 1 over are obtained, then $5/6$ or 83.33 percent of the rounds fell short of the target, and, by using the dispersion ladder, the target must be 1.52 probable errors beyond the center of impact $(50\%+25\%+8.33\%=83.33\%$ and this computes to $1\ e_p+\frac{8.33}{16}$ e_p or $1.52\ e_p$ beyond the center of impact). Note that 33.33 percent of the rounds fell between the center of impact and the target. By using the probability tables, we find .3333 as representing 1.43 probable errors, to the nearest hundredth, which is a more accurate estimate of the distance of the target from the center of impact. Use of the preponderance rule described in chapter 18 indicates the target to be 1.33 probable errors beyond the center of impact: $\frac{(5-1)\text{ fork}}{2\times 6}=\frac{1}{3}\text{ fork}=$ $1.33\ e_p$. Probability tables provide the most accurate answer.

Section IV. SINGLE SHOT HIT PROBABILITY AND ASSURANCE

624. Single Shot Hit Probability

The single shot hit probability (SSHP) is the probability of hitting a target or area of finite dimensions with any one round.

a. The probability of a round hitting in any one of the areas bounded by $1\ e_{pr}$ and $1\ e_{pd}$ is the product of the probability of attaining that range error and the probability of attaining that deflection error. This basic principle is applied in computing the SSHP. To use the probability tables, the specified error must be reduced to equivalent probable errors.

b. Computation of SSHP is based on the assumption that the center of impact is at the exact center of the target or area. This means, for example, that if the target is 40 yards long, the limit of error is 20 yards (fig. 225). The same principle holds true for deflection. Therefore, in order to reduce target dimensions to equivalent probable errors, it is first necessary to determine the limit of error for range (i. e., one-half that target dimension parallel to the GT line) and for deflection (i. e., one-half that target dimension perpendicular to the GT line). Then, the limits

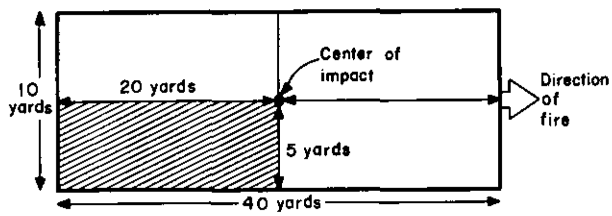


Figure 225. Single shot hit probability.

of error are divided by the respective firing table probable errors for the weapon, charge, and range being used. This quotient (t) is the argument for entering the probability tables to determine the the range probability and the deflection probability. The product of these 2 probabilities gives the probability of hitting a specific quarter of the 4 quarters of the target as shown by the shaded area in figure 225. Since a hit in any 1 of the 4 quarters constitutes success, the probability of getting a hit in any quarter must be multiplied by 4.

c. For example, the target is a bridge 10 yards by 40 yards with the long axis parallel to the direction of fire. Range to target is 15,000 yards.

By assuming that the center of impact is correctly located at the center of the target in each instance, computation of SSHP is as follows:

(1) *8-inch howitzer*, charge 7, range 15,000.

From firing table: $e_{pr}=13$ yd; $e_{pd}=4$ yd

Range $t=\frac{\frac{1}{2}(40)}{13}=\frac{20}{13}=1.54$

Deflection $t=\frac{\frac{1}{2}(10)}{4}=\frac{5}{4}=1.25$

From probability tables: $t(1.54)=.3506$; $t(1.25)=.3003$

SSHP$=4(.3506)(.3003)=.4211=42.11\%$

(2) *155-mm gun*, normal charge, range 15,000.

From firing table: $e_{pr}=43$ yd; $e_{pd}=5$ yd

Range $t=\frac{\frac{1}{2}(40)}{43}=\frac{20}{43}=.47$

Deflection $t=\frac{\frac{1}{2}(10)}{5}=\frac{5}{5}=1.00$

From probability tables: $t(.47)=.1242$; $t(1.00)=.2500$

SSHP$=4(.1242)(.2500)=.1242$ or 12.42%

625. SSHP for Bias Targets

a. A target is said to be biased when its specified dimensions are not parallel or at right angles to the direction of fire. The only change in procedure required is that the specified length and width of the target must first be converted to an effective length and width which fits the dispersion pattern with respect to the GT line. Once the effective length and width are known, the computation of SSHP proceeds as in paragraph 624. Figure 226 illustrates a bias target.

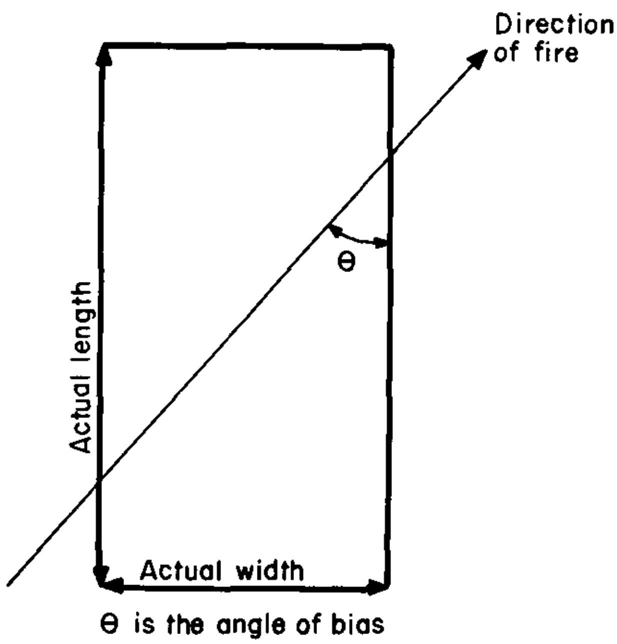


Figure 226. Bias target.

b. The following tabulation can be used to approximate these effective dimensions. Greater accuracy is not warranted in view of the approximate dimensions of the target itself and the approximation of the angle of bias. The angle of bias is the smallest angle measured between the long axis of the target and the direction of fire.

Angle of bias between	*Effective length*	*Effective Width*
0–400 mils	Actual length	Actual width
401–650 mils	2×actual width	.5×actual length
651–950 mils	1.41×actual width.	.71×actual length
951–1,200 mils	1.15×actual width.	.87×actual length
1,201–1,600 mils.	Actual width	Actual length

c. For example, the target is a bridge 8 yards by 40 yards with the long axis at an 800₥ angle to direction of fire. The range is 11,000 yards. By assuming that the center of impact is at the center of the target, the computation of the SSHP for an 8-inch howitzer firing charge 7 is as follows:

Effective length$=1.41$ (from table)$\times 8=11.3$ yd (11.28)

Effective width$=.71$ (from table)$\times 40=28.4$ yd

From firing table: $e_{pr}=10$ yd

Range $t=\frac{\frac{1}{2}(11.3)}{10}=\frac{11.3}{20}=.56$

Deflection $t=\frac{\frac{1}{2}(28.4)}{2}=7.1$

From probability tables: $t(.56)=.1472$; $t(7.1)=.5000$

SSHP$=4(.1472)(.5000)=.2944$ or 29.44%

626. Assurance and Assurance Graphs

The term assurance is another way of saying probability. Single shot hit probability is a specific instance of assurance wherein only one round is considered. Assurance is a broader term associated with the probability of hitting a target with any given number of rounds, assuming a constant SSHP. As used in this manual, assurance will always imply the probability of hitting a target with two or more rounds.

a. The assurance formulas for at least 1 hit, 2 hits, 3 hits, etc., may be graphed as shown in figures 227, 228, and 229. The only computation necessary is the SSHP. Once that is known, the graph provides a rapid determination of either the

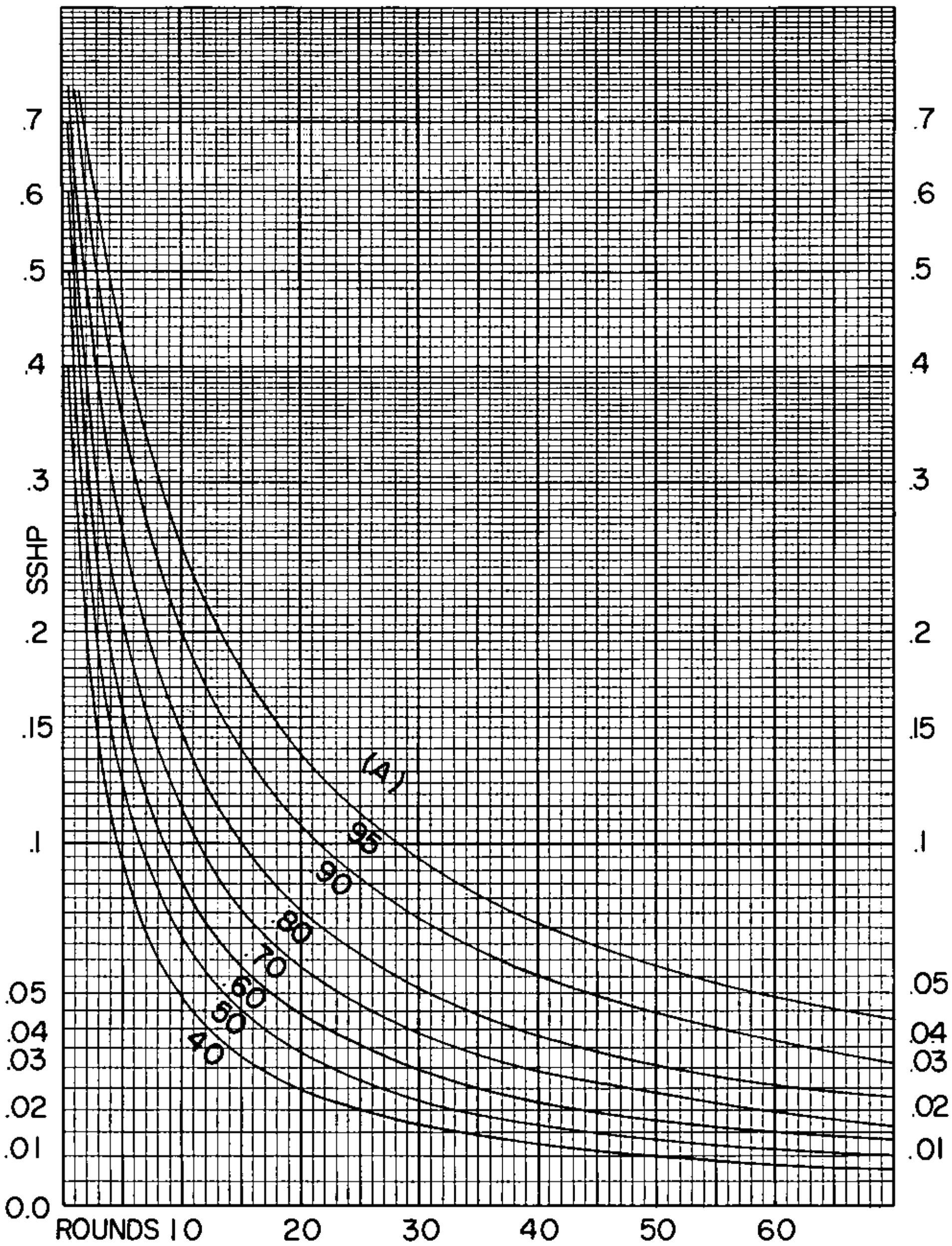


Figure 227. Assurance of at least one hit for "N" rounds when SSHP is known.

assurance obtainable from firing a specified number of rounds or the number of rounds required for a desired assurance.

b. The number of rounds is indicated along the bottom of the graph, the SSHP is indicated up the side of the graph, and the assurance is indicated by the curves drawn within the graph. To use the assurance graph, first, find the intersection of the two known elements and, then, read the desired element opposite this intersection. Interpolation between numbered graduations is permissible.

c. For example, determine the assurance of getting at least 1 hit out of 20 rounds when the SSHP is .045. (Answer: .60, fig. 227). Determine the number of rounds required for at least 2 hits when the SSHP is .08 and the desired assurance is .70. (Answer: 30 rounds, fig. 228).

d. Although it is impossible to be certain of the number of rounds needed to hit or destroy a target, use of the graphs will permit an approximation. Probability (assurance) is a substitute for fact and, until the fact is actually known, probability

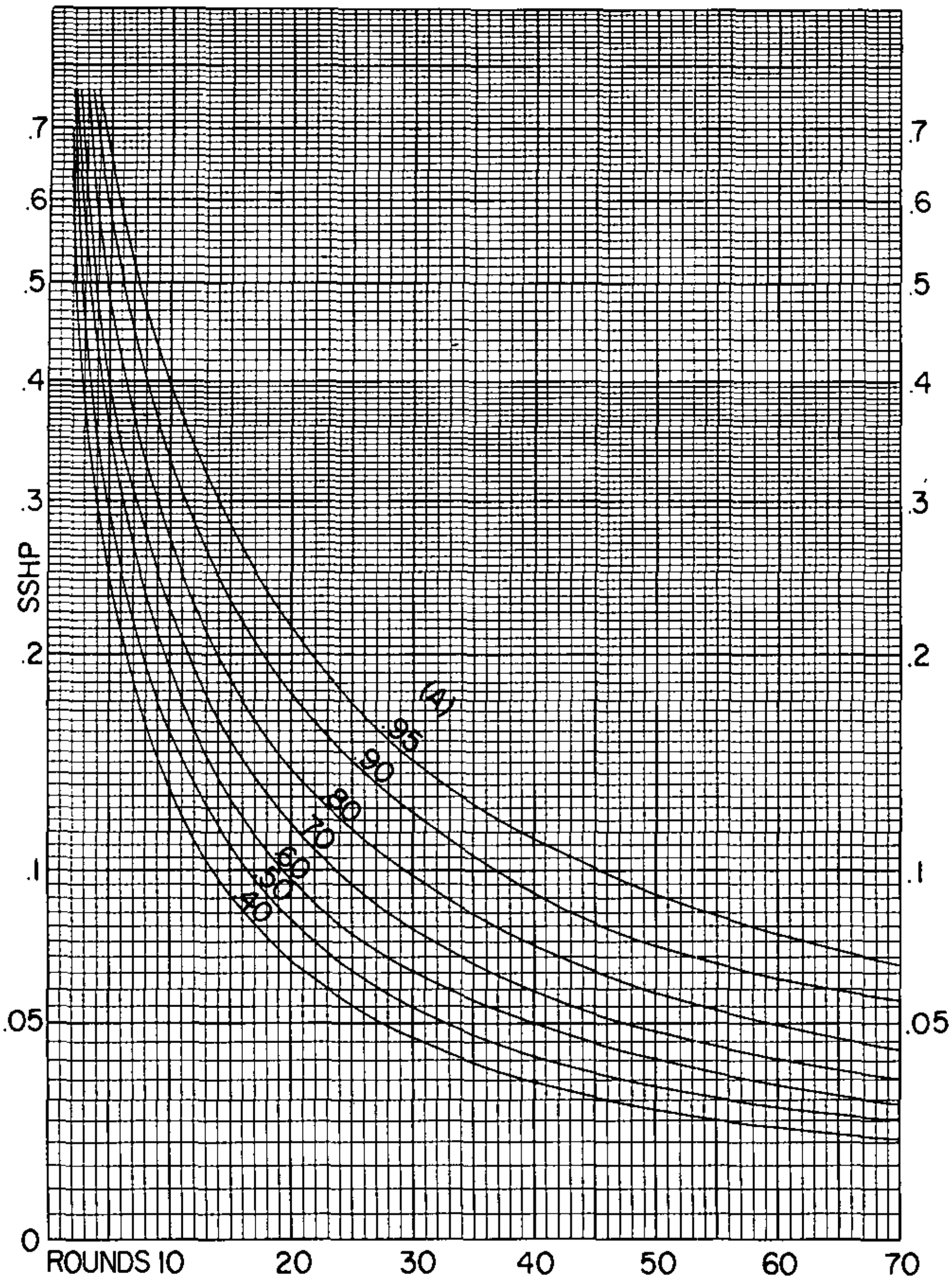


Figure 228. Assurance of at least two hits for "N" rounds when SSHP is known.

provides the best guide as to what to expect. Unfortunately, the SSHP and assurance levels are usually less than the ones derived from the method in *a* through *c* above, because the center of impact usually is not at the center of the target as assumed. For example, an apparent center of impact located by the mean of 12 rounds is more accurate than 1 located by the mean of only 6 rounds. An estimate of the probable error of the CI as a function of the number of rounds from which it was determined can be found by multiplying the firing table probable error by the appropriate factor shown below.

Number of rounds	*Factor*
2	0.71
4	.50
6	.41
8	.35
10	.32
12	.29
14	.27
16	.25
18	.24
20	.22

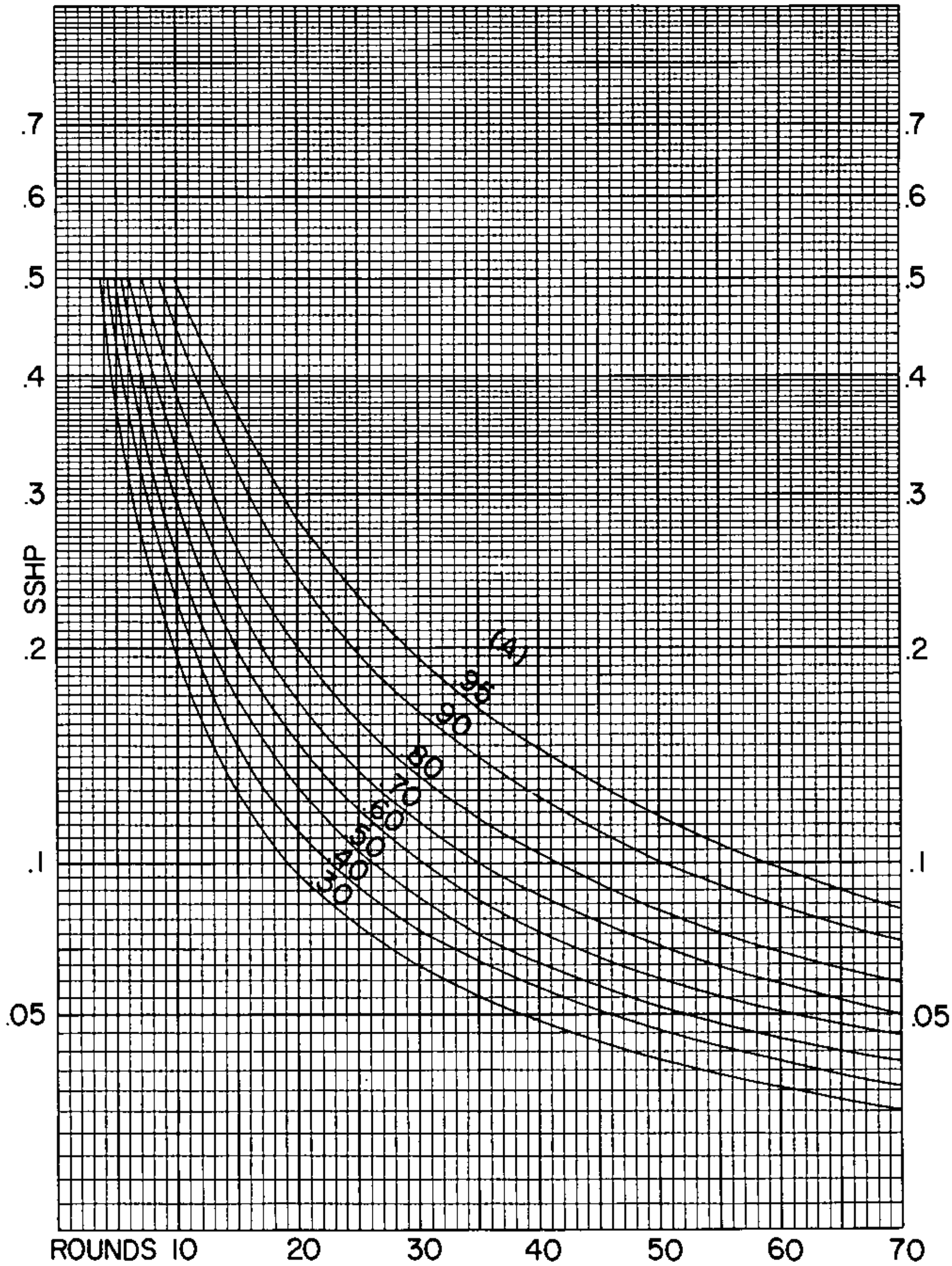


Figure 229. Assurance of at least three hits for "N" rounds when SSHP is known.

In the 155-mm gun example shown in paragraph 624*c*, if the adjusted data of the CI were based on 6 rounds, then the range probable error of the CI at that time would be 18 yards ($.41 \times 43 = 17.63$). This has the effect in SSHP computations of an apparent increase in the weapon e_p. The magnitude of the apparent weapon e_p is approximately equal to the square root of the sum of the squares of the weapon e_p and the center of impact e_p or, in this case, $\sqrt{(43)^2 + (18)^2}$, which equals 47 yards to the nearest yard. Hence, 47 yards would be used in the place of 43 yards in the computation of SSHP. The deflection e_p can be found in a similar manner although the change will normally not be significant. The method outlined above is valid for only one round in fire for effect. Thus, it is not to be used with the assurance graphs.

Section V. RADIAL (CIRCULAR) PROBABLE ERRORS AND RELATED SSHP

627. General

Some weapons (e. g., guided missiles) are characterized by a circular dispersion pattern. Also, many targets are pictured as being circular in shape, particularly if the use of atomic munitions is contemplated. (The circular concept of targets aids in damage assessment from atomic munitions because blast, thermal, and radiation effects are more or less radial in nature.) Therefore, the combination of weapons with rectangular dispersion patterns firing on circular target areas as well as on rectangular areas must be considered. Also, weapons with circular dispersion patterns firing on both rectangular and circular target areas must be considered.

628. Radial and Circular Probable Error (CPE)

a. Circular probable error and radial probable error are the same in principle. The circular probable error is defined as the radius of the circle which incloses the 50-percent zone: that is, it is the radius of the circle, center at the center of impact, within which rounds will fall as often as they do not. However, the radial probable error is defined as that radial error which is exceeded as often as it is not exceeded; hence, the circle it describes also incloses the 50-percent zone. The absolute requirements for a circular dispersion pattern in a weapon are as follows:

(1) The errors in one dimension are independent of the errors in the other dimension.

(2) The probable error in one dimension is equal to the probable error in the other dimension.

(3) The errors in each dimension are normal in distribution.

b. When the requirements in *a* above are not met, it is better to treat the weapon as having a rectangular dispersion pattern. In that case, probability is more accurately defined as two independent variables of different magnitude (range and deflection). Targets can be converted into an equivalent shape which is characteristic of the dispersion pattern of the weapon. This conversion aids in solving the probability problem and will provide a greater degree of accuracy in obtained assurance values.

629. Conversion of Target Shapes

a. There are four possible combinations of weapon dispersion patterns and target area shapes, as shown below:

Type	*Weapon dispersion pattern*	*Target area shape*
1	Rectangular	Rectangular
2	Rectangular	Circular
3	Circular	Circular
4	Circular	Rectangular

As a general rule, the target area shape is converted to the shape of the weapon dispersion pattern in computing SSHP. The underlying principle is that, as a result of the conversion, the magnitude of the original target area has not changed.

b. To convert from a rectangular shape to a circular shape, the product of the square roots of the sides of the given rectangle is multiplied by .5642 $\left(\text{the factor .5642 is } \frac{1}{\sqrt{\pi}} \text{ where } \pi=3.1416\right)$. The product is the radius of a circle which has an area equal to the original rectangle. For example, the radius of an equivalent circle for a rectangular target 300 meters by 400 meters is 195.4 meters ($.5642\sqrt{300}\sqrt{400}=195.4$ meters).

c. To convert from a circular shape to a rectangular shape, the radius of the given circle is multiplied by 1.7725 (the factor 1.7725 is $\sqrt{\pi}$ where $\pi=3.1416$). The product is the side of a square which has an area equal to the original circle. For example, the dimensions of an equivalent rectangle for a circular target of 200 meters radius are 354.5 meters by 354.5 meters ($200\times 1.7725=354.5$ meters).

630. Circular Probability Tables (Table XIV)

In paragraphs 624 through 626, the use of table XIII in computing SSHP was described. Table XIV is a similar type of probability table. It is used in computing SSHP for weapons with circular dispersion patterns. The figures in the body of the table represent volumes under the normal probability surface. Entry into the table is in terms of *r*. The quotient *r* is defined as the magnitude of the target's radius expressed as equivalent radial or circular probable errors. (*r* equals the radius of the target area divided by the circular probable error of the weapon.) The body of the table gives SSHP for *r*. No further modification

Table XIV. Probability Tables (Circular), Volumes Under Normal Circular Probability Surface

[*r* is expressed in circular probable errors]

r	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0001	0.0003	0.0006	0.0011	0.0017	0.0025	0.0034	0.0044	0.0055
0.1	.0068	.0083	.0099	.0116	.0134	.0154	.0175	0198	.0222	.0247
0.2	.0273	.0301	.0330	0360	.0391	.0424	.0458	.0493	.0529	.0566
0.3	.0604	.0644	.0685	.0727	.0770	.0814	.0859	.0905	.0952	.1000
0.4	.1050	.1100	.1151	.1203	.1256	.1310	.1365	.1420	.1476	.1533
0.5	.1591	.1650	.1709	.1769	.1830	.1892	.1954	.2017	.2080	.2144
0.6	.2208	.2273	.2339	.2405	.2472	.2539	.2606	.2674	.2742	.2810
0.7	.2879	.2949	.3019	.3089	.3159	.3229	.3299	.3370	.3441	.3512
0.8	.3583	.3654	.3726	.3797	.3869	.3940	.4011	.4082	.4154	.4225
0.9	.4296	.4367	.4438	.4509	.4580	.4651	.4721	.4791	.4861	.4931
1.0	.5000	.5069	.5138	.5207	.5275	.5343	.5411	.5478	.5545	.5611
1.1	.5677	.5743	.5808	.5873	.5938	.6002	.6065	.6128	.6191	.6253
1.2	.6314	.6375	.6436	.6496	.6555	.6614	.6673	.6731	.6788	.6845
1.3	.6901	.6956	.7011	.7066	.7120	.7173	.7225	.7277	.7329	.7380
1.4	.7430	.7479	.7528	.7576	.7624	7671	.7718	.7764	.7809	.7854
1.5	.7898	.7941	.7984	.8026	.8068	.8109	.8149	.8189	.8228	.8266
1.6	.8304	.8341	.8378	.8414	.8449	.8484	.8519	.8553	.8586	.8619
1.7	.8651	.8682	.8713	.8744	.8774	.8803	.8832	.8860	.8888	.8915
1.8	.8942	.8968	.8993	.9018	.9043	.9067	.9091	.9114	.9137	.9159
1.9	.9181	.9202	.9223	.9244	.9264	.9284	.9303	.9322	.9340	.9358
2.0	.9375	.9392	.9409	.9425	.9441	.9457	.9472	.9487	.9502	.9516
2.1	.9530	.9543	.9556	.9569	.9582	.9594	.9606	.9618	.9629	.9640
2.2	.9651	.9662	.9672	.9682	.9692	.9701	.9710	.9719	.9728	.9737
2.3	.9745	.9753	.9761	.9769	.9776	.9783	.9790	.9797	.9804	.9810
2.4	.9816	.9822	.9828	.9834	.9839	.9844	.9849	.9854	.9859	.9864
2.5	.9869	.9874	.9878	.9882	.9886	.9890	.9894	.9898	.9902	.9905
2.6	.9908	.9911	.9914	.9917	.9920	.9923	.9926	.9929	.9932	.9935
2.7	.9937	.9939	.9941	.9943	.9945	.9947	.9949	.9951	.9953	.9954
2.8	.9956	.9958	.9960	.9961	.9963	.9964	.9966	.9967	.9968	.9969
2.9	.9971	.9972	.9973	.9974	.9975	.9976	.9977	.9978	.9979	.9980
3.0	.9981	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986
3.1	.9987	.9988	.9988	.9989	.9989	.9990	.9990	.9991	.9991	.9992
3.2	.9992	.9992	.9992	.9993	.9993	.9993	.9993	.9994	.9994	.9994
3.3	.9995	.9995	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9998	.9998	.9998	.9998
3.5	.9998	.9998	.9998	.9998	.9998	.9998	.9998	.9999	.9999	.9999
3.6	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.9999
3.7	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.9999	1.0000	1.0000

is required; that is, the probability depicted for a given *r* is not just a segment of the circle but is the *total SSHP*. This table differs from table XIII in that the rectangular probability table gives the probability for only ¼ of the total rectangle and multiplication by 4 is required. Interpolation is an unnecessary refinement.

631. SSHP for Type 1 (Weapon and Target Rectangular)

The SSHP problem for a type 1 combination is the same as discussed in detail in paragraphs 624 through 626, and the procedure is identical.

a. Example: Compute the SSHP for a missile that has a range probable error of 500 meters and a deflection probable error of 300 meters and is launched at an enemy supply dump 800 meters long and 500 meters wide with respect to the launcher-target line. (Assume that the center of impact as at the center of the target area.)

b. Solution (use table XIII):

$e_{pr}=500$; $e_{pd}=300$

$$\text{Range } t=\frac{\frac{1}{2}(800)}{500}=\frac{400}{500}=.80$$

$$\text{Deflection } t=\frac{\frac{1}{2}(500)}{300}=\frac{250}{300}=.83$$

From probability tables: $t(.80)=.2054$; $t(.83)=.2123$

$\text{SSHP}=4(.2054)(.2123)=.1744=17.44\%$

Note. The above procedures are equally applicable even when the e_{pd} of the missile is larger than its e_{pr} as long as each is related to its corresponding dimension in the target area with respect to the launcher-target (or gun-target) line.

632. SSHP for Type 2 (Weapon Rectangular and Target Circular)

In an SSHP problem for a type 2 combination, it is first necessary to determine the side of a square the area of which is equal to the area of the circle defined by the radius of the target. This computed side is then used as both the range and deflection dimension of the target area, and the SSHP is computed as for type 1.

a. Example: Compute the SSHP for a missile which has a range probable error of 300 meters and a deflection probable error of 100 meters and is launched at a target area the radius of which is 400 meters. (Assume that the center of impact is at the center of the target area.)

b. Solution (use table XIII):

Side of square(s) = 400(1.7725) = 709 meters (use 710)

e_{pr} = 300 meters; e_{pd} = 100

$$\text{Range } t=\frac{\tfrac{1}{2}(710)}{300}=\frac{355}{300}=1.18$$

$$\text{Deflection } t=\frac{\tfrac{1}{2}(710)}{100}=\frac{355}{100}=3.55$$

From probability tables: $t(1.18)=.2869$; $t(3.55)=.4916$

SSHP = 4(.2869)(.4916) = .5642 = 56.42%

633. SSHP for Type 3 (Weapon and Target Circular)

The SSHP problem for a type 3 combination requires only the computation of r; that is, the target area radius divided by the circular probable error of the weapon. The value in the probability table for a given r is the SSHP for that ratio.

a. Example: Compute the SSHP for a missile which has a circular probable error of 200 meters and is launched at a target area the radius of which is 250 meters. (Assume that the center of impact is at the center of the target area.)

b. Solution (use table XIV):

$$r=\frac{\text{target radius}}{\text{weapon CPE}}=\frac{250}{200}=1.25$$

From probability table: $r(1.25)=.6614$

Therefore, SSHP = .6614 = 66.14%

634. SSHP for Type 4 (Weapon Circular and Target Rectangular)

In an SSHP problem for a type 4 combination, it is first necessary to determine the radius of a circle the area of which is equal to the area of the rectangular target. The radius so determined is then used as the radius of the target area, and the SSHP is computed as for type 3.

a. Example: Compute the SSHP for a missile which has a circular probable error of 200 meters and is launched at a target area 200 meters by 400 meters. (Assume that the center of impact is at the center of the target area.)

b. Solution (use table XIV):

Target radius = $.5642\sqrt{200}\sqrt{400}$ = 159.6 meters (use 160 meters)

$$r=\frac{160}{200}=.80$$

From probability table: $r(.80)=.3583$

Therefore, SSHP = .3583 = 35.83%

635. Alternate Solution for Type 4

Table XIII can be used with the SSHP problem for a type 4 combination by multiplying the known circular probable error by .5727 and using the product as the range probable error of the weapon as well as its deflection probable error. The solution for the preceding problem by using this procedure would be as follows:

a. Equivalent e_{pr} and $e_{pd}=CPE\times.5727=$ 200 (.5727) = 114.54 (use 115)

$$\text{Range } t=\frac{\tfrac{1}{2}(200)}{115}=\frac{100}{115}=.87$$

$$\text{Deflection } t=\frac{\tfrac{1}{2}(400)}{115}=\frac{200}{115}=1.75$$

Note. Since there is a common denominator of 115, it makes no difference which dimension of the target area is assumed to be range and which is assumed to be direction.

From probability tables: $t(.87)=.2214$; $t(1.75)=.3811$

SSHP = 4(.2214)(.3811) = .3375 = 33.75%

b. The method in *a* above, as an exception to the general rule of converting the target area shape to fit the weapon dispersion pattern, is preferred when the dimensions of the target area are such that 1 dimension is 3 or more times the other dimension.

636. Computation of SSHP When Location Probable Error Is Known

The probable error of target location and center of impact error is construed to be radial in nature except as discussed in paragraph 628. The effect on the computation of SSHP in either or both cases is an apparent increase in the probable error of the weapon. This apparent increased weapon probable error is approximately equal to the square root of the sum of the squares of weapon probable error and location probable error. By using these modified weapon probable errors, SSHP is computed as described in paragraphs 629 through 635.

a. Example: Compute the apparent circular probable error of a weapon the given circular probable error of which is 200 meters when the center of impact is known only with a probable error of 80 meters.

Solution: Apparent weapon

$$\text{CPE}=\sqrt{(200)^2+(80)^2}=215.4 \text{ meters.}$$

Therefore, use 215 meters in computing r.

b. Example: Compute the apparent range and deflection probable errors for a weapon the e_{pr} of which is 300 and the e_{pd} of which is 100 when the center of impact is known only with a probable error of 80 meters.

Solution: In this case, it is first necessary to convert the probable error of center-of-impact location (which is radial) to increments of range and deflection by finding the size of a square of equivalent area.

$$s=80\times 1.7725=141.8 \text{ (use 142)}$$

$$\text{Then apparent } e_{pr}=\sqrt{(300)^2+(142)^2}=331.9$$

$$\text{And apparent } e_{pd}=\sqrt{(100)^2+(142)^2}=173.7$$

Therefore, in computing range t, use 332 meters, and, in computing deflection t, use 174 meters.

Note. Computation of probable errors, as shown above, is valid for only one round in fire for effect.

637. Summary

a. The need for a knowledge of probabilities stems from the need to estimate properly both the accuracy and effectiveness of fires which are planned as well as to evaluate fire that has been delivered. Probability is at best a substitute for fact; it indicates the relative likelihood of an event or outcome with respect to other events or outcomes considered.

b. Probability is no more valid than the data from which it is deduced. This is particularly true for those problems dealing with SSHP. Probable errors in locating the center of impact with respect to the target considerably reduce SSHP and assurance. Continued firing when the center of impact is in error results in a systematic error with a further reduction of the SSHP. That is, each projectile or missile deviates from its own center of impact according to normal distribution; the center of impact must be estimated and computations continued from there.

c. Firing tables indicate the probable errors of a weapon in various dimensions (range, deflection, and height of burst or radial and height of burst). By utilizing round-to-round data from center-of-impact registrations and fall of shot calibrations, a positive check is available on the performance of weapon crews and weapons. The developed probable error can be approximated by multiplying the maximum dispersion observed (longest range minus shortest range) of the group of rounds considered by the appropriate factor from the following tabulation (n is the number of rounds in the group).

n	*Factor*
2	0.5978
3	.3885
4	.3276
5	.2900
6	.2661
7	.2494
8	.2369
9	.2271
10	.2192
11	.2126
12	.2070
13	.2022
14	.1980
15	.1943
16	.1910
17	.1880
18	.1853
19	.1828
20	.1806

For example, the maximum observed range dispersion in a group of 8 rounds is 150 yards. The approximate developed range probable error is 36 yards to the nearest yard ($.2369 \times 150 = 35.535$).

d. Probability tables and pertinent graphs simplify applying statistical methods to artillery fires; however, proper use of these tables and graphs requires a true picture of the problem at hand. To set up a problem in probability, the law of errors and characteristic dispersion patterns must be known.

e. Probabilities associated with the firing of successive volleys are combined with lethal areas and disposition of specific targets to serve as a guide toward a more intelligent selection of weapons and ammunition in the attack of targets. These ramifications are discussed in chapter 23.

f. The distinction between accuracy and precision must be recognized. Firing table probable errors define precision; that is, the magnitude of the dispersion pattern around the mean. They do not define accuracy completely but only a part of it. Accuracy is defined by the combined probable errors of all the elements used in computing or deriving firing data. For example, the accuracy of K-transfers depends on the accuracy of survey, target location, current registration corrections, laying and normal dispersion, etc. Also, the accuracy of met plus VE transfers depends on accuracy of survey, target location, met data (at the time and place used), the VE used, laying, etc. Accuracy, therefore, is affected by many contributing sources of error. Most of these sources can be expressed by an independent probable error. To predict correctly the accuracy of contemplated fire, the probable errors of all applicable elements must be known and combined into what is known as a systems probable error. The method for combining several independent probable errors is to express them in a common unit of measure (e. g., yards), square these values, add all of the squares, and then take the square root of this sum. It is not the purpose of this manual to define the magnitude of these separate sources of error. The purpose is only to point out the fact that the firing table probable error is only one of many sources of error which affect accuracy.

CHAPTER 28
CALIBRATION

Section I. GENERAL

638. Introduction

a. Calibration is the comparison of the muzzle velocity of a given piece with some accepted standard performance. That standard may be selected arbitrarily from the performance of a group of weapons being calibrated together, as in *comparative calibration;* or it may be the standard defined in the firing tables, as in *absolute calibration.*

b. Initially, calibration is directed toward a proper grouping of the weapons under a command. For example, all weapons within a battalion will not have like shooting strengths or muzzle velocities even when a common ammunition lot is being fired. Therefore, it is desirable to minimize wide discrepancies in shooting strengths within each battery by grouping weapons of like performance. Calibration data are also used in computing certain corrections to basic firing data; in general, however, they encompass the following:

(1) To determine corrections which will equalize variations in velocities of weapons in the battery.

(2) To determine corrections which will equalize variations in velocities of base pieces in the battalion.

(3) To determine corrections which will equalize variations in velocity from the firing table standard.

639. Necessity for Calibration

a. The effectiveness of artillery depends on its ability to deliver accurate and timely fires. Constant efforts are being made to improve accuracy so that suitable targets can be neutralized, damaged, or destroyed before countermeasures can be used by the enemy. For improved accuracy, an important element to determine is the velocity of the weapon-ammunition combination.

b. Calibration serves three purposes—first, it permits individual piece corrections to produce the most effective pattern of bursts; second, it provides a point of departure for the use of met plus VE delivery techniques in new positions; and third, it serves as a measure of validity against which later VE's (computed as a result of registrations and concurrent met data) can be evaluated. Comparative calibration serves only the first purpose. Absolute calibration serves all purposes.

c. Having weapons of like velocity, in any one battery, reduces the frequency with which individual piece corrections must be applied. Calibration data makes it possible to group weapons of nearly equal shooting strength.

d. Developing atomic warheads for field artillery weapons has accentuated the importance of absolute calibration data because of the requirement for a predicted fire capability. Predicted firing data, that is, firing data determined without benefit of registration or adjustment, is a refinement of the met plus VE techniques described in chapter 19.

640. Types of Calibration

a. Calibration can be done with a muzzle velocity measuring device called a chronograph. It can also be performed with fall of shot procedures of varying complexity. Both techniques result in a variation from the accepted standard performance expressed in feet per second. A variation determined by chronograph is called a measured velocity variation (MVV). A variation determined from fall of shot procedures, regardless of the complexity, is called velocity error (VE).

b. Measuring the muzzle velocity developed by a weapon-ammunition combination results in *absolute calibration data.* However, MVV's do not tie a group of weapons together unless a common or like lot of ammunition is used. Developed muzzle velocity is a function of two variables—the weapon and the ammunition—and, in order to reference one, the other must be kept a constant. A group of weapons calibrated with a chronograph will be considered in a state of absolute calibration with respect to firing table standards if a common lot of ammunition is used. However, unless the ballistic coefficient of the projectile lot is standard, the VE determined from a fall of shot absolute calibration will not match MVV determined from an instrumental absolute calibration. Unless the ballistic coefficient change (BCC) is known and therefore can be stripped from the fall of shot data as one of the nonstandard conditions, the VE determined is not absolute in the true sense. Despite an unknown ballistic coefficient, the VE so determined is usable in the absolute sense within the confines of present met plus VE techniques.

c. Fall of shot calibration can result in comparative or absolute calibration. The firing is conducted similarly to that for center-of-impact registrations.

d. In fall of shot *comparative calibration*, the mean developed range for each piece is determined. That range is compared with the mean developed range of the piece accepted as standard. Each piece then has a range differential with respect to this standard. The differential is reduced to a VE by dividing by the appropriate muzzle velocity unit effect. This procedure assumes that the mean developed ranges of all pieces were equally influenced by every nonstandard condition with the exception of muzzle velocity. The resultant VE is usable only in relation to the piece accepted as standard and to effect uniformity of performance. It has no relation to the firing table standard.

e. In fall of shot *absolute calibration*, the mean developed range for each piece is compared with the range which would have been realized under the standard conditions defined in the firing table. Each piece then has a range differential with respect to the firing table standard range. From this differential must be stripped the effect of all nonstandard conditions which existed at the time of firing with the exception of muzzle velocity. The residual, in yards, is attributed to nonstandard velocity and reduced to a VE as in comparative calibration.

641. Ordnance Support

a. Periodically, field artillery units are visited by ordnance teams who calibrate the pieces by using a chronograph. Units will usually have sufficient notice of these visits to prepare for a concurrent fall of shot calibration, preferably of the absolute type discussed in paragraphs 652 and 653. This practice is recommended in view of the divergence between MVV's and VE's of the absolute type (par. 640*b*).

b. Equipment used by these teams will be one of two types, either the skyscreen or the radar doppler. Skyscreen equipment is a set of photoelectric cells which are placed along a carefully surveyed base. The base is under a prolongation of the tube when it is laid. Passage of the projectile overhead changes the light intensity striking the cells which in turn activates an electronic timer. The ordnance team computes the mean developed muzzle velocity of the rounds fired from each piece. The unit must determine, and compensate for, the effect of nonstandard powder temperature and projectile weight. The unit must reduce the corrected muzzle velocity to an MVV.

c. Chronographs of the radar doppler type are far more flexible than skyscreen equipment. The radar doppler set operates from a vehicle to the rear of the piece. Positioning of the set requires only a paced survey. The equipment can follow changes in direction and elevation as rapidly as the piece can be laid. The set transmits a continuous wave radio frequency. A portion of the wave is reflected off the moving projectile and returns to the set at a changed frequency. The amount of the change is proportional to the velocity of the projectile. An electronic computer performs the required computations. The team adjusts the indicated velocity to a muzzle velocity under standard conditions. The radar doppler equipment is flexible and is capable of day or night operation. It is ideally suited for use during tactical situations. Accuracy attained with the radar doppler chronograph is equal to the accuracy attained with the skyscreen chronograph. Calibration can be accomplished without expending ammunition just for that purpose. Regardless of these advantages, the unit should still attempt to perform a concurrent fall of shot calibration when possible.

d. Ordnance teams are also equipped to make wear measurements for all weapons ranging in caliber from 75-mm to 240-mm. The equipment used is called a pullover gage. This gage allows a precise measurement of the distance between the lands in the bore near the start of rifling. Tube wear in this region is a fair indication of remaining tube life. Wear measurements should not be substituted for calibration. Nevertheless, they can be used to detect extremes in velocities within a group of weapons; however, any attempt to assign relative magnitudes of these extremes (that is, a constructed VE) is of questionable validity. Also, calibration reflects the comparative or absolute performance of a weapon-ammunition combination. Tube wear, as measured by a pullover gage, cannot take into account the differences between ammunition lots and charges. Pullover gage readings can be used to group weapons initially when immediate calibration is not feasible. Changes in the readings may be used as a guide in scheduling recalibration.

642. Frequency of Calibration

The type and caliber of weapon that is being fired, and the frequency (by charge) of firing, govern the need for calibration. All new tubes should be calibrated as soon after receipt as possible. Thereafter, any weapon in service should be recalibrated at least once annually. If a great deal of firing takes place, recalibration may be needed more than once annually. If an accurate and reliable record of the change in VE determined from registrations and concurrent met data is maintained, recalibration may not be needed until the velocity loss approaches four range probable errors. Wear tables will also give a general indication of the need for recalibration.

Section II. FALL OF SHOT COMPARATIVE CALIBRATION

643. Preliminary Considerations

a. General. Comparative calibration is based on the premise that the total effects of nonstandard conditions (except velocity deviation from standard) have equal influence on the locations of the CI's. This premise assumes, therefore, that the difference in range between CI's is an indication of the difference in velocity. This assumption is valid only within certain limits. For example, it does not mean that weather conditions can be ignored. Relatively stable wind is a condition which must be sought for calibration; and no fall of shot calibration, either comparative or absolute, should be attempted during the passage of a weather front.

b. Ammunition. Regardless of recent improvements made in the manufacture of ammunition, there is still a significant difference of performance between lots both with respect to propellant velocity and projectile efficiency. By arrangement with the issuing agency, a stable lot should be procured. It is recommended that 10 rounds per light or medium piece and 8 rounds per heavy or very heavy piece be fired during the calibration; this includes 2 rounds for conditioning the piece (warming rounds). The calibration can be conducted with fewer rounds consistent with ammunition allowances but with some sacrifice of overall reliability. The propellant and the projectile must each be of a single lot; however, if the fuzes are not available in a single lot, it is permissible to calibrate with fuzes of the same type from different lots.

c. Optimum Charge. The VE (or MVV) of a given weapon will vary from charge to charge. The only method of determining the VE (or MVV) precisely with any particular charge is to calibrate with that charge. However, it is never possible to calibrate all weapons with all charges. Usually, calibration is accomplished with only one charge, and hence it is necessary to select the charge which will cover the ranges most frequently fired. Grouping of weapons must be based on calibration with one charge. Comparative calibration data determined with one charge work fairly well as a basis for individual piece corrections for all other charges for howitzers but not too well for guns. Absolute calibration data as such are valid only for the specific combination fired.

d. Quadrant Elevation. When fall of shot calibration of the absolute type is being performed, the weapon should be calibrated at a QE between 240 mils and 460 mils. A low QE minimizes the effect of nonvelocity elements absorbed into the VE in application.

e. Emplacement of Weapons. The weapons to be calibrated should be emplaced in a level position area with about 2 feet between pieces. Cant must be eliminated since laying for QE will be by gunner's quadrant. The weapons may be laid for direction by any of the methods described in chapter 5. The use of special corrections to deflections for laying all weapons on a common point is not required. The target area should be level and, if at all possible, should be at about the same altitude as the position area. The weapons should be located to a survey accuracy of not less than 1:1,000 (TM 6–200).

f. Observation. If possible, coordination should be effected with the observation battalion which will normally provide the required flash base from which the center of impact achieved by each weapon is determined. Organic observation may be used, provided the observers are trained and equipped to provide the high degree of accuracy required for fall of shot calibration. When organic observation is used, four OP's must be installed, each equipped with a battery commander's telescope. The OP's must be located to a survey accuracy of not less than 1:1,000 and tied to a common reference point of the same accuracy (TM 6–200). Each observer will record both azimuth and vertical angle for each round. Care must be exercised in recording so that rounds can be related to their respective pieces. An erratic round can be defined as one which falls more than four range probable errors away from the true center of impact. In a strict interpretation of this definition, it would be impossible to detect all erratic rounds at the time observed. This is because the apparent center of impact of the sample is not known until all rounds have been fired and the apparent center of impact itself is only an approximation of the true center of an infinite number of rounds. Nevertheless, a round which obviously does not fit the pattern of the remaining rounds should be classified as erratic and should not be included in the location of the CI. This necessitates a quick check of azimuths recorded by the two flank observers before releasing a piece from the calibration site. If, for the same round, both of these observers recorded an azimuth quite different from all others in that CI, then an additional round should be fired from that piece. The decision to fire additional rounds is made by the officer in charge. Additional rounds are fired after all scheduled firing in comparative calibration and after the scheduled firing for each piece in absolute calibration.

g. Accuracy. To insure maximum accuracy, all personnel should be briefed on the importance of the calibration. They should be specifically instructed to use extreme care in performing their duties during calibration; this pertains equally to survey, FDC, weapon crews, and supervisory personnel. A reliable system of communications and exchange of commands, data, and information should be worked out. If necessary, the system should be rehearsed well in advance of firing. An SOP should be developed for the conduct of firing. It is especially important that bubbles are centered exactly before each round is fired. The pieces should be serviced and checked to insure that they are in proper working condition. A bench-checked (ordnance tested) gunner's quadrant should be used on all pieces. At least one reliable powder thermometer per piece should be obtained before the firing.

644. Conduct of Firing

a. Have the range and height, in yards, and the azimuth, in mils, from the weapon to the desired point of impact determined. These data may also be obtained graphically from a reliable map, the scale of which is no smaller than 1:25,000, or by trigonometric solution. Have these data converted into quadrant elevation and deflection for the pieces. Have the azimuth and vertical angle from each OP to the expected point of impact computed.

b. Have the pieces put in position with about 2 feet between pieces, and then have the trunnions leveled and the pieces bore-sighted.

c. Have the interior of each tube washed until clean and absolutely free of oil film, using hot soapy water or a solution of a good grade detergent, and then have the tube dried.

d. Have the ammunition prepared (use impact fuze). This should be done sufficiently in advance of the firing to insure uniform weather conditioning. Powder temperature must be recorded for at least four rounds at each weapon just prior to firing. Normal storage precautions should be exercised.

e. Have the OP personnel alerted and give the approximate time of firing. The first two rounds fired to condition the tube will be used by the OP personnel to improve pickup data. For each round, have ON THE WAY and SPLASH sent to the OP's. Laying for elevation for these and all subsequent rounds will be done by using the gunner's quadrant; the method of fire for all rounds will be salvo fire. Allow sufficient time between rounds for the OP personnel to change the pickup data on their instruments (40 seconds between rounds for a well-trained crew; at least 60 seconds for the average crew). Have the conditioning rounds used to check the entire system of picking up, reporting, and recording data. Have on-the-spot corrections made as necessary.

f. Have the calibration rounds fired as soon as possible after the conditioning rounds. They should be fired as rapidly as possible within the capabilities of the weapon and the observers. In the event of a misfire, have the piece called out, the observers notified of the action, and the firing of the other pieces continued. Accuracy and safety precautions take precedence over any requirement to complete the firing as rapidly as possible.

g. Have each OP checked to make sure that all rounds have been recorded. Erratic rounds should be reported by the observers so that refiring can be accomplished immediately.

645. Determination of Average Range and Altitude

a. General. When the observation battalion provides the flash base, it determines the range, azimuth, and altitude for each round fired. This permits a more complete evaluation of the calibration, particularly with respect to erratic rounds or gross errors. When the unit provides its own observation, it computes data only for the CI. This requires a careful screening of each observer's recorded data; not only for the detection and deletion of obviously erratic rounds, but also for the detection of questionable observer data.

b. Graphical Check. If survey, observer orientation, and observer readings are correct, all rays, as plotted from their respective OP's, would theoretically intersect at a common point. Normally, however, the rays, either for a single round or a CI, will not intersect but will form a polygon, referred to as the polygon of error. Observation battalion personnel are trained to reconcile these polygons of error. The normal accuracy limitations of unit observation do not warrant such a refinement. However, if observer data appear to be of questionable accuracy, a graphical check on the magnitude and nature of the polygon of error will detect it. To accomplish the graphical check, plot all OP's on a gridded sheet to a scale of 1:6,250 and plot the azimuths of the round or CI in question as rays from their respective OP's. If the graphical check indicates that only one observer is appreciably in error, delete these data and use the data of the other three observers. If more than one observer is appreciably in error, then it is best to use the data from all observers as being equally valid because it is not possible to pick out the specific observers at fault. The size of the polygon of error accepted is a good measure of the accuracy of resultant range data and, hence, the calibration itself. A graphical check should be made on the common reference point before firing begins.

c. Determination of CI Range and Azimuth. To determine the CI range and azimuth—

(1) Compute the mean azimuth for usable rounds as recorded by each observer. (Conditioning rounds and erratic rounds are not used.)

(2) Form three target area bases by using selected pairs of OP's as shown in figure 230.

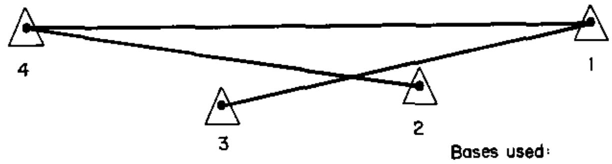


Figure 230. Target area bases.

(3) Compute three sets of coordinates for each CI by using each base in turn (TM 6–200).

(4) If an appreciable difference in the three sets of coordinates occurs, perform a graphical check.

(5) Average the three sets of coordinates to arrive at a mean CI location.

(6) Use the resultant CI coordinates and weapon coordinates to arrive at azimuth and range to the CI (TM 6–200).

d. Determination of CI Vertical Interval. To determine the CI vertical interval—

(1) Compute the altitude of the CI from each OP (pars. 337–391).

(2) Average the four resultant altitudes to arrive at a mean CI altitude which will be used in later computations.

646. Conversion to a Standard

The ranges obtained must be adjusted for differences in altitude to place them on the same horizontal plane. The procedure described in paragraph 645*c* and *d* serves the same purpose as stripping developed site from the QE fired as in absolute calibration. However, the procedure is more convenient in comparative calibration. Comparative calibration is accomplished as follows:

a. Select a reference altitude and determine a range correction for each piece to this altitude. This puts all bursts in the same horizontal plane. The reference altitude need not be the average of all the altitudes recorded. It can be any convenient altitude (including the altitude of the pieces) which simplifies computing the range correction. Divide the difference in altitude by the tangent of the angle of fall to compute the range correction. This procedure is recorded as follows:

Piece No.	Alt piece	Alt CI	Vertical interval	Angle of fall*	Tangent of fall	Range correction
1	210	233	+23	356	.36	+64
2	210	231	+21	356	.36	+58
3	210	233	+23	356	.36	+64
4	210	234	+24	356	.36	+67
*	*	*	*	*	*	*
17	210	232	+22	356	.36	+61
18	210	233	+23	356	.36	+64

*From firing tables at QE fired (in this example, 105-mm howitzer, charge 5, QE 315).

b. Adjust the measured range for each CI by applying the corrections for altitude. In the example in *a* above, this would be recorded as follows:

Piece No.	Measured range	Alt correction	Corrected range
1	5,240	+64	5,304
2	5,130	+58	5,188
3	5,230	+64	5,294
4	5,200	+67	5,267
*	*	*	*
17	5,170	+61	5,231
18	5,210	+64	5,274

c. Find the average powder temperature of the rounds comprising each CI, and then average the CI temperature to find an overall average. The overall average is accepted as standard. If the powder temperature of any CI differs from this standard, convert the difference (diff) to a muzzle velocity change and then modify the VE's by a corresponding amount. For example, if the average powder temperature has been determined to be 80° F., the computation of powder temperature corrections is as follows:

Average temperature 80° F. (+3.0 f/s)

Piece No.	Powder temp	Change in velocity f/s	Diff change in velocity f/s
1	82	+3.8	+0.8
2	79	+2.7	−0.3
3	83	+4.2	+1.2
4	80	+3.0	0
*	*	*	*
17	78	+2.4	−0.6
18	78	+2.4	−0.6

647. Determination of VE

a. The range achieved by the piece shooting the longest distance is selected as standard and the VE for this piece will be zero.

b. Determine the difference between the standard range and the range achieved by each piece. Convert this difference by VE by dividing it by the unit effects factor for velocity from the firing tables at the range corresponding to the elevation fired. As a final step, correct for differences in powder temperature and round off resultant VE.

c. The following is an example of computation of VE's for a battalion of 105-mm howitzers at charge 5, rounds fired at elevation 315:

Standard range 5,360 (range of piece shooting the longest distance)

Tube No.	Corrected range	Deviation from standard range	MV factor	VE f/s	Corr for powder temp	Final VE
101	5,304	−56	+8.0	−7.0	−0.8	−8
102	5,188	−172	+8.0	−21.5	+0.3	−21
103	5,294	−66	+8.0	−8.2	−1.2	−9
104	5,267	−93	+8.0	−11.6	0	−12
*	*	*	*	*	*	*
117	5,231	−129	+8.0	−16.1	+0.6	−16
118	5,274	−86	+8.0	−10.8	+0.6	−10

648. Comparative Calibration at Battery Level

a. At times it will be advisable and necessary to conduct comparative calibration at battery level with each battery calibrating on a different day rather than at battalion level with all batteries calibrating on the same day. This usually happens because—

(1) The available area will not accommodate all weapons in the battalion at one time.

(2) All batteries cannot be assembled at one time because of other requirements.

(3) Improved results can be expected by reducing the overall time lag from salvo to salvo.

b. When comparative calibration is conducted at battery level, the procedures in (1) through (3) below are used to convert the separate calibrations to a common calibration for the battalion. (This is necessary in order to properly group the weapons within the battalion.)

(1) The first battery to calibrate takes with it 1 weapon from each of the other 2 batteries. These weapons will be used later with their respective batteries as control pieces.

(2) Each separate calibration is conducted and computed as outlined in paragraphs 643 through 647.

(3) When all batteries have been calibrated, different sets of data are adjusted to a common level by applying a constant to the VE's of the second and third batteries to calibrate. This correction is the number of feet per second required to bring the VE of the control piece when calibrated with its own battery to the VE of the control piece when calibrated with the first battery.

c. An example of adjusting separate battery calibrations to a common level is given in (1) through (6) below.

(1) Respective battery VE's (Battery A calibrated first; Battery B, second; and Battery C, third).

A		B		C	
Weapon	VE	Weapon	VE	Weapon	VE
A–1	0	B–1*	-8	C–1**	−5
A–2	−4	B–2	−3	C–2	−1
A–3	−7	B–3	0	C–3	−6
A–4	−8	B–4	−5	C–4	−7
A–5	−12	B–5	−9	C–5	0
A–6	−15	B–6	−11	C–6	−4
B–1*	−2				
C–1**	−9				

*Battery B control weapon.
**Battery C control weapon.

(2) In order to adjust the VE's of Battery B, note that +6 f/s must be added to the VE for B–1 to bring it to the VE obtained with Battery A; hence, +6 f/s must be added to all VE's in Battery B.

(3) Similarly, for Battery C an additional −4 f/s is required to bring the VE of C–1 to the VE it obtained with Battery A; hence, −4 f/s must be applied to all VE's in Battery C.

(4) By using these correction factors, the calibration data can be rewritten (adjusted to a common level) as follows:

A		B		C	
Weapon	VE	Weapon	VE	Weapon	VE
A–1	0	B–1	−2	C–1	−9
A–2	−4	B–2	+3	C–2	−5
A–3	−7	B–3	+6	C–3	−10
A–4	−8	B–4	+1	C–4	−11
A–5	−12	B–5	−3	C–5	−4
A–6	−15	B–6	−5	C–6	−8

(5) The weapons can now be listed in order of decreasing shooting strength and the VE's adjusted so that the strongest shooting weapon has a VE of 0; the correction required to bring the strongest shooting piece to 0 must be applied similarly to all weapons.

Order of strength	First adjusted VE	Final adjusted VE
B–3	+6	0
B–2	+3	−3
B–4	+1	−5
A–1	0	−6
B–1	2	−8
B–5	−3	−9
A–2	−4	−10
C–5	−4	−10
B–6	−5	−11
C–2	−5	−11
A–3	−7	−13
A–4	−8	−14
C–6	−8	−14
C–1	−9	−15
C–3	−10	−16
C–4	−11	−17
A–5	−12	−18
A–6	−15	−21

(6) The final adjusted VE's are the basis for regrouping the weapons. They represent comparative calibration equal to a battalion-type calibration.

d. This technique can also be used for howitzers when a common lot of ammunition is not available for all three batteries. The correction factor, usually, will compensate for differences in interior and exterior ballistic performance of the ammunition. The charge fired, however, should be the same. Results for gun-type weapons will not be very satisfactory if more than one ammunition lot is involved.

Section III. FALL OF SHOT ABSOLUTE CALIBRATION

649. Preliminary Considerations

a. Nonstandard Conditions. The effects of muzzle velocity must be isolated from the effects of all other nonstandard conditions; however, certain deviations from this basic requirement are accepted in present techniques and will be noted as such. Careful preparation must be made for obtaining and using met data. Coordination between the officer in charge of the calibration and the officer in charge of the met station is essential. The met station is ideally located at a point between weapon and target and as close to the ground projection of the summit of the trajectory as possible. This will seldom, if ever, prove feasible; but proximity of the met station must be considered in the overall planning. The time of the initial met message and the frequency of additional messages thereafter should be agreed upon. Met messages should be scheduled at no greater than 2-hour intervals and should bracket the entire firing period.

b. Selecting the QE. To avoid line interpolation of the met message, the QE fired can be selected so that the maximum ordinate will be equal to an altitude of a line number of the met message. The method of bringing an acceptable QE (240 mils to 460 mils) into agreement with a line number of the met message involves the use of the table of maximum ordinates for the charge fired. This table is included in each firing table as well as the height of each line of the met message. The following example illustrates the method of selecting the QE to be fired in calibrating the 105-mm howitzer M1 with charge 5.

Altitude of met line numbers

Line 2: 1,500 feet
Line 3: 3,000 feet
Line 4: 4,500 feet

From the table of maximum ordinates, a maximum ordinate of 1,500 feet results in a horizontal range of between 5,500 and 6,000 yards. Quadrant elevations for these ranges are in the vicinity of 350 mils, an ideal elevation for calibration. A maximum ordinate of 1,500 feet would, therefore, be selected as the basis for determining the elevation at which to fire. The QE which produces this maximum ordinate is 328.2 mils (range 5,500 yards). For convenience, this QE can be rounded off to 330 mils. It can then be used as the quadrant elevation in the calibration firing.

c. Selecting Pieces for Calibration. It is not necessary to bring every artillery piece into a state of absolute calibration. Pieces selected for absolute calibration should be those whose wear measurements or records of past performance indicate stronger shooting strengths. Preferably, 3 pieces per battalion are selected, although 1 is satisfactory. The measurements on which this selection is based should be done by ordnance teams. Calibration firing and computing the absolute type data will be performed at division artillery level or higher, except for separate or isolated units. Pieces will then be assigned to battalions where comparative calibration will be conducted for all pieces. By knowing the comparative calibration data of all pieces and the absolute calibration data of one or more pieces, comparative data can be converted to absolute data with acceptable accuracy.

d. Other Considerations. Except as stated herein, preliminary considerations are the same as those for comparative calibration.

650. Conduct of Firing

Firing is conducted in the same manner as for comparative calibration firing, except that salvo fire is not used. Each piece will complete the firing of its CI before the next piece fires. Each CI should be fired as rapidly as possible consistent with the weapon and personnel involved in order to minimize range effects due to changes in weather. (Speed should not, however, take precedence over accuracy.)

651. Computation of Absolute VE

a. To compute the VE, first locate the CI for each weapon by using the method described in paragraph 645. Compute the developed CI range. Compute site by using the difference between the piece and CI altitudes. Strip this site from the QE set on the piece and interpolate in the firing tables for the range corresponding to the resultant elevation. This is the standard horizontal range that would have been achieved if all firing table standard conditions had existed at the time of firing. The difference between the developed range and the standard range (developed minus standard) shows the total range effect of all variations from standard that did exist.

Note. This procedure does not compensate for tube droop as a separate factor, as is done in 280-mm gun procedure, but, instead, absorbs droop effect into the resultant VE. Strictly speaking, the point of departure for VE computations should be the *QE fired*, which is equal to the algebraic sum of the QE set on the breech quadrant seats, tube droop, and, with some firing tables, vertical jump. Such a refinement is not warranted, however, except in the case of the 280-mm gun.

b. All unit effects for nonstandard conditions are taken from the firing table at the range (nearest 100 yards) corresponding to the elevation fired (QE minus site).

c. The variations from standard conditions entered on the data correction sheet must reflect the following factors:

(1) The powder temperature used is the average of all powder temperatures recorded at a particular piece during the firing of its CI.

(2) If the situation precludes firing a QE such that the maximum ordinate achieved by the projectile is equal to an altitude of a line number of the met message, then it is necessary to interpolate between line numbers of the met message. For example: Assume that calibration is fired with charge 7, 105-mm howitzer, with a QE of 300 mils; 300 mils corresponds to a range (nearest 100 yards) of 7,900 yards and will result in a maximum ordinate (nearest 100 feet) of 2,300 feet; and 2,300 feet is .5 (nearest .1) of the way between 1,500 feet (line 2) and 3,000 feet (line 3). Hence, met data would be interpolated for line 2.5 as follows:

Line No.	*Wind dir*	*Wind velocity*	*Air density*	*Air temp*	
2------	33	26	947	45	
(2.5---	35	23	943	44)	(interpolated)
3------	37	20	939	43	

(3) Time interpolation of met data is required for those CI's not fired concurrently with the taking of a met message. For example: Assume that a CI in question was fired at 0840 and that the nearest bracketing met messages were taken at 0800 and 1000, respectively. Data for the appropriate line number would be interpolated linearly as ⅓ of the change between the 2 messages as follows:

Time	*Line*	*Wind dir*	*Wind velocity*	*Air density*	*Air temp*	
0800---	2	48	21	956	40	
(0840--	2	51	23	949	42)	(interpolated)
1000---	2	57	27	935	46	

d. The range effects determined by completing DA Form 6–15 (Data Correction Sheet) are subtracted from the total range effects as computed in *a* above. The result is divided by the unit effect for muzzle velocity.

Example (105-mm howitzer, charge 5):

CI range = 5,607 yards
CI height (with respect to piece) = +31 yards
Site +6.4 QE fired (365 minus site +6.4) = 358.6 mils
Standard range (for 358.6 mils) = 5,921 yards
Total range effect of all variations from standard = developed range (5,607) minus standard range (5,921) = −314 yards
Total range effect of line and time interpolated met data, mean powder temperature, and projectile weight (unit effects taken for range 5,900 yards) = −142 yards
Range effect attributed to VE = −172
Unit effect for muzzle velocity at 5,900 yards = 8.6

$$\text{VE} = \frac{-172}{8.6} = -20 \text{ f/s}$$

e. The VE of −20 f/s in *d* above approximates absolute calibration for this weapon-ammunition combination. However, if such a calibration is conducted in conjunction with an ordnance chronograph calibration, the officer in charge should not be unduly alarmed if the MVV computed is of a different magnitude. Primary reasons for this difference are—

(1) A projectile lot which is more or less efficient in overcoming air resistance than the projectile lot used to construct the firing table which shows up as an increase or decrease in range not otherwise accounted for.
(2) Errors in the met data used.
(3) Limitations of present computational procedures and firing tables.
(4) Errors in survey.
(5) Errors in the QE used (to include droop).

f. The officer in charge should examine the magnitude and sign of the differences (VE minus MVV) and recheck computations for any sample that deviates from the pattern followed by most of the weapons. In the following example, piece 4 should be rechecked.

Piece No.	*VE*	*MVV*	*Difference*
1	−24	−18	−6
2	−30	−25	−5
3	−22	−15	−7
4	−37	−21	−16
5	−27	−23	−4
6	−25	−20	−5

Section IV. REDISTRIBUTION OF WEAPONS

652. Grouping of Pieces According to Velocity

a. Grouping After Calibration by Fall of Shot. Prepare a list by tube number of all pieces calibrated, ranging in order from the strongest shooting piece to the weakest. These pieces should then be assigned to batteries based on their shooting strength; i. e., the strongest ⅓ in 1 battery (normally A), the weakest ⅓ in another battery (normally C), and the remaining ⅓ in the remaining battery (normally B). Within batteries, the base pieces should be the piece the shooting strength of which is nearest the battery average. To equalize wear among the tubes in service, the piece shooting the longest distance should be assigned all destruction missions and other missions, such as harassing and interdictory fires, which may call for only part of the pieces of the battery. The following example illustrates the method of grouping pieces according to shooting strength:

Tube No.	*VE comparative calibration*	*Adjustment of VE's to absolute scale*	*Battery****
51180	0	−11	A 1
51242	−1	−12	A 2
51177*	−3	−14	A (base piece)
51359	−4	−15	A 4
51628	−5	−16	A 5
51032	−5	−16	A 6
51768	−6	−17	B 1
51535	−8	−19	B 2
51640	−10	−21	B (base piece)
51819	−11	−22	B 4
51225	−12	−23	B 5
51275	−13	−24	B 6
51393	−14	−25	C 1
51410	−14	−25	C 2
51733	−15	−26	C 3
51366	−16	−27	C 4
51136	−19	−30	C (base piece**)
51250	−22	−33	C 6

*Absolute calibration performed with this tube.

** In the event that the designation of the average piece as the base piece causes calibration corrections (par. 384) to be carried on one or more of the pieces, another piece may be designated as the base piece.

***Assignment to batteries only; does not infer piece numbering within batteries.

Note.—When more than one weapon in a battalion is in a state of absolute calibration with the same ammunition combination, the adjustment of VE's to the absolute scale employs the mean difference between the comparative VE and respective absolute VE, as shown below:

Piece No.	*Comparative VE*	*Absolute VE*	*Difference*
1	0	−12	−12
2	−1	−14	−13
3	−3	−14	−11
		Mean	−12

Therefore, −12 f/s should be applied to the comparative VE's of all weapons to adjust to the absolute scale.

b. Grouping After Calibration by Chronograph. The results of chronograph calibration (MVV's) are absolute calibration data. When such data are available, they permit the most effective grouping. They are also the basis for the most reliable corrections for variations in shooting strength between weapons. When MVV's and VE's of either the comparative or absolute type are determined concurrently, the MVV's should be used as the basis for grouping and subsequent computation of individual piece corrections.

653. Computation and Application of Calibration Corrections

a. Once the weapons have been calibrated and grouped, corrections must be applied to compensate for the difference in shooting strengths between the base pieces of the batteries within the battalion and for differences between the base pieces and other weapons within the battery. Computing and applying these corrections are explained in paragraphs 381 through 386.

b. When either MVV's or VE's of the absolute type are to be used as a basis for computation in the met plus VE techniques (pars. 368–376), the following factors should be considered:

(1) When both MVV's and VE's are available for the same calibration, the VE's will normally prove more successful in present techniques. The VE's at least partly compensate for variation in projectile lot

efficiency (from the firing table lot) and droop, whereas the MVV's do not.

(2) VE's are subject to errors of met data and survey. They are also subject to limitations of present computing procedures which are unique to a particular calibration.

(3) The MVV or VE used in this respect is valid only for the weapon-ammunition combination for which it was determined; however, it may be used to construct a fairly reliable VE of the absolute type for another charge and lot if both lots and charges have been fired from the same tube.

c. The following rules should be used as a guide in applying calibration data when MVV's and VE's are both available.

(1) MVV's are preferred to either type of fall of shot calibration data for grouping pieces and computing individual piece corrections.

(2) VE's of the absolute type are preferred to MVV's for computing corrections to firing data as in met plus VE techniques.

(3) If MVV's and comparative type VE's only are available, the MVV's are preferred for all aspects of application (grouping, individual piece corrections, and corrections to firing data).

Section V. HEAVY ARTILLERY

654. General

Calibrating heavy and very heavy artillery, grouping the weapons, and the subsequent computation and application of calibration corrections are performed in the same fashion as for light and medium artillery. There is, however, an additional consideration with heavy and very heavy artillery. With the exception of the 8-inch howitzer, loss in muzzle velocity per round fired with weapons of this group is significant. Unless the same number of rounds is fired by all weapons of a battery, calibration data must be altered periodically. It is, therefore, necessary to maintain an accurate record of calibration data, subsequent firing, and corrections applied to calibration data. The record of firing is maintained in DA Forms 9–13 and 9–13–1 (Weapon Record Book). A complete record of calibration data is kept at battery and battalion FDC.

655. Wear Tables

Wear tables may prove helpful in filling in the gaps between actual calibrations. However, wear tables in effect estimate the erosion a gun tube will be subjected to as a result of firing a certain number of rounds with specified charges. From this estimated erosion, a certain loss in muzzle velocity will have occurred. Hence, wear tables have the limitations of actual wear measurements described in paragraph 641*d* in addition to the inherent limitations of estimating erosion.

PART SIX

TRAINING

CHAPTER 29

SERVICE PRACTICE

656. General

a. Service practice is a practical exercise using service ammunition in the conduct of observed fire. The primary purpose of service practice is to teach the principles of observed fire through practical application. The ultimate goal is to develop an ability to apply accepted procedures to any observed fire problem. Effective application will insure that a minimum amount of time and ammunition is consumed in bringing effective fire on the target. The prescribed gunnery procedures and techniques should be adhered to rigidly except when judgment clearly indicates that a departure will expedite the mission.

b. Service practice, being a part of the tactical field training of field artillery units, should combine all elements of training—tactical employment, mobility, communications, preparation and execution of fire commands, and conduct of fire. Service practice should be initiated early in the unit training program. It should continue through the final phase of training for battle.

c. Observer procedure in the conduct of fire is of equal importance with other elements of training included in service practice. This chapter will serve as a guide in training personnel in observer procedure in the conduct of fire.

657. Commanding Officer

The commanding officer of an installation is responsible for the preparation, maintenance, and assignment of firing ranges allotted to his command. He must issue necessary directives to insure compliance with the safety precautions prescribed in AR 385–63. A range officer and detail assist the commanding officer in the discharge of this duty.

658. Officer in Charge of Firing

The officer in charge of firing is that officer charged with the conduct of any training which involves the firing of live ammunition. He is responsible for safety in firing. Normally, he has safety officers as assistants and, in some instances, a range officer. The officer in charge must verify that all corrections pertaining to safety limits are immediately disseminated to, and applied by, the safety officer. These corrections include met and/or VE corrections and registration corrections.

659. Range Officer

a. The range officer is responsible to the commanding officer for the proper preparation and maintenance of the range. He must issue instructions and warnings necessary to insure that the danger areas are clear of all individuals prior to firing; that range guards and/or barriers with signs are posted at all entrances to the danger areas to prevent trespassing during firing; and that warning signals are displayed.

b. The range officer is responsible for the preparation, authentication, and distribution of the safety card (fig. 231). The safety card will be reproduced in accordance with paragraph 20*a*, AR 310–1. He must insure that the safety limits are correct and in accordance with regulations (pars. 669 and 670*b*).

660. Safety Officer

The safety officer at the firing point represents the officer in charge of firing. Orders issued by the safety officer which prohibit firing are lawful and can be rescinded only by the officer in charge of firing. In the discharge of his duties, the safety officer should interfere as little as possible with the delivery of fire. He should not be detailed to check and correct errors or inaccuracies in the laying or servicing of the piece other than those affecting safety.

661. Training for Service Practice

a. The techniques of preparation, execution, and conduct of fire must be taught and proficiency

SAFETY CARD

Date 27 July 1956
Time 0800 To 1800

Unit Firing 150th FA Bn Type Weapon 105-mm How M2
Firing Point 6213038467 Map Ft Sill 1/25000 Reference Point GN Az 0 *
Ammunition Shell HE - WP Fuze M51 - M500
Officer in charge Lt Col Dean E. Painter
Left Limit Az 6,030 Right Limit Az 350
Minimum Range 4,500 Maximum Range 6,000 Yards
Special instructions Use this card with charges 3, 4, and 5 only. From Az 6,030 to Az 6,330, the maximum range is 5,000 yards.

Left Limit Az 6,030 Deflection
Intermediate Limit Az 6,330 Deflection

Right Limit Az 350 Deflection
Prepared By William E. Hartline Authenticated By O P Tyssen
Major, Arty Major, Arty
* S3 Range Officer

Direction may be designated by a reference point on the ground and an approximate azimuth thereto, in such a case, the left and right limits would be designated as so many mils left or right of the reference point.

Figure 231. A type safety card.

attained before service practice. This proficiency is attained by nonfiring exercises in the gun park and in the classroom with terrain board, terrain plot, and other available training aids. Accuracy is the foundation of proficiency and must be emphasized.

b. The service practice OP is not the place to learn conduct of fire procedure. Familiarity with procedure can be attained by firing simulated missions. A simple and effective method of practicing simulated missions is the "matchbox problem." Matchbox problems require no equipment except a small object, such as a matchbox, and a piece of paper on which a mil scale has been drawn. Two or more officers should work together on these problems, using a table or any convenient surface. A match box is used as the target and a folded piece of paper with a mil scale drawn on it to represent the scale of the reticle in the observer's binoculars is placed on the table in front of the target (fig. 232). The officer acting as observer, facing the target and mil scale, announces the fire request and OT distance to the officer who stands beside the table and announces the FDO order and ON THE WAY. After announcing ON THE WAY, the officer at the table places the top of a pencil on the table for a moment to simulate each burst. The observer senses the burst or volley, using the mil scale, and gives the next command. The officer at the table again announces ON THE WAY, and simulates the burst or bursts, and the observer gives his next command. This procedure is continued until the mission is complete. The officer at the table critiques the mission and changes place with the officer acting as the observer.

662. Conduct of Service Practice

a. Service practice should be conducted under the direction of the battalion commander or higher commander. The best qualified officers should be used as instructors for observer personnel. Service practice should be conducted initially under classroom conditions to reduce distractions.

b. It is often advisable to conduct a service practice as part of a tactical field exercise which requires the artillery unit to occupy and fire from a selected position. After the tactical occupation of position by the artillery unit, the observer personnel may be assembled at a selected observation post(s). This type of service practice serves as a test for the unit and the observers.

c. The officer in charge (instructor) must strive to instill confidence in the observer personnel and to arouse and maintain their interest in the service practice. Above all, he must take maximum advantage of the expenditure of time and ammunition to teach proper observer procedures and techniques.

d. The officer in charge (instructor) should have a logical system for conducting the service prac-

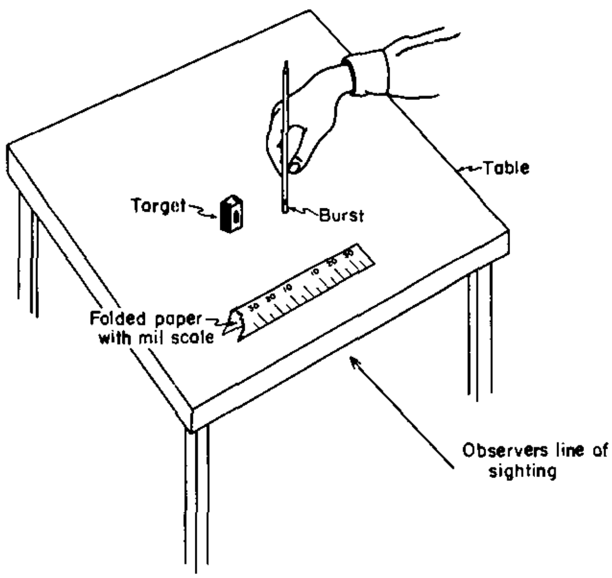


Figure 232. Matchbox problem setup.

tice. This system should extend in detail to each of the following steps:

(1) *Preparation for service practice.* Well in advance of the scheduled service practice, the officer in charge should—

(*a*) Make a ground reconnaissance of the area. The observation post (OP) should be selected carefully to give the desired angle *T* and observation.

(*b*) Prepare a map and plot on it the locations of the batteries, observation post, safety limits, and the registration points.

(*c*) Select appropriate reference points and targets.

(*d*) Submit the limits of the desired impact area (overlay or written form) to the range officer for approval. This request is used as a basis for the preparation of the safety card. One copy of the approved safety card must be delivered to the safety officer(s) prior to the service practice and one copy retained by the officer in charge of firing. The officer in charge of firing must check the safety cards and, if they are not correct, attain a reconciliation through the range officer. This check should include verification that the limits established on the safety card are such that adequate protection is afforded unit installations from projectile dispersion and fragmentation.

(2) *Procedure at OP prior to firing.*

(*a*) The officer in charge of firing must arrive sufficiently in advance of the participating personnel to insure that the OP is properly organized. Figure 233 depicts a typical nontactical OP arrangement. Preparation must include, but need not be limited to a—thorough check of communications to include all means available; check of range control to insure that range is clear; and organization of OP to insure that all observers have a good view of the target area.

Caution: It is imperative that the officer in charge of firing insure that the first round fired will land in the impact area. When firing is to be conducted at long ranges and under unfavorable weather conditions, the range error resulting from velocity error and effects of met may at times exceed 1,000 yards. This potential error also makes the use of time fire extremely hazardous until after registration corrections are obtained. The best data available should always be used.

(*b*) An orientation on the terrain must be given to all observer personnel and should include the limits of the target area. A good method is to describe a tactical situation involving frontlines, zones of action, and final objective. For subsequent target designation, the orientation should define reference points and the azimuth for one or more of the points. If possible, these points should be on the horizon and not more than *200* mils apart.

(*c*) The observers 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. Type of fuzes and projectiles available should not be given at this time ((3) (*c*) below). The observer should be told to consider all types of fuzes and projectiles *authorized* in the basic load in selecting the ammunition to request; however,

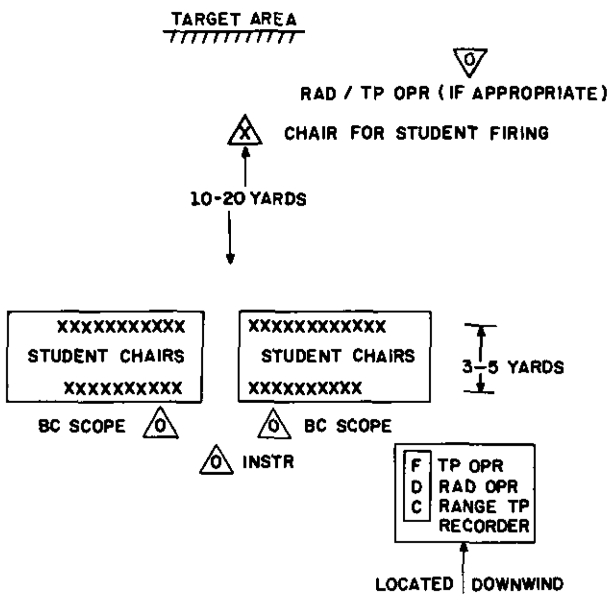


Figure 233. A typical nontactical observation post arrangement.

the best type of fuze and projectile *available* will be used.

(*d*) A target should be designated and enough time allowed for observer personnel to prepare initial data. Normally, 2 minutes is adequate early in training. For realism, a registration point normally should not be selected and fired on as the first mission. For safety, targets selected prior to a registration should be located near the center of the impact area. All observer personnel should prepare the initial data for each mission and keep a record of the missions fired.

(3) *Designation of targets.*

(*a*) All targets should be designated in a uniform manner. This enables the personnel to become accustomed to a routine and to devote their effort to making precise measurements. Normally, targets should be designated by announcing size, nature, and location relative to the nearest reference point and the skyline. As far as possible, the target will be realistically described in a sound tactical location; e. g., OP on a point that affords observation or mortars in defilade.

(*b*) Target locations should be exact (deviations should be checked with a battery commander's telescope). Immediately prior to target designation, the officer in charge should verify his description of the target by using his field glasses.

(*c*) The nature of targets must be varied to *cause observers to consider selection of proper fuze and projectile.* The description should depict a realistic target. The following are examples of proper designation of targets:

1. TARGET: 2 MORTARS; FROM LONE TREE, LEFT 86; FROM SKYLINE, DOWN 16; YELLOW MATERIEL. THAT IS THE ADJUSTING POINT.

2. TARGET: INFANTRY PLATOON IN OPEN; FROM HILL 216, RIGHT 97; FROM SKYLINE, DOWN 34; A LARGE TREE, THE NEAR TREE OF 2 APPROXIMATELY IN LINE. THAT IS THE ADJUSTING POINT.

3. TARGET: CAVE ENTRANCE; FROM MARKER, LEFT 74; FROM SKYLINE, DOWN 19; YELLOW ROCK. THAT REPRESENTS A CAVE ENTRANCE.

(*d*) In the selection of targets, careful consideration should be given to prescribed safety limits. No target should be assigned so close to a boundary that a reasonable bracket (200 yards) cannot be obtained.

(4) *Supervision of firing.*

(*a*) The individual firing must understand that the successful completion of the mission is his responsibility. During the conduct of a mission, the officer in charge may change observers, calling on another observer to replace the one presently firing. Changing observers one or more times during a service practice will insure continued interest in all firing problems. In the event the person firing is having difficulty, this change may result in a more rapid and effective accomplishment of the mission, thus adding to its instructional value.

(*b*) In cases other than that described in (*a*) above, the officer in charge should not interfere with the conduct of a mission unless safety is jeopardized or repeated errors are made which, if continued, would decrease the instructional value of the mission. In such cases, the officer in charge may give help or he may reassign or stop the mission.

(*c*) The *inexperienced observer* should be required to *announce* his sensings promptly and clearly before announcing corrections. The observer must sense rounds as soon as the burst is observed; this leads to more accurate sensings and, in some cases, may help the observer to gain confidence. The officer in charge should stress that accurate firing data depend on accurate observer sensings and corrections.

(5) *Critiques.* The officer in charge of firing should conduct a constructive and impersonal critique immediately after each

mission. It should be specific, limited to essentials, and conducted generally in the following order ((*a*)–(*d*) below):

(*a*) Restatement of the assigned mission.

(*b*) A concise statement as to whether or not the mission was accomplished in a satisfactory manner.

(*c*) A discussion of the essential reasons why the mission was or was not satisfactory, to include how additional time and ammunition could have been saved (if applicable) and the effect on the target. Mention the good points first and then cover any bad points which will be of instructional value. Avoid a round-by-round analysis of the mission, limit the number of points discussed, and discuss at least one good point.

(*d*) A request for any questions or comments.

Example: "The mission, neutralization of an OP, was accomplished in a satisfactory manner. The officer firing gave good initial data but could have saved time and ammunition by making *positive* range sensings. Any questions or comments on the mission?"

(6) *Grading.* When the officer in charge of firing desires to grade the personnel firing, the following ((*a*) and (*b*) below) may be used as a guide:

(*a*) Service practice missions are graded on results. Each individual mission is to be graded on its own merits; hence, the officer in charge must use discretion in grading to compensate for the discrepancy between easy and difficult missions. He must place himself in the position of the person firing and decide for each round or volley whether or not he could have done better, making allowance for the advantage (surveyed and/or memorized target area knowledge) he has over the person firing. He must not be hasty in assessing cuts for sensings of DOUBTFUL on off-line rounds. An *obvious* range sensing must be based on fact, not guesswork. Except to verify fire for effect, the officer in charge should limit himself to the same observing instruments as those used by the person firing.

(*b*) The grading sheet as shown below is based on an observer-target distance of 3,000 yards or less and on the assumption that the observer has good visibility in the area near the target. If these conditions do not exist, the mission should be considered a difficult one. Grading is then based on the instructor's estimate of the judgment used by the person firing. The grading sheet is only a guide and cannot be applied rigidly to all missions.

663. Procedure at Close of Firing

The officer in charge should notify the range officer and the unit firing as soon as the service practice is at an end.

664. Other Considerations

A series of service practices should be conducted from various observation posts with different impact areas being used, if possible. Periodically, service practice with maximum weapon range and/or large angle *T* should be conducted to acquaint observers with the effects of dispersion.

SERVICE PRACTICE GRADING SHEET

	CUT		
1. INITIAL DATA PHASE			
a. Azimuth error 100 mils or greater (if not corrected)	(5)	____	
b. Location (maps available):			
(1) 200–400 yards	(10)	____	
(2) Over 400 yards	(15)	____	
(3) OT distance more than 3,000 yards or observation is difficult, use 400–800 yards for (1) and over 800 yards for (2).			
c. Omission of obvious altitude difference	(5)	____	
d. Procedure errors, each	(2)	____	
e. Excessive time (announcing data):			
(1) 31–60 seconds	(3)	____	
(2) 61–120 seconds	(15)	____	
f. Changing data after announcement (excess time)	(3)	____	
g. TOTAL cuts (maximum 25)			____
2. ADJUSTMENT PHASE			
a. Procedure errors, each	(2)	____	
b. Wasted ammo (each round or volley) caused by improper range bound, jumped bracket, failure to take terrain sensings, improper shift resulting in doubtful sensings, etc	(10)	____	
c. Excessive time (each incident)	(3)	____	
d. TOTAL cuts (maximum 30)			____
e. If no bracket is obtained after 2 range changes and observers next command is not FFE with a change of not more than 50 yards, cut 35 plus total previous cuts and eliminate observer from mission	(35)	____	____
3. FIRE FOR EFFECT PHASE			
a. Exactly 50 yards error (moves away from bracketing volley in adjustment or in proving volley brackets)	(10)	____	
b. More than 50 yards error	(35)	____	
c. Improper height of burst or fuze	(15)	____	
d. Wrong method of attack (if corrected by observer, cut 10 only)	(35)	____	
e. TOTAL cuts (maximum 35)			____
4. SURVEILLANCE OF FIRE FOR EFFECT PHASE			
a. Precision—each incorrect sensing (if first 3 are missensed, cut 35 for effect)	(5)	____	
b. Area—incorrect surveillance	(10)	____	
c. Total cuts (maximum 10)			____
TOTAL cuts			____
Possible score			100
Minus cuts			____
Grade			____

CHAPTER 30
DUTIES OF SAFETY OFFICER

665. General

The duties of the safety officer(s) are to assure that the pieces are laid and loaded so that, when fired, the rounds will land in the impact area and to see that all safety precautions are observed at the firing point. He will be assigned no other duties during firing.

666. Duties of Safety Officer Before Firing

The duties of the safety officer before firing are as follows:

a. Verify that the safety card (fig. 231) applies to the unit, exercise, date, and time.

b. Verify that the battery is in position as specified on safety card.

c. Prepare safety diagram (pars. 670–672).

d. Check weapons for bore sighting.

e. Verify laying of the battery.

f. Verify minimum elevations (ME) determined by the executive. Compare executive's ME with elevation for minimum range on safety diagram, using the larger of the two as the minimum elevation.

g. Supervise the placing of safety-stakes.

h. Verify that ammunition to be fired is the type specified on the safety card.

i. Insure that chiefs of sections are informed of maximum and minimum quadrant elevations, right and left limits, and minimum fuze settings.

j. Visually check line of metal for parallel laying.

k. Verify that range clearance has been obtained.

l. Ascertain that visible portion of range is clear of personnel.

m. Assure that Department of the Army regulations, post regulations, and local special instructions pertaining to safety are complied with.

667. Duties of Safety Officer During Firing

After his preliminary checks are made, the safety officer should indicate that safety-wise the battery is ready to fire. He must keep safety uppermost in his mind and stress it to the firing battery personnel. Duties of the safety officer during firing are as follows:

a. Verify serviceability of ammunition.

b. Insure that charge, projectile, and fuze being fired are limited to those prescribed on the safety card.

c. Insure that rounds are not fired below minimum *quadrant* elevation nor above maximum *quadrant* elevation, remembering that 1 mil of site equals 1 mil of elevation.

d. Insure that rounds are not fired outside the lateral safety limits.

e. Insure that time fuzed rounds are not fired with fuze settings below minimum time prescribed on safety diagram.

f. On all commands which are unsafe to fire, command UNSAFE TO FIRE and give reasons therefor.

Examples: UNSAFE TO FIRE, 3 MILS OUTSIDE RIGHT SAFETY LIMIT. UNSAFE TO FIRE, 5 MILS BELOW MINIMUM ELEVATION.

g. Apply registration corrections to safety limits immediately after registration (par. 671).

h. Indicate to executive SAFE TO FIRE, when appropriate.

i. Report accidents and malfunction of ammunition to the officer in charge of firing, request ambulance if needed, and be prepared to make report as indicated in SR 700–45–6.

j. Bring to the attention of the executive any unsafe conditions observed and suspend firing until they are corrected; for example—

(1) Safety features of weapon not operative.
(2) Powder bags exposed to fire.
(3) Personnel smoking near pieces.
(4) Improper handling of ammunition.
(5) Time fuzes previously set and not reset to safe.
(6) With separate-loading ammunition, primer inserted before breech is closed.

(7) Failure to inspect powder chamber and bore after each round.

(8) Failure to swab powder chamber after each round on weapons using separate-loading ammunition.

(9) Misfires (par. 668).

668. Misfires

(AR 385–63)

A misfire is sometimes the result of a mechanical failure and sometimes the result of a human failure. Whatever the cause, when a misfire has occurred, the rules in *a* and *b* below should be observed.

a. Fixed or Semifixed Ammunition. With fixed or semifixed ammunition, two additional attempts will be made to fire the piece. Wait 2 minutes after the last attempt to fire before opening the breech and removing the round. With semifixed ammunition, remove only the cartridge case and charge and inspect the primer. If the primer is dented, a faulty primer is indicated and the cartridge case must be replaced by a new one. If the primer is not dented, the firing lock and trigger mechanism should be inspected for faulty operation.

b. Separate-Loading Ammunition.

(1) Two additional attempts will be made to fire.

(2) If the primer is heard to fire, wait a minimum of 10 minutes before opening the breech and replacing faulty charge and igniter pads.

(3) If the primer fails to fire after the third attempt and it can be removed by a person standing clear of the path of recoil, wait 2 minutes, remove primer, and insert new primer. If primer cannot be removed by person standing clear of recoil, wait 10 minutes before removing primer.

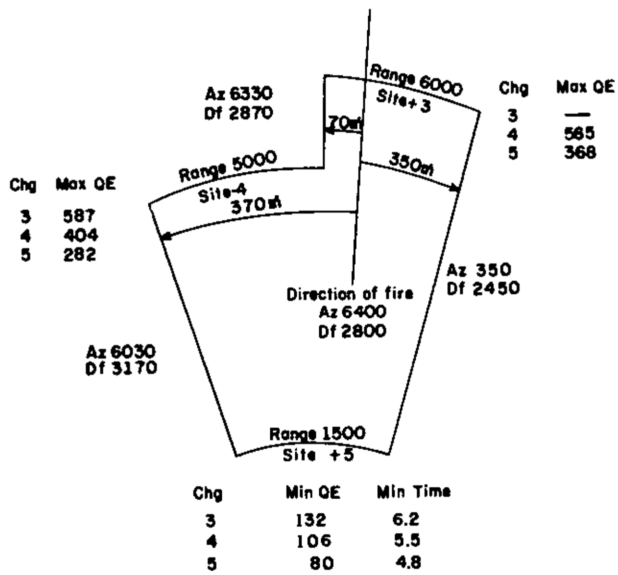
669. Safety Card

A safety card (fig. 231) which prescribes hours of firing, the area where the firing will take place, the location of the weapon position, limits of the impact area (in accordance with AR 385–63), and other pertinent data is approved by the range officer and sent to the officer in charge of firing. The officer in charge of firing gives a copy of the card to the safety officer, who constructs a diagram based on the prescribed limits.

670. Safety Diagram

a. The safety officer, on receipt of the safety card, constructs a safety diagram (fig. 234). The diagram need not be drawn to scale but must accurately list the piece settings which delineate the impact area; it serves as a convenient means of checking the commands announced to the weapon crews against those commands which represent the safety limits. The diagram shows the right and left limits, expressed in deflection which would hit those limits; the maximum and minimum quadrant elevations; and the minimum time settings (when applicable) for *each charge to be fired.* Maximum fuze settings are not necessary, since a projectile fired with too great a fuze setting but with the proper maximum elevation would result in an impact burst at maximum range.

b. The impact area is the area within which all rounds must be directed. The range officer takes into account the dispersion of the weapon. In making the safety cards he modifies the available target area so that rounds fired with range and deflection settings (registration corrections applied) for the limits of the area authorized by the safety card will land within a safe area, even though maximum dispersion and fragmentation occur.



Note. Prior to and after registration this diagram must be modified as prescribed in paragraph 671 i.

Figure 234. The safety diagram.

671. Construction of Safety Diagram from Azimuth Reference

To construct a safety diagram from azimuth reference—

a. A line is drawn depicting the line of fire on which the battery is laid and labeled with the azimuth and the deflection.

b. The angular measurement to the right and left limits is computed by comparing the azimuth on which the battery is laid with the azimuths of the lateral limits and the limits are sketched in in proper relation to the line representing the battery's initial line of fire. The computed angles are labeled right and left from the line of fire as shown in figure 234.

c. The deflections (modified when the distance from the firing point for any piece exceeds the displacement, normally 100 yards, authorized by the safety card) which represent the lateral limits are determined and each deflection limit is labeled.

d. The minimum and maximum range limits are sketched in by drawing arcs and these limits are labeled.

e. The elevations corresponding to the minimum and maximum ranges for each charge to be fired are determined by using graphical firing tables. If the GFT cannot be read to the exact mil, the next higher mil for the minimum elevation and the next lower mil for the maximum elevation are read. If the minimum or maximum ranges are not included on the graphical equipment for any charge, tabular firing tables must be used. When tabular equipment is used, elevation to the nearest tenth of a mil is interpolated and rounded off to the next higher mil for minimum elevation and to the next lower mil for maximum elevation.

f. Site to the *highest* point on the minimum range line and to the *lowest* point on the maximum range line is determined. The usual method is to determine altitude from a map and compute site with the appropriate GST. If an isolated point of high ground limits the minimum quadrant elevation, site may be computed for that area and a separate quadrant elevation applied between the deflections which bracket the high ground.

g. The sites determined for the minimum and maximum ranges (*f* above) are added algebraically to the appropriate elevations to obtain the minimum and maximum *quadrant elevations*. If the minimum QE changes from one side of the sector to the other, as a result of high ground at one point, a separate minimum QE is determined for each different site. The safety officer must assure that the QE fired for any deflection is within his QE limits for that deflection.

Example:

Largest site to minimum range (except between df 2,950 and df 3,000)	+5
Elevation to minimum range	120
Minimum quadrant elevation (except between df 2,950 and df 3,000)	125
Largest site to minimum range, df 2,950 to df 3,000	+8
Elevation to minimum range	120
Minimum QE (df 2,950 to df 3,000)	128
Smallest site to maximum range	−6
Elevation to maximum range	350
Maximum QE	344

h. Fuze settings are determined to the nearest tenth of a second for the minimum elevation for each charge to be fired. Maximum fuze settings are not determined.

i. Before determining registration corrections, the safety diagram must be modified. Two forks at the maximum range are subtracted from the maximum QE; two forks at the minimum range are added to the minimum QE. The left deflection limit must be moved right and the right deflection limit must be moved left by 8 deflection probable errors determined at maximum range (AR 385–63). When available, met and/or VE corrections should be used to further modify safety limits before registration. These decreased limits will apply until a registration has been conducted.

j. When high-angle fire is to be used, the deflection for the right limit is moved left by the maximum drift for the charges authorized and the deflection for the left limit is moved left by the minimum drift for the charges authorized. Before a registration, the modification in *i* above applies.

k. After a registration has been fired and corrections obtained, the safety officer modifies his original safety diagram. The elevations are changed to correspond with the GFT setting and the deflection correction is applied to the deflection for the lateral limits.

Example: Before registration, the minimum *quadrant* elevation for a 105-mm howitzer battery, firing charge 4, minimum range 1,500 yards, is determined to be 110ɱ (elevation 101ɱ+2 forks (4ɱ)+site (computed from map altitude) to the highest point on the minimum range line (+5ɱ)). A registration is conducted and the following GFT setting is obtained: GFT B: chg 4, lot X, rg 4,000, el 310. The corrected minimum elevation (103ɱ) is read under the elevation gageline, with the hairline over the minimum range. The site (+5) is added to this elevation to obtain the corrected minimum *quadrant* elevation (108ɱ). A deflection correction of R10, determined from the registration, must be applied to the lateral limits to obtain the deflections which are safe to fire. R10 is applied to the left limit (2,830ɱ) and to the right limit (2,440ɱ) to obtain corrected deflection limits of 2,820 mils (left) and 2,430 mils (right).

l. If the minimum QE computed for any charge by the safety officer is *less* than the ME computed by the executive for the same charge, the ME determined by the executive is used.

672. Construction of Safety Diagram From Visible Reference Point

Occasionally, a safety card will specify a reference point instead of an azimuth and will list the lateral limits by means of angular measurements right and left of that reference point. The procedure for the preparation of the safety diagram is as follows (reference point, marker on hill 156; left limit, 350ɱ left; right limit, 200ɱ right):

a. After the weapons are laid and the aiming posts alined, the smallest angle between the line of fire and the reference point is determined by using the panoramic telescope of the base piece. Since only clockwise angles can be measured with the panoramic telescope, angles measured to the left of the line of fire are determined by subtracting the reading on the telescope sight from 3,200. It is assumed that the battery has been laid and aiming posts have been alined at deflection 2,800. The referred deflection to the designated reference point (left front) is 3,100. The angle from the direction of fire to this reference point is 100 mils (3,200 minus 3,100).

b. The proper deflection to lay the piece on the reference point (deflection 2,800 plus (left) 100 equals deflection 2,900) is determined by using the LARS rule.

c. To determine the deflections for the lateral limits, the angular shift from the reference point to the left and right limits is applied to the deflection determined in *b* above by using the LARS rule.

Left limit: deflection 2,900 plus (left) 350 equals deflection 50.

Right limit: deflection 2,900 minus (right) 200 equals deflection 2,700.

d. Minimum and maximum QE's and minimum fuze settings are computed for each charge, and the diagram is prepared and modified as described in paragraph 671.

673. Safety Stakes

a. Safety stakes are commonly used with each piece as an additional aid to the safety officer in checking lateral limits. These stakes are placed 10 to 15 yards to the right and left front of each piece along the lateral limits prescribed on the safety card. By standing to the rear of a piece and glancing along the tube, the safety officer can easily tell whether the tube is pointed close to the safety limits. If such is the case, the safety officer is forewarned to make careful checks on the deflection set off and on the actual lay of the tube.

b. The most convenient method of placing safety stakes is by setting off the appropriate angles on the panoramic telescope and alining the stakes with the vertical hairline of the sight. In figure 235, the left limit is 370 mils to the left of the initial direction of fire. First, the piece is laid on the initial direction of fire by setting off deflection 2,800 and laying on the aiming posts.

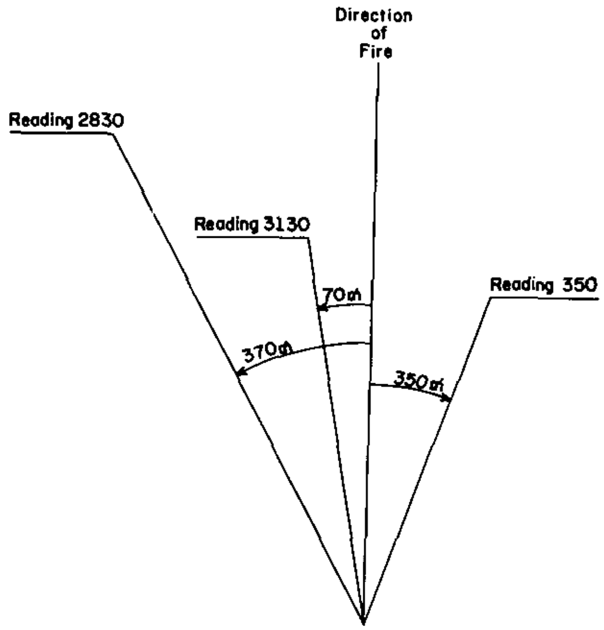


Figure 235. Diagram of safety stake emplacement.

Then, *without moving the tube*, a reading of 2,830 (3,200 minus 370) is set off and the stake is placed out in line with the vertical hairline of the panoramic telescope. The intermediate stake(s) (the stakes defining the deflection limits corresponding to changes in minimum or maximum range within the lateral limits) will be placed at a reading of 3,130 (3,200 minus 70). In a like manner, the right limit is computed to be 350 mils right of the initial direction of fire, and the safety stakes for the right limit will be put out at a reading of 350.

c. Another method of placing safety stakes is by actually laying the tube on the lateral limits and alining the stakes by sighting through the tube. This method, however, is more time-consuming and may necessitate shifting trails.

CHAPTER 31
FIELD ARTILLERY GUNNERY TRAINING

Section I. GENERAL

674. Purpose

This chapter provides general guidance in field artillery gunnery training. Specific guidance is provided in pertinent Army training programs. Initially, training should be aimed at developing the minimum proficiency required for combat operations. Commanders must give the highest priority to attaining this minimum proficiency in the shortest possible time. When this has been attained, commanders must then strive for maximum proficiency and versatility in their units by more advanced and detailed training.

675. Equipment and Training Aids

Instructors should use, but should not limit themselves to, equipment authorized in tables of organization and equipment and training aids kits. Instructors may devise simple but effective training aids to increase the efficiency of their instruction. However, training with the actual equipment is more effective. Instructors are reminded that learning is accomplished best through the sense of sight, followed by hearing and touch. The more senses to which the instructor can appeal, the more permanent will be his teaching.

676. General Training Notes

a. Training will be conducted in accordance with the doctrines and procedures described in FM 21–5, FM 21–6, and TM 6–605.

b. The training should be conducted with the precision and discipline required in artillery units. The dignity of the individual soldier must be respected at all times. He should be encouraged to ask questions about material which may be obscure to him. When possible, the trainee should take part in the instructional program, either through practical exercises or discussion periods.

c. Training in fundamentals may be held in classrooms; however, as soon as the status of training permits, classes and practical training should be held outdoors under simulated or actual combat conditions. Habits formed in training should be so ingrained in the individual that they will not be altered by the stress of combat. The highest standards of discipline, performance, precision, and accuracy are essential. Stress should be placed on the importance and necessity of developing maximum speed consistent with accuracy.

d. Instructors should thoroughly prepare and rehearse material before conducting the training. Care must be exercised in briefing assistant instructors to achieve coordination. Trainees who have had previous training or experience should be interviewed or tested. Those who have attained proficiency might be utilized as assistant instructors.

e. Each period presented should incorporate a logical approach to the material to be taught. Normally, the student learns best when the material is developed in an easy-to-hard sequence or a known-to-unknown sequence. Previous instruction forms an excellent foundation for succeeding instruction and should be so used when possible. Study assignments facilitate the logical development of the subject matter.

f. Instruction which is common to two or more sections may be combined. Large classes (over 20) should not be convened unless it is impossible or impractical to break them into smaller units. Time permitting, individuals should be trained in more than one phase of the unit's operation and have a general knowledge of all other phases.

g. The necessity to develop initiative and leadership on the part of instructors and trainees alike should be an integral part of the training program.

h. The overall effectiveness of the training should be measured frequently. During each period of instruction, oral or short written quizzes can be used to accomplish this aim. At the conclusion of each subcourse, a comprehensive examination should be given. This examination should be of the performance type whenever possible.

677. Phases

Training is divided into three phases—individual, section, and unit.

a. Individual Phase. The individual phase consists of instruction which treats the individual trainee as an instructional unit. The instruction is designed to prepare the trainee to occupy a position as a member of a team by acquainting him with methods, procedures, equipment, and experience factors.

b. Section Phase. The section phase begins when individuals are proficient enough to permit team practice. Emphasis is placed first on the correct performance of the team or section. It is then gradually shifted to drills designed to improve speed and accuracy. Careless or haphazard performance should not be tolerated at any time during the drills.

c. Unit Phase. The unit phase begins when the various sections are proficient enough to permit coordinated and integrated training as a unit. Continuation of individual and section proficiency while developing intersection coordination is emphasized.

Note. Applicable portions of FM 6–125, weapon TM's, and weapon FM's should be used to determine proficiencies gained at the termination of this training.

678. Methods

The methods of instruction are usually listed as Conference (C), Demonstration (D), and Practical Exercise (PE). Commanders may change the method of instruction to make better use of their facilities.

Section II. FIELD ARTILLERY GUNNERY TRAINING CHECKLISTS

679. General

Frequent inspections of gunnery training and service practice are necessary to insure efficient units. The training of the unit and the leadership of the noncommissioned and commissioned officers is reflected in the efficiency of the unit. Observer, firing battery, fire direction, and communication training should be combined when possible, to provide team training for the unit. The checklists presented in paragraphs 680 through 683 may be used in conducting gunnery training inspections.

680. Observer Training Checklist

Observer training must include—

a. Continuous training of all officers, as observers, to include firing matchbox, blackboard, or other simulated problems daily.

b. Proper radiotelephone procedures.

c. Preparation of terrain sketches and range estimation.

d. Map reading and method of indexing a map by the observers.

e. Emphasis on the necessity for obtaining a bracket before requesting fire for effect.

f. Emphasis on battlefield intelligence as a very important byproduct of artillery observation.

g. Training of all officers in air observer's procedures for conduct of fire.

h. Procedure in adjustment and use of illuminating and smoke shells.

681. Firing Battery Training Checklist

Firing battery training must include—

a. A daily, short but precisely conducted gun (howitzer) section team drill. Emphasize accuracy, speed, and proper procedures throughout the drill. Organize drill so that all personnel are occupied with worthwhile training.

b. Bore sighting and checking of fire control equipment correctly and at appropriate times in order to insure accuracy in firing.

c. Stressing that the chiefs of sections constantly check all settings.

d. Stressing extreme accuracy in laying the pieces. All gunners, when laying for direction, must be cautioned as to correct point of placing hairline of sight on aiming circle or aiming posts.

e. Stressing that gun tube be free of all oil and clean and dry prior to firing.

f. Keeping Weapon Record Book (DA Forms 9–13 and 9–13–1) up to date and recording of VE's, calibration data, and other pertinent data.

g. Segregating ammunition by lot number and the proper handling, storing, and protecting of the ammunition.

h. Procedures in conduct of direct fire.

682. Fire Direction Training Checklist

Fire direction training must include—

a. Daily team drill for FDC personnel, emphasizing speed and accuracy.

b. Computing a VE when registration and concurrent met message are available.

c. Determining and applying a GFT setting, if VE and met data are available.

d. Conducting high-burst and center-of-impact registrations.

e. Conducting high-angle fire and determining corrections from high-angle registrations.

f. Conducting illumination and smoke missions.

g. Applying special corrections when required by battery positions or targets.

h. Radiotelephone procedure.

i. Calibrating graphical equipment.

j. Setting up the firing chart on inspected coordinates if any scale map is available and survey is not completed or available. If no map or survey is available, an observed firing chart must be constructed.

683. Miscellaneous Training Checklist

Miscellaneous training checklists should include—

a. Duties of the safety officer, to include modifying safety limits and/or minimum range lines by the amount of met and VE corrections or registration corrections.

b. Calibrating weapons and grouping weapons according to VE. Battery VE's should be recorded in the battalion FDC. Comparative VE's should be recorded in each battery FDC.

c. Training to correct deficiencies disclosed by battery and battalion tests.

d. Practice battery and battalion tests in areas where the unit does not habitually train.

e. Gunnery portion of unit SOP.

f. A unit officer's school, to include a comprehensive gunnery course and examination.

Section III. STANDARD TIMES FOR ARTILLERY FIRE

684. General

The mission of the artillery is to deliver accurate and timely fire in support of infantry and armor. To accomplish the mission, certain standards of accuracy and speed must be met. Accuracy must not be sacrificed in gaining speed; however, every effort should be made to eliminate wasted action, loss of time, and use of incorrect procedures both in training and in combat. Total times required for a mission measure the efficiency of a unit as a whole. A continuous program of timing and use of comparative graphs by commanders should assist in locating and eliminating time losses. The ultimate goal must be to reduce the time required for the will adjust mission to the absolute minimum in order to make it closely approximate the effectiveness of fire without adjustment. This can be done if units will constantly stress the necessity for a timely determination of accurate initial data and the smooth, efficient functioning of all members of the artillery team.

685. Fire Mission Phases

a. The will adjust mission is only a substitute for the more effective surprise mission since it results in a loss of surprise and, consequently, the kill capabilities of a sudden volume of accurately placed fire. Adjustment requires a longer use of wire and radio communication, thus inviting enemy jamming of radio and overloading of wire lines. In addition, as time for firing increases, exposure time to enemy counterbattery measures is also increased.

b. The will adjust mission can be divided in three phases—first, the initial data phase; second, the adjustment phase; and third, the fire for effect phase.

(1) The initial data phase starts when a target is seen or identified and ends when the first round of adjustment is on the way. During this phase, the target has not been alerted and urgency will depend on the nature of the target. For example, a target such as a column of infantry proceeding toward a point requires much faster reaction than a target such as a command post. More time spent in this phase may reflect better initial data and, consequently, less time and fewer volleys for completion of the mission. However, during training under service practice conditions, stress must also be placed on speed in the initial data phase to emphasize the importance of speed in accomplishing the artillery mission.

(2) The adjustment phase starts when the initial round or volley lands near the target. From that instant on, the target is warned and evasive action can and will be taken.

(3) The fire for effect phase starts when the observer commands FIRE FOR EFFECT and ends with completion of the mission. The fire for effect rounds

should normally follow the last rounds of adjustment as quickly as possible.

686. Standards of Proficiency

a. Timing standards should only be used as a guide in measuring the overall efficiency of a field artillery unit. Accuracy must not be sacrificed to obtain speed. Faster adjustments and reduction of exposure time depend on—

(1) Improving initial data.

(2) Decreasing the number of adjusting rounds or volleys required.

(3) Speeding up action of personnel through better training and elimination of lost motion.

b. The timing standards contained in table XV are based on average terrain and weather conditions, impact fuze in adjustment, impact or VT fuze in FFE, a maximum of 4 volleys in adjustment, a time of flight not greater than 25 seconds, and observer distance of 3,000 yards or less. Although no standard times are given for weapons other than the 105-mm and 155-mm howitzers, the times listed can be used as a guide for all artillery weapons. The only changes required will be to allow more time for loading and laying the larger weapons and usually for a longer time of flight.

Note. The standards in table XV do not separate telephone and radio operator time intervals. The efficiency of operators can be judged by the number of repeatbacks required. If communications are not efficient, the total time standards will not be met.

Table XV. Standards of Proficiency (Speed) for Artillery Fires

Type of fire	Element	Event timed	Standards—minutes and seconds: Weapon	Superior	Excellent	Very satisfactory	Satisfactory
Area fire	Observer	Determination and transmission of initial data. (Time from last word of target identification to last element of observer's initial fire request.)	Note 3	01 00	01 30	02 00	02 30
		Per volley, determination and transmission of corrections. (Time from last burst of volley to last element of observer's correction.)	Note 3	00 12	00 15	00 18	00 21
	Fire direction center	Plotting target and determination of firing data for initial volley. (Time from last element of observer's initial fire request to elevation command to battery.)	Note 3	00 30	00 45	01 00	01 15
		Per volley, determination of firing data subsequent to initial volley. (Time from last element of observer's correction to elevation command to battery.)	Note 3	00 15	00 20	00 25	00 30
		Mass battalion after FFE is ordered by observer.	Note 1	00 42	00 52	01 02	01 12
		(Time from observer's FFE to ON THE WAY for the last battery.)	Note 2	00 57	01 07	01 17	01 27
	Firing battery	Initial volley in adjustment.	Note 1	00 15	00 20	00 25	00 30
		(Time from FDC elevation to ON THE WAY.)	Note 2	00 30	00 35	00 40	00 45
		Per volley, subsequent to initial volley.	Note 1	00 10	00 15	00 20	00 25
		(Time from FDC elevation to ON THE WAY.)	Note 2	00 25	00 30	00 35	00 40
		FFE, battery volley.	Note 1	00 15	00 20	00 25	00 30
		(Time from FDC elevation to ON THE WAY for the last round.)	Note 2	00 30	00 35	00 40	00 45
	Overall firing time	Time from first ON THE WAY to ON THE WAY for the last round in FFE.	Note 1	04 25	05 17	06 09	07 01
		(Based on four volleys in adjustment.)	Note 2	05 25	06 17	07 09	08 01
Precision fire	Observer	Determination and transmission of initial data. (Time from last word of target identification to last element of observer's initial fire request.)	Note 3	01 00	01 30	02 00	02 30
		Per round, determination and transmission of corrections. (Time from burst to last element of observer's correction.)	Note 3	00 10	00 13	00 16	00 19
		Per round in FFE, determination and transmission of sensing. (Time from burst to last element of observer's sensing.)	Note 3	00 08	00 11	00 14	00 17
	Fire direction center	Plotting target and determination of firing data for initial round. (Time from last element of observer's initial fire request to elevation command to battery.)	Note 3	00 30	00 45	01 00	01 15
		Per round, determination of firing data subsequent to initial round. (Time from last element of observer's correction to elevation command to battery.)	Note 3	00 15	00 20	00 25	00 30

See notes at end of table.

Table XV. Standards of Proficiency (Speed) for Artillery Fires—Continued

Type of fire	Element	Event timed	Standards—minutes and seconds				
			Weapon	Superior	Excellent	Very satisfactory	Satisfactory
	Firing battery	Initial round in adjustment.	Note 1	00 15	00 20	00 25	00 30
		(Time from FDC elevation to ON THE WAY.)	Note 2	00 30	00 35	00 40	00 45
		Per round, subsequent to initial round, including FFE.	Note 1	00 10	00 15	00 20	00 25
			Note 2	00 25	00 30	00 35	00 40
	Overall problem time	Adjustment only.	Note 1	04 00	04 52	05 44	06 36
		(Time from first ON THE WAY to ON THE WAY for first round in FFE (based on four rounds in adjustment).)	Note 2	05 00	05 52	06 44	07 36
CI or HB registration	Overall firing time	Per round fired.	Note 1	01 00	01 15	01 30	01 45
		(Time from ON THE WAY to next ON THE WAY. Includes report of instrument readings from two OP's.)	Note 2	01 15	01 30	01 45	02 00
		Total registration time.	Note 1	07 00	08 45	10 30	12 15
		(Time from first ON THE WAY to last OP report of registration.)	Note 2	08 45	10 30	12 15	14 00
Fire for effect without adjustment	Overall problem time	Battery mission.	Note 1	00 45	01 00	01 15	01 30
		(Time from last element of fire request to ON THE WAY.)	Note 2	01 00	01 15	01 30	01 45
		Battalion mission.	Note 1	00 57	01 12	01 27	01 42
		(Time from last element of fire request to ON THE WAY for last battery to fire.)	Note 2	01 12	01 27	01 42	01 57

Note 1—105-mm howitzer.
Note 2—155-mm howitzer.
Note 3—Both 105-mm and 155-mm howitzers.

c. Table XVI is a detailed breakdown of timing averages for the "excellent" column of area fire, table XV.

Table XVI. Service Practice Timing

From—	To—	Time interval (in seconds)
Target identified	Observer ready with initial fire request (IFR).	74
Observer starts IFR	Observer completes IFR	16
Observer completes IFR.	Deflection sent to weapons (exec).	38
Deflection sent to weapons (exec).	Elevation sent to weapons (exec).	7
Elevation sent to weapons (exec).	Elevation announced to chief of section.	5
Elevation announced to chief of section.	Chief of section reports READY.	13
Chief of section reports READY.	Weapons are fired	2
(Weapons are fired.)	(ON THE WAY announced to observer.)	(4)
Target identified	Weapons are fired	155
Initial volley bursts in target area.	Observer completes subsequent fire request.	15
Observer completes subsequent fire request.	Deflection sent to weapons (exec).	14
Deflection sent to weapons (exec).	Elevation sent to weapons (exec).	6
Elevation sent to weapons (exec).	Elevation announced to chief of section.	4
Elevation announced to chief of section.	Chief of section reports READY.	8
Chief of section reports READY.	Weapons are fired	3
(Weapons are fired.)	(ON THE WAY announced to observer.)	(4)
Initial volley bursts in target area.	Subsequent volley or fire for effect volley is fired.	50

d. Table XVII lists the times allotted for will adjust, low-angle missions in the current Army Training Test 6–5.

Table XVII. Credit Allotted for Speed of Adjustment (ATT 6–5)

Light artillery	Medium artillery	Credit (percent)
0 to 8 min	0 to 9 min	100
8 min, 1 sec to 9 min	9 min, 1 sec to 10 min	90
9 min, 1 sec to 10 min	10 min, 1 sec to 11 min	80
10 min, 1 sec to 11 min	11 min, 1 sec to 12 min	70
11 min, 1 sec to 12 min	12 min, 1 sec to 13 min	60
Over 12 min	Over 13 min	0

Note 1. Time starts when the ground observer identifies the target, and time stops when the battery or batteries are ready to fire for effect.
Note 2. For high-angle adjustment, add 5 minutes for 105-mm howitzer and 7 minutes for 155-mm howitzer.
Note 3. For adjustment with fuze time, add 2 minutes.

APPENDIX I

REFERENCES

1. Publications Indexes

Department of the Army Pamphlets of the 310-series should be consulted frequently for latest changes or revisions of references given in this appendix and for new publications relating to material covered in this manual.

2. Army Regulations

AR 310-3 ...... Military Publications, Preparation and Processing.
AR 385-63 ..... Regulations for Firing Ammunition for Training, Target Practice, and Combat.

3. Special Regulations

SR 320-5-1 .... Dictionary of United States Army Terms.
SR 320-50-1 ... Authorized Abbreviations.
SR 700-45-6 ... Report of Malfunctions and Accidents Involving Ammunition and Explosives (During Training or Combat).
SR 750-115-20 .. Weapon Record Book for Other Than Small Arms.

4. Department of Army Pamphlets

DA Pam 108-1 .. Index of Army Motion Pictures, Television Recordings, and Filmstrips.
DA Pam 310-series. Index of Military Publications.

5. Field Manuals

FM 3-5 .... Tactics and Technique of Chemical, Biological, and Radiological Warfare.
FM 6-18 ...... Field Artillery Mortar Battery, Infantry Division.
FM 6-20 .... Artillery Tactics and Technique.
FM 6-21 ...... Division Artillery, Infantry Division.
FM 6-50 .... 4.2-inch Mortar M30.
FM 6-55 .... 4.5-inch Multiple Rocket Launcher M21, Towed.
FM 6-75 .... 105-mm Howitzer M2 Series, Towed.
FM 6-76 .... 105-mm Howitzer M4 on Motor Carriage M37.
FM 6-77 ...... 105-mm Howitzer M52, Self-Propelled.
FM 6-81 .... 155-mm Howitzer M1, Towed.
FM 6-82 .... 155-mm Howitzer on Motor Carriage M41.
FM 6-87 .... 155-mm Gun M2, on Motor Carriage M40, and 8-inch Howitzer M2, on Motor Carriage M43.
FM 6-90 .... 155-mm Gun M2, 8-inch Howitzer M2, Towed.
FM 6-92 .... 155-mm Howitzer M44, Self-Propelled.
FM 6-95 .... 8-inch Gun M1 and 240-mm Howitzer M1, Towed.
FM 6-96 .... 280-mm Gun T131 on Carriage T72.
FM 6-101 ...... The Field Artillery Battalion.
FM 6-110 ...... Pack Artillery.
FM 6-115 ...... The Field Artillery Searchlight Battery.
FM 6-120 ...... The Field Artillery Observation Battalion and Batteries.
FM 6-125 ...... Qualification Tests for Specialists, Field Artillery.
FM 6-140 ...... The Field Artillery Battery.
FM 6-160 ...... Radar Set AN/MPQ-10.
FM 11-40 ...... Signal Photography.
FM 17-12 ...... Tank Gunnery.
FM 17-78 ...... Tank, 90-mm Gun M47.
FM 17-79 ...... Tank, 90-mm Gun, M48.
FM 17-80 ...... Tanks, 76-mm Gun, M41 and M41A1.
FM 21-5 .... Military Training.
FM 21-6 .... Techniques of Military Instruction.
FM 21-26 ...... Map Reading.
FM 21-30 ...... Military Symbols.
FM 23-92 ...... 4.2-inch Mortar M2.
FM 24-5 .... Signal Communications.
FM 44-2 .... Light Antiaircraft Artillery (Automatic Weapons).
FM 44-3 .... Light Antiaircraft Artillery (Skysweeper).
[O] FM 44-4 .... Medium and Heavy Antiaircraft Artillery.
FM 44-21 ...... Antiaircraft Artillery Service Practice.
FM 44-27 ...... Service of the Piece, 90-mm AA Gun, M2 Series.

FM 44–28...... Service of the Piece, 120-mm AA Gun.

FM 44–61...... Self-Propelled Twin 40-mm Gun M42.

FM 44–69...... Service of the 75-mm AA Gun Skysweeper.

FM 100–5...... Field Service Regulations; Operations.

6. Technical Manuals

TM 5–230...... General Drafting.

TM 5–236...... Surveying Tables and Graphs.

TM 6–200...... Artillery Survey.

TM 6–230...... Logarithmic and Mathematical Tables.

TM 6-240...... Rule, Slide, Military, Field Artillery, with Case, 10-inch.

TM 6–605...... Field Artillery Individual and Unit Training Standards.

TM 9–308A.... 76-mm Gun T91E3.

TM 9–319...... 75-mm Pack Howitzer M1A1 and Carriage M8.

TM 9–324...... 105-mm Howitzer M4, Mounted in Combat Vehicles.

TM 9–324A.... 105-mm Howitzer T96E1.

TM 9–325...... 105-mm Howitzer M2A1, Carriages M2A1 and M2A2, and Combat Vehicle Mount M4 and M4A1.

TM 9–331A.... 155-mm Howitzer M1 and 155-mm Howitzer Carriages M1A1 and M1A2.

TM 9–331B.... 155-mm Howitzer M1 and Mount M14 (Mounted on 155-mm Howitzer Motor Carriage M41).

TM 9–336...... 8-inch Gun M1 and Carriage M2.

TM 9–338–1.... 280-mm Gun T131 and 280-mm Gun Carriage T72.

TM 9–341...... 240-mm Howitzer Materiel M1.

TM 9–350...... 155-mm Gun M2; Carriage M1 and M1A1; Gun Mount M13; Heavy Carriage Limber M2 and M5; and Firing Platform M1.

TM 9–361...... 75-mm Guns T83E6 and T83E7 and 75-mm Antiaircraft Gun Mount T69.

TM 9–372...... 90-mm Gun M2 and Antiaircraft Mount M2.

TM 9–380...... 120-mm Gun M1 and Antiaircraft Mount M1.

TM 9–524...... 12-inch Graphical Firing Tables.

TM 9–525...... Graphical Firing Tables M39, M40, M41, M42, M43, M44, M45, M46, M47, M48, M49, M50, and M51.

TM 9–575...... Auxiliary Sighting and Fire Control Equipment.

TM 9–717...... 105-mm Howitzer Motor Carriage M37.

TM 9–717A.... Self-Propelled 105-mm Howitzer T98E1.

TM 9–718A.... 90-mm Gun Full Tracked Combat Tank M47.

TM 9–730...... 76-mm Gun Tanks M41 (T41E1) and T41E2.

TM 9–744...... 155-mm Howitzer Motor Carriage M41.

TM 9–747...... 155-mm Gun Motor Carriage M40 and 8-inch Howitzer Motor Carriage M43.

TM 9–761A.... Self-Propelled Twin 40-mm Gun M42 (T141).

TM 9–1372A... Ordnance Maintenance: 90-mm Gun M2 and AA Mount M2.

TM 9–1372B... Ordnance Maintenance: Combination Fuze Setter-Rammer M20, Motor Drive M2A1; and Amplifier M1A1 for 90-mm Guns M2 and M2A1 and Antiaircraft Gun Mount M2.

TM 9–1380..... Ordnance Maintenance: 120-mm Gun M1 and Antiaircraft Mount M1.

TM 9–1676..... Ordnance Maintenance: Remote Control Systems M6 and M6A1.

TM 9–1900..... Ammunition, General.

TM 9–1901..... Artillery Ammunition.

[C] TM 9–1907. Ballistic Data, Performance of Ammunition (U).

TM 9–1950..... Rockets.

TM 9–2008..... Operation and Organizational Maintenance: 4.2-Inch Mortar Carriage M30 and 4.2-Inch Mortar Mounts M24 and M24A1.

TM 9–2009..... 4.2-inch Mortar M30 (T104) and 4.2-inch Mortar Mount M24 (T61).

TM 9–3004..... 8-inch Howitzer M2, Carriage M1 and Heavy Carriage Limber M5.

TM 9–3007..... 105-mm Howitzer M2A1, 105-mm Howitzer Recoil Mechanisms M2A1, M2A2, and M2A3, 105-mm Howitzer Carriages M2A1 and M2A2, and 105-mm Howitzer Mounts M4 and M4A1.

TM 9–3019..... 280-mm Gun T131 and 280-mm Gun Carriage T72.

TM 9–3036..... Operational and Organizational Maintenance: 4.5-inch Multiple Rocket Launcher M21.

TM 9–7004..... Self-Propelled 155-mm Howitzer M44 (T194).

TM 9–7012..... 90-mm Gun Full Tracked Combat Tanks M48 and M48A1.

TM 9–7212..... Self-Propelled 155-mm Gun T97.

TM 9–7220..... Operation and Organizational Maintenance: 8-inch Full Tracked Self-Propelled Howitzer M55 (T108.)

TM 11–287..... Radio Sets AN/VRQ–1, AN/VRQ–2, and AN/VRQ–3.

TM 30–245..... Photographic Interpretation Handbook.

7. Training Films

TF 6-1696------ Fire Direction Procedures—Part I: Precision Fire.

TF 6-1697----- Fire Direction Procedures—Part II: Area Fire.

TF 6-1703------ Fire Direction Procedures—Part III: Observed Fire Chart.

8. Tables of Organization and Equipment

TOE 6-537R--- Field Artillery Battery, 280-mm Gun.

TOE 6-627C---- Field Artillery Battery, 4.2-inch Mortar.

9. Firing Tables

FT 4.2-F-1----- Mortar, 4.2-inch, M30.

FT 8-J-1------- Firing Tables for Howitzer, 8-inch, M1.

FT 40AA-A-3-- Firing Tables; Gun, Automatic, 40-mm, M1, and Gun, Dual, Automatic 40-mm, M2.

FT 90AA-B-3-- Firing Tables; Gun, 90-mm, AA, M1, M1A1, and M2.

FT 105-H-4---- Firing Tables; Howitzer, 105-mm, M2A1 and M4.

FT 155-Q-2---- Firing Tables; Howitzer, 155-mm, M1.

FT 155-S-2---- Firing Tables; Gun, 155-mm, M2.

[C] FT 280-A-1- Firing Tables for Gun, 280-mm T131 (U).

FT 280-B-1----- Gun, 280 mm, T131, Firing Shell, HE, T122.

10. DA Ordnance Supply Manuals

SM 9-5-1305--- Ammunition, through 30 millimeter.

SM 9-5-1310--- Ammunition, over 30 millimeter up to 75 millimeter.

SM 9-5-1315--- Ammunition, 75 millimeter through 125 millimeter.

SM 9-5-1320--- Ammunition, over 125 millimeter.

SM 9-5-1330--- Grenades, Hand and Rifle, and Related Components.

SM 9-5-1340--- Rockets and Rocket Ammunition.

SM 9-5-1345--- Land Mines and Components.

SM 9-5-1375--- Ammunition Explosives, Bulk Propellants, and Explosive Devices.

SM 9-5-1390--- Ammunition; Fuzes and Primers.

11. DA Ordnance Standard Nomenclature Lists

SNL A-85------ Mortar, 4.2-inch, M30; Mount, Mortar, 4.2-inch, M24 and M24A1.

SNL C-20------ Howitzer, Pack, 75-mm, M1A1; Carriage, Howitzer (Pack), 75-mm, M8.

SNL C-21------ Howitzer, 105-mm, M2A1, Carriage, Howitzer, 105-mm, M2A1 and M2A2; Mount, Howitzer, 105-mm, M4 and M4A1.

SNL C-39------ Howitzer, 155-mm M1; Carriage, Howitzer, 155-mm, M1A1 and M1A2; Mount, Howitzer, 155-mm, M14.

SNL C-63------ Howitzer, 105-mm, M4; Mount, Gun, Combination, M52 and M71.

SNL C-82------ Gun, 76-mm, M32 (T91E3); Mount, Combination Gun, M76 (T138E1); Mount, Combination Gun, M76A1 (T138E2).

SNL C-86------ Howitzer, 105-mm, T96E1; Mount, Howitzer, 105-mm, T67E1.

SNL C-90------ Launcher, Rocket, Multiple, 4.5-inch, M21 (T123).

SNL D-24------ Gun, 155-mm, M2 and M2A1; Carriage, Gun, 155-mm, M1; Limber, Carriage, Heavy, M5; Platform, Firing, 155-mm Gun, M1; Mount Gun, 155-mm, M13.

SNL D-29------ Howitzer, 8-inch, M2; Carriage, Howitzer, 8-inch, M1; Limber, Carriage, Heavy, M5.

SNL D-31------ Howitzer, 240-mm, M1; Carriage, Howitzer, 240-mm, M1; Wagon, Cannon Transport, M2A1; Wagon, Carriage Transport, M3A1.

SNL D-32, Vol I- Gun, 120-mm, M1, M1A1, and M1A2; Mount, Gun, 120-mm, AA, M1, and M1A1.

SNL D-33------ Gun, 8-inch, M1; Carriage Gun, 8-inch, M2; Wagon, Cannon Transport, M1A1; Wagon, Carriage Transport, M3A1.

SNL D-38----- Gun, 90-mm, M2, M2A1, and M2A2; Mount, Gun, Antiaircraft, 90-mm, M2.

SNL D-48----- Gun, Automatic, 75-mm, T83E6 and T83E7; Mechanism, Recoil, T47E2 and T47E3; Loader-Rammer, T23; Mount, Gun, AA, 75-mm, T69 (Includes Fire Control System, T38).

SNL D-49----- Howitzer, 8-inch, T89; Gun, 155-mm, T80; Mount, 155-mm Gun. and 8-inch Howitzer, T58.

SNL D-52----- Gun, 90-mm, M36 (T119E1).

SNL D-57----- Gun, 280-mm, T131; Carriage, Gun, 280-mm, T72.

SNL D-58----- Gun, 90-mm, M41 (T139).

SNL D-63----- Howitzer, 155-mm, M45 (T186E1).

SNL G-232---- Carriage, Motor, 155-mm Gun, M40; Carriage, Motor, 8-inch Howitzer, M43.

SNL G-236---- Carriage, Motor, 155-mm Howitzer, M41.

SNL G-253---- Gun, Twin, 40-mm, Self-Propelled, M42 (T141).

SNL G-254---- Tank, 90-mm Gun, M48 and M48A1.

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SNL G–258	Howitzer, 105-mm, Self-Propelled, T98E1.
SNL G–259	Gun, Self-Propelled, Full Tracked, 155-mm, T97 and Howitzer, 8-inch, Self-Propelled, Full Tracked, 8-inch T108.
SNL G–262	Tank, 90-mm Gun, M47.
SNL G–279	Howitzer, Self-Propelled, Full Tracked, 155-mm, M44 (T194).
SNL P–5	Ammunition for Antiaircraft Artillery.
SNL R–1	Ammunition, Fixed and Semifixed, Including Subcaliber, for Pack, Light and Medium Field, Aircraft, Tank, and Antitank Artillery, Including Complete Round Data.
SNL R–4	Ammunition, Mortar, Including Fuzes, Propelling Charges, and Other Components.
SNL S–9	Rockets, All Types and Components.

12. DA Forms

DA Form 6–12	Record of Precision Fire.
DA Form 6–12–1	Record of Precision Fire for 4.2-Inch Mortar.
DA Form 6–13	Firing Battery Section Data Sheet.
DA Form 6–14	Firing Battery Data Sheet.
DA Form 6–15	Data Correction Sheet.
DA Form 6–16	FDC Computer's Record.
DA Form 6–16–1	FDC Computer's Record for 4.2-Inch Mortar.
DA Form 6–17	Firing Battery Recorder's Sheet.
DA Form 6–51	Firing Data Correction Sheet (280-mm).
DA Form 6–52	Correction Sheet, 280-mm Gun.
DA Form 6–53	Target Grid.
DA Form 9–13	Weapons Record Book—Part I.
DA Form 9–13–1	Weapons Record Book—Part II.

13. Joint Army Navy Air Force Procedure

JANAP 164	Joint Radio and Telephone Procedure for Conduct of Artillery and Naval Gunfire.

APPENDIX II

4.2-INCH MORTAR GUNNERY

1. General

a. Mortar procedures and techniques are based on the same principles as those used in the indirect firing of other artillery weapons. Procedures used for the 4.2-inch mortar differ from those used for the 105-mm howitzer in that the mortar is fired with a constant elevation and variable charge, vertical interval between the mortar position and the target is converted to a range effect, and corrections for this range effect are applied as *charge corrections*. These differences necessitate minor changes in basic procedures and techniques contained in other portions of this manual.

b. The principle of firing artillery mortars by using a constant elevation makes possible a simple procedure for transferring fires. To provide flexibility, more than one constant elevation is required. Therefore, ballistic scales have been designed for 3 elevations; i. e., 800, 900, and 1,065.

2. Observer Procedure

Field artillery observer procedure, as set forth in part Three, will be used by ground and air observers for 4.2-inch mortar units. As a guide, the following is a partial list of appropriate mortar targets:

a. Troops in the open or dug in.

b. Areas or points to be screened by smoke.

c. Reverse slopes and defiladed areas behind buildings or embankments.

d. Machine gun and mortar positions.

e. Assembly areas.

f. Infantry with tanks.

3. Firing Battery

a. The field artillery battery, 4.2-inch mortar, is composed of personnel and equipment as outlined in TOE 6–627C. The basic fire unit is the mortar platoon.

b. As a safety measure, the mask and overhead clearance must be checked prior to firing.

c. Minimum charge is computed instead of minimum elevation because a constant elevation is used in firing the 4.2-inch mortar. The minimum charge is computed in a manner similar in concept to the procedure used in the computation of maximum elevation in high-angle fire as described in paragraph 83. Minimum charge is the charge required to reach the minimum safe range. Minimum safe range is the total of the following three components:

(1) Minimum range.

(2) Vertical interval plus vertical clearance. Vertical clearances for the 4.2-inch mortar are the same as those for the 105-mm howitzer (ch. 5). The sum of vertical interval and vertical clearance is added as a horizontal effect if the sum total is an altitude above that of the mortar. If the total of vertical interval and vertical clearance is an altitude below that of the mortar, the vertical interval and vertical clearance component is not included in the computation of minimum charge.

(3) Eight range probable errors.

d. Examples of computation of minimum charge are as follows:

(1) *First example.*

Elevation 900, without extension
Fuze quick
Minimum range=1,500 yards
Altitude at mortar=456 yards
Altitude at minimum range=479 yards
Vertical clearance for fuze quick=0 yards
Range probable error at minimum range=21.8 yards, round up to 22 yards.

Minimum range (*c*(1) above)	1,500 yards
Vertical interval plus vertical clearance, 23 yards (479−476) +0 yards (*c*(2) above)	23 yards

8 range probable errors, 8×22 (c(3) above) ... 176 yards

Minimum safe range ... 1,699 yards

Minimum charge (for minimum safe range) = 8 and 2/8+, round up to 8 and 3/8.

(2) *Second example.*

Elevation 900, with extension
Fuze VT
Minimum range = 3,800 yards
Altitude at mortar = 512 yards
Altitude at minimum range = 463 yards
Vertical clearance factor fuze VT = 80 yards
Range probable error = 50 yards

Minimum range (c(1) above) ... 3,800 yards
Vertical interval plus vertical clearance (c(2) above) ... 31 yards
Altitude at minimum range ... 463 yards
Vertical clearance ... 80 yards
543 yards
Altitude at mortar ... 512 yards
Vertical interval plus vertical clearance ... 31 yards
8 range probable errors (c(3) above) ... 400 yards

Minimum safe range ... 4, 231 yards
Minimum charge = 29 and 6/8+, round up to 29 and 7/8.
The minimum charge is modified by met and VE corrections, when appropriate.

Note. If fuze quick were used instead of fuze VT, the vertical clearance would be 0 yards instead of 80 yards and the resultant vertical interval plus vertical clearance would be −49 yards and as such would not be included in computation.

e. When live ammunition is being fired in training, a clearance zone of 300 yards or 100 yards plus 8 range probable errors, whichever is larger (AR 385–63), is prescribed between personnel and the minimum range line. This zone is increased by 50 percent when time fuzed shell is fired.

f. Detailed duties of firing battery personnel are covered in FM 6–50.

4. Fire Direction

Mortar fire direction procedures and techniques are based on the same principles as those used in the indirect firing of other artillery weapons. The constant elevation and the variable charge used with the mortar necessitate the following changes (*a–f* below) in FDC procedures:

a. Charge. Charge is the term applied to the number of charge units used to fire the mortar projectile. The smallest unit of charge is ⅛ charge. The charges used for firing are from 5 through 41. The command CHARGE includes the units of propellant corresponding to chart range, plus (minus) corrections for vertical interval, plus (minus) any other corrections applied.

Caution: The use of charges less than charge 5 may result in the projectile sticking in the tube and/or nonarming of the fuze. Certain restrictions have also been placed on the firing of shell HE, M329 and M329B1, *without cartridge container extension* during periods of low air temperatures. Owing to physical characteristics of the propellant, firing at low temperatures results in excessive chamber pressures. Restrictions limiting the charge unit that may be fired at given air temperatures without cartridge container extension are listed below:

*Temperature, degrees F.**	*Possible charge units*
Over 60°	5 through 25 and ⅛
20° to 60°	5 through 23
0° to 20°	5 through 20
−40° to 0°	5 through 17
Below −40°	No firing without cartridge container extension.

*No temperature restrictions are placed on firing *with* cartridge container extension.

b. Range Charge. Range charge is the firing table charge corresponding to the chart range. The range charge corresponds to firing table elevation for guns and howitzers.

c. Adjusted Range Charge. Adjusted range charge is the combination of the range charge and range corrections expressed in units of charge. The adjusted range charge corresponds to adjusted elevation for guns and howitzers.

d. Site Charge. Site charge is a correction in units of charge to compensate for the vertical interval between the mortar position and the target. The vertical interval (VI) between the mortar position and the target is converted to a horizontal range effect based on the angle of fall. This horizontal range effect is compensated for by converting *the range effect in yards* to a corresponding value in *units of charge* and applying this value as a correction to the range charge. The site charge for a 100-yard vertical interval is read on the site scale of the GFT fan opposite the charge under the charge gageline. The site scale is plotted in $\frac{1}{8}$ charge units (fig. 236). When the target is above the mortar position, the sign of the site charge is plus; when the target is below the mortar position, the sign of the site charge is minus. Site charges for vertical intervals other than 100 yards are computed by multiplying the site charge read from the GFT fan by the VI (in yards or meters) divided by 100. When the computed site charge is less than $\frac{1}{16}$, it is ignored. For example—

Elevation 900, without extension; chart range 3,230, VI −40 yards.

Site charge read from GFT fan for 100-yard VI is $\frac{3}{8}$.
Site charge for −40 yard VI $= (\frac{3}{8} \times (-40/100)) = -\frac{1}{8}$.

e. Adjusted Charge. Adjusted charge is the charge required to place the mean point of impact on the target. The adjusted charge corresponds mathematically to the adjusted quadrant elevation for guns and howitzers.

f. Charge Gageline. A charge gageline is constructed on the mortar GFT fan in the same way that an elevation gageline is constructed for other artillery weapons. The charge gageline is constructed to read the adjusted range charge when the hairline is set over the chart range.

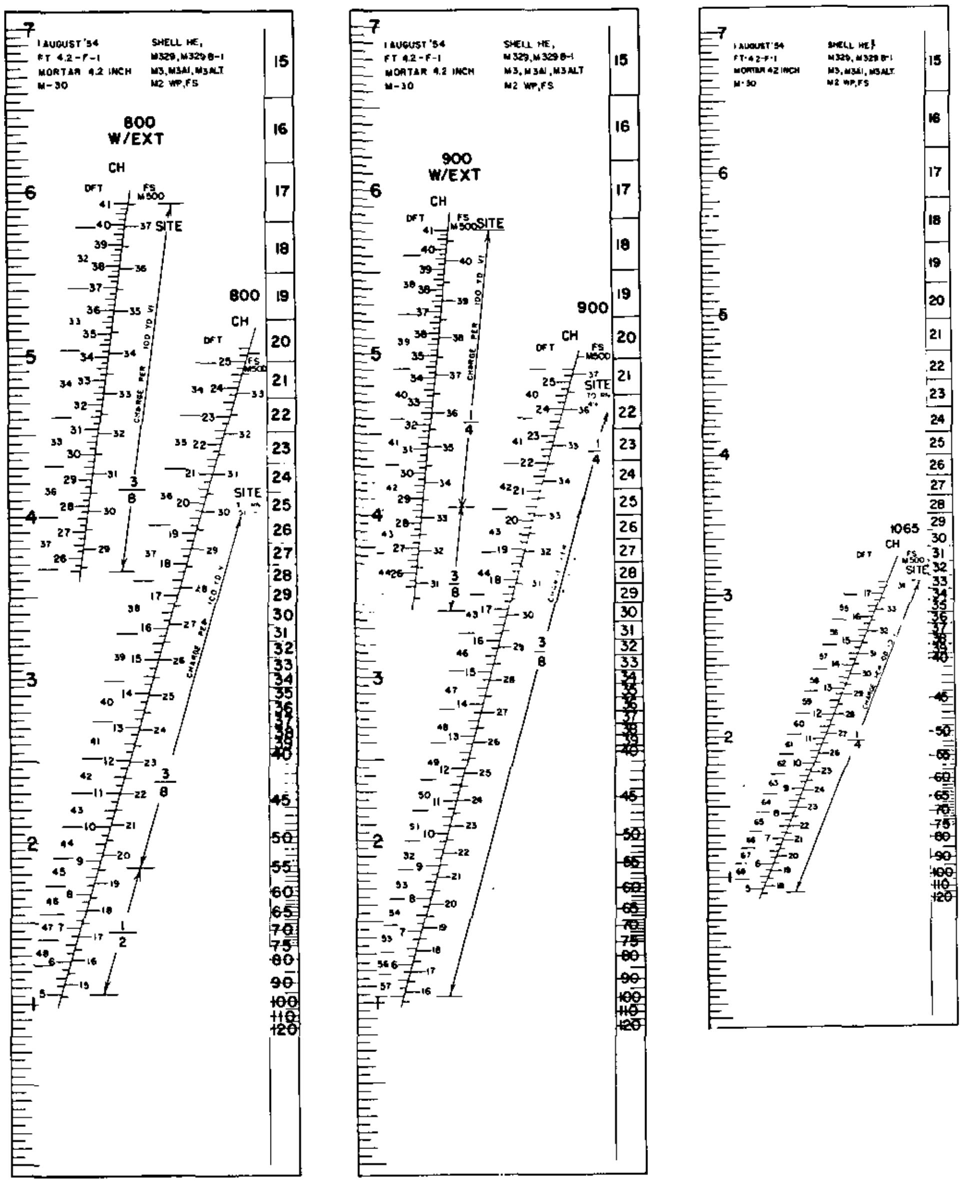

Figure 236. Mortar ballistic scales.

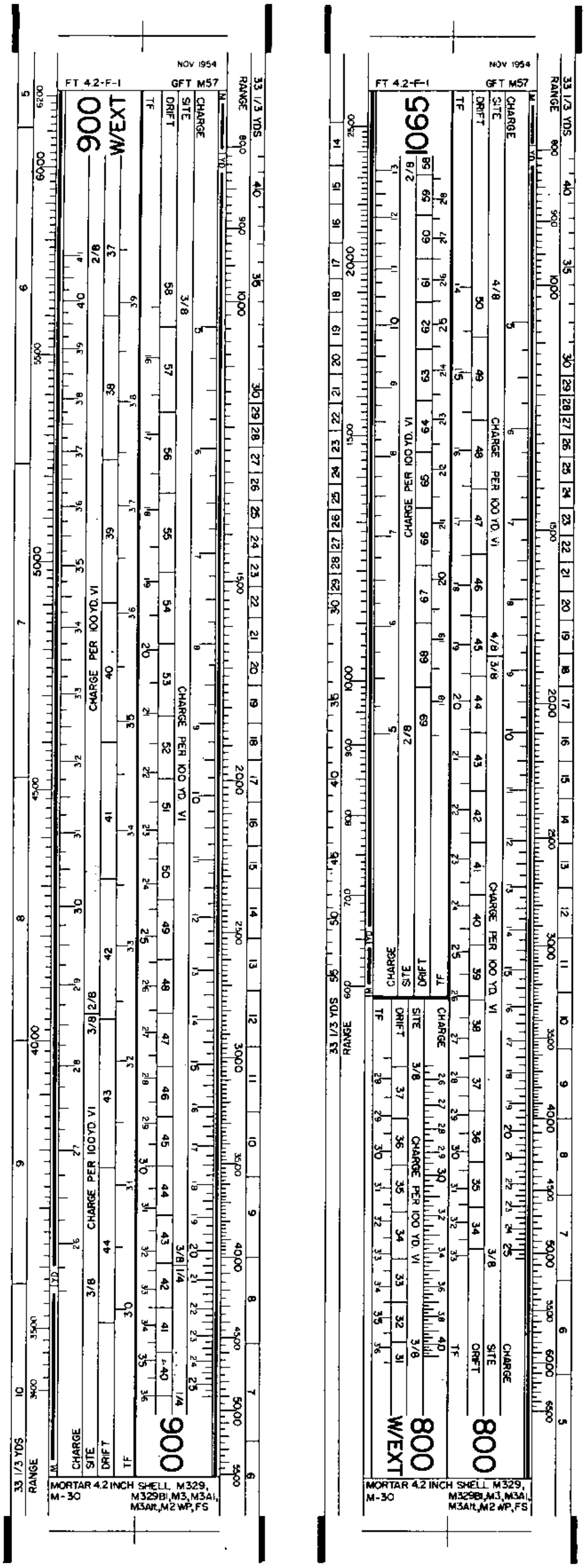

Figure 237. GFT, M57.

5. FDC Equipment

The present 105-mm howitzer FDC equipment, with certain modifications, is appropriate for use with the 4.2-inch mortar.

a. Mortar ballistic scales (fig. 236) are designed for use in firing at 3 elevations (800, 900, and 1,065). On each of the ballistic scales for elevations 800 and 900, the ballistic data lines are divided into 2 segments. One segment provides ballistic data for use in firing without the cartridge container extension; the other segment provides ballistic data for use in firing with the cartridge container extension. Only 1 segment (without cartridge container extension) is provided for elevation 1,065.

b. Units not equipped with the GFT fan will use the GFT, M57 (fig. 237), and the range-deflection fan as a substitute. Procedures are the same in principle as those used with the GFT fan. Technique is changed only in those matters that are peculiar to the use of a GFT and a range-deflection fan. Techniques in using the GFT and a range-deflection fan are explained in greater detail in chapter 17.

c. The Target Grid (DA Form 6–53) has a diameter representing approximately 5,000 meters (scale 1:25,000). At mortar chart ranges, use of the Target Grid is facilitated by folding (cutting) that part of the Target Grid that covers the plotted battery position.

6. Selection of Elevation

Of the 3 elevations (800, 900, and 1,065), 900 is normally used because it best approximates the optimum for stable, accurate and lethal fire. In addition, elevation 900 can be fired within 125 yards of minimum range and 175 yards of maximum range. The other elevations may be used to fire minimum or maximum range or to change height of burst when VT fuze is used. They may also be required because of the terrain or the tactical situation.

7. Mortar Fire Commands

a. The sequence of mortar fire commands differs from that used in other artillery fire commands since charge and elevation are announced in reverse order.

Howitzer commands	*Mortar commands*
BATTERY ADJUST	PLATOON ADJUST
SHELL HE	SHELL HE
CHARGE 5	ELEVATION 900
FUZE QUICK	FUZE QUICK
CENTER 1 RND	CENTER 1 RND
CORRECTIONS RIGHT 8	
DEFLECTION 2815	DEFLECTION 2849*
SITE 305	(No command for site)
ELEVATION 400	CHARGE 29 AND ⅛**

* *Includes deflection correction.*
** *Includes site charge.*

b. When the cartridge container extension is *not* to be used for firing, the command for elevation is announced as ELEVATION (SO MUCH), WITHOUT EXTENSION; when the cartridge container extension is to be used for firing, the command for elevation is announced as ELEVATION (SO MUCH).

c. The command for site to compensate for the vertical interval is eliminated. The site charge is added algebraically to the adjusted range charge to obtain the charge to be fired.

d. The CHARGE is announced to the nearest one-eighth of a charge unit; for example, CHARGE TWO SIX AND FOUR-EIGHTHS (26 and 4/8).

e. A FDC Computer's Record for 4.2-inch mortar (DA Form 6–16–1) is shown in figure 238.

8. Precision Registrations

Mortars are registered to determine an adjusted deflection and an adjusted range charge. The adjusted deflection is determined in the same manner described in chapter 18. The determination of the adjusted range charge differs from normal procedures in that range changes are made by changing the charge rather than the elevation. Within the range limits of the 4.2-inch mortar, a change of ⅜ charge equals approximately 50 yards on the ground; therefore, in FFE, ⅜ charge is substituted for 1 fork. The charge is changed ⅜ in the appropriate direction when 3 rounds fired at the same charge are all in the same sense; e. g., over, for range. An adjusted charge is determined after six rounds in FFE have yielded positive FDC range sensings of both over and short. Requirements of a valid registration are the same as those for the 105-mm howitzer. After six positive FDC range sensings have been obtained and requirements of a valid registration have been met, the adjusted range charge is determined as follows (*a–f* below):

a. With an equal number of overs and shorts, all rounds fired at the same charge, the adjusted range charge is the charge fired minus the site charge.

b. With an equal number of overs and shorts, rounds fired at both limits of a ⅜-charge bracket,

FDC COMPUTER'S RECORD FOR 4.2-INCH MORTAR
(FM 6-40)

BATTERY	PLATOON	TIME MISSION	RECEIVED	COMPLETED	DATE	CONCENTRATION NUMBER
A	2d		1300	1315	15 Jan 57	AE 102

FIRE MISSION		INITIAL FIRE COMMANDS
Thunder 48, FM, Coordinates 76213450, Azimuth 6310, Inf platoon, WA.	DEFLECTION 2827	Plat ADJUST, Sp Corr
	DRIFT CORRECTION L 46	Shell HE — Lot X
	RANGE 3250	El 900 — ☐ WITH EXTENSION ☒ WITHOUT EXTENSION
FDO ORDER Alt 500, 2d Plat, Lot X, Center, El 900 w/o ext, 5 volleys, Conc AE 102		Fz Q
	RANGE CHARGE 16 2/8	MF C (1)
		Df 2873
	SITE CHARGE 3/8	Ti —
		Chg 16 5/8 — (2)

OBSERVER CORR		SUBSEQUENT FIRE COMMANDS									
DEVIATION	RANGE	Fz, MF	DRIFT Corr	CHART df	Piece df	Rg	Ti	Si chg	Rg chg	Chg	AMMO EXPENDED
L 100	+400		L 44	2858	2902	3650	-	3/8	18 2/8	18 5/8	4
R 50	-200		L 45	2846	2891	3450	-	3/8	17 2/8	17 5/8	6
	-100		L 45	2845	2890	3350	-	3/8	16 6/8	17 1/8	8
L 10	+50 FFE	plt (5)	L 45	2848	2893	3400	-	3/8	17	17 3/8	38

EM Est 10 casualties; Remainder withdrawing

DATA FOR REPLOT

COORDINATES	ALTITUDE	FUZE	CONCENTRATION NUMBER
76153465	500	Q	AE 102

AMMUNITION

TYPE	M329	M2 (WP)	M3A1	Fz VT	Fz M51			
TOTAL	325	100	50	100	325			
RECEIVED	—	—	—	—	—			
ON HAND	325	100	50	100	325			
EXPENDED	38	—	—	—	38			
REMAINING	287	100	50	100	287			

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Figure 238. Computer's record for mortar, 4.2-inch, M30.

the adjusted range charge is the mean charge minus the site charge.

c. With an unequal number of overs and shorts, the adjusted range charge is computed as follows:

Adjusted range charge = mean charge ± charge change − site charge.

Note. Charge change =

$$\left(\frac{\text{difference in number of overs and shorts}}{2\times\text{number of rounds fired}}\times\frac{4}{8}\right)$$

d. Fractional values of the charge change are rounded to the nearest ⅛ charge.

e. A target hit during adjustment is used as the first round in fire for effect, and five more rounds are fired at the same charge. In the computation of charge change, a sensing of TARGET is considered as both ½ over and ½ short and is disregarded in determining the difference in number of overs and shorts.

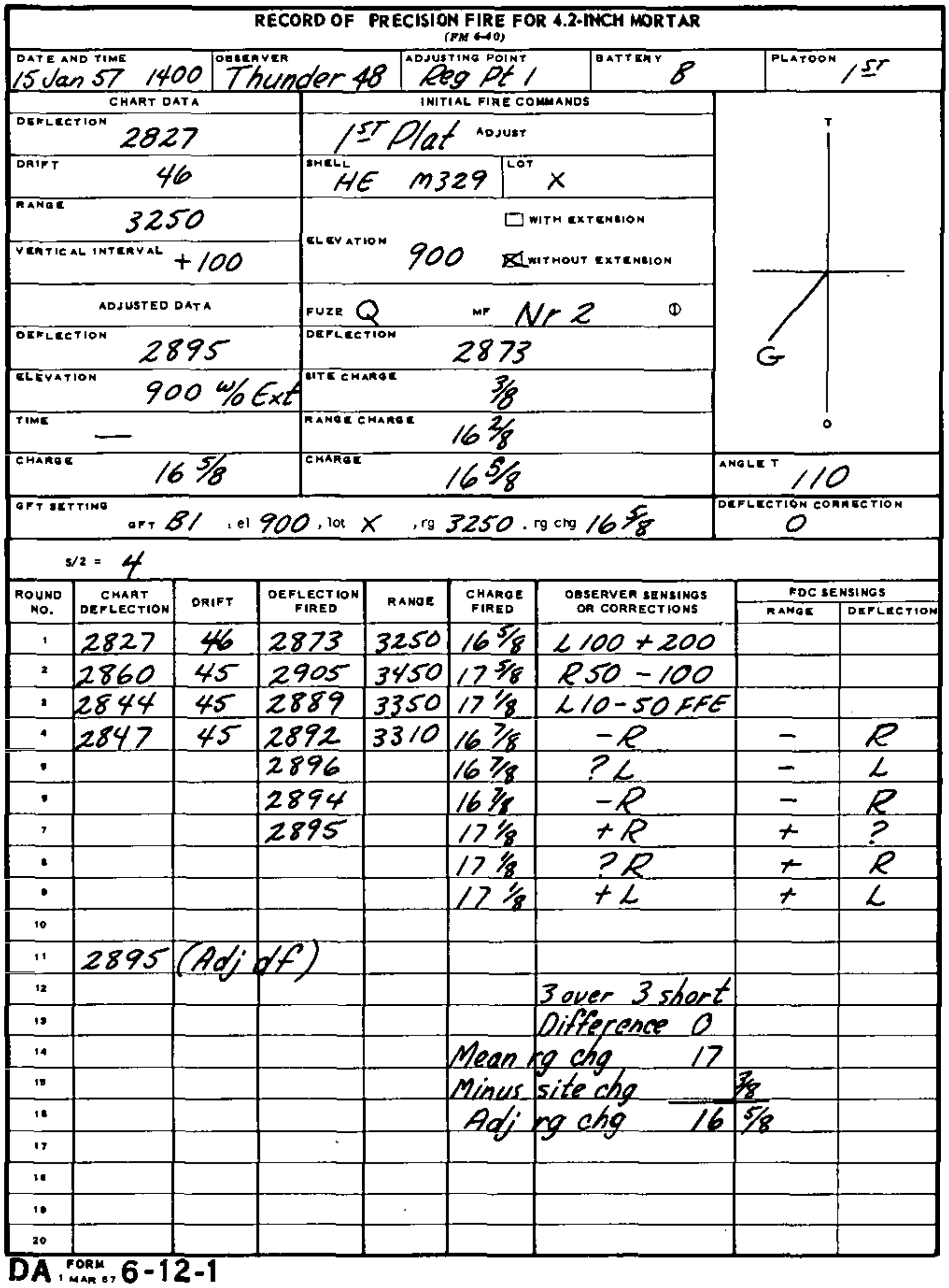
f. A Record of Precision Fire for 4.2-Inch Mortar (DA Form 6–12–1) is shown in figure 239.

9. Examples of Computation of Adjusted Range Charge

a. Example 1. All rounds in fire for effect are fired at the same charge. The site charge applied is minus ⅜. Firing is as follows:

	Charge	*FDC sensings*
First 3 rounds	36 and ⅛.	− − +
Second 3 rounds	36 and ⅛.	+ − −

The registration is valid since one or more rounds are in the opposite sense from the others. Since all rounds were fired at the same charge, the mean charge is 36 and ⅛. The preponderance is



RECORD OF PRECISION FIRE FOR 4.2-INCH MORTAR (FM 6-40)

DATE AND TIME	OBSERVER	ADJUSTING POINT	BATTERY	PLATOON
15 Jan 57 1400	Thunder 48	Reg Pt 1	B	1st

CHART DATA		INITIAL FIRE COMMANDS	
DEFLECTION	2827	1st Plat ADJUST	
DRIFT	46	SHELL HE M329	LOT X
RANGE	3250	ELEVATION 900	☐ WITH EXTENSION ☒ WITHOUT EXTENSION
VERTICAL INTERVAL	+100		
ADJUSTED DATA		FUZE Q	MF Nr 2
DEFLECTION	2895	DEFLECTION	2873
ELEVATION	900 w/o Ext	SITE CHARGE	⅜
TIME	—	RANGE CHARGE	16 ⅞
CHARGE	16 ⅝	CHARGE	16 ⅝

ANGLE T 110

DEFLECTION CORRECTION 0

GFT SETTING GFT B1, el 900, lot X, rg 3250, rg chg 16 ⅝

s/2 = 4

ROUND NO.	CHART DEFLECTION	DRIFT	DEFLECTION FIRED	RANGE	CHARGE FIRED	OBSERVER SENSINGS OR CORRECTIONS	FDC SENSINGS RANGE	FDC SENSINGS DEFLECTION
1	2827	46	2873	3250	16 ⅝	L100 +200		
2	2860	45	2905	3450	17 ⅝	R50 −100		
3	2844	45	2889	3350	17 ⅛	L10 −50 FFE		
4	2847	45	2892	3310	16 ⅞	−R	−	R
5			2896		16 ⅞	?L	−	L
6			2894		16 ⅞	−R	−	R
7			2895		17 ⅛	+R	+	?
8					17 ⅛	?R	+	R
9					17 ⅛	+L	+	L
10								
11	2895 (Adj df)							
12						3 over 3 short		
13						Difference 0		
14					Mean rg chg	17		
15					Minus site chg	⅜		
16					Adj rg chg	16 ⅝		
17								
18								
19								
20								

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Figure 239. Record of precision fire for mortar, 4.2-inch, M30.

2 shorts (4 shorts less 2 overs). Computation of adjusted range charge is as follows:

Adjusted range charge = mean charge ± charge change − site charge

Mean charge = 36 and ⅛

Charge change $= \left(\frac{4-2}{2\times6}\times\frac{4}{8}\right) = \frac{1}{12}$ (round off to ⅛)

Site charge = −⅜

Adjusted range charge = 36 and ⅛ + ⅛ − (−⅜) = 36 and ⅝.

b. Example 2. The 6 rounds in FFE are fired at 2 different charges. The site charge applied is plus ⅜. Firing is as follows:

	Charge	*FDC sensings*
First 3 rounds (Since all 3 rounds are the same sense (+), the charge is decreased by ⅜ and 3 more rounds are fired.)	22 and ⅜	+ + +
Second 3 rounds	22	− − +

The registration is valid since one or more rounds are in the opposite sense. The preponderance is 2 overs (4 overs less 2 shorts). The mean charge is 22 and ⅛. Computation of adjusted range charge is as follows:

Adjusted range charge = mean charge ± charge change − site charge.

Mean charge = 22 and ⅛

Charge change $= \left(\frac{4-2}{2\times6}\times\frac{4}{8}\right) = \frac{1}{12}$ (round off to ⅛)

Site charge = +⅜

Adjusted range charge = 22 and ⅛ − ⅛ − (+⅜) = 21 and ⅝.

10. Transfer Limits

Transfer limits for mortar fire are the same as those for other field artillery weapons. When transfer limits include both segments of a ballistic data line, separate corrections should be obtained for each segment. Corrections obtained from one segment are not applicable to the other segment; therefore, a separate registration must be made for each segment of the ballistic data line.

11. Temporary Deflection Index

A temporary deflection index is constructed on the firing chart as described in paragraph 297. Because of the large drift effect, this index is offset by the amount of the drift correction to the registration point or to the center of sector. An arbitrary offset of 40 mils (e. g., deflection 2,840 mils) may be used instead of the computed drift correction. By including drift in the temporary deflextion index, the necessity of applying a drift correction to each round fired prior to the construction of the deflection index is eliminated.

a. Example 1. The mortar platoon is laid on the registration point. The referred deflection to the aiming posts is 2,800.

Drift at registration point range (3,000 yards), elevation 900, without extension	= R 47 mils
Drift correction	= L 47 mils

The temporary deflection index is constructed at deflection 2,847.

b. Example 2. The mortar platoon is laid on azimuth 5,600 (center of sector). The referred deflection to the aiming posts is 2,800.

Drift at range to center of sector (5,000 yards), elevation 900, with extension	= R 39 mils
Drift correction	= L 39 mils

The temporary deflection index is constructed at deflection 2,839.

12. Deflection Corrections

Since the mortar sight does not contain a gunner's aid, deflection corrections are made in the FDC for each round fired. The total (chart deflection plus or minus deflection corrections) is announced by the FDC personnel. Separate deflection correction scales are used for each segment of the ballistic data line. The deflection index is based on the adjusted deflection obtained from the initial registration. All corrections from later registrations or met messages are applied as stated in paragraph 349.

13. Charge Corrections

a. Charge corrections are applied to the GFT fan as follows: Construct a GFT setting for either segment of the ballistic data line. This setting is constructed by placing the hairline over the chart range. Then a charge gageline is drawn from the vertex of the cursor through the adjusted range charge (par. 343) on the segment of the ballistic data line from which the adjusted range charge is obtained. As ballistic data are not interchangeable between segments, a separate GFT setting is required for each segment of the ballistic data line that is to be used for firing (fig. 240).

b. A GFT setting is recorded as follows: GFT B 1 (1st Platoon): elevation 900, lot X, range 4,500, range charge 32 and ⅜.

14. VT Fuze

Since mortar fire is high-angle fire, no correction for height of burst in firing the VT fuze is necessary.

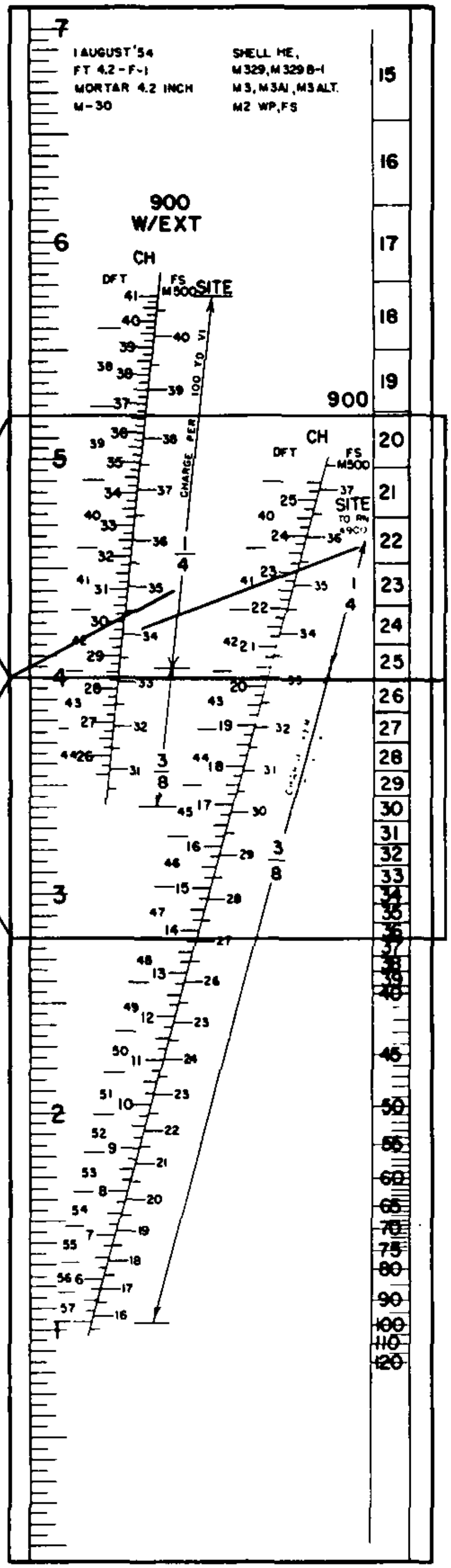


Figure 240. Charge gagelines.

15. Time Fire

Time fire for area fire missions is not normally used because of the large fuze height-of-burst probable error. Time fire may be used for illumination and smoke. High-burst registrations, while possible, normally should not be attempted.

16. Data For Replot

Procedures for reporting data for replot are the same as for low-angle artillery fire (par. 420). Procedures for determining coordinates to be reported, differs from normal procedures owing to the use of variable charges.

a. To determine the replot deflection, the deflection correction is stripped from the adjusted deflection in the same manner as in high-angle artillery fire. The replot range is read from the GFT fan under the hairline when the charge gageline is set over the adjusted range charge.

b. When a grid sheet firing chart is used, the altitude assigned to the target is the altitude determined from the initial fire request.

c. If the firing chart is a map, the replot altitude assigned to the target is the map altitude determined from the replot location of the target. In firing percussion or VT fuze, if the site charge determined from the altitude of the initial replot location of the target does not agree with the site charge fired, the replot site charge must be stripped from the charge fired. The replot range must then be changed to agree with the new adjusted range charge, and a site charge must be determined from the altitude of the new replot location. This procedure is repeated until two consecutive computations yield the same site charge. This last site charge is stripped from the charge fired to determine the correct adjusted range charge. The correct replot range is read from the GFT fan under the hairline when the charge gageline is over this corrected adjusted range charge.

Example (GFT B 1: elevation 900, without extension; lot X; range 3,200; range charge 16 and 6/8):

Elevation	900 (without extension)
Charge fired	19 and 5/8
Site charge fired	+3/8
First apparent adjusted range charge	19 and 1/4 (range 3,630 yards)
Site charge determined from initial replot position.	+3/8

Second apparent adjusted range charge	19 and ⅜ (range 3,670 yards)
Site charge from second replot position.	+⅜
Correct adjusted range charge (set gageline over).	19 and ⅜
Replot range (read under hairline from GFT fan when charge gageline is over adjusted range charge).	3,670 yards

d. Coordinates reported in data for replot are obtained by using the deflection and range determined as stated in *a* and *c* above.

17. Tabular Firing Tables

An appendix to the Tabular Firing Table FT 4.2–F–1 contains ballistic information that is necessary in using the constant elevation variable charge system. The system of combining elevation changes and charge changes, as covered in the main body of the firing table, normally is not used by field artillery mortar units.

18. Met Computations

Met computations and corrections are determined and applied in the same manner as for light artillery, except that the effects of deviations from standard air temperature are not considered. Since these effects are negligible in the mortar trajectory, no corrections are applied for them.

19. Computation of Velocity Error

Velocity error is computed for the 4.2-inch mortar in the same manner as for light artillery, with the following exceptions:

a. An adjusted range charge, rather than an adjusted elevation, is determined from registration.

b. The range corresponding to the adjusted range charge is read from the GFT fan opposite the adjusted range charge.

Example: A 4.2-inch mortar platoon has registered on the registration point, using elevation 900, without extension. Met range (rg) effect computed from a concurrent met message is −75 yards. The adjusted charge from registration is 22 and ⅜. The site charge fired is plus ⅛. Computation is as follows:

Adjusted charge	22 and ⅜
Site charge	−(+⅛)
Adjusted range charge	22 and ¼
Range corresponding to adjusted range charge (22 and ¼) (to nearest 10 yards) (read from GFT fan opposite adjusted range charge).	=4,360 yards
Chart range to registration point	4,180 yards
Total range corrections (at 4,180 yards)	−180 yards
Total range effect (with charge 22 and ¼)	+180 yards
Met range effect as computed from concurrent met message (charge 22 and ¼).	−75 yards
VE range effect (total range effect minus met range effect) (−180−(−75)).	−105 yards
MV unit effect (charge 22 and ¼)	+8.3 yards

$$\text{VE (f/s)} = \frac{\text{VE rg effect}}{\text{MV unit effect}} = \frac{-105}{+8.3} = -12.6 \text{ f/s (round off to } -13 \text{ f/s)}$$

20. Center-of-Impact Registration

a. Deflection corrections from a center-of-impact (CI) registration are determined and applied in the manner described in paragraph 353.

b. For range corrections, the altitude of the CI having been determined, the vertical interval is computed and converted to site charge. The site charge is then stripped from the adjusted charge to obtain the adjusted range charge. (The adjusted charge is the charge at which all rounds are fired.) The charge gageline is constructed on the GFT fan by placing the hairline over the chart range (range to CI) and drawing the charge gageline from the cursor vertex through the adjusted range charge.

21. Calibration

Comparative calibration of the 4.2-inch mortar (for grouping of weapons) is conducted and applied in the manner described in chapter 28.

APPENDIX III
4.5-INCH ROCKET LAUNCHER GUNNERY

1. General

The 4.5-inch rocket launcher is an area fire weapon to be used on targets when surprise fire in tremendous volume is desired. Rockets are designed to supplement the fires of other weapons and to saturate an area with a blanket of fire. The rockets have inherently large dispersion factors, and for this reason care must be exercised in selecting and firing on targets near supported troops.

2. Capabilities

a. Rocket launchers are either self-propelled or towed. The towed type has many advantages; it is compact and relatively light, has a low silhouette, is highly maneuverable, and may be lifted by helicopter, thus adding firepower to an otherwise lightly equipped combat force. The launcher may be emplaced well forward and in concealed positions, and it can be moved into these positions more rapidly and easily than heavier, less mobile weapons. It possesses high mobility on roads as well as across country and may be moved manually for short distances. A 4.5-inch rocket battery equipped with 12 launchers M21 can fire 300 rockets in 12 seconds. This volume of fire is the approximate equivalent of a 1-volley TOT fired by 17 battalions of 105-mm howitzers. The high-explosive 4.5-inch rocket projectile is comparable to the 105-mm howitzer high-explosive shell in both concussion and fragmentation effects.

b. Rocket fire can be readily shifted in width and depth, positions can be changed, and units can be regrouped to bring great firepower to bear on important targets.

3. Limitations

The limitations of the rocket launcher are that—

a. Flash and blast of the burning propellant may disclose the launcher position. The propellant burns for about 90 feet after leaving the launcher, leaving a distinct trail of flame, and the blast produces a cloud of smoke, dust, and debris, the size and character of which is dependent on the type of soil, vegetation, and weather conditions. The disclosure of the position by flash and blast is minimized by selecting positions in deep defilade, under trees or behind houses, or on hard, damp, or grass-covered soil; by smoke screening the position area; by using flash and smoke to simulate firing from dummy positions; or by coordinating with artillery and other arms to neutralize enemy observation by smoke or fire.

b. The launcher position generally must be in the vicinity of or forward of the light artillery position areas because of the limited range of the rocket. The dispersion and low muzzle velocity of rockets make their employment as a close-range, direct-fire weapon impractical.

c. The blast from the rocket propellant is dangerous to personnel and materiel 50 yards to the rear and at least 50 feet to either flank of the launcher (FM 6–55). The service of the launcher therefore is impeded, since ammunition for successive loadings must be placed at a distance from the launcher.

4. Dispersion Pattern

The shape of the dispersion pattern varies with (1) range and (2) low- and high-angle fire. Table XVIII shows range and lateral dispersion in yards at various ranges; figure 241 illustrates the relative shapes of dispersion patterns at varying ranges.

Table XVIII. Dispersion for T160E5 (M32) Rockets

Range (yards)	Range dispersion (8 probable errors) (yards)	Lateral dispersion (8 probable errors) (yards)
1,000	768	40
2,000	768	72
3,000	760	112
4,000	744	152
5,000	728	192
6,000	704	232
7,000	672	272
8,000	616	328
8,980	448	456
8,000 (HA)	528	560
7,000 (HA)	608	608

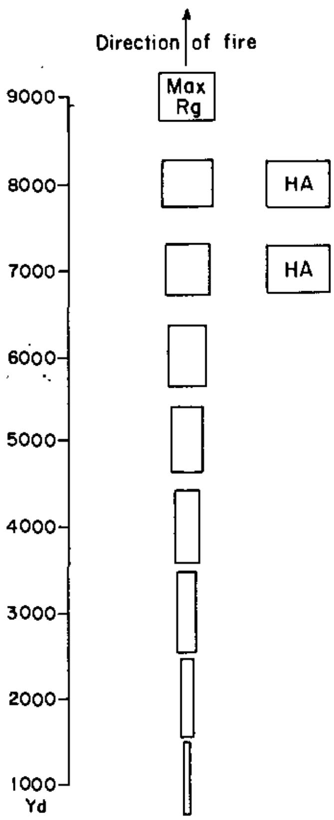


Figure 241. Relative shape of dispersion patterns for T160 (M32) rockets.

5. Mission

Any of the missions that are assigned to field artillery (FM 6–101), except direct support, may be assigned to the rocket battalion (battery).

6. Firing Battery

Normal procedure as described in chapter 5 is used in laying the rocket battery for direction. Elevation scales are used in laying for elevation, the command being received from the fire direction center as ELEVATION (SO MUCH). Since there is no on-carriage site scale on the rocket launcher, elevation is always a quadrant elevation. The gunner's quadrant may also be used in laying for elevation, the command being QUADRANT (SO MUCH). Duties of firing battery personnel are covered in detail in FM 6–55.

7. Observer Procedure

Observer procedure used in rocket fire is like the standard observer procedure stated in chapters 7 through 14 except as shown in *a* and *b* below.

a. Precision Fire.

(1) *Registration.* In view of the dispersion of the 4.5-inch rocket, a normal registration is impractical because the corrections obtained would be questionable. To determine approximate registration corrections for the 4.5-inch rocket, rounds for a center-of-impact registration should be fired from the same launcher tube.

(2) *Destruction.* The rocket launcher, because of its great dispersion factor, is not suitable for destruction missions.

b. Area Fire. The principles of bracketing used with area fire apply to rocket fire. Fire is opened with two-round salvos fired from one launcher, preferably the launcher nearest the battery or platoon center. The object of adjustment is to inclose the target area in a range bracket of suitable depth, properly centered for direction. The following procedure is used by the observer once the fire request has been sent to the fire direction center:

(1) The observer moves the fire in range bounds of 400 yards or multiples thereof until a range bracket is established.

(2) The observer moves the fire in deflection bounds of 200 yards until a deflection bracket is established.

(3) When these brackets (400 yards in range and 200 yards in deflection) have been established, the observer splits them and requests fire for effect.

c. Example. The following example illustrates the procedure (communication procedures omitted) for a typical area fire adjustment by a ground observer for a 4.5-inch rocket:

Observer: FIRE MISSION.
FDC: SEND YOUR MISSION.

Observer: COORDINATES 257688, AZIMUTH 3750. INFANTRY COMPANY ASSEMBLED IN WOODS, FUZE DELAY, WILL ADJUST.

FDC: ON THE WAY.

Observer correction: LEFT 200, ADD 400 (sensing was air, short, right).

FDC: ON THE WAY.

Observer correction: RIGHT 100, DROP 200, FIRE FOR EFFECT (sensing was air, over, left).

FDC: ON THE WAY.

Observer: END OF MISSION. INFANTRY DISPERSED, ESTIMATED 50 CASUALTIES (sensing was mixed, range correct, line).

Note that in the above example, the observer quickly established both a 400-yard range bracket and a 200-yard deflection bracket and entered fire for effect on splitting them. If the observer attempts to refine the above brackets, time will be wasted, accuracy will not be improved, and the rocket launcher site may be disclosed.

8. Survey

Principles of survey as explained in TM 6–200 apply to rocket battalion survey. Survey operations in the rocket battery or platoon are usually confined to a position area survey with control provided by battalion or by other artillery units in the vicinity. The battery or platoon center is located as quickly as possible, usually by a short traverse. When time permits, a registration point may be located and plotted on the firing chart and an orienting angle that is used in laying the battery or platoon for direction is determined. Normally, the initial direction of fire is established by grid azimuth.

9. Fire Direction Technique

In general, the principles of fire direction as described in part FOUR of this manual apply to fire direction in rocket units except as noted in *a* through *d* below.

a. All firing charts are maintained at the battery or platoon FDC.

b. The rocket battery is responsible for fire direction and control of fire. The platoon may establish and operate its own FDC in case it is detached from the battery.

c. On receipt of a fire mission, the target is plotted on the firing chart in the normal manner, and firing data are determined and sent to the rocket platoons.

d. Fire commands for rocket platoons are similar to those for howitzer (gun) batteries and follow the same sequence. In rocket fire, the term *ripple* is used as a preliminary command to indicate the number of complete loadings to be prepared for firing in order to avoid delay between volleys or salvos. The preliminary command THREE RIPPLES READY indicates that three complete loadings will be prepared for each launcher. Examples of fire commands are as follows:

(1) *Fire for effect mission:*

PLATOON ADJUST	PA
SHELL HE	SH HE
LOT X	LOT X
FUZE VT	FZ VT
CORRECTIONS 0	CORR 0
DEFLECTION 3005	DF 3005
PLATOON RIGHT, 1 RIPPLE	PR, 1 RIP
AT MY COMMAND	AMC
ELEVATION 428	EL 428

(2) *Will adjust mission (using two-round salvo in adjustment):*

PLATOON ADJUST	PA
SHELL HE	SH HE
LOT X	LOT X
FUZE QUICK	FZ Q
CORRECTIONS 0	CORR 0
DEFLECTION 2661	DF 2661
NO. 3, 2 ROUNDS	NO. 3, 2 RNDS
ELEVATION 316	EL 316

(3) *Center-of-impact registration:*

NO. 3 ADJUST	NO. 3 A
SHELL HE	SH HE
LOT X	LOT X
FUZE QUICK	FZ Q
CORRECTIONS 0	CORR 0
DEFLECTION 2916	DF 2916
NO. 3, 1 ROUND	NO. 3, 1 RND
ELEVATION 497	EL 497

10. Corrections

a. The procedure for determining corrections for rocket firing is essentially the same as for other field artillery. A center-of-impact (CI) registration is normally fired. This registration is accomplished by firing single rounds at short time intervals from a single launcher and determining the center of impact of the group. A registration should not require more than 5 minutes' active firing and should be conducted from an alternate launcher position. The launcher must be bore sighted immediately before registering, and the same tube must be used for each round. Twelve usable rounds should be fired to determine the center of impact; however, if time is limited, a minimum of accuracy may be obtained with six. The location of the center of impact is then computed and plotted on the chart, and a range and deflection correction is determined. A GFT setting, a deflection correction, and a deflection correction scale are established by using the procedures outlined in chapter 19. Transfer limits are not fixed as in other artillery; unobserved transfers should be fired within close limits of the CI registration point. It is desirable that every effort be made to obtain observation and to adjust all rocket fire visually.

b. Should it become necessary to deliver unobserved rocket fires without registration, met corrections may be determined and applied. Only four effect factors are considered in computing met corrections for use with rockets. They are—

(1) Temperature of propellant.
(2) Density.
(3) Wind.
(4) Drift.

c. In computing range effects, the usual method of *variation from standard multiplied by unit effect* is followed. Since rocket fires corrected only by met data may be only a little better than map data uncorrected, delivery of such fires closer than 800 yards to friendly elements is not advisable.

11. Suitable Targets

a. Suitable targets for 4.5-inch rocket artillery are—

(1) Troops in open, in trenches, or in assembly areas.
(2) Strong points and light fortifications.
(3) Formations of lightly armored vehicles, tanks, or self-propelled guns.
(4) Vehicle assembly areas.
(5) Command posts, ammunition, and supply installations.
(6) Helicopter landing zones.

b. In defensive combat, platoons or batteries may be attached to other artillery units in order to cover the widest possible front. Rocket fire is particularly effective for—

(1) Beach defense to destroy landing craft and disembarking troops.
(2) Firing chemical or screening agents.
(3) Breaking up hostile attacks.

c. Other missions on which rocket artillery may be employed are—

(1) Reinforcing or adding depth or width to fires, especially in preparation and counterpreparation.
(2) Harassing fires.

12. Types of Fire

In general, rocket fires are classified as are other artillery fires as to the type of observation, form, effect sought, and degree of prearrangement. The application of each of these principles to rocket fire is shown in *a* through *d* below.

a. Observation. Rocket fires are observed when possible to insure accuracy and effectiveness of fire. The observer makes the necessary corrections if successive salvos are to be fired. Unobserved fires should not fall closer than 800 yards to friendly troops.

b. Form. Normally, rocket fire is delivered in dense concentrations. It is best utilized on targets requiring a large volume of fire rather than accuracy. The use of rocket fire for barrages is not advisable because of the size and variance of dispersion patterns. Firing of single launchers is confined to registrations and adjustments.

c. Effect Sought. The rocket launcher is ideal for use in neutralization fires. The sudden, intense volume of rocket fire has the advantage and effect of surprise. By causing severe personnel losses and some materiel destruction, the enemy's combat strength is greatly reduced.

d. Prearrangement. Rocket fires are prearranged when possible and integrated into artillery fire plans.

13. Selection and Assignment of Targets

a. The commander to whose command the rocket unit is attached decides the way to attack a target, giving due consideration to the rocket unit commander's recommendations. The commander to whose command the rocket unit is attached should know the status of rocket ammunition before assigning targets. 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 size or limiting points.
(3) Type and nature of target—personnel, materiel, or fortifications; whether in the open, in trenches, or otherwise protected.
(4) Purpose of fire—to neutralize, harass, interdict, or screen.
(5) Time to open fire—on call, without delay, or prearranged as to time or to an event.

(6) Duration of fire and number of rounds to be fired.

(7) Type of ammunition and fuze desired.

(8) Special instructions, such as restrictions on registration and responsibility for furnishing observation of fires.

b. To obtain maximum effectiveness in the attack of a target, the following items should be considered:

(1) Type of ammunition and fuze appropriate to the mission.

(2) Distribution in width and depth for proper coverage.

(3) Amount of ammunition required.

(4) Number of launchers or firing units required.

(5) Selection of position area best suited to the mission.

c. The rules that apply to selection of fuze and projectile for normal artillery apply in general to rocket fire. The types of shells are restricted to chemical (smoke) and high explosive (HE) with superquick, delay, and VT fuzes. High explosive shell with fuze VT or superquick is employed against personnel in the open, vehicles, and materiel. Fuze delay may be used to secure ricochet bursts against personnel who are dug in, to destroy materiel, or to attack troops in dense woods or tall trees. Fuze VT is also particularly suitable for use against personnel dug in without overhead cover.

d. 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 can be determined. The determination of proper distribution of rocket fire in width and depth therefore depends on the proper application of the 67 percent dispersion rectangle to the target (fig. 242).

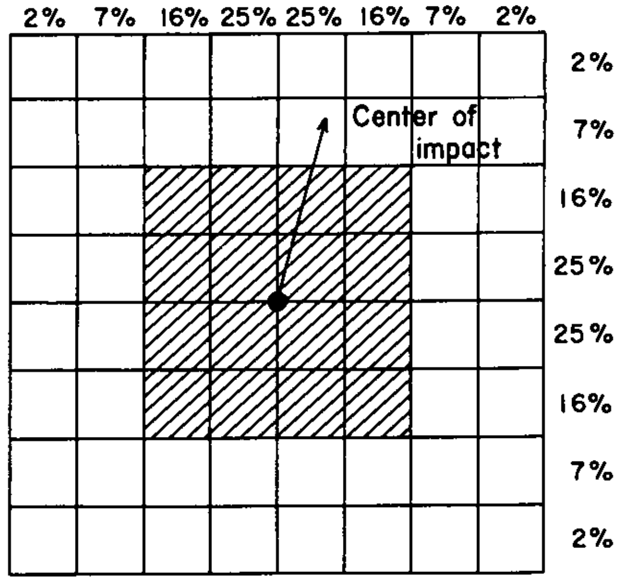


Figure 242. Dispersion zone (note that 67 percent or ⅔ of rounds fall in crosshatched area).

(1) Distribution in width may require special sheaves or require 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 a target is wider than four deflection probable errors, a normal sheaf is employed. When the target is wider than 4 deflection probable errors plus 100 yards, the width of the target is divided into zones, each zone being 4 deflection probable errors in width, and a firing unit is assigned to each zone. If the number of firing units is limited, each firing unit may be employed to attack a number of zones successively.

(2) Distribution in depth may require attack of targets at center range or, targets in depth may require a range spread between firing units. In general, when the target is deeper than 4 range probable errors, the target is divided into zones of 4 range probable errors in depth, and firing units are assigned to each zone or range.

APPENDIX IV

280-MM GUN GUNNERY, SHELL, HE, T122

Section I. INTRODUCTION

1. General

Techniques used in the firing of the 280-mm gun with shell, HE, T122, vary in certain respects from the firing techniques discussed in part Four. Fundamentally, the determination of deflection (azimuth), fuze setting (time of flight), and quadrant elevation are the same. The primary differences are in the refinement of data.

2. Scope

This appendix contains information on 280-mm gun firing technique pertaining to—

a. Ballistic elements.

b. Tabular firing tables, FT 280–B–1.

c. Met messages.

d. Determination of velocity error.

e. Computation of firing data.

f. Delivery techniques.

g. Predicted fire.

h. Met plus VE technique.

i. High-burst and center-of-impact registrations with K transfer.

j. Precision registration and time registration with K transfer.

k. Adjustment and fire for effect.

l. Organization of the FDC.

m. Determination of minimum elevation.

Section II. BALLISTIC ELEMENTS

3. General

The principles of ballistics in chapters 25 and 26 apply to this weapon. Accurate firing requires that special consideration be given to the following four factors:

a. Ramming.

b. Barrel curvature (muzzle droop).

c. Condition of the tube.

d. Tube memory.

4. Ramming

Uniformity of ramming is essential to accuracy of fire. Uniform ramming reduces round-to-round velocity differences caused by variations in rotating band seating and the minor changes in powder chamber volume.

5. Barrel Curvature (Muzzle Droop)

a. Elevations listed in the firing tables for the 280-mm gun are based on settings at the muzzle end of the tube. There is a difference of approximately 3 mils between the elevation at the muzzle end of the tube and the breech. This variation is known as barrel curvature, or droop. A difference in barrel curvature will occur between conditions of sunlight and shade or between daylight and darkness.

b. The value of droop listed in FT 280–A–1 (classified), should be used if droop cannot be measured. Droop corrections should be included in the computation of firing data.

c. It is more desirable to find the magnitude of barrel curvature and make the correction as a separate item of firing data than to absorb it in a VE. The correction for barrel curvature is stripped from the adjusted elevation prior to finding weapon VE. In firing at points at the same altitude as the gun with charge 4, a barrel curvature of 3.0 mils represents 10.2 feet per second (f/s) at a range of 20,000 yards, but it is equivalent to only 3.3 f/s at a range of 28,000 yards. Similarly, since magnitude of barrel curvature varies, the correction for barrel curvature is stripped from adjusted elevation prior to computing data for replot. This will insure accurate refiring on targets of opportunity.

d. In predicted fire and met plus VE technique (par. 25*b* and *c*, this app), a correction for barrel curvature must be included to get more accurate firing data. Zero curvature is considered standard. The correction is obtained by changing the sign of the curvature effect. Correction for barrel curvature is applied to quadrant elevation and not to time of flight.

6. Condition of Tube

It is important that the tube be clean and dry prior to firing. If the tube is oily, the first rounds fired may be erratic because of excessive muzzle velocity variation.

7. Tube Memory

Analysis of 280-mm gun firings indicates that, in changing from one charge to another, the muzzle velocity of initial rounds of a charge is influenced by the preceding charge fired. Therefore, a tube from which the last round was fired with the same charge as the charge required for the mission should be selected. If a tube must be used from which the last round was fired with a charge higher than the charge required for the mission, indications are that the first round fired will frequently produce a muzzle velocity much greater (15 to 30 f/s) than the mean velocity of subsequent rounds of that charge. Conversely, the first round of a charge higher than the charge used for preceding rounds may produce a muzzle velocity lower (10 to 20 f/s) than the mean velocity of subsequent rounds of the same charge.

Section III. TABULAR FIRING TABLES, FT 280–B–1

8. General

a. Firing tables for the 280-mm gun, although containing the same information as other firing tables, are in a slightly different format. The firing table includes a complete description of content and use.

b. At any range, trajectories to points above or below the gun will vary in time of flight and terminal velocity when compared with trajectories to points at the same range which are at the same altitude as the gun. For a given range, trajectories to points above the gun have longer times of flight, lesser terminal velocities, and are affected more by deviations from standard weather and ammunition. Consequently, unit correction factors will be greater. The reverse is true for trajectories terminating at points below the gun; however, the variation is not of the same magnitude. FT 280–B–1 provides data for these trajectories.

9. Use of Firing Tables

a. The type of firing table, which provides uncorrected data and correction factors as a function of range and height, is termed *two dimensional* and its use requires *double interpolation.*

b. The following is an example of procedures involved in double interpolation for FT 280–B–1, 280-mm gun, charge 2, target range 14,040 yards, target altitude +1,000 feet, gun altitude 250 feet, target height above gun 750 feet.

(1) Enter firing table at range 14,000 (p. 81) and move to the right under +500 feet and record elevation (381.6); then move to the right under next column, +1,000 feet, and record elevation (395.2).

(2) Enter firing table again at range 14,100 and move to the right under same columns as above and record elevations (386.0 and 399.6).

(3) Interpolate between elevations for 14,000 yards and 14,100 yards at +500 and +1,000 feet height of target to obtain elevations for 14,040 yards at +500 and +1,000 feet height of target.

	+500 feet	*(+750 feet)*	*+1,000 feet*
14,000 yards	381. 6m̸	----	395. 2m̸
(14,040 yards)	--------	(?)	--------
14,100 yards	386. 0m̸	----	399. 6m̸
Change for 100 yards	4. 4m̸	----	4. 4m̸
x 40 yards/100 yards	. 4m̸	----	. 4m̸
Change for 40 yards	1. 76m̸	----	1. 76m̸
14,000 yards	381. 60m̸	----	395. 20m̸
14,040 yards	383. 36m̸	(?)	396. 96m̸

(4) Interpolate between elevations for 14,040 yards at +500 and +1,000 feet height

of target to obtain elevation for 14,040 yards at +750 feet height of target.

	14,040 yards
Elevation for +1,000 feet	396.96 mils
Elevation for +750 feet	(?)
Elevation for +500 feet	383.36 mils
Change for 250 feet $\left(\frac{396.96-383.36}{2}\right)$	6.80 mils
Elevation for +750 feet	390.16 mils

c. Corrections for time of flight and nonstandard conditions of weather, ammunition, and materiel are computed by using unit correction factors found in firing tables. Exact factors are determined by double interpolation and using range and height above gun to the target for entering the tables.

Section IV. THE MET MESSAGE

10. General

The types of met messages used in 280-mm gunnery and the procedures that differ from heavy artillery met computation procedures are explained in this section. The procedures used are basically the same as those in chapters 19 and 28.

11. Types and Required Frequency of Met Messages

Type 3 (charge 1 only) and type 4 met messages are used in the solution of 280-mm gun firing data. Electronic messages are required for predicted fire, met plus VE technique, and calibration fires. Visual messages may be used for registration or adjustment; however, the electronic message is used when available. Met support for 280-mm gun firing requires 1 met message every 2 hours. The use of the latest met information improves initial data and may result in the saving of ammunition.

12. Evaluation of Met Message

The FDO must try to establish the validity of the met message. An indication of validity may be obtained by making the following checks:

a. Compare the message with previous messages to see if changes in reported weather conditions appear to follow a logical trend.

b. Compare the message with another message taken at the same time in order to detect gross errors in report of weather. A second electronic station, if nearby, can furnish the message for this purpose. A message obtained from a nearby visual station can be used to verify wind speed and direction.

c. Compare values, line to line, for logical changes; this may disclose errors made in the transmission of the message.

13. Determination of Met Message Line Number

a. Under certain conditions, improved accuracy in use of the met values may be required. This accuracy may be achieved by met message line number refinement to the nearest 0.1 by interpolation. Met message line number refinement is justified only under conditions stated in paragraph 362*c* through *f*, when predicted fire or met plus VE technique is used (par. 25, this app). It is not justified for other techniques. Met message line numbers, to the nearest line, are taken from table L, FT 280–B–1, when interpolation is not required.

b. Tables XIX through XXII list the line numbers to the nearest 0.1 to be used in solving met messages. The QE fired, or expected to be fired, is used to find the met message line number (par. 362). If data are not available which could be used to show the approximate QE to be fired, the uncorrected QE that corresponds to chart range and computed height of burst above the gun is used to enter the tables for line number. If the line number that corresponds to the first corrected QE differs from the first line number used, data are recomputed from the met message and a second corrected QE is found by using the new line number. Further refinement in met message line interpolation is not warranted.

c. The met message line number to the nearest 0.1 may be found by using table M, FT 280–B–1. Enter the table at chart range and height of burst above the gun to find the maximum ordinate by interpolation. Compare the result with the altitude for the line number shown in the table on page XIV, introduction to FT 280–B–1 and interpolate to the nearest 0.1 line number.

Example: The relationship between the maximum ordinate and the standard altitude used in finding the met message line number for the trajectory determined by the following burst data is illustrated in figure 243.

Shell T122
Charge 2
Range 17,400 yards
Height above gun +2,100 feet

Table XIX. Line Number of Met Message, Shell T122, Charge 1

QE	Line No.	QE	Line No.	QE	Line No.	QE	Line No.
121–129	0. 7	242–252	2. 0	386–394	3. 3	499–506	4. 6
130–137	0. 8	253–265	2. 1	395–405	3. 4	507–513	4. 7
138–146	0. 9	266–278	2. 2	406–415	3. 5	514–520	4. 8
147–157	1. 0	279–289	2. 3	416–426	3. 6	521–527	4. 9
158–167	1. 1	290–300	2. 4	427–436	3. 7	528–537	5. 0
168–178	1. 2	301–312	2. 5	437–444	3. 8	538–552	5. 1
179–188	1. 3	313–323	2. 6	445–451	3. 9	553–568	5. 2
189–198	1. 4	324–334	2. 7	452–459	4. 0	569–585	5. 3
199–207	1. 5	335–344	2. 8	460–466	4. 1	586–590	5. 4
208–216	1. 6	345–354	2. 9	467–474	4. 2	591–603	5. 5
217–225	1. 7	355–364	3. 0	475–482	4. 3		
226–234	1. 8	365–375	3. 1	483–490	4. 4		
235–241	1. 9	376–385	3. 2	491–498	4. 5		

Table XX. Line Number of Met Message, Shell T122, Charge 2

QE	Line No.	QE	Line No.	QE	Line No.	QE	Line No.
182–189	1. 9	315–322	3. 5	423–434	5. 1	598–605	6. 7
190–196	2. 0	323–329	3. 6	435–446	5. 2	606–614	6. 8
197–206	2. 1	330–335	3. 7	447–458	5. 3	615–623	6. 9
207–216	2. 2	336–345	3. 8	459–469	5. 4	624–632	7. 0
217–225	2. 3	346–349	3. 9	470–480	5. 5	633–642	7. 1
226–234	2. 4	350–356	4. 0	481–491	5. 6	643–652	7. 2
235–243	2. 5	357–363	4. 1	492–502	5. 7	653–663	7. 3
244–252	2. 6	364–370	4. 2	503–513	5. 8	664–675	7. 4
253–260	2. 7	371–376	4. 3	514–525	5. 9	676–687	7. 5
261–268	2. 8	377–382	4. 4	526–535	6. 0	688–694	7. 6
269–276	2. 9	383–388	4. 5	536–545	6. 1	695–702	7. 7
277–285	3. 0	389–394	4. 6	546–555	6. 2	703–710	7. 8
286–292	3. 1	395–401	4. 7	556–566	6. 3	711–719	7. 9
293–299	3. 2	402–407	4. 8	567–577	6. 4	720–728	8. 0
300–307	3. 3	408–414	4. 9	578–588	6. 5	729–740	8. 1
308–314	3. 4	415–422	5. 0	589–597	6. 6	741–753	8. 2

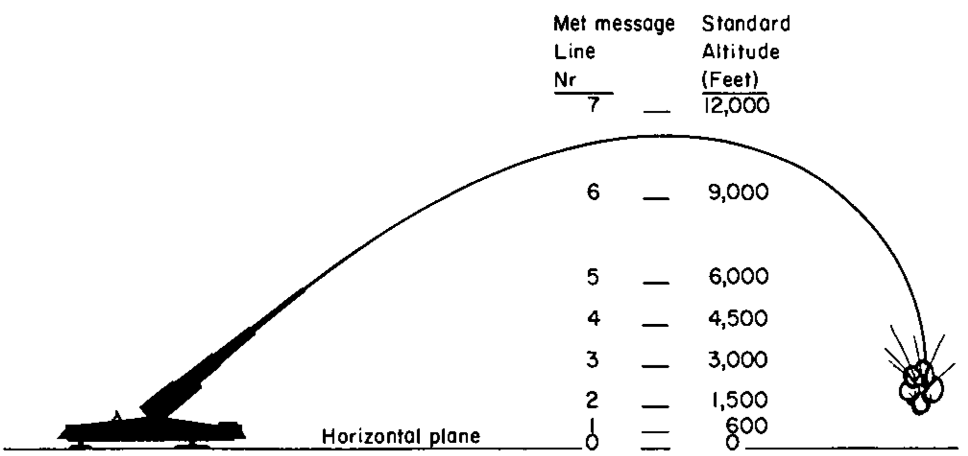


Figure 243. Comparison between the maximum ordinate and standard altitude in deriving met message line number.

Table XXI. Line Number of Met Message, Shell T122, Charge 3

QE	Line No.	QE	Line No.	QE	Line No.	QE	Line No.
155–160	1.9	286–291	3.8	418–426	5.7	578–585	7.6
161–167	2.0	292–297	3.9	427–435	5.8	586–592	7.7
168–176	2.1	298–303	4.0	436–444	5.9	593–600	7.8
177–184	2.2	304–308	4.1	445–454	6.0	601–608	7.9
185–192	2.3	309–314	4.2	455–462	6.1	609–616	8.0
193–199	2.4	315–319	4.3	463–470	6.2	617–624	8.1
200–207	2.5	320–325	4.4	471–478	6.3	625–633	8.2
208–214	2.6	326–330	4.5	479–486	6.4	634–640	8.3
215–221	2.7	331–336	4.6	487–494	6.5	641–646	8.4
222–228	2.8	337–341	4.7	495–506	6.6	647–652	8.5
229–235	2.9	342–346	4.8	507–513	6.7	653–659	8.6
236–242	3.0	347–351	4.9	514–521	6.8	660–666	8.7
243–248	3.1	352–359	5.0	522–529	6.9	667–673	8.8
249–255	3.2	360–369	5.1	530–537	7.0	674–680	8.9
256–261	3.3	370–379	5.2	538–545	7.1	681–691	9.0
262–267	3.4	380–388	5.3	546–554	7.2	692–707	9.1
268–274	3.5	389–398	5.4	555–563	7.3	708–725	9.2
275–279	3.6	399–408	5.5	564–570	7.4	726–755	9.3
280–285	3.7	409–417	5.6	571–577	7.5		

Table XXII. Line Number of Met Message, Shell T122, Charge 4

QE	Line No.	QE	Line No.	QE	Line No.	QE	Line No.
198–205	3.0	293–296	4.9	432–438	6.8	553–558	8.7
206–209	3.1	297–303	5.0	439–444	6.9	559–563	8.8
210–213	3.2	304–311	5.1	445–451	7.0	564–569	8.9
214–220	3.3	312–319	5.2	452–457	7.1	570–579	9.0
221–225	3.4	320–327	5.3	458–464	7.2	580–590	9.1
226–231	3.5	328–335	5.4	465–471	7.3	591–601	9.2
232–236	3.6	336–343	5.5	472–477	7.4	602–612	9.3
237–241	3.7	344–351	5.6	478–484	7.5	613–623	9.4
242–245	3.8	352–359	5.7	485–490	7.6	624–635	9.5
246–250	3.9	360–366	5.8	491–497	7.7	636–648	9.6
251–255	4.0	367–374	5.9	498–503	7.8	649–656	9.7
256–260	4.1	375–381	6.0	504–509	7.9	657–665	9.8
261–265	4.2	382–389	6.1	510–515	8.0	666–675	9.9
266–269	4.3	390–396	6.2	516–521	8.1	676–685	10.0
270–274	4.4	397–403	6.3	522–528	8.2	686–695	10.1
275–278	4.5	404–410	6.4	529–534	8.3	696–706	10.2
279–283	4.6	411–418	6.5	535–540	8.4	707–718	10.3
284–287	4.7	419–424	6.6	541–546	8.5	719–733	10.4
288–292	4.8	425–431	6.7	547–552	8.6	734–747	10.5

By interpolation in the *maximum ordinate* table, the maximum ordinate is found to be 11,242 feet. 11,242 feet is $\frac{2242}{3000}$ of the distance between heights of 9,000 feet (line 6) and 12,000 feet (line 7). By interpolating, the line number is equal to 6.7 $\left(6.0+\frac{2242}{3000}=6.7\right)$.

d. If the corrected QE (or QE fired) is used in the above procedure, chart range is altered by selecting a range in the firing table that corresponds to the corrected QE at the same height of burst above the gun.

Example: (By using the same chart data as that in the example in *c* above, nonstandard conditions result in a corrected QE of 630.8 for initial solution of met message by using line 6.7.)

Range corresponding to QE 630.8 = 17,700 yards at 2,100 feet.

Maximum ordinate of 17,700 at = 11,900 feet 2,100 feet.
Line number for second solution = 7.0 line number of met message.

e. For computation of VE, met corrections applicable at the time of firing are computed based on met values obtained from interpolation between lines by using the QE fired to determine the appropriate met message line number to the nearest 0.1.

14. Interpolation Between Lines of Met Message

Following the determination of the proper line number to the nearest 0.1 of a line, the elements of the met message to be used are determined by interpolating between the appropriate 2 lines of the met message. For example—

a. The line number has been determined to be 6.7. The elements of the met message to be used are determined by interpolating between the appropriate 2 lines of the met message; e. g., lines 6 and 7 of a met message are—

Line No.	*Wind direction*	*Wind velocity*	*Air density*	*Air temp*
6	57	42	968	52
7	60	54	959	52

b. In determining each of the elements corresponding to line 6.7, 0.7 of the difference between lines 6 and 7 is added algebraically to elements of line 6. This computation results in the following values

Line No.	*Wind direction*	*Wind velocity*	*Air density*	*Air temp*
6.7	59	50	962	52

c. Corrections for variations from standard weather conditions are computed by using unit correction factors.

15. Unit Correction Factors

a. Unit correction factors are used to compute corrections for variations from standard weather conditions. Unlike the procedure for other artillery, no conversion of effects from yards to corrections in mils or seconds is required.

b. Unit correction factors are found, double interpolating in firing tables where necessary, by using—

(1) Measured (chart) range to the nearest 100 yards (except rotation corrections which are based on range, direction of fire, and latitude, to the nearest listed value in the firing tables).

(2) Computed height of burst above gun to the nearest 100 feet.

(3) Measured azimuth to the nearest 100 mils.

16. Time-Interpolated Met Corrections

Improvement in the accuracy of the velocity error can be obtained if met corrections applicable at the time of firing are available. This is particularly true if firing occurs during a period of changing weather or if firing is delayed materially after the time of taking the met message. The following procedure is used to determine met corrections applicable at the time of firing:

a. If the time of the met message does not correspond to the time of firing, then two met messages which bracket the time of firing are selected.

b. Correction factors based on the location of each round fired (or the mean location of rounds fired) are used to compute new corrections.

c. The met message line number is selected based on the QE fired. Met corrections for each of the messages are computed for air density, air temperature, and range wind.

d. The sum of the corrections for each message is determined and a linear time interpolation for each round is made to determine corrections applicable at the time of firing. For example (280-mm gun, charge 3, range 20,150 yards, height of burst above gun +1,130 feet)—

(1) Data:

Rnd	*Time fired*	*Uncorr QE*	*Met corr**	*Other corr***	*QE fired*
1	1910	485.73	−14.92m̸	−5.12m̸	465.7m̸
2	1925	485.73	−14.92m̸	−5.12m̸	465.7m̸

*Met corrections are based on a 1640 hours met message which was the latest available at time of firing.
**Corrections for MV, weight of projectile, rotation, and barrel curvature.

(2) Computed burst location:

Rnd	*Range*	*Height of burst above gun*
1	20, 190 yards	+899 feet
2	20, 297 yards	+1, 156 feet
Mean	20, 244 yards	+1, 028 feet

(3) Correction factors are determined for a range of 20,200 yards and height of burst above gun of +1,000 feet. Met message elements are interpolated at line 6.2 which corresponds to QE 465.7. Corrections for the two bracketing met messages (1838 hours and 2033 hours) are—

	1838 met message	*2033 met message*
Air density	−23.56m̸	−24.78m̸
Air temperature	+1.73	+2.02
Range wind	+3.92	+3.92
Total correction	−17.91m̸	−18.84m̸

(4) Corrections applicable for each round at the time of firing are determined as follows:

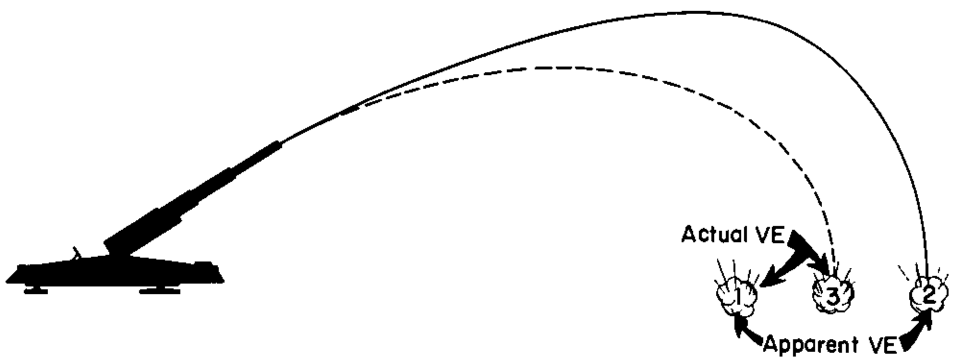
Total time between met messages (1838 to 2033)	115 min
Time from 1838 met message to rnd 1 (1838 to 1910)	32 min
Time from 1838 met message to rnd 2 (1838 to 1925)	47 min
Total met corr diff 1838 met message to 2033 met message (−18.84−(−)17.91)	−0.93m̸
Total met corr rnd 1 (32/115×(−)0.93=−0.26m̸; −17.91+(−)0.26=−18.17m̸)	−18.17m̸
Total met corr rnd 2 (47/115×(−)0.93=−0.38; −17.91+(−)0.38=−18.29m̸)	−18.29m̸

e. The sum of the corrections that apply for each round at the time of firing is compared with the sum of the same corrections used during firing. For example—

Rnd	*Time fired*	*QE fired*	*Density, air temperature, and range wind corrections* Used*	Should use*	Diff
1	1910	465.7m̸	−14.92m̸	−18.17m̸	−3.25m̸
2	1925	465.7m̸	−14.92m̸	−18.29m̸	−3.37m̸

*MV, projectile weight, rotation, and barrel curvature corrections which are not weather corrections are not included in time interpolation computations.

f. An adjustment in the elevation error indicated by fall of shot (fig. 244) is made before VE is computed to compensate for the difference caused by wrong met corrections. To compute the VE, see paragraph 20, this appendix.



1. Desired point.
2. Location of burst by using old met corrections (-14.9m̸); fired with QE of 465.7m̸.
3. Theoretical location of burst if actual met corrections (-18.3) had been used (QE 462.3).

Figure 244. QE error and met error, round 2.

Section V. DETERMINATION OF MUZZLE VELOCITY

17. General

a. One of the most important elements used to compute firing data for the 280-mm gun is the variation, from the firing table standard muzzle velocity, that a tube will develop when a certain propellant lot and projectile lot combination are used. This knowledge can best be found by field calibration. The variation from standard may be determined by using one of the following methods:

(1) Measure the velocity at or near the muzzle by using a chronograph or like device. The difference between the measured velocity (corrected to standard conditions) and the firing table standard velocity is called the measured muzzle velocity variation (MVV).

(2) Convert the range error from fall of shot to velocity error in f/s after stripping effects of all known nonstandard conditions (except MVV) from the error.

b. When possible, calibration should be performed by using both methods listed in *a* above. The comparison of MVV and VE indicates the degree of success achieved in identifying variations from standard for a specific tube and ammunition. If the mean MVV is within 5 f/s of the mean VE, either method in *a* above may be used. The result will determine variations from firing table standard muzzle velocity for the calibrated tube and ammunition, and the predicted fire technique may be used.

c. Small differences (5 f/s or less) between measured muzzle velocity and muzzle velocity inferred from VE are due largely to effects of inaccurate met messages on VE; errors in fall-of-shot locations or chronograph results; slight changes in projectile ballistic coefficient; and the errors resulting from computations required by the firing table format. Errors due to inaccurate met messages may be reduced by arranging calibration firings so that only 1 or 2 rounds are fired based on any 1 met message. This action tends to mean met message errors.

d. Large differences (over 5 f/s) are due to a greater change in projectile ballistic coefficient than the ballistic coefficient of the lot on which the firing table is based and/or to larger errors due to the factors mentioned in *c* above. In such cases, VE must be used to compute subsequent firing data.

e. Research is being continued to find and use the ballistic coefficient of a projectile lot to produce more accurate firing data. Until the exterior ballistic elements that cause mean differences of more than 5 f/s can be accurately identified and corrected, inferred velocity from fall of shot should be used to compute firing data in preference to measured muzzle velocity.

18. MVV Calibration

Muzzle velocity variation of a tube is found by the use of a chronograph or other like electronic means. In using a chronograph, or like device, the following procedure is used:

a. Check all components of ammunition to be fired to make sure they are of the same lot number.

b. Confirm by VE calibration at least four usable rounds (except the first round fired) for a valid calibration. MVV is confirmed if the VE and MVV means are within 5 f/s.

c. Convert measured velocities obtained by instrument readings to muzzle velocities under standard conditions. The chronograph team applies corrections for drag, gravity, weight of projectile, and powder temperature to correct to standard muzzle velocity.

d. Compute the mean muzzle velocity of the rounds fired.

e. Compare the developed (corrected) muzzle velocity (*c* above) with standard velocity. A difference (MVV) is determined. This difference expressed as a loss or gain in standard velocity may be used in later computations of firing data, when it is within 5 f/s of the VE.

f. Muzzle velocity variation or developed muzzle velocity is expressly associated with a tube number, projectile type, propellant lot number, projectile lot number, and charge. A change in either the propellant or projectile lot may invalidate MVV.

g. A high-burst or a center-of-impact registration is conducted at the same time as the chronograph calibration is made. This permits the chronographed muzzle velocity to be compared with the velocity error obtained by the registration. A high-burst registration may also show a fuze error for which correction may be made in later firings.

19. VE Calibration

a. When chronograph teams are not present, a calibration as outlined in chapter 28 as absolute VE determination is made.

b. Calibration by the method described in chapter 28 requires a minimum of seven usable rounds and the same judgment exists for the rejection of rounds too far from the mean CI. However, the firing should be slow enough to allow 3 met messages to be taken with each 7-round group. Three met messages taken at 2-hour intervals will usually meet the requirement, one prior to firing, one during firing, and one after firing. If the VE obtained is verified by a chronograph, or like device, calibration may be made with four usable rounds. This verification is established when there is an almost constant variation between MVV and VE.

c. It is well to calibrate at ranges that approximate the ranges at which most firing is to take place. Calibration at about 75 percent of maximum range for the charge permits use of VE from 60 to 90 percent of charge range (±15 percent of maximum range from range at which VE is determined).

d. In addition to actual calibration firings, VE should be computed in conjunction with each mission fired. This practice assists in keeping VE data current and complete.

Note. VE's determined by calibration should not be changed until a new average VE based on seven additional rounds can be determined.

e. VE may change with charge and seasons. Therefore, firing of training ammunition should be spread throughout the year to get the best data.

20. Computation of VE

a. VE is based on the error in fall of shot when effects of all known variations from standard, except muzzle velocity, are removed from the total error. Except for exact weather effects at the time of firing, corrections for all known variations are included in firing data. The difference between the location of the point(s) at which the round(s) was (were) fired and of the point(s) at which the round(s) burst is the apparent error in fall of shot. This error is most easily determined in terms of QE error. To determine an apparent QE error, the uncorrected QE of each round fired is compared with the uncorrected QE corresponding to the high-burst (center-of-impact) location of that round. This apparent QE error is added algebraically to the difference between the met corrections used and those that should have been used according to time interpolation of met corrections. This is done in order to compensate for met effects at the time of firing. The result is the VE in mils. For example—

	Rnd 1	*Rnd 2*
Uncorrected chart QE*--	485. 73	485. 73
Uncorrected QE to HB**-	483. 00	493. 56
Apparent QE error-----	−2. 73	+7. 83
Met corrections (used)--	−14. 92	−14. 92
Met corrections (should have been used)***---	−18. 17	−18. 29
Difference in met corrections-------------	−3. 25	−3. 37
True QE error (VE in mils)---------------	−6. 0 (5. 98)	+4. 5 (4. 46)

*Corresponds to range 20,150 yards, height above gun + 1,130 feet, chg 3.
**Corresponds to location of burst (par. 16*d*(2), this app).
***Time interpolated met correction (par. 16*d*(4), this app).

b. The appropriate correction factor(s) for muzzle velocity variation from standard is (are) found in the firing tables, by using the range and height to the high-burst (center-of-impact) location. By dividing the VE in mils by the factor, a VE in f/s of muzzle velocity is obtained. Selection of the proper unit correction factor is determined as follows:

(1) If standard muzzle velocity was assumed or if the VE used in the first computation of firing data results in an apparent larger VE with the same sign, the factor used for changing VE in mils to f/s will be obtained from the correction table shown by the sign of the apparent VE.

Example 1:

Standard muzzle velocity assumed:

Apparent VE (round 2, *a* above)--	+4. 5₥
Unit correction factor (from increase MV table, charge 3)*----	0. 594₥ (per f/s)
VE of round, $\frac{4.5}{0.594}$-------------	+7. 6 f/s

Example 2:

Apparent VE with the same sign of VE used originally:

Original VE used---------------	+5. 0 f/s
Apparent VE------------------	+4. 5₥
Unit correction factor (from increase MV table, charge 3)*----	0. 594₥ (per f/s)
Apparent VE, $\frac{4.5}{0.594}$-----------	+7. 6 f/s
Add original VE used-----------	+5. 0 f/s
VE of round------------------	+12. 6 f/s

(2) The factor used to change VE in mils to f/s will be the average of the factors for the decrease and increase in MV when the computation of firing data results in an apparent VE opposite in sign from that used originally. The sign of the apparent VE in mils is maintained. The apparent VE in f/s is then added algebraically to the original VE to obtain the VE of the round fired.

Example:

Apparent VE with opposite sign of VE used originally:

Original VE used---------------	−5. 0 f/s
Apparent VE------------------	+4. 5₥
Average of increase and decrease unit correction factors (charge 3)*: $\frac{(0.594+0.754)}{2}$---------------	0. 674₥ (per f/s)
Apparent VE, $\frac{4.5}{0.674}$------------	+6. 7 f/s
Add original VE used-----------	−5. 0 f/s
VE of round------------------	+1. 7 f/s

*Corresponds to range 20,297 yards, height above gun +1,156 feet (par. 16*d*(2), this app), rounded off to 20,300 yards, height above gun +1,200 feet.

Section VI. FIRING DATA, GENERAL

21. General

This section deals with general procedures and principles used in computing firing data that will apply to all delivery techniques employed with the 280-mm gun. Specific procedures for each delivery technique are covered in sections VIII through XI, this appendix. A check on the accuracy of firing data computations can be had by using two or more computers working independently.

22. Chart Data

Azimuth to the nearest mil and range to the nearest 10 yards are measured from the firing chart. Graphical data are used to determine the right met message line number, to select the unit correction factors, and to determine the drift and rotation corrections. It is also one means of verifying computed ranges and azimuths. Use of measured range, in lieu of computed range for met message solution, permits a faster solution of met corrections when a two-computer system is employed (sec. XII, this app).

a. For speed and convenience, drift correction is found by using chart range to the nearest 100 yards.

b. Corrections for rotation of the earth are made by using chart range, direction of fire, and the latitude to the nearest listed value in the firing tables.

23. Computed Data

a. Computed data are the basis for determination of gun firing data; i. e., azimuth (deflection), range and height of target (quadrant elevation), and time of flight (fuze setting).

b. Azimuth and range are computed from coordinates by using logarithms.

c. Height of target (height of burst above gun) is computed by comparing the altitude of the gun and the altitude of the target (plus the height of burst for time fire).

d. To determine uncorrected quadrant elevation and time of flight, firing tables are entered at computed range to the nearest 10 yards and height of target to the nearest 10 feet (by double interpolation if necessary).

e. Corrections for nonstandard conditions of weather, ammunition, and materiel are made by using unit correction factors found in the firing tables. These corrections are applied to the uncorrected quadrant elevation and time of flight.

24. Firing Data Accuracy

a. In computation of firing data, the degree of refinement required is that shown below:

Element	*Computed to nearest*
(1) Azimuth	0.1 mil
(2) Deflection	1 mil
(3) Height of target	10 feet
(4) Height of burst above gun	10 feet
(5) Time of flight	0.01 second
(6) Fuze setting	0.01 second
(7) Range	1 yard
(8) Quadrant elevation (QE)	0.01 mil

b. Fire commands, data rounded off after computation, are given to the gun crews to include deflection to the nearest 1 mil, time (when applicable) to the nearest 0.1 second, and quadrant to the nearest 0.1 mil.

Note. Fire commands differ from normal fire commands (pars. 414 and 415) in that special corrections are combined with the pertinent elements and are never given separately. In addition, the command CORRECTION, which shows the deflection correction to be set on the gunner's aid, is omitted.

Section VII. DELIVERY TECHNIQUES

25. General

a. There are six delivery techniques which may be used. These techniques are—

(1) Predicted fire.
(2) Met plus VE.
(3) High-burst registration with K transfer.
(4) Center-of-impact registration with K transfer.
(5) Precision registration and time registration with K transfer.
(6) Adjustment and fire for effect.

b. Predicted fire technique is the delivery of artillery fire on a target of known location, without the use of prior registration and regard to range transfer limitations. Predicted fire requires accurate firing data for a specific target. Data must include all nonstandard conditions of weather, materiel, and ammunition and rotation of the earth. In this type of fire, survey, electronic met data, and measured muzzle velocity should be accurate. It must be presumed that the projectile lot to be fired has a standard ballistic coefficient and projectile weights are correct; that weight errors and ballistic coefficient change (BCC) are small enough to be ignored (MVV and VE within ± 5 f/s).

c. Met plus VE technique as it applies to the 280-mm gun is the same as predicted fire technique, except that VE is substituted for MVV. Velocity error may contain BCC and other nonvelocity elements (i. e., error in survey and fall-of-shot location, met errors, and firing table limitations). Therefore, this technique should only be used within ± 15 percent of the maximum range (for the charge computed) from the range at which the VE was determined. For example, VE at range 18,000 yards, charge 3; maximum range, charge 3 (FT 280–B–1) is 24,300 yards.

Range limits are as follows:

24,300×.15	= 3, 645
Lower range limit (18,000−3,645)	=14, 355
Upper range limit (18,000+3,645)	=21, 645

In the event that MVV and VE differ by more than ± 5 f/s, this delivery technique should be used rather than predicted fire.

d. Registrations and adjustments (*a*(3)–(6) above) are conducted by using standard procedures modified as required for firing the 280-mm gun. Corrections based on a range K and a time K (if it applies) computed at the range of the registration are applied.

e. Transfer limits for the registration techniques are the same as those for very heavy artillery, except that vertical transfer limits are 1,500 feet above or below the registration point.

f. With the time fuzes currently in use, accurate time fire with shell HE should not be expected at ranges exceeding 15,000 yards.

26. Tactical Considerations

a. Surprise, accuracy, allocation of ammunition, enemy counter-battery, and time are the main factors considered in the selection of the right delivery technique.

b. The degree of surprise required is the primary consideration in the selection of the delivery technique. When the element of surprise is essential, the following methods will be used in the order listed:

(1) Predicted fire or met plus VE technique, if muzzle velocity or velocity error of the gun and propellant to be used is known and accurate met data are available.

(2) High-burst or center-of-impact registrations with K transfer.

(3) Precision registration with K transfer.

c. When the element of surprise is not essential, the following methods will be used in the order listed:

(1) Adjustment and fire for effect.

(2) High-burst or center-of-impact registrations with K transfer.

(3) Precision registration with K transfer.

d. The degree of accuracy required for all delivery techniques is based primarily on the nearness of the target to friendly troops and nature and size of the target. Results to be expected will vary with the delivery technique, state of training of the unit, and accuracy of determined data.

Section VIII. PREDICTED FIRE OR MET PLUS VE TECHNIQUES

27. General

a. This section sets forth the conditions under which the predicted fire or met plus VE delivery techniques may be used and the steps used in the computation of firing data. When predicted fire or met plus VE technique is feasible, targets may be attacked with more surprise and less ammunition expenditure than can be accomplished with any other delivery technique employed with the 280-mm gun.

b. Under conditions of rapid weather changes, the use of predicted fire or met plus VE technique is not advised. The requirements listed below should be met if maximum accuracy is to be obtained. Failure to meet all requirements does not preclude use of these techniques, but fire may be less accurate. The requirements for optimum accuracy are that—

(1) Mean muzzle velocity (tube and ammunition) by using VE or MVV is computed within 1 f/s.

(2) Propellant temperature is determined within 1° F.

(3) Barrel curvature is determined within 0.1 mil.

(4) Projectile weight is determined within 1 pound.

(5) Charge to be used is the same as the charge last fired in the tube.

(6) Quadrant scales are correct to within 0.1 mil.
(7) Tube is clean and dry (oil film removed).
(8) Quadrant elevation and fuze setting are properly computed and checked.
(9) Bore sighting is accurate to nearest mil.
(10) An electronic met message, not older than 2 hours, is available.
(11) Survey is to an accuracy of 1:1,000, proven by closure.

28. Elements of Firing Data

The elements of firing data used in predicted fire or met plus VE technique are the uncorrected data and the corrections for the variations in weather, ammunition, and materiel. The algebraic sum of the corrections are applied to the appropriate uncorrected data to get firing data to be applied to the gun.

a. Uncorrected data are—
(1) Azimuth (computed from coordinates).
(2) Time of flight (corresponding to computed range and height of burst above gun).
(3) Quadrant elevation (corresponding to computed range and height of burst above gun).

b. Corrections determined for the following items are applied to the uncorrected azimuth:
(1) Drift.
(2) Cross wind.
(3) Rotation of the earth.

c. Corrections determined for the following items are applied to the uncorrected quadrant elevation and the time of flight:
(1) Muzzle velocity variation (velocity error) corrected for effect of nonstandard powder temperature.
(2) Barrel curvature for *QE* only.
(3) Air density and temperature.
(4) Projectile weight.
(5) Range wind.
(6) Rotation of the earth.

29. Determination of Firing Data

a. In determining firing data for the delivery of fire by using predicted fire or met plus VE technique, the following procedure is used:
(1) Determine azimuth, range, and height of burst in relation to gun as indicated in paragraph 23, this appendix.
(2) Obtain met message line number as indicated in paragraph 13, this appendix.
(3) Determine variations from standard by using evaluated met message as explained in paragraph 12, this appendix.
(4) Select unit correction factors as indicated in paragraph 15, this appendix, and determine corrections for variations from standard. Include elements of firing data listed in paragraphs 28*b* and *c*, this appendix.
(5) Apply met corrections to uncorrected azimuth, time of flight, and QE for computed direction, range, and height.
(6) Convert corrected azimuth to deflection.

b. An example of determining firing data by using predicted fire or met plus VE technique is given in (1) through (15) below.
(1) Situation: Battery A, 701st FA Battalion, has been directed to fire a TOT at 0100 hours. Met plus VE delivery technique is to be employed. The computation of firing data is accomplished by using the Firing Data Correction Sheet (DA Form 6–51) (fig. 245).

Note. The 280-mm gun fire order *always* includes type of shell and type of fuze.

(2) An electronic, type 4, met message is used:

MIF07	23504
01032	95768
xxxxx	xxxxx
60113	95962
70124	96965
xxxxx	xxxxx

Note. Evaluation of met information is accomplished by comparing the message to previous messages or to a message from another electronic station.

(3) The executive reports that the powder temperature is 75° F. and the weight of the projectile to be fired is 602 pounds.
(4) The battery is laid on azimuth 1,200 and the latitude of the battery is 34° north. The muzzle velocity of the gun has been determined by calibration to be 2,476.5 feet per second for charge 4.
(5) Data determined from chart *measurement* to the target are—

Azimuth: 1,200 mils
Range: 24,980 yards

Height of target, feet	1, 300
Height of gun, feet	800
Height of burst above gun, feet	500

FIRING DATA CORRECTION SHEET
(FM 6-40)

METRO MESSAGE	ALT. MDP	TIME	TYPE	LINE NO.		MPH		
	700	2350	4	6.7	0100 ₥	21	96.7 %	64 °

CHART DATA	CHARGE 4	FIRE ORDER Alt 1,300 ft, A, Tube No. 32, 54 HE, Lot XX, Chg 4, Fz Q, 1 Rnd, AMC, Met + VE, Conc EE 310
RANGE, YARDS Measured	24,980	

ALTITUDE OF MDP, FT	700	CORR FOR DIFF ALT	+ ⊖ .3 %	+ ⊖ .3 °
ALTITUDE GUN, FT	800	CORRECTED VALUES	96.4 %	63.7 °
GUN ABOVE/BELOW MDP, FT	100			

WIND — LATERAL: VEL 21 × COMP R.88 = Ⓡ/L 18.5 MPH × 0.37 = CORR Ⓛ/R 6.8 ₥

WIND — RANGE: VEL 21 × COMP −.47 = R/Ⓗ 10 MPH

POWDER TEMP 75°

MUZZLE VELOCITY	
DEVELOPED MV	2,476.5 f/s
CORR FOR POW. TEMP ⊕ −	3.5 f/s
COMPUTED DEV MV	2,480.0 f/s

CORRECTIONS at range 25,000 + 500 feet

			KNOWN VALUES	STANDARD VALUES	VARIATION STANDARD	UNIT CORRECTIONS	QE +	QE −	UNIT CORRECTIONS	TF +	TF −
HEIGHT OF T, FT	1,300	MV	2,480.0 f/s	2,500 f/s	Ⓓ/I 20	+.527	10.54				
HEIGHT OF BURST ABOVE T, FT	———	AIR DENSITY	96.4 %	100 %	Ⓓ/I 3.6	−3.82		13.75			
TOTAL HEIGHT OF BURST	1,300	AIR TEMP	64 °	59 °	D/Ⓘ 5	+.220	1.10				
HEIGHT OF GUN, FT	800	PROJ WEIGHT	602 #	600 #	D/Ⓘ 2	+.10	.20				
HEIGHT ABOVE/BELOW GUN FT ⊕ −	500	RANGE WIND	R/Ⓗ 10 MPH	0 MPH	R/Ⓗ 10	+.449	4.49				
DIRECTION OF WIND	100	ROTATION	LAT 34 Ⓝ/S					2.6			
+ 6400 IF NECESSARY	6,400	BARREL CURVATURE	−1.40	0 ₥	+ −		1.40				
TOTAL	6,500					TOTAL	17.73	16.35			
LESS DIR OF FIRE	1,200					NET CORRECTIONS	+1.38				
CHART DIR OF WIND	5,300	RANGE (Yards) 26,010		HEIGHT OF BURST (Feet) +500		QE AND TF UNCORRECTED	430.54			52.2	
						QE AND TF CORRECTED	431.92				

AZIMUTH OF FIRE	1201.5 ~~1200~~
DRIFT CORR	L 18.6
CROSSWIND CORR	L 6.8
ROTATION	L 1.0
TOTAL AZIMUTH CORRS	L 26.4
CORRECTED AZIMUTH	1,175.1
GUN LAID ON AZIMUTH	1,200
SHIFT FOR TGT Ⓛ/R	24.9
DF TO FIRE FOR TGT	

Df	2,200
Ⓛ/R	25
Df	2,225

FIRE COMMANDS
No. 2 Adj
54 HE
Lot XX
Chg 4
Fz Q
No. 2 ① AMC
Df 2225
QE 431.9

RD NO.	POWDER TEMP	WT	QE	FZ	DF	TIME FIRED	SHELL LOT	POWDER LOT
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

BTRY	FA BN	PSN	CONC NO.	COORD	ALT	DATE	GUN TUBE NO.
A	701st	1	EE 310	(13038.8 — 60779.5)	800	30 MAY 1956	32

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Figure 245. Data correction sheet showing the computation of met plus VE firing data.

(6) Range of 25,000 yards (24,980 rounded to nearest 100 yards) and height of burst above gun of +500 feet (QE 430.2) are used to select met message line number 6.7, by using table M to determine the maximum ordinate and interpolating in the table on page XIV. In this case, met message line number interpolation is justified (par. 362).
(7) Variations from standard are determined by using the met message.
(8) Unit correction factors are selected by using range 25,000 yards and height of burst above gun of +500 feet.
(9) Drift is determined from the ground data table opposite range 25,000 yards (L18.6).
(10) Uncorrected azimuth, QE, and time of flight are determined from computed azimuth (1,201.5), range 25,010, and height of burst above gun of +500.
(11) Corrections are applied to the QE (430.54) to obtain an apparent corrected QE (431.92). This QE is used to determine a new met message line number (6.7). Since there is no change in line number, the corrected QE is 431.92.
(12) Corrections are applied to the computed azimuth (1,201.5) to obtain a corrected azimuth (1,175.1) which is converted to deflection (2,225).
(13) Since time fuze is not being employed, no corrections for time of flight are computed.
(14) In order to accomplish the TOT of 0100 hours, the uncorrected time of flight of 52.2 seconds is subtracted from 0100 hours (corrected time of flight when fuze time is used). In this case, the gun would be fired at 0059 hours 8 seconds.
(15) Data to fire are DEFLECTION 2225, QUADRANT 431.9.

Section IX. HIGH-BURST AND CENTER-OF-IMPACT REGISTRATIONS WITH K TRANSFER

30. General

a. The 280-mm gun procedures for firing high-burst or center-of-impact registrations followed by K transfers are generally the same as those discussed in chapter 18. The principal difference is in the determination and use of a time K in place of a time correction (high-burst only).

b. The procedures for the delivery techniques differ in that the center-of-impact technique uses an impact fuze and, as a result, no time computations or time transfers are made. Procedures will be set forth in terms of high-burst technique in this section. Use of either technique allows determination of registration corrections with least expenditure of ammunition and delivery of surprise fire within normal transfer limits (time transfer with high burst).

31. Firing Data for Registration Rounds

a. When met and velocity information are available, the firing data for registration rounds are computed as for predicted fire or met plus VE technique, except that met message line interpolation is never warranted, and will include corrections as outlined in paragraph 28, this appendix. Use of the best possible firing data will facilitate location of the bursts by the OP personnel.

b. When met information is not available, the firing data are based on the uncorrected QE and time of flight for the registration point. To facilitate location of the burst of the initial round, an estimate of the corrections for weather is applied to uncorrected QE and time of flight before firing by changing the range to fire by the estimated correction. An estimate of the range correction may be based on information from other artillery units including observation battalions and division artillery met sections in the area; results of previous 280-mm gun firing; the season of the year; and geographic conditions, such as altitude, which affects density. Corrections should also be made for known or estimated conditions of drift, materiel and ammunition.

c. A weapon should be selected from which the last round was fired with the same charge with which registration is to be performed. If this is not possible, more than one round should be used to register.

32. Determination of Firing Data for High-Burst Registration, Met Data Not Available

a. In determining firing data for high-burst registration when met data are not available, firing data for the selected point are based on

FIRING DATA CORRECTION SHEET
(FM 6-40)

METRO MESSAGE	ALT. MDP	TIME	TYPE	LINE NO.		MPH
					㎖	

ALTITUDE OF MDP, FT		CORR FOR DIFF ALT	+ – %
ALTITUDE GUN, FT		CORRECTED VALUES	%
GUN ABOVE/BELOW MDP, FT			

CHART DATA	CHARGE 3
RANGE, YARDS Measured	10,000
HEIGHT OF T, FT	1,107
HEIGHT OF BURST ABOVE T, FT	120
TOTAL HEIGHT OF BURST	1,227
HEIGHT OF GUN, FT	977
HEIGHT (ABOVE) BELOW GUN FT	(+) 250
DIRECTION OF WIND	
+ 6400 IF NECESSARY	
TOTAL	
LESS DIR OF FIRE	
CHART DIR OF WIND	
AZIMUTH OF FIRE	2,131.0
DRIFT CORR	L 5.7
CROSSWIND CORR	
ROTATION	
TOTAL AZIMUTH CORRS	
CORRECTED AZIMUTH	2,125.3
GUN LAID ON AZIMUTH	2,300
SHIFT FOR TGT	(L) R 174.7
DF TO FIRE FOR TGT	

Df	2,200	
SHIFT	(L) R	175
Df	2,375	

FIRE ORDER Alt 1,107 ft B, Tube No. 50, Sh HE, Lot XV, Chg 3, Fz Ti, AMC, 4 Rnds.

High Burst Registration, Reg pt 1.

WIND					
LATERAL	VEL	X COMP	= R/L	MPH X	= CORR L/R ㎖
RANGE	VEL	X COMP	= R/H	MPH	

POWDER TEMP	20°

MUZZLE VELOCITY	
DEVELOPED MV	2,130 f/s
CORR FOR POW. TEMP	+ (–) 31 f/s
COMPUTED DEV MV	2,099 f/s

CORRECTIONS

	KNOWN VALUES	STANDARD VALUES	VARIATION STANDARD	UNIT CORRECTIONS	QE +	QE –	UNIT CORRECTIONS	TF +	TF –
MV	f/s	f/s	D I						
AIR DENSITY	%	100 %	D I						
AIR TEMP	°	59 °	D I						
PROJ WEIGHT	598 #	600 #	D I						
RANGE WIND	R H MPH	0 MPH	R H						
ROTATION	LAT N S	x							
BARREL CURVATURE		0 ㎖	+ –						
				TOTAL					
				NET CORRECTIONS					
RANGE (Yards) 10,500		HEIGHT OF BURST (Feet) + 250		QE AND TF UNCORRECTED	168.75			19.00	
				QE AND TF CORRECTED			Fz setting	19.00	

General weather indicates 5% loss in range; 10,000 + 5% = 10,500

FIRE COMMANDS
No. 1 Adj
Sh HE
Lot XV
Chg 3
Fz Ti
No. 1 (1) AMC
Df 2375
Ti 19.0
QE 168.8

RD NO.	POWDER TEMP	WT	QE	FZ	DF	TIME FIRED	SHELL LOT	POWDER LOT
1	20°	598	168.8	19.0	2375	1300	X	V
2	20°	598	168.8	19.0	2375	1311	X	V
3	20°	598	168.8	19.0	2375	1321	X	V
4	20°	598	168.8	19.0	2375	1330	X	V
5								
6								
7								
8								
9								
10								

BTRY	FA BN	PSN	CONC NO.	COORD	ALT	DATE	GUN TUBE NO.
B, 702d		1	High Burst	1571558979	977	1 May 1956	50

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Figure 246. Data correction sheet (met data not available).

chart data modified by an estimated range correction. The Data Correction Sheet (DA Form 6–51) (fig. 246) is used to facilitate the determination of the firing data. Weight of projectile and powder temperature are noted for comparison later with other rounds.

b. When more than one round is used in the registration, round-to-round corrections are made to basic firing data to compensate for variations in powder temperature and weight of projectile. Whenever possible, projectiles of the same weight should be used. The data for one round (nearest mean weight and powder temperature of series) will be selected as the adjusted data. The computation of the location of the high burst is as described in paragraph 334.

c. An example of determining firing data for a high-burst registration, met data not available, is given in (1) through (8) below.

(1) Situation: Battery B, 702d FA Battalion, has occupied position and is preparing to fire a 4-round high-burst registration. Met data are not available.

(2) The azimuth and range to the registration point are determined to be 2,131 mils and 10,000 yards, respectively. Registration and transfer will be fired with charge 3.

(3) Information obtained from heavy artillery units in the vicinity indicates a 5 percent loss in range due to weather. To facilitate location of the burst of the initial round, 500 yards (5 percent of 10,000) is added to the registration point range.

(4) The drift correction (L5.7) corresponding to measured chart range (10,000 yards) is added algebraically to the azimuth of the selected point of impact (2,131.0) to obtain a corrected azimuth (2,125.3).

(5) Height of burst above registration point (120 feet) is added to the altitude of the registration point (1,107 feet) to give an altitude of burst of 1,227 feet. The altitude of the gun (977 feet) is subtracted from the total altitude of burst to give a height of burst above the gun of +250 feet.

(6) The uncorrected QE (168.75) and time of flight (19.00) are determined based on a range of 10,500 yards (expected to hit at approximately 10,000 yards) and height of burst above gun of +250 feet. Since met data are not available, no other correction can be made to the uncorrected QE and time of flight.

Note. Since estimated corrections are applied for weather conditions, minor variations in muzzle velocity (±5 f/s) and ammunition weight (±5 lb) may be ignored for initial rounds. Larger variations should be considered in determining initial firing data.

(7) For fuze MTSQ T330 the fuze setting is the same as the time of flight.

(8) Data to fire are DEFLECTION 2375, TIME 19.6, QUADRANT 168.8.

33. Computation of Site

a. It is necessary to compute site to the location of the high burst prior to the determination of the range K. The site to the high burst is stripped from the QE fired to derive the adjusted elevation. Site is computed for the target plus height of burst before application of a range K in determining firing data for a transfer mission. This site is added to the elevation for the corrected horizontal range to obtain the QE to fire.

b. The elevation (QE) tables of the firing table are used in computing the site. The difference in the firing table elevations for zero height and height of the high burst or desired location of the transfer is the value of the site. Range is rounded off to the nearest 100 yards and height to the nearest 10 feet for the purpose of computing site.

c. An example of site computation is given in (1) and (2) below.

(1) Situation: Firing of a high burst was accomplished according to the example given in paragraph 32*c*, this appendix. Location of the high burst has been determined based on information reported by observers (par. 329) and from this the following data have been computed:

Azimuth	2,127.3 mils
Range	9,910 yards
Height above gun	+200 feet

(2) Site: To determine site, the firing tables are entered at range 9,900 and the following data are obtained:

Height above gun +200 feet.	QE 155.22
Height above gun 0	El 148.3
Site	+6.92 mils

34. Computation of Range *K*

a. The procedure used in the computation of range *K* is set forth in paragraph 340. Range *K* expressed as a formula is shown below:

$$\text{Range } K = \frac{(rg \text{ corresponding to adj el}) - (HB \text{ computed chart } rg)}{(HB \text{ computed chart } rg/1{,}000)}$$

The adjusted elevation is based on the QE of the round nearest the mean weight and powder temperature of the series of rounds fired. Range *K* is always expressed relative to the weight of projectile and powder temperature corresponding to the round used in determining the adjusted data; for example, range $K = +66$ yards/1,000 yards (598 lb, 20°). A Correction Sheet, 280-mm Gun (DA Form 6–52) (fig. 247) is used to facilitate the computation.

b. An example of range *K* computation is given in (1) through (3) below.

(1) Situation: Continuation of example in paragraph 33, this appendix.

(2) Adjusted elevation is determined by stripping site of +6.92 mils (par. 33*c*, this app) from QE fired.

QE fired	168. 80
Site	−(+)6. 92
Adjusted elevation	161. 88

(3) The following computations are made to determine range *K*:

Rg corresponding to el 161.88 (10,562).	10,560	yards
Rg to *HB* location	9,910	yards
Rg correction	+650	yards

$Rg\ K = \frac{650}{9.9} = +66$ yards/1,000 yards (598 lb, 20°).

35. Computation of Time *K*

a. The time (fuze setting) corresponding to the high-burst location is subtracted from the time fired (adjusted time) to obtain the total time correction. When the data differ on the rounds used in the registration, the adjusted time is based on the same round used in determining the range *K*. The time *K* is always expressed relative to the weight of projectile and powder temperature corresponding to the round used in determining adjusted data.

b. Time *K* expressed as a formula is shown below:

$$\text{Time } K = \frac{(\text{adjusted time}) - (\text{time corresponding to } HB \text{ location})}{(HB\ rg/1{,}000)}$$

c. The following computations are made to determine the time *K* (fig. 247):

Adjusted time	19. 0
Time to *HB* location (*Rg* 9,910, height above gun +200 feet)	17. 62

Time correction, seconds $(19.0 - 17.62) = +1.38$

$\text{Time } K = \frac{+1.38}{9.9} = +0.139$ second/1,000 yards (598 lb, 20°)

36. Computation of Deflection Correction

a. The deflection correction is determined by comparing the azimuth fired with the azimuth obtained and stripping the correction for drift corresponding to the high-burst location from the difference. If the azimuth obtained is greater than the azimuth fired, the correction is left. If the azimuth obtained is less than the azimuth fired, the correction is right. Deflection correction expressed as a formula is shown below:

Total deflection correction = (azimuth fired) − (azimuth obtained)

Deflection correction = (total deflection correction) − (drift correction with sign reversed).

b. In the example (fig. 247), an azimuth of 2,125 was fired and an azimuth of 2,127.3 was obtained. Subtracting 2,127.3 from 2,125 produces a total deflection correction of −2.3 (L2.3).

c. Drift correction at the high-burst location is obtained from the firing tables (range 9,900 (9,910) yards) and determined to be L5.6. Drift correction is stripped out by reversing its sign and adding it to the total deflection obtained in *b* above.

Total deflection correction	L2.3
Drift correction with sign reversed	R5.6
Deflection correction	R3.3

37. Determination of Firing Data for a Target With *K* Transfer

Firing data for a target to be fired as a *K* transfer is computed by using the range *K*, time *K*, and deflection correction determined from the high-burst registration. The Firing Data Correction Sheet (DA Form 6–51) is used to help in making these computations (fig. 248).

a. In a continuation of the situation set forth in paragraphs 32 through 36, this appendix, a

CORRECTION SHEET, 280-MM GUN
(FM 6-40)

HIGH BURST OR CENTER OF IMPACT DATA: RANGE 9,910 *(Yards)*, HT ABOVE GUN 200 *(Feet)*, AZIMUTH 2,127.3 *(mils)*

COMPUTATION OF K'S AND DF CORRECTION	MILS	SECS	MILS
ELEV, TF AND AZIMUTH FIRED *(Elev = QE 168.80 – Site + 6.92)*	161.88	19.0	2,125.0
RN CORRESPONDING TO ELEV FIRED *(Zero Height)*	10,560 YDS		
LESS HB RN, TF CORRESPONDING TO HB, AND HB AZ	– 9,910	– 17.62	*– 2,127.3
RN, TF AND DF CORRECTION	+ – 650	+ – 1.38	*L R 2.3
STRIP DRIFT CORR *(HB Rn and Ht)*			R 5.6
NET DF CORRECTION			L R 3.3
WT PROJ 598 LBS, POWDER TEMP 20 ° K'S PER 1000 YDS OF RN *(HB Rn)*	+ – 66	+ – 0.139	
COMPUTATION AND APPLICATION OF CORRECTIONS, HB OVER OR NEAR TARGET			
QE, TF AND AZ FIRED *(Uncorrected)*	mils	SECS	mils
LESS QE, TF AND AZ *(HB Location Uncorrected)*	–		*–
QE, TF AND AZ CORRECTIONS	+ –	+ –	L *R
THE FOLLOWING IS USED FOR APPLYING ADDITIONAL CORRS FOR ALL PROCEDURES:			
CORR FOR WT DIFF, WT ____ TO ____ LBS	+ –	+ –	
CORR FOR +5f/s *(MV Diff)* AND POWDER TEMP ____ TO ____ °	+ –	+ –	
CORR FOR DRIFT DIFF			R
TOTAL CORRECTIONS	+ –	+ –	
DATA FIRED OR COMPUTED			
CORRECTED DATA, TO BE FIRED			

Range $K = \frac{+650}{9.9} = +65.6$

Time $K = \frac{+1.38}{9.9} = +0.1394$

* *NOTE: If HB Az is greater than Az fired, the Df Correction is LEFT, If Less - RIGHT.*

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Figure 247. Correction sheet (range K, time K, and deflection correction).

FIRING DATA CORRECTION SHEET
(FM 6-40)

METRO MESSAGE	ALT. MDP	TIME	TYPE	LINE NO.		MPH		
					₥		%	°

CHART DATA	CHARGE 3	FIRE ORDER Alt 1,107 ft, B, Tube No. 50, Sh HE, Lot XV, Chg 3, Fz Ti, 1 Rnd DNL	ALTITUDE OF MDP, FT	CORR FOR DIFF ALT	+ % + ° / – % –
RANGE, YARDS Computed	11,060	Transfer from Reg pt 1, Conc EE 409	ALTITUDE GUN, FT		
			GUN ABOVE/BELOW MDP, FT	CORRECTED VALUES	% °

HEIGHT OF T, FT	1,047	WIND	LATERAL	VEL X COMP = R/L MPH X = CORR L/R ₥	MUZZLE VELOCITY
HEIGHT OF BURST ABOVE T, FT	60		RANGE	VEL X COMP = R/H MPH	POWDER TEMP 23° · DEVELOPED MV f/s
TOTAL HEIGHT OF BURST	1,107				CORR FOR POW. TEMP + – f/s
HEIGHT OF GUN, FT	967	CORRECTIONS			COMPUTED DEV MV f/s
HEIGHT (ABOVE) BELOW GUN FT (+) –	140				

			KNOWN VALUES	STANDARD VALUES	VARIATION STANDARD	UNIT CORRECTIONS	QE +	QE –	UNIT CORRECTIONS	TF +	TF –	FIRE COMMANDS
DIRECTION OF WIND		MV	f/s	f/s	D / I							No. 1 Adj
+ 6400 IF NECESSARY		AIR DENSITY	%	100 %	D / I							Sh HE
TOTAL		AIR TEMP	°	59 °	D / I							Lot XV
LESS DIR OF FIRE		PROJ WEIGHT	#	#	D / I							Chg 3
CHART DIR OF WIND		RANGE WIND	R / H MPH	0 MPH	R / H							Fz Ti
AZIMUTH OF FIRE	2,121.0	ROTATION	LAT N/S									No. 1 (1) DNL
DRIFT CORR	L6.6	BARREL CURVATURE		0 ₥	+ / –							Df 2382
CROSSWIND CORR						TOTAL site	4.37					Ti 21.8
~~ROTATION~~ Df Corr	R3.3	*Projectile weight and Powder Temperature				NET CORRECTIONS	* + 0.54		Total Corr	1.56		QE 193.7
TOTAL AZIMUTH CORRS	L3.3	RANGE (Yards) 11,790		HEIGHT OF BURST (Feet) 0		QE AND TF UNCORRECTED	188.77			** 20.29		
CORRECTED AZIMUTH	2,117.7	**Uncorrected time of flight (rg 11,060, height of burst + 140 feet)				QE AND TF CORRECTED	193.68			21.85		

GUN LAID ON AZIMUTH	2,300	Df 2,200	Rg K = +66 yd/1000 yd
SHIFT FOR TGT	(L) R 182.3	(L) R 182	Ti K = +0.139 Sec/1000 yd
DF TO FIRE FOR TGT		Df 2,382	

RD NO.	POWDER TEMP	WT	QE	FZ	DF	TIME FIRED	SHELL LOT	POWDER LOT
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

Rg Corr (11.1 × (+66)) = +732.6 yd. Ti Corr (11.1 × (+.139)) = +1.54 Sec

Computed rg = 11,060

Corrected rg = 11,793

BTRY	FA BN	PSN	CONC NO.	COORD	ALT	DATE	GUN TUBE NO.
B, 702d		1	EE 409	1571558979	967	1 May 1956	50

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Figure 248. Data correction sheet (application of range and time K and deflection correction, K transfer techniques).

CORRECTION SHEET, 280-MM GUN
(FM 6-40)

HIGH BURST OR CENTER OF IMPACT DATA: RANGE ______ (Yards), HT ABOVE GUN ______ (Feet), AZIMUTH ______ (mils)

COMPUTATION OF K'S AND DF CORRECTION	MILS	SECS	MILS	
ELEV, TF AND AZIMUTH FIRED (Elev = QE ______ − Site ______)				
RN CORRESPONDING TO ELEV FIRED (Zero Height)	YDS			
LESS HB RN, TF CORRESPONDING TO HB, AND HB AZ	−	−	* −	11.1 × (+0.139) = +1.54 Sec
RN, TF AND DF CORRECTION	+ −	+ −	* L R	
STRIP DRIFT CORR (HB Rn and Ht)			R	
NET DF CORRECTION			L R	
WT PROJ ______ LBS, POWDER TEMP ______ ° K'S PER 1000 YDS OF RN (HB Rn)	+ −	+ −		
COMPUTATION AND APPLICATION OF CORRECTIONS, HB OVER OR NEAR TARGET				
QE, TF AND AZ FIRED (Uncorrected)	mils	SECS	mils	20° to 23° = +1.8 f/s
LESS QE, TF AND AZ (HB Location Uncorrected)	−		* −	1.8 × (−.168) = −0.3024 mils
QE, TF AND AZ CORRECTIONS	+ −	+ −	L R	1.8 × (−.010) = −0.0180 Sec
THE FOLLOWING IS USED FOR APPLYING ADDITIONAL CORRS FOR ALL PROCEDURES: Corr for Time K		+1.54		598 to 604 = +6 lb
CORR FOR WT DIFF, WT 598 TO 604 LBS	+ − 0.84	+ − 0.04		6 × (+.14) = +0.84 mils
CORR FOR +5f/s (MV Diff) AND POWDER TEMP 20° TO 23°	+ − 0.30	+ − 0.02		6 × (+.006) = +.036 Sec
CORR FOR DRIFT DIFF			R	
TOTAL CORRECTIONS	+ − 0.54	+ − 1.56		
DATA FIRED OR COMPUTED	193.15	20.29		
CORRECTED DATA, TO BE FIRED	193.69	21.85		

* NOTE: If HB Az is greater than Az fired, the Df Correction is LEFT, If Less - RIGHT.

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Figure 249. Correction sheet showing additional corrections, K transfer technique.

target has been assigned and K transfer target data now available are—

Measured range	11,080 yards
Measured azimuth	2,120 mils
Height above gun	140 feet
Range K	+66 yards/1,000 yards (598 lb, 20°)
Time K	+0.139 sec/1,000 yards (598 lb, 20°)
Deflection correction	R3.3 mils
Weight of projectile	604 pounds
Powder temperature	23°

b. The following computations are made to determine corrected QE:

Computed range	11, 060 yards
Range correction (11.1 x (+66)).	+733 yards
Corrected range	11, 793 yards
Elevation corresponding to range 11,790 yards (0 height).	188. 77 mils
Site (range 11,100, height of burst above gun +140 feet).	+4. 37 (177.77−173.40) mils
QE	193. 14 mils
Correction for projectile weight (fig. 249)* +0.84 mils.	
Correction for powder temperature (fig. 249)* −0.30 mils.	
Elevation correction (+0.84+(−0.30)).	+0. 54 mils
Corrected QE	193. 68 mils

c. The following computations are made to determine the corrected fuze setting:

Computed time of flight (range 11,060 yards, height of burst above gun +140 feet).	20.29 seconds
Correction for projectile weight (fig. 249)*.	+0.04 seconds
Correction for powder temperature (fig. 249)*.	−0.02 seconds
Time correction (11.1×(+.139))	+1.54 seconds
Total correction	+1.56 seconds
Corrected time of flight (20.29+1.56).	21.85 seconds
Corrected fuze setting	21.8 (21.85) seconds

*Computations are based on computed range at 0 height. Change in unit correction factors between 0 height and actual height of target above guns is negligible for HB transfers.

d. The total deflection correction is the sum of the deflection correction from registration and the correction for drift. In the computation of data (fig. 248), the deflection correction from registration (R3.3) is added algebraically to the firing table drift (L6.6) for range 11,100 (11,060) yards to produce a total deflection correction of L3.3. This correction is added to the computed azimuth (2,121.0) to give a corrected azimuth of 2,117.7 which is converted to deflection 2,382.

e. Data to fire are DEFLECTION 2382, TIME 21.8, QE 193.7.

Section X. PRECISION REGISTRATION AND TIME REGISTRATION WITH *K* TRANSFER

38. General

The procedure for conducting a precision registration and a time registration are the same as set forth in paragraphs 310 through 321 and 516. However, this delivery technique is the least desirable method of obtaining corrections since it requires the use of a large amount of ammunition and is time-consuming.

39. Determination of Time *K* From Time Registration

The time correction is determined by subtracting the time corresponding to the registration point range from the adjusted time as computed. The time K is obtained in the same manner as that for a high-burst registration (par. 35, this app); i. e.,

$$\text{Time } K = \frac{(\text{adjusted time}) - (\text{time corresponding to registration point range})}{(\text{registration point range}/1{,}000 \text{ yards})}$$

Section XI. ADJUSTMENT AND FIRE FOR EFFECT

40. General

a. This section sets forth the procedures used when preparation for fire for effect can be accomplished by adjusting on the target by using observed fire procedures. These procedures may be used when the location of gun and/or target is in doubt, when predicted fire or met plus VE technique elements are lacking, when a flash base is not available for a high-burst or center-of-impact registration, or when surprise is not essential.

b. In order to facilitate adjustment, the best available firing data are used. Known or estimated met and velocity information is incorporated in firing data. A firing chart is used to obtain chart data for each round, and corrections are plotted by using a Target Grid (DA Form 6–53).

41. Determination of Firing Data for Initial Round

When graphical firing tables are not available, tabular firing tables are used to compute corrected deflection, time of flight, and QE. These data are based on chart data corrected for known or estimated effects of variations from standard conditions. The initial target plot is relocated by polar plotting the target at the corrected deflection and corrected range of the initial round. This is done during the time that firing data for the initial round are being sent to the adjusting piece. The target grid is centered on the corrected plot and oriented on the observer's azimuth. This procedure results in including the corrections determined for the first round in adjustment as constants in the chart data of subsequent rounds. Subsequent observer corrections will then be applied to the corrected initial plot location. For example—

a. Situation: Battery A, 701st FA Battalion, has been directed to fire a mission, using time fire, at coordinates 67505975, altitude of target 1,500 feet. Neither a flash base nor met support is available, and the mission must be accomplished from a gun position located by inspection from a small-scale map. Adjustment will be by a ground observer. Inspected gun position coordinates are 87466635 and altitude of gun position is 1,180 feet. The gun is laid on azimuth 4,600, deflection 2,200.

b. Target. The target is plotted on a firing chart and deflection (az) and range are measured and announced as DEFLECTION 2327 (AZ 4473), RANGE 22,930. Experience from recent firing in this area at about the same range has indicated that effects of nonstandard conditions (weather, VE, etc.) have averaged approximately +600 yards. An estimated correction of −600 yards is therefore added algebraically to the announced chart range (22,930 yards) to give a corrected range of 22,330 yards. The FDO directs that charge 4 and fuze T330 will be used for the mission.

c. Drift. The drift correction, L15.5 (*rg* 22,900 yards) is added algebraically to the announced deflection (2,327) to give a corrected deflection of 2,342.

d. Height. Target height above gun is +320 feet (1,500−1,180). To this +320 feet, 60 feet (20 yards) must be added to raise the burst above the ground. Site is determined by entering the firing table at range 22,900 and multiplying the difference in QE at 0 height and the QE at +500 feet by 0.76 $\left(\frac{380}{500}\right)$. The product, 5.78 mils ($7.6 \times .76 = 5.78$), is the site to be added to the elevation for corrected range.

e. QE and Time of Flight. Uncorrected QE and time of flight corresponding to corrected range of 22,330 yards at 0 height above guns are 341.74 mils and 43.49 seconds, respectively. If an average correction for time of flight is known, it is applied to the time of flight for the corrected range. Since none is known in this case, the time announced to the gun crew is 43.5. The quadrant elevation announced to the gun crew is 347.5 (341.74+(+5.78)).

f. Firing Data for the Initial Round. Firing data for the initial round are DEFLECTION 2342, TIME 43.5, QUADRANT 347.5.

g. Replot. The chart operator then replots the location of the burst of the initial round at deflection 2,342, range 22,330 and orients the target grid on the observer's azimuth (4,470).

42. Determination of Firing Data for Subsequent Rounds

Subsequent observer corrections are plotted, and new chart data are announced. Time of flight and QE are determined for each round by one or more computers by using the firing table. Site corrections are determined by using chart range (less range correction applied in relocating target by polar plotting) to the nearest 100 yards. Propellant temperature variations causing MV effects of 2 f/s or less are disregarded during the adjustment.

a. In a continuation of the situation in paragraph 41, this appendix, the observer's correction for the second round is RIGHT 600, UP 40, REPEAT RANGE. Having plotted the correction, the chart operator announces DEFLECTION 2316, RANGE 22,310. The computer determines firing data as follows:

(1) *Deflection.* Since the range change from the initial round is not large, the drift correction has not changed significantly (exceeding ±1 mil). Therefore, the measured chart deflection of 2,316 is announced to the gun crew.

(2) *Site.* Ranges of the initial and second round being the same (to the nearest 100 yards), site correction is determined by multiplying 7.6 mils $\times$ 0.24 $\left(\frac{120}{500}\right)$ to give a correction of +1.82 mils to the old site. New site is +7.60 mils (+5.78 +(+1.82)).

(3) *QE and time of flight.* Time of flight 43.43 and elevation 341.18 are determined for range 22,310, height above gun 0. To elevation 341.18 is added site of 7.60 mils to give QE of 348.78 mils.

(4) *Firing data.* Firing data announced to the gun crew for the second round of the adjustment are DEFLECTION 2316, TIME 43.4, QUADRANT 348.8.

b. Observer correction for third round is UP 40, DROP 400. Having plotted the correction, the chart operator announces DEFLECTION 2316, RANGE 21,910. The computer determines firing data as follows:

(1) *Deflection.* Range change of 400 yards causes a drift change of less than 1 mil (L14.7−L14.2=R0.5). Therefore, a correction to the measured deflection (2,316) is not necessary.

(2) *Site.* Site correction is determined by multiplying 7.7 mils (difference in QE between 0 height and +500 feet at range 22,500 (21,910+600))$\times$0.24 to give a correction of +1.85 mils to the site for the second round. New site is +9.45 mils (+7.60+(+1.85)).

(3) *QE and time of flight.* Time of flight 42.23 and elevation 330.27 are determined for range 21,910, height above gun 0. To elevation 330.27 is added site of 9.45 mils to give QE of 339.72 mils.

(4) *Firing data.* Firing data announced to the gun crew for the third round of the adjustment are DEFLECTION 2316, TIME 42.2, QUADRANT 339.7.

c. Observer correction for fourth round is RIGHT 100, ADD 200. Having plotted the correction, the chart operator announces DEFLECTION 2311, RANGE 22,110. The computer determines firing data as follows:

(1) *Deflection.* Range change of 200 yards is not enough to cause a 1-mil change in drift. Therefore, the measured chart deflection (2,311) is announced to the gun crew.

(2) *Site.* No observer correction for height having been requested, the site (+9.45) remains unchanged.

(3) *QE and time of flight.* Time of flight 42.83 and elevation 335.67 are determined for range 22,110, height above gun 0. To elevation 335.67 is added site of +9.45 mils to give QE of 345.12 mils.

(4) *Firing data.* Firing data announced to the gun crew for the fourth round of the adjustment are DEFLECTION 2311, TIME 42.8, QUADRANT 345.1.

d. Observer correction for fifth round is DOWN 20, DROP 100, FIRE FOR EFFECT. (Observer was instructed to enter FFE upon splitting 200-yard bracket since value of fork exceeds 150 yards.) Having plotted the correction, the chart operator announces DEFLECTION 2311, RANGE 22,010. Projectile weight and powder temperature remain unchanged. The computer determines firing data as follows:

(1) *Deflection.* The measured chart deflection of 2,311 is announced to the gun crew (drift is negligible).

(2) *Site.* Site correction is determined by multiplying 7.6 mils (difference in QE between 0 height and +500 feet at range 22,600)$\times$0.12 $\left(\frac{60}{500}\right)$ to give a correction of −0.91 mils to the site for the fourth round. New site is +8.54 mils (+9.45 +(−.91)).

(3) *QE and time of flight.* Time of flight 42.53 and elevation 332.97 are determined for range 22,010, height above gun 0. To elevation 332.97 is added site of +8.54 to give QE of 341.51 mils.

(4) *Firing data.* Firing data announced to the gun crew for fire for effect are DEFLECTION 2311, TIME 42.5, QUADRANT 341.5.

43. Special Considerations

a. A more rapid computation of firing data may be achieved by simplification of procedures for determining deflection and site during adjustment.

(1) Round-to-round drift differences may be ignored during adjustment and fire for effect.

(2) A 100-yard site factor may be established to the nearest 0.1 mil and used through-

out adjustment and fire for effect to apply observer corrections for height of burst. In the illustrative problem (pars. 41 and 42, this app) the 100-yard site factor would be 4.6 $\left(\frac{300}{500} \times 7.6\right)$. Use of the 100-yard site factor from the second round through the final round results in a final site that is the same as the final site determined in paragraph 42*d*(2), this appendix. To use the 100-yard site factor, multiply factor by observer's correction; i. e., observer's correction of UP 40 corresponds to a site correction of +1.84 mils ($.4 \times 4.6 = 1.84$).

b. Adjustment and fire for effect should be conducted by using projectiles of the same weight. During the adjustment, corrections for variations of weights are ignored. After the first round variation from standard has been corrected, subsequent round-to-round variations in weight do not have a significant effect. For example, throughout most firings with charge 4, the effect of a 1-pound variation is about 0.1 mil. Corrections for weight variations are required in fire for effect if the failure to correct will cause an error above one-half of a range probable error.

Section XII. ORGANIZATION OF THE FDC

44. Table of Organization

The fire direction section of the 280-mm gun firing battery consists of 1 chief fire direction computer, 4 fire direction specialists (computers), and 2 radio operators. No fire direction officer is authorized by the table of organization. In addition to the battery commander, there is an executive, a reconnaissance and survey officer, and two gun platoon commanders. From these, a fire direction officer must be selected. Specific functions of fire direction personnel in the production of firing data is based on the equipment used—tabular or graphical. Suggested functions are outlined for personnel listed in TOE 6–537R.

45. Duties of FDC Personnel Using Tabular Firing Tables

a. Fire Direction Officer. The fire direction officer—

(1) Supervises the FDC.
(2) Announces fire order.
(3) Checks fire direction computer's computations.
(4) Resolves disagreements in computations between computers.
(5) Determines and announces range correction for estimated weather.

b. Chief Fire Direction Computer. The chief fire direction computer—

(1) Maintains Firing Data Correction Sheet (DA Form 6–51) and Correction Sheet, 280-mm Gun (DA Form 6–52).
(2) Computes and announces height of burst above gun.
(3) Determines line number of met message to be used, and, after corrections for MDP and gun height differences, announces ballistic met elements to be used.
(4) Applies powder temperature effect to muzzle velocity (from MVV or VE) and announces corrected muzzle velocity.
(5) Records correction to QE for barrel curvature.
(6) Applies net corrections to uncorrected azimuth, time of flight, and QE.
(7) Announces fire commands to gun crews.
(8) Maintains all records of firing, muzzle velocities, velocity errors, and ammunition expenditures.

c. Computer 1. Computer number 1—

(1) Computes and announces uncorrected QE for measured range.
(2) Determines and announces correction to deflection (azimuth), time of flight, and QE for rotation effects.
(3) Computes and announces uncorrected time of flight and QE for computed range.
(4) Checks, by independent computation, work of computer number 2.

d. Computer 2. Computer number 2—

(1) Maintains and operates firing chart.
(2) Computes and announces corrections to deflection (azimuth) for lateral wind and to time of flight and QE for range wind.
(3) Determines and announces deflection (azimuth) correction for drift.
(4) Checks, by independent computation, work of computer number 1.

e. Computer 3. Computer number 3—

(1) Computes and announces corrections to time of flight and QE for muzzle velocity and air density.

(2) Computes and announces site during adjustment missions.

(3) Checks, by independent computation, work of computer number 4.

f. Computer 4. Computer number 4—

(1) Computes azimuth and range to target, using logarithms.

(2) Computes and announces corrections to time of flight and QE for air temperature and weight of projectile.

(3) Checks, by independent computation, work of computer number 3.

Section XIII. DETERMINATION OF MINIMUM ELEVATION

46. General

The minimum elevation for the 280-mm gun is computed generally the same as those in paragraphs 76 through 82. Since value of complementary angle of site is not a separate element in 280-mm gun firing tables (FT 280–B–1), minor variations in computation procedures are necessary. Minimum elevation is normally computed for each weapon and is used to the nearest 0.1 mil.

47. Computation of Minimum Elevation

a. The following procedure is used in computing the minimum elevation for the 280-mm gun:

(1) The angle of site reported by the chief of section and the vertical clearance are converted into height above gun in feet by using the mil relation.

(2) By using the height above gun in feet and the mask range, quadrant elevation is determined by interpolation in table A of the firing table.

(3) Two forks at mask range are determined in table D.

(4) The minimum elevation (sum of the value of quadrant elevation and 2 forks) is reported to FDC to the nearest 0.1 mil.

b. An example of minimum elevation computation is given in (1) and (2) below.

(1) Piece mask information:
Range: 1,800 yards.
Measured angle of site: +43 mils.

(2) Computation (charge 1):

(*a*) Convert 43 mils to feet:
$43 \times 1.8 \times 3 = 232.2$ feet.

(*b*) Convert 5-yard vertical clearance to feet and combine with height above gun in feet (*a*) above: $232.2 + 15$ $(5 \times 3) = 247.2$ feet.

(*c*) Enter firing table at range 1,800 yards, height of burst above gun 250 feet, and determine QE of 96.60 mils.

(*d*) Enter firing table at range 1,800 yards and determine value of 2 forks of 2.0 mils (2×1).

(*e*) Minimum elevation (QE) is 98.6 mils $(96.60 + 2.0 = 98.60 \cancel{m})$.

APPENDIX V

SURFACE GUNNERY WITH ANTIAIRCRAFT ARTILLERY WEAPONS

1. General

a. This appendix presents the characteristics, organization, and gunnery techniques of an antiaircraft artillery (AAA) unit when employed in a surface mission firing indirect fire. When antiaircraft artillery is used in a field artillery role, the principles of gunnery contained in this manual, as modified by this appendix, are applicable.

b. For additional discussion on the employment of AAA weapons, the advantages and limitations of AAA in the surface mission, and the necessary modifications in AAA materiel and methods for surface firing, see FM 44–2, FM 44–3, FM 44–4, FM 44–21, and FM 44–61.

c. Antiaircraft artillery weapons suitable for indirect fire include the 120-mm gun, 90-mm gun, 75-mm gun (Skysweeper), and twin 40-mm gun on motor carriage M42.

2. Characteristics

Characteristics of antiaircraft artillery weapons that influence their performance in a surface firing role are—

a. High rate of fire.

b. Long range (except 40-mm).

c. Unlimited traverse.

d. High muzzle velocity and resulting flat trajectory.

e. Large range dispersion.

f. Fixed ammunition.

g. Relative lack of tactical mobility (except 40-mm).

3. Ammunition

The following data are a guide to ammunition in general use by AAA units firing in the surface role:

Caliber	*Projectile*	*Fuze*
120-mm	HE M73	MT M61 M506 M507 T226 (M513)
90-mm	HE M71	M97 M43 M67 T226 (M513) M78 M51 M55 M500 M502 T286E1 (M518) T177E3
	WP M313	M48 M57
	*APC–T M82	M68BD

*Many other antitank rounds are available for the 90-mm gun. However, most of these require adjustment of the recoil mechanism and are not generally used by AAA units in the surface role.

75-mm (Skysweeper)	HE T50E6	T286E1 (M518) T177E3 T226 (M513) M502 T234E2
40-mm	HE–T Mk 2	Mk 27 (Quick) M64A1

4. Organization

The TOE of antiaircraft artillery units does not provide for fire direction personnel. Personnel from existing TOE positions should be trained in fire direction duties and other duties peculiar to the surface role.

a. 120-mm and 90-mm Units.

(1) The artillery fire control system M33 is

not used by these units in the surface role.

(2) The gun platoon leader performs the duties of the field artillery battery executive officer, unless the TOE strength is augmented with a battery executive officer.

(3) The fire control platoon leader acts as the battery fire direction officer (FDO) under the supervision of the battery commander.

(4) Personnel from the battery fire control platoon should be trained to perform fire direction duties in addition to their other duties. The job duties are based on the type of fire direction equipment issued to the unit. Check charts should be located at the battery fire direction center (FDC).

(5) The S3 and assistant S3 act as battalion fire direction officers. Personnel from the battalion operations and intelligence section and from the battalion radar section normally perform the duties of battalion fire direction personnel.

(6) Other officers, warrant officers, and NCO's may be used as observers when necessary.

b. 75-mm Skysweeper Units.

(1) The battery gunnery officer acts as the battery FDO.

(2) Personnel from the target acquisition and tactical control section should be trained to perform duties in the battery FDC.

(3) The battalion S3 and the electronics officer normally act as battalion fire direction officers. The operations sergeant and the intelligence sergeant act as chief computers. Enlisted personnel from the operations and intelligence section and the radar section should be trained to perform the duties of the other battalion fire direction personnel.

c. 40-mm Units. Units equipped with the twin 40-mm gun, motor carriage M42, are normally used in platoon strength with an FDC at the platoon position. The platoon leader acts as the FDO, and enlisted personnel from the platoon should be trained in fire direction duties. The platoon FDC consists of the FDO, a primary chart operator, a check chart operator, and a computer. The assistant platoon leader (platoon sergeant) acts as executive for the guns.

5. Emplacement

a. When AAA weapons are to be emplaced for surface firing, the flat trajectory and dead space created by emplacing these weapons in defilade must be considered. The positions should be selected to provide flash defilade but with the least dead space.

b. The basis for selecting a position area is similar to those for a field artillery position except that level, firm ground is more essential because of the weight of the weapons. The 120-mm and 90-mm weapons are leveled and oriented the same as for antiaircraft firing. The 75-mm gun and the twin 40-mm guns have no provisions for leveling; therefore, positions should be selected that are as level as possible to minimize the effects of cant. The 75-mm gun is oriented by using gunnery techniques outlined for field artillery weapons. The 40-mm guns are oriented by using the known datum point or backsighting method (FM 44-2).

6. Calibration

Owing to the high muzzle velocities of antiaircraft artillery weapons, the point of impact on the ground will vary for small differences in wear between guns. This variation means that guns in the battery and between batteries in the battalion must be calibrated with each other. Steps for performing this calibration are outlined in chapter 28 of this manual.

7. Gunnery Techniques

Table XXIII is presented as a guide for the most desirable widths of open sheaves:

Table XXIII. Open Sheaf

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
120-mm	150	--------	200	--------
90-mm	100	--------	140	--------
75-mm	--------	100	--------	130
40-mm	60	--------	80	--------

a. 120-mm and 90-mm Units.

(1) *Fire commands.* Fire commands are generally the same as those for field artillery weapons except that the command for charge is omitted, and the command for

direction is given in terms of azimuth rather than deflection. No separate command for site is used. Quadrant elevation is used to lay the tube for elevation. When the gunner's quadrant is used, the command is QUADRANT (SO MUCH). When the elevation indicator-regulator is used, the command is ELEVATION (SO MUCH).

(2) *Firing charts.* Field artillery methods are used in the construction of firing charts. Since azimuths rather than deflections are used, a different system is used to measure direction from the firing chart. In referring to other parts of this manual the term "azimuth" should be substituted where the term "deflection" appears. The terms "temporary azimuth index" and "azimuth index" are used in place of the field artillery terms "temporary deflection index" and "deflection index." Temporary azimuth indexes for use with antiaircraft weapons are constructed at the azimuth (to the nearest 100 mils) from the center battery to the center of sector. Temporary azimuth indexes for other batteries are constructed at the same azimuth as that for the center battery. For example, the azimuth from the center battery to the center of sector is 376 mils; therefore, temporary azimuth indexes for all batteries are constructed at azimuth 400. The aluminum range-deflection protractor or plastic range-deflection fan is numbered to read *azimuth;* the azimuth increases to the *right* and decreases to the *left* (fig. 250).

(3) *Corrections from registration.* After registration, the azimuth index is constructed in the same way as the deflection index shown in chapter 17 of this manual. The azimuth correction scale is constructed in the same way as the deflection correction scale but the azimuth correction is applied at the battery FDC rather than given to the guns. (There is no gunner's aid dial on 90-mm or 120-mm antiaircraft weapons.) Elevation and time gagelines are constructed in the same way as those for field artillery weapons.

(4) *Corrections from a met message.* Section II of FT 90AA–B–3 gives necessary data for solving a met message for surface firing with the 90-mm gun. (Note that type 4 message is used.) Necessary firing table data for solving a met message for surface firing with the 120-mm gun have not been published. Data in FT 90AA–B–3 are presented in a manner that requires double interpolation for the effects of various nonstandard conditions. These tables are entered with the chart range to the nearest 100 yards (corresponding to the adjusted elevation). The effects of existing nonstandard conditions are determined to an accuracy equivalent to that given in the met message. The value determined is the *effect* of the existing nonstandard condition.

b. 75-mm Skysweeper. When the 75-mm Skysweeper is employed in the surface role, a panoramic telescope and range quadrant must be mounted on the weapon since the carriage cannot be leveled. By use of adapter blocks, the panoramic telescope and range quadrant are mounted on the direct fire sight mounts (FM 44–3). When this sighting equipment has been mounted, the weapon may be fired by using gunnery techniques outlined for field artillery weapons. Since this weapon uses fixed ammunition, the command for charge is omitted. Corrections from a met message cannot be computed because necessary 75-mm gun firing table data have not been published.

c. 40-mm Units.

(1) *Fire commands.* The term "platoon" is used to refer to all weapons of the platoon. Terms "center," "left," and "right" are used as in field artillery to refer to two-gun groups within the platoon. Owing to the different maximum ranges obtainable before self-destruction, the command for a high explosive projectile is followed by specifying the type of tracer element if different types are on hand in the platoon. The Mk 11 tracer burns from 7 to 12 seconds, depending on the lot of ammunition and the existing ballistic conditions. This burning time gives a maximum range varying from 3,700 yards to 5,200 yards. The M3A1 tracer also has a variable burning time with a maximum range of

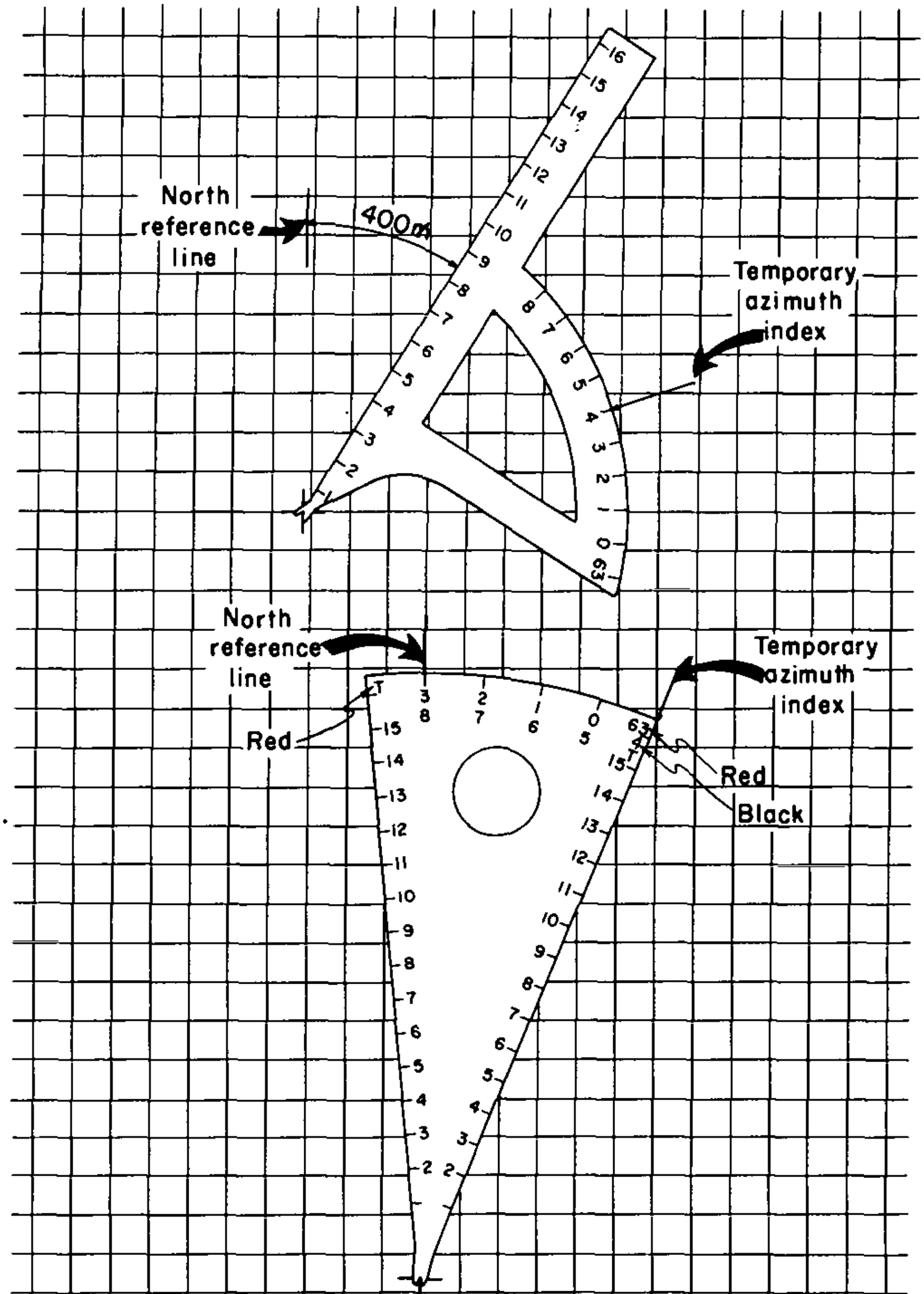


Figure 250. Numbering the range-deflection protractor and range-deflection fan.

approximately 5,700 yards (FT 40AA–3 and TM 9–1901). The fuze command is omitted because there is no fuze action other than quick available. The method of fire command indicates the firing of both barrels of each weapon unless otherwise specified. If only one barrel is to be fired, the method of fire command specifies which barrel is to be used; for example, CENTER, LEFT BARREL, ONE ROUND. The command QUADRANT (SO MUCH) is used to lay the weapon for the proper quadrant elevation.

(2) *Firing chart.* The firing chart may be a grid sheet or a battle map. The temporary azimuth index is constructed and the fan is numbered in the same way as that shown for 120-mm and 90-mm units (*a*(2) above).

(3) *Corrections from registration.* Registration corrections may be found by assuming azimuth and quadrant to be correct when the observer obtains a trial range or by following a modified precision registration procedure. In the modified precision registration procedure, the "C" is used rather than the fork for finding elevation changes in fire for effect and in the elevation change formula. The azimuth correction and adjusted elevation are used in the same way as that shown for 120-mm and 90-mm units (*a*(3) above). Since there are no drift data available for the 40-mm gun, azimuth corrections for drift are not used.

(4) *Corrections from met message.* No firing table data for met corrections are available for the 40-mm gun; therefore, corrections from a met message cannot be determined.

8. FDC Procedures

Except as modified by this appendix, FDC procedures, as shown in chapter 20, apply to antiaircraft units.

APPENDIX VI

ARMOR EMPLOYED IN A FIELD ARTILLERY MISSION

1. General

a. Tank guns should not be considered as artillery. This is due to the high velocity, flat trajectory, and short tube life of tank guns and the small bursting radius of the ammunition. However, under exceptional circumstances, a command decision may be made to employ tanks in an indirect fire role under the operational control of the supported field artillery. The tank unit may either be attached or given a reinforcing mission. The field artillery unit is responsible for fire control, communication, and survey, and, when the tank unit is attached, for ammunition, gasoline, rations, and other supplies. Whether attached or reinforcing, the tank unit must retain the capability of immediately reverting to its primary role of direct fire.

b. This appendix deals with the gunnery techniques used when the tank unit is under the control of the field artillery. For information on the mission and the tactical employment of tank units, characteristics of the tank and fire control materiel, and information on direct fire with tank weapons, see the FM 17 series.

2. Ammunition

The following types of ammunition (as applied to the field artillery role) are available for tank weapons:

a. Projectiles.

Caliber	*Type*
Gun, 76-mm	HE and Smoke (WP)
Gun, 90-mm	HE and Smoke (WP)

b. Basic Load. A typical basic load will include approximately 60 percent HE, 15 percent WP, and 25 percent antitank ammunition.

c. Fuzes. Shell HE and WP are issued with combination superquick and delay fuzes. Combination mechanical time and superquick or concrete-piercing fuzes may be obtained and substituted for the normal fuzes if required.

Note. See TM 9-1901 and table III of this manual for further ammunition information.

3. Observer Procedure

Field artillery observer procedures as covered in part THREE are used.

4. Fire Direction

a. Firing Chart. Each tank platoon is plotted on the field artillery firing chart, and the GFT fan (range-deflection fan) is numbered in the same way as for field artillery. The temporary deflection index is placed at deflection 3,200. If tank weapon firing tables are not available to the FDC, the tank unit normally fires only observed fire in the indirect role. If firing tables and/or GFT's are available, a registration should be conducted and the deflection index and deflection correction scale should be set up by using the procedures described in chapter 19 of this manual. During adjustment, corrections sent by the observer are plotted by using the target grid as described in chapter 17.

b. Fire Commands. Fire commands are sent from the FDC to the tank unit fire control officer, who is responsible for tank fire. The elements and sequence of fire commands differ slightly from field artillery procedure. An example of the sequence is shown in the following fire command:

PLATOON
HE
12,000, UP 10
FROM REFERENCE POINT, RIGHT 115
MORTARS FIRING
FIRE

(1) *Platoon.* The normal method of employing tanks in an indirect fire role is by platoon (five tank weapons). To alert (pieces to follow) all five weapons, the command is PLATOON.

(2) *HE.* The ammunition command is similar to that for field artillery except that the word "shell" is omitted and the fuze is also part of the command; i. e., HE DELAY. If fuze quick is desired, only

the shell command is given; i. e., HE. As all tank ammunition is fixed, no charge command is given.

(3) *12,000, up 10.* The range command (12,000) is given to the nearest 100 yards. The elevation to be fired is determined at the tank position. When the target is at a different altitude from that of the tank, an angle of site is computed in mils and included as part of the command (UP 10). If the artillery FDC has firing tables or GFT's, an elevation is normally computed instead of range. The command QUADRANT, which includes the angle of site, is sent to the tanks; i. e., QUADRANT 430. The tank weapons may be laid for elevation by using either the gunner's quadrant or the elevation quadrant. Since the range of most tank weapons is limited by their inability to elevate to high angles, it may be necessary either to dig in the rear of the tanks or to place them on a ramp which slopes away from the direction of fire.

(4) *From reference point, right 115.* The direction command is given in terms of a reference point. In the indirect fire role, the tanks are laid on an azimuth, and this azimuth is considered the reference point. When the tank is laid, the azimuth indicator is zeroed. Changes in direction are given as right or left of the reference point (azimuth on which laid). Aiming posts may be set out and alined on a common deflection, usually 2,600 or 2,800 mils (this is to right front). As the tank does not have a panoramic sight, the aiming post deflection is merely an offset angle out of the line of fire. During lulls in firing, the aiming posts are used to check tank displacement without the gunner's turning the turret (tube) back to the aiming circle. As tank units zero the gunner's aid between direction changes, the FDC personnel must send the difference in deflection to the tank. For example, a tank platoon is laid on azimuth 1,600 and a deflection index has been placed on the chart at deflection 3,200. The chart deflection to an announced target is 3,085 mils (azimuth 1,715). The direction command to the tank is FROM REFERENCE POINT, RIGHT 115. The turret (tube) is turned 115 mils to the right and the gunner's aid is zeroed. The chart deflection to the target plot after the observer correction is 3,093 mils (azimuth 1,707). The direction command is LEFT 8. An alternate method of direction control, which has the advantage of minimizing directional errors by the nonadjusting tanks, is to give all direction commands as *deflections* in the same manner as that used with artillery weapons. Although the azimuth indicator must be zeroed after the tank is laid, the gunner's aid is *not* moved or zeroed between rounds. The turret (tube) is moved until the reading on the azimuth indicator is the commanded deflection. In the above example, the initial direction command is DEFLECTION 3085. The gunner moves the turret until 3085 is read on the azimuth indicator (fig. 251). The gunner's aid is not zeroed. The next direction command is DEFLECTION 3093. The turret is moved until 3093 is read on the azimuth indicator (fig. 252).

(5) *Mortars firing.* The nature of the target is announced to the tank unit as a fire command.

(6) *Fire.* The command to open fire is FIRE. In tank gunnery, this command is the last element in the sequence of fire

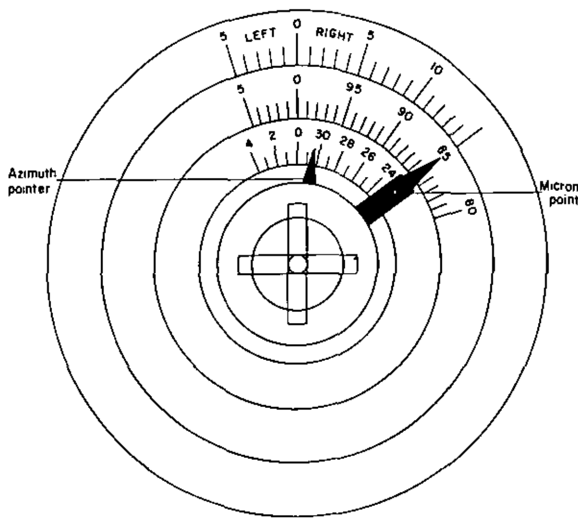


Figure 251. Deflection 3085 on azimuth indicator.

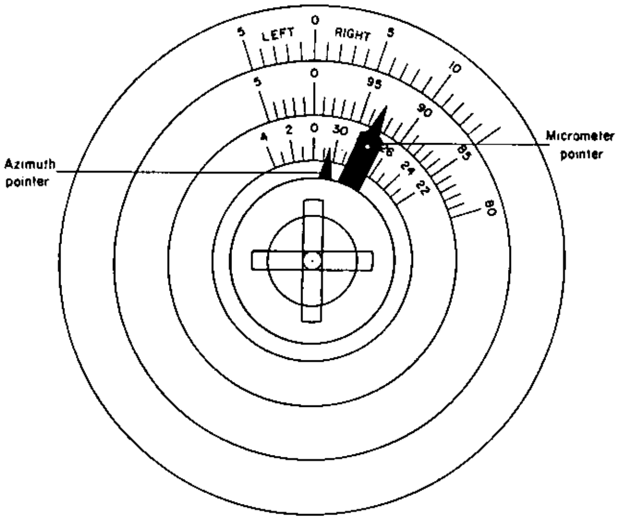


Figure 252. Deflection 3093 on azimuth indicator.

commands, because the tank gunner is trained to hold his fire until this command is received.

(7) *Other fire commands.* Other fire commands used by the artillery not mentioned in the above sequences, which at times would logically apply to the tank unit (e. g., pieces to fire, method of fire) are sent to the tanks in the simplest and most understandable manner. Common sense and liaison between artillery and armor should overcome difficulties caused by lack of formal procedure. This problem is further alleviated through the use of prearranged data sheets.

c. Distribution. The normal width of a tank platoon front in the position area is about 150 yards. For tanks armed with the 90-mm gun, a normal sheaf produces an effective pattern of bursts with this position area width. For tanks armed with guns of other calibers and for position areas of different widths, it is necessary to adjust the width of sheaf in order to obtain the most effective pattern of bursts.

5. Alternate Methods

Other methods which may be employed to control the indirect fire of tanks are—

a. Use of the fire direction equipment and personnel organic to the tank battalion to form, with artillery assistance, a fire direction center. The tank platoon may then operate semi-independently.

b. Each tank battalion handles its own indirect fire missions from prearranged data sheets. Interdiction and harassing types of area fires are the types most effectively handled in this manner. Survey control, met computations, prearranged data sheets, and assistance in laying the tanks may be furnished by supported artillery. When only limited assistance from artillery units is available, this method may be mandatory.

6. Survey

The survey necessary for the indirect firing of the tanks, such as the establishment of their position area location, is made by the field artillery battalion. This is done prior to the arrival of the tanks or as soon after their arrival as possible.

APPENDIX VII
NAVAL GUNFIRE SUPPORT

Section I. INTRODUCTION

1. General

Naval gunfire may be required to replace artillery support temporarily in an amphibious operation or to reinforce artillery in coastal operations. While naval gunfire is used for support of land forces, the Navy is responsible for control and command. Naval gunfire should be requested only when targets cannot be engaged adequately by field artillery.

2. Characteristics of Naval Gunfire Support

General characteristics of naval gunfire are—

a. A variety of guns is available, ranging from 20-mm machine guns to the 16-inch guns of battleships.

b. A wide latitude in the initial choice of projectiles and fuzes and a high rate of fire. However, the limited capacity of ship magazines and the need to retain a portion of the ammunition for air defense or action against surface forces restricts the use of the available ammunition for fire support.

c. High muzzle velocity, which gives naval guns the power to penetrate and destroy material targets, particularly those with vertical faces.

d. Small deflection pattern, which is valuable when supporting fire can be delivered parallel to friendly lines. The range patterns of naval batteries are larger than the range patterns of like calibers of field artillery. These larger patterns require special caution when fire cannot be delivered parallel to friendly lines.

e. Accurate and flexible fire control, which permits accurate delivery of fire while the ship is moving. Direct fire is excellent because of efficient shipboard optical instruments which are integrated with the fire control systems.

f. Mobility of the ship, which enables, within the limits of hydrography, the selection of the most favorable direction of fire and the firing position suitable to the mission. Unfavorable hydrographic conditions, such as shallow water, reefs, or shoals, may limit the position of the ship to less desirable locations for direction of fire and range.

g. Because of the flat trajectories of naval guns, it is difficult to place fire on targets in defilade. The use of reduced charges, with or without proximity fuzes, permits naval gunfire support on reverse slopes.

h. Communication with shore agencies must be maintained by radio or visual means.

i. Because the position of the ship relative to reference points or targets cannot always be accurately made and kept, transfer of fires from a registration point or fires based on corrected map data may not be accurate when compared with field artillery fires. Also, the ship is normally moving, and it may be difficult to adjust firing data obtained at odd times from different positions of the ship. It is possible to transfer fires, in reason, from a target just fired on if transfer distances are not great and there is not a long time lapse between missions.

j. The accuracy of initial salvos or unobserved fires depends directly on the accuracy with which the position of the firing ship can be determined. Use of the radar beacon or radar fixes aids in establishing the position of the ship when a lack of land markers exists; this will in turn help to improve the accuracy of initial salvos and unobserved fires.

k. Execution of radical turns or reversal of course may cause fire to be checked (par. 7b, this app) if the line of fire passes through or near the superstructure or exposed personnel at other stations on the ship.

l. 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.

3. Naval Weapons

A variety of weapons is available for naval gunfire support, the various combinations being determined by the type of vessel. Calibers of weapons available on United States Navy vessels are 3-inch, 5-inch, 6-inch, 8-inch, 12-inch, and 16-inch guns and 5-inch rockets.

4. Ammunition

Types of projectiles, charges, and fuzes 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.

a. Guns of 5-inch caliber and larger are provided with high explosive (HE) ammunition, 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 guns of 6-inch caliber 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.

b. Full and reduced charges are available for calibers of guns above 3 inches. The reduced charge for the 5-inch gun produces 1,200 feet per second muzzle velocity and a trajectory similar to that of charge 6 for the 105-mm howitzer.

c. The fuzes vary with different calibers and projectiles but generally include quick, delay, time, and variable time (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 VT fuze is available for the 3-inch, 5-inch and 6-inch guns. Because of the design of the VT fuze, 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. Even at the greater ranges the danger of a premature firing of a VT fuze over the heads of troops should be clearly recognized.

5. Prearrangement

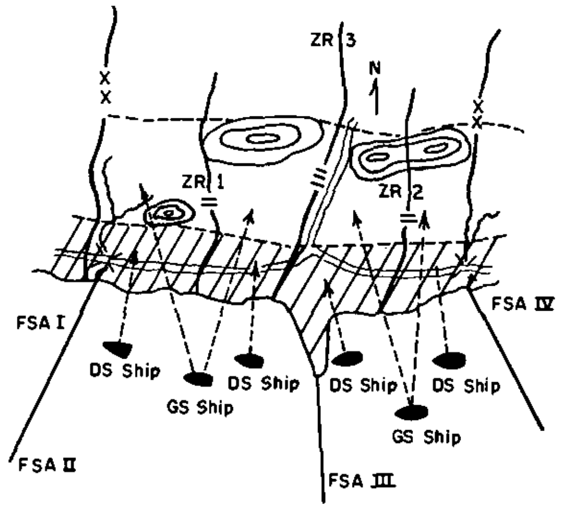
a. Rehearsals for observers, communication personnel, and fire support ships should be held before each operation to develop teamwork and mutual understanding. The naval gunfire spotter (par. 7*l*, this app) and other observers must be furnished the necessary maps or map substitutes to be used in target designation. They also must be furnished the grid systems and codes that are to be used and be familiar with them. They must know the plan of communication between themselves and the firing ship. They must be told about the calibers of weapons to be used and how they can get fire support of vessels other than those directly supporting the action.

b. Preparation fires (preliminary bombardment) are planned jointly under Army requirements. Preplanning of naval gunfire support is started as soon as the directive for the conduct of an amphibious operation is received. An exchange of staff officers between appropriate headquarters aids the planning of naval gunfire support.

c. 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. Besides, zones of responsibility ashore are assigned to ships by number. These compare to zones of action for field artillery units (fig. 253). The boundaries usually conform to preplanned unit boundaries ashore and are marked by prominent terrain features. A general support ship, for example, will be assigned an FSA for its position area. It also will be assigned one or more zones of responsibility in which it will place its fires. The spotter for the direct support ship and the observers should have the above information, including adjacent areas, plotted on their maps, charts or overlays. They then will have a general idea of the gun-target line and can ask that the direct support or other ship be sent to a specified FSA. From this area, the ship can execute enfilade fire properly when firing close to frontline troops or behind hills which defilade the target.

6. Organization

The naval officer in tactical command (OTC) commands the fire support ships from his command ship afloat. His gunnery officer, whose duties are similar to those of the artillery S3, controls the naval gunfire (NGF) ships by authority



LEGEND: Cross hatched area represents area in which direct support ships will provide close support Area north of close support area (ZR 1, ZR 2, and ZR 3) represent assigned zones of responsibility to general support ships. Fire support areas (FSA) are sea areas occupied by fire support ships. These areas do not conform to tactical areas ashore.

Figure 253. Example of fire support areas and zones of responsibility.

delegated by the attack force commander. Based on the request of the landing force, he will assign direct or general support missions to the ships of the attack force. Control ashore is exercised by specially trained personnel furnished by the landing force and the Navy.

a. Landing Force (Corps) Naval Gunfire Officer. The landing force (corps) has a naval gunfire officer (normally an artillery officer) with one or more naval officers as assistants and the necessary communication personnel. His duties are to advise the landing force commander on naval gunfire matters, to prepare requests for naval gunfire support, and to consolidate requests from lower echelons. These requests are combined to form the landing force naval gunfire requests. He assigns missions to the general support ship of the landing force and helps to coordinate naval gunfire with air and artillery support.

b. Division Naval Gunfire Officer. The division naval gunfire officer's (normally an artillery officer) duties for the division are the same as those for the corps naval gunfire officer (*a* above). He has one or more naval officers as assistants and the necessary communication personnel. He assigns missions to the general support ship of the division and helps to coordinate naval gunfire with air and artillery support.

c. Naval Gunfire Liaison Officer. Control of naval gunfire is accomplished by a naval gunfire liaison officer (HGLO) (a naval officer) and the necessary communication personnel. The NGLO advises the unit commander on naval gunfire matters. He consolidates and passes on the fire request, controls the fires of the direct support ship, and helps to coordinate naval gunfire with air and artillery support.

d. Shore Fire Control Party. Each major combat element will be assigned a shore fire control party. The shore fire control party is formed of two teams.

(1) The naval gunfire liaison team consists of a naval gunfire liaison officer (a naval officer) and necessary Army communication personnel. The naval gunfire liaison officer advises the battalion commander on the use of naval gunfire. He supervises the spotter (forward observer), and coordinates gunfire with artillery and air support.

(2) Naval gunfire spotting teams consist of a spotter, an assistant spotter, and the necessary communication personnel. The spotter should be an artillery officer assigned by division artillery for the sole purpose of adjusting naval gunfire.

e. Other Spotters or Observers. Any spotter or observer, who is familiar with the basic principles of naval gunfire support and has a means of communicating with the landing force, may call for and adjust naval gunfire. Calls for fire normally must be processed through FDC of the lowest echelon that has the means of relaying messages between the observer and the supporting ship.

f. Diagram of Control Agencies.

Attack force	Gunnery officer (*Navy*)
Landing force (corps)	Naval gunfire officer (*Artillery*)
Division	Naval gunfire officer (*Artillery*)
Combat element	Naval gunfire liaison officer (*Navy*)
Rifle company	Artillery forward observer (through relay) (*Navy*) Naval gunfire spotter (direct)

7. Terminology

Terminology prescribed for adjusting field artillery will be used by Army observers when they are acting as spotters for naval gunfire except as listed below.

a. Bearing—A horizontal angle expressed in degrees or mils (grid, magnetic, or true). Unit must be specified (degrees or mils). Used in place of AZIMUTH.

b. Check Fire—To interrupt firing temporarily. Fire control problem continues to be generated. *This term is sent by the spotter.*

c. Delay—Indicates that there will be a temporary suspension of fire. *This term is sent by the fire control personnel on the ship.*

d. End of Target—An order given to terminate firing on a specific target. Used in place of END OF MISSION.

e. Fresh Target—A procedure for engaging a new target by using corrections to existing target data.

f. Go On—Cancels CHECK FIRE.

g. Neglect—Term used to indicate that the last salvo was fired with incorrect data.

h. Record as Target—The order used to denote that data on the target is to be recorded for future engagement.

i. Shot—Term used to indicate that the guns have been fired. Used in place of ON THE WAY.

j. So Many Gun(s), So Many Salvo(s)—A request for fire for effect, in which the number of guns to be fired simultaneously in each salvo and the number of salvos are specified.

k. Spot—To determine, by observation, deviations of gunfire from the target for the purpose of supplying necessary information for the adjustment of fire.

l. Spotter—An individual who adjusts or spots for naval gunfire support.

m. Spotting Line—Either the gun-target line, observer-target (OT) line, or the reference line used by the spotter in making spot corrections. Unit of measure must be specified (degrees or mils).

n. Spreading Fire—Indicates that fires are about to be distributed over an area.

o. Stand By—Warning order given to spotter 5 seconds before the expected time of burst. Used in place of SPLASH.

p. Target Number—Preparatory command indicating that a target is to be assigned. Also an arbitrary reference number assigned to a target.

q. Trend—The straying of the fall of shot such as one that is caused by incorrect speed settings. *Erroneous correction for speed of ship and current cause succeeding rounds or salvos to stray away from the target.*

r. Vertex—Highest point of the trajectory. Expressed in yards, feet, or meters. If yards or meters are not specified, the unit of measure will be feet. Used in place of MAXIMUM ORDINATE.

Section II. COMMUNICATION

8. General

Successful naval gunfire support depends on good communication. Personnel must be well trained in communications and procedures to conduct naval gunfire. Good communications may be expected if the following conditions are met:

a. Use of suitable communication equipment, properly tuned and in good condition.

b. Proficiency by personnel in shifting frequency and reestablishing contact to avoid natural or enemy interference.

c. Designation of auxiliary channels of communication for use in emergencies.

d. Alertness by radio operators to act as linking or relay stations if necessary.

e. Provision for sufficient suitable frequencies.

f. Proficiency by personnel in voice and radiotelegraph procedures.

g. Strict radio discipline.

h. Complete familiarity with the gunfire support brevity code and the use of authentication by personnel.

i. A thorough knowledge by personnel of the gunfire procedure described in this field manual.

9. Minimum Communication Nets

The minimum naval gunfire nets required for effective naval gunfire support are—

a. Shore fire control spot net.

b. Naval gunfire control net.

c. Naval gunfire airspot net.

10. Shore Fire Control Spot Net

a. The shore fire control spot net provides communication between a ground spotter and the firing ship. The purpose of this net is to enable the spotter to call for and adjust naval gunfire.

When sufficient frequencies are available, each net should be assigned to its own clear frequency. The ground spotter will act as net control.

b. The spotter ashore normally will employ low-powered, high-frequency radio equipment. To establish the net, the spotter will call his assigned ship on the proper frequency. The ship will set watch on the assigned spotting frequency 30 minutes before firing is scheduled to commence or upon allocation to a spotter if there is less than 30 minutes before scheduled firing. The spotter will make repeated calls to the ship until communication is established. The ship normally should not transmit until called. Since the radio sets used by spotters may drift in frequency, the ship may be required to search over a wide frequency band. In order to establish initial contact with a spotter, the ship transmitter frequency must be tuned to that of the spotter. Once initial contact has been established, the ship can then assist the spotter in returning to the assigned frequency.

11. Naval Gunfire Control Net

a. The purpose of the naval gunfire control net is to provide the officer in tactical command with means to control and coordinate the activities of all naval gunfire support agencies. This net should be guarded by all fire support ships and by designated headquarters ashore. The OTC normally will act as net control station. This net is primarily for operational traffic.

b. The naval gunfire control net normally is established prior to naval gunfire activities, as designated in the operation order. It may be used by the naval gunfire representative of the OTC to perform the following tasks:

(1) Assign fire support ships to spotters as required.

(2) Relieve and reassign fire support ships.

(3) Give information about general ammunition levels when tactical conditions so require.

(4) Pass intelligence affecting naval gunfire support.

(5) Pass information concerning prearranged fires.

(6) Receive requests from ashore regarding support requirements.

(7) Pass information regarding trajectory.

(8) Pass orders and instructions relative to massing of fires, time on target, and lifting of fires.

(9) Request services of an airborne spotter.

12. Naval Gunfire Airspot Net

a. The naval gunfire airspot net provides communication between a firing ship and an airborne spotter. Normally, it is employed to call for and adjust fire. The spotter acts as net control station.

b. Ships carrying their own spotting aircraft will employ airborne spotters as required, using their assigned frequency and call signs as prescribed in the operation plan or order.

c. For ships that do not carry their own spotting aircraft but do require an air spotter, requests are made on the naval gunfire control net. Assignment of spotting aircraft must include—

(1) Frequency to be used.

(2) Call sign of air spotter.

(3) Time aircraft is to report.

(4) Method of transmission to be used.

d. Before calling the firing ship, the spotter reports to Air Control for last-minute instructions. He reports again after release by the firing ship.

e. The airborne spotter will open the net by calling his assigned ship. The ship's radio operator must search the frequency band on either side of the assigned frequency when establishing initial contact. The ship must tune its transmitter to the frequency of the spotting aircraft. Owing to the difficulty of shifting frequency (except for preset channels) in aircraft in flight, it is not wise to try minor changes once contact has been established. Tuning of aircraft radio sets prior to takeoff must be accurate to avoid mutual interference with other circuits.

f. When equipment and available frequencies permit, naval gunfire airspot nets should be designated in the VHF–UHF band. The use of preset, crystal-controlled channels will make for flexibility and speed in assigning airborne spotters.

13. Army Communication Nets

Forward observers, air observers, and other observers send calls for naval gunfire over existing Army nets to the FDC at the lowest echelon having the means of relaying calls for fire to the supporting ship.

14. Call Signs and Frequencies

Call signs and frequencies for spotters and/or liaison officers and fire support ships will be prescribed in the operation plan or order. It is mandatory that each ship, naval gunfire spotter, and liaison officer be furnished with a list of call signs and frequencies assigned to all naval gunfire activities. This will permit a more flexible plan for the use and assignment of firing ships.

15. Procedure

Standard communication procedures may be abbreviated if it does not cause confusion. These abbreviations are—

a. Elimination of call signs after the call for fire.

b. Limited use of procedural words and phrases.

c. A short-phrase repeat-back method of transmission, accomplished without special operating instructions, such as "Read back," etc.

d. Divergence from the normal or abbreviated normal message format.

16. Precedence

A call for fire will be considered equivalent to an *emergency* message and will be given that precedence classification. The word "emergency" will not be shown in the message heading. The progress of transmission will be interrupted only by *flash* messages.

17. Codes and Ciphers

Codes and ciphers to be used for security purposes will be prescribed in the operation plan or orders. In selecting and designating the codes and ciphers to be used by spotters and liaison officers, the possibility of capture or compromise must be considered.

18. Authentication

The system of authentication to be used in naval gunfire nets will be prescribed in the operation plan or order. Because of the possibility of deception by enemy radio stations, which could result in the shifting of fire onto friendly troops, detailed instructions must be issued for the use of authentication.

19. Naval Gunfire Support Brevity Code

A classified brevity code is used in communication transmissions for naval gunfire support. This code will vary from fleet to fleet. If code units other than those indicated are used, the appropriate group must be added to the code list.

a. A forward observer normally sends a call for naval gunfire to the artillery FDC. The call for fire is then transmitted to the supporting ship through the naval gunfire liaison officer. The naval gunfire liaison officer acts as a relay between the observer and the ship throughout the mission. The forward observer may call for naval gunfire through a naval gunfire spotter when both are at the same location.

b. An air observer will send calls for naval gunfire to the FDC with which he normally maintains communication. The naval gunfire liaison officer at the FDC relays the mission to the supporting ship.

Section III. INITIAL FIRE REQUEST

20. General

The initial fire request normally will include the following elements of information and will be transmitted in the sequence indicated (unnecessary elements may be omitted):

a. Call.

b. Target number.

c. Bearing of spotting line.

d. Location of target.

e. Description of target.

f. Danger to friendly troops.

g. Number of guns for adjustment and armament required.

h. Ammunition.

i. Fuze.

j. Control of fire.

21. Call

The call is made in accordance with standard communication procedure, and the call signs effective for the operation are used.

22. Target Number

Target numbers are allotted in accordance with the system of numbering designated in operation orders. Announcement of the target number serves to warn the ship that firing on a target is desired immediately.

23. Bearing of the Spotting Line

The spotter selects a spotting line in relation to which he will make sensings and corrections in adjusting the fire. This spotting line may be the observer-target (OT) line, the gun-target (GT) line, or any other reference line that the spotter can readily identify on the ground. A compass or other direction measuring instrument, or a map, may be used to determine the bearing of the spotting line. In the absence of these, the spotter must estimate the bearing. The bearing is expressed in mils or degrees and as true, magnetic, or grid.

a. Observer-Target Line. A ground observer normally uses the OT line as the spotting line. To announce this element he might send BEARING 100 MILS MAGNETIC.

b. Gun-Target Line. When a ground or airborne spotter is using the GT line as a spotting line, he sends BEARING GUN-TARGET LINE. The ship informs the spotter of the GT bearing and subsequently informs him whenever the bearing alters by more than 10°.

c. Other Reference Lines. A spotter may use a reference line other than the OT line or GT line for ease of spotting; for example, a line from a prominent feature on the ground to the target or an imaginary line through the target parallel to a straight road running close to the target. In announcing the bearing of such a line, the spotter uses the direction running away from friendly troops towards the enemy.

24. Location of Target

The spotter may give the location of the target in any manner that is clearly understandable and should always include the altitude of the target in feet, meters, or yards. (Unless otherwise specified, unit of measure for altitude will be in feet.) Usual methods for the spotter to give location of target are—

a. By giving the coordinates of the target or adjusting point, using the designated grid reference system.

b. By giving the polar coordinates to the target from a reference point, the chart location of which is known to the ship.

c. By shifting from a target being fired on to a fresh target, provided the fresh target is within 1,000 yards of the target being fired on and that END OF TARGET has not been ordered.

25. Description of Target

The spotter must describe the target in sufficient detail to permit evaluation by the firing ship.

26. Danger to Friendly Troops

When friendly troops are within approximately 1,500 yards of the target, the warning DANGER followed by the direction of friendly troops from the target and their proximity (in yards) to the target is sent by the spotter. If gunfire is required within 600 yards of friendly troops, the order CLOSE is added after DANGER; e. g., DANGER, CLOSE, SOUTH 500.

27. Number of Guns for Adjustment and Armament Required

The spotter normally signifies the number of guns he recommends for use during adjustment and the armament to be used.

28. Ammunition

The spotter specifies the type of ammunition desired by sending ARMOR PIERCING, HIGH EXPLOSIVE, ILLUMINATING, or SMOKE. If the spotter does not specify a particular type, the firing ship will use high explosive.

29. Fuze

The spotter specifies the type of fuze desired by sending FUZE DELAY, FUZE TIME, or FUZE VT. If this element is omitted from the call for fire, the firing ship will use fuze quick.

30. Control

The spotter always specifies the method of control of fire. He may change the method of control during any single adjustment. The following terms are used to indicate the desired method of control:

a. Will Adjust—The spotter controls the fire and is responsible for the adjustment. He announces corrections with relation to the spotting line. In the ship, these are converted to corrections with respect to the GT line and are then applied to the armament.

b. Will Observe—The spotter observes the bursts and makes a correction, calculated to bring the next salvo on the target. Adjustment is carried out by the ship, assisted by the spotter for combined observation.

c. Ship Will Adjust—The spotter designates the target, but spotting and adjustment are carried out by the ship.

d. Cannot Observe—The spotter is unable to observe and adjust the fire but believes a target exists at the indicated location and that it is of sufficient importance to justify firing on it without adjustment.

e. At My Command—The spotter desires to regulate the time of firing salvos. This is announced as a preface to the method of control; for example, AT MY COMMAND, WILL ADJUST. When the spotter is airborne, AT MY COMMAND will always be used.

Section IV. ADJUSTMENT PROCEDURE

31. General

Adjustment is carried out relative to the spotting line. Line adjustment is done by correcting to the spotting line; range adjustment, by the process of bracketing. Corrections are made to adjust time fuze to the desired height of burst. The procedures used and considerations involved in the adjustment of naval gunfire are essentially the same as for field artillery fire.

32. Reports to the Observer Prior to Firing

The ship will make the following reports to the observer prior to firing when appropriate:

a. Delay. The term "Delay" indicates that the ship is not ready to fire. DELAY is followed by an estimate of time in minutes. If sent during an adjustment, it is subsequently followed by READY.

b. Ready. The term "Ready" indicates that the ship is ready to fire. For the first salvo, READY is always announced, followed by the time of flight in seconds; the ship then awaits the spotter's order to fire. For subsequent salvos, READY is transmitted only if AT MY COMMAND or DELAY has been announced, in which case the time of flight is omitted.

c. Bearing of the Gun-Target Line. The ship reports the bearing of the GT line, as soon as it is known, by announcing GUN-TARGET LINE (so much).

d. Noncompliance with Spotter's Call for Fire. Any action by the ship which is not in accordance with the call for fire must be reported to the spotter. This report may include such items as the use of secondary armament or of ammunition other than that requested.

e. Location of the First Salvo. When DANGER s included in the call for fire, the location of the first salvo is reported in the form FIRST SALVO AT (coordinates or bearing and distance in yards or meters from indicated target location). Unless otherwise specified, unit of measure will be yards.

f. Vertex Height. The vertex height (maximum ordinate) must be reported by the ship if the spotter is airborne.

33. Opening Fire

Fire normally is opened with two or more guns, depending on conditions of visibility and the caliber of the guns. The term "Shot" is announced at the moment of firing. The term "Stand by" is announced 5 seconds before a salvo is due to land. These terms are transmitted every time a salvo is fired, except during fire for effect when they are sent only for the first salvo.

34. Line Adjustment

If the first salvo does not fall on, or close to, the spotting line, a correction of the size necessary to bring the next salvo to the spotting line is made. This correction is transmitted as RIGHT (LEFT) (so much) in yards or meters. Unless otherwise specified unit of measure will be yards.

35. Height of Burst Adjustment

When fuze time is being used, the spotter adjusts height of burst by transmitting UP (DOWN) (so much) in feet, yards, or meters. Unless otherwise specified, unit of measure will be feet.

36. Range Adjustment

a. As soon as a salvo can be sensed positively for range as *over* or *short*, a bracket is commenced along the spotting line. Range corrections should be in the amount of 800, 400, or 200 yards, whichever is necessary to insure a bracket. Once established, a bracket is reduced by further corrections until a 200-yard bracket or its equivalent, has been obtained.

b. If the correction required to bring the initial salvo to the target is greater than 800 yards, the spotter announces the required correction and the firing ship checks the solution. If no error can be found, the announced correction will be applied by the firing ship.

c. The equivalent of a 200-yard bracket is obtained in the following cases:

(1) A target hit.

(2) A straddle with a multigun salvo.

(3) An *over* and *short* obtained from two salvos not separated by a range adjustment by the spotter.

d. Range dispersion (100 to 400 yards) is an important factor affecting bracketing, since it is about 4 times greater than that for line (deflection) dispersion.

e. A range correction is transmitted as ADD (DROP) (so much) in yards or meters. Unless meters are specified, unit of measure will be yards.

f. If no range correction is desired, the spotter announces REPEAT.

37. Corrections for Ammunition and Fuze

During adjustment, the spotter may request a change in ammunition or fuze by announcing the type of ammunition or fuze desired.

38. Other Reports by the Spotter During Firing

In addition to sending adjustment corrections and requests for change in ammunition and fuze, the spotter may send other reports to affect the time of firing or to provide information to the firing ship. Such reports may include any of the following terms:

a. AT MY COMMAND may be used at any time to control the time of firing. This ship must then report READY to the spotter and await the spotter's order to fire for each salvo.

b. WHEN READY cancels AT MY COMMAND.

c. CHECK FIRE is used to interrupt firing temporarily.

d. GO ON cancels CHECK FIRE.

e. TARGET is sent when a salvo falls on the target.

f. STRADDLE is sent when a multigun salvo straddles the target It may be followed by a more detailed report giving a correction to move the mean point of impact (MPI) to the target.

g. MIXED is used when the ship is adjusting height of air burst. It indicates that the salvo is correctly adjusted for height of burst and contains both air and impact bursts, the largest proportion of which are in the air.

h. LARGE SPREAD is used to indicate that the spread is excessive.

i. TREND is sent if salvos are observed to be creeping off the target, and is followed by an indication of direction; for example, TREND SOUTHWEST.

j. LOST is sent if a salvo is unobserved. The ship will take appropriate action to make the next salvo visible either by applying a correction calculated to bring the next salvo into the spotter's field of view, or, if visibility is bad, by firing a multigun salvo or a smoke shell. The spotter may be able to judge the location of lost bursts by sound, in which case he may send LOST followed by a correction.

k. FRESH TARGET is used to indicate a new target and is followed by an abbreviated call for fire in which the location is given by coordinates or by a shift from the target being engaged. If coordinates are used, the ship converts the difference between the old and the new coordinates and applies that difference to the armament. Any difference in height will be reported as UP (DOWN) (so much). "Fresh target" procedure insures that the information gained from previous adjustment is not lost, and bracketing should not be necessary.

39. Reports by the Ship During Firing

a. NEGLECT is the term used to inform the spotter that the last salvo was fired with incorrect settings. The ship immediately will correct the error and fire again unless AT MY COMMAND is in effect, in which case a new report of READY will be made.

b. SHOT and STAND BY are terms which are used as explained in paragraph 7, this appendix.

c. WILL NOT FIRE is the term used to indicate that the ship is not able to fire, for safety or for other reasons. For example, the ship may be under attack.

Section V. FIRE FOR EFFECT

40. General

Fire for effect is begun when a 200-yard range bracket, or its equivalent, has been obtained, after adjusting the MPI as necessary. The final correction for range usually is one that will split the 200-yard bracket.

41. Volume of Fire

The volume of fire for effect is determined by the results desired and by the nature of the target. The spotter is best able to determine the caliber and number of guns required to achieve the desired effect. In his fire for effect request he specifies the number of guns per salvo and the number of salvos required. The final decision as to the number of guns and quantity of ammunition to be used rests with the firing ship, based on policy contained in orders and a requirement for economy in firing naval guns. Since the quantity of ammunition carried in ships is relatively small, it is important that none should be wasted either by engaging unsuitable targets or by expending more than is necessary to achieve the desired result. The comparatively short life of naval guns is another cogent reason for exercising economy.

42. Destruction Fires

Accuracy is of prime importance in executing destruction fires; this is most successfully accomplished when the target is visible from the ship. If the target is not visible from the ship, a ground or airborne spotter should be made available. If the ship is stationary (anchored or stemming a buoy), the destruction will be achieved more quickly. One gun is normally used both in the adjustment and in fire for effect. Fire for effect is continued until the target is destroyed, spotting corrections being applied as necessary for each round fired.

43. Neutralization Fires

The procedure used for neutralization fires depends on the conflicting demands of speed and accuracy. For engaging such targets as concentrations of troops or vehicles likely to move, speed is the primary consideration. Adjustment should therefore be obtained by bold spotting, and fire for effect should be fired as rapidly as possible. In other cases, accuracy of adjustment and adherence to a time schedule may take precedence over speed. Neutralization is best achieved during fire for effect by firing salvos at irregular, rather than regular, intervals.

44. Repeat Fire for Effect

If the fire for effect initially delivered is insufficient, the spotter should make a correction if necessary and request REPEAT FIRE FOR EFFECT.

45. Termination of Fire

a. RECORD AS TARGET is announced by the spotter after engagement of a target to signify that further fires may be required at a future time. It normally will not be possible for ships to record targets unless at anchor. On receipt of RECORD AS TARGET from a spotter, the ship records the data used. Before engaging the target again, the ship must allow for any change in data, such as a difference in ballistic data or in the initial position.

b. END OF TARGET is the term used to terminate a fire mission. It may be sent by the spotter or the ship. At END OF TARGET the ship's fire control problem ceases to be generated, and further fire cannot be started without fresh adjustment.

c. The spotter gives a brief report of damage assessment and effectiveness of fire.

Section VI. EXAMPLES

46. Mission Number 1

a. The naval gunfire spotter for an assault element is in communication with a destroyer which is in direct support of the element. Having discovered an enemy mortar at coordinates 598600, 800 yards north of friendly troops, he decides to fire the ship on the target. Bearing to the target measured from a gridded map is 5,460 mils. Observation is good and the spotter is not personally under fire. Line of fire is approximately parallel to friendly lines. The spotter sends the following initial fire request:

KANGAROO, THIS IS KIDNEY
TARGET NUMBER 1357
BEARING 5460 MILS GRID
COORDINATES 598600
HEIGHT 120
MORTAR
DANGER, SOUTH 800
2 GUNS--MAIN ARMAMENT
WILL ADJUST

Ammunition and fuze request are not transmitted since 5-inch AAC, normal charge, with time fuze set on SAFE is the standard load and is satisfactory for this mission.

b. The ship reads back the initial fire request to the spotter and sends the following message:

GUN-TARGET LINE 1200 MILS GRID
FIRST SALVO AT NORTH 800
READY, 25 (time of flight)

c. The spotter announces FIRE, and the ship sends—

SHOT . . . STAND BY

d. The ship's first salvo lands 150 yards left of the target, and the spotter is unable to determine whether the salvo is over or short. At this time the spotter's observation is obscured by drifting smoke. In order to bring the impact to the observer-target line and provide for intermittent observation, the spotter announces—

RIGHT 150
REPEAT
AT MY COMMAND

e. The ship reports READY, and the spotter commands FIRE. The next salvo lands 20 yards left of the target and clearly over. The spotter makes a cautious shift since the target is within 800 yards of friendly troops. He sends—

RIGHT 20
DROP 200

f. The ship reports READY and the spotter commands FIRE. The next salvo lands over the target and approximately on line. The spotter sends—

DROP 200

g. The ship reports READY, and the spotter commands FIRE. The next salvo lands short and approximately on line. The spotter now has established a 200-yard bracket and a satisfactory line adjustment, so he is ready to enter fire for effect. He transmits—

ADD 100
6 GUNS, 3 SALVOS
FIRE FOR EFFECT
WHEN READY

h. The ship reports SHOT and STAND BY for the first salvo in fire for effect and ROUNDS COMPLETE when all the rounds have been fired.

i. The 18 rounds in fire for effect land in a close pattern around the target and the mortar ceases to fire. The spotter sends—

END OF TARGET
FIRE EFFECTIVE
MORTAR SILENCED

47. Mission Number 2

a. An artillery air observer with a division that has a battleship in general support discovers an enemy tank battalion proceeding towards a friendly beachhead 6 miles away. The head of the column is at coordinates 243962. After sending a FLASH message reporting the presence and location of the tanks, the observer decides to take the head of the column under fire with the main battery of the battleship. He sends the following initial fire request to the division artillery FDC.

GOLF BRAVO, THIS IS ALFA DELTA 24
FIRE MISSION FOR KING KONG
BEARING GUN-TARGET LINE
COORDINATES 243962

HEAD OF TANK COLUMN, PROCEEDING
SOUTH, SPEED 10 MILES PER HOUR
1 GUN—MAIN ARMAMENT
AT MY COMMAND, WILL ADJUST

b. The naval gunfire officer relays the initial fire request to the ship and then relays the following message from the ship to the observer:

GUN-TARGET LINE 1540 MILS GRID
VERTEX 1100 FEET
READY, 39

c. The observer commands FIRE, and the ship reports SHOT . . . STAND BY. The ship's first round lands an estimated 200 yards left and 800 yards short of target. The observer sends RIGHT 200, ADD 800.

d. The ship reports READY.

e. The observer commands FIRE, and the ship reports SHOT . . . STAND BY. The second round lands an estimated 100 yards left and 200 yards over the target. The observer sends—

RIGHT 100
DROP 200

f. The ship reports READY.

g. The observer commands FIRE, and the ship reports SHOT . . . STAND BY. The third round lands an estimated 100 yards short of target and approximately on the GT line. The observer sends—

ADD 100
3 GUNS, 3 SALVOS
FIRE FOR EFFECT

h. The ship reports READY.

i. The observer commands FIRE, and the ship reports SHOT . . . STAND BY . . . ROUNDS COMPLETE.

j. Target hits are obtained disabling three tanks and the remainder of the column is dispersing and withdrawing. The observer sends—

RECORD AS TARGET
END OF TARGET
FIRE EFFECTIVE
3 TANKS BURNING, REMAINDER DISPERSED

k. Ship repeats back—

RECORD AS TARGET
END OF TARGET
FIRE EFFECTIVE
OUT

48. Mission Number 3

A flank element with a light cruiser in direct support is attacking along the coast. The advance is being held up by enemy personnel in a log and sandbag pillbox located 400 yards south of the leading elements, at coordinates 1348Q. The target is visible from the ship. The artillery observer sends the following initial fire request to the artillery liaison officer:

KANE 21, THIS IS KANE 23
FIRE MISSION FOR KANGAROO
COORDINATES 1348 QUEBEC
HEIGHT 140
LOG AND EARTH PILLBOX
DANGER, CLOSE, NORTH 400
SHIP WILL ADJUST

The naval gunfire liaison officer relays the fire mission to the ship. The ship will attack the target by direct fire, and report the results to the observer through the NGLO. Bearing, guns and armament, ammunition, and fuze are not required to be announced by the observer.

49. Mission Number 4

An artillery forward observer has adjusted naval gunfire on a target and has fired for effect with good results but has not sent END OF TARGET to the ship. He suddenly observes a number of enemy tanks and infantry approaching in the same general area. He examines the new target, measures the shift required from the last salvo fired on the old target, and sends—

FRESH TARGET
BEARING 5440 MILS GRID
RIGHT 300
ADD 100
5 TANKS AND PLATOON OF INFANTRY
DANGER, SOUTH 1200
RAPID FIRE, 6 GUNS, 5 SALVOS
FIRE FOR EFFECT

INDEX

[AG 353 (19 Nov 56)]

By Order of *Wilber M. Brucker*, Secretary of the Army

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NG: State AG; units—same as Active Army.
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For explanation of abbreviations used, see SR 320–50–1.

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