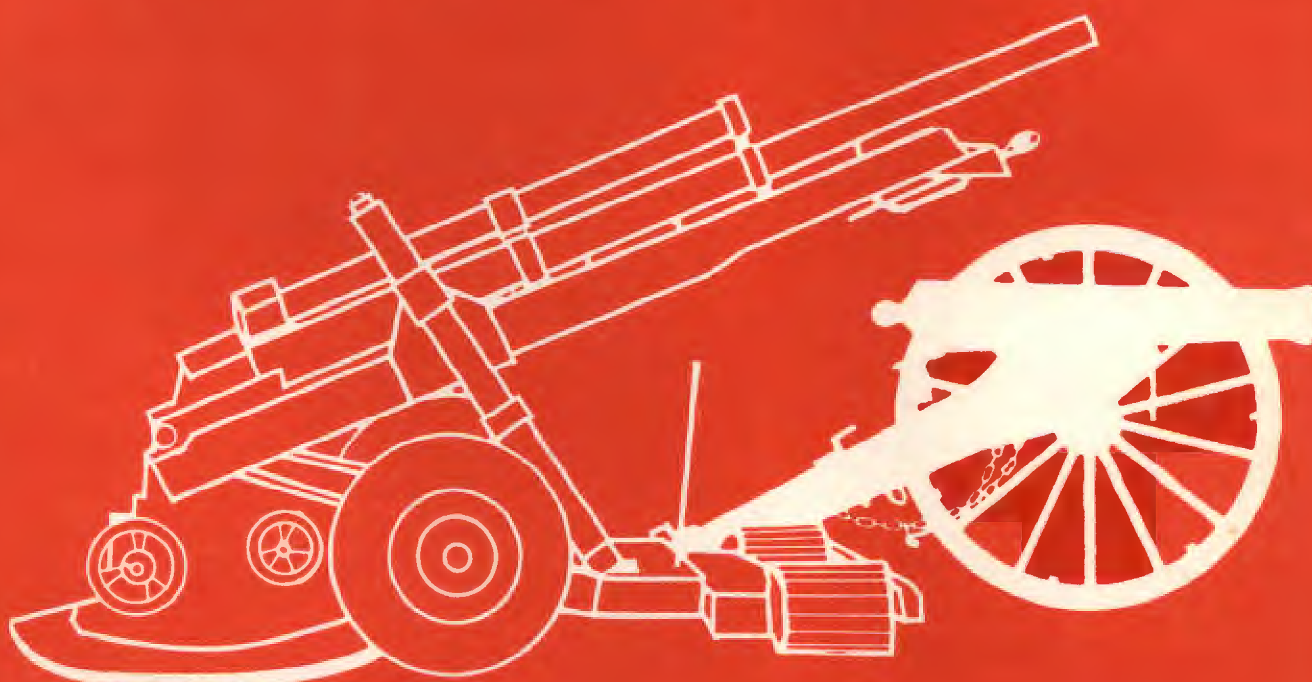
FM 6-40

FIELD ARTILLERY CANNON GUNNERY



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FIELD ARTILLERY CANNON GUNNERY

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PART ONE
GENERAL
CHAPTER 1
INTRODUCTION

Section I. GENERAL

1-1. Purpose

This manual explains the field artillery cannon gunnery problem and presents a practical application of the science of ballistics and the procedures essential for the timely delivery of effective artillery fire. This manual is intended to be used only as a guide; therefore, modifications may be made based on the knowledge of the gunnery supervisor and the state of training of unit personnel. Any modifications which result in the loss of either speed or accuracy should be seriously questioned.

1-2. Scope

a. This manual encompases all aspects of field artillery gunnery for cannons. The material presented herein is applicable to both nuclear and nonnuclear warfare. The scope includes—

(1) Characteristics and capabilities of weapons and ammunitions.

(2) Fundamentals of ballistics.

(3) Firing battery gunnery.

(4) Observer procedures.

(5) Fire direction.

(6) Miscellaneous gunnery information.

b. The term "Field Artillery" as used within this manual applies to cannon artillery only, except when specified otherwise.

1-3. Changes or Corrections

Users of this manual are encouraged to submit recommended changes or comments to improve the manual. Comments should be keyed to the specific page, paragraph, and lines of the text in which the change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. **Comments should be forwarded direct to US Army Field Artillery School, ATTN: ATSF-CTD-DL, Fort Sill, Oklahoma 73503.**

For your convenience, a self-addressed DA Form 2028-1 (Test), Recommended Changes to Publications, is available as a tear-out sheet in the back of this publication. If this form has been removed, use DA Form 2028.

1-4. References

See appendix A for list of references.

1-5. The Field Artillery Gunnery Problem

Field artillery cannons normally are emplaced in defilade to conceal them from the enemy. For the vast majority of targets, placing cannons in defilade preclude sighting the weapon directly at the target (direct fire). Consequently, indirect fire must be employed to attack the targets. The gunnery problem is primarily the problem of indirect fires. The solution of this problem requires weapon and ammunition settings which, when applied to the weapon and the ammunition, will cause the projectile to burst on, or at a proper height above, the target. The steps in the solution of the gunnery problem are—

a. Location of the target and battery.

b. Determination of chart data (direction, range, and vertical interval from weapon to target).

c. Conversion of chart data to firing data.

d. Application of firing data to the weapon and ammunition.

1-6. The Field Artillery Gunnery Team

The coordinated efforts of the field artillery gunnery team must be interconnected by an adequate communications system. The elements of the gunnery team are—

a. Observers. The observers (to include all target acquisition devices) detect and report to the fire direction center the location of suitable targets, initiate calls for fire, and conduct an adjustment if necessary.

b. Fire Direction Center. The fire direction center (FDC) evaluates the information received from the observers, determines firing data, and furnished these data in the form of fire commands to the firing battery.

c. Firing Battery. The firing battery applies the firing data to the weapons and fires the weapons. The firing battery is the fire unit for field artillery.

1–7. Basic Principles of Employment of Field Artillery Firepower

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

b. For artillery fire to be effective, it must be of suitable density and must arrive at the target at the proper time and with the appropriate projectile and fuze.

c. Good observation permits delivery of the most effective fire. Limited observation results in a greater expenditure of ammunition and less effective fire. Some type of observation is desirable for every target fired on 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 is 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 fire on targets by adjustment procedures; however, lack of observation must not preclude firing on targets that can be located by other means.

d. Field artillery fires must be delivered by the most accurate means which time and the tactical situation permit. When possible, survey will be used to locate the firing position and targets accurately. Under some 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 reduces the confidence of supported troops in their artillery support.

e. The immediate objective is to deliver a mass of accurate and timely fire so that the maximum number of casualties are inflicted. 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 on the target should be reduced to the minimum.

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

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

Section II. CANNON ARTILLERY

1–8. General

a. Cannon artillery is classified according to caliber and maximum range capability as light, medium, heavy, and very heavy.

(1) Light—120mm and less.

(2) Medium—Greater than 120mm but less than or equal to 160mm.

(3) Heavy—Greater than 160mm but less than or equal to 210mm.

(4) Very heavy—Greater than 210mm.

b. Cannon artillery is also classified according to the method of organic transportation.

(1) *Towed*—Cannons mounted on carriages designed to be towed behind prime movers.

(2) *Self-propelled*—Cannons permanently installed on full-track vehicles which provide motive power for the piece and from which the weapon is fired.

1–9. Characteristics and Capabilities

Some of the characteristics and capabilities of field artillery weapons used in an indirect fire role are listed in table 1–1.

Table 1-1. Characteristics and Capabilities of Field Artillery Cannons

CALIBER AND MODEL	MAXIMUM MUZZLE VELOCITY M/S	MAXIMUM RANGE (METERS)	MAXIMUM CHARGE RATE OF FIRE (rd/min) (first 3 min)*	SUSTAINED RATE OF FIRE (rd/min)	LIFE IN FULL SERVICE ROUNDS (See TM 9-1000-202-10)	MINIMUM ELEVATION (mils)	MAXIMUM ELEVATION (mils)	MAXIMUM RIGHT TRAVERSE (mils)	MAXIMUM LEFT TRAVERSE (mils)	WEIGHT OF HE PROJECTILE (nearest pounds)	WEIGHT, COMBAT LOADED	LENGTH, TRAVELING (feet-inches) (approx)	WIDTH, TRAVELING (feet-inches) (approx)	HEIGHT, TRAVELING (feet-inches) (approx)	TIME TO EMPLACE (minutes)	PRIME MOVER	FM	TM
1. 105-mm HOWITZER M101A1, TOWED	465	11,000	10	3	M2A1—5,000 M2A2—7,500	−90	1,155	409	400	33	4,980	19'8"	7'0"	5'0"	3	HEL 2½-TON	6-75	9-1015-203-12
2. 105-mm HOWITZER M102, TOWED	494	11,500	10	3	M137—5,000 M137E1—5,000	−89	1,333	6400		33	3,140	22'	6'4"	5'3"	4	HEL PRCT 1¼-TON	6-70	9-1015-234-12
3. 155-mm HOWITZER M114A1, TOWED	564	14,600	4	1	M1—2,000 M1A1—7,500	0	1,156	448	418	95	12,700	24'0"	8'0"	5'11"	5	5-TON	6-81	9-1025-200-12
4. 155-mm HOWITZER M109, SP	561	14,600	4	1	M126—5,000 M126E1—7,500	−53	1,333	6400		95	52,461	21'8"	12'0"	10'0"	1	–	6-88	9-2350-217-10
5. 155-mm HOWITZER M109A1, SP	701	18,000	1/1 for 60 Min	1/3 after 60 Min	M185E1—5,000	−53	1,333	6400		95	53,436	28'9"	12'0"	10'1"	1	–	6-88	9-2350-217-10
6. 175-mm GUN M107, SP	914	32,700	1.5	0.5	M113—400 M113A1—1,200	+85	1,156	533	533	147	62,100	37'1"	10'4"	11'5"	3	–	6-94	9-2300-216-10
7. 8-INCH HOWITZER M110, SP	594	16,800	1.5	0.5	M2A1 and M2A1E1—7,500	+35	1,156	533	533	200	28,500	24'6"	10'4"	9'7"		–	6-94	9-2300-216-10

*Except M109A1

Table 1-2. Cartridge / projectile - fuze combinations for field artillery cannons.*

* This chart is not authority to fire listed combinations as they are subject to change.

NOTE: VT fuze will not be fired with charge 7, 105-mm Howitzer.

FUZE

PD										MT					MTSQ							TSQ	BD		PROX				
M48A2	M48A3	M51A4, A5	M572	M57 (MOD)	M57 (MOD) W/BOOSTER	M78 SERIES (CP)	M508 SERIES	M535	M557	M67A3	M577	XM563 SERIES	M565	M565 (MOD)	M501 SERIES	M520 SERIES	M548	M548 (MOD)	M554	M564	M582	M55A3	M62 SERIES	M91 SERIES	M513 SERIES	M514 SERIES	M728	CARTRIDGE / PROJECTILE	WEAPON
												X																APERS-T, XM 546	105 MILLIMETER
X	X														X													BE, H84, H84B1	
													X				X											CS, XM 629	
		X			X	X		X	X	X						X				X	X	X						HE, M1 (NORMAL CAVITY)	
		X			X	X		X	X	X						X				X	X	X			X		X	HE, M1 (DEEP CAVITY)	
																			X									HE, M 413 (ICM)	
														X				X										HE, M 444 (ICM)	
																							X					HEAT, M 67	
																								X				HEAT-T, M 67	
																							X					HEP, M 327	
																								X				HEP-T, M 327	
		X			X	X		X	X	X						X					X	X						HE, RA, XM 548	
							X																					GB, M 360	
															X													ILLUM, M 314A2, M 514A2B1	
													X				X											ILLUM, M 314A2E1	
		X			X			X	X	X						X				X	X	X						SMOKE, WP OR GAS, H, HD, M 60	
X	X														X													BE, M116	155 MILLIMETER
													X				X											CS, XM 631	
							X																					GB, OR VX, M 121A1	
		X			X	X		X	X	X						X				X	X	X						HE, M107 (NORMAL CAVITY)	
		X			X	X		X	X	X						X				X	X	X				X	X	HE, M107 (DEEP CAVITY)	
									X												X					X	X	HE, RA, M 549	
											X		X				X											HE, M 449 (ICM)	
											X		X															HE, M 483 (ICM)	
															X													ILLUM, M118 SERIES	
													X				X											ILLUM, M485 SERIES	
		X			X			X	X	X						X				X	X	X						SMOKE, WP OR GAS, HD, M110	
		X			X			X	X	X						X				X	X	X						SMOKE, WP, M105	
							X																			X	X	GB OR VX, M 426	8-INCH
		X			X	X		X	X	X						X				X	X	X						HE, M 106 (NORMAL CAVITY)	
		X			X	X		X	X	X						X				X	X	X				X	X	HE, M 106 (DEEP CAVITY)	
											X		X				X											HE, M 404 (ICM)	
			X																		X					X	X	HE, M 437	175 MILLIMETER

Section III. AMMUNITION

1–10. General

A complete round of artillery ammunition contains all the components necessary to propel the projectile from the weapon and cause it to burst at the desired time. The components are the primer, propelling charge, projectile, and fuze. Depending on the manner in which the components are assembled, artillery ammunition is classified as fixed, semifixed, separate-loading, and separated. See TM 9–1300–203 for details on artillery ammunition. See table 1–2 for ammunition available for each cannon.

1–11. Primers

Primers are used to ignite the propelling charge. Percussion primers are ignited by a sharp blow with a firing pin Electric primers are ignited by sending a small electric current through a resistor imbedded in an explosive. If the primer is not capable of igniting the propellant, an igniter charge is added to the propellant and placed between the primer and the propellant.

1–12. Propelling Charge

A propelling charge is a low-order explosive, which, when burned, generates pressure within the chamber and, thereby, furnishes the energy to propel the projectile. Propelling charges are packed loose in shell cases (fixed ammunition), in cloth bag increments (semifixed or separate-loading ammunition) or, in the case of the 4.2-inch mortar, in sheetlike bundles attached to a cartridge container. Greater flexibility in projectile range and angle of fall is provided by varying the number of increments to be fired, which varies the muzzle velocity.

1–13. Projectiles

A projectile is an object that is propelled from a weapon by an explosive propellant charge. All projectiles are of the same general shape in that they have cylindrical bodies and an ogival head.

a. High-Explosive Projectiles. High-explosive (HE) burster type projectiles are hollow projectiles filled with either composition B or TNT and are designed to inflict casualties through fragmentation or damage through impact with a hard target. The terminal ballistics and effects of these projectiles are discussed in chapter 2.

b. Base-Ejection Projectiles. Base-ejection projectiles are smoke, propaganda, illuminating, or improved conventional munitions. The contents of the projectile are ejected from the base of the projectile through the action of the time fuze and expelling charge before the projectile reaches the point of impact.

c. Burster-Type Chemical Projectiles. Burster-type chemical projectiles include gas projectiles and smoke projectiles. The contents of the projectiles are expelled upon action of a burster projectile charge which runs through the long axis of the projectile.

d. High-Explosive, Plastic Projectiles. The 105-mm high-explosive, plastic (HEP) projectile is used primarily against armored targets. The cartridge has one bag of propellant M6 for its propelling charge. The projectile body is a thin-walled casing containing composition A3 and is internally threaded at the base to receive a base detonating (BD) fuze. When the cartridge is fuzed with the M91 or M91A1 BD fuze, it is designated high-explosive plastic tracer (HEP–T) (the BD 91 series fuzes contain a tracer). When the cartridge is fuzed with the BD M62A1 fuze, which has no tracer, it is designated high-explosive plastic.

1–14. Fuzes

The proper fuze must be used to cause the projectile to function at the time and place desired. Fuzes are classified according to the method of functioning as time, impact, or proximity (VT).

a. Time fuzes contain a graduated time element similar to the works in a clock that may be set, prior to firing, to a predetermined setting. After the projectile has been fired, the time fuze functions as soon as the time corresponding to this setting has elapsed.

b. Impact fuzes function when they strike a solid object. Impact fuzes are further classified according to the dealy of action after impact as superquick, nondelay, delay, and concrete piercing (CP). Concrete piercing is a special purpose impact fuze characterized with a hard nose shield and with delay action for penetration and nondelay action for clearing away rubble.

c. Proximity (VT) fuzes function when they approach any object which will reflect with sufficient strength the signal radiated from the fuze.

Note. See table 1–2 for fuze interchangeability.

CHAPTER 2
FUNDAMENTALS OF FIELD ARTILLERY GUNNERY

Section I. ELEMENTS OF FIRING DATA

2–1. General

a. The data required to lay (point) an artillery cannon so that the projectile, when fired, will burst at the desired location are called firing data. These data are based on the direction, horizontal range, vertical interval, and meteorological conditions from the weapons to the target and on the desired pattern of bursts at the target.

b. The principal unit of angular measurment in field artillery is the mil. A mil is the angle subtended by an arc which is 1/6400 of the circumference of a circle.

2–2. Direction

Direction is expressed as a horizontal angle measured from a fixed reference. The field artillery normally uses grid north (the direction of the north-south grid lines on a military map) for the fixed reference and measures the angle clockwise from grid north. When pieces are emplaced, they are laid for direction, and the direction in which they are laid is used as a basis for angular shifts to point the pieces at the target. The direction to the target may be computed, determined graphically or estimated.

2–3. Range

Range is the horizontal distance from the gun to the target and is expressed in meters. Range may be computed, measured graphically, or estimated. The range achieved by a projectile is a function of the charge (muzzle velocity) and the vertical angle (elevation) to which the tube is raised. (For other factors affecting range, see paragraph 2–9).

2–4. Vertical Interval

Vertical interval is the difference in altitude between the battery or observation post and the target or point of burst. The altitudes are determined from a map, by surveys, or by a shift from a known point.

2–5. Distribution of Bursts

Distribution of bursts is the pattern of bursts in the target area. Normally, all pieces of a battery fire with the same deflection, fuze setting, and quadrant elevation. However, since targets may be of various shapes and sizes, it is sometimes desirable to adjust the pattern of bursts to the shape and size of the target.

a. In some cases, individual piece corrections for deflection, fuze setting, and/or quadrant elevation are computed and applied to obtain a specific pattern of bursts. These corrections are called special corrections.

b. The term "sheaf" is used to denote the lateral distribution of the bursts of two or more pieces fired together. The width of the sheaf is the lateral distance (perpendicular to the direction of fire) between the centers of the flank bursts. The front covered by any sheaf is the width of the sheaf plus the effective width of one burst. A sheaf may be formed in any one of the following patterns:

(1) *Parallel (normal) sheaf.* A parallel sheaf is one in which the trajectories of all pieces are parallel (fig 2–1).

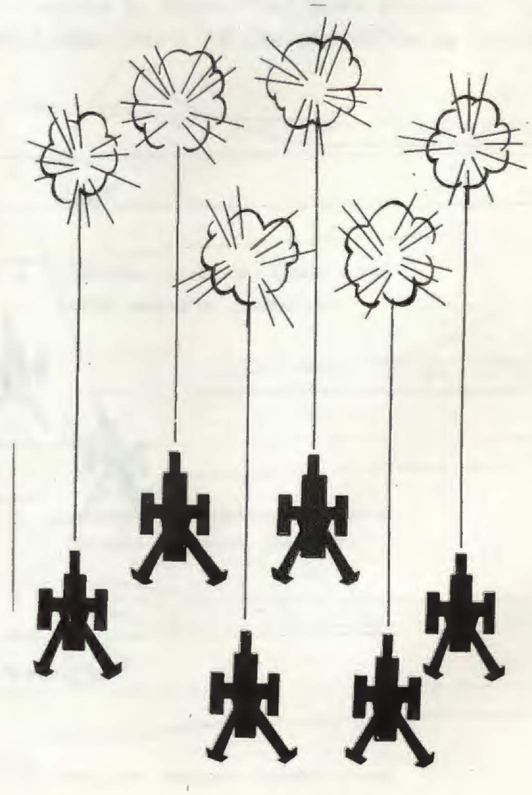


Figure 2–1. Parallel (normal) sheaf.

(2) *Converged sheaf.* A converged sheaf is one in which the horizontal and vertical planes of the trajectories intersect at the target (fig 2-2).

(3) *Open sheaf.* An open sheaf is one in which the lateral distance between the center of two adjacent bursts is equal to the maximum effective width of one burst (table 2-1 and fig 2-3).

(4) *Special sheaf.* A special sheaf is any sheaf other than one of those described in (1) through (3) above.

Table 2-1. Open Sheafs

Caliber	Width (in meters) of open sheaf			Front (in meters) covered by an open sheaf		
	2-piece battery	4-piece battery	6-piece battery	2-piece battery	4-piece battery	6-piece battery
105-mm	30	90	150	60	120	*180
155-mm	50	150	250	100	200	*300
175-mm	95	285		190	380	
8-inch	80	240		160	320	

*For fire planning purposes, final protective fires by a 6-piece howitzer battery normally will be—
a. 200 meters for 105-mm.
b. 300 meters for 155-mm.

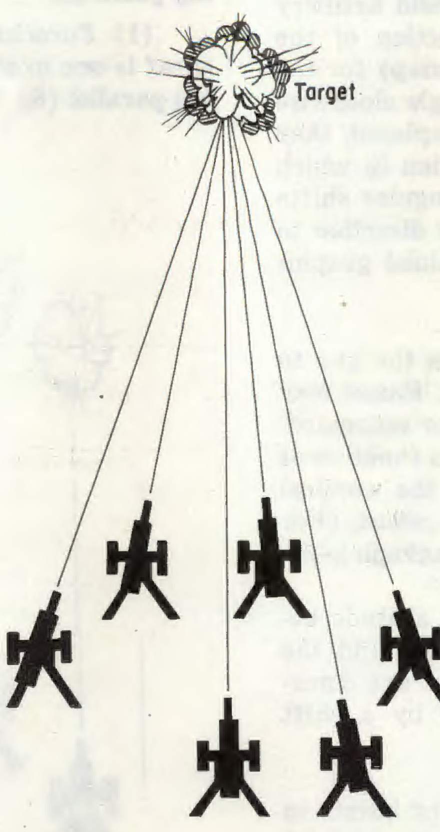


Figure 2-2. Converged sheaf.

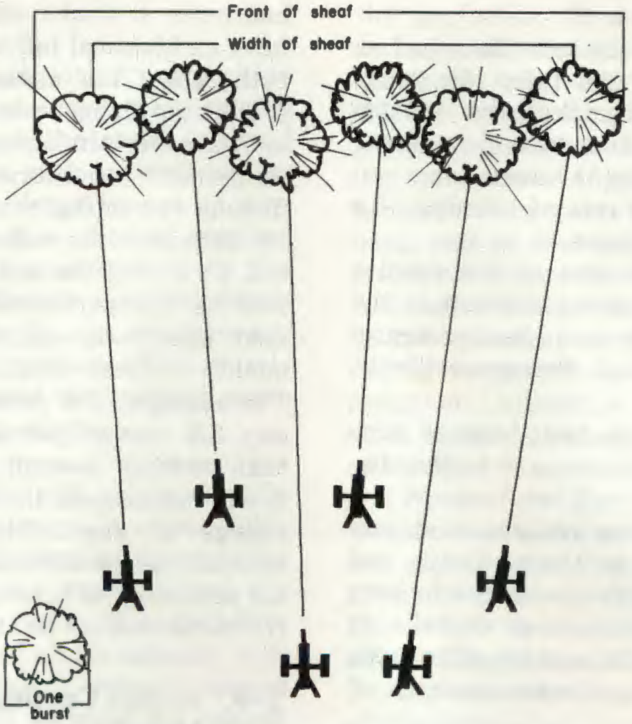


Figure 2-3. Open sheaf.

Section II. INTERIOR BALLISTICS

2-6. General

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 meters per second. Actual measurements of the muzzle velocity of a series of rounds, corrected for nonstandard conditions, depict the performance of a certain weapon-ammunition combination. The variation from standard can be obtained by comparison of the results of these measurements with the standard velocities listed in the firing table for the charge fired. Application of corrections to compensate for nonstandard muzzle velocity is one of the most important elements in the preparation of accurate firing data.

2-7. Nature of Propellants and Projectile Movement

a. A propellant is a low-order explosive which burns rather than detonates. In artillery cannons using separate-loading ammunition, the propellant is burned in a chamber consisting of the powder chamber and the base of the projectile; in cannons using fixed and semifixed ammunition, the propellant is burned in a chamber consisting of 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 begins to move.

b. The gas pressure builds up quickly to a peak and gradually subsides shortly after the projectile begins to move. The peak pressure, together with the travel of the projectile in the bore

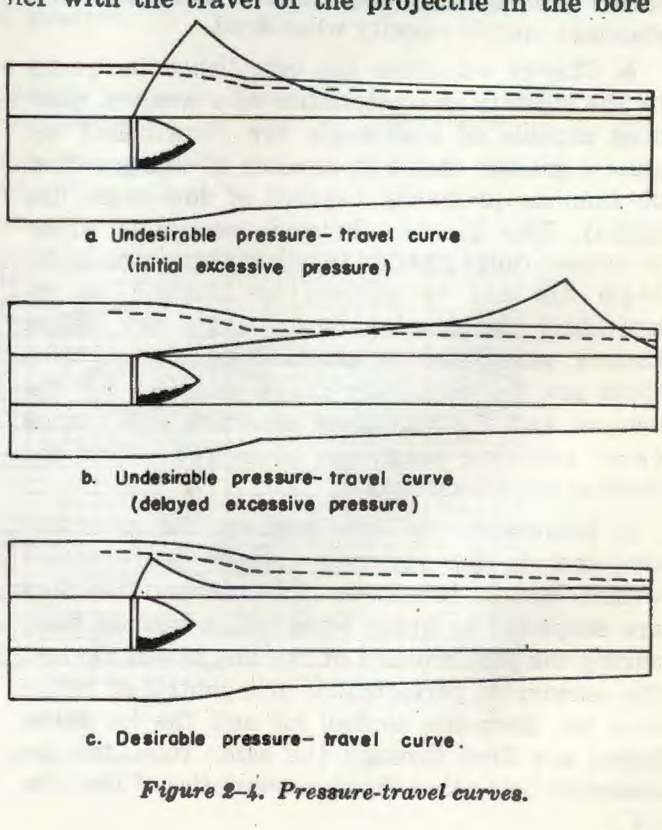


Figure 2-4. Pressure-travel curves.

(pressure-travel curve), determines the speed at which the projectile leaves the tube (fig 2–4).

c. Various factors which affect the velocity performance of a weapon-ammunition combination are given in (1) through (5) below.

(1) An increase in the rate of burning of a propellant increases 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 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 the tube and on the projectile and by differences in heat between the inner and outer surfaces of the tube.

2–8. Standard Muzzle Velocity

a. Appropriate firing tables give the standard value of muzzle velocity for each charge. 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 in a given instance; that is, a specific weapon-ammunition combination cannot be selected with the knowldege that it will result in a standard muzzle velocity when fired.

b. Charge velocities are established indirectly by the military characteristics of a weapon. Cannons capable of high-angle fire (howitzers) require a greater choice in number of charges than do cannons primarily capable of low-angle fire (guns). This greater choice is needed in order to achieve range overlap between charges in high-angle fire and to achieve the desired range-trajectory combination in low-angle fire. Other factors considered in establishing charge velocities 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, the assumption being that the characteristics of the tube have an identical influence on the performance of both lots. This assumption, although accurate enough for firing tests, is not entirely correct and allows a certain amount of error in propellant assessment procedures. (Assessment procedures include correcting charge weights for the tested lot 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 quality control over manufacture is exercised. For example, if a cannon develops a muzzle velocity 3.0 meters per second faster (or 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 that the prediction of future performance based on past results should not be attempted.

2–9. Factors Causing Nonstandard Muzzle Velocity

In gunnery techniques, nonstandard velocity is expressed as a variation (plus or minus so many meters per second) from an accepted standard. Round-to-round corrections for dispersion cannot be made. In the discussion in *a* through *p* below, each factor is treated as a single entity, assuming no influence from related factors.

a. *Velocity Trends*. Not all rounds of a series fired from the same weapon using the same ammunition lot will develop the same muzzle velocity. The variations in muzzle velocity follow a normal probability distribution about the average muzzle velocity. This phenomenon is called velocity dispersion. Under most conditions, the first few rounds follow a somewhat regular pattern rather than the random pattern associated with normal dispersion. This phenomenon is called velocity trend. The magnitude and extent (number of rounds) of velocity trends vary with the cannon, the charge and tube condition at round 1 of the series, and firings preceding the series. Velocity trends cannot be accurately predicted; therefore, any attempt to correct for the effect of a velocity trend is impractical. Characteristic velocity trends for some weapons, however, can be detected. Figure 2–5 shows a comparison of velocity trends for a 105mm howitzer when a series of rounds is fired starting with an oily tube, a series is fired starting with a tube that has been cleaned with rags only, and a series is fired starting with a tube that has been cleaned with soap and water. Generally, 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.

b. 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 (PE) within each lot is about the same, the mean velocity developed by one lot may be much higher or lower than that of another lot. For separate-loading ammunition, both the propellant and the projectile lots must be identified. Variations in the projectile, e.g., the diameter and hardness of the rotating band, affect muzzle velocity. (Projectile variations have a much more apparent effect on exterior ballistics.)

c. Tolerances in New Weapons. All new cannons of a given caliber and model will not necessarily develop the same muzzle velocity. In a new tube, the predominant factors affecting muzzle velocity are variations in the powder chamber and the interior dimensions of the bore. If a battalion armed with new cannons fired all the cannons with a common lot of ammunition, a velocity spread of 3 or 4 meters per second between the cannon with the highest muzzle velocity and the cannon with the lowest muzzle velocity would not be unusual. Therefore, cannons must be calibrated even though they are new.

d. Wear of Tube. Continued firing of a cannon wears away portions of the bore by the action of hot gases, by chemical action, and by movement of the projectile. These erosive actions are more pronounced when higher charges are being fired. Increased tube wear tends to decrease muzzle velocity by allowing the projectile to be seated farther forward in the tube and 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 by 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.

e. Nonuniform Ramming. Although a weak ram would decrease the volume of the propellant chamber and thereby theoretically increase the push given the projectile (the pressure of a gas varies inversely with the volume), this is only a partial effect. Improper seating (cocking) of the projectile, caused by improper ramming, allows some of the expanding gases to escape and results in lower velocity. The combined effect of escaping gases and a smaller propellant chamber is hard to predict. Weak, nonuniform ramming produces an increase in the dispersion pattern. Hard, uniform ramming is required for all rounds. When fixed and semifixed ammunition are being fired, the principles of varying the volume of the pro-

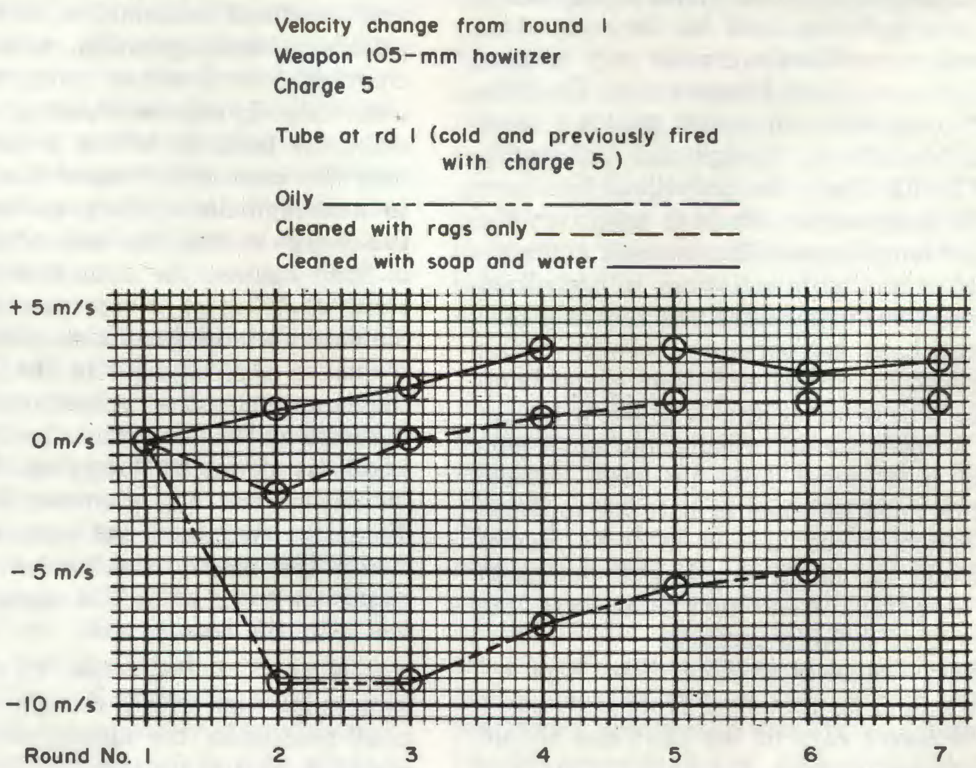


Figure 2–5. Velocity trends.

pellant chamber 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.

f. Rotating Bands. Ideal rotating bands allow proper seating, provide obturation, create proper resistance to initial projectile movement to allow uniform pressure buildup, and also provide a minimum dragging effect on the projectile once motion has started. Dirt or burs on the rotating band cause improper seating, which increases tube wear and contributes to velocity dispersion. If excessively worn, the lands may not sufficiently engage the rotating bands to impart the 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 requested to determine the serviceability of each tube by wear measurements and other checks.

g. 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. Appropriate corrections to firing data can be computed; however, such corrections are valid only as they reflect the true propellant temperature. The temperature of propellants in sealed packing cases remains fairly uniform, though not necessarily standard (70° F). Once the propellant has been unpacked, its temperature tends to approach the prevailing air temperature. Exposure of ammunition to weather results in variations in propellant temperature between rounds as well as variations in mean propellant temperature between firing sections. The extent of the variations depends on the time and type of exposure. It is not practical to measure propellant temperature and apply corrections for each round fired by each cannon. Positive action must be taken to maintain uniform propellant temperatures; failure to do so results in erratic firing. The effect of a sudden change in propellant temperature can invalidate even the most recent registration corrections.

(1) 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 airspace between the ammunition and protective covering. This procedure allows propellants to approach atmospheric temperature at a uniform rate.

(2) A sufficient number of rounds should be unpacked in advance so that it is not necessary during a mission to mix freshly unpacked ammunition with ammunition which has been opened for some time.

(3) Rounds should be fired in the order in which they are unpacked.

(4) Propellant temperatures of ready ammunition should be taken at random points in the ammunition stack and checked periodically at intervals dependent on the changes in ambient temperatures. The rounds so checked should not be removed from the rest of the ammunition but should be measured in place so that a true mean temperature can be obtained. The thermometer should penetrate the propellant and must not touch any metal.

(5) Propellants should be exposed to a heated powder chamber for the shortest possible time.

h. Moisture Content of Propellant. Changes in the moisture content of propellant are caused by improper handling and storage. These changes will affect muzzle velocity. The moisture content of the propellant cannot be measured or corrected for; therefore, ammunition must be provided maximum protection from the elements.

i. Position of 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. In separate-loading ammunition, however, the position of the propellant depends on how the cannoneer inserts the charge. In order to insure ignition of the propellant, he must insert the charge so that the base of the propellant bag is flush against the obturator spindle at the instant of firing of the primer. Variations in the diameters of the bags also affect propellant performance. An increase in the bag diameter for the same amount of propellant tends to increase the rate of burning and the resultant velocity. Loose tie straps or wrappings have the effect of increasing the bag diameter from the original diameter; therefore, the cannoneer should check the wrappings for tightness even when the full charge is being used. The straps should never be tied over the ignitor pad.

j. Weight of Projectile. The weights of like projectiles vary within certain weight zones. For most projectiles the appropriate weight zone is stenciled on the projectile. For these projectiles that are not grouped in weight zones, the weight is marked in pounds. A heavier than standard projectile is harder to push throughout the length of the tube and therefore, its velocity is lower than normal. A lighter projectile than standard is easier to push throughout the length of the tube and therefore, its velocity is higher than standard. (Weight of projectile is also a factor in exterior ballistics.)

k. Coppering. Coppering is the deposit of a thin film of copper on the bore. Coppering occurs in the tube when the velocity is high enough to develop sufficient friction to remove the outer surface of the rotating band. The amounts of copper deposited vary with velocity. Coppering is more pronounced in high-velocity weapons than in low-velocity weapons, and firing with higher charges results in more coppering than does firing with lower charges. Slight coppering, such as that resulting from firing a few rounds at the higher charges with a howitzer tends to increase muzzle velocity; excessive coppering causes erratic velocity performance by varying the resistance of the bore to projectile movement. The removal of excessive copper is an ordance function.

l. Propellant Residues. Residues from the burned propellant and certain chemical agents mixed with the expanding gases are deposited on the bore surface. Unless the tube is properly cleaned and cared for, these residues aggravate subsequent tube wear by causing pitting and augmenting the abrasive action of the projectile.

m. Tube Conditioning. The temperature of the tube has a direct bearing on the developed velocity. For example, a cold tube offers a different resistance to projectile movement than a warm tube. A cold tube is less susceptible to coppering even at high velocities. Additional factors are the weapon, the charge fired, oiliness of the tube, and the degree of coppering.

(1) 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.

(2) 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 465), it will be slightly overconditioned for charge 4 (MV 262). Also, if firing is performed immediately with the lower charge, a tendency toward higher than normal velocities will be experienced on the first one or two rounds. Going from a lower to higher charge also introduces the possibility that the first one or two rounds will have a lower than normal velocity. It is doubtful whether 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, the average variation from standard velocity for the 105-mm howitzer when firing is started with charge 3 may be 3.0 to 4.6 meters less than that when firing with charge 3 is preceded by firing with charge 7. The tactical situation seldom allows the firing of conditioning rounds. However, the lack of tube conditioning is a factor that the S3 must consider in attacking targets without adjustment or in firing close to friendly troops. Likewise, possible velocity trends should be considered in mean-point-of-impact (MPI) and high-burst (HB) registrations and calibration firing.

(3) In general tube conditioning involves two different effects. One effect is that of heating the tube until the temperature differential from inner to outer surfaces is stabilized for the rate of fire and charge to be used. The other effect is that of bringing the bore resistance from coppering and propellant residues to a 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 cannons because of the many variations between the conditioned tube and the unconditioned tube.

(4) When calibration involves more than one charge, the higher charge is fired first, since conditioning for the lower charge occurs with fewer rounds if the first 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. When calibrations are conducted with the lower charges of the 105-mm, 155-mm, and 8-inch howitzers and the 175-mm gun without prior conditioning with higher charges, more rounds will be required for reaching a conditioned tube status. If conditioning has been accomplished with one charge and a change to another charge is required, at least one

conditioning round should be fired with the new charge.

(5) Guns are more sensitive to changes in the rate of fire than howitzers. The accuracy of preparation fire is adversely affected by rapid firing followed by intermittent lulls of varying length.

(6) The previous conditioning of any weapon is affected by lulls in firing and the ambient air temperature. If the lull is no longer than 1 hour, the firing of one round will normally bring the cannon to the previous velocity level. If the tube is 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 described in *a* above may be expected. The conditioning of the tube is destroyed more quickly during lulls in firing in extremely cold temperature than in warm temperature. During cold weather, the firing of more rounds may be necessary to bring the cannon to the proper velocity level.

(7) Oil or moisture in the tube or on the rotating band tends to increase the velocity of a particular round by causing a better initial gas seal and reducing projectile friction on the bore surface. The oily tube condition usually exists concurrently with the cold tube condition. Hence, the high velocities induced by oil, combined with the erratic velocities characteristic of a cold tube, complicate normal velocity trends. When these factors are coupled with the effects of coppering and powder residues, it is hard to predict corrections for velocity trends. Moisture on the projectile normally affects only that particular round. Generally, 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 2-5 illustrates velocity trends measured under the conditions stated. The graph in figure 2-5 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 cannon and condition specified after repeated observations.

n. Determination of Muzzle Velocity. The accuracy of artillery fires could be improved if actual muzzle velocities developed by each tube at the 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 and velocity performance must be predicted on this basis. The velocity level of each weapon must be determined at every opportunity. Methods used to determine comparative and absolute velocity performance of a group of weapons are discussed in chapter 22. Some of the factors involved in calibration are discussed in detail in paragraphs 2-10 through 2-27.

o. Charge-to-Charge Propellant Performance. One of the major problems in gunnery is how best to extend to all other charges the data developed from firing one charge. From the viewpoint of muzzle velocities only, there is no basis in available data for stating that charge-to-charge performance follows a convenient ratio. Since propellants are manufactured to provide 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 has been 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.

p. Projectile Temperature. The effect of temperature on the projectile casing and the filler may cause a warping of the projectile casing, including the fuze cavity (specifically the threads in the cavity). This effect may then result in improper seating of the projectile in the tube. When this occurs, the sealing action of the rotating band may not be complete and gases may escape upon combustion of the propellant. The result will be a loss in developed muzzle velocity and a subsequent decrease in range. When the fuze well does not permit the proper seating of the VT fuze, either fuze quick or fuze time should be fired with that projectile or the projectile should be rejected. Improper seating of the VT fuze may cause it to activate prematurely. Since there is no method of detecting the effect of temperature on the projectile casing with regard to proper seating, positive action must be taken to prevent sudden changes or varying changes in the temperature of the projectile. Those procedures that apply to the storage of propellants are also applicable to projectiles.

Section III. EXTERIOR BALLISTICS

2–10. General

a. Exterior ballistics is the science which deals with the factors affecting the motion of a projectile after it leaves the muzzle of a weapon; at that instant, the total effect of interior ballistics in terms of developed muzzle velocity and spin has been imparted to the projectile. Were it not for gravity and atmosphere, the projectile would continue indefinitely at a constant velocity along a prolongation of the tube.

b. Gravity causes the projectile to return to the surface of the earth. If the projectile were fixed in a vacuum, the path, or trajectory, would be simple to trace. All projectiles, regardless of size, shape, or weight, should follow paths of the same shape and would achieve the same range for a given muzzle velocity and tube elevation. However, when the projectile is fired in the atmosphere, the path becomes a complex curve. There are two reasons for this. First, projectiles of different sizes or weights respond differently to identical atmospheric conditions. Second, although a standard atmosphere can be defined, a standard atmosphere is seldom experienced. The combinations and permutations of the variables affecting the atmosphere (and, thus, the path of a projectile) are numerous. 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.

2–11. The Trajectory

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 point of burst (fig 2–6).

2–12. Elements of the Trajectory

The elements of the trajectory are classified into three groups—intrinsic elements, initial elements, and terminal elements. Intrinsic elements are those which are characteristic of a trajectory by its very nature. Initial elements are those that are characteristic at the origin of the trajectory. Terminal elements are those which are characteristic at the point of impact or point of burst.

2–13. Intrinsic Elements

The intrinsic elements of the trajectory (fig 2–7) are discussed in *a* through *g* below.

a. Origin. The location of the center of gravity of the projectile when it leaves the muzzle of the piece is designated the origin of the trajectory. However, the magnitude and the direction of jump and therefore the line of departure (para 2–14*b* and *c*) cannot be predetermined. Therefore, for the remaining definitions relating to the elements of the trajectory, the term "origin" will be used to designate the center of the muzzle when the piece has been 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 of the trajectory. It is the end of the ascending branch.

e. Maximum Ordinate. The maximum ordinate is the difference in altitude between the origin and the summit.

f. Level Point. The level point is the point on

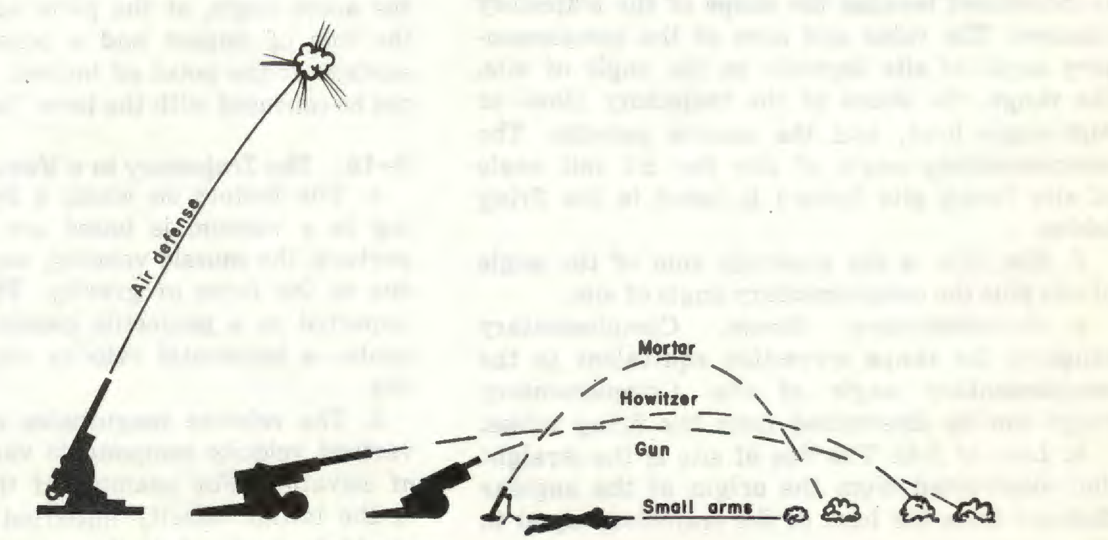


Figure 2–6. Typical trajectories.

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.

2-14. Initial Elements

The initial elements of the trajectory (fig 2-8) are discussed in *a* through *j* below.

a. Line of Elevation. When the piece is laid, the line of elevation is the axis of the tube extended.

b. Line of Departure. The line of departure is a line tangent to the trajectory at the instant the projectile leaves the tube.

c. Jump. Jump is the displacement of the line of departure from the line of elevation that exists at the instant the projectile leaves the tube. Jump is caused by the shock of firing during the interval from the ignition of the propelling charge to the departure of the projectile from the tube.

d. Angle of Site. The angle of site is the smaller angle in the vertical plane from the base of the trajectory to the straight line joining the origin and the target. The angle of site is plus when the target is above the base of the trajectory and minus when the target is below the base of the trajectory. The angle of site compensates for the vertical interval (para 2-4).

e. Complementary Angle of Site. The complementary angle of site (comp site) is an angle which is algebraically added to the angle of site to compensate for the nonrigidity of the trajectory. The trajectory may be rotated vertically about the origin an amount equal to small angles of site without significantly affecting its shape. When large angles of site or the longer ranges for any one charge are involved, significant error is introduced because the shape of the trajectory changes. The value and sign of the complementary angle of site depends on the angle of site, the range, the shape of the trajectory (low- or high-angle fire), and the muzzle velocity. The complementary angle of site for ± 1 mil angle of site (comp site factor) is listed in the firing tables.

f. Site. Site is the algebraic sum of the angle of site plus the complementary angle of site.

g. Complementary Range. Complementary range is the range correction equivalent to the complementary angle of site. Complementary range can be determined from the firing tables.

h. Line of Site. The line of site is the straight line constructed from the origin at the angular distance from the base of the trajectory equal to site.

i. Angle of Elevation. The angle of elevation is the smaller angle at the origin in a vertical plane from the line of site to the line of elevation.

j. Quadrant Elevation. The quadrant elevation is the smaller angle at the origin in a vertical plane from the base of the trajectory to the line of elevation. Quadrant elevation is the algebraic sum of site plus the angle of elevation. Quadrant elevation can also be computed by algebraically adding the angle of site to the angle of elevation corresponding to range plus complementary range. The two methods of computing quadrant elevation, one using the complementary angle of site and the other using complementary range, both compensate for the nonrigidity of the trajectory. Either complementary angle of site or complementary range may be used when the firing data are being determined from the firing table; complementary angle of site is used when site is being determined with the graphical site table.

2-15. Terminal Elements

The terminal elements of the trajectory (fig 2-9) are discussed in *a* through *e* below.

a. Point of Impact. The point of impact is the point at which the projectile first strikes in the target area. (The point of burst or point of ejection for base ejection projectile, is the point at which a projectile bursts or ejects in the air.)

b. Line of Fall. The line of fall is a 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. Line of Impact. The line of impact is a line tangent to the trajectory at the point of impact.

e. Angle of Impact. The 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."

2-16. The Trajectory in a Vacuum

a. The factors on which a firing table for firing in a vacuum is based are the angle of departure, the muzzle velocity, and the acceleration due to the force of gravity. The initial velocity imparted to a projectile consists of two components—a horizontal velocity and a vertical velocity.

b. The relative magnitudes of horizontal and vertical velocity components vary with the angle of elevation. For example, if the elevation were 0, the initial velocity imparted to the projectile would be horizontal; there would be no vertical

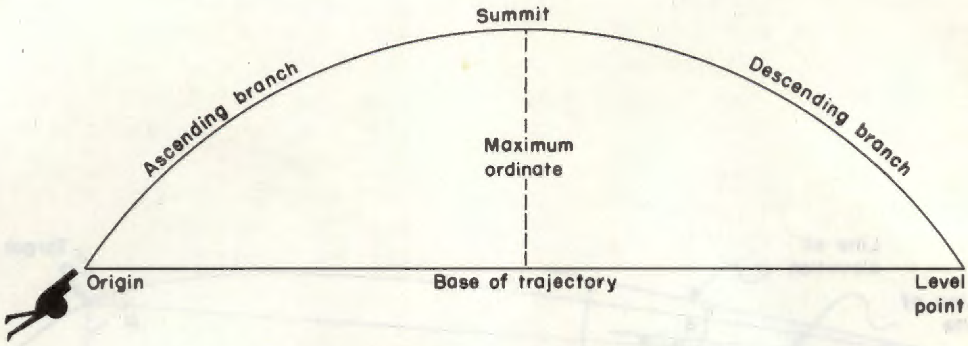
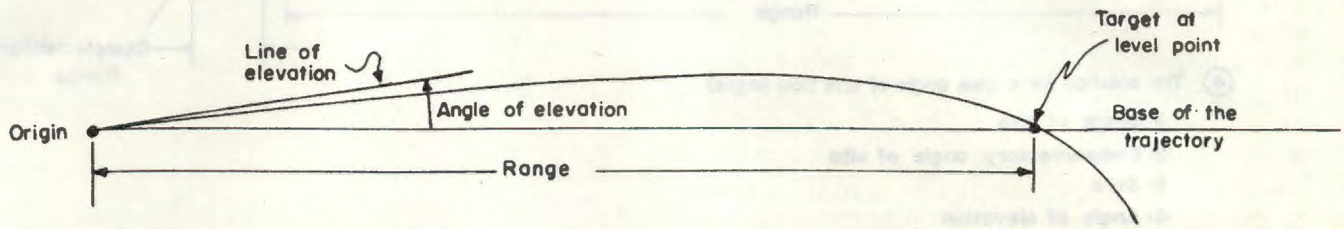
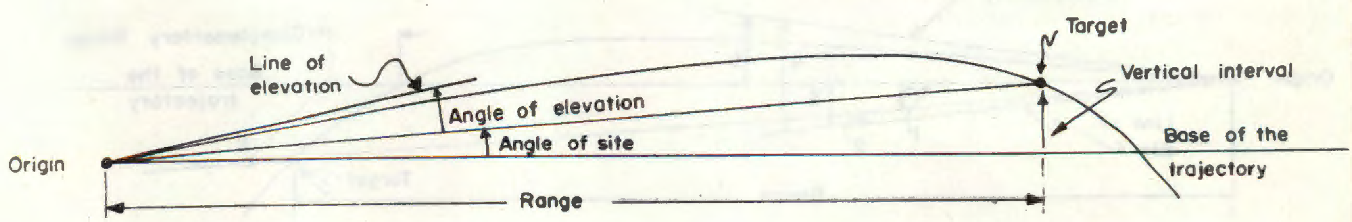


Figure 2-7. Intrinsic elements of the trajectory.

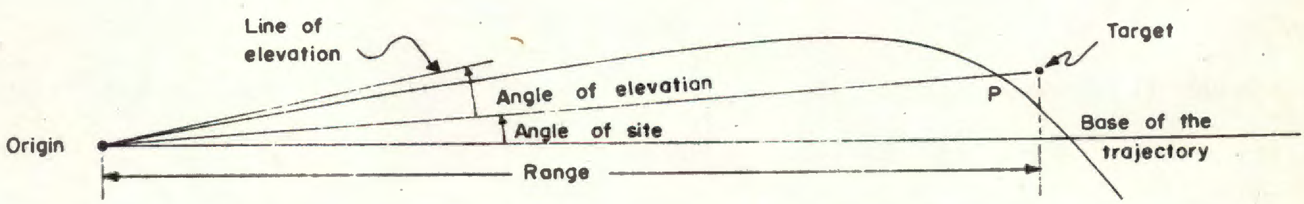


(1) Trajectory with zero angle of site

Figure 2-8. Initial elements of the trajectory.

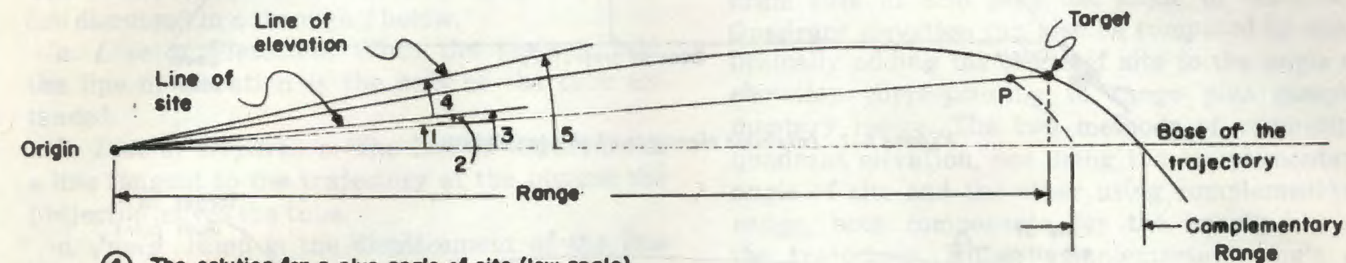


(2) Hypothetical (rigid) trajectory



(3) Actual (nonrigid) trajectory

Figure 2-8—Continued.



④ **The solution for a plus angle of site (low angle)**

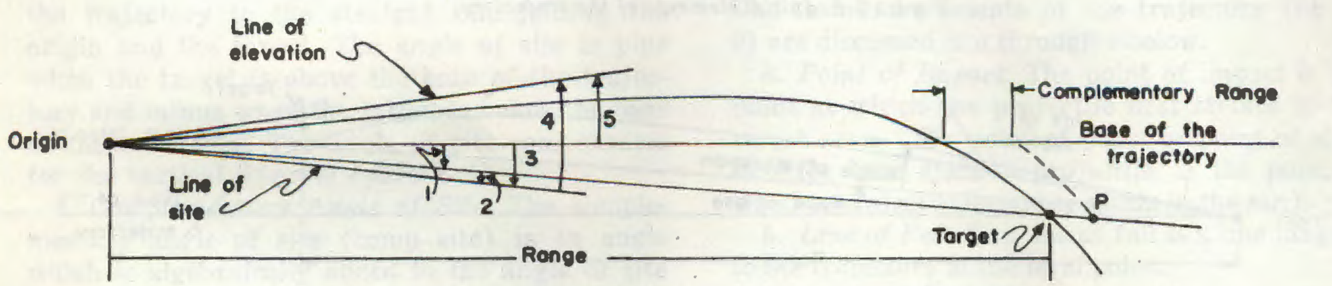
1: Angle of site

2: Complementary angle of site

3: Site

4: Angle of elevation

5: Quadrant elevation



⑤ **The solution for a minus angle of site (low angle)**

1: Angle of site

2: Complementary angle of site

3: Site

4: Angle of elevation

5: Quadrant elevation

Figure 2–8—**Continued.**

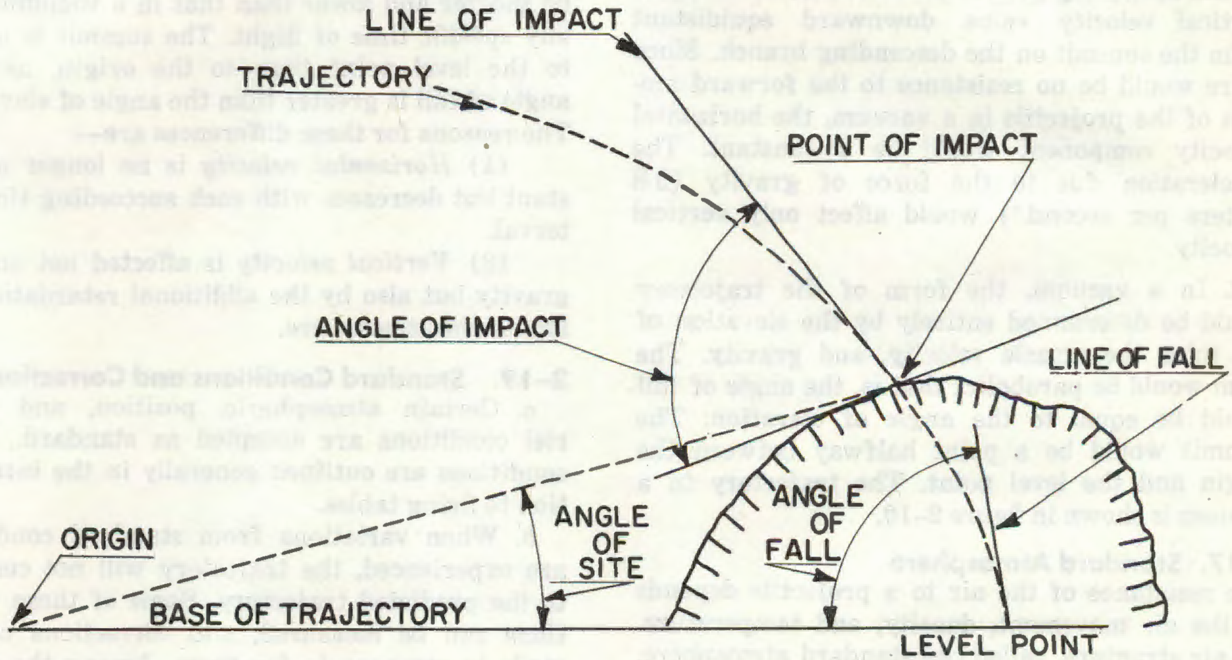


Figure 2–9. Terminal elements of the trajectory.

component. If the elevation were 1,600 mils (disregarding the effect of rotation of the earth), the initial velocity imparted to the projectile would be vertical; there would be no horizontal component.

c. Gravity causes a projectile in flight to fall to the earth. 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. In a vacuum, the vertical velocity would decrease from the initial velocity to 0 on the ascending branch of the trajectory and would increase from 0 to the initial velocity on the descending branch. Zero vertical velocity would occur at the trajectory summit. For every vertical velocity value upward on the ascending branch there would be an equal vertical velocity value downward equidistant from the summit on the descending branch. Since there would be no resistance to the forward motion of the projectile in a vacuum, the horizontal velocity component would be a constant. The acceleration due to the force of gravity (9.8 meters per second ^{2}) would affect only vertical velocity.

d. 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; that is, the angle of fall would be equal to the angle of elevation. The summit would be a point halfway between the origin and the level point. The trajectory in a vacuum is shown in figure 2-10.

2-17. Standard Atmosphere

The resistance of the air to a projectile depends on the air movement, density, and temperature. An air structure, called the standard atmosphere, is derived from assumed conditions of air density and air temperature and a condition of no wind. This standard atmosphere is used as a point of departure for computing firing tables.

2-18. 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 2-11). This reduction occurs mainly because, in the atmosphere, the horizontal velocity component is not a constant but is continually decreased by the retarding effect of the air. The vertical velocity component is likewise affected by air resistance. The characteristics of a trajectory in standard atmosphere differ from the characteristics of a trajectory in a vacuum as follows:

a. The velocity at the level point is less than the velocity at the 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, the descending branch is shorter than the ascending branch, and the angle of fall is greater than the angle of elevation. Also, since the mean vertical velocity beyond the summit is less than the mean vertical velocity before the summit, the time of descent is greater than the time of ascent.

c. Because of air resistance, the response of the projectile to the initially imparted spin is different from that in a vacuum.

d. The trajectory in standard atmosphere, will be shorter and lower than that in a vacuum after any specific time of flight. The summit is nearer to the level point than to the origin, and the angle of fall is greater than the angle of elevation. The reasons for these differences are—

(1) *Horizontal velocity* is no longer a constant but decreases with each succeeding time interval.

(2) *Vertical velocity* is affected not only by gravity but also by the additional retardation effect of the atmosphere.

2-19. Standard Conditions and Corrections

a. Certain atmospheric, position, and materiel conditions are accepted as standard. These conditions are outlined generally in the introduction to firing tables.

b. When variations from standard conditions are experienced, the trajectory will not conform to the predicted trajectory. Some of these variations can be measured, and corrections can be made to compensate for them. Among the conditions for which corrections may be determined are—

(1) Vertical interval.
(2) Propellant temperature.
(3) Drift.
(4) Ballistic wind.
(5) Muzzle velocity.
(6) Air temperature.
(7) Air density.
(8) Weight of projectile.
(9) Rotation of the earth.

2-20. Firing Tables

a. Firing tables are based on actual firings of the piece and its ammunition under, or correlated to, a set of conditions defined and accepted as standard. These standards are points of departure and corrections are used to compensate for variables in the weapon-weather-ammunition

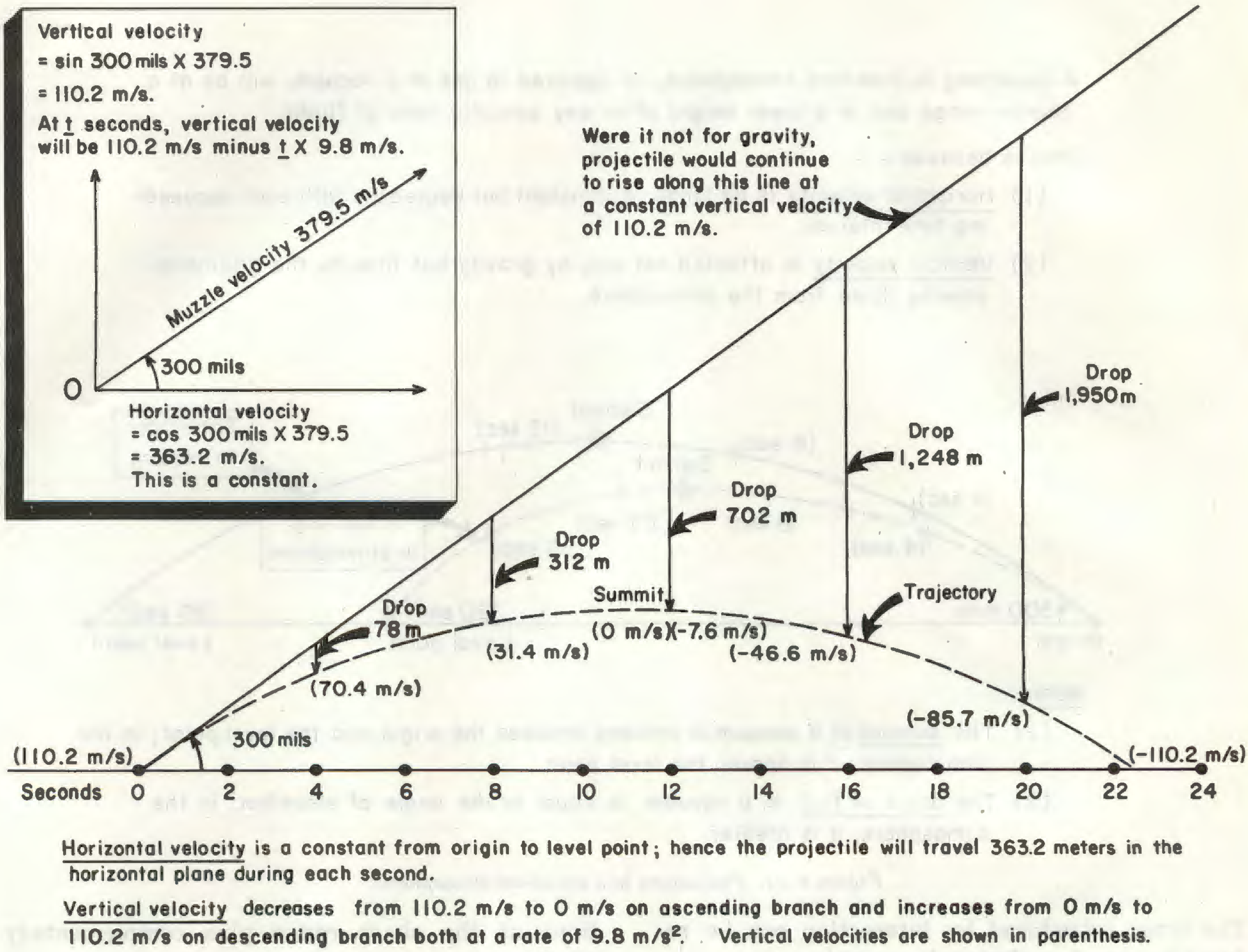


Figure 2-10. Trajectory in a vacuum.

combination that are known to exist at a given instant and location. The atmospheric standards accepted in US firing tables reflect the mean annual condition in the North Temperate Zone.

b. The principal elements measured in experimental firings include angle of elevation, angle of departure, muzzle velocity, achieved range, drift, and concurrent atmospheric conditions.

c. 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. Data for firing tables are obtained from firings 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 are then adjusted to the measured results and data are tabulated. Data for elevations not fired are determined by interpolation. Firing table data define the performance of a projectile of known properties under conditions of standard muzzle velocity and weather and a motionless earth.

2-21. Unit Corrections

a. Firing tables list unit corrections as range correction for an increase (decrease) in each of the following factors: muzzle velocity, range wind, air temperature, air density, and projectile weight. The appropriate unit correction for each listed range is given in meters.

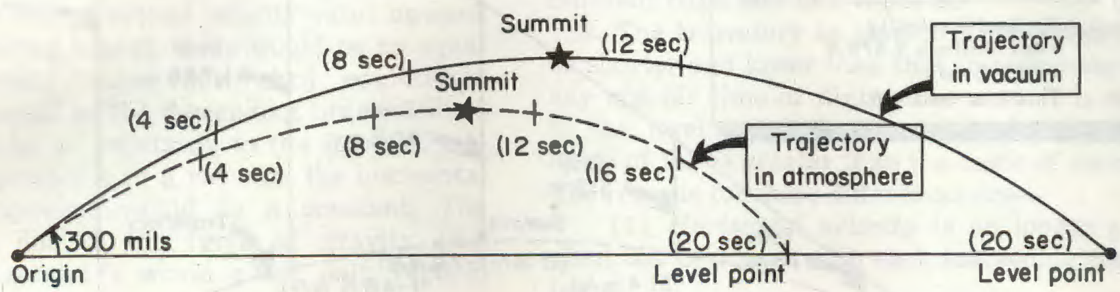
b. Each correction is computed on the assumption that all other conditions are standard. Actually, any given correction will differ slightly from that computed if one or more of the other conditions are nonstandard. The amount of difference depends on the effect of the other nonstandard conditions. The effect of one nonstandard condition on the effect of another nonstandard condition is known as an interaction effect.

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 decreases 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 2–11. Trajectory in a standard atmosphere.

The error introduced by interaction can be reduced by use of an electronic computer.

c. Effects and corrections, in meters or mils, are not of equal magnitude when computed at the same range. The relationship between effects and corrections at a given range can be shown by the following example: An MPI registration is fired by a 155-mm howitzer (M109) firing charge 7, elevation 322 (standard elevation for 10,000 meters). The measured range to the mean-point-of-impact is 9500 meters. The total effect of all nonstandard conditions is –500 meters. The graphic firing table (GFT) setting from the MPI registration is GFT A: Charge 7, lot ZT, range 9500, elevation 322. Based on the GFT setting, the elevation to achieve range 10,000 meters is 351 (the elevation for 10,520 meters). The total range correction is +520 meters.

2–22. Extracting Data From Firing Tables

a. The effect of a nonstandard condition is a function of the time the projectile is exposed to that condition. In common firing tables, the relationship of corrections to time of flight can be resolved by entering the tables for unit corrections at the chart range plus complementary range.

b. When corrections are being computed, slightly more accurate data can be obtained by making a second computation at the first apparent corrected entry range. (This procedure is called successive approximation.) However, the improvement is marginal and is not recommended.

c. The weather, as described in the meteorological message, that affects a projectile is that at the maximum ordinate achieved. This maximum ordinate is most nearly a function of the quadrant elevation fired.

2–23. Standard Range

a. The standard range is the range opposite a given elevation in the firing tables. It is assumed to be 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 distance from the origin to the level point.

b. The achieved range is the range which is developed as a result of firing with a certain elevation of the tube. If actual firing conditions duplicate the ballistic properties and meteorological conditions upon which the firing table is based, the achieved range and standard range will be equal.

c. The corrected range is the range which corresponds to the elevation that must be fired to reach the target.

2-24. Effect of Nonstandard Conditions

a. Deviations from standard conditions, if not corrected in computing firing data, will cause the projectile to impact or burst at a point other than the desired point.

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 to the location of the mean point of impact with respect to a desired point.

2-25. Range Effects

a. Vertical jump is the angle formed by the line of elevation and the line of departure. The shock of firing causes a momentary vertical and rotational movement of the tube prior to the ejection of the projectile. Vertical jump has the effect of a small change in elevation. The effect of vertical 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, vertical jump cannot be predicted and is usually small. For these reasons vertical 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 on the basis of measurements at the muzzle. For example, if droop for a certain weapon is −3 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-mil elevation, a setting of 363 will be necessary. For most weapons, droop 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 achieved range. Velocity error often becomes a catch-all for many nonvelocity elements. When this occurs, accuracy is adversely affected in subsequent applications of the velocity error.

d. The weight of the projectile 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 normally lower. An increase in projectile efficiency increases range, but a decrease in muzzle velocity decreases range. In firing tables, corrections for these two opposing factors are combined into a single correction. The change in muzzle velocity predominates at shorter times of flight; the change in projectile efficiency predominates at longer times of flight. Hence, for a heavier than standard projectile, the correction is plus at the shorter times of flight. The reverse is true for a lighter than standard projectile.

e. 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 achieved 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—

(1) *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. Although air densities may vary widely with changes in location and time, the effect of altitude changes on air density can be determined by special computations considering temperature and moisture conditions, for this reason, the standard trajectories reflected in the firing tables are computed with a fixed relation between density and altitude.

(2) *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 resistance of 1 percent air density (hence, 1 percent drag) increases with an increase of charge; that is, an increase in muzzle velocity. The drag is approximately proportional to the square of the velocity until the projectile approaches the velocity of sound. When the velocity approaches the velocity of sound, drag increases more rapidly because of the increase in pressure behind the sound wave.

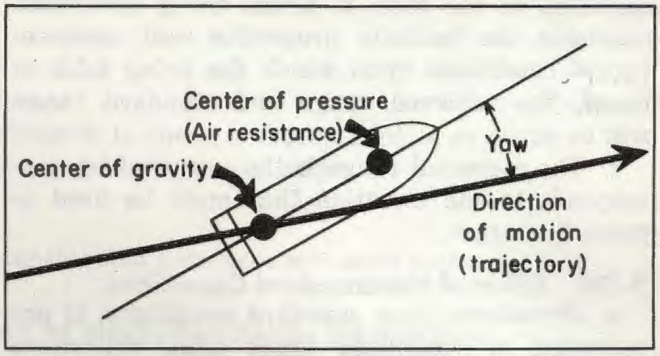
(3) *Diameter.* Two projectiles of identical shape but different size will not experience the same drag. For example, a large projectile will offer a large area for the air to act upon; hence, its drag will be increased by this factor. For projectiles of the same shape, drag is proportional to the square of the diameter of the projectile.

(4) *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 2-12)) and the mach number (the ratio of the velocity of the projectile to the speed of sound (fig 2-13)).

f. The shell surface finish affects muzzle velocity. A rough surface on the projectile or fuze will increase air resistance and thereby decrease range.

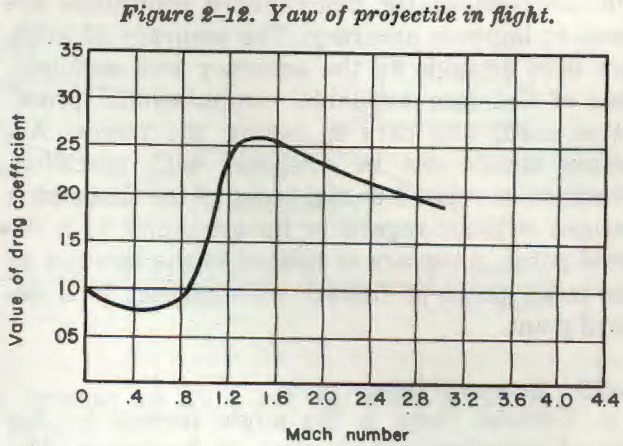
g. The ballistic coefficient of a projectile relates its efficiency in overcoming air resistance to that of an assumed standard projectile. For ease in computations, all projectile types are classified into certain standard groups. Each projectile, however, has its own efficiency level. Each projectile 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 the same type may not have the same ballistic coefficient as the one reflected in the firing tables. A more efficient lot (that is, a lot with a higher ballistic coefficient than the firing table standard) will achieve a greater range when fired. The reverse is true for a less efficient projectile lot. In present gunnery procedures, variations in ballistic coefficient are considered an element of muzzle velocity.

h. As the air temperature increases, the drag decreases, and range increases. This does not hold true as the velocity of the projectile approaches the speed of sound. Here drag is related to the mach number and the relationship changes abruptly in the vicinity of mach 1.



(Air resistance is least when center of pressure is on the trajectory; that is, zero yaw)

Figure 2-12. 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 2-13. Effect of velocity (mach number) on drag coefficient of projectile type 1.

i. The effects of air density on drag, and thus on range, are discussed in *e*(1) above.

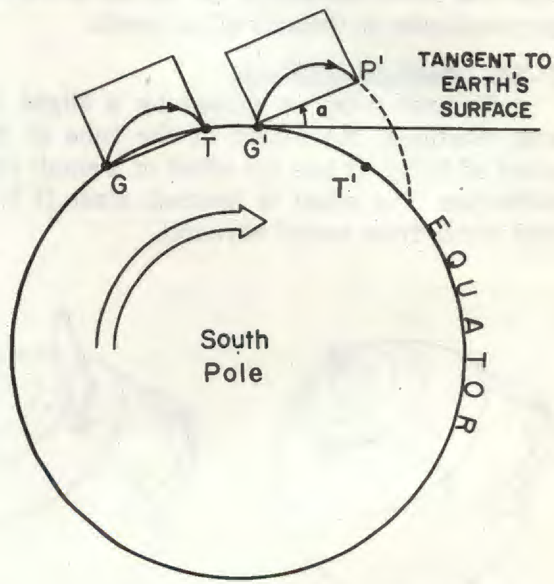
j. Range wind is that component of the ballistic wind blowing parallel to the direction of fire and the plane of fire. The plane of fire is a vertical plane that contains the line of elevation. Range wind changes the relationship between the velocity of the projectile and the velocity of the air near the projectile. If the air is moving with the projectile (tailwind), it offers less resistance to the projectile and results in a longer range. A headwind has the opposite effect.

k. Although the earth rotates at a constant rate, corrections for rotation vary with a number of factors and, therefore, rotation is more readily considered a nonstandard condition. Factors influencing the effect of rotation of the earth on the travel of a projectile are the direction of fire, the angle of departure, the velocity of the projectile, the range to the target, and the latitude of the gun. Corrections for these factors are combined in convenient tabular form in firing tables. The correction tables provide all the data needed to compensate for rotation in the gunnery problem. However some background theory of rotational effects may assist in an understanding of ballistics.

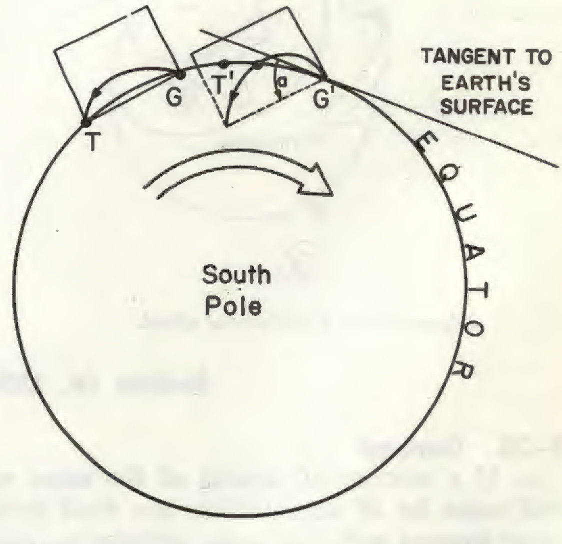
(1) Because of rotation of the earth, a point on the Equator has an eastward linear velocity of approximately 457 meters per second. This linear velocity decreases to 0 meters at either pole. Consider a gun on the Equator firing due east at a target. (①, fig 2–14). During the time of flight of the projectile, the gun and target will travel from G to G′ and from T to T′, respectively, along the circumference of the earth. The projectile, however, will travel in a vertical plane, the base of 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 east of, or in this instance, beyond, the target. The normal trajectory of the projectile is interrupted. Consider the same gun firing westward (②, fig 2–14). Again, the projectile will fall to the east of the target, but in this instance, the round is short of the target. The effect in each example is as if the quadrant elevation fired where in error by the amount of angle a, which is the angle formed by the base line G′P′ and a tangent to the earth at G′. When the gun is firing eastward, angle a is plus (range over); when the gun is firing westward, angle a is minus (range short).

(2) A second consideration is the curvature effect. Curvature effect exists because the range used in computing firing data is measured on a map, on which the surface of the earth is assumed to be flat, whereas the actual range is measured on a sphere. The gun-target (GT) range is computed for a plane tangent to the surface of the earth at the gun. When the projectile reaches this range, it is still above the curved surface of the earth and will continue to drop. Therefore the true range will be slightly longer than the desired range. This effect is of little significance except at very long ranges. It is disregarded when firing tables are used, since firing table ranges include curvature effect.

(3) A final rotational effect is described as the latitudinal effect. When the gun and target are at different latitudes, the eastward rotational velocity of the projectile is different to the rotational velocity of the target. For example, if the gun is nearer the Equator (①, fig 2–15), the projectile will travel faster and therefore farther to the east than the target (the effect left or right depends on the hemisphere). When the gun and target are at the same latitude (②, fig 2–15), the projectile will also be deflected away from



① Rotational effects on range firing eastward



② Rotational effects on range firing westward

Figure 2–14. Rotational effects.

the target. This is because the projectile tends to travel in the plane of the great circle containing the gun and target at the time of firing. Because of the rotation of the earth, this great circle plane is continuously changing with respect to its original position. As viewed from above, the great circle containing the gun and target would appear to be turning with respect to the great circle followed by the projectile. An additional latitudinal effect is pictured in ③, figure 2-15. 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 but is not perpendicular to the axis of the earth.

2-26. 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 small and varies from round to round.

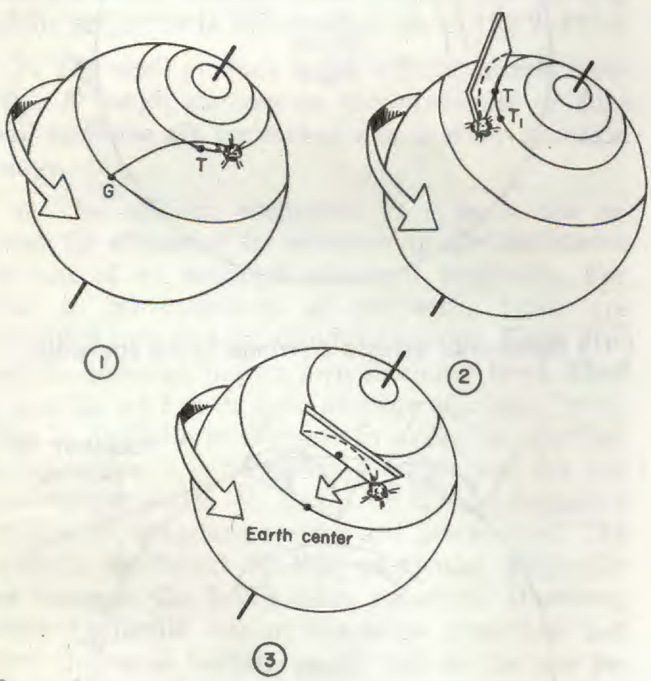


Figure 2-15. Latitudinal effect.

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; therefore, it is fundamental in the design of projectiles 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 toward the direction of the spin. Therefore, since artillery projectiles have a clockwise spin, they drift to the right in the descending branch of the trajectory. The magnitude of drift (expressed at lateral distance on the ground) depends on the time of flight and rotational speed of the projectile and the curvature of the trajectory.

c. Crosswind is that component of the ballistic wind blowing across the direction of fire. Crosswind 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 are described in paragraph 2-25*k* (3) and illustrated in figure 2-15.

2-27. Time of Flight

Those nonstandard conditions which affect range also affect time of flight. The fuze settings for current time fuzes, although approximating time of flight, are not interchangeable with the time of flight.

Section IV. DISPERSION AND PROBABILITY

2-28. General

a. If a number of rounds of the same caliber and same lot of ammunition are fired from the same weapon with the same settings in quadrant elevation and deflection, the rounds will not fall at a single point but will be scattered in a pattern of bursts. In discussions of artillery fires, the natural phenomenon of chance is called dispersion. The array of the bursts on the ground is the dispersion pattern.

b. The points of impact of the projectiles will be scattered both laterally (deflection) and in depth (range). Dispersion is the result of minor variations of many elements from round to round and must not be confused with variations in point of impact caused by mistakes or constant errors. Mistakes can be eliminated and constant errors compensated for. Those inherent errors which are caused in part by—

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

(2) *Conditions in the carriage.* Direction and elevation are affected by play (looseness) in the mechanisms of the carriage, by physical limitations on precision in setting scales, and by 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, air density, and air temperature from round to round.

2–29. Mean Point of Impact

For any large number of rounds fired, it is possible to draw a diagram showing a line perpendicular to the line of fire that will divide the points of impact into two equal groups. Half of the rounds considered will be beyond the line, or *over,* when considered from the weapon; half will be inside the line, or *short,* when considered from the weapon. For this same group of rounds, the diagram will also show a line parallel to the line of fire that will divide the round into two equal groups. Half of the rounds will fall to the right of the line; half will fall to the left of the line. The first line, perpendicular to the line of fire, represents the mean range; the second line, parallel to the line of fire, represents the mean deflection. The intersection of the two lines is the mean point of impact (MPI) (fig 2–16).

2–30. Probable Error

Consider for a moment only the rounds that have fallen over the mean point of impact. At some point along the line of fire beyond the mean point of impact, a second line perpendicular to the line of fire can be drawn that will divide the overs into two equal parts (line AA, fig 2–17). All the rounds beyond the mean point of impact manifest an error in range—they are all *over.* Some of these rounds are more in error than others. If the distance from the mean point of impact to line AA is a measure of error, it is clear that half of the rounds *over* manifest a greater error and half of the rounds *over* manifest a lesser error. The distance from the mean point of impact to line AA thus becomes a convenient unit of measure. This distance is called one probable error (PE). The most concise definition of a probable error is that it is the error which is exceeded as often as it is not exceeded. Probable error is also manifested by the rounds which fell short of the mean point of impact.

2–31. Dispersion Pattern

In a normal burst pattern the number of rounds short of the mean point of impact will be the same as the number of rounds over the mean point of impact. The probable error will be the same in both cases.

a. It is a coincidence of nature that for any normal distribution (such as the artillery dispersion pattern) a distance of 4 probable errors on either side of the mean point of impact will include virtually all the rounds in the pattern. This is not precisely true, since a very small fraction of the rounds (approximately 7 out of 1,000) will fall outside 4 probable errors on either side of the mean point of impact, but it is true for all practical purposes.

b. The total pattern of a large number of bursts is roughly elliptical (fig 2–17). However, since 4 probable errors on either side of the mean point of impact (in range and deflection) will encompass virtually all rounds, a rectangle normally is drawn to include the full distribution of the rounds. This rectangle is the 100-percent rectangle (fig 2–18).

2–32. Dispersion Scale

If 1 probable error is used as the unit of measurement to divide the dispersion rectangle evenly into eight zones in range, the percentage of rounds falling in each zone will be as indicated in figure 2–18. By definition of probable error, the 50 percent of rounds nearest the mean range line (line through the mean point of impact) fall within 1 probable error. The other percentages have been found to be true by experiment. Again, what is true in range will be true also in deflection. If range dispersion zones and deflection dispersion zones are both considered, a set of small rectangles is created. The percentages of the rounds falling in each rectangle are shown in figure 2–19.

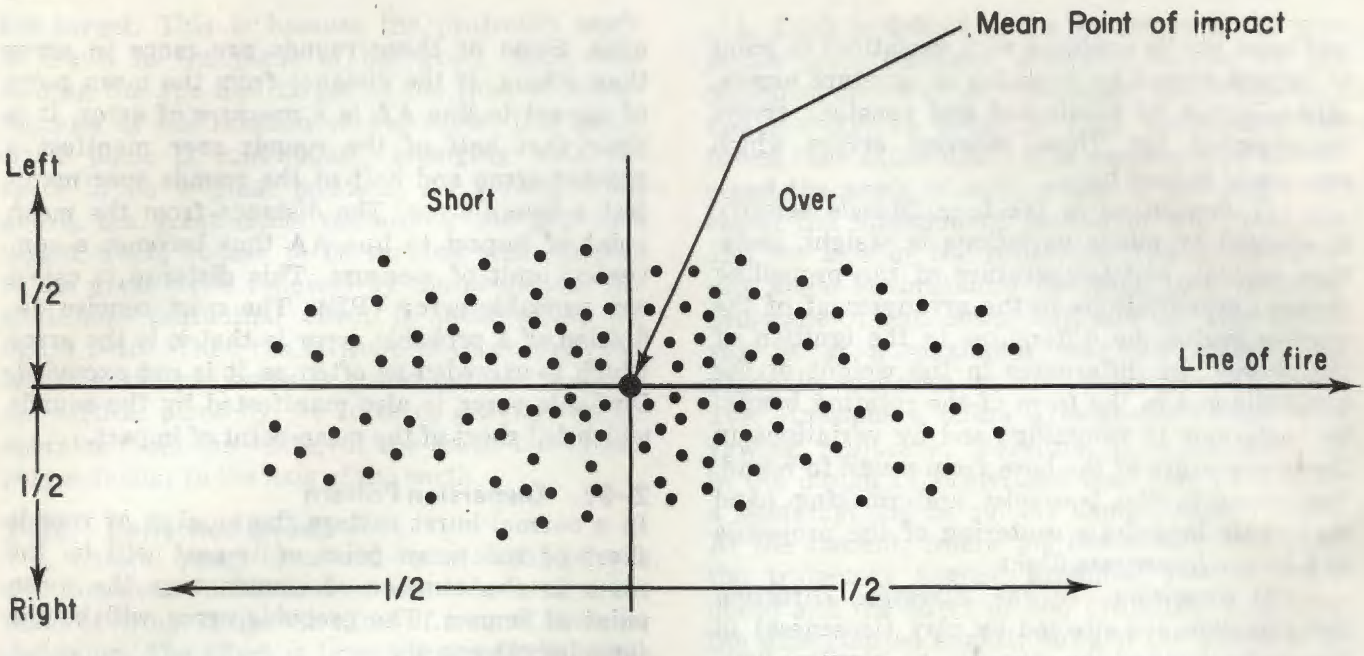


Figure 2-16. Dispersion.

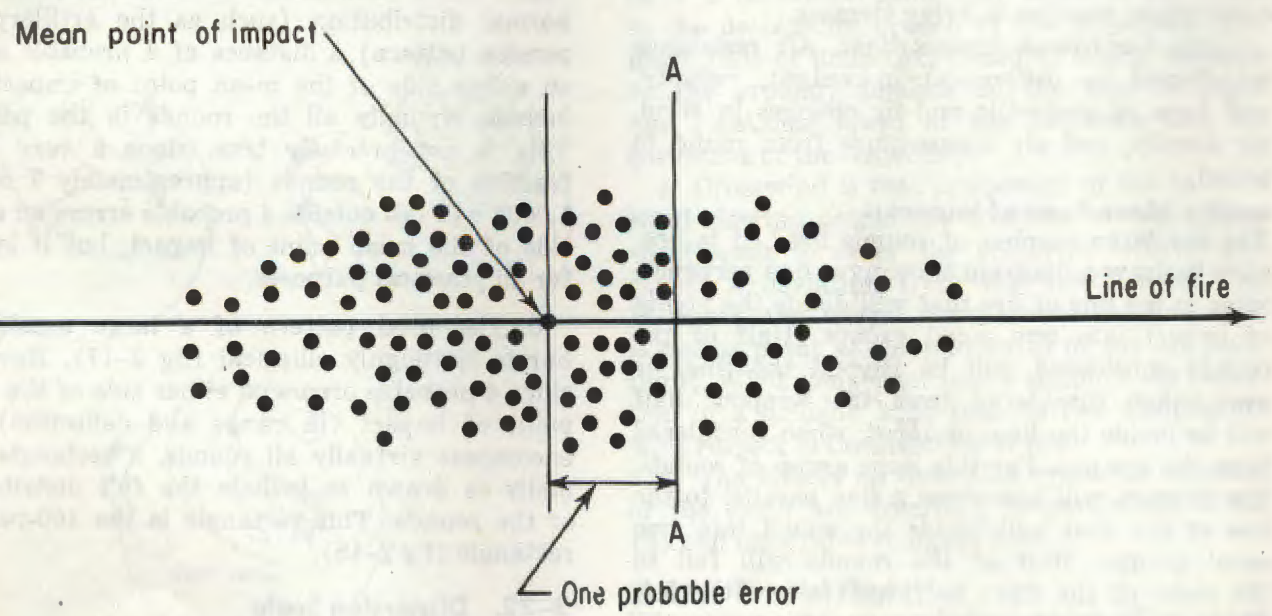


Figure 2-17. Range probable error.

2-33. Normal Probability Curve

a. The dispersion of artillery projectiles follows the laws of probability and normal distribution. The pattern of bursts on the ground can be graphed with a normal probability curve, a common method of representing 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 2-20) measured to the right and left of the center represent errors in excess (over) or in deficiency (short). The area under the curve enclosed by vertical lines cutting the base line and the curve represents the probability of the occurrence of an error within the magnitudes represented by the ends of the base line segment considered. In figure 2-20 the shaded area represents the number of rounds falling over and within 1 probable error of the mean point of impact, which is 25 percent.

c. The curve (fig 2-20) expresses the following facts:

(1) In a large number of samples, errors in excess and errors in deficiency are equally fre-

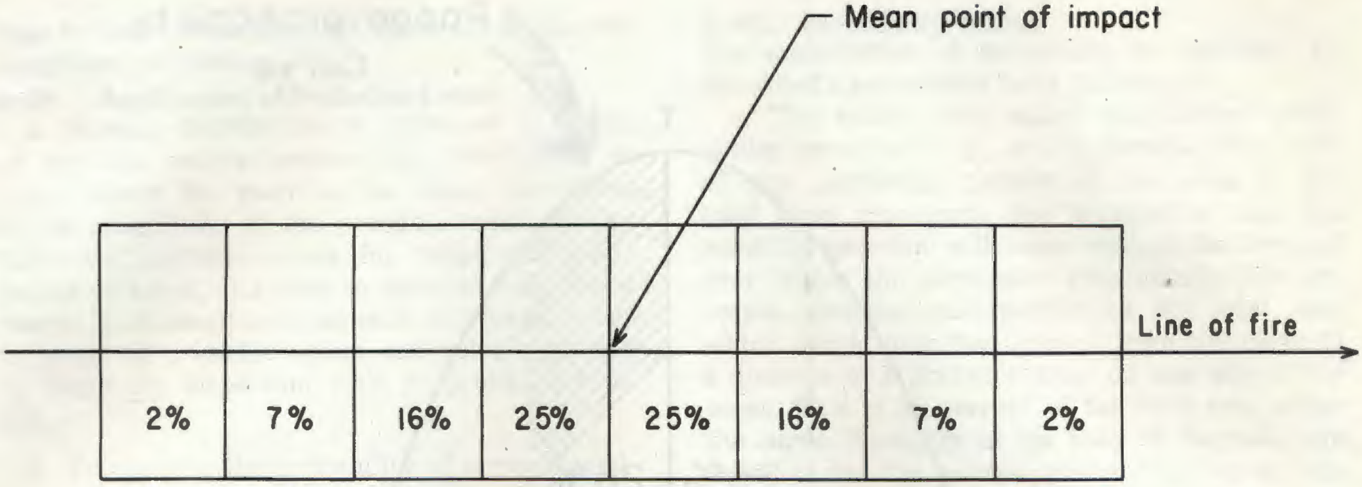


Figure 2-18. The 100-percent rectangle.

	.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 2-19. Dispersion rectangle.

quent (probable), as shown by the symmetry of the curve.

(2) The errors are not uniformly distributed. The smaller errors occur more frequently than the larger errors, as shown by the greater height of the curve in the middle.

2-34. Range Probable Error

The approximate value of the probable error in range (PE_R) is shown in the firing tables and can be taken as an index of the precision of the piece. Firing table values for probable errors are based on the firing of specific ammunition under controlled conditions. The actual round-to-round probable error experienced in the field will normally be larger.

2-35. Fork

Fork is the term used to express the change in elevation in mils necessary to move the mean point of impact 4 range probable errors. The value of the fork is given in the firing tables. For example, for a 155-mm howitzer (M109) firing charge 5 green bag at a range of 6,000 meters, the fork is 3 mils.

2-36. Deflection Probable Error

The value of the probable error in deflection (PE_D) is given in the firing tables. For cannons, the deflection probable error is considerably smaller than the range probable error.

2-37. Vertical Probable Error

The range probable error given in the firing tables is based on firing on a horizontal plane. If the target is a vertical surface (or even a steep incline), the probable error for range will be different. If the target is truly vertical, the probable error against the target surface is equal to the range probable error divided by the cotangent of the angle of fall (fig 2-21). Precise computation of the size of the probable error against a vertical or steep surface is seldom made. It suffices to recognize that the vertical dispersion is a function of the range dispersion, the angle of fall, and the angle of the target surface with respect to the horizontal. Except in high-angle fire, the vertical probable error (PE_H) will normally be smaller than the range probable error.

2-38. Airburst Probable Error

a. Time to Burst Probable Error. The value of probable error in time to burst (PE_{TB}) is shown in the firing tables and can be taken as the weighted average (root mean square) of the precision of the timing mechanism of the fuze and the actual time of flight of the projectile.

b. Height of Burst Probable Error. When the projectile is fuzed to burst in the air, the probable error in height of burst (PE_{HB}) is the vertical component of 1 time to burst probable error times velocity. Values of the height of

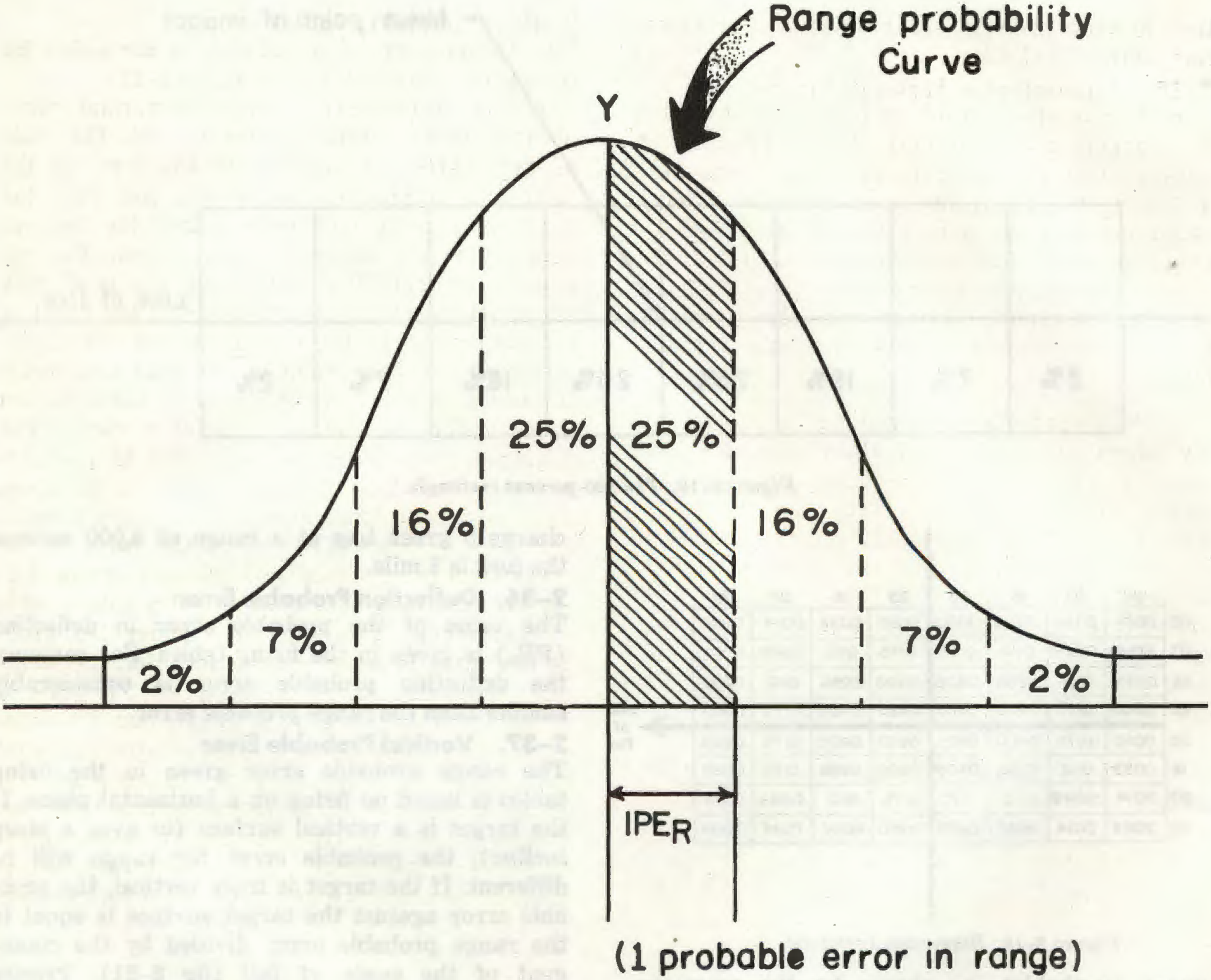


Figure 2–20. Areas under the normal probability curve.

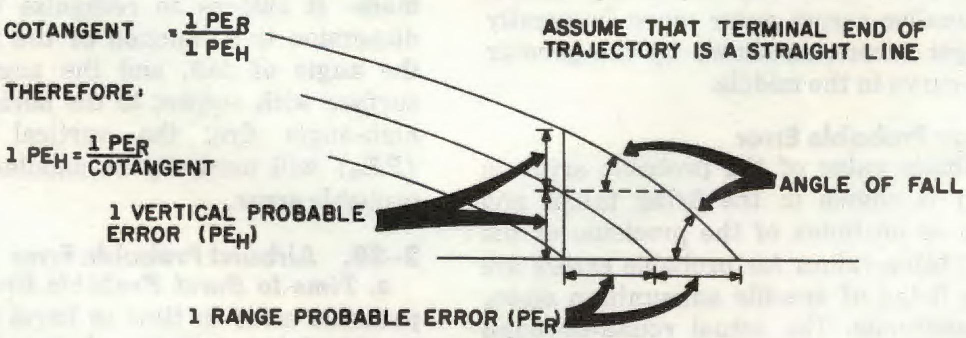


Figure 2–21. Vertical dispersion.

burst probable error for a particular time fuze are given in the firing tables. Height of burst probable error for VT fuze cannot be predicted because the height of burst varies with the type of terrain over which the projectile is passing. The height of burst probable error for fuze VT can be estimated by observing and analyzing results obtained from firing over a given terrain.

c. Range to Burst Probable Error. When the projectile is fuzed to burst in the air, the total probable error in range to burst (PE_{RB}) is 1 time to burst probable error times the horizontal component of velocity.

2-39. Application of Probable Errors

a. Normal distribution is expressed in terms of probable errors because the distribution of bursts about the mean is the same, regardless of the magnitude of the probable error. Firing tables list probable errors for range, deflection, height of burst, and time to burst at each listed range. It is possible to express a given distance in terms of probable errors and solve problems by using the dispersion scale or probability tables.

b. To compute the probability of a round landing within an error of a certain magnitude, reduce the specified error to equivalent probable errors in one direction along the dispersion scale and multiply the sum by 2. For example, a 155-mm howitzer (M109) has fired a number of rounds with charge 7 and the mean point of impact has been determined to be at 11,500 meters. What is the probability that the next round fired will fall within 60 meters of the mean point of impact?

Solution:

PE_R at 11,500 meters (charge 7) = 30 meters

Equivalent PE_R for 60 meters (60/30) = 2

Percentage of rounds falling within 2 PE_R = 2 (25% + 16%) = 82% (fig 2-18)

2-40. Probability Tables

The computation of probability is simplified by the use of a probability table (table 2-2).

a. The entire area under the normal probability curve is unity, or 100 percent. The ratio of any particular portion of the area to the total area represents the probability that the burst 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 one side of the mean. This is 25 percent of the total area under the curve. 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 0.5000, or 50 percent, or ½. Therefore, the numbers in the body of the table actually represent the probability that the event in question will occur within various probable errors from the mean and on one side only of the mean. Interpolation in the tables is an unnecessary refinement. A complete set of probabilities for one side of the mean is shown in table 2-2.

Table 2-2. Normal Probability Table, 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

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
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	.4826	.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
4.9 ------	.4995	.4996	.4996	.4996	.4996	.4996	.4996	.4996	.4996	.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 2-39*b* can be solved by the use of the probability table as follows:

Equivalent PE_R's for 60 meters --- 2.0
Value from table 2-2 ----------- 0.4113
Probability (0.4113 x 2) ---- 82.26 percent

The answer differs slightly from that obtained by use of the dispersion scale because probability tables are to an accuracy of four decimal places and are entered with probable error expressed to the hundredth, whereas the dispersion scale is to an accuracy of only two decimal places and is entered with whole probable errors. Probability tables provide the more accurate answer.

c. In some problems, the probability is required for only one side of the mean, in which case the multiplication by 2 is omitted. For example, the mean height of burst is 350 meters above the ground and the height of burst probable error is 75 meters. What is the probability that a burst will be closer to the ground than 100 meters?

Solution:

Specified error (meters) = 350 − 100 = 250; 250 meters below the mean is 100 meters above ground.

Error in PE_{HB} = 250/75 = 3.33

From table 2-2, 3.33 corresponds to 0.4877, which is the probability that the burst will be between the mean and 100 meters above the ground. Since the total probability for a burst being below the mean is 0.5000, then the probability of a burst being less than 100 meters above the ground, (that is, more than 250 meters below the mean) is 0.5000 − 0.4877 = 1.23 percent.

By extension, the probability that the burst will occur at either less than 100 meters above the ground (250 below the mean) or more than 600 meters above the ground (250 above the mean) is 1.23 percent + 1.23 percent = 2.46 percent. Any combination of height limitations above the ground can be similarly solved. The maximum and minimum limits specified need not reduce 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 probability tables give the probability of not exceeding a certain error or, by subtraction, the probability of making an error equal to or less than a specified error. The probability tables cannot give the probability of making a particular error. Though there is little application for the computation in artillery, a computation could be made to give the probability of making an error falling within a prescribed range. By combining some of the computations already discussed, it would be relatively simple to determine the probability of making an error greater than 100 meters or less than 100 meters.

e. The major reason for the difference in figures derived from the dispersion scale and those from the probability table is that linear interpolation is used with the dispersion scale when the conversion of a distance to probable errors results in a fractional value. The assumption that the distribution of bursts is uniform within the limits of 1 probable error is false.

2-41. Most Probable Position of the Mean Point of Impact

Thus far, only the probability of an outcome of a future event has been considered. This is not always the problem. For example, the observer's spottings in the fire-for-effect phase of a registration are the outcome of the rounds fired, but they do not in themselves define the relative location of the mean point of impact and target which yielded the spottings. The problem is to find the most probable relative locations.

a. There are simple methods of determining the most probable location of the target with respect to the mean point of impact. These methods are based on, first, the fact that the definite range spottings used are of two outcomes only—either over or short—and, second, the assumption that the small number or rounds observed follows normal distribution exactly.

b. For example, if five shorts and one over are obtained, $\frac{5}{6}$ or 83.33 percent, of the rounds fell short of the target. According to the dispersion scale, the target must be 1.52 probable errors beyond the mean point of impact (1 PE + $\frac{8.33}{16}$ PE, or 1.52 PE beyond the mean point of impact). By definition, 50 percent of the rounds fell short of the mean point of impact; therefore, 33.33 (83.33 − 50.00) percent of the rounds fell between the mean point of impact and the target. In the probability tables, 0.3333 represents 1.43 probable errors, to the nearest hundredth, which is a more accurate estimate of the distance of the target from the mean point of impact. Use of the preponderance formula described in chapter 19 indicates the target to be 1.33 probable errors beyond the mean point of impact.

$$\frac{5 \text{ shorts} - 1 \text{ over}}{2 \times 6} \times \text{fork} = \tfrac{1}{3} \text{ fork} = 1.33 \text{ PE}.$$

Probability tables provide the most accurate answer; however, the preponderance formula is used because of its simplicity and because the small number of rounds considered (six) does not warrant striving for the extra theoretical precision of the probability table.

2-42. Single Shot Hit Probability and Assurance

Single shot hit probability (SSHP) is the probability of hitting a target or an area of finite dimensions with any one round.

a. The probability of a round hitting in any one of the areas bounded by 1 range probable error and 1 deflection probable error is the product of the probability of not exceeding that range error and the probability of not exceeding that deflection error. This basic principle is applied in computing the single shot hit probability. Before the probability tables can be used, the specified error must be reduced to equivalent probable error.

b. Computation of single shot hit probability is based on the assumption that the mean point of impact is adjusted to the exact center of the target or area. This means, for example, that the limit of error is 20 meters if the target is 40 meters deep (fig 2-22). The same principle is 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., ½ that target dimension parallel to the GT line) and for deflection (i.e., ½ that target dimension perpendicular to the GT line). Then, the limits of error are divided by the respective firing table probable errors for the weapon, charge, and range being used. The quotient (t) is the limit of the error expressed in probable errors and is the argument for entering the probability tables to determine the range probability and the deflection probability.

Since the range probability determined is for only half the dimension (fig 2-22), it must be multiplied by 2 to determine the SSHP for range ($SSHP_R$). The same is true for deflection ($SSHP_D$). The SSHP for the entire target is the product of $SSHP_R$ times $SSHP_D$.

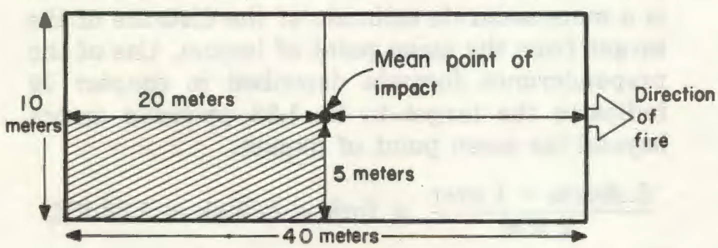


Figure 2-22. Single shot hit probability.

c. For example, the target is a bridge 10 meters by 40 meters with the long axis parallel to the direction of fire. Range to target is 9,870 meters. The mean point of impact is adjusted on the center of the target by use of precision fire techniques. After the mean point of impact has been correctly adjusted on the center of the target, the single shot hit probability, for an M109 howitzer, firing charge 7, is determined as follows:

PE_R = 27 meters
PE_D = 4 meters

$$\text{Range } t = \frac{\frac{1}{2}(40)}{27} = 0.74$$

Range probability = (0.1911) × 2 = 0.3822

$$\text{Deflection } t = \frac{\frac{1}{2}(10)}{4} = 1.25$$

Deflection probability = (0.3003) × 2 = 0.6006
SSHP = (0.3822)(0.6006) = 22.95 percent

2-43. Single Shot Hit Probability for Bias Targets

a. A target is said to be biased when its specified dimensions are neither parallel to nor at right angles to the direction of fire. The only change in procedure required is that the specified dimensions of the target must first be converted to an effective depth and width to fit the dispersion pattern with respect to the GT line. Once the effective depth and width are known, the single shot hit probability is computed as discussed in paragraph 2-42. Figure 2-23 illustrates a bias target.

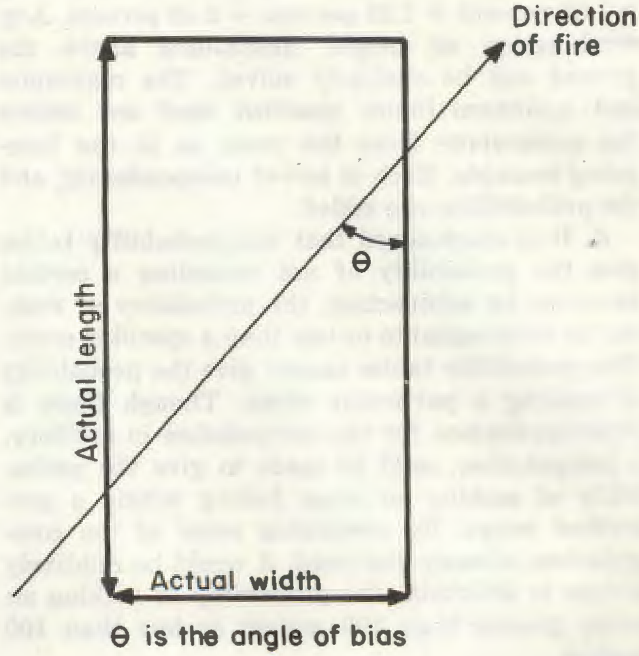


Figure 2-23. Bias target.

b. The tabulation below can be used to approximate the 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 smaller angle measured between the long axis of the target and the direction of fire.

c. For example, the target is a bridge 8 meters by 40 meters with the long axis at an 800-mil angle to the direction of fire. The range is 11,040 meters. After the mean point of impact has been adjusted to the center of the target, the single shot hit probability for a 155-mm howitzer M109 firing charge 7 is determined as follows:

Effective depth = 1.41 (from *b* above) × 8 meters = 11.28 (use 11)

PE_R = 29 meters

$$\text{Range } t = \frac{\frac{1}{2}(11)}{29} = \frac{11}{58} = 0.19$$

Range probability = (0.0511) × 2 = 0.1022

Effective width = 0.71 (from *b* above) × 40 meters = 28.40 (use 28)

PE_D = 4 meters

$$\text{Deflection } t = \frac{\frac{1}{2}(28)}{4} = 3.50$$

Angle of bias between	*Effective depth*	*Effective width*
0 and 400 mils	Actual length	Actual width
401 and 650 mils	2 × actual width	0.5 × actual length
651 and 950 mils	1.41 × actual width	0.71 × actual length
951 and 1,200 mils	1.15 × actual width	0.87 × actual length
1,201 and 1,600 mils	Actual width	Actual length

Deflection probability = (0.4908) × 2 = 0.9816

SSHP = (0.1022) (0.9816) = 10.03 percent

2–44. Conversion of a Circular Target to an Equivalent Square

a. Many targets are described as circular. In order to compute single shot hit probability for a circular target, it is necessary to convert the target to a square of the same area. This conversion is necessary because the dispersion pattern of cannons is elliptical and can be reasonably defined by a rectangle.

b. A circular shape is converted to a square shape by multiplying the radius of the circle by 1.7725 (1.7725 is the square root of π). The product is the length of a side of a square which has an area equal to the area of the original circle.

2–45. Assurance and Assurance Graphs

Assurance is a broad term associated with the probability of hitting a target with any given number of rounds, assuming a constant single shot hit probability.

a. The assurance formulas for a specified number of hits may be graphed as shown in figures 2–24 through 2–26. The only computation necessary is that for the single shot hit probability. Once that is known, the graph can be used for rapidly determining either the assurance obtainable from firing a specified number of rounds (N) or the number of rounds required for a desired assurance.

b. The number of rounds is indicated along the bottom of the graph, the single shot hit probability is indicated on either side of the graph, and the assurance is indicated by the curves drawn within the graph. When the assurance graph is used, the intersection of the two known elements is found and then the desired element is read opposite this intersection. Interpolation between numbered graduations is permissible.

c. For example, what is the assurance of getting at least one hit when 20 rounds are fired and the single shot hit probability is 0.045? (Answer: 0.60, fig 2–24). What is the number of rounds required for at least two hits when the single shot hit probability is 0.08 and the desired assurance is 0.70. (Answer: 30 rounds, fig 2–25.)

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 provide an approximation. Probability (assurance) is a substitute for fact, and, until the fact is actually known, probability provides the best guide as to what to expect. Unfortunately, the single shot hit probability and assurance levels are usually less than those derived from the method in *a* through *c* above, because the mean point of impact usually is not at the center of the target as assumed. For example, an apparent mean point of impact located by the mean of 12 rounds is more accurate than one located by the mean of only 6 rounds. An estimate of the probable error of the mean point of impact 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	0.7
4	0.5
6	0.4
8	0.4
10	0.3
12	0.3
14	0.3
16	0.3
18	0.2
20	0.2

e. In the example shown in paragraph 2–42*c* for the 155-mm howitzer, if the adjusted data of the mean point of impact were based on six rounds, then the range probable error of the mean point of impact at that time would be 11 meters (0.40 × 27 = 10.80). This has the effect in SSHP computations of an apparent increase in the weapon probable error. The magnitude of the apparent weapon probable error is approximately equal to the square root of the sum of the squares of the weapon probable error and the mean point of impact probable error or, in this case, $\sqrt{(27)^2 + (11)^2}$ equals 29 meters to the nearest meter. Hence, 29 meters would be used in the place of 27 meters in the computation of single shot hit probability. If the target is to be attacked without adjustment, the apparent weapon probable error is assumed to be twice the weapon probable error. The deflection probable error can be found in a similar manner although the change normally will 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.

2–46. Developed Probable Error

Firing tables indicate the probable errors of a cannon in various dimensions (range, deflection, height of burst, and time to burst). The use of round-to-round data from mean-point-of-impact registrations and fall-of-shot calibrations will provide a positive check on the performance of cannons and crews. The developed probable error

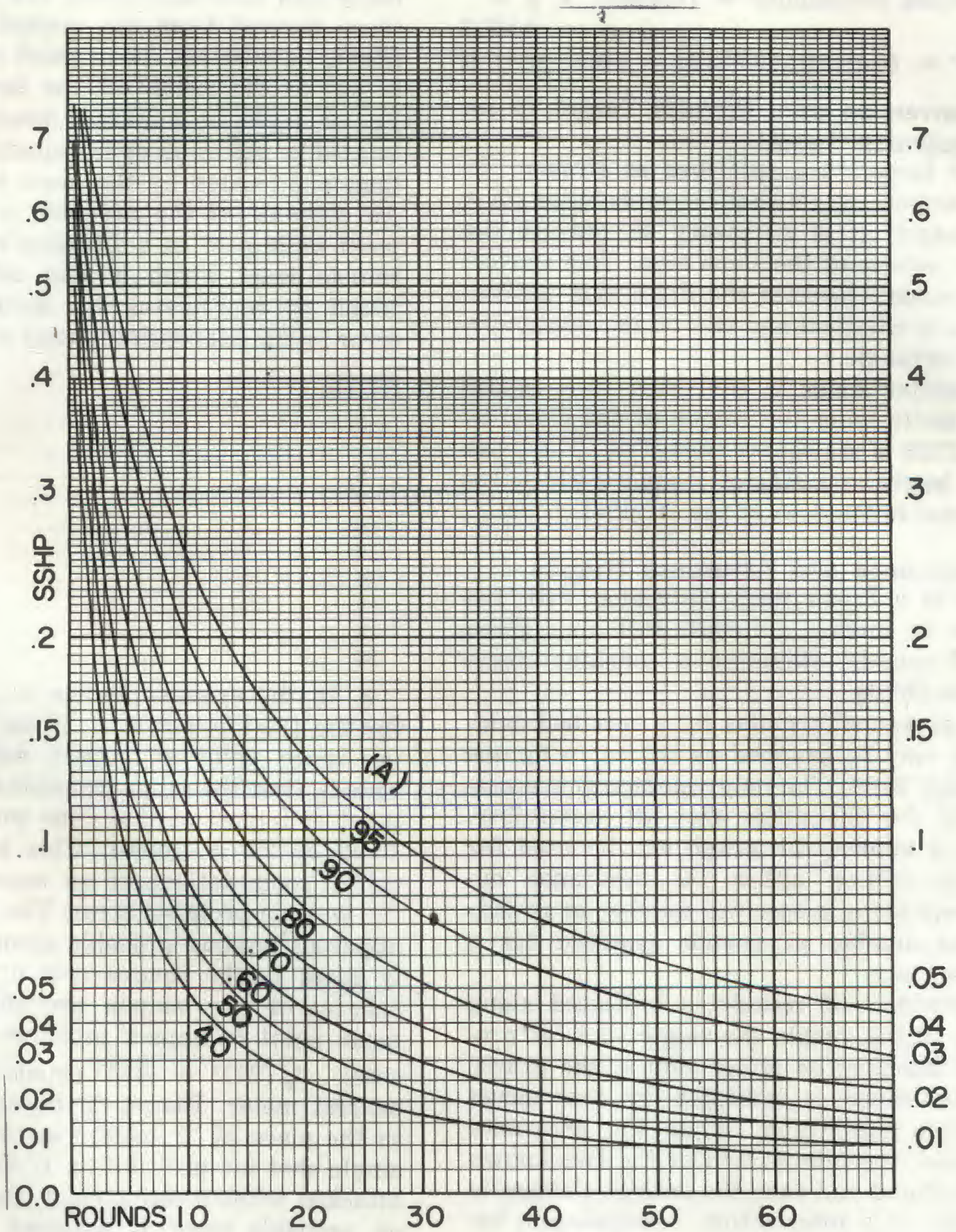


Figure 2-24. Assurance of at least one hit for "N" rounds when single shot hit probability is known.

can be approximated by multiplying the maximum dispersion observed (longest range minus shortest range) in a group of rounds by the appropriate factor from the following tabulations (n is the number of rounds in the group).

n	*Factor*
2	0.60
3	0.39
4	0.33
5	0.29
6	0.27
7	0.25
8	0.24
9	0.23
10	0.22
11	0.21
12	0.21

For example: the maximum observed range dispersion in a group of eight rounds is 150 meters. The approximate developed range probable error is 36 meters to the nearest meter (0.24 × 150 = 36.0).

2-47. Circular Error Probable (CEP)

a. In this manual, one CEP represents the

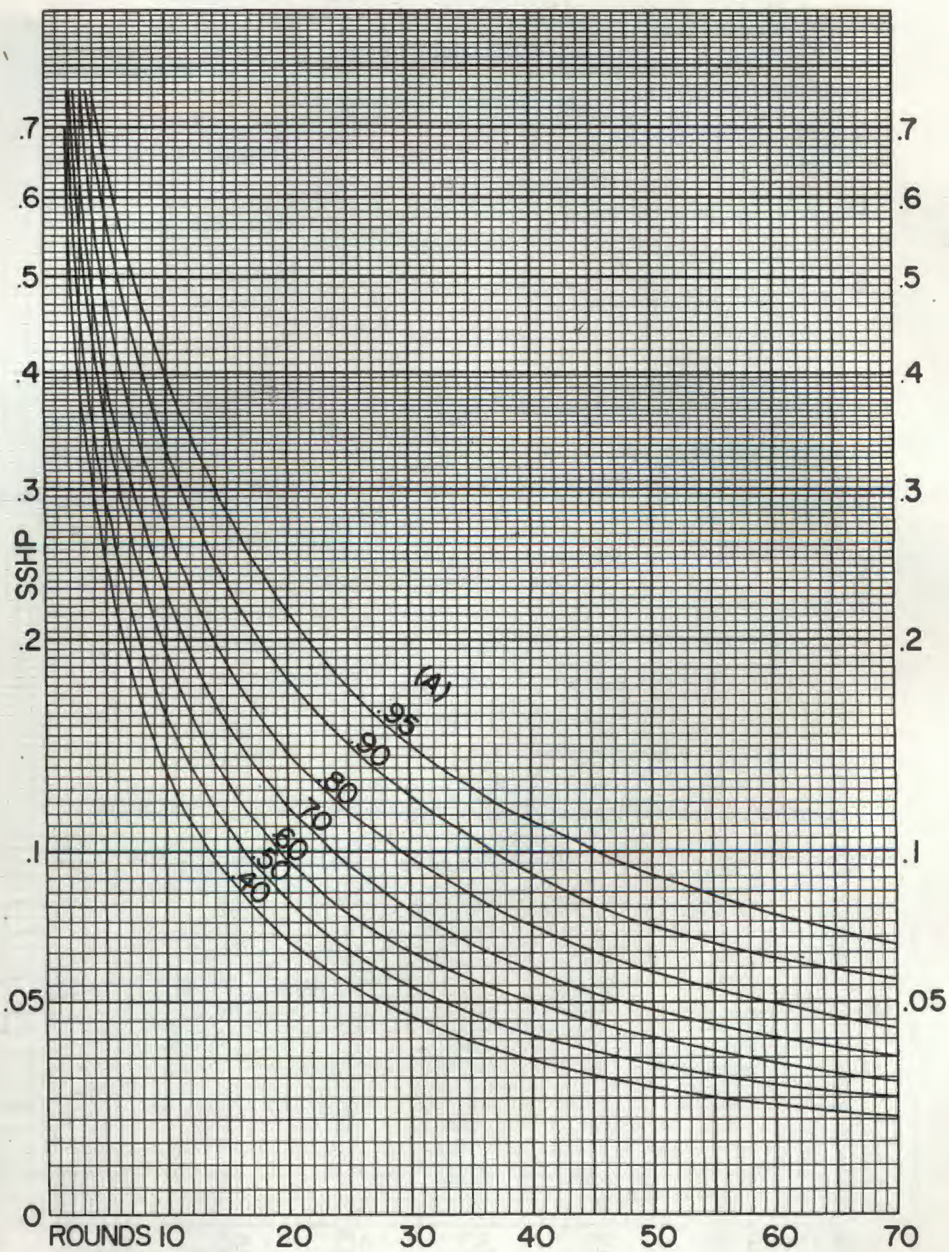


Figure 2–25. Assurance of at least two hits for "N" rounds when single shot hit probability is known.

radius of a circle which will contain 50 percent of all battery volley mean points of impact, where the mean of the distribution pattern represents target center. Figure 2–27 is a graphical representation of normal circular distribution about the intended center of impact for a large number of battery volleys. A 2-CEP circle, which is twice the radius of a 1-CEP circle, includes approximately 94 percent of the volleys fired. A 4-CEP circle contains essentially all battery volleys fired. Some volleys, though very few, may fall outside the 4-CEP circle.

b. For example, assume that in order to achieve 40 percent coverage of a circular target area, the center of the effects pattern must fall within 100 meters of the center of the target. Further, assume that a weapon system has a 1-CEP system error of 50 meters due to K-transfer fire direction procedures. Under the stated conditions, the probability of the next effects pattern covering at least 40 percent of the target is 0.937.

1 CEP = 50 meters
2 CEP = 100 meters.
2 CEP = 0.937 (probability).

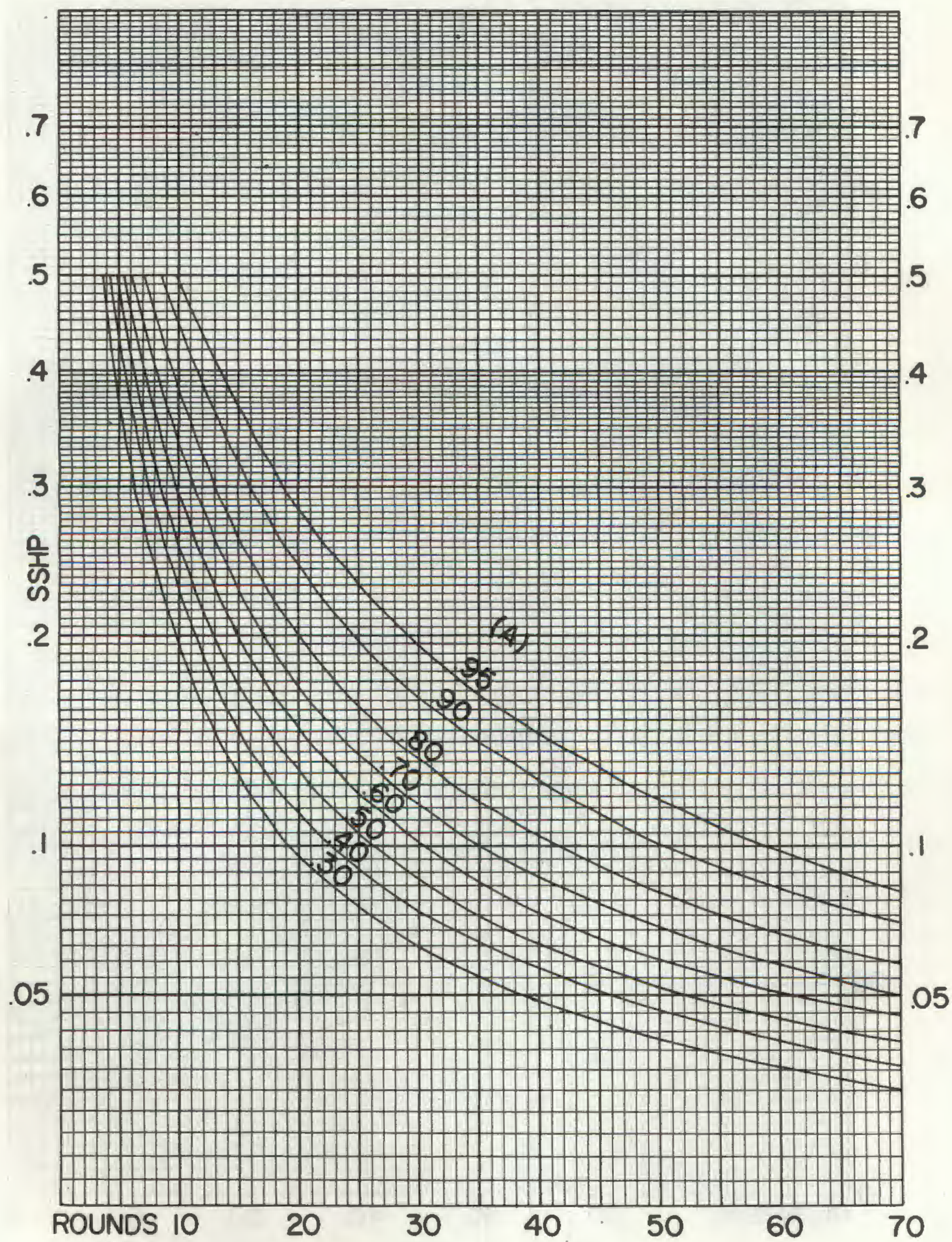


Figure 2-26. Assurance of at least three hits for "N" rounds when single shot probability is known.

c. Computation of circular error probabilities can be facilitated by using table 2-3. For example, it is assumed that in order for a certain weapon system to achieve a required coverage the center of the volley effects pattern must fall within 1.6-CEP of the center of the target. From the table it can be determined that there is a 0.83 probability that the next volley mean point of impact will fall within 1.6-CEP of target center.

d. If a circle is drawn about a distribution mean, using any radius selected at random, the number of battery volley mean points of impact enclosed by the circle divided by the total volleys fired is the probability that the next battery volley mean point of impact will land within the circle.

CIRCULAR PATTERN-NORMAL DISTRIBUTION

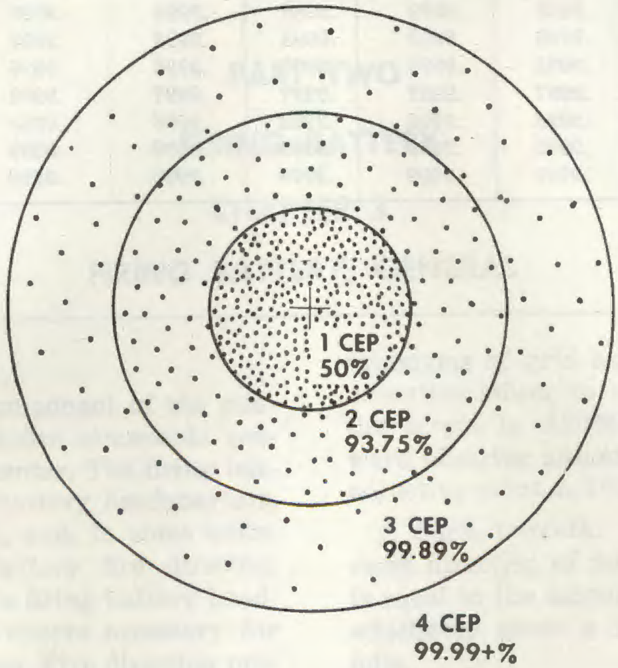


Figure 2-27. Circular distribution pattern.

Table 2-3. Volumes Under the Normal Circular Probability Surface

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

r*	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
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

*Expressed in circular errors probable.

PART TWO

FIRING BATTERY

CHAPTER 3

FIRING BATTERY, GENERAL

3–1. Introduction

The firing battery is that component of the gunnery team that executes the fire commands generated at the fire direction center. The firing battery consists of the firing battery headquarters, the howitzer (gun) sections, and, in some units, an ammunition section. Battery fire direction personnel are assigned to the firing battery headquarters and maintain the charts necessary for the processing of fire missions. Fire direction procedures are discussed in part four.

3–2. Map and Azimuth Terms

The map and azimuth terms used in the firing battery are defined in *a* through *i* below.

a. Grid Line. A grid line is a line extending north and south or east and west on a map, photomap, or grid sheet. A grid is composed of two intersecting sets of lines. The east-west lines are parallel to the central meridian and the north-south lines are perpendicular to the central meridian of the grid zone in question. The parallel lines are normally 1,000 meters apart and are used to measure grid coordinates.

b. Magnetic North. Magnetic north (fig 3–1) is the direction to the magnetic North Pole.

c. True North. True north (fig 3–1) is the direction to the geographic North Pole.

d. Grid North. Grid north (fig 3–1) is the north direction of the vertical grid lines on a military map, photomap, or grid sheet.

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

(1) *Magnetic azimuth (fig 3–1),* measured from magnetic north.

(2) *True azimuth (fig 3–1),* measured from true north.

(3) *Grid azimuth (fig 3–1),* measured from grid north. Grid azimuth is the azimuth normally employed in the field artillery. The artilleryman also uses the terms "azimuth" and "direction" as synonyms of grid azimuth. The command to the executive officer to indicate the grid azimuth of the target is AZIMUTH (so much). The forward observer announces the grid azimuth to his adjusting point as DIRECTION (so much).

f. Back-Azimuth. A back-azimuth is the reverse direction of an azimuth. The back-azimuth is equal to the azimuth plus or minus 3,200 mils, whichever gives a result between 0 and 6,400 mils.

g. Grid-Magnetic Angle. The grid-magnetic angle is the smaller angle between grid north and magnetic north. It is measured east or west from grid north and is the grid azimuth of magnetic north. This angle is shown in the marginal data of military maps.

h. Magnetic Variation. Magnetic variation is the smaller angle between true north and magnetic north. This angle is measured as east or west of true north and is indicated in the marginal data of maps. Since the magnetic variation changes slightly from year to year, a correction factor (the annual magnetic change) also is shown in the marginal data of military maps.

i. Grid Convergence. Grid convergence is the smaller angle between true north and grid north. Grid convergence is indicated in the marginal data of maps as east or west of the north.

j. Declination constant. Declination constant (fig 3–1) is a constant correction applied to the readings of a compass instrument which represents the horizontal clockwise angle between grid north and magnetic north as indicated by that instrument. The declination constant for each instrument is recorded and is applied to determine the azimuth of grid north from the measured azimuth of magnetic north. The constant for any instrument may vary in different localities and the constants of different instruments in the same locality may vary.

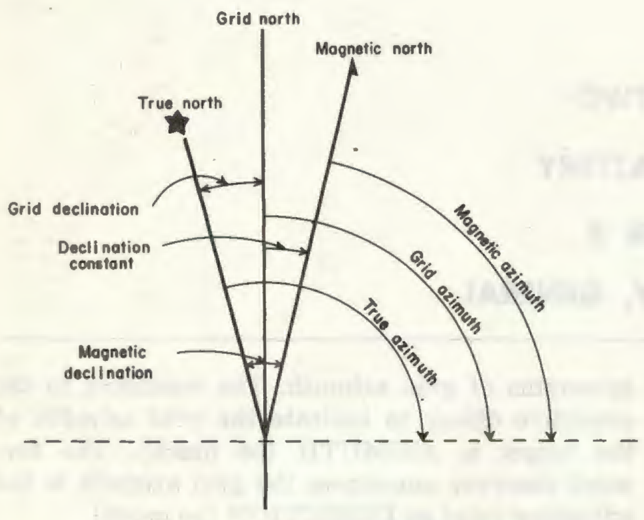


Figure 3-1. Map and azimuth terms.

3-3. Artillery Firing Battery Terms

a. Aiming Point. An aiming point is a sharply defined point that is used as a reference in laying an artillery piece for direction. There are two general types of aiming points—distant aiming points and close-in aiming points.

(1) *Distant aiming point.* A distant aiming point may be used as a reference in laying for direction or as a means of boresighting artillery weapons. When a distant aiming point is used, it should be at least 1,500 meters from the position area so that normal displacement of the panoramic telescope due to firing or traverse will not cause an error of more than ½ mil in direction. If greater accuracy is desired, a greater distance must be used. Advantages of using a distant aiming point are that it may be used immediately upon occupation of a position or it may be used as an alternate aiming point in the event the close-in aiming point is rendered useless. Disadvantages of using a distant aiming point are that it may be obscured by darkness, dust, fog, or smoke; illumination is not practicable; and the pieces are not parallel when laid with a common deflection to the distant aiming point (para 4-7*a*(2)).

(2) *Close-in aiming point.* There are two types of close-in aiming points.

(*a*) *Infinity collimator.* The infinity collimator is normally used as the primary aiming point for each piece. The collimator is an optical instrument which simulates an aiming point at infinity. The collimator is emplaced 4 to 15 meters from the panoramic telescope on the weapon. Use of the collimator permits application of corrections for weapon displacement.

(*b*) *Aiming posts.* Two aiming posts may be used instead of the collimator as the primary aiming point for each piece. The aiming posts are placed so that the two aiming posts and the panoramic telescope form a straight line and so that the near aiming post is halfway between the panoramic telescope and the far aiming post.

b. Alternate Aiming Point. An alternate aiming point is one that is used when the primary aiming point is rendered useless. It can be either a distant aiming point or a close-in aiming point. When a 6,400-mil capability is required, at least two aiming points must be used because at certain angles of elevation the primary aiming point will be masked by the tube or, in the case of certain self-propelled weapons, by the commander's cupola. For towed weapons, two close-in aiming points 3,200 mils apart are normally used.

c. Battery Center. The battery center is a point materialized on the ground at the geometric center of the howitzer (gun) sections. It is the point which is plotted on the firing charts to represent the location of the battery.

d. Base Piece. The base piece normally is the piece with the shooting strength closest to the average shooting strength of the battery. It is placed on or near the battery center and normally is used for registrations.

e. Gun-Target Line. The gun-target line is an imaginary straight line from the gun to the target. Line of fire and direction of fire are familiar expressions in the artillery vocabulary which are sometimes used as synonyms for the gun-target line. However, direction of fire is most often used when the battery is laid with the tubes pointed toward the center of the zone of fire.

f. Orienting Line. An orienting line is a line of known direction established on the ground near the firing battery to serve 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. The end of the orienting line may be marked by any sharply defined point, such as a steeple, flagpole, or stake.

g. Orienting Station. An orienting station is a point on the orienting line near the gun position over which the aiming circle is emplaced when orienting the battery.

h. Orienting Angle. An orienting angle is the horizontal clockwise angle from the line of fire to the orienting line.

i. Reference Point. A reference point is a prominent and easily located point on the terrain and is used for orientation. This may be used as a distant aiming point or as an alternate aiming point.

j. Deflection. Deflection is the horizontal, clockwise angle measured from the line of fire, or the rearward extension of the line of fire, to the line of sight to a designated aiming point, with the vertex at the instrument.

k. Refer. To refer is to measure the deflection to a given point without moving the tube of the weapon or the orientation (0 to 3200) line of the instrument. The command REFER means to measure and to report the deflection. If the deflection is to be recorded, the command, RECORD REFERRED DEFLECTION, is given.

l. Indirect Laying. Indirect laying is the aiming of a piece by sighting on an aiming point. 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 panoramic telescope is on the aiming point and by leveling the appropriate bubbles. The piece is laid for elevation by setting the quadrant elevation on the elevation quadrant or gunner's quadrant and elevating or depressing the tube until the appropriate bubble is level.

m. Direct Laying. Direct laying is the aiming of a piece by sighting directly on the target.

3-4. Aiming Circle

a. The aiming circle is an instrument for measuring horizontal and vertical angles. It is the instrument usually used for laying the battery. The head of the instrument has two motions, called the lower (nonrecording) motion and the upper (recording) motion. On the lower motion, which may be locked in any desired position, is an azimuth scale (fig 3-2), graduated every 100 mils and numbered every 200 mils. The scale is numbered from 0 to 62 (6200); the upper half of the scale, (the half numbered 32 to 62 (3200 to 6200)), has a second set of numbers (in red) from 0 to 30 (0 to 3000). The upper motion has an index (for the azimuth scale on the lower motion), an azimuth micrometer (graduated in mils from 0 to 100), a magnetic needle, a reticle used in centering the magnetic needle, and a telescope. The reticle for centering the needle is located directly below the axis of the telescope. When the needle is centered in the reticle, the line of sight of the telescope is in the direction in which the needle is pointing. When the upper motion is moved with respect to the lower motion, the horizontal clockwise angle from the 0 to 3200 line of the lower motion to the line of sight of the telescope can be determined by combining the values read opposite the appropriate indexes on the azimuth scale and the azimuth micrometer.

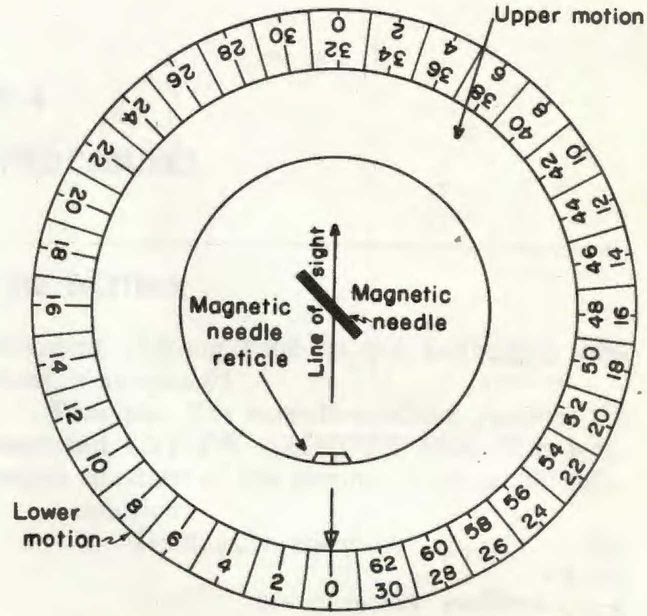


Figure 3-2. Schematic drawing of aiming circle.

b. When the magnetic compass of the aiming circle is being used, all objects (helmets, small arms, etc.) which may attract the needle must be kept away from the instrument. The aiming circle should be set up no closer to the objects listed below than the distances indicated.

	Meters
High-tension powerlines	150
Railroad tracks	75
Medium and heavy towed artillery pieces and all self-propelled artillery pieces	60
Light towed artillery pieces, telegraph wire, and vehicles	40
Barbed wire and small metal objects	10

3-5. Panoramic Telescope

The panoramic telescope (sometimes called the sight or pantel) is mounted on the piece and measures horizontal clockwise angles in mils. Panoramic telescopes used on current field artillery weapons are as follows:

Weapon	*Series*	*Max Df*
M101A1	M12	3200
M102	M100	6400
M107	M100	6400
M108	M100	6400
M109	M100	6400
M110	M100	6400
M114A1	M12	3200

CHAPTER 4

FIRING BATTERY PROCEDURES

Section I. LAYING THE BATTERY

4-1. General

a. When a battery occupies a position, the tubes of the pieces must be pointed in a known direction. The known direction should be the direction toward the center of the assigned zone of fire. The direction in which the battery is to be laid may be furnished to the battery executive officer, or it may be estimated by the executive officer on the basis of his knowledge of the situation.

b. Normally, the battery is laid in two steps:

(1) The 0 to 3200 line of the aiming circle is established parallel to the direction of fire.

(2) The howitzer (gun) tubes are laid parallel to the 0 to 3200 line of the aiming circle (reciprocal laying (para 4-3)).

c. In rare cases, the battery may be laid without an aiming circle (para 4-7).

4-2. Orienting the Aiming Circle

There are several methods that can be used to orient the 0 to 3200 line of the aiming circle in the direction of fire, but the three methods described in *a* through *c* below (azimuth, orienting angle, and aiming point and deflection) are the ones used most often. The three methods are similar in that a deflection (the horizontal clockwise angle from the axis of the tube to an aiming point) is determined and set on the aiming circle and the lower motion of the aiming circle is then used to sight on the aiming point.

a. Orienting by Grid Azimuth. Magnetic north is used as the aiming point in orienting by grid azimuth. To orient the 0 to 3200 line of the aiming circle on a grid azimuth, the executive officer must determine the horizontal clockwise angle from that azimuth to magnetic north, set that reading on the aiming circle with the upper motion, and sight on magnetic north by centering (with the lower motion) the magnetic needle. He computes the deflection to be set on the aiming circle by subtracting the grid azimuth from the declination constant of the instrument (adding 6400 to the declination constant, if necessary).

Example: The executive officer receives the command LAY ON AZIMUTH 5250. The declination constant of the aiming circle is 200 mils.

Solution:

Declination constant -------	200
	+6,400
	6,600
Minus the grid azimuth ----	5,250
Deflection to be set on the aiming circle ----------	1,350

After the aiming circle has been set up where it is away from all magnetic attractions and where it is visible to all pieces (if possible), 1350 is set on the aiming circle with the upper motion. The magnetic needle is centered with the lower motion without disturbing the setting of 1350. The 0 to 3200 line of the aiming circle is now oriented on azimuth 5250 (fig 4-1).

b. Orienting by Orienting Angle. An orienting line must be established when the battery is to be laid by the orienting angle. The orienting line is established on the ground between a stake over which the aiming circle is to be set up (orienting station) and a distant point, which may be a stake or a terrain feature (end of orienting line). The orienting angle is the horizontal clockwise angle from the direction of fire (axis at the tubes) to the orienting line. The executive officer normally is given the orienting angle; however, if he knows the azimuth of the orienting line and the azimuth of the direction of fire, he can compute the orienting angle by subtracting the azimuth of the direction of fire from the azimuth of the orienting line (6400 mils is added to the azimuth of the orienting line, if necessary). He uses the upper motion to set the orienting angle on the aiming circle and uses the lower motion to sight the aiming circle on the end of the orienting line. The 0 to 3200 line is now established parallel to the direction of fire.

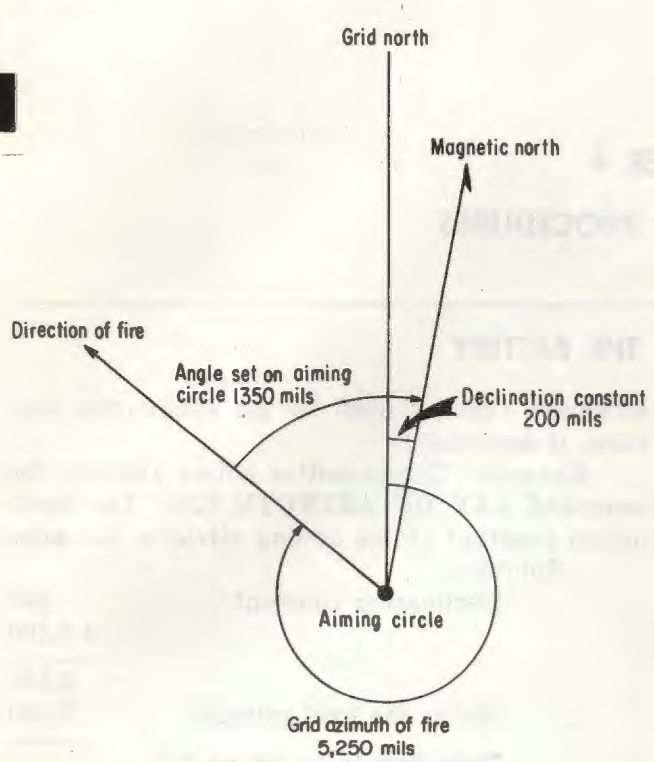


Figure 4-1. Orienting by grid azimuth.

Example: The azimuth of the orienting line is 1300 mils. The azimuth on which the executive officer wishes to lay is 2500 mils. The orienting angle is 5200 mils (1300 + 6400 = 7700 − 2500 = 5200). The aiming circle is set up over the orienting station. The executive officer uses the upper motion to set 5200 mils on the aiming circle. He then uses the lower motion to sight on the end of the orienting line. The 0 to 3200 line of the aiming circle is now oriented (fig 4-2).

c. Orienting by Aiming Point and Deflection. In some cases, when a battery is occupying a position, the executive officer is given an aiming point and a deflection on which to lay. To orient the aiming circle, the executive officer sets off the deflection, using the upper motion, and sights on the aiming point, using the lower motion. The 0 to 3200 line of the aiming circle is then parallel to the direction of fire.

4-3. Reciprocal Laying

a. General. Reciprocal laying is a procedure by which the 0 to 3200 line of one instrument (aiming circle) and the 0 to 3200 line of another instrument (panoramic telescope) are laid parallel. When the 0 to 3200 lines of an aiming circle and a panoramic telescope are parallel and the piece has been properly boresighted, the tube of the piece is parallel to both 0 to 3200 lines. The principle of reciprocal laying is based on the geometric theorem which states that if two parallel lines are cut by a transversal, the alternate interior angles are equal. The parallel lines are the 0 to 3200 lines of the instruments; the transversal is the line of sight between the two instruments. The alternate interior angles are the equal deflections placed on the instruments (fig 4-3).

b. Procedure. After the 0 to 3200 line of the aiming circle has been established parallel to the direction of fire (para 4-2), the executive officer, using the upper motion, sights on the objective lens of the panoramic telescope, reads the deflection on the azimuth scale and azimuth micrometer, and announces the deflection to the gunner on the piece. The gunner sets off the announced deflection on the panoramic telescope and causes the piece to be moved until the telescope is sighted on the objective lens of the aiming circle. Because the panoramic telescope is offset laterally from the axis about which the carriage is moved, the telescope is displaced horizontally. When the telescope has been sighted on the aiming circle, the gunner reports READY FOR RECHECK and the executive officer again sights on the objective lens of the telescope and reads and announces the deflection. This procedure is repeated until the gunner reports a difference of 0 mils between successive deflections. The piece has then been laid.

Example: The following commands and procedures are used in reciprocal laying:

(1) *Executive officer*—BATTERY ADJUST, AIMING POINT THIS INSTRUMENT.

(2) *Gunner of number 3*—NUMBER 3, AIMING POINT IDENTIFIED. (All gunners report in this manner. For brevity, only the commands of number 3 will be shown here. Other pieces are laid in the same manner.)

(3) *Executive officer*—NUMBER 3, DEFLECTION 3091. (The executive had referred the aiming circle to the objective lens of the telescope.)

(4) *Gunner of number 3*—NUMBER 3, DEFLECTION 3091. (The gunner sets 3091 on his telescope and causes the carriage to be shifted until the line of sight is within 10 mils of the aiming circle. Then, he uses the traversing mechanism to place the line of sight exactly on the aiming circle. In the meantime, the executive officer is laying other pieces.) When the gunner of number 3 piece has completed his laying with deflection 3091, he announces NUMBER 3 READY FOR RECHECK.

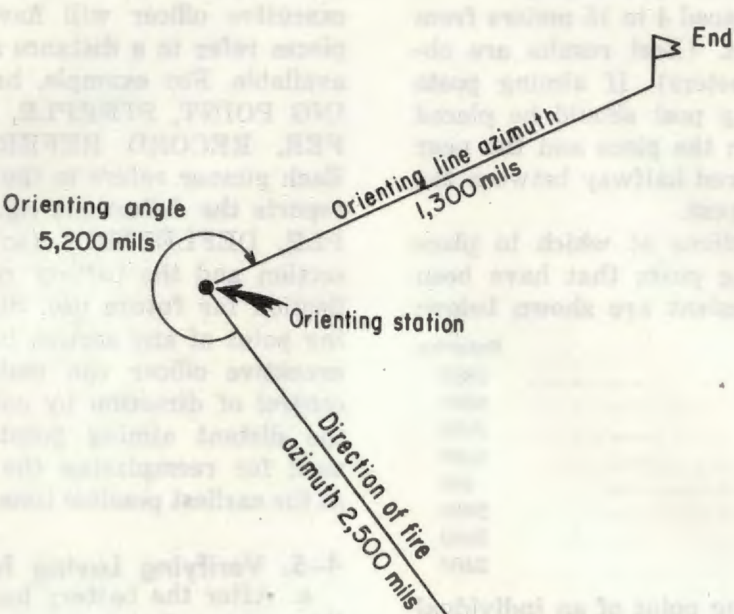


Figure 4-2. Orienting by orienting angle.

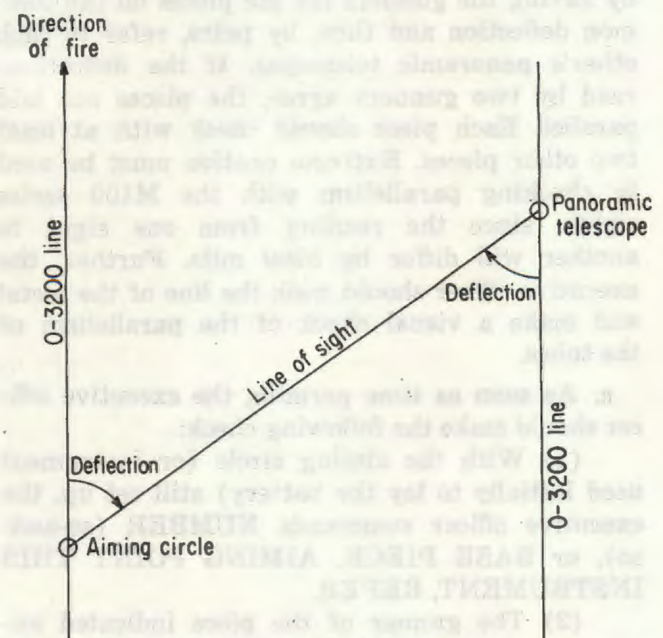


Figure 4-3. Principle of reciprocal laying.

(5) *Executive officer*—NUMBER 3, DEFLECTION 3093.

(6) *Gunner of number 3*—NUMBER 3, DEFLECTION 3093, 2 MILS. (This indicates a 2-mil difference between this deflection and the previous deflection.) After setting off 3093 and traversing the piece until the telescope is again sighted on the aiming circle, the gunner announces NUMBER 3 READY FOR RECHECK. The executive officer continues to lay the same piece once it is within 3 mils of the announced deflection.

(7) *Executive officer*—NUMBER 3, DEFLECTION 3093.

(8) *Gunner of number 3*—NUMBER 3, DEFLECTION 3093. ZERO MILS.

(9) *Executive officer*—NUMBER 3 IS LAID. (Unit standing operating procedure will specify the deflection at which the aiming posts or collimator will be placed upon completion of laying.)

4-4. Recording Laying for Direction

a. Under normal circumstances, after the battery has been laid parallel, the executive officer will direct the crew of each piece to refer to a common deflection and to set the collimator or aiming posts along the resulting line of sight (the tube is not moved). If this procedure is followed, each piece will have an aiming point and a deflection which, when used, will cause the tube to be pointed in the direction in which it was initially laid without again going through the process of reciprocal laying. Furthermore, the direction in which the battery is initially laid and the corresponding deflection are used as references from which the fire direction center (FDC) can derive firing deflections for future targets.

b. The collimator is placed 4 to 15 meters from the sight of the weapon. (Best results are obtained from 6 to 12 meters). If aiming posts are used, the far aiming post should be placed at least 100 meters from the piece and the near aiming post must be placed halfway between the piece and the far aiming post.

c. The referred deflections at which to place the collimator or aiming posts that have been found to be most convenient are shown below:

Weapon	*Deflection*
105-mm (M101A1)	2800
105-mm (M102)	2800
105-mm (M108)	2600
155-mm (M114A1)	2400
155-mm (M44)	600
155-mm (M109)	2600
8-inch (M110, M115)	2400
175-mm (M107)	2400

d. If the close-in aiming point of an individual piece cannot be placed at the announced common deflection because of ground contour, foliage, trees, or other conditions, the gunner turns the azimuth micrometer knob until the azimuth scale is on another even 100-mil graduation. The collimator or aiming posts are alined at this new deflection. The chief of section reports the altered deflection to the executive officer: NUMBER (so-and-so), COLLIMATOR (AIMING POSTS) AT (so many hundred), DEFLECTION (common deflection) IN LAKE (or other reason). The executive officer will then command NUMBER (so-and-so), DEFLECTION (as appropriate to the weapon) REFER. If the piece is equipped with the M12 series panoramic sight, the gunner, at this command, 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.

e. If the sight is equipped with a reset counter, the gunner alines the collimator or aiming posts at the referred deflection as indicated in *c* above by using the azimuth counter. He then resets the reset counter by pushing and turning the reset knob. The counter will automatically reset to 3200. If it is not possible to place the collimator or aiming posts on the referred deflection indicated in *c* above, the gunner may aline the collimator or aiming posts at any convenient deflection by using the azimuth counter. He then resets the reset counter to 3200. In either case, 3200 then becomes the referred deflection for the weapon.

f. As soon as the battery has been laid parallel and referred to the close-in aiming point, the executive officer will have the gunners of all pieces refer to a distance aiming point, if one is available. For example, he may command AIMING POINT, STEEPLE, RIGHT FRONT, REFER, RECORD REFERRED DEFLECTION. Each gunner refers to the steeple and reads and reports the deflection; e.g., NUMBER 3, STEEPLE, DEFLECTION (so much). The chief of section and the battery recorder record the deflection for future use. Should the close-in aiming point of any section be rendered useless, the executive officer can maintain parallelism and control of direction by using this deflection and the distant aiming point. This information is used for reemplacing the close-in aiming point at the earliest possible time.

4-5. Verifying Laying for Direction

a. After the battery has been laid, the executive officer should direct checks to insure that the pieces have been laid parallel and in the proper direction.

b. The executive officer can check parallelism by having the gunners lay the pieces on the common deflection and then, by pairs, refer to each other's panoramic telescopes. If the deflections read by two gunners agree, the pieces are laid parallel. Each piece should check with at least two other pieces. Extreme caution must be used in checking parallelism with the M100 series sights, since the reading from one sight to another will differ by 3200 mils. Further, the executive officer should walk the line of the metal and make a visual check of the parallelism of the tubes.

c. As soon as time permits, the executive officer should make the following check:

(1) With the aiming circle (or instrument used initially to lay the battery) still set up, the executive officer commands NUMBER (so-and-so), or BASE PIECE, AIMING POINT THIS INSTRUMENT, REFER.

(2) The gunner of the piece indicated announces AIMING POINT IDENTIFIED, 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 NUMBER (so-and-so), DEFLECTION (so much).

(3) The executive officer refers the aiming circle to the panoramic telescope of the designated (base) piece.

(4) If the deflection read by a gunner does not agree with that read by the executive officer,

the executive officer can correct the lay of that piece for direction by giving the gunner the proper deflection.

d. The executive officer verifies the azimuth or orienting angle by one of the following procedures:

(1) If the battery was laid with the magnetic compass (by azimuth), the executive officer centers the needle with the upper motion and reads the azimuth scale and azimuth micrometer. He subtracts this reading from the declination constant, adding 6400 mils if necessary. The result is the azimuth on which the battery is laid. If the azimuth determined is within 2 mils of the initial azimuth, the lay may be considered verified for direction.

(2) If the battery was laid on an orienting angle, the executive officer sights on the end of the orienting line with the upper motion. If the resulting reading on the azimuth scale and azimuth micrometer agrees with the initial orienting angle, the lay is considered verified for direction.

4-6. Conversion of Data for Direction

a. Preparation for Converting Data. If no azimuth of fire has been given the executive officer upon occupation of position, he lays the battery parallel in the direction which appears to be more appropriate, considering his knowledge of the situation, and records a referred deflection. When a fire command prescribing a different azimuth of fire and/or a different method of laying is received, he can accomplish the change by announcing a new deflection with reference to the aiming point. In order to be prepared for any eventuality, the executive officer

(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 deflections (refer) to visible aiming points. (He also has the gunner of another piece 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 an azimuth and a command for another azimuth is received, the executive officer computes the difference between the two azimuths. He next applies this difference to the original deflection in the proper direction; an increase in grid azimuth decreases the deflection, and a decrease in grid azimuth increases the deflection (fig 4-4). The result is the deflection necessary to lay the battery on the new grid azimuth.

c. Shift From One Orienting Angle to Another. If the battery is laid on an orienting angle and a command for another orienting angle is received, the executive officer computes the difference between the two orienting angles. He next applies this difference to the original deflection in the proper direction; an increase in orienting angle increases the deflection, and a decrease in orienting angle decreases the deflection (fig 4-5). The result is the deflection necessary to lay the battery on the new orienting angle.

d. Shift From an Azimuth to an Orienting Angle. After the battery has been laid parallel on an azimuth, an orienting line may be established and an orienting angle announced. This will necessitate a shift from grid azimuth to the announced orienting angle. The executive officer sets the aiming circle over the orienting station and measures the orienting angle on which the battery is laid. He compares this angle with the announced orienting angle, commands an appropriate deflection, and has the close-in aiming point realined.

e. Relaying Single Pieces on a New Azimuth. If, after a large deflection shift has been made, the gunner is unable to sight on the aiming point because the line of sight is obstructed or he is unable to take up the correct sight picture because of excessive displacement of the weapon, the weapon should be relaid with an aiming circle. The procedure is as follows:

(1) The executive officer converts the announced deflection into an azimuth.

(2) The executive officer orients the aiming circle on the computed azimuth.

(3) The crew shifts the weapon to the appropriate direction of fire and the gunner lays it reciprocally on the desired azimuth.

(4) The gunner has the aiming posts or collimator realined on the announced deflection.

Note. If the weapon is equipped with the M100 series sight, the weapon is relaid with the azimuth 6400-mil counter dial (upper window). The gunner alines the collimator (or aiming posts) by using the azimuth 3200-mil counter dial (lower window). THE RESET COUNTER IS *NOT* RESET TO 3200. When this procedure is used, the original deflection index on the firing chart is still valid and does not have to be displaced.

4-7. Laying the Battery Without an Aiming Circle

At times, it may be necessary to lay the battery without an aiming circle. Among the situations that would indicate use of the methods described

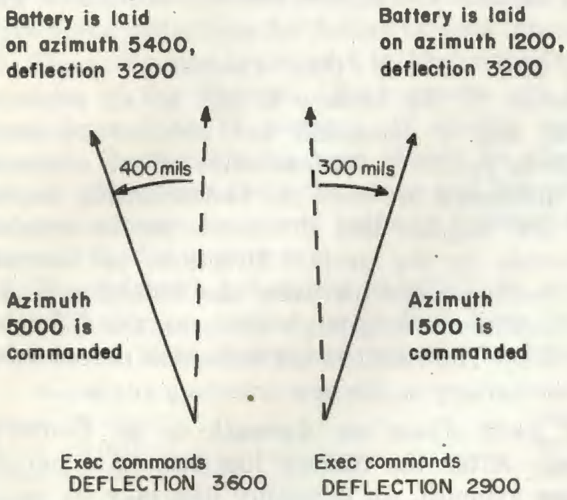


Figure 4-4. Shifts to compensate for difference in grid azimuth.

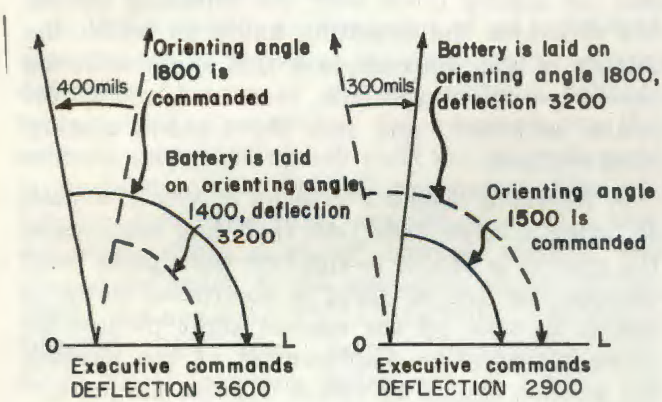


Figure 4-5. Shifts to compensate for difference in orienting angles.

below are the lack of an aiming circle or the lack of time to lay by normal procedures.

a. Aiming Point and Deflection. The executive officer can use either of two methods ((1) and (2) below) to lay by aiming point and deflection. He can determine the deflection on which to sight on the selected aiming point by comparing the desired direction of fire with the azimuth to the aiming point. For example, if the direction of fire is 600 mils right of the azimuth to the aiming point, the deflection would be 2600 (3200 − 600). If the direction of fire is 600 mils left of the azimuth to the aiming point, the deflection would be 3800 (3200 + 600).

(1) In the first method, the executive officer commands (to the first piece prepared for action) NUMBER (so-and-so) ADJUST, AIMING POINT (so-and-so), DEFLECTION (so much). The gunner sets the announced deflection and sights on the aiming point by moving the tube. This action causes the tube to be laid in the desired direction. The executive officer then commands BATTERY ADJUST, ON NUMBER (so-and-so) LAY PARALLEL. The gunner then lays the other pieces reciprocally with the panoramic telescope in the same manner as that used for laying with the aiming circle (para 4-3).

(2) In the second method the executive commands BATTERY ADJUST AIMING POINT (so-and-so), DEFLECTION (so much). Each gunner sets off the announced deflection and sights on the aiming point by moving the tube. If the aiming point is at the flank of the battery and a common deflection is given to all pieces, the battery can be considered as laid parallel. 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 in ① figure 4-6. The convergency is corrected and the sheaf is formed parallel by means of individual shifts as shown in ② figure 4-6.

Example: It is desired to form the sheaf parallel on the number 3 piece (fig 4-6). The shifts are determined for each piece by use of the mil relation (para 8-3*b*), R being the range to the aiming point and W being the perpendicular distance from the piece concerned to a line through the aiming point and number 3 piece. If the aiming point is to the rear, the sheaf will diverge. Individual shifts are computed as above to form the sheaf parallel.

b. M2 Compass. The command to the executive officer to lay the battery by azimuth is LAY ON AZIMUTH (so much). This command is not repeated to the sections. The executive officer places the compass on a steady object, away from objects which might affect the magnetic needle and in a place where it can be used as an aiming point for base piece. He then—

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

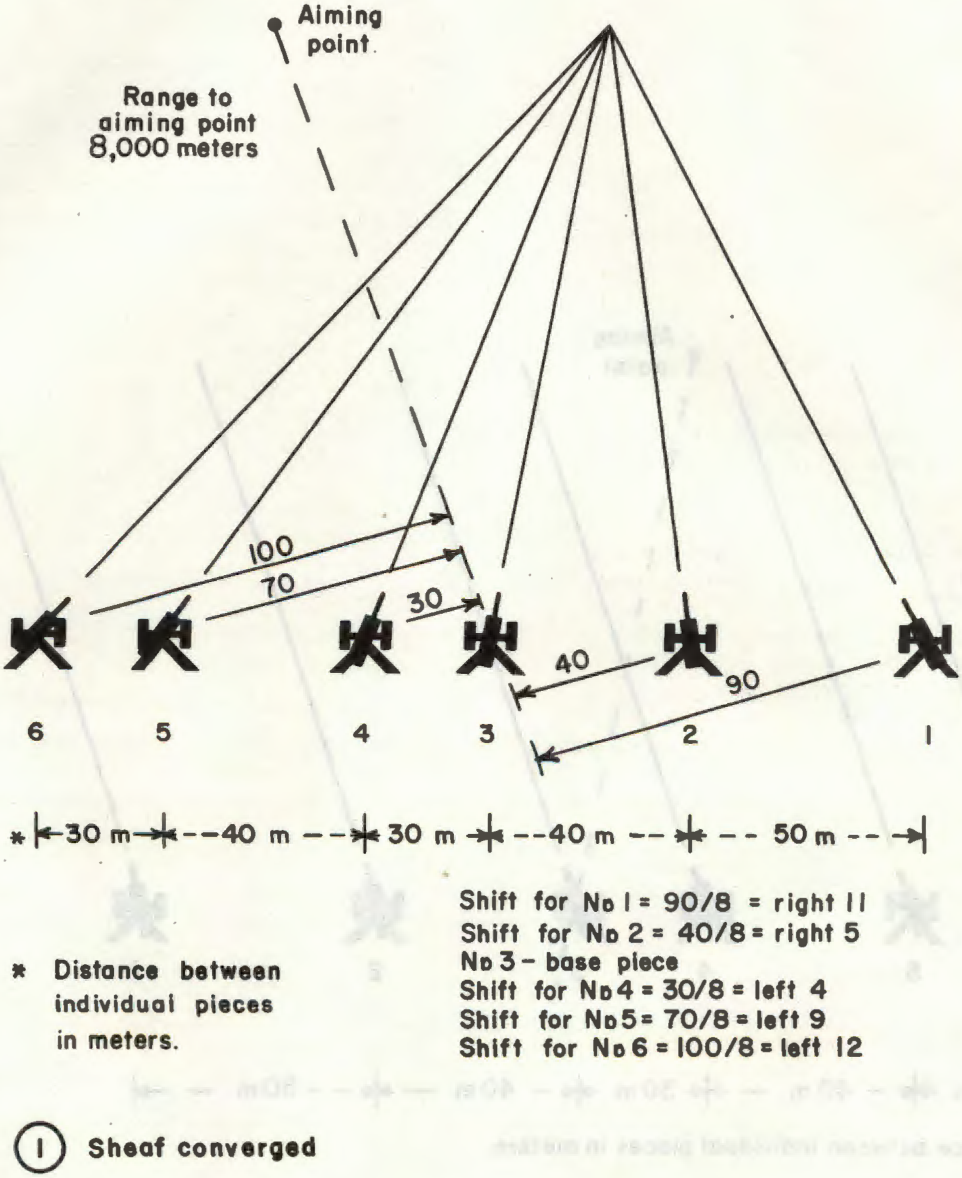
(2) Subtracts the announced azimuth from the azimuth which he measured (adding 6400 if necessary).

(3) Uses the remainder (minus 3200, if necessary; as the deflection and uses the compass as an aiming point to lay the base piece (fig 4-7).

(4) Orders the gunner of the base piece to lay the other pieces reciprocally.

4-8. Laying By Aircraft, High Airburst, or Flare

a. No specific command is prescribed for laying the battery by sighting on an aircraft, an airburst, or a flare. The executive may lay the



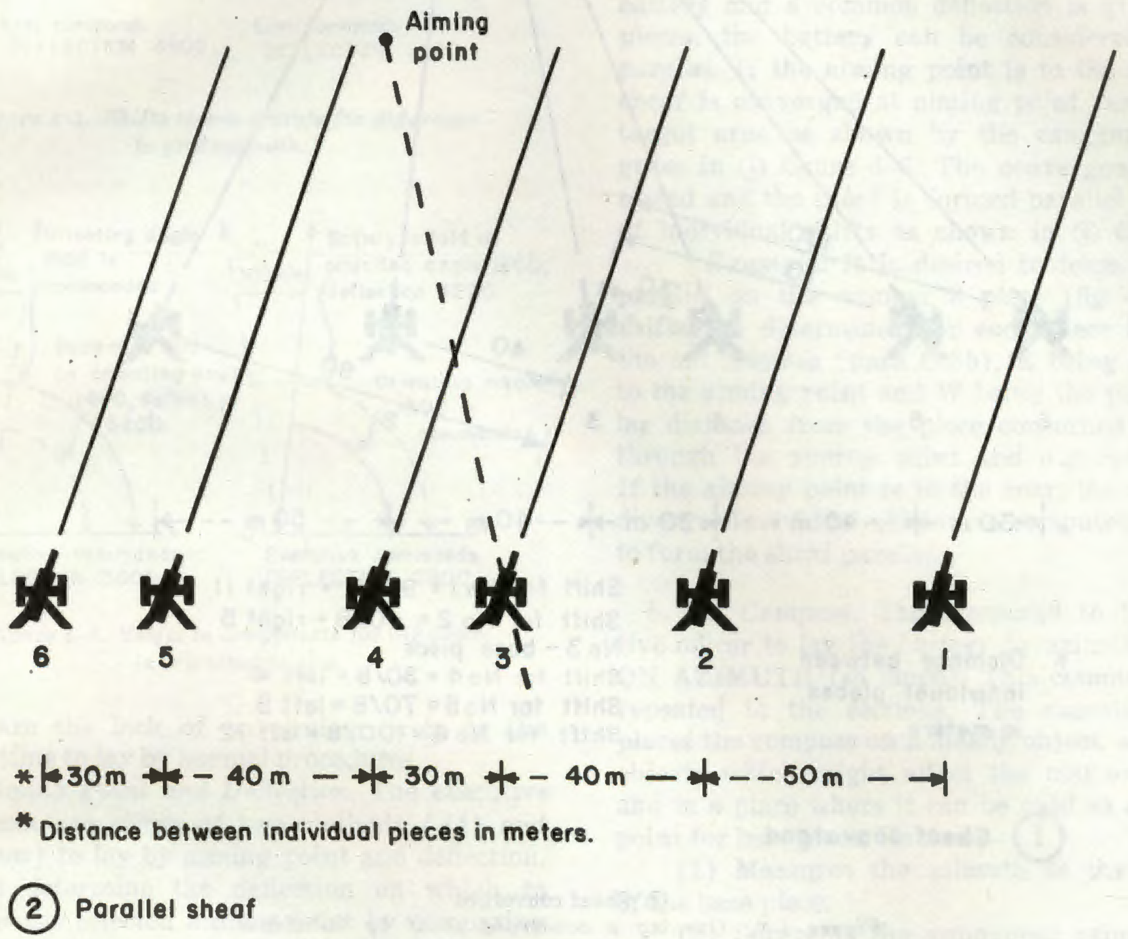
① Sheaf converged

Figure 4-6. Opening a converged sheaf by individual shifts to obtain a parallel sheaf.

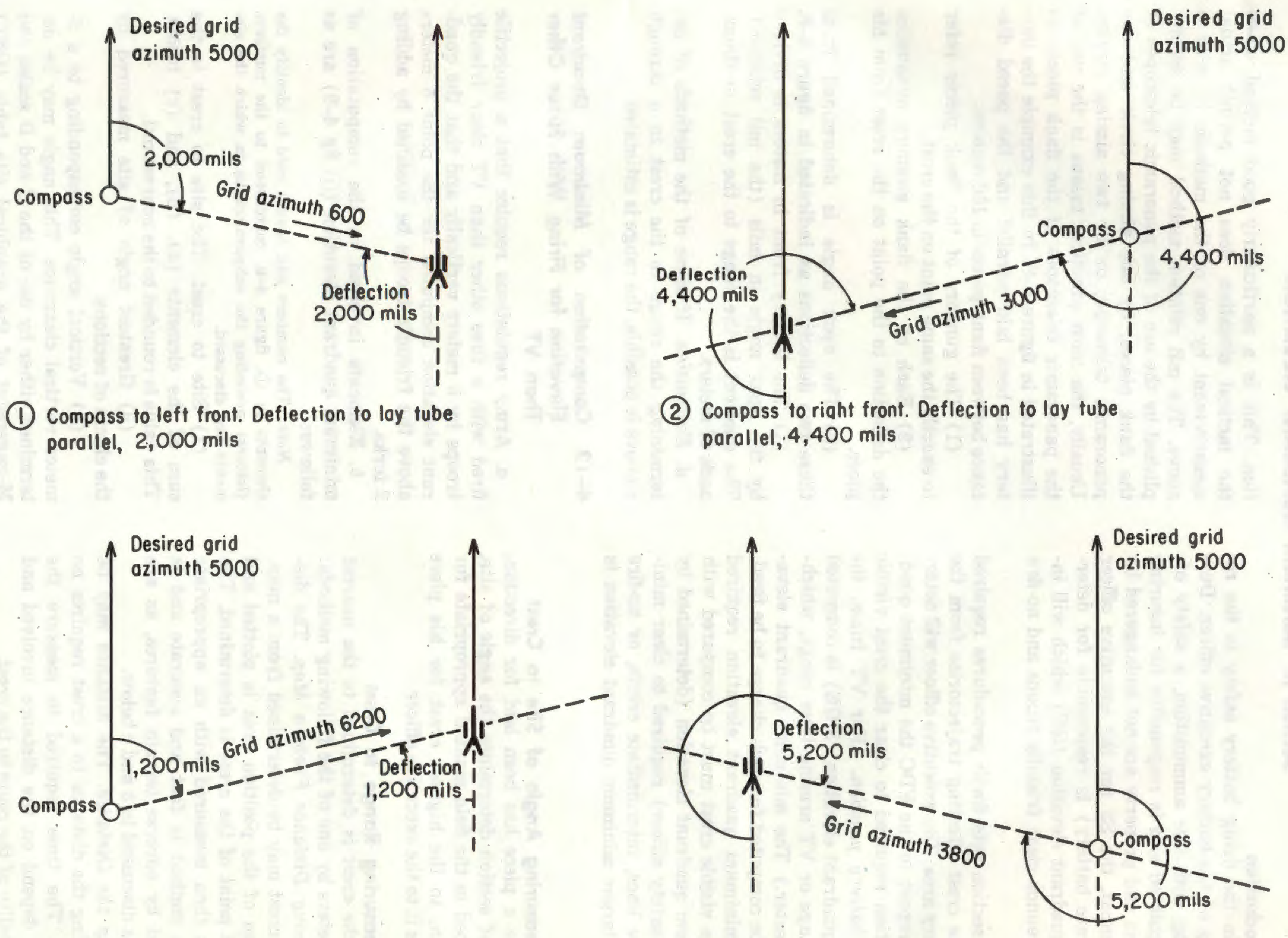
battery initially for direction by sighting with an instrument on the aircraft, high airburst, or flare. When no visible point is suitable for use as an aiming point, an aircraft may be employed to fly over the battery position toward, or away from, a point in the target area. The line of flight is used to establish a line of direction.

b. The high airburst or flare should be over the target area. The high airburst is fired by another unit, which has been laid perviously for direction. The flare may be fired by an air observer or a ground observer.

c. 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. He zeroes the azimuth scale and azimuth micrometer 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 officer lays the pieces reciprocally.



② Parallel sheaf
Figure 4-6—Continued.



(1) Compass to left front. Deflection to lay tube parallel, 2,000 mils

(2) Compass to right front. Deflection to lay tube parallel, 4,400 mils

(3) Compass to left rear. Deflection to lay tube parallel, 1,200 mils

(4) Compass to right rear. Deflection to lay tube parallel, 5,200 mils

Figure 4–7. Use of M2 compass to lay by grid azimuth.

Section II. MINIMUM QUADRANT ELEVATION

4-9. Introduction

a. Within the firing battery safety is the responsibility of the battery executive officer. During training with live ammunition, a safety officer is appointed and is responsible for insuring that persons and property are not endangered by fire. In combat, the S3 (or the executive officer of a separate battery) is responsible for determining a quadrant elevation (QE) which will insure that rounds clear friendly troops and no-fire lines.

b. This section sets forth procedures required to clear the crest affecting trajectories from the firing battery area. The executive officer will determine and report to the FDC the minimum quadrant elevation required to clear the crest *visible from the battery position.* (For VT fuzes, the minimum quadrant elevation (MQE) is computed at crest range or VT arming time range, whichever is greater.) The minimum quadrant elevation must be computed for each charge to be fired.

c. The minimum quadrant elevation required to clear the visible crest must be compared with the minimum quadrant elevation (determined by the S3 or safety officer) required to clear minimum range lines, intermediate crests, or no-fire lines. The larger minimum quadrant elevation is used.

4-10. Measuring Angle of Site to Crest

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

4-11. Measuring Range to Crest

Range to the crest is determined to the nearest hundred meters by one of the following methods:

a. Obtaining Distance From a Map. The distance to a crest may be determined from a map. The location of the position area is plotted and the highest point of the crest is determined. The distance is then measured with an appropriate scale. This method is fast and accurate and is not affected by adverse terrain features, as are the methods discussed in *b* and *c* below.

b. Pacing the Distance. The distance may be paced. Pacing the distance to a crest requires no equipment. The time required to measure the range will depend on the distance involved and the accessibility of the route to the crest.

c. Use of the Mil Relation. The range to a crest may be determined by use of the mil relation. This is a particularly good method when the tactical situation does not permit actual measurement by one of the methods in *a* or *b* above. The mil relation method may be accomplished by the use of the panoramic telescopes of the flank pieces, by one aiming circle and one panoramic telescope, or by two aiming circles. Usually, the most practical means is the use of the panoramic telescopes of the flank pieces as illustrated in figure 4-8. In this example the battery has been laid parallel and the paced distance between flank pieces is 150 meters.

(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 4-8.

(4) The battery front in meters is divided by the apex angle in mils (the mil relation). The quotient is the range to the crest in thousands of meters.

d. Estimation. If none of the methods of determining the range to the crest in *a* through *c* above is possible, the range is estimated.

4-12. Computation of Minimum Quadrant Elevation for Firing With Fuzes Other Than VT

a. Army regulations require that a projectile fired with a fuze other than VT clear friendly troops by 5 meters vertically and that the quadrant elevation computed for the point 5 meters above the friendly troops be modified by adding 2 forks.

b. Elements involved in the computation of minimum quadrant elevation (① fig 4-9) are as follows:

Note. The numbers and letters used to identify the elements in ①, figure 4-9, correspond to the numbers (letters) preceding the subparagraphs in which the elements are discussed.

(1) Site to crest. The site to crest is the sum of the elements (*a*), (b), and (*c*) below. This value is rounded to the nearest mil.

(*a*) Greatest angle of site measured by the chiefs of sections.

(*b*) Vertical angle corresponding to a 5-meter vertical clearance. This angle may be determined either by use of the C and D scales and M-gagepoint of the graphical site table (GST) or by use of the mil relation (5 meters divided by crest range in thousands to nearest hundred

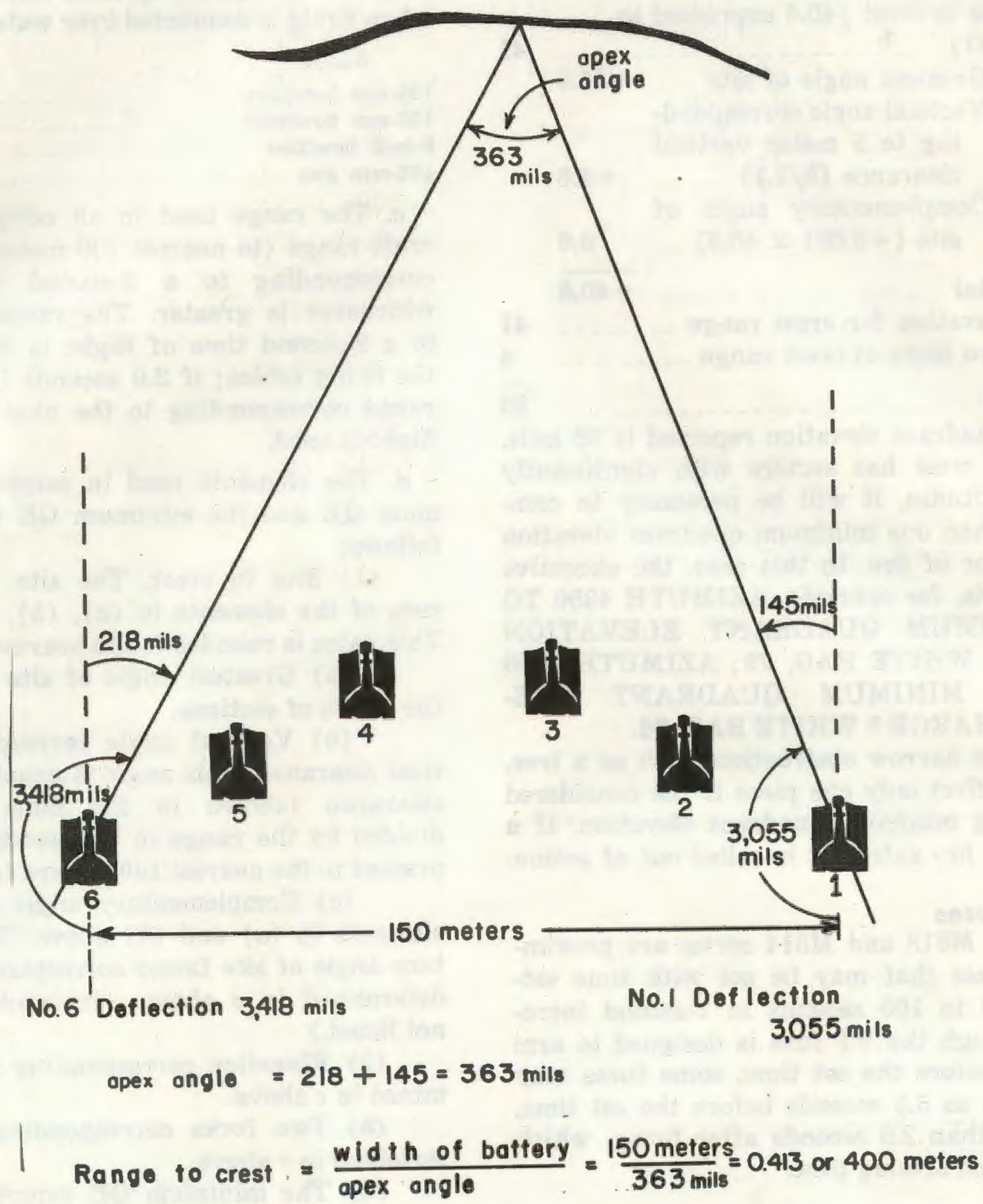


Figure 4–8. Determining range to crest.

meters). Example problems in this chapter have been solved by use of the GST. Unless otherwise informed, the executive officer will assume that the crest is occupied by friendly elements.

(*c*) Complementary angle of site for elements in (*a*) and (*b*) above. The comp site factor for the crest range to the nearest 100 meters will be used.

(2) Elevation corresponding to range to crest.

(3) Two forks at range to crest.

c. The sum of the elements in *b*(1) (*a*) and (*b*) above is the angle of site to the point 5 meters above the crest. The sum of the elements in *b*(1) (*a*), (*b*), and (*c*) above is the site to the point 5 meters above the crest. The sum of the elements in *b*(1), (2), and (3) above is reported as the minimum quadrant elevation in the executive officer's report. The elements in *b*(1) (*a*), (b), and (*c*) above are determined to the nearest 0.1 mil; the elements in *b*(1), (2), and (3) above is reported as the minimum quadrant elevation to the nearest 1 mil.

Example: 155-mm howitzer M109, charge 5 white bag, range to crest 1,100 meters; angles of site reported by chiefs of sections +35, +36, +35, +34, +36, +35.

Solution:

(1) Site to crest (40.6 expressed as 41)	41
(*a*) Greatest angle of site	+36.0
(*b*) Vertical angle corresponding to 5 meter vertical clearance (5/1.1)	+4.6
(*c*) Complementary angle of site (+0.001 × 40.6)	0.0
Total	+40.6
(2) Elevation for crest range	41
(3) Two forks at crest range	4
Total	86

Minimum quadrant elevation reported is 86 mils.

d. If the crest has sectors with significantly different altitudes, it will be necessary to compute more than one minimum quadrant elevation for the sector of fire. In this case, the executive officer reports, for example, AZIMUTH 4850 TO 5200, MINIMUM QUADRANT ELEVATION CHARGE 5 WHITE BAG, 79; AZIMUTH 5200 TO 5600, MINIMUM QUADRANT ELEVATION CHARGE 5 WHITE BAG, 86.

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

4-13. VT Fuzes

Fuzes of the M513 and M514 series are proximity (VT) fuzes that may be set with time settings from 5 to 100 seconds in 1-second increments. Although the VT fuze is designed to arm 3.0 seconds before the set time, some fuzes may arm as much as 5.5 seconds before the set time, but not less than 2.0 seconds after firing, which is the minimum arming time.

4-14. Computation of Minimum Quadrant Elevation for Firing With VT Fuzes (Low-Angle Fire) in Combat

a. Some fuzes have armed as early as 5.5 seconds prior to the time set on the fuze. Thus, the probability of premature arming requires that a safety factor of 5.5 seconds be added to the time flight to the point where arming is permitted. Since time is set on the setting ring to the whole second, the time determined is rounded up to the whole second and this becomes the minimum safe time.

b. Army regulations require that a projectile armed with a VT fuze clear friendly troops by at least the number of meters indicated in the table below. The clearances indicated should be increased by 50 percent when firing is conducted over wet or marshy ground and by 100 percent when firing is conducted over water.

Weapon	*Vertical clearance*
105-mm howitzer	80 meters
155-mm howitzer	100 meters
8-inch howitzer	150 meters
175-mm gun	150 meters

c. The range used in all computations is the crest range (to nearest 100 meters) or the range corresponding to a 2-second time of flight, whichever is greater. The range corresponding to a 2-second time of flight is determined from the firing tables; if 2.0 seconds is not listed, the range corresponding to the next higher time of flight is used.

d. The elements used in computing the minimum QE and the minimum QE reported are as follows:

(1) Site to crest. The site to crest is the sum of the elements in (*a*), (*b*), and (*c*) below. This value is rounded to the nearest mil.

(*a*) Greatest angle of site as reported by the chiefs of sections.

(*b*) Vertical angle corresponding to vertical clearance. This angle is equal to the vertical clearance (shown in the table in *b* above) divided by the range in thousands of meters expressed to the nearest 100 meters (*c* above).

(*c*) Complementary angle of site for the elements in (*a*) and (*b*) above. The complementary angle of site factor corresponds to the range determined in *c* above. (Interpolate for ranges not listed.)

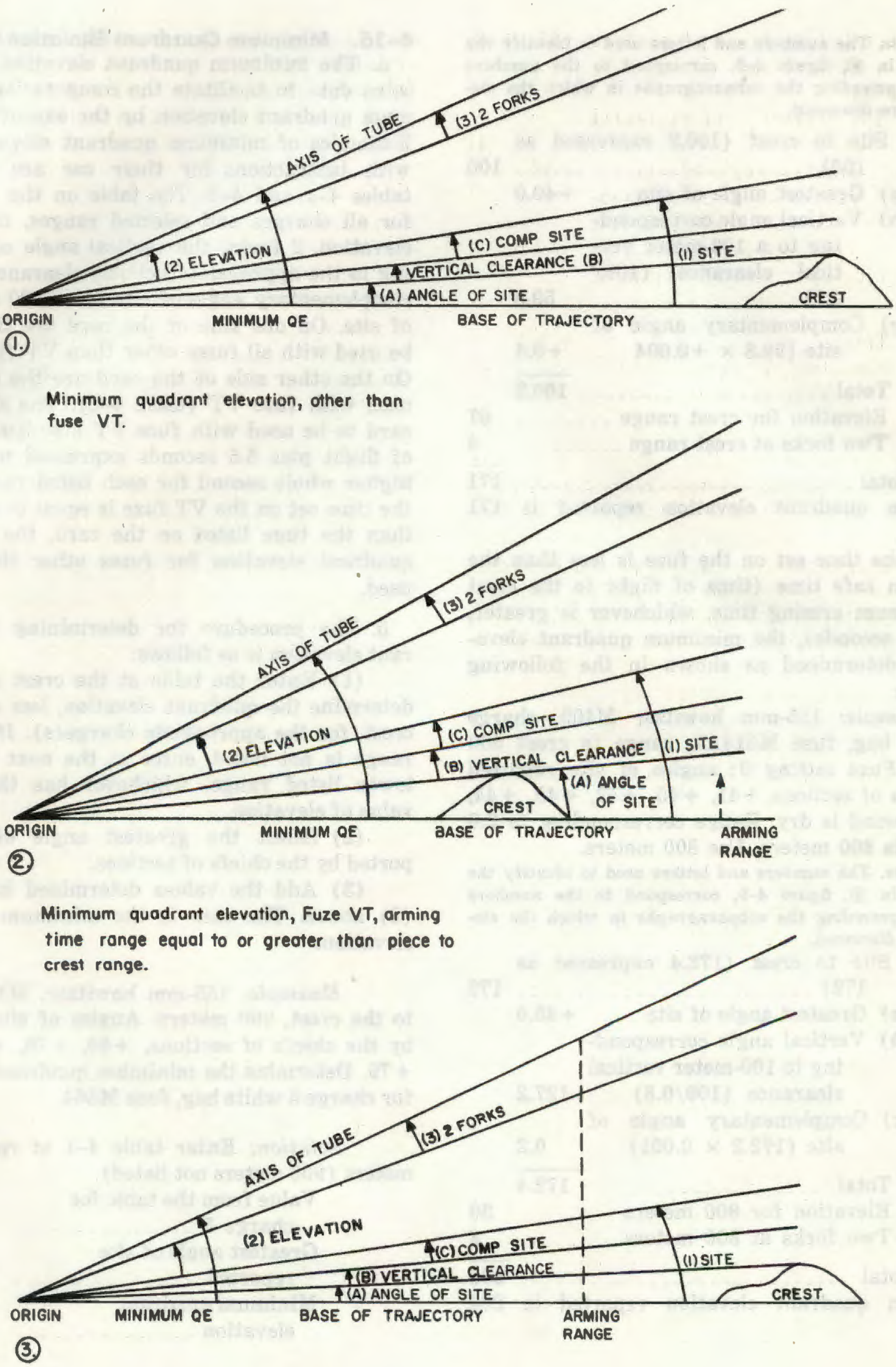
(2) Elevation corresponding to range determined in *c* above.

(3) Two forks corresponding to range determined in *c* above.

(4) The minimum QE reported is the sum of the elements in (1), (2), and (3) above.

e. If the time set on a VT fuze is equal to, or greater than, the time of flight to the crest plus 5.5 seconds, the minimum quadrant elevation computed for other fuzes is used (②, fig 4-9).

Example: 155-mm howitzer M109, charge 5 white bag, fuze M514A1, range to crest 1,700 meters, fuze setting 10.0 seconds; angles of site reported by chiefs of sections +40, +39, +40, +38, +39, +40; ground is dry. Time of flight to the crest at range 1,700 meters is 4.9 seconds (4.9 seconds plus 5.5 seconds is 10.4 seconds). Range corresponding to 2.0 seconds is 800 meters. Use 1,700 meters.



1. Minimum quadrant elevation, other than fuse VT.

2. Minimum quadrant elevation, Fuze VT, arming time range equal to or greater than piece to crest range.

3. Minimum quadrant elevation, Fuze VT, arming time range less than piece to crest range.

Figure 4–9. Minimum quadrant elevation.

Note. The numbers and letters used to identify the elements in ⑧, figure 4-9, correspond to the numbers (letters) preceding the subparagraphs in which the elements were discussed.

(1) Site to crest (100.2 expressed as 100) 100
 (*a*) Greatest angle of site ... +40.0
 (*b*) Vertical angle corresponding to a 100-meter vertical clearance (100/1.7) 59.8
 (*c*) Complementary angle of site (99.8 × +0.004 ... +0.4
 Total 100.2
(2) Elevation for crest range 67
(3) Two forks at crest range 4
 Total 171

Minimum quadrant elevation reported is 171 mils.

f. If the time set on the fuze is less than the minimum safe time (time of flight to the crest or minimum arming time, whichever is greater, plus 5.5 seconds), the minimum quadrant elevation is determined as shown in the following example:

Example: 155-mm howitzer M109, charge 5 white bag, fuze M514A1, range to crest 500 meters. Fuze setting 0; angles of site reported by chiefs of sections +41, +45, +43, +45, +44, +44; ground is dry. Range corresponding to 2.0 seconds is 800 meters. Use 800 meters.

Note. The numbers and letters used to identify the elements in ⑧, figure 4-9, correspond to the numbers (letters) preceding the subparagraphs in which the elements are discussed.

(1) Site to crest (172.4 expressed as 172) 172
 (*a*) Greatest angle of site .... +45.0
 (*b*) Vertical angle corresponding to 100-meter vertical clearance (100/0.8) . 127.2
 (*c*) Complementary angle of site (172.2 × 0.001) .. 0.2
 Total 172.4
(2) Elevation for 800 meters ... 30
(3) Two forks at 800 meters 4
 Total 206

Minimum quadrant elevation reported is 206 mils.

4–15. Minimum Quadrant Elevation Card

a. The minimum quadrant elevation card contains data to facilitate the computation of minimum quadrant elevation by the executive officer. Examples of minimum quadrant elevation cards with instructions for their use are shown in tables 4–1 and 4–2. The table on the card lists, for all charges and selected ranges, the sum of elevation, 2 forks, the vertical angle corresponding to the appropriate vertical clearance, and the complementary angle of site for +300 mils angle of site. On one side of the card are the data to be used with all fuzes other than VT (table 4–1). On the other side of the card are the data to be used with fuze VT (table 4–2). The side of the card to be used with fuze VT also lists the time of flight plus 5.5 seconds expressed to the next higher whole second for each listed range. When the time set on the VT fuze is equal to or greater than the time listed on the card, the minimum quadrant elevation for fuzes other than VT is used.

b. The procedure for determining the quadrant elevation is as follows:

(1) Enter the table at the crest range and determine the quadrant elevation, less site to the crest, for the appropriate charge(s). If the crest range is not listed, enter at the next higher or lower listed range, whichever has the greater value of elevation.

(2) Select the greatest angle of site reported by the chiefs of sections.

(3) Add the values determined in (1) and (2) above. The sum is the minimum quadrant elevation.

Example: 155-mm howitzer, M109; range to the crest, 900 meters. Angles of site reported by the chiefs of sections, +80, +78, +79, +80, +79. Determine the minimum quadrant elevation for charge 5 white bag, fuze M564.

Solution: Enter table 4–1 at range 1,000 meters (900 meters not listed).

Value from the table for charge 5 46
Greatest angle of site reported .... +80
Minimum quadrant elevation .... 126 mils

Table 4–1. Minimum Quadrant Elevation (Less Angle of Site), 155-mm Howitzer M109, Shell HE M107, Fuzes M557, M500, M520, and M564, FT 155–AH–2.

Crest range	Charge (white bag)					Crest range	Charge (white bag)				
	3	4	5	6	7		3	4	5	6	7
200	42	39	36	34	32	1400	106	82	63	45	32
400	43	37	31	27	23	1600	120	91	70	49	35
600	52	42	34	26	22	1800	134	107	79	55	39
800	63	50	40	30	23	2000	152	116	89	61	43
1000	76	60	46	34	26	2500	193	145	113	77	53
1200	89	70	55	38	28						

Instructions:

1. Enter the table at the crest range and at the appropriate charge(s). If the crest range is not listed, enter at the next higher or lower listed range, whichever has the greater value of elevation in the body of the table.
2. To obtain the minimum quadrant elevation, add the greatest angle of site reported by the chiefs of sections to the value taken from the body of table.

Table 4–2. Minimum Quadrant Elevation and Time (Less Angle of Site), 155-mm Howitzer M109, Shell HE, M107, Fuze M514A1, FT 155–AH–2.

Crest range	Charge (white bag) 3		4		5		6		7	
	El	Ti	El	Ti	El	Ti	El	Ti	El	Ti
200	216	8.0	185	8.0	161	8.0	139	8.0	115	8.0
400	216	8.0	185	8.0	161	8.0	139	8.0	115	8.0
600	216	8.0	185	8.0	161	8.0	139	8.0	115	8.0
800	184	9.0	172	9.0	161	8.0	139	8.0	115	8.0
1000	173	10.0	157	9.0	143	9.0	131	8.0	115	8.0
1200	170	10.0	151	10.0	135	9.0	119	9.0	109	8.0
1400	175	11.0	151	10.0	132	10.0	114	9.0	101	9.0
1600	181	12.0	152	11.0	131	11.0	110	10.0	96	9.0
1800	188	13.0	157	12.0	133	11.0	109	10.0	93	9.0
2000	200	13.0	164	12.0	137	12.0	109	11.0	91	10.0
2500	232	15.0	184	14.0	152	13.0	116	12.0	92	11.0

Instructions:

1. Enter the table at the range to crest and at the appropriate charge(s). If the range to crest is not listed, enter at the next higher or lower listed range, whichever has the greater value listed in the column headed "El."
2. To obtain the minimum quadrant elevation, add the greatest angle of site reported by the chiefs of sections to the value listed in the column headed "El."
3. Use the minimum quadrant elevation determined from this table whenever the fuze setting is less than the value in the column headed "Ti." If the fuze setting is equal to or greater than the value under the column headed "Ti," use the minimum quadrant elevation determined for fuze M564.

Section III. DETERMINING AND REPORTING DATA

4–16. Introduction

The battalion fire direction center requires data from the firing battery for various purposes, such as construction of firing charts and checks on laying. The battery executive officer requires the same data for the charts at the battery fire direction center. The battery executive officer is responsible for reporting the necessary data to the fire direction center. This section describes the executive officer's duties in determining and reporting data.

4–17. Executive Officer's Report

a. As soon as possible after occupying position and laying the battery, but without interfering with firing, the executive officer reports the azimuth and deflection on which the battery is laid, the minimum quadrant elevation(s), and the distribution of pieces. The distance of each piece from battery center is reported to the nearest 5 meters. The direction in which the battery was laid is used as the reference direction. When time permits, the executive officer submits a position area sketch showing the distribution of pieces (fig 4–10). A typical executive officer's report is shown in the following example:

Example:
BATTERY IS LAID
AZIMUTH (ORIENTING ANGLE) (so much), DEFLECTION (so much)
MINIMUM QUADRANT ELEVA-

TION(S), CHARGE (so-and-so), (so much)

DISTRIBUTION OF PIECES, NUMBER 1 (so many) METERS RIGHT (LEFT), (so many) METERS BEHIND (IN FRONT OF) BATTERY CENTER; NUMBER 2, etc.

b. As soon as possible, the executive officer also determines and reports the—

(1) Amount, type, and lot numbers of ammunition.

(2) Weights of projectiles by lot.

(3) Propellant temperature.

(4) Lateral limits (azimuths or deflections). These limits indicate the azimuths or deflections between which the pieces can be laid without shifting trails.

(5) Maximum elevation, when high-angle fire is being used.

4–18. Reporting Correct Deflection

After a registration has been completed, the executive officer should determine the correct deflection and report it to the fire direction center. The executive officer must determine the correct deflection before announcing END OF MISSION to the base piece. He goes to the base piece, verifies the sight picture, and reads the deflection on the sight. If the sight picture is not correct, he corrects it by referring the sight to the correct picture before reading the deflection on the sight. (The tube must not be moved.) He reports the deflection read as CORRECT DEFLECTION (so much).

4–19. Reporting Correct Azimuth

In order to report the correct azimuth, the executive officer must first determine the correct deflection (para 4–18) and then compute the correct azimuth by comparing the correct deflection with the deflection corresponding to the azimuth on which the battery was initially laid and applying the difference to the azimuth on which the battery was laid.

Example: The battery is laid on azimuth 5000, deflection 3200. After adjustment on the registration point, the FDC commands REPORT CORRECT AZIMUTH. The executive officer determines the correct deflection to be 3315 mils. Deflection 3315 is 115 mils to the left of deflection 3200. The executive officer applies left 115 to azimuth 5000 and reports CORRECT AZIMUTH 4885.

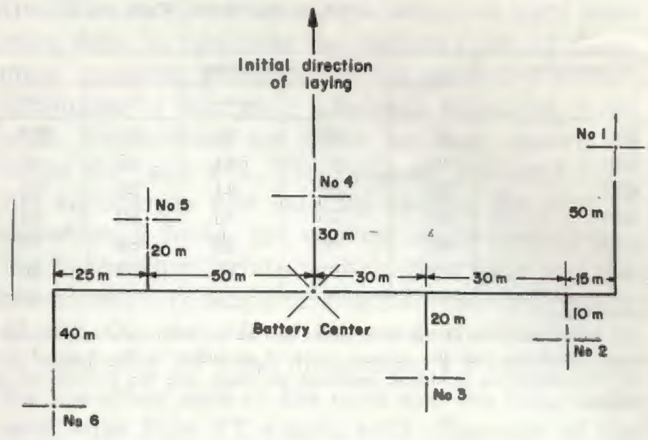


Figure 4–10. Position area sketch.

4–20. Measuring the Azimuth of the Direction of Fire

Upon completion of a registration and prior to announcing END OF MISSION, the executive officer should measure the azimuth and report the measured azimuth to the FDC when required. The procedure for measuring and reporting the azimuth is as follows:

a. Set up the aiming circle so that it is away from magnetic attractions and so that it can be seen from the base piece. Aline the 0–3200 line approximately parallel to the tube of the base piece.

b. The executive officer commands BASE PIECE, AIMING POINT THIS INSTRUMENT, REFER.

c. The gunner of the base piece announces AIMING POINT IDENTIFIED, turns the sight of the piece until the line of sight is on the designated instrument, and announces the reading of the sight scale as DEFLECTION (so much).

d. The executive officer sets this reading on the azimuth and azimuth micrometer scale of the instrument with the upper motion, and, with the lower motion, sights on the panoramic telescope of the piece.

e. Release the magnetic needle and center it, using the upper motion.

f. Determine the reading on the aiming circle and subtract that reading from the declination constant (adding 6400 to the declination constant if necessary). The result is the measured azimuth.

4–21. Measuring The Orienting Angle

When an orienting line has been established, the executive officer should measure the orienting angle (fig 4–11) upon the completion of a registration and report the measured orienting angle to the FDC when required. The procedure for measuring the orienting angle is as follows:

a. Set the aiming circle over the orienting station.

b. Have the gunner of the base piece lay the aiming circle parallel to the tube of the base piece.

c. With the upper motion, refer to the end of the orienting line. Read the orienting angle on the aiming circle.

4–22. Determining Instrument Direction

When the 0 to 3200 line of an aiming circle is pointing in an unknown direction, the following procedure is used for determining the grid azimuth of that direction:

a. Release the needle and center it, using the upper motion.

b. Subtract the reading on the scales from the declination constant (adding 6400 to the declination constant if necessary). The remainder is the grid azimuth of the 0 to 3200 line.

4–23. Measuring Azimuth to a Point

The following procedure is used for measuring the azimuth to a point (fig 4–12):

a. Place the aiming circle so that the 0 to 3200 line is in an approximate north-south direction and the large 0 of the scale is toward the south.

b. With the upper motion, set off the declination constant (①, fig 4–12).

c. Release the needle and, with the lower motion, center the needle to direct the line of sight to magnetic north and the 0 to 3200 line of the instrument to grid north (②, fig 4–12).

d. Lock the needle and, with the upper motion, refer the line of sight to the desired point. Read the grid azimuth to the designated point from the azimuth scale and azimuth micrometer; (③, fig 4–12).

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

4–24. Correction for Boresighting Error After Registration

a. Tactical considerations may require registration before sight tests and adjustments are made. In such cases, the pieces must be boresighted at the earliest practicable time, usually during a lull in firing. If boresighting discloses that the 0 to 3200 line of the sight (panoramic telescope) was not parallel to the tube, the executive officer must take corrective measures and report them to the fire direction center.

b. When a deflection is read from a sight or when an azimuth is measured, the deflection or azimuth determined is that of the 0 to 3200 line of the sight as read from the azimuth counter. Only if the weapon is properly boresighted is the deflection or azimuth that of the tube. When the FDC commands MEASURE THE AZIMUTH (ORIENTING ANGLE), the azimuth (orienting angle) of the tube is desired. Therefore, if the weapon is not properly boresighted, the azimuth (orienting angle) measured is false by the amount of the error in boresighting.

Figure 4–11. Measuring the orienting angle with the aiming circle.

c. At the first opportunity after a registration, the base piece is boresighted. The azimuth counter (not the reset counter) is used during boresighting. The tube is pointed at the aiming point (either a distant aiming point or the appropriate "butterfly" on the test target), and the sight is zeroed. If the sight is pointed to the right of the appropriate aiming point, the tube is pointed to the left of the 0 to 3200 line of sight. It follows that any azimuth measured prior to this time was greater than the azimuth of the tube and that any orienting angle measured was smaller than the true orienting angle. If the sight is pointed to the left of the appropriate aiming point, measured azimuths are less than the azimuth of the tube and measured orienting angles are too large. The amount of the error is determined by referring the sight, with the tube still sighted on its aiming point, to the aiming point and reading the deflection. He compares the referred deflection with 3200, and the

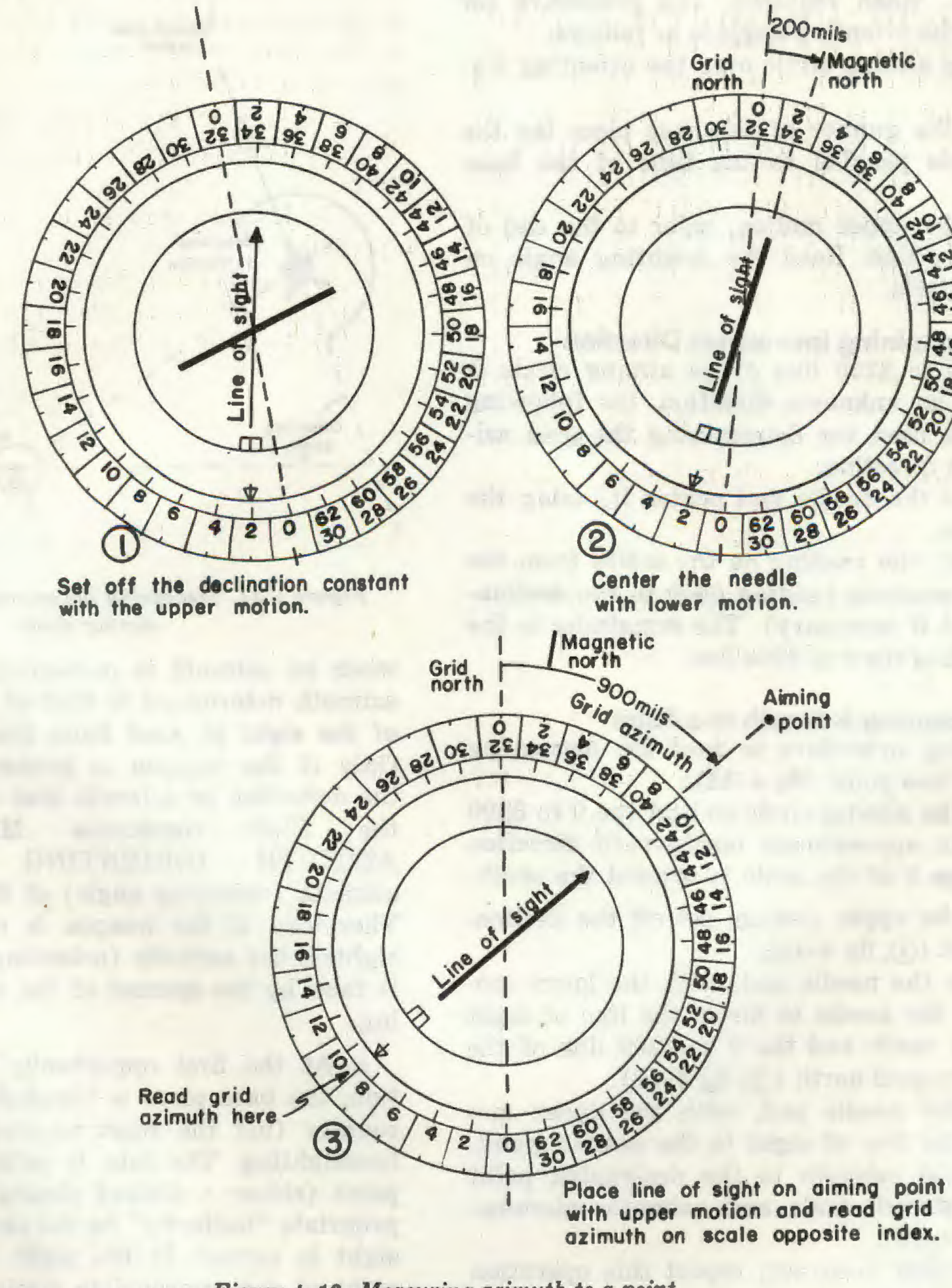


Figure 4-12. Measuring azimuth to a point.

difference is the amount of the error in boresight. He corrects the previously determined azimuths or orienting angles, completes the boresighting, and reports the actions taken.

Example 1: A battery has occupied a position. Before the base piece can be boresighted, a registration is conducted. At the conclusion of the registration, the executive officer determines 2595 to be correct on the azimuth counter (3195 on the reset counter) and measures an azimuth of 1800. A short time later, the piece is boresighted. With the tube pointed at the appropriate aiming point and the azimuth counter reading 3200, the sight is pointed to the right of the aiming point. The executive officer then refers the sight to the aiming point and reads a deflection of 3,192 mils. The tube is pointed 8 mils to the left of the 0 to 3200 line of the sight (①, fig 4-13). Therefore, the azimuth of the tube after registration is 1792 (1800 − 8). When the weapon is boresighted, a deflection of 2595 (3195 on the reset counter) will not point the tube on azimuth 1792. To correct this error, the executive officer adds 8 mils to the deflection and it becomes 2603 as read on the azimuth counter (3203 on the reset counter) (②, fig 4-13). The executive officer then directs the gunner to return the base piece to the initial lay by setting the azimuth counter deflection at 2600 and the reset counter at 3200. After correcting the boresighting, the executive officer reports ERROR OF 8 MILS IN BORESIGHTING ON BASE PIECE, CORRECT AZIMUTH WHEN LAID ON REGISTRATION POINT IS 1792, CORRECT ADJUSTED DEFLECTION 3203, BORESIGHTING HAS BEEN CORRECTED.

Example 2: Assume that in example 1 an orienting angle of 853 mils had been measured. After the 8-mil error in boresighting is determined, the corrected orienting angle is 861 mils (fig 4-14). The executive officer reports ERROR OF 8 MILS IN BORESIGHTING OF NUMBER 3, CORRECT ORIENTING ANGLE IS 861, CORRECT ADJUSTED DEFLECTION 3202, BORESIGHTING HAS BEEN CORRECTED.

4-25. Site by Firing (Executive Officer's High Burst)

a. Upon completion of an observed firing chart registration with time fuze, the command OBSERVE HIGH BURST, MEASURE ANGLE OF SITE, 3 ROUNDS, followed by the adjusted data, may be received from the fire direction center. This command indicates that the FDC desires the executive officer to fire three rounds and to measure and report the observed angle of site to the mean burst center of the three rounds. The executive officer—

(1) Sets up the aiming circle or BC scope (battery commander's telescope) near the base piece.

(2) Has the gunner lay the instrument reciprocally.

(3) Determines the angle of site necessary to make the bursts visible from the gun position.

(4) Determines the quadrant elevation to

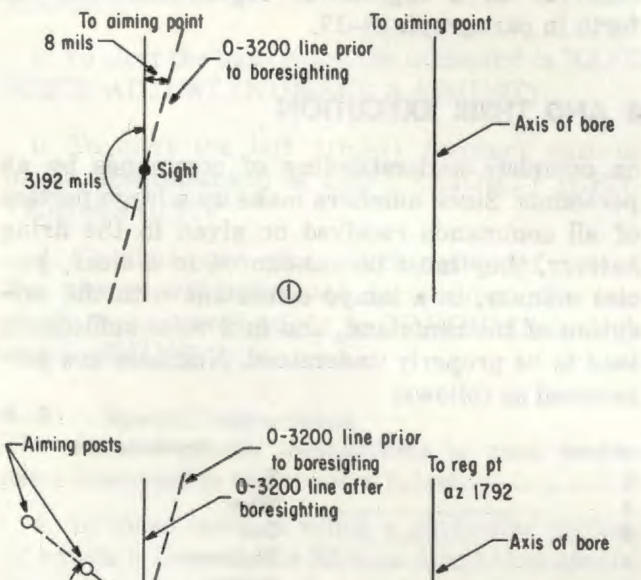


Figure 4-13. Example of error revealed by boresighting.

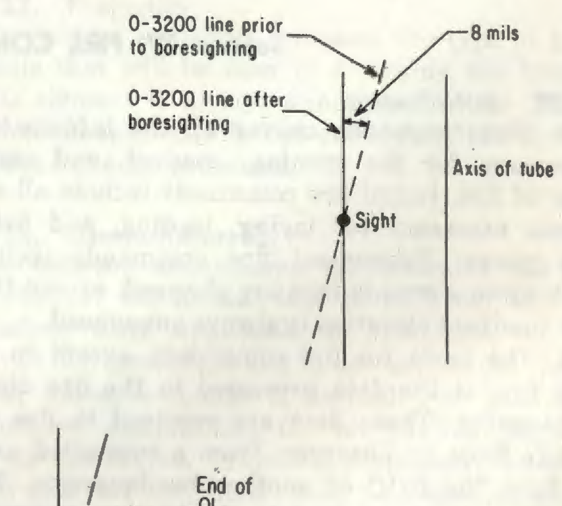


Figure 4-14. Example of error in orienting angle due to error in boresighting.

be fired by adding the angle of site determined in (3) above to the adjusted quadrant elevation.

(5) Fires three rounds, using the announced adjusted deflection and time and the quadrant elevation determined in (4) above.

(6) Measures, with the instrument, the angle of site to each burst and computes the mean angle of site.

(7) Reports to the fire direction center the mean angle of site and the quadrant elevation fired.

b. See paragraph 26-9 for associated FDC procedures.

4-26. Computation of Deflection Difference

a. When the width of the desired sheaf is different from the width of the battery front, a deflection difference is used. The sheaf is opened or closed on any desired piece (normally the base piece) a computed number of mils. The amount by which the sheaf is opened or closed is determined in the following manner:

(1) Determine the difference between the width of the desired sheaf and the width of the battery front (with respect to the direction of fire).

(2) Divide the value determined in (1) above by one less than the number of pieces in the battery.

(3) Divide the value determined in (2) above by the range in thousands of meters.

b. The sheaf is opened when the width of the desired sheaf is greater than the width of the battery front and closed when the width of the desired sheaf is less than the width of the battery front.

c. No corrections are applied to equalize the lateral intervals between adjacent bursts.

Example: A 155-mm howitzer battery is in position with a battery front 250 meters wide. The executive officer receives fire commands which include BATTERY ADJUST, SHEAF 100 METERS AT 5000. He determines that the difference between the width of the desired sheaf (100 meters) and the width of the battery front (250 meters) is 150 meters. He divides 150 meters by 5 (six pieces in the battery). He divides the result (30) by the range in thousands of meters (5.0). The amount by which the sheaf is to be closed is 6 mils. The fire commands to the howitzers will include DEFLECTION 3239, ON NUMBER 3, CLOSE 6.

d. For an explanation of the application of deflection difference by the gunner, see paragraph 4-38*c*.

4-27. Axial Observer in High-Burst Registration

The executive officer may act as an axial observer for a high-burst registration. His instrument must be placed over a surveyed location (battery center or orienting station) and oriented on a surveyed direction. The precise procedures for an observer in a high-burst registration are set forth in paragraph 13-17.

Section IV. FIRE COMMANDS AND THEIR EXECUTION

4-28. Introduction

a. Fire commands convey all the information necessary for the opening, 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 quadrant elevation is always announced.

b. The basis for fire commands, except in direct fire, is the data processed in the fire direction center. These data are received in fire requests from an observer, from a supported unit, or from the FDC of another headquarters. The fire commands are sent to the battery executive officer by the best available means of communication. The executive officer insures that the howitzer (gun) sections receive and execute the fire commands as prescribed in this manual and in unit standing operating procedures.

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 in a voice sufficiently loud to be properly understood. Numbers are pronounced as follows:

Number	*Pronounced 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

4-29. Sequence of Commands

a. Fire commands are announced to the firing battery in the sequence shown in table 4-3.

b. The elements of the fire commands are explained in paragraphs 4-30 through 4-40. Some of the elements are used only under special circumstances and are not announced when they have no practical application.

4-30. Pieces to Follow Commands

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

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

b. To alert the base piece, the command is BASE PIECE ADJUST (NUMBER 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. For example, a command might be NUMBERS 2, 3, 4, and 5 ADJUST.

4-31. Special Instructions

The element *special instructions* is used in the cases discussed in *a* through *d* below.

a. In those cases in which a particular pattern of bursts is desired, the S3 may direct that special corrections be applied. Special corrections are the sum of position corrections and calibration corrections and usually are computed at the fire direction center. When special corrections are to be used in a mission, the command SPECIAL CORRECTIONS is given as the second element of the initial fire commands to alert all personnel that a separate deflection, fuze setting, and quadrant elevation will be announced for each piece throughout the mission.

b. The application of a deflection difference is a rapid method of obtaining a width of sheaf different from the width of a parallel sheaf. When the S3 directs that a deflection difference be applied, the fire commands from the FDC will contain, as the second element, the data necessary for the executive officer to compute the deflection difference; namely, the desired width of sheaf and the range to the target. An example of such a command is BATTERY ADJUST, SHEAF 100 METERS AT 5000, SHELL HE, etc. The desired width of sheaf and the range to the target are not announced to the pieces. The command to the pieces to apply a deflection difference is part of the element of direction (para 4-38*c*).

c. In units in which the pieces are equipped with on-carriage elevation fire control instruments, the command USE GUNNER'S QUADRANT is announced as the second element of the fire commands in all missions in which the use of the gunner's quadrant is desired.

d. When a large deflection shift is indicated, loss of time, caused by shifting trails, can be minimized by announcing a rough azimuth as special instructions immediately following BATTERY ADJUST. Example: BATTERY ADJUST, AZIMUTH 1000.

4-32. Projectile

The element *projectile* indicates the type of projectile that will be used in attacking the target. This element is always announced in the initial fire commands and is not announced thereafter, unless a change is desired.

4-33. Ammunition Lot

The element *ammunition lot* indicates the lot number of the ammunition to be fired. The lot number, when applicable, is announced in the initial fire commands and is not announced thereafter unless a change is desired. For 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. For separate-loading ammunition, the lot number pertains to a specific projectile-propellant combination and may be coded XY, in which X is the projectile lot and Y is the propellant lot. Large-quantity lots are reserved for registrations and subsequent transfers of fire. The lot number will be announced by the FDC or pre-

Table 4-3. Sequence of Fire Commands

Sequence			When announced	
Number	Element of fire command	Example	Initial fire command	Subsequent fire command
1	Pieces to follow commands	BATTERY ADJUST	Always	Never
2	Special instructions	SPECIAL CORRECTIONS USE GUNNER'S QUADRANT	When applicable	When applicable
3	Projectile	SHELL HE	Always	When changed
4	Ammunition lot	LOT XY	When applicable	When changed
5	Charge	CHARGE 5	Always (except for fixed ammunition)	When changed
6	Fuze	FUZE QUICK	Always	When changed
7	Pieces to fire	CENTER	Always	When either is changed
8	Method of fire	1 ROUND, BATTERY 3 ROUNDS TIME IN EFFECT	Always	When either is changed
9	Direction	DEFLECTION 3239	Always	When changed
10	Fuze setting	TIME 18.0	When applicable	When changed
11	Quadrant elevation	QUADRANT 293	Always	Always

arranged between the FDC and the firing battery. Small-quantity lots should be used on battery observer-adjusted missions. The chiefs of sections must segregate ammunition by lot number and must keep an accurate record of lots available.

4-34. Charge

The element *charge* indicates the amount of propellant to be used. This element is always announced in the initial fire commands for weapons that use other than fixed ammunition. If more than one type of propellant is available, the type (white bag or green bag) to be used is designated by the lot of propellant announced in the initial fire commands. If ammunition has numbered charges, the command specifies the number of the charge to be fired.

4-35. Fuze

The element *fuze* indicates the type of fuze to be employed. This element is always announced in the initial fire commands. It is announced in subsequent fire commands only when a change of fuze is desired.

4-36. Pieces to Fire

The element *pieces to fire* designates the pieces that are to be fired. This element is always announced in the initial fire commands. It is not announced in the subsequent fire commands unless it is changed or the method of fire is changed.

a. Any or all of the pieced alerted by the first element of the fire commands may be designated to fire. If an adjustment is to be made in area fire, the two center pieces normally will be fired during the adjustment.

b. When all pieces in the battery are to be fired, the command is BATTERY. When the pieces in a platoon are to be fired, the command is LEFT (CENTER) (RIGHT). Any other combination of pieces within the battery or an individual piece is designated by number; e.g., NUMBERS 1 AND 6 or BASE PIECE (NUMBER 1) (NUMBER 2).

4-37. Method of Fire

The element *method of fire* indicates the number of rounds that are to be fired by the pieces designated to fire and the way in which those rounds are to be fired. This element is always announced in the initial fire commands. It is not announced in the subsequent fire commands unless it is changed or the pieces to fire is changed. If an adjustment is to be conducted on an area target, the method of fire for the adjusting battery may be followed by certain commands applicable to fire for effect (*c* below). If any restriction is imposed on the time of opening fire (*e*(1), (2), and (3) below), the restrictive command is announced as part of the method of fire.

a. (So many) ROUNDS. The command for firing one round from one piece or from each of several pieces is 1 ROUND. In precision fire or assault fire, the pieces to fire and the method of fire in the adjustment usually are BASE PIECE 1 ROUND OR NUMBER (so-and-so) 1 ROUND. In area fire, the pieces to fire and the method of fire in the adjustment usually are CENTER 1 ROUND. The command for firing two or more rounds from one piece is (so many) ROUNDS. The first round is fired on the executive officer's command FIRE. The subsequent rounds are fired on the command of the chief of section as rapidly as possible consistent with accuracy. The command for firing two or more rounds from each of several pieces also is (so many) ROUNDS. The first rounds from the pieces are fired simultaneously on the executive officer's command FIRE. Each piece fires the designated number of subsequent rounds on the command of the chief of section as rapidly as possible consistent with accuracy and without regard to the readiness of the other pieces.

b. Right (Left). The command for firing the pieces in succession at 5-second intervals is RIGHT (LEFT). On the executive officer's command FIRE, the right (left) piece is fired, followed at 5-second intervals by each successive piece to the left (right). If an interval other than 5 seconds is desired, the desired interval is announced as part of the method of fire; for example, RIGHT (LEFT) AT 2 SECONDS. If more than one round per piece is to be fired, the command is RIGHT (LEFT) (so many) ROUNDS. On the executive officer's command FIRE, the first round is fired from the right (left) piece, followed at 5-second intervals by the first round from each successive piece to the left (right). The subsequent rounds from each piece are fired in a similar manner.

c. Rounds In Effect. The initial fire commands for an adjusting battery in an area mission will include, immediately following the pieces to fire and method of fire to be used in the adjustment, the pieces to fire for effect, the method of fire to be used in fire for effect, and the fuze and/or shell to be used in fire for effect when other than that to be used in the adjustment; for example, CENTER 1 ROUND, BATTERY 4 ROUNDS VT IN EFFECT or CENTER 1 ROUND, BATTERY 5 ROUNDS IN EFFECT.

d. Continuous Fire. Continuous fire is a method of fire in which all pieces fire as rapidly as possible consistent with the prescribed rate of fire for the weapon. At the command CONTINUOUS FIRE, the crews will load and begin firing. Firing will continue until it is terminated by the command END OR MISSION or is temporarily suspended by the command CEASE LOADING or CHECK FIRING. CANCEL CEASE LOADING AND CANCEL CHECK FIRING, respectively, negate CEASE LOADING and CHECK FIRING.

e. Restrictions on Opening Fire. Unless the FDC imposes a restriction on the opening of fire by including a supplemental command with the method of fire, the executive officer commands FIRE when the pieces to fire are ready to fire. The supplemental commands that are used by the FDC to control the opening of fire are discussed in (1) through (3) below.

(1) *At my command.* To control the exact time of opening fire by the pieces to fire, the FDC announces AT MY COMMAND immediately after the method of fire; for example, 1 ROUND, AT MY COMMAND. When the pieces to fire are ready to fire, the executive officer reports the fact to the FDC; for example, BATTERY IS READY. The executive officer gives the command FIRE when he receives it from the fire direction center. The command AT MY COMMAND remains in effect during a mission until it is superseded by a method of fire not coupled with AT MY COMMAND.

(2) *By piece at my command.* To control the time of firing of each piece to fire, the FDC announces BY PIECE AT MY COMMAND immediately following the method of fire; for example, 1 ROUND, BY PIECE AT MY COMMAND. When the pieces to fire are ready to fire, the executive officer reports the fact to the FDC; for example, BATTERY IS READY. The executive officer repeats the commands to fire when he receives them from the FDC; for example, NUMBER 1, FIRE; NUMBER 2, FIRE; and so on. BY PIECE AT MY COMMAND remains in effect during a mission until it is superseded by a method of fire not coupled with BY PIECE AT MY COMMAND.

(3) *Do not load.* When exact firing data or time of firing has not been determined, it may be desirable for the pieces to be laid but not loaded. In such a case, the FDC announces initial fire commands and includes the command DO NOT LOAD with the method of fire; for example, 3 ROUNDS, DO NOT LOAD. The fire commands alert the executive officer of the fire mission. By announcing the fire commands, he can cause the crews to lay the pieces and to make the necessary preparations for firing the mission. When the pieces to fire are laid in accordance with the fire commands, the executive officer reports the fact to the FDC; for example BATTERY IS LAID. To cancel DO NOT LOAD, the FDC must announce in subsequent fire commands a method of fire not coupled with DO NOT LOAD.

f. Zone Fire.

(1) Zone fire is a method of fire in which the designated pieces fire in a constant direction at several quadrant elevations. The normal command for zone fire consists of two parts—the number of rounds to be fired at each quadrant elevation and the zone (in mils). The quadrant elevation, announced as the last element of the fire commands, establishes the center of the zone. The normal command is (so many) ROUNDS, ZONE (so many) MILS. The executive officer has the designated pieces fire the announced number of rounds at the announced quadrant elevation and then the same number of rounds at plus and minus the announced number of mils from the center quadrant elevation. If, for example, the commands include BATTERY 3 ROUNDS ZONE 5 MILS, QUADRANT 240, the executive officer has each piece in the battery fire three rounds at quadrant elevation 240, three rounds at 245, and three rounds at 235.

(2) In some cases, the executive officer may receive the command (so many) ROUNDS, ZONE (so many) MILS, 5 QUADRANTS. The executive officer has the designated pieces fire the designated number of rounds at the announced quadrant elevation and then, in any sequence, has the pieces fire the designated number of rounds at four other quadrant elevations the announced number of mils apart. If, for example, the commands include BATTERY 2 ROUNDS, ZONE 5 MILS, 5 QUADRANTS, QUADRANT 190, the executive officer has each piece in the battery fire two rounds at quadrant elevation 190, two at 200, two at 180, two at 185, and two at 195.

(3) The zone command is not transmitted to the weapons. The executive officer controls the battery by announcing each quadrant elevation in turn. Because of the large expenditure of ammunition during zone fire, the executive officer, as soon as possible, must notify each piece of the number of rounds to prepare.

g. Fire At Will. Fire at will is a method of fire used for direct fire. The command for pieces to fire at will 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 chiefs of sections as the situation and target necessitate.

h. Shifting Fire.

(1) When the width of the target is so great that the target cannot be covered effectively with an open sheaf, the target may be attacked by successive shifts.

(2) In shifting fire, the battery is laid first on one portion of the target and then successively laid on the other portions to be covered. Fire by the battery is delivered alternately on each portion of the target.

4-38. Direction

The element *direction* indicates the deflection on which the piece(s) is to be laid.

a. The command to lay the piece for direction is DEFLECTION (so much). This element is always given in the initial fire commands but is given in subsequent fire commands only when it is changed. The gunner sets off the deflection on his panoramic telescope and then traverses until he is sighted on the proper aiming point. The announced deflection is the sum of the chart deflection and the deflection correction, if any.

b. If special corrections are to be used, the computer at the FDC combines the special corrections for deflection, the deflection correction, and the chart deflection and announces the total deflection for each piece (e.g., DEFLECTION NUMBER 1, 3263; NUMBER 2, 3261; etc).

c. If a deflection difference is to be applied, the deflection difference is announced as part of the direction element, following the common deflection (e.g., DEFLECTION 3222, ON NUMBER 3, CLOSE 2). Each gunner determines the deflection difference for his piece by multiplying the announced number of mils by the number of piece intervals between his piece and the piece on which the sheaf is being opened or closed. The gunner applies the computed deflection difference in the proper direction. For example, if the direction element includes the command ON NUMBER 3, CLOSE 3, the gunners will apply corrections as follows: number 1, left 6; number 2, left 3; number 3, 0; number 4, right 3; number 5, right 6; number 6, right 9. The command for a deflection difference remains in effect until the end of the mission unless a command for another deflection difference is given or the command PARALLEL, which cancels the deflection difference, is given.

d. The unit standing operating procedure may specify that the deflection correction be applied to the gunner's aid for each piece. In such a case, the direction element will include a command indicating the direction and magnitude of the deflection correction; i.e., CORRECTION, LEFT (RIGHT) (so much), DEFLECTION (so much). The deflection correction is announced in the initial fire commands only. The deflection correction must be applied to the gunner's aid before the chart deflection is set off. When special corrections are to be used, the FDC combines the deflection correction (from the deflection correction scale) and the special correction for deflection and announces the total deflection correction for each piece (e.g., CORRECTION, NUMBER 1 LEFT (RIGHT) (so much)) prior to the announcement of the common (chart) deflection.

4-39. Fuze Setting

The element *fuze setting* indicates the proper setting for time fuze or VT fuze and is given only when applicable to the mission.

a. When time fuze in effect has been specified, a fuze setting will be required in the fire commands after the adjustment with fuze quick. The element is announced thereafter only when a change in fuze setting is desired. The same procedure applies when a fuze setting with VT fuze is used. Fuze setting for time fuze is computed and announced to the nearest tenth (e.g., TIME 17.4), but fuze setting for VT fuze is announced as a whole number expressed to the tenth (e.g., TIME 17.0 or 21.0).

b. When special corrections are to be used, the FDC combines the special correction for fuze setting and the common fuze setting and announces the total fuze setting for each piece (e.g., TIME, NUMBER 1, 28.4; NUMBER 2, 28.6; etc.).

4-40. Quadrant Elevation

The element *quadrant elevation* indicates the quadrant elevation at which the piece(s) is to be fired. This element is always announced in the initial fire commands and in subsequent fire commands.

a. Quadrant elevation is the sum of elevation plus site. The command to lay for quadrant elevation is QUADRANT (so much).

b. When special corrections are to be used, the FDC combines the special correction for elevation and the common quadrant elevation and announces the total quadrant elevation for each piece (e.g., QUADRANT, NUMBER 1, 293; NUMBER 2, 296; etc.).

c. The command for quadrant elevation is the command to load the piece, except when DO NOT LOAD is a part of the method of fire or when a salute is being fired.

d. Unless the method of fire includes BY PIECE AT MY COMMAND, AT MY COMMAND or DO NOT LOAD, the command for quadrant elevation received from the FDC gives the executive officer the authority to fire when ready. When all pieces to fire are ready, the executive officer commands FIRE. The chiefs of section will repeat the command FIRE as it is given. The command FIRE should be delayed only when a substantial reason for a delay exists; for example, a safety or accuracy check.

4-41. Examples of Fire Commands

All commands received from the FDC are repeated by the executive officer or designated personnel of the firing battery unless otherwise noted.

a. An example of the initial fire commands for a precision registration is shown below.

BASE PIECE ADJUST
SHELL HE
LOT XY
CHARGE 4
FUZE QUICK
BASE PIECE 1 ROUND
DEFLECTION 3450
QUADRANT 315

b. An example of the initial fire commands for zone fire is shown below.

BATTERY ADJUST
SHELL HE
LOT XY
CHARGE 5
FUZE QUICK
BATTERY 1 ROUND
ZONE 4 MILS
DEFLECTION 3480
QUADRANT 268. (QUADRANT elevations 268, 272, and 264 will be fired.)

4-42. Check Firing

The command CHECK FIRING normally is given by the executive officer but, in an emergency, may be given by anyone. 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 originates from the observer or FDC and the piece is loaded, the executive officer reports NUMBER 2 (or other piece) LOADED. If firing is stopped by someone at the position, the executive officer reports that fact and the reason to the fire direction center. Firing is resumed at the announcement of CANCEL CHECK FIRING followed by the quadrant.

4-43. End of Mission

The command END OF MISSION means that the fire mission has been completed.

4-44. Repetition of Commands

a. By Chief of Section.

(1) *Voice communication.* When the executive officer controls the battery by means of voice communication, the chief of section repeats the commands FIRE and CHECK FIRING. He repeats any other commands given by the executive officer only when he is requested to do so or when the commands obviously have not been heard or understood by the crew. The request for repetition is stated as a question (e.g., DEFLECTION NUMBER (so-and-so)?; QUADRANT NUMBER (so-and-so)?).

(2) *Intrabattery communication.* When wire communication is used between the executive officer's command post and the individual sections, the read-back of elements of the fire commands will be governed by unit standing operating procedure. The cannoneer operating the telephone must announce each element of the fire commands to his section.

b. By Executive Officer. The repetition of commands by the executive officer or the person transmitting commands to the pieces after he has announced them is always preceded by THE COMMAND WAS (e.g., THE COMMAND WAS, DEFLECTION 2768). When special corrections have been announced as a special instruction, the person transmitting the commands should after a request for repetition, repeat the special corrections for the requesting piece as it relates to that element of the fire commands (e.g., THE COMMAND WAS NUMBER 3, TIME 21.8).

4-45. Signals

Arm and hand signals are used in conjunction with oral commands to achieve greater clarity. The chief of section extends his right arm vertically, with the palm of his hand toward the executive officer (the ready position), to indicate that his piece is ready to fire. When he cannot be seen by the executive officer, he reports NUMBER (so-and-so) READY. The commands Fire and CHECK FIRING usually are given by arm signals as well as by voice. The signal for FIRE is either 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 CHECK FIRING is to raise the hand in front of the forehead, palm to the front, and swing the hand and forearm up and down in front of the face.

4-46. Final Protective Fires

a. The battery final protective fire (FPF) is a prearranged barrier of fire designed to be fired quickly on a critical line or area. It is a high priority fire mission that takes precedence over all other fire missions. When the battery is not firing other missions, it is laid on its final protective fire and appropriately prepared rounds are kept at the pieces.

b. The final protective fire may be initiated by the command FIRE THE FINAL PROTECTIVE FIRE or by a prearranged signal. If the command or signal is received when the crews are resting, the piece sentinels begin firing immediately on the command FIRE THE FINAL PROTECTIVE FIRE or on receipt of the prearranged signal.

4-47. Reports

The executive officer 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, CHECK FIRING), the following specific reports are made:

a. SHOT (NUMBER (so-and-so) SHOT)—when the first round of a series has been fired. The number of the piece that is firing is included in the report (e.g. NUMBER 1 SHOT) only if BY PIECE AT MY COMMAND was included in the method of fire.

b. ROUNDS COMPLETE—when the number of rounds specified in fire for effect have been fired (other than NUMBER (so-and-so) 1 ROUND).

c. MISFIRE NUMBER (so-and-so)—when a misfire has occurred. The executive officer reports NUMBER (so-and-so) IS READY when the piece is again ready to fire and the fire mission has not been completed.

d. number (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)—when the fire mission has been completed.

f. Errors—when any round has been fired with incorrect data. The chief of section must report immediately to the executive officer all errors that have caused a round to be fired with incorrect data. The executive officer has these errors corrected and reports to the FDC; e.g., NUMBER 2 FIRED 20 MILS RIGHT: ERROR HAS BEEN CORRECTED.

4-48. Checking Setting During Firing

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

4-49. Correcting Fire Commands by Executive Officer

a. If an incorrect command has been announced but the command FIRE has not been given, the executive officer announces CORRECTION and then announces the correct command and all subsequent elements.

b. If the command FIRE has been given, the executive officer announces CHECK FIRING. He then announces CANCEL CHECK FIRING and announces the correct command and all subsequent elements. Firing continues with the announcement of QUADRANT.

Section V. ASSAULT AND DIRECT FIRE

4-50. Assault Fire

a. Assault fire is a special technique of indirect fire. Fire is conducted 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 portions of the target. Only one piece is used on a mission, and the FDC for the mission normally is located at the gun (howitzer) position. Thorough planning, reconnaissance, and coordination must be completed before the gun (howitzer) 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 howitzer, and the 175-mm gun. 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 meters for the 8-inch howitzer and 2,500 meters for the 155-mm howitzer and the 175-mm gun.

4-51. Assault Fire 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 has been obtained; further changes are made to the nearest ¼ mil. One-fourth mil can be set on weapons equipped with the M100 sights. For weapons with other sights, a deflection board attached to an aiming post is used for this purpose. The deflection board (fig 4-15) enables the gunner to make deflection changes to ¼ mil. The black and white bands (lines) are ¼ mil in width when viewed through the sight of the piece at a distance of *exactly 50 meters.* The gunner lays on the desired portion of the board by centering the vertical crosshair of the sight on a black (white) band on the board. To move ¼ 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 ½ mil he moves the vertical crosshair two bands; etc.

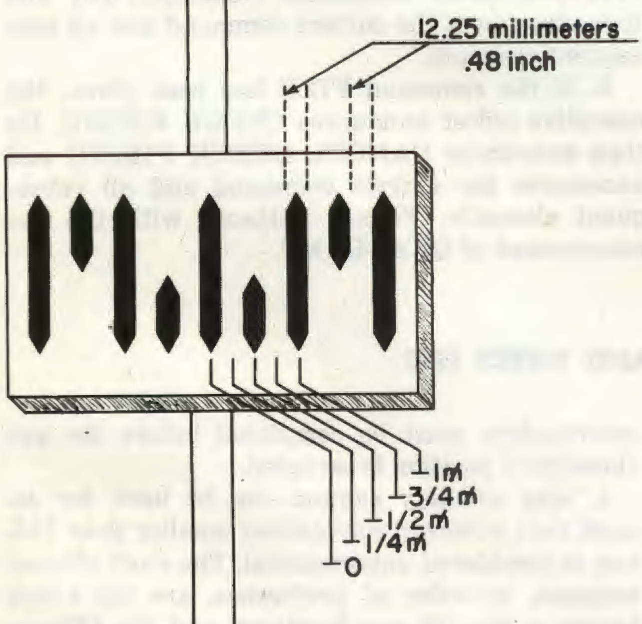


Figure 4-15. Deflection board.

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

4-52. Direct Fire

Firing by direct laying is a special technique that demands a high standard of training. The section must operate as an independent unit. Enemy targets taken under fire by direct laying procedures are usually those capable of returning fire at pointblank range; therefore, speed and accuracy in direct fire are of the utmost importance.

a. Methods of Sighting.

(1) *Two-man, two-sight.* In the two-man, two-sight system, the gunner establishes lead with the panoramic telescope and the assistant gunner establishes elevation with the direct fire telescope. This system is the fastest and most accurate method of sighting and permits the assistant gunner to check the direction of lead. A canted reticle in the direct fire telescope will prevent satisfactory direct fire on moving targets because an unacceptable range error is introduced when lead is changed.

(2) *Two-man, one-sight.* In the two-man, one-sight system, the gunner establishes lead with the panoramic telescope and the assistant gunner sets elevation on the elevation quadrant at the command of the chief of section. This system is most effective when the target is moving on flat terrain.

(3) *One-man, one-sight.* In the one-man, one-sight system, the gunner lays for lead and elevation with the reticle of the panoramic telescope. This system should not be used if the target is moving on a steep slope.

b. Methods of Laying.

(1) *Reticle laying with deflection zero.* The gunner maintains lead by placing the verticle hairline the proper number of mils ahead of the center of the target.

(*a*) *Continuous tracking.* Lead and elevation are laid and maintained in tracking the target.

(*b*) *Laying ahead.* The gunner does not track the target but lays ahead of it for lead and adjusts the elevation as the target approaches the correct lead.

(2) *Central laying.* The gunner sets the lead in mils on the azimuth micrometer scale of the panoramic telescope and maintains the verticle hairline of the reticle on the center of the target. A modification on the knob of the M100 series panoramic telescope, called click sights, permits the gunner to set off lead in 5-mil in-

crements, by sound or feel, without removing his eye from the sight.

c. Direct Fire Characteristics. The direct fire characteristics of current standard field artillery weapons vary widely. For a discussion of a particular weapon, see the field manual for the weapon involved.

CHAPTER 5
FIRING BATTERY OPERATIONS AND TRAINING

Section I. GENERAL

5-1. Introduction
Field artillery doctrine demands the delivery of timely and accurate fires. The firing battery, as part of the gunnery team, bears a large share of the responsibility for the delivery of effective fire. The battery executive officer is in direct charge of the training and operation of the firing battery. During training he must institute practices and procedures which will assure the accurate and timely execution of fire commands.

5-2. Principles of Training
a. Proper training of the firing battery starts with the training of each individual in the specific duties in service of the piece prescribed in the appropriate manual. Next is the training of the section as a team. Finally, the sections are brought together and trained as the firing battery. Standing operating procedures must be developed as training progresses.

b. Accuracy must be emphasized in the initial stages of each phase of training. As training progresses, speed is gradually gained but loss of accuracy is not tolerated.

c. The firing battery must be trained to occupy position and execute fire commands during darkness and inclement weather.

5-3. Conduct of Service-of-the-Piece Drill
a. Successful operation of the firing battery depends primarily on instilling pride into the firing battery personnel in the rapid and precise execution of all commands. The success of service-of-the-piece drill depends on the ability of the chiefs of sections and the executive officer and his assistants to recognize unsafe, incorrect, or careless performance of duties by individuals. Service-of-the-piece drills provide practice and test the whole team as well as the individual members. Pieces should be placed close together to facilitate observation and supervision. Telephone communications may be installed to train section personnel in the use of telephones for receipt of commands.

b. Drills should be kept interesting, short, and snappy, with frequent rest periods. The gunner and all cannoneers may exchange positions after they have gained full proficiency in their own jobs. The executive officer frequently should time the sections with a stopwatch to emphasize speed as well as accuracy. Specific individuals should be assigned to observe and check specific items. The use of command cards will speed and improve the conduct of the drill. Occasionally, the chiefs of sections should be drilled separately in setting the gunner's quadrant, to include making changes in elevation to the nearest 0.1 mil.

c. The battery must be trained to execute all possible fire commands. 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 that require shifting of trails should be avoided except when training is being conducted in trail shifting. The method of fire should be changed frequently to teach the various 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.

5-4. 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. Leveling Vial. After the breech is closed and before the weapon is fired, the bubbles of the leveling vials must be centered exactly.

b. Indexes. The proper graduation must be alined exactly with the index.

c. Micrometer Knobs. When the scales are being set, the last motion of the micrometer knobs must be from the lower to the higher reading.

d. Traverse. The last motion of the traversing handwheel should cause the vertical hairline of the panoramic telescope to approach the aiming point from left to right; if the collimator is being used, the appropriate lead line in the reticle pattern of the panoramic telescope should approach the aiming point from left to right. If the vertical hairline or appropriate lead line 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 of the aiming posts when exactly vertical) or with the appropriate lead line lined up with the number displayed in the collimator.

e. Fuze Setters and Fuzes. When settings on the fuze setter are being made, the last motion should be in the direction of increasing readings.

f. Elevation. When the tube of any field artillery piece is elevated or depressed, the last motion of the handwheel should be in the direction which offers the greatest resistance. If the desired elevation is passed, the handwheel should be turned back one complete turn before the bubble is centered.

g. Aiming Posts. The far aiming post should be approximately 100 meters from the sight of the piece. The near aiming post must be halfway between the piece and the far aiming post. The chief of section and the gunner must check to insure that the aiming posts are placed at the proper distances and that they are exactly vertical and alined.

h. Uniformity in Ramming. Uniform ramming helps prevent unusual variations in muzzle velocity. Nonuniform ramming may cause variation 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. Hard ramming is essential to safety. If the projectile is not seated firmly, particularly at high quadrant elevations, it may slip back into the powder chamber and rest on the charge. Firing the weapon with the projectiles in this position may cause a premature detonation, which could result in a serious accident.

5-5. Equipment Checks

a. 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. Sighting and laying equipment should be checked immediately after the battery goes into firing position. Some tests and adjustments are made periodically or when the need is evident. Refer to the appropriate technical manual for those adjustments which may be made by battery personnel.

b. Boresighting is the process by which the optical axes of the panoramic and elbow telescopes are made parallel, to the axis of the bore, when the scales of the mounts and telescopes are set at 0 or 3200 as appropriate. (Refer to the specific weapon field manual for the methods of boresighting.)

Section II. FIELD OPERATIONS OF THE FIRING BATTERY

5-6. Duties of the Battery Executive Officer

The duties of the battery executive officer in field operation of the firing battery are as follows:

a. Before the battery leaves the motor park or assembly area, he—

(1) Insures that equipment and ammunition are complete, serviceable, and properly stored.

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

b. At the firing position, he—

(1) Supervises the occupation of position.

(2) Lays the battery or verifies the laying of the battery.

(3) Checks communications.

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

(5) Determines minimum quadrant elevations.

(6) Gives the executive officer's report to the FDC.

(7) Has the pieces boresighted when time permits.

(8) Directs and supervises the firing battery in the delivery of fire.

(9) Insures compliance with safety rules.

(10) Insures uniform and adequate storage of ammunition.

(11) Supervises accounting of ammunition to include lot segregation and control.

(12) Supervises fire direction when the mission is being conducted by the battery.

c. Prior to entering combat (actual or simulated), he 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, light discipline, and other measures.

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

(5) Operating efficiently within safety rules.

5-7. Duties of the Recorder

a. The recorder is an assistant to the battery executive officer. As his title implies, he maintains certain records for the executive officer. In addition, he installs and operates the necessary telephones. Among those records that he maintains are—

(1) DA Form 3623 (Firing Battery Recorder's Sheet), (fig 5-1), on which he records laying data, fire commands, and a running total, by type and lot, of ammunition on hand in each section. (DA Form 3623 is available through normal AG Publication supply channels.)

(2) A file of data on prearranged fires to include the final protective fire data.

(3) A record of the minimum quadrant elevations and a record of the referred deflections for each weapon.

b. When directed to do so, the recorder announces fire commands to the pieces.

5-8. Records and Data Maintained in the Firing Battery

In addition to the records kept by the recorder (para 5-7), the following records are also kept in the firing battery and must be checked by the executive officer for completeness and accuracy:

a. A Firing Battery Section Data Sheet (DA Form 4007) (fig 5-2) for each section is usually prepared by the FDC for prearranged and close-in defensive fires. The section data sheet contains the information necessary to permit the chief of section to fire the listed targets. The chief of section is responsible for announcing the fire commands directed on the section data sheet. (DA Form 4007 is available through normal AG publication supply channels.)

b. Each section maintains a US Army equipment log book for recording the history of the carriage or mount and the tube data. DA Form 2408-4, (Weapon Record Data) which is filed in the equipment log book, serves as a permanent life history of a weapon and must accurately reflect the ammunition fired and the dates of firing. Entries must be checked periodically, especially calibration data and ordnance service entries. The artillery mechanic keeps an up-to-date record of all maintenance performed on the weapon to supplement data in the weapon record book.

FIRING BATTERY RECORDER'S SHEET

For use of this form, see FM 6-40; proponent agency is US Army Training and Doctrine Command.

BATTERY	DATE	PAGE NUMBER
A	19 Aug	1

BATTERY LAID ON			
AZIMUTH	AZIMUTH OF OL	ORIENTING ANGLE	DEFLECTION
1620	2150	530	3200

FIRE COMMANDS										AMMUNITION AND FUZES ON HAND									
										HE X	HE V	HE T	WP W	SMK Z	GB Y	WB U	M 557	M 564	M 514 A-1
PIECES TO FOLLOW	SP INSTR	SH	LOT	CHG	FZ	PIECES TO FIRE/MF	DF	TI	QE	200	100	50	30	20	300	100	200	100	50
										AMMUNITION EXPENDED									
BA	AZ 1800	HE	XY	5	Q	C ① B①UT	3070	—	306	②					②		②		
							3036	—	314	④					④		④		
							3042	—	310	⑥					⑥		⑥		
					VT	B①		19.0	310	⑫					⑫				⑥
				E	M	TGT	AF7	001		188	100	50	30	20	288	100	194	100	44
BA	SP CORR	HE	XU	7	Ti	B③ AMC													
						#1	3148	14.8	228										
						#2	3150	14.8	229										
						#3	3151	14.9	231										
						#4	3153	14.9	232										
						#5	3154	14.8	228										
						#6	3155	14.8	227	⑱						⑱		⑱	
				E	M	TGT	AF7	036		170	100	50	30	20	288	82	194	82	44
#6 A	UGQ*	HE	TY	5	D	#6①	0018		367.3			①			①		①		
	AZ 4700						0019		368.0			②			②		②		
*Use gunner's	quadrant.				E	M TGT	AF 70	02		170	100	48	30	20	286	82	192	82	44

DA FORM 1 AUG 70 3623

REPLACES DA FORM 6-17, 1 AUG 62, WHICH IS OBSOLETE.

Figure 5–1. Firing Battery Recorder's Sheet (DA Form 3623).

FIRING BATTERY SECTION DATA SHEET For use of this form, see FM 6-40; proponent agency is US Army Training and Doctrine Command.							SECTION			BATTERY		DATE / PAGE NO.
TGT NO.	TIME		AMMUNITION				METHOD OF FIRE	CORR	DF	TIME	QE.	REMARKS
	FROM	TO	SH.	LOT	CHG	FZ.						
AF 7403	0515	0519	HE	XY	5	Ti	B⑧		3362	17.5	260	
AF 7405	0522	0524	HE	XY	5	Q	B②		3261		236	
AF 7412	0525	0527	HE	XY	5	VT	B④		3181	14.5	218 221 215	ZONE 3 m/
AF 7410	0528	0530	HE	XY	5	Q	B④		3518			
FPF	ON CALL		HE	XY	4	Q	CONT FIRE	#1	3314		217	
								#2	3316		216	
								#3	3313		217	
								#4	3315		213	
								#5	3317		215	
								#6	3316		218	

DA FORM 4007, 1 JAN 73

REPLACES DA FORM 6-13, 1 DEC 63, WHICH IS OBSOLETE.

Figure 5-2. Firing Battery Section Data Sheet (DA Form 4007).

Section III. CARE AND HANDLING OF AMMUNITION

5-9. Ammunition References

The technical manual issued with each weapon contains a list of authorized ammunition, instructions for marking and packing ammunition, and other technical information. For a general discussion of ammunition, see TM 9-1300-200; for characteristics of all types of artillery ammunition, see TM 9-1300-203.

5-10. 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. Firing battery personnel must have detailed knowledge of the marking, purpose, and functioning of each component.

b. Basic principles of ammunition handling for firing battery personnel are as follows:

(1) Know in detail how to assemble and prepare the ammunition.

(2) Do not tumble, drag, throw, or drop boxes of ammunition or ammunition components.

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

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

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

(6) Never make unauthorized alterations on ammunition or mix components of one lot or round of ammunition with those of another.

(7) Do not reuse cartridges or projectiles which have been extracted from weapons by ramming. Extraction difficulty may have been caused by some nonstandard condition in the ammunition, or the fuze may have been damaged during extraction.

5-11. Projectiles

a. Each projectile must be inspected to insure that there is no leakage of the contents, that it is correctly assembled, and that the bourrelet and rotating band are smooth and free of burs and large dents. If the rotating band is burred or nicked, it should be smoothed with a flat, fine-grained file or with crocus cloth backed with a small block of wood. Projectiles, especially those that are issued unfuzed, are relatively safe from detonation by small-arms fire or shell fragments. On separate-loading ammunition, the lifting plug should be kept tight in the shell nose until the projectile is ready for use. This will prevent moisture from affecting the explosive and prevent the lifting plug from rusting in place. The rotating band grommet must be secure and tight to prevent nicking and scarring the comparatively soft rotating band.

b. High-explosive projectiles issued for use with VT fuzes are standard projectiles with the fuze and booster cavities deepened to accommodate the longer VT fuze. Each of these projectiles is issued with a removable supplementary charge so that the projectile may be used with either an impact fuze, a mechanical time fuze or a VT fuze. The supplementary charge is removed only when the projectile is used with a VT fuze and must be in place when the projectile is used with a mechanical time fuze or an impact fuze.

Warning: **Do not attempt to remove the supplementary charge by any means other than the lifting loop. If the charge cannot be removed by the lifting loop, the round may be disposed of or fired with a PD fuze or an MT or MTSQ fuze. The deep cavity may be lined with a paper tube and bottom cup which help support the high-explosive filler. This lining will not be removed at any time.**

5-12. Propelling Charges

a. Care must be exercised to insure that all increments of a propelling charge 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 a propelling charge for firing must count and identify by number not only the increments removed from a charge but also the increments not removed. This precaution will help eliminate mistakes in the preparation of the charge and will also enable the cannoneer to detect missing or duplicate increments. Propellant bags should not be torn or ripped, and there should be no leakage of contents. Before the charge for a round of separate-loading ammunition is loaded, the data tag and igniter pad cover must be removed. Ammunition which has been prepared for a certain charge should be carefully segregated from other ammunition. 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, a higher charge than originally planned may be fired or the ammunition may be repacked conveniently. Increments left over from charges already fired are immediately removed to a point 30 to 40 feet from the nearest weapon or ammunition until the battery personnel can dispose of them.

b. It is not practical to salvage unused increments. Unused increments may be burned in the open in small quantities. If large quantities of unused increments are burned, they may explode. When it is necessary to destroy the base charge of a round of separate-loading ammunition, the igniter pad should be separated from the base charge and handled in accordance with the provisions of TM 9-1300-206. The person disposing of the igniter pad should not cut it open with a metallic object, such as a knife, since it may cause premature ignition.

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 and from the direct rays of the sun. High temperatures greatly accelerate the normal rate of deterioration and cause excessive and irregular chamber pressures in firing, which result in erratic ranges (para 2-9*g*). Sudden changes in temperature may also cause moisture to condense on the charges. At the battery position, the propellant temperature of ready ammunition (propellant charges) that is representative of ammunition designated for early use should be checked periodically. The rounds or propellant charges so checked should not be removed from the rest of the ammunition. The temperature should be measured in place so that a true mean can be obtained. The thermometer should penetrate the charge that is being used, and it must not touch any metal.

5-13. 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. Striking the base of a cartridge case may cause accidental firing of the primer. A badly corroded cartridge case is difficult to extract from the chamber and may rupture. With semifixed ammunition, it is important that the mouth of the case not be deformed. A deformed case is difficult to load and may result in a serious blowback if fired.

5-14. Fuzes

a. Fuzes are sensitive to shock. Moisture or high temperature may impair the functioning of a fuze. Each fuze should be inspected carefully to ascertain that it is properly assembled and set. A separate fuze should be tightened as much as possible by hand and then should be firmly seated with a sharp snap of the M18 fuze wrench. Care must be taken to start the mesh of the threads properly. When a fuze is 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.

b. In an adjust fire mission, *initial* fuze settings for the nonadjusting batteries will not be set on the fuzes. In a mission in which the method of fire includes DO NOT LOAD, fuze settings will not be set on the fuzes until a method of fire that permits loading the weapons is received. (When the mechanical time fuze setter is used, the time is set on the fuze setter when the time is announced.) This will preclude setting the fuze more than once if a different fuze setting is required when the final time is announced. When time fuze has been set but not fired, the fuze is reset to SAFE and the safety pin is inserted before the fuze is replaced in the container.

c. A fuze setter graduated to suit the fuze is required for accurate and rapid setting of a time fuze. A number of models of fuze setters have been standardized. The details of the use of fuze setters are contained in the appropriate field manual for the weapon.

d. Proximity VT fuzes belong to a class of special fuzes for use with deep cavity high-explosive projectiles (para 5-11*b*). The length of the fuze booster assembly of a VT fuse is longer than that of a standard impact fuze. The VT fuze is completely boresafe. The arming mechanisms or the M513- and M514-series fuzes provide an additional safe period during the first 2 seconds time of flight. A fuze setting is made manually with a mechanical fuze setter. It is important that the time scale of the fuze setter correspond to the time ring of the fuze (0-100 with either the M513 or M514 series). The individual setting the fuze should look down on the nose of the fuze and rotate 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 0 setting line (2.0 seconds) is the lowest point at which VT action can be expected from the fuze. The ammunition caliber is stenciled on the fuze body. For details on the care and use of fuzes, refer to appropriate ordnance technical publications.

Note. The M513 (T226), M513B1 (226B1), M514 (T227), and M514B1 (T227B1) fuzes do not have a PD setting and should not be used when PD action is desired. The PD element is armed by the VT element and is for self-destruction only.

5-15. Primers

Primers are sensitive to shock and moisture. Primers will be kept away from propellant bags and will be left in their sealed containers until ready for use. Before a primer is used, it should be carefully cleaned and inspected. If it shows signs of corrosion or if the seal is not firmly in place, the primer should be rejected.

5-16. Flash Reducers

Flash reducers are used with white bag (multi-perforated) propelling charges for separate-loading ammunition and are assembled to a particular charge as prescribed in TM 9-1300-203. Because of their hygroscopic qualities, flash reducers must not be removed from the containers until just before they are to be used. Flash reducers must not be allowed to contact damp ground. Discarded increments should be disposed of in the same manner as discarded igniter pads (para 5-12*b*).

5-17. Chemical Projectiles (Cartridges)

a. When toxic chemicals are being fired, all personnel should wear protective masks and personnel handling the ammunition should wear gloves. Decontaminating agents should be held in readiness.

b. White phosphorus (WP) projectiles will be stacked vertically and protected from high temperature. If WP projectiles are stacked horizontally in the hot sun, the WP filler (melting point 110° F.) in a projectile may shift to one side of the projectile cavity and cause the projectile to become unbalanced.

5-18. Segregation of Ammunition Lots

Different ammunition lots have different ballistic qualities. Registration corrections derived from firing one lot of ammunition are not necessarily valid for another lot; therefore, the ammunition must be segregated in the position area by lot. Proper segregation requires control and accounting by the chiefs of sections, recorder, and fire direction center. The lot number for each stack of ammunition (or a unit code designation for that number) should be prominently displayed. As a general rule, the firing of the lot used for a registration is restricted to transfers and missions in which two or more batteries are to mass. In units which fire separate-loading ammunition, both propellants and projectiles must be segregated by lot and the desired propellant-projectile combination must be designated in the initial fire commands. In units which fire fixed or semifixed ammunition, the lot for the complete round is announced (para 5-10*b*(6)).

5-19. Replacing Ammunition in Containers

Great care must be exercised to insure that all ammunition returned to containers is completely serviceable. Before a round is replaced in a container, a certificate, prepared by an officer of the battery, will be inserted under the tape used to seal the container so that the certificate will be visible when the container is sealed. The certificate will certify that—

a. All increments are present.

b. All increments are serviceable and undamaged.

c. All increments are in proper numerical order.

d. All increments have the same lot number.

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

5-20. Data for Computation of Corrections

The executive officer supplies the fire direction center with the following ammunition data for computing corrections:

a. Weight of Projectile. The weight of the projectile is reported as it is marked on the projectile; e.g., 1 square, 2 squares, etc., or (so many) pounds.

b. Propellant Temperature. The propellant 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 using the propellant thermometer will vary with the type of ammunition. Propellant temperatures are taken as follows:

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

(2) *Semifixed.* Insert the thermometer in the charge and replace the charge in the cartridge case.

(3) *Fixed.* With fixed ammunition, there is a temperature lag between the inside and outside of the cartridge case. To approximate the

propellant temperature, place the cased thermometer inside an empty ammunition container.

5-21. 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 stored on the prime movers, on the ammunition vehicles, or, when authorized, at a battery dump. Establishment of a battery ammunition dump is a matter for command decision, since use of a dump impairs the mobility of the battery. Proper cover reduces the risk of damage by enemy fire and also serves to protect the ammunition from moisture and extremes of temperature.

5-22. Unloading the Piece

When practicable, a loaded piece should be fired rather than unloaded. However, troops should be instructed in the proper method of unloading. They should be assured that unloading can be accomplished safely if the pieces are not overheated and the proper procedures are followed. Details on unloading are contained in the appropriate field manual for the weapon.

5-23. Accidents

AR 75-1 prescribes the method for reporting premature explosions or other ammunition accidents. The officer in charge at the battery position must—

a. See that first aid is rendered to injured personnel.

b. Notify his immediate superior.

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

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

e. Record all data required by AR 75-1.

Section IV. COMMON MISTAKES AND MALPRACTICES

5-24. 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 by 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. A further preventive for errors is to establish in training proper supervisory procedures for the executive officer, chief of firing battery, and chiefs of sections so that all errors are detected and corrected prior to firing. This section tabulates some of the more common firing battery errors.

5-25. 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 a wrong charge.

(2) Referring to the higher (lower) numbered graduation instead of the lower (higher) numbered graduation on a fuze when setting a time between numbered graduations.

(3) Lifting a timed fuze projectile with the hand around the fuze, thereby disturbing the fuze setting.

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

(5) Referring to the higher (lower) numbered graduation instead of the lower (higher) numbered graduation on a micrometer when setting a reading between numbered graduations.

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

(7) Leveling the gunner's quadrant at the wrong angle of elevation or using the wrong guner's quadrant shoes, especially in high-angle fire.

(8) Laying on the aiming posts of another section, especially at night or when there is little lateral interval between pieces.

(9) Failing to take up lost motion correctly.

(10) Failing to center all bubbles.

(11) Failing to zero the gunner's aid.

(12) Transposing numbers in deflection or quadrant.

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

(1) Attaching the lanyard on the 105-mm howitzer directly to the trigger shaft rather than to the firing shaft bracket assembly. This practice permits firing the weapon before it has returned to battery, and results in damage to the recoil mechanism and carriage and possible 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. The practice breaks the lugs forming the T on the end of the firing pin holder.

(3) Attempting to gain greater ranges by firing propellant charges other than those authorized by firing tables. This practice results in excessive heat and chamber pressures, which cause metal fatigue.

(4) Loading the 155-mm howitzer without using the tray. This practice may result in burred breech threads, damaged rotating bands, and improper seating and, thus, erratic fires.

(5) Removing the safety latch firing mechanism plunger on the M114A1 or the follower assembly on the M109 so that the firing mechanism and primer can be inserted before the breech is closed. This practice may result in blown breechblocks and housings.

(6) Exceeding the maximum rate of fire and thus causing the gun tube to become extremely hot. When a cool projectile is placed in a hot gun tube, the projectile may crack. The filler may then melt and run out of the cracks into the powder chamber, where it may explode. If fired, a broken projectile endangers friendly troops. When the maximum rate of fire is exceeded, the recoil mechanism also becomes extremely hot. This causes a marked increase in pressure within the recoil system, which in turn, may damage the system.

(7) Digging the gun pit in such a manner that the bottom of the pit slopes upward toward the rear. A weapon emplaced in such a pit will be tilted forward; this will reduce the maximum elevation attainable by the weapon and may restrict the firing of high-angle fire.

(8) Using the rammer-extractor upside down when ramming.

(9) Failure to tighten fuzes with approved fuze wrench.

5–26. Use of the Aiming Circle

Some of the errors made by the firing battery personnel in using the aiming circle are—

a. Failing to clamp the vertical shaft securely (M1 only).

b. Failing to clamp the instrument fixing screw securely.

c. Turning the telescope with the upper (lower) motion instead of the lower (upper) motion when sighting through the eyepiece.

d. Failing to level the longitudinal bubble before reading angles of site (M1 only).

e. Failing to determine and apply the vertical angle correction to measured angles of site.

f. Having objects containing magnetic metals on the person, especially eyeglasses (para 3–4*b*).

g. Making a 100-mil error in reading or setting as a result of reading the azimuth scale in a counterclockwise direction instead of a clockwise direction; for example, setting or reading 3697 instead of 3597 because the azimuth index is near 36.

h. Failing to take up lost motion correctly.

i. Failing to set up the tripod so that one leg points in the approximate direction of sighting.

j. Failing to set up the instrument the prescribed distance from the nearest piece.

k. Failing to orient the 0 to 3200 line in the appropriate direction of fire.

l. Failing to set up the aiming circle where it can be seen from all pieces.

m. Reading the red figures instead of the black figures on the azimuth scale.

5–27. Miscellaneous Errors

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

a. Failing to check boresighting in the firing position.

b. Failing to place the thermometer in the propellant in the proper manner.

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

d. Firing rounds from oily tubes.

e. Failing to set the near aiming post halfway between the piece and the far aiming post.

f. Lining up the lead line on the wrong side of the vertical hairline with the number displayed in the collimator.

g. Placing the collimator too far from or too close to the weapon.

h. Failing to make prefire checks.

CHAPTER 6

DUTIES OF THE SAFETY OFFICER

6-1. General

Safety is a command responsibility. Under peacetime conditions, a safety officer is required to assist the commander in accomplishing this responsibility. The safety officer normally should be a regularly assigned officer of the battery so that there will be no divided responsibility between battery and battalion levels. Proficiency in the functioning of the safety officer should be treated in the same light as proficiency in the functioning of the battery executive. In either case, low standards dissipate the required sense of urgency and result in slow firing. The safety officer has two principal duties. First, he must insure that the pieces are laid and loaded so that the rounds, when fired, will land in the prescribed impact area. Second, he must insure that all safety precautions are observed at the firing point. While serving as safety officer, he will not be assigned other duties. Particularly, he will not be required to check the accuracy of the gun crews except to insure that bursts impact in the designated impact area.

6-2. Duties of Safety Officer Before Firing

Before firing is begun, the safety officer must—

a. Verify that the safety card applies to the unit, exercise, date, and time.

b. Verify that the battery is in the position specified on the safety card.

c. Prepare a safety diagram.

d. Check the pieces for boresighting.

e. Verify the laying of the battery.

f. Verify the minimum quadrant elevations determined by the executive officer. The safety officer must compare the executive's minimum quadrant elevation with the quadrant elevation (low-angle fire) for minimum range on the safety diagram and use the larger of the two as the minimum quadrant elevation.

g. Supervise the placing of safety stakes.

h. Verify that ammunition to be fired is of the type specified on the safety card.

i. Insure that the chiefs of sections are informed of the maximum and minimum quadrant elevations, right and left limits, and minimum fuze settings.

j. Verify that range clearance has been obtained.

k. Ascertain that the visible portion of the range is clear of personnel.

l. Insure that Department of the Army regulations, post regulations, and local special instructions pertaining to safety are complied with.

6-3. Duties of Safety Officer During Firing

After his preliminary checks are made, the safety officer should indicate that from the point of view of safety the battery is ready to fire. During firing, the safety officer will—

a. Verify the serviceability of ammunition.

b. Insure that the charge, projectile, and fuze being fired are limited to those prescribed on the safety card.

c. Insure that rounds are not fired below the minimum quadrant elevation or above the maximum quadrant elevation for the charge being fired.

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 the minimum fuze settings prescribed on the safety diagram.

f. Instruct the executive officer not to fire until the safety officer has given a positive indication that it is safe to fire.

g. Command UNSAFE TO FIRE on all commands that are unsafe to fire and give the reasons therefor. Two examples are—

(1) UNSAFE TO FIRE, 3 MILS OUTSIDE RIGHT SAFETY LIMIT AND 20 MILS ABOVE MAXIMUM QUADRANT ELEVATION.

(2) UNSAFE TO FIRE, 5 MILS BELOW MINIMUM QUADRANT ELEVATION.

h. Apply registration corrections to the safety limits immediately after registration.

i. Report accidents and malfunctions of ammunition to the officer in charge of firing, request an ambulance(s) if needed, and be prepared to make a report as indicated in AR 75-1.

j. Bring to the attention of the executive officer any unsafe conditions observed and check firing until the conditions have been corrected.

Examples of unsafe conditions are—

(1) Safety features of piece not operable.

(2) Propellant increments exposed to flames.

(3) Personnel smoking near pieces.

(4) Improper handling of ammunition.

(5) Fuzes and projectiles stored together.

(6) Time fuzes previously set and not reset to safe.

(7) Primer inserted before the breech is closed (separate-loading ammunition).

(8) Failure of cannoneer to inspect the propellant chamber and bore after each round fired.

(9) Failure of cannoneer to swab the propellant chamber after each round of separate-loading ammunition fired.

6–4. Misfire

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 action required in TM 9–1300–203 must be observed.

6–5. Safety Card

a. A safety card prescribing the hours of firing, the area in which the firing will take place, the location of the gun position, the 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 safety diagram based on the prescribed limits.

b. There is no prescribed format for the safety card; however, the format shown below generally is used.

Safety limits for: 155-mm how M109, sh HE fz M564, M514, M557,

Type of fire: low angle.

Firing point: 8632196586.

Reference point: GN; grid az—approx: 0.

Left limit: Az 4730.

Right limit: Az 5450.

Minimum range: 4,300 meters.

Maximum range: 8,000 meters.

Special instructions: Use only chg 5 GB with this card. From az 4730 to az 5030, maximum range is 7,000 meters.

6–6. Safety Diagram

a. The safety officer, on receipt of the safety card, constructs a safety diagram. The diagram need not be drawn to scale but must accurately list the piece settings which delineate the impact area; the diagram serves as a convenient means of checking the commands announed to the gun crews against those commands which represent the safety limits. The diagram shows the right and left limits, expressed in deflections corresponding to those limits; the maximum and minimum quadrant elevations; and the minimum fuze settings (when applicable) for each charge to be fired. The diagram should not be cluttered with unnecessary information. 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 within safety limits for range.

b. The basic safety diagram is a graphical portrayal of the data on the safety card. On the basic safety diagram are shown the minimum, maximum, and intermediate (if any) range lines; the left, right, and intermediate (if any) azimuth limits; the deflections corresponding to the azimuth limits; and the direction in which the battery is laid. The safety officer determines the deflection limits by comparing the azimuth on which the battery is laid with the azimuth limits and applying the difference to the referred deflection (3200 for M100 series sights).

Example: A 155-mm howitzer M109 battery is laid on azimuth 5100. The counter reset deflection is 3,200 mils. The safety card for the position occupied is that shown in paragraph 6–5*b*. The basic safety diagram for this situation is shown in figure 6–1.

c. Unless a registration has been fired and corrections have been applied, all rounds must be fired in the central portion of the impact area.

6–7. Minimum Quadrant Elevation (Low-Angle Fire)

The minimum QE is computed for each authorized charge. The minimum QE consists of the following elements:

a. Site to the Highest Point on Minimum Range Line. The safety officer determines the highest point on the minimum range line by plotting the minimum range line on a map and inspecting for the altitude of the highest point.

Note. If an isolated peak causes an unnecessary limitation along the minimum range line, a separate site is computed and only the firing in the immediate area of the peak is limited by the minimum quadrant elevation determined for the peak.

b. Elevation for Minimum Range. If corrections are known, the corrections must be applied when the elevation is computed.

6–8. Minimum Fuze Setting (Low-Angle Fire)

The minimum fuze setting for time fuzes is the fuze setting corresponding to the elevation for minimum range plus the fuze correction (if known). The minimum fuze setting for VT fuzes

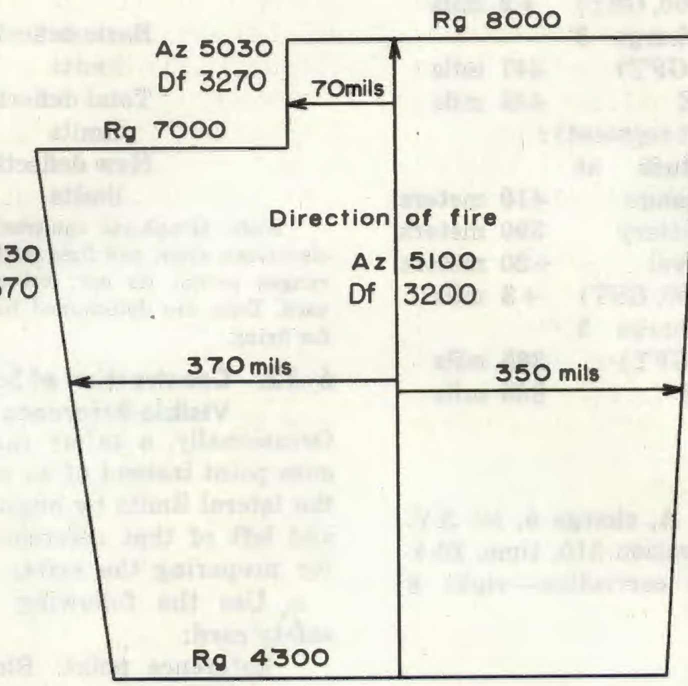


Figure 6–1. Basic safety diagram.

is the time of flight corresponding to the elevation for minimum range plus 5.5 seconds. If the sum is not a whole number, the minimum safe time for VT fuzes is the next higher whole number.

6–9. Maximum Quadrant Elevation (Low-Angle Fire)

The maximum QE for each authorized charge is the sum of the following elements:

a. Site to the Lowest Point on the Maximum Range Line.

b. Elevation for the Maximum Range. If corrections are known, the corrections must be applied when the elevation is computed.

6–10. Deflection Limits

After a registration has been fired, the safety officer must correct the deflection limits of the basic safety diagram by adding the total deflection correction to each deflection limit.

6–11. Sample Problem

a. Prior to Registration.

Given:

Safety card (para 6–5*b*).
Basic safety diagram (fig 6–1).
Altitude of battery—390 meters.
Altitude of highest point at minimum range—411 meters.
Altitude of lowest point at maximum range (right)—405 meters.
Altitude of lowest point at maximum range (left)—410 meters.

Find:

Minimum QE, minimum fuze setting (time), and maximum QE.

Solution:

Minimum QE:

Altitude of highest point at minimum range	411 meters
Altitude of battery	390 meters
Vertical interval	+21 meters
Site (+21/4300, GST)	+5 mils
Elevation (charge 5 green bag, GFT)	196 mils
Minimum QE	201 mils

Minimum fuze setting for fuze M564:

Fuze setting corresponding to minimum elevation	13.4

Minimum fuze setting for fuze M514:

Time of flight corresponding to minimum elevation	13.5
	+5.5
	19.0

Minimum fuze setting for fuze M514 is 19.0.

Maximum QE (right segment):

Lowest altitude at maximum range	405 meters
Altitude of battery	390 meters

Vertical interval	+15 meters
Site (+15/8000, GST)	+2 mils
Elevation (charge 5 green bag, GFT)	447 mils
Maximum QE	449 mils

Maximum QE (left segment):

Lowest altitude at maximum range	410 meters
Altitude of battery	390 meters
Vertical interval	+20 meters
Site (+20/7000, GST)	+3 mils
Elevation (charge 5 green bag, GFT)	365 mils
Maximum QE	368 mils

b. After Registration

Given:

GFT setting GFT A, charge 5, lot XY, range 6,000, elevation 315, time, 20.4. Total deflection correction—right 8 mils.

Find:

Minimum QE, minimum fuze setting, maximum QE, and new deflection limits.

Solution:

Minimum QE:

Site to highest point at minimum range	+5 mils
Elevation (GFT)	208 mils
Minimum QE	213 mils

Minimum fuze setting for fuze M564:

Fuze setting at minimum range (GFT)	13.9

Minimum fuze setting for fuze M514:

Time of flight corresponding to elevation 208	14.3
	+5.5
	19.8

Minimum fuze setting for fuze M514 is 20.0.

Maximum QE (right segment):

Site to lowest point at maximum range	+2 mils
Elevation (GFT)	482 mils
Maximum QE	484 mils

Maximum QE (left segment):

Site to lowest point at maximum range	+3 mils
Elevation (GFT)	391 mils
Maximum QE	394 mils

Deflection Limits:

	Left	Intermediate	Right
Basic deflection limits	3570	3270	2850
Total deflection limits	R8	R8	R8
New deflection limits	3562	3262	2842

Note. Graphical equipment is used for determining elevations, sites, and fuze settings for the fuze M564 when ranges permit its use; otherwise, tabular equipment is used. Data are determined to the same accuracy as that for firing.

6–12. Construction of Safety Diagram From Visible Reference Point

Occasionally, a safety card will specify a reference point instead of an azimuth and will specify the lateral limits by angular measurements right and left of that reference point. The procedure for preparing the safety diagram is as follows:

a. Use the following information from the safety card:

Reference point: Blockhouse Signal Mountain.

Left limit: 350 mils left.

Right limit: 200 mils right.

b. After the pieces have been laid and the collimators have been emplaced, determine the smallest angle between the line of fire and the reference point by using the azimuth counter on the panoramic telescope of the base piece as an angle-measuring instrument. (Assume that the battery has been laid, the collimator has been emplaced at deflection 2600, and an angle of 100 mils has been measured from the line of fire to the reference point (fig 6–2).)

Note. Since the panoramic telescope measures only clockwise angles, determine those angles measured to the left of the line of fire by subtracting the reading on the azimuth counter of the sight from 3200 and determine angles measured to the right of the line of fire by subtracting 3200 from the reading on the azimuth counter of the sight. In this example, measuring to the reference point would produce a reading of 3100 (3200 minus 3100 equals 100 mils).

c. Using the LARS rule (left, add; right, subtract), determine the proper deflection to *lay* the pieces on the reference point (deflection 3200, left 100, equals deflection 3300).

d. Again using the LARS rule, apply the right and left angular measurements from the reference point specified on the safety card to the deflection required to lay on the reference point (fig 6–2).

(1) Left limit: From deflection 3300, left 350 equals deflection 3650.

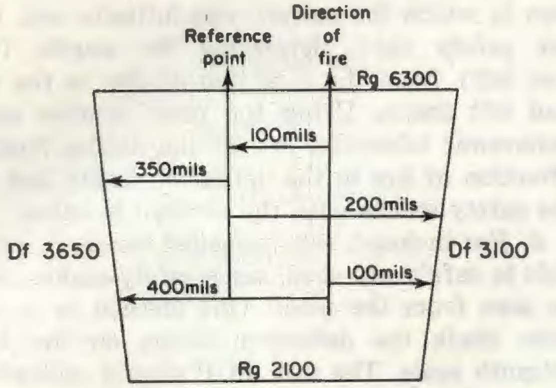


Figure 6-2. Safety diagram from visible reference point.

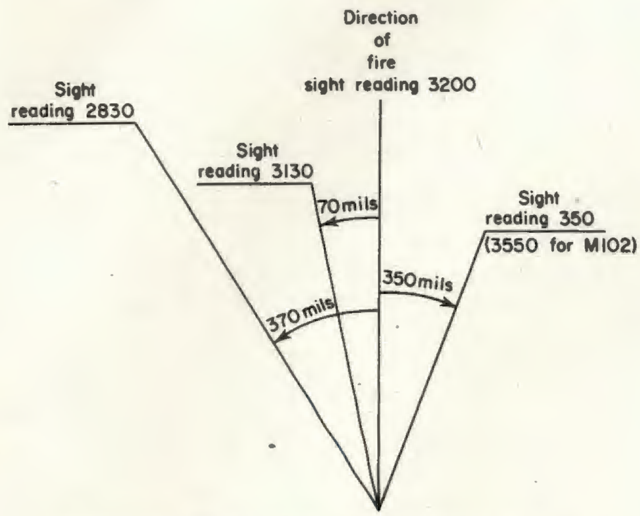


Figure 6-3. Safety stake diagram based on basic safety diagram.

(2) Right limit: From deflection 3300, right 200 equals deflection 3100.

e. If the reference point is not visible because of weather conditions and the azimuth to the reference point is not given on the safety card, the safety officer must compute the azimuth by using the grid coordinates of the reference point. The pieces may then be laid on that azimuth or on any other convenient azimuth.

6-13. Special Situations

a. High-Angle Fire. When high-angle fire is employed, the safety limits are computed in the following manner:

(1) *Maximum quadrant elevation.* The maximum QE for minimum range is the sum of the elevation (to the nearest mil) for minimum range and the site (to the nearest mil) to the highest point on the minimum range line.

(2) *Minimum quadrant elevation.* The minimum QE for maximum range is the sum of the elevation (to the nearest mil) for maximum range and the site (to the nearest mil) to the lowest point on the maximum range line.

(3) *Deflection limits.* When high-angle fire is employed, the deflection limits on the basic safety diagram are always modified to consider the drift. The right deflection limit is moved to the left by the amount of the maximum drift for the cannon for the charges within the range limits to be fired. The left deflection limit is moved to the left by the amount of the minimum drift for the cannon for the charges within the range limits to be fired. After a high-angle registration, the deflection limits are determined in the same manner and are further modified by the amount of the GFT deflection correction.

b. Illuminating Projectile. When illuminating projectiles are employed, the safety diagram is computed using the illuminating tabular firing tables. The procedures are the same as those used for shell HE in low angle fire except as follows:

(1) The range fuze function column is used to determine the minimum quadrant elevation and the minimum fuze setting.

(*a*) The minimum quadrant elevation is determined by lowering the height of burst, in 50 meter increments, to the highest point on the minimum range line.

(*b*) The minimum fuze setting is determined in the same manner as is minimum fuze setting determined for shell HE, fuze M564.

(2) The range to impact column is used to determine the maximum quadrant elevation to the lowest point on the maximum range line.

Note. Tests are presently being conducted to determine the debris area for the illuminating projectile. When this data is available it will be published in appropriate firing tables.

c. Improved Conventional Munitions. When improved conventional munitions (ICM) are employed, the safety diagram is determined as for shell HE in low angle fire except as follows:

(1) The minimum quadrant elevation is determined by adding the ICM correction for QE to the minimum QE for HE.

(2) The maximum elevation is determined using the range to impact column and site for shell HE.

(3) The minimum fuze setting is determined by adding the ICM correction for fuze setting to the minimum fuze setting for fuze M564.

6-14. Safety Stakes

a. Safety stakes are visual aids that mark the lateral safety limits for each piece. The stakes are placed approximately 10 meters forward of each piece along the lateral limits specified on the safety card. By standing to the rear of a

PART THREE

OBSERVED FIRE

CHAPTER 7

FIELD ARTILLERY OBSERVER

Section I. INTRODUCTION

7-1. General

a. Field artillery employment normally requires some type of observation. It may be visual observation, it may be electronic observation, or it may be indirect observation through study of aerial photographs.

b. Electronic devices generally fall into two classes—radar equipment and sound ranging equipment. Employment of these devices is described in FM 6-120, FM 6-121, FM 6-122, and FM 6-161.

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 and observation are based, relieve the observer of many functions normally required of him by other gunnery systems. However, 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. His ability to observe and his knowledge of the battle situation must be exploited so that his unit is adequately informed at all times. Moreover, the observer must know and understand the problems and procedures of the fire direction center. He can then combine this knowledge with his own judgment to effectively perform his duties as a member of the gunnery team.

7-2. Purpose

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

a. Target acquisition involves detecting suitable targets and determining their ground locations. Target information is reported to the FDC, where it may be used in the production of firing data.

b. Adjustment of fires is necessary to obtain effective fire on the target when the accuracy of battery or target location data is questionable and when current meteorological or registration corrections are not available.

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 fire direction center. This report should include an accurate account of damage and any appropriate shifts necessary to make the fire more effective.

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

7-3. Duties of the Observer

For a discussion of field artillery observer duties and tactics, see FM 6-20 and FM 6-140.

Section II. PREPARATORY OPERATIONS

7-4. General

The observer's preparatory operations contribute to his speed and accuracy in locating targets and reporting information to the fire direction center.

a. Before occupying an observation post (OP) or joining the infantry or tank company that he is to support, the observer should—

(1) Check his equipment.

(2) Report to the proper artillery and infantry (tank) personnel for briefings.

(3) Brief his section.

(4) Make a map reconnaissance.

(5) Check communications.

b. Upon occupying an observation post or joining the infantry (tank) company that he is to support, the observer should—

(1) Check communications.

(2) Orient his map and plot those points the locations of which can be determined.

(3) Report his location and field of observation to the fire direction center.

(4) Prepare an observed fire (OF) fan.

(5) Prepare a terrain sketch to supplement the map.

(6) Prepare target location data for points at which targets may appear.

c. The observer should never delay a call for fire merely to complete preparatory operations.

7-5. Orienting for Direction

a. Observer procedures are based on a line of direction that is known to the observer and to the FDC, usually the grid azimuth from the observer to the target. The observer should orient himself for direction (dir) by determining and recording the grid azimuth to a number of sharply defined terrain features tht he has chosen as reference points.

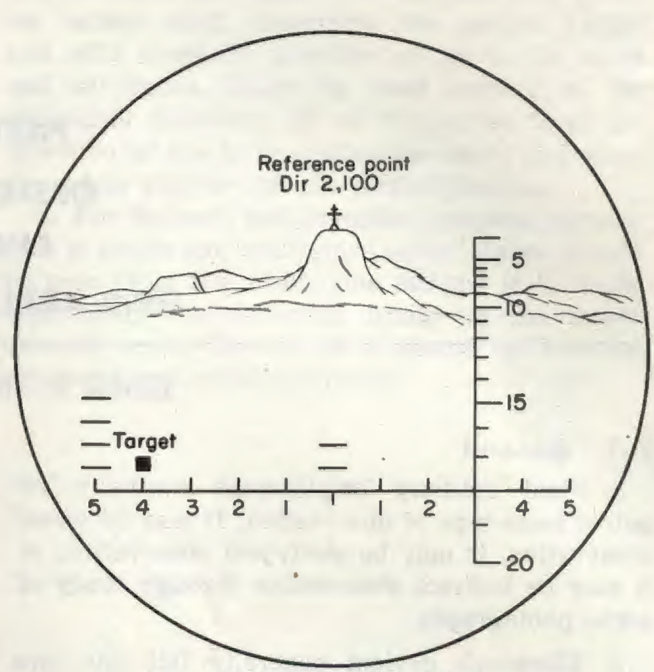
b. Grid azimuths normally are measured with a declinated magnetic instrument. Azimuth may also be measured from a map when the observer's position is known and has been plotted.

c. After a number of reference point azimuths have been recorded, the observer can determine the direction 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 7-1, the target is 40 mils left of the reference point. Direction to the target is 2,060 mils (2100−40).

d. The tank-mounted observer is faced with a special problem in determining direction because magnetic instruments will not function properly in a tank. If the tank is stationary and the observer knows his location, he can determine direction from a map. If the tank is moving, the problem can be solved by using the gun-target line, a prominent linear terrain feature, or a cardinal direction, upon which corrections can be applied.

7-6. Location of Known Points

To facilitate the location of targets, the observer and FDC select points in the target area which can be identified by the observer and which are plotted on the firing chart. The location of the *known points* may be determined from maps, by survey, or by firing.



The vertical scale on right of the lens is not used by the FO in determining data for his call for fire. It is used primarily by the infantry for sighting automatic weapons.

Figure 7-1. Use of reference point direction and binocular scales to determine direction to target.

7-7. Location of the Firing Battery

Although target grid procedures do not require that the observer know the location of the battery that is firing his mission, knowledge of the location will give the observer a greater appreciation of the effects he observes.

7-8. 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, he also prepares a visibility diagram.

b. The observer augments the map with lines of direction radiating from the observer's position at convenient angular intervals. Using the observer's position as the center, he intersects those lines with arcs of distance (fig 7-2). The observer then marks points of importance that were not printed on the map. He also marks any points that he might frequently need, such as reference points, registration points, targets, and likely points of enemy activity.

c. The observer may use an observed fire (OF) fan instead of marking the map as indicated in b above. The observed fire fan (fig 7-3), a fan-shaped protractor constructed of transparent material, covers a 1,600-mil sector. This fan is divided by radial lines 100 mils apart. Arcs representing distances from the OP are printed on the fan in increments of 500 meters from 1,000 to 6,000 meters. To use the OF fan, the observer orients the fan on his map with the vertex on his OP location, the fan centered approximately on the zone of observation, and one of the radial lines parallel to a grid line or another line of known direction. He then tapes or tacks the fan to the map. He labels the line of known direction with its correct direction, and then labels the other radial lines with their directions. If he perfers, he may label only every other line.

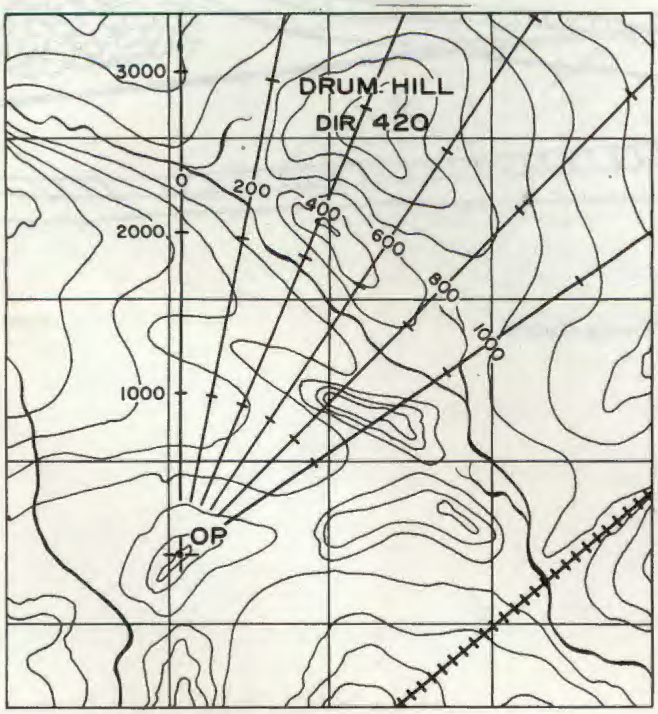


Figure 7-2. Map augmented to show lines of direction and distance from the observer position.

d. Another device that the observer uses to assist in the location of targets is the terrain sketch (fig 7-4). The terrain sketch is a panoramic representation of the terrain, sketched by the observer, showing reference points, registration points, targets, and points of probable activity. The terrain sketch is also a rapid means of orienting relief personnel.

e. When photographs of the area of observation are available, the observer should mark the photographs to show pertinent points and lines of direction and use them in conjunction with the terrain sketch. Copies of the photographs and the terrain sketch may be required for reference at the fire direction center.

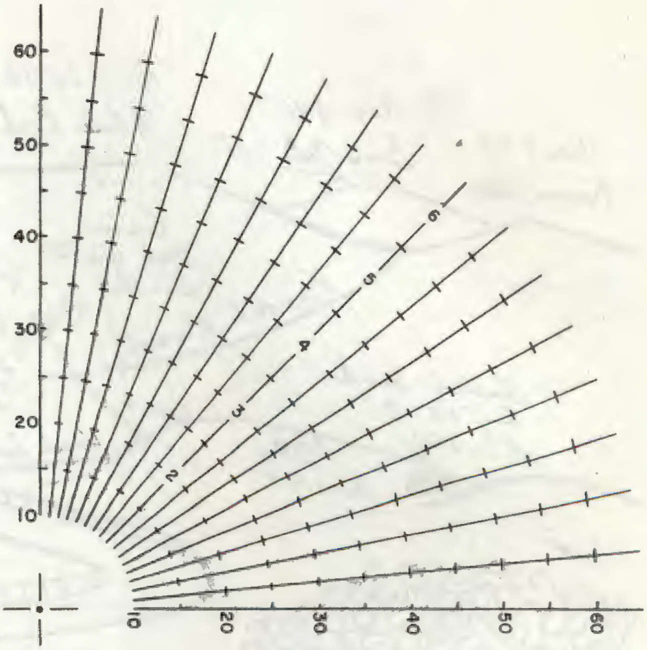


Figure 7-3. The observed fire fan.

f. The visibility diagram (fig 7-5), a sketch of the area of observation drawn to map scale, shows those portions of the area that cannot be observed from a given observation post. This diagram may be prepared by observer personnel, or it may be prepared by FDC personnel if the position of the observation post is plotted on FDC maps. When the observer prepares the visibility diagram, he sends a copy on overlay paper to the fire direction center.

(1) The diagram is prepared by constructing profiles of the terrain along radial lines emanating from the observation post (FM 21-26). Each adjacent pair of rays should form an angle no greater than 100 mils. Straight lines are then 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 a ray with the ground are blindspots (fig 7-6). These blindspots 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 7-5).

(2) Use of visibility diagrams will reduce the chance of observer error in reporting target locations. If the target is plotted in an area that

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.

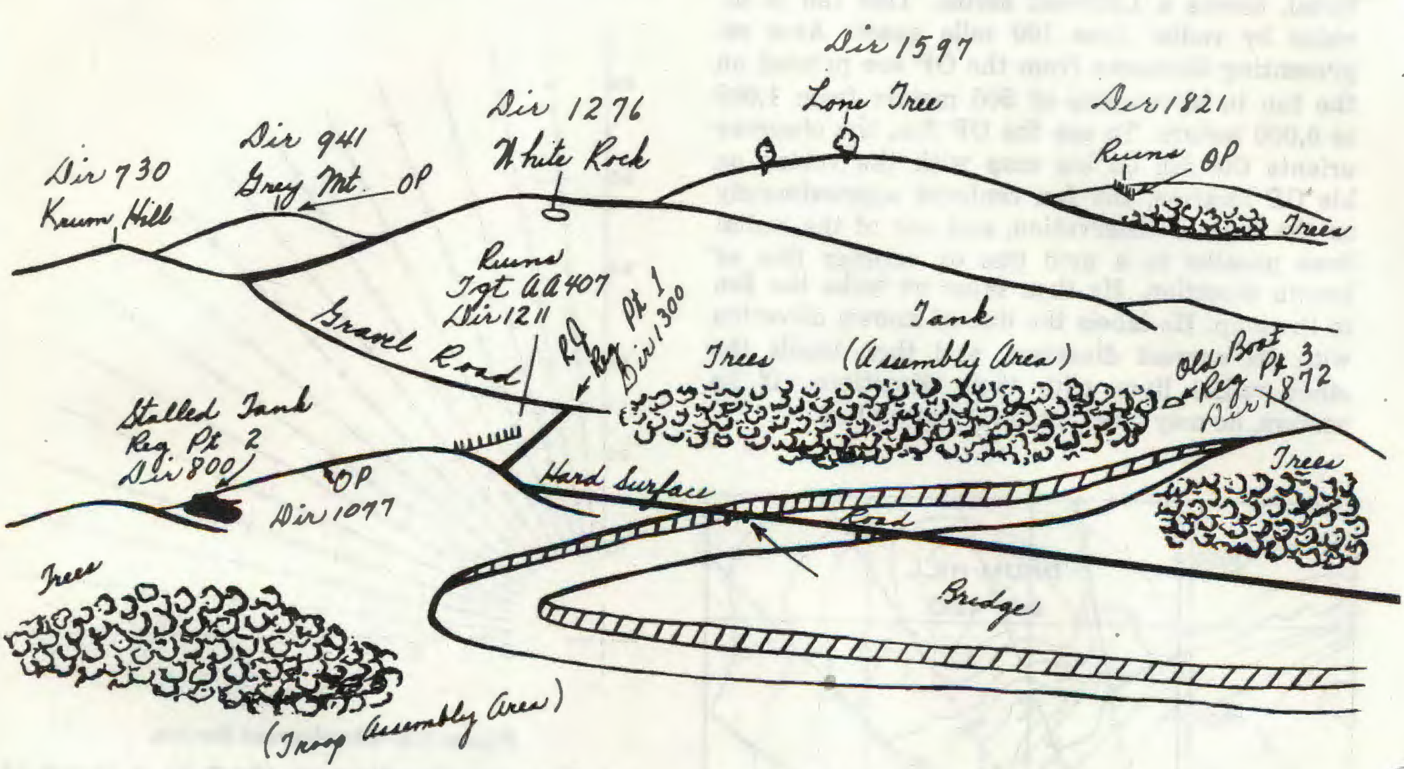


Figure 7–4. Terrain sketch.

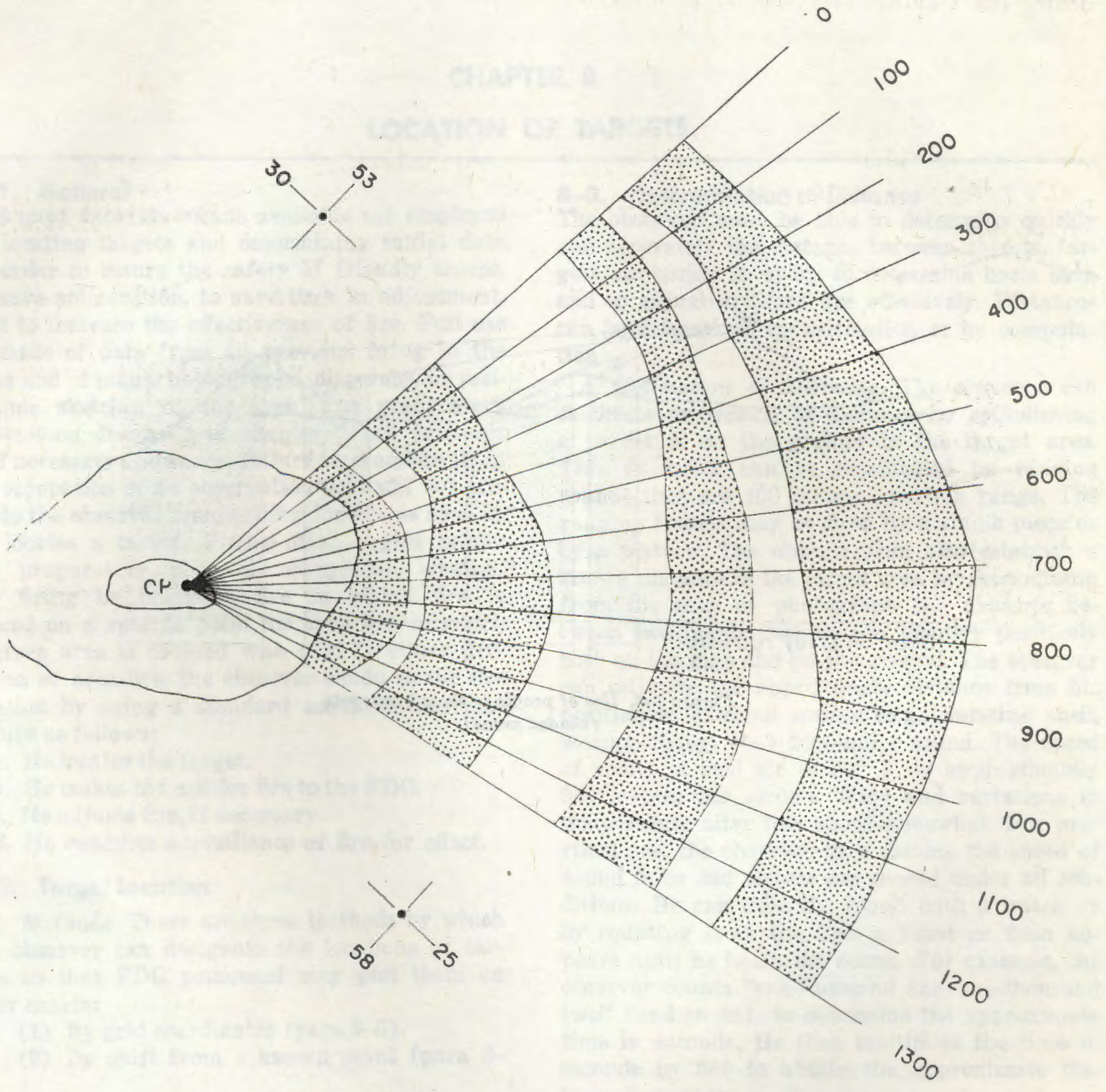


Figure 7–5. Construction of visibility diagram by use of direction rays.

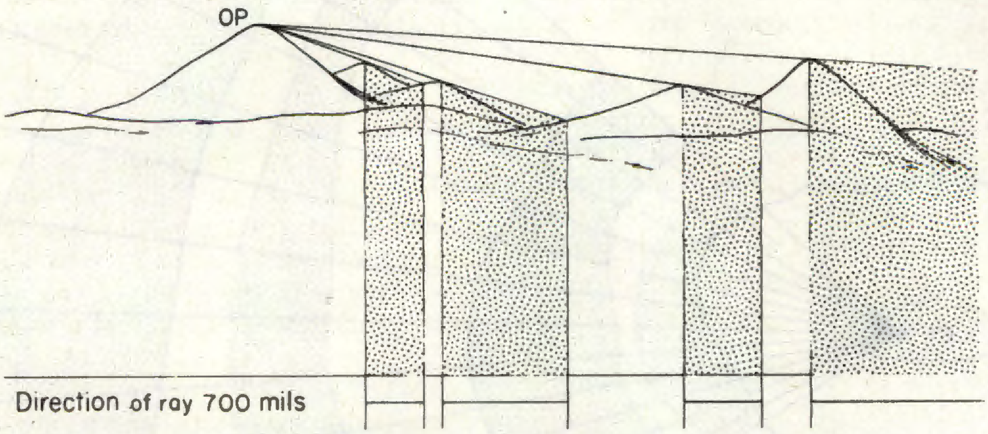


Figure 7-6. Use of profile to show blindspots (shaded areas).

CHAPTER 8
LOCATION OF TARGETS

8-1. General

The most accurate means available are employed in locating targets and determining initial data in order to insure the safety of friendly troops, to save ammunition, to save time in adjustment, and to increase the effectiveness of fire. Full use is made of data from all previous firing in the area and of maps, photographs, diagrams, or panoramic sketches of the area. The preparatory operations discussed in chapter 7 are desirable and necessary; however, failure to complete them on occupation of an observation post will not preclude the observer from calling for fire as soon as he locates a target. Firing often begins before the preparatory phase is completed, whether the firing be precision fire in which fire is placed on a specific point, or area fire in which a given area is covered with fire. In either precision or area fire, the observer conducts the fire mission by using a standard sequence and procedure as follows:

a. He locates the target.

b. He makes the call for fire to the FDC.

c. He adjusts fire, if necessary.

d. He conducts surveillance of fire for effect.

8-2. Target Location

a. Methods. There are three methods by which the observer can designate the locations of targets so that FDC personnel may plot them on their charts:

(1) By grid coordinates (para 8-5).

(2) By shift from a known point (para 8-6).

(3) By polar coordinates (para 8-7).

b. Accuracies and Announcement of Data. All data for target locations in calls for fire and subsequent corrections are determined to an accuracy consistent with the equipment used for determination. The observer will normally round off and announce his data as follows:

(1) Direction to the nearest 10 mils.

(2) Deviation to the nearest 10 meters.

(3) Vertical change to the nearest 5 meters.

(4) Range to the nearest 100 meters.

(5) Grid coordinates to the nearest 10 meters.

8-3. 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 by estimation or by computation.

a. Estimation of Distance. The observer can facilitate estimation of distance by establishing a yardstick on the ground in the target area. This yardstick can be established by ranging rounds that are 400 meters apart in range. The ranging rounds may be fired by a single piece or by a platoon. The observer can also establish a known distance in the target area by determining from his map or photograph the distance between two points that he can identify positively both on the map and on the ground. The observer can estimate the approximate distance from his position to a sound source (e.g., bursting shell, weapon firing, etc.) by timing sound. The speed of sound in still air at 59° F. is approximately 340 meters per second. Wind and variations in temperature alter this speed somewhat. For practical use, the observer may assume the speed of sound to be 350 meters per second under all conditions. He can time the sound with a watch or by counting from the time a burst or flash appears until he hears the sound. For example, the observer counts "one-thousand one, one-thousand two" (and so on), to determine the approximate time in seconds. He then multiplies the time in seconds by 350 to obtain the approximate distance in meters.

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 counts 4 seconds; therefore, the distance from the burst to his position is approximately 1,400 meters (350×4).

b. Computation of Distance. Using the angle measured from one point to another and the known lateral distance between the two points, the observer may compute the distance by applying the mil relation. The mil relation is based on the assumption that an angle of 1 mil will subtend a width of 1 meter at a distance of 1,000 meters. The relation is expressed as $\not{m} = \frac{W}{R}$, where $\not{m}$ is the angular measurement in mils between the two points, R is the distance in thousands of meters (expressed to the nearest 100) to the known point, and W is the width in meters between the points from which angle $\not{m}$ was measured (fig 8-1).

Example: An observer measures an angle of 5 mils between the ends of a flat car that is 16 meters long. He determines the distance from his position to the flat car by substituting in the relation $R = \frac{W}{\not{m}}$ ($R = \frac{16}{5} = 3.2$). The distance is 3,200 meters.

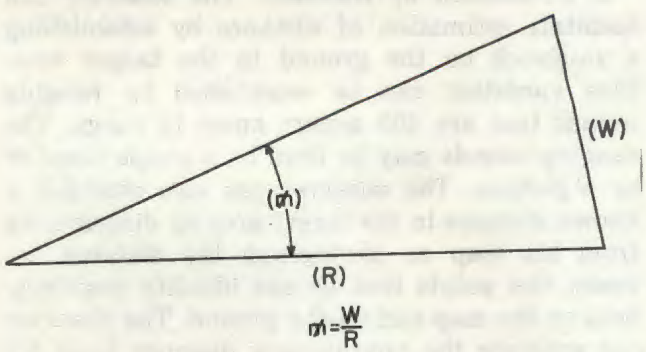


Figure 8-1. The mil relation.

8-4. Measurement of Angles

An observer usually uses some angle-measuring device, such as field glasses, an aiming circle, or a battery commander's periscope (BC scope), to measure angles. When instruments are not available, he can measure angles by using the hand and finger held at a fixed distance from the eye. Before he goes to the field, he must determine the specific angles subtended by the hand in various attitudes and must record and memorize them for rapid use (fig 8-2).

8-5. Target Location by Grid Coordinates

a. Auxiliary map data greatly simplifies the determination of accurate grid coordinates of a target. When the observer sees a target that is located where it cannot be plotted by rapid inspection, he must first determine the grid azimuth to the target. He determines the azimuth by using any of the methods described in paragraph 7-5.

b. After the observer has determined his location and the azimuth to the target, he refers to the corresponding line of direction on the map (or observed fire fan). He selects the point on this line that 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 8-3, the observer has measured an azimuth of 680 mils to a target that is located on a small hill an estimated distance of 3,000 meters from the observer's location. He has pinpointed the target on the map by plotting a distance equivalent to approximately 3,000 meters along a ray corresponding to an azimuth of 680 mils on the observed fire fan. A study of the contour lines aids the observer in locating the target more accurately.

c. After the observer has located the target on the map, he marks the location and determines the grid coordinates by use of 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 coordinate of a target, the observer first determines the grid coordinates of the lower left corner of the grid square containing the target. Starting at this grid intersection, he slides the coordinate scale to the right, keeping the horizontal scale in coincidence with the E-W grid line, until the target is reached by the vertical scale. He then reads the distance east and the distance north from the scale (fig 8-4) and adds these readings to the coordinates of the grid square to obtain the coordinates of the target. For example, the grid coordinates of the target shown in figure 8-4 are 53152475.

d. He may determine grid coordinates by relating the target location to 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 (e.g., road junction, building, bridge, etc.). He can make a rapid check of the accuracy of the coordinates by use of the contour lines on the map. If the altitude determined from the target plot shows marked disagreement with the actual ground conformation, the plot should be verified.

8-6. Target Location by Shift from a Known Point

In order to locate a target by a shift from a known point, FDC personnel must have the location of the known point plotted on their charts. Either the observer or the S3 may select points for use as known points, but both the observer and FDC personnel must know their locations and designations. Registration points, prominent terrain features, and previously fired targets are commonly used as known points. To locate a

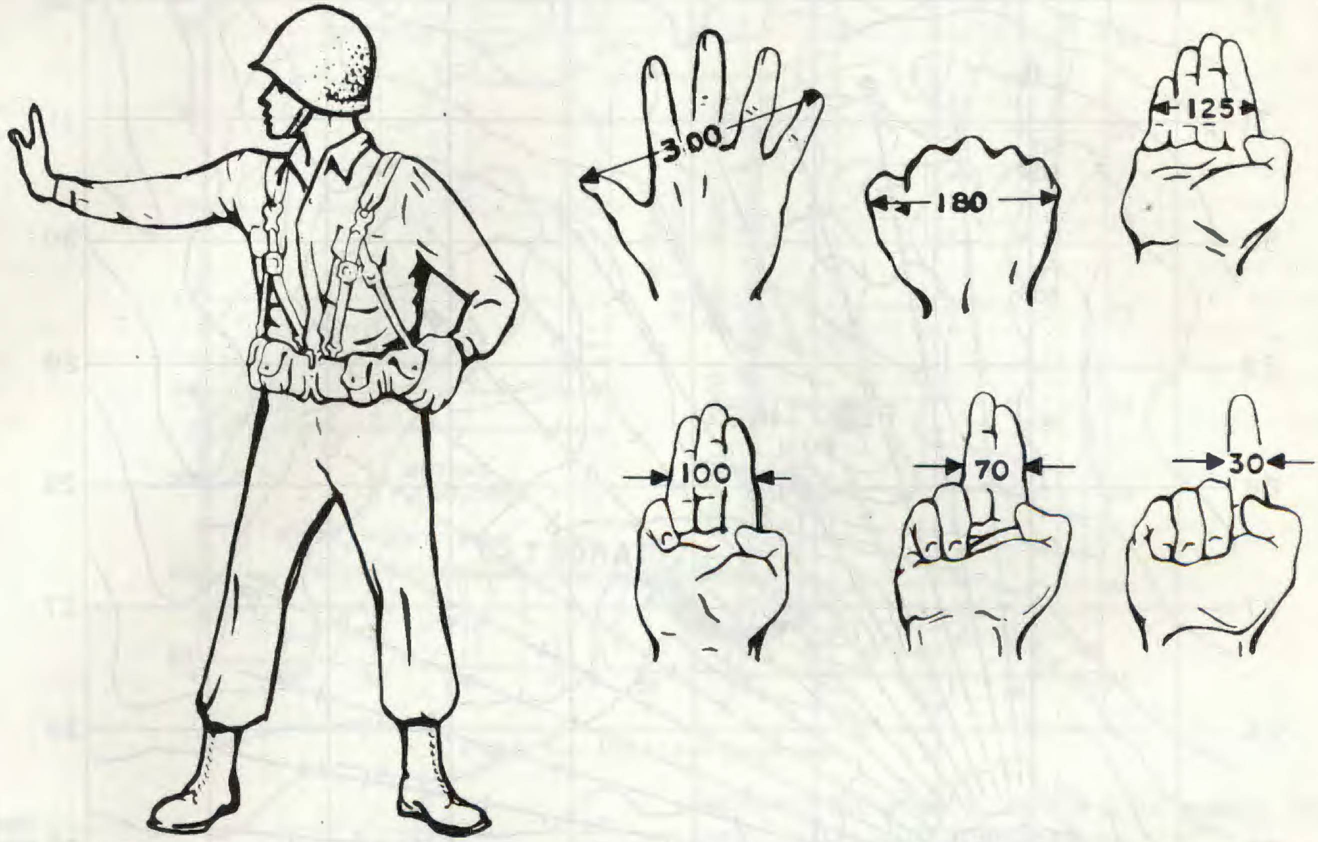


Figure 8-2. Examples of measuring angles with the hand.

target by a shift from a known point, the observer must determine the observer-target (OT) direction, a horizontal shift, and a vertical shift.

a. Observer-Target Direction. Normally, the observer determines the observer-target direction by measuring the angular deviation from a reference point to the target and applying the measured deviation to the direction from his position to the reference point. The measured deviation is added if the target is to the right of the reference point and substracted if the target is to the left of the reference point. Observer-target direction may also be measured with a properly declinated magnetic instrument.

b. Horizontal Shift. The horizontal shift (fig 8-5) from a known point to the target consists of a lateral shift in meters and a range shift in meters. The lateral shift is the distance from the known point to the OT line along a perpendicular dropped from the known point. The range shift is the distance from the intersection of the perpendicular with the OT line to the target. The shifts are plotted in the FDC on a target grid oriented on the OT direction. The method used by the observer to compute the horizontal shift depends on the size of the angular deviation measured from the known point to the target.

(1) *Deviation of less than 600 mils.* When the angular deviation from a known point to the target is less than 600 mils, the observer uses the mil relation (para 8-3*b*) in computing the lateral shift. He determines the shift in range by comparing the distance from his position to the known point with the distance from his position to the target.

Example: An observer measures the angular deviation from registration point 1 to the target as right 250 mils. He knows the distance to registration point 1 to be 3,200 meters and estimates the distance to the target to be 3,700 meters (fig 8-5). He determines the lateral shift by substituting in the relation $W = R m$ ($W = 3.2 \times 250$, or right 800 meters). The range shift is add 500 ($3700 - 3200 = 500$ meters). The observer announces the shift as RIGHT 800, ADD 500.

(2) *Deviation of 600 mils or greater.* When the angular deviation from a known point to the target is 600 mils or greater, the mil relation is

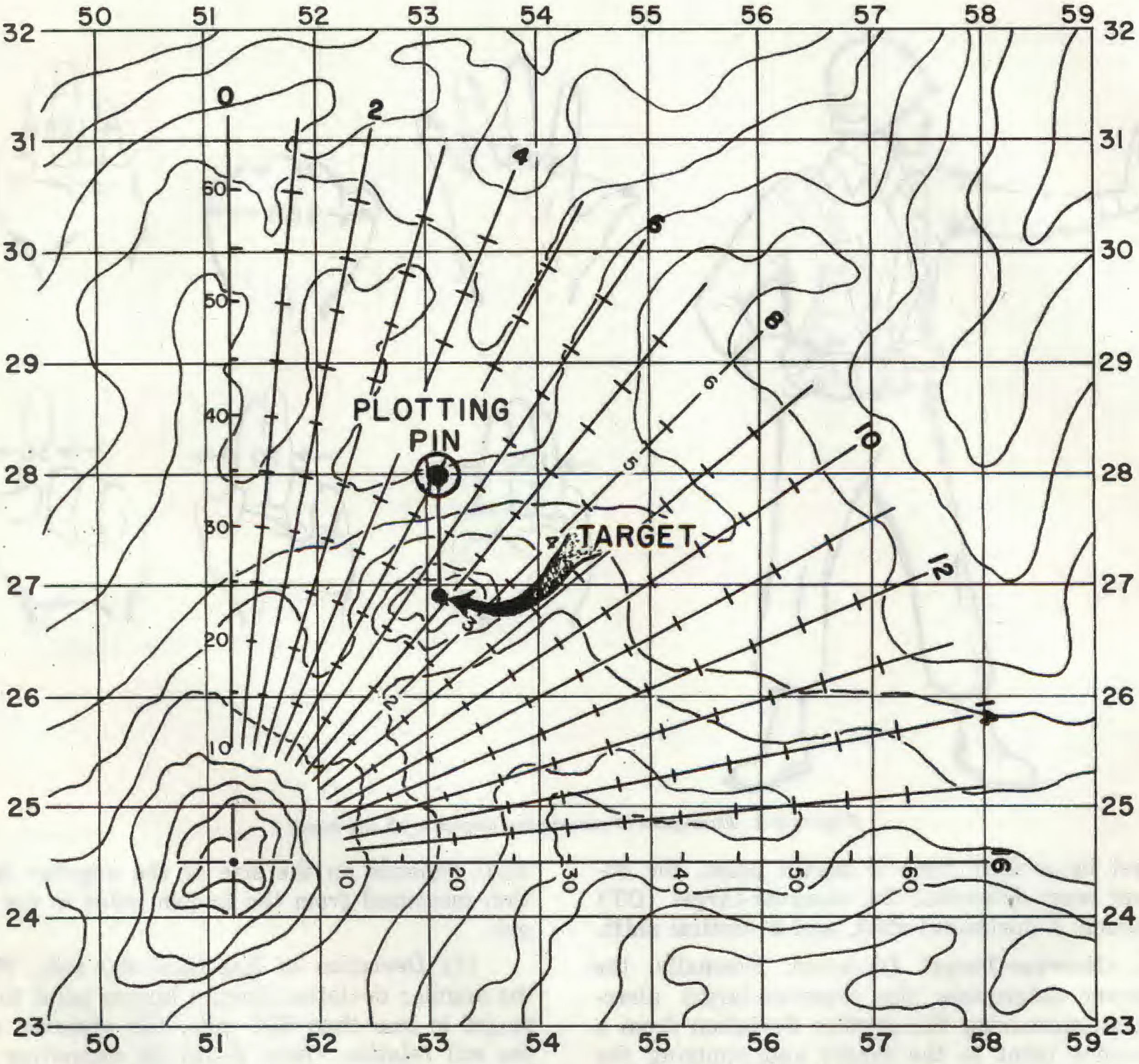


Figure 8-3. Use of observed fire fan to assist in reading coordinates.

not suitable for computing the lateral shift and a trigonometric function must be used for determining the horizontal shift. A trigonometric function is the ratio between two sides of a right triangle. One of these trigonometric functions is the sine (sin). In figure 8-6, the sine of angle A is the length of the side opposite angle A divided by the length of the hypotenuse. The formula for use of the sine factor is $F = \frac{W}{D}$ where F is the sine factor for the angular deviation ℳ (value taken to the nearest 100 mils), D is the distance to the known point (hypotenuse), and W is the width of the side opposite the angle ℳ. Note that D, or distance, is not reduced to units of thousands of meters when sine factors are used. The sine factors are as follows:

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
1000	0.8
1100	0.9
1200	0.9
1300	1.0

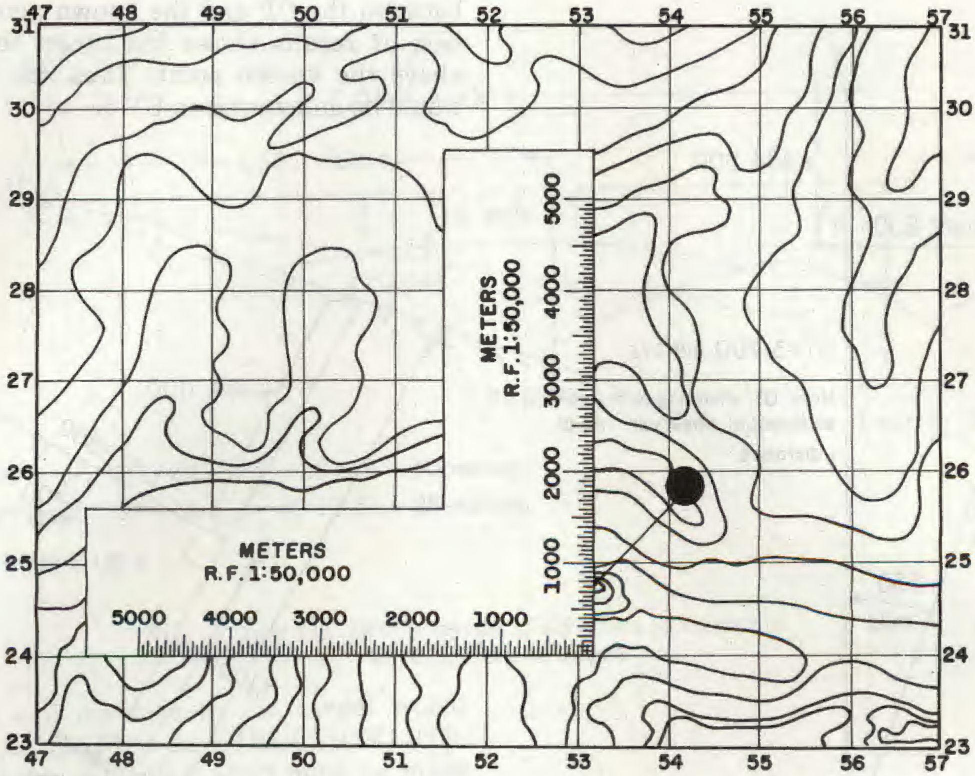


Figure 8–4. Use of coordinate scale.

1400	1.0
1500	1.0
1600	1.0

The observer computes the lateral shift by substituting in the relation W = F × D, where F is the sine factor of the angular deviation from a known point to the target and D is the distance (to the nearest 100 meters) to the known point. To determine the range shift, the observer must first determine the distance from his position to the point at which a perpendicular from the known point to the OT line strikes the OT line (T′). He accomplishes this by substituting again in the relation W = F × D, where, this time, F is the sine factor of the angle complementary to the angular deviation and D is, again, the distance from the observer to the known point. He determines the range shift by comparing the OT′ distance with the OT distance.

Example: An observer measures the angular deviation from registration point 1 to the target as left 700 mils. The distance from the observer to registration point 1 is 2,500 meters, and the estimated distance from the observer to the target is 3,100 meters (fig 8–7). The lateral shift, or W, = 0.6 (sine factor for 700 mils) ×2500, or left 1500. OT′, or W, = 0.8 (sine factor for 900 mils) × 2500 = 2,000 meters. The range shift is ADD 1100 (meters).

c. Vertical Shift. When the shift from a known point method is used, a vertical shift must be announced if there is an obvious difference in the altitude of the known point and the altitude of the target. The vertical shift is normally estimated; however, it may be computed if an angle-measuring instrument (M2 compass, aiming circle, or BC scope) is available. The following procedure is used for computing a vertical shift: The observer measures the vertical angle to the known point. Knowing the distance from his observation post to the known point and using the mil relation, the observer determines the vertical interval, or the amount in meters by which the known point is above or below his observation post. He then computes the vertical interval between his OP and the target. By comparing the known point vertical interval with the target vertical interval, he determines the vertical shift (up or down) from his known point to the target.

Example: An observer measures a vertical angle of minus 10 mils from the OP to a target (fig 8–8). The distance to the target is 2,500 meters. The distance and the vertical angle from the OP to the known point are 1,500 meters and

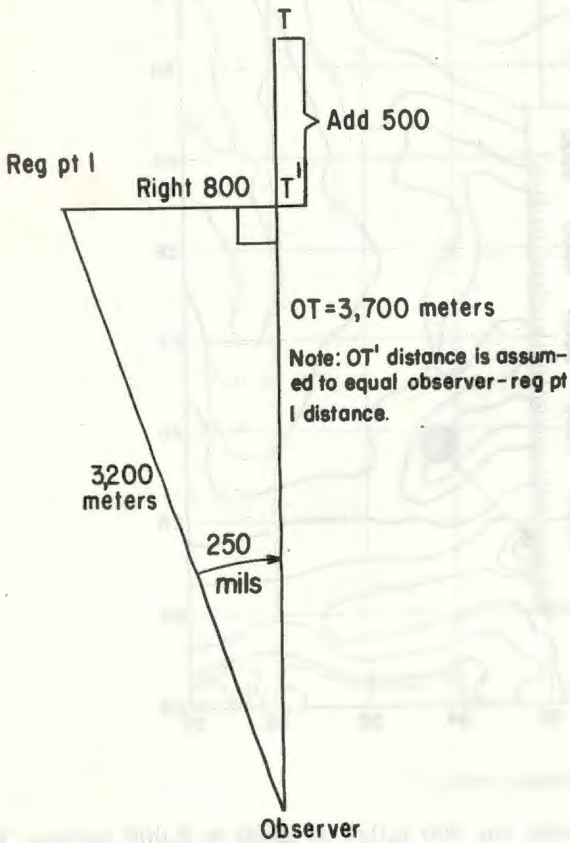


Figure 8-5. Computation of lateral and range shifts.

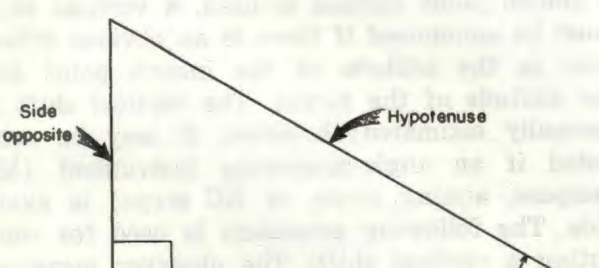


Figure 8-6. Sine function.

minus 20 mils, respectively. In the relation $W = R\not{m}$, W represents the vertical interval to the target (known point), $\not{m}$ represents the measured angle in mils to the target (known point), and R represents the distance to the target (known point) in thousands of meters. Therefore, $W = -10 \times 2.5 = -25$ meters vertical interval between the OP and the target and $W = -20 \times 1.5 = -30$ meters vertical interval between the OP and the known point. A comparison of results shows the target to be 5 meters above the known point. Thus, the vertical shift would be announced as UP 5.

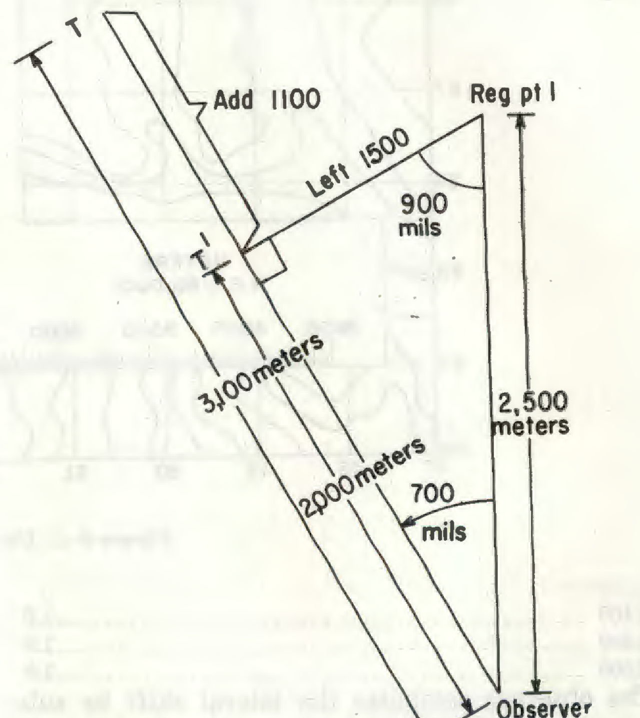


Figure 8-7. Computation of lateral and range shifts by use of sine factor.

8-7. Target Location by Polar Coordinates (Polar Plot)

Polar coordinates consist of the direction and distance from the observer to the target, and, if there is an obvious difference in altitude between the observer's location and the target, a vertical shift. The observer's location must be plotted on the charts at the FDC if the polar coordinate method is to be used. The principal advantage of the polar coordinates method is the rapidity with which the observer can determine the target location. If the direction is correct and accurate corrections are applied to firing data, the first round(s) fired should fall on or close to the line that passes through the observation post and the target (OT line). Subsequent corrections are then easier to determine. As in the grid coordinate method, the observer measures or computes the direction and estimates the distance to the target. In figure 8-9,

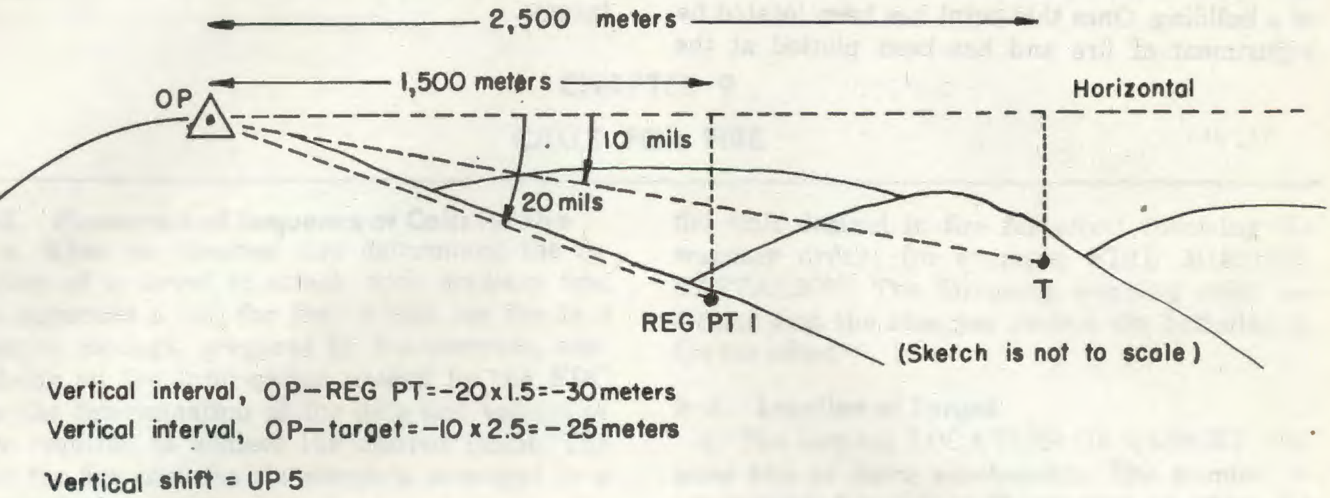


Figure 8–8. Determination of difference in heights of known point and target.

the direction and distance to the target would be reported to the FDC as DIRECTION 1000, DISTANCE 1400. A vertical shift must be made if there is an obvious difference in altitude between the observer's location and the target. The observer, using a BC scope, an aiming circle, or an M2 compass, 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 for $\textit{m}$ and the estimated distance to the target for R in the mil relation, the observer computes the vertical shift.

Example: The observer measures the vertical angle to the target as +20 mils. The estimated distance to the target from the observation post is 2,000 meters. According to the mil relation, $20 = \frac{W}{2.0}$, W = 40 meters. The observer would report the polar coordinates of the target as follows: DIRECTION 1000, DISTANCE 2000, UP 40.

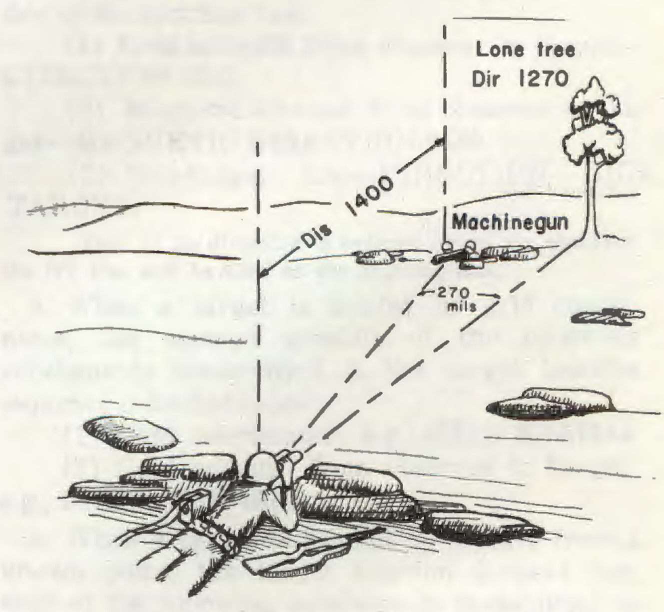


Figure 8–9. Polar coordinates (polar plot).

8–8. Marking Rounds

Poor visibility, unreliable maps, deceptive terrain, or rapid movement through unfamiliar terrain sometimes makes it difficult, if not impossible, for the observer to orient himself. The observer may call for a marking round(s) to be fired on a registration point, a previously fired target, or a prominent terrain feature (e.g., MARK REGISTRATION POINT OR MARK HILL 437). As a last resort, the observer may call for a round(s) to be fired into the center of the target area (e.g., MARK CENTER OF SECTOR). The observer usually calls for a type of projectile that is easily identifiable, such as white phosphorus, or for a high airburst. The FDC prepares data that will place the round(s) at the point of impact or point of burst requested by the observer. If the observer fails to see the round(s), the FDC prepares new data that will move the next round(s) to a different point of impact or that will raise the burst higher in the air. This procedure is continued until the observer positively identifies the round(s). He then orders a shift from the point of impact (burst) of the identified round(s) to a target or an object that is permanent or semipermanent in nature, such as a tree, a road junction, a barn, or the ruins of a building. Once this point has been located by adjustment of fire and has been plotted at the FDC, the observer may use it as a known point from which shifts may be made to subsequent targets.

CHAPTER 9

CALLS FOR FIRE

9-1. Elements and Sequence of Calls for Fire

a. When an observer has determined the location of a target to attack with artillery fire, he transmits a call for fire. A call for fire is a concise message, prepared by the observer, containing all the information needed by the FDC for the determination of the data and volume of fire required to achieve the desired result. The call for fire contains six elements arranged in a prescribed sequence.

b. A list of the elements in the sequence in which they are transmitted is shown in (1) through (6) below. These elements are discussed in paragraphs 9-3 through 9-8.

(1) Observer identification.
(2) Warning order.
(3) Location of target.
(4) Description of target.
(5) Method of engagement.
(6) Method of fire and control.

9-2. Standardization of Terminology

Many military operations involve forces of Allied nations. Therefore, the sequence of the elements and the terminology used in calls for fire have been standardized among Allied nations so that an observer may call for and adjust the fires of the artillery of another nation. For example, *azimuth* is stated as *direction* and *coordinates* are stated as *grid.* Other examples are evident in the succeeding paragraphs.

9-3. Observer Identification

The element OBSERVER IDENTIFICATION consists of appropriate call signs or codes necessary to establish contact between the observer and the unit FDC to which he is transmitting the call for fire. For example, the observer transmits BIG STALLION 18 (call sign of FDC), THIS IS BIG STALLION 26 (call sign of observer).

9-4. Warning Order

The element WARNING ORDER is the notice sent by the observer to achieve communication priority and to alert the fire direction center. The warning order is announced as FIRE MISSION. The observer may indicate the size of the fire unit desired in fire for effect following the warning order; for example, FIRE MISSION, BATTALION. The foregoing warning order indicates that the observer desires the battalion to fire for effect.

9-5. Location of Target

a. The element LOCATION OF TARGET contains two or more subelements. The number of subelements depends on the manner in which the location is reported by the observer. One subelement that is always required in the call for fire by the ground observer is the spotting line. The following are examples of reporting the direction of the spotting line:

(1) Grid azimuth from observer to target—DIRECTION 4310.

(2) Magnetic azimuth from observer to target—MAGNETIC DIRECTION 2450.

(3) Gun-target line—DIRECTION GUN TARGET.

Note. If no direction is ordered by an air observer, the GT line will be used as the spotting line.

b. When a target is located by grid coordinates, the element consists of the following subelements transmitted in the target location sequence indicated below:

(1) Grid coordinates; e.g., GRID 67551344.

(2) Grid azimuth from observer to target; e.g., DIRECTION 4310.

c. When a target is located by a shift from a known point, the target location element consists of the following subelements transmitted in the sequence indicated below:

(1) Known point; e.g., FROM TARGET AF7011.

(2) Observer-target azimuth; e.g., DIRECTION 1670.

(3) Lateral shift (if any); e.g., RIGHT (LEFT) 200.

(4) Range shift (if any); e.g., ADD (DROP) 400.

(5) Vertical shift (if any); e.g., UP (DOWN) 20.

Note. If there is no shift in a particular dimension, that element is omitted; e.g., FROM REGISTRATION POINT 1, DIRECTION 860. RIGHT 400, UP 40 (no range shift) or FROM TARGET AF7012, DIRECTION 1060, ADD 400, UP 20 (no lateral shift).

d. If a known point (e.g., a previously identified target or another location known by the fire direction center and the observer) is to be fired on, the target location is reported as shown in the following examples:

(1) REGISTRATION POINT 2, DIRECTION 4320.

(2) TARGET AF7031, DIRECTION 120.

e. When the location of the target is reported by polar coordinates, the elements of target location are transmitted in the order of direction (10 mils), distance (100 meters), and vertical shift (5 meters); e.g., DIRECTION 1620, DISTANCE 2500, UP 25.

9-6. Description of Target

The element *DESCRIPTION OF TARGET* is a brief but sufficiently informative statement to enable the S-3 to determine the relative importance of the target and the best manner of attack. The observer should include the *number* (15,30,50), the *type* (infantry, vehicles, POL, or tanks), the *activity* (digging in, moving, stationary) of the target. When the target is some type of installation, include the degree of protection provided (e.g., 50 INFANTRY, 2 TANKS 1 TRUCK IN OPEN). The observer should give a clear description of the target size and shape if these are significant. When the target is rectangular, the observer gives the length and width in meters and the azimuth of the long axis to the nearest 50 mils (e.g., 400 BY 200, ALTITUDE 2850). When the target is circular, the observer gives the radius (e.g., RADIUS 200).

9-7. Method of Engagement

The element *METHOD OF ENGAGEMENT* indicates the desired type of adjustment, type of trajectory, type of ammunition, and distribution of fire.

a. Type of Adjustment. In adjustment, two types of fire may be employed, area or precision.

(1) If no specific type of adjustment is designated, area fire will be used. In area fire, the adjustment normally is conducted with the two center pieces of the battery.

(2) When precision fire is desired, the observer announces either REGISTRATION or DESTRUCTION, depending on the reason for firing. Only one piece is used during a precision mission.

(3) The term DANGER CLOSE will be included in the type of adjustment when the target is within 600 meters of friendly troops.

b. Type of Trajectory. A choice of two trajectories normally is available: low-angle or high-angle. When low-angle fire is desired, this element is omitted. If the observer desires high-angle fire, he requests HIGH ANGLE. When the observer omits a reference to trajectory but computations in the FDC indicate that high-angle fire is necessary, the FDC will notify the observer that high-angle fire will be used.

c. Ammunition. If the observer does not request a specific projectile or fuze, shell HE, fuze quick will be used.

(1) The observer may initially request one type of projectile or fuze and subsequently request another type of projectile or fuze to complete the fire mission.

(2) When the observer requests smoke, the S3 normally will direct the use of HE initially in the adjustment and the use of smoke for the completion of the adjustment and fire for effect.

(3) When the observer wants a combination of projectiles and/or fuzes in effect, he must so state in this element of the call for fire; e.g., HE AND WP IN EFFECT or VT AND QUICK IN EFFECT.

(4) The observer may also request the volume of fire he deems necessary in fire for effect; e.g., 3 ROUNDS.

d. Distribution of Fire.

(1) A parallel sheaf usually is fired on an area target in fire for effect. When another type of sheaf is desired, the observer must so announce; e.g., CONVERGE or SHEAF 100 METERS.

(2) The observer may request that the fires of the battalion be spread in direction or in range. The standard spread is 100 meters. One battery fires at the adjusting point and the other batteries fire the spread. One of the batteries firing the spread fires 100 meters beyond or right of the adjusting point and the other battery fires 100 meters short or left of the adjusting point.

(3) If the observer desires to spread the fires of the battalion, he will request either RANGE SPREAD or LATERAL SPREAD. The fires of the battalion can also be fired as a half-range or a half-lateral spread. In order to determine which spread will be most effective, the observer must keep in mind that all spreads are fired in relation to the gun-target line, not the observer-target line.

9-8. Method of Fire and Control

The element *method of fire and control* indicates the desired manner of attacking the target, indicates whether or not the observer desires to control the time of delivery of fire, and indicates whether or not an adjustment is to be made.

a. Method of Fire. In area fire, the adjustment normally is conducted with the two center pieces of the adjusting battery firing simultaneously. If for any reason the observer determines that PLATOON RIGHT (LEFT) will be more adequate, he may request it. The normal interval of time between rounds fired by a platoon or battery right or left is 5 seconds. If the observer wants some other interval, he may so specify.

b. Method of Control. Method of control is announced by the observer by use of the terms below.

(1) *At my command.* If the observer wishes to control the time of delivery of fire, he includes AT MY COMMAND in the method of control immediately preceding ADJUST FIRE ((2) below) or FIRE FOR EFFECT ((3) below). When the pieces are ready to fire, the FDC announces BATTERY (BATTALION) IS READY; the observer announces FIRE when he is ready for the pieces to fire. AT MY COMMAND remains in effect until the observer announces CANCEL AT MY COMMAND.

(2) *Adjust fire.* If the observer considers that an adjustment is necessary and if he can see and adjust the fire, he announces ADJUST FIRE. Unless the observer has announced AT MY COMMAND, ADJUST FIRE indicates that the firing unit may begin firing when ready.

(3) *Fire for effect.* When the location of a target is sufficiently accurate to eliminate the requirement for an adjustment, the observer announces FIRE FOR EFFECT. Accurate, immediate fire for effect has appreciable surprise value and is preferred whenever possible. Fire for effect without an adjustment is warranted where the target is at a surveyed location, where the target has been fired previously, or where the target has been accurately located by an observer. FIRE FOR EFFECT indicates that the observer can see the fires and, unless the observer has requested that the mission be conducted AT MY COMMAND, that the firing unit may begin firing when ready.

(4) *Cannot observe.* CANNOT OBSERVE indicates that the observer is unable to adjust 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.

9-9. Short Phrase Read-Back

The read-back method of radiotelephone transmission is used in the conduct of fire without the transmission instruction to read back. The observer divides the elements of the call for fire into short phrases, each of which he transmits to the FDC in a separate transmission. As each phrase is received, the FDC operator reads it back to the observer. The number of elements in each phrase depends on the established procedures and on the capabilities of the personnel involved in the conduct of fire. Examples of the elements and subelements of a call for fire are shown in table 9-1. Basic radiotelephone procedure is prescribed by ACP-125.

Table 9-1. The Call for Fire

		Examples				
Element	When omitted	1. Registration using surveyed chart	2. Area mission using polar plot	3. Destruction mission using shift from a known point	4. Area mission using prearranged data	5. Area mission firing high-angle fire
a. Identification of observer	Never	BIG BOY 18, THIS IS BIG BOY 25	RED BACK 18, THIS IS RED BACK 26	WHITE HORSE 18, THIS IS WHITE HORSE 26	LONG ROPE 18, THIS IS LONG ROPE 25	DARK NITE 18, THIS IS DARK NITE 26
b. Warning	Never	FIRE MISSION	FIRE MISSION	FIRE MISSION	FIRE MISSION, BATTALION	FIRE MISSION
c. Location of target	Never	REGISTRATION POINT 2, Direction 4670	DIRECTION 2720, DISTANCE 3500, UP 30	FROM REGISTRATION POINT 1, DIRECTION 2120, LEFT 400, ADD 600 DOWN 30	TARGET AF 7302 DIRECTION 4600	GRID 712684, DIRECTION 4060
d. Description of target	In a registration	Omitted	60 INFANTRY IN OPEN, 150 BY 300, ATTITUDE 800	CONCRETE BUNKER	5 TANKS AND COMPANY OF INFANTRY	MORTAR FIRING
e. Method of engagement:						
(1) Type of adjustment	Area fire	REGISTRATION	Omitted	DESTRUCTION	Omitted	DANGER CLOSE
(2) Trajectory	Low-angle fire	Omitted	Omitted	Omitted	Omitted	HIGH ANGLE
(3) Ammunition						
(*a*) Type of projectile	When shell HE is desired.	Omitted	Omitted	Omitted	HE AND WP, 3 ROUNDS	Omitted
(*b*) Fuze action	When fuze quick is desired or when HC smoke or illuminating shell is requested.	Omitted	TIME IN EFFECT	Omitted	Omitted	VT IN EFFECT
(4) Distribution of fire	When a parallel sheaf at center range is desired.	Omitted	Omitted	Omitted	RANGE SPREAD	CONVERGE
f. Method of fire and control.	Never	ADJUST FIRE	PLATOON RIGHT, ADJUST FIRE	ADJUST FIRE	FIRE FOR EFFECT	ADJUST FIRE

9-10. Correction of Errors

a. Errors are sometimes made by the observer in transmitting data or by the FDC personnel in reading back the data. If an observer realizes that he has made an error in his transmission or that the FDC has made an error in the read-back, he announces CORRECTION and transmits the correct data. If two or more elements or subelements of the call for fire were contained in an erroneous transmission, but only one element or subelement was in error, the observer will correct only the erroneous element or subelement provided the remainder of the transmitted data will not be affected by the correction.

Example: The observer has transmitted FROM REGISTRATION POINT 2, DIRECTION 4680, OVER. He immediately realizes that he should have sent DIRECTION 5680. He then announces CORRECTION, DIRECTION 5680, OVER. After receiving the correct read-back, he continues to send the remainder of the call for fire.

b. When an error has been made in a subelement and the correction of that subelement will affect other transmitted data, the observer will announce CORRECTION and then transmit the correct subelement and all affected data in the proper sequence.

Example: The observer has transmitted LEFT 200, ADD 400, UP 40, OVER. He then realizes that he should have sent DROP 400. To correct this element, he will send CORRECTION, LEFT 200, DROP 400, UP 40, because the LEFT 200 and UP 40 will be canceled if they are not included in the corrected transmission.

c. If the observer has transmitted his entire call for fire and then discovers that he has transmitted an incorrect element or subelement or has omitted an element or a subelement, he must transmit the correct version of that element or subelement together with all affected data.

Example: The observer has sent BIG STALLION 18, THIS IS BIG STALLION 25, FIRE MISSION OVER—FROM REGISTRATION POINT 2, DIRECTION 5680, OVER—LEFT 200, ADD 400, UP 40, OVER—INFANTRY IN OPEN, TIME IN EFFECT, ADJUST FIRE, OVER. He then realizes that fuze VT would be more effective than fuze time on this target. To correct this error, he must send CORRECTION, VT IN EFFECT, OVER.

9-11. Calls for Fire From Higher Headquarters

Calls for fire from higher headquarters and calls for fire from the observer are similar in format. The call for fire from higher headquarters will specify in the warning order the fire unit to fire for effect, whereas the observer's call for fire can only request the fire unit. An example of a call for fire from higher headquarters is as follows:

Warning order	FIRE MISSION, BATTALION
Target location	TARGET AF 1201
Description of target	INFANTRY BATTALION ASSEMBLY AREA
Method of engagement	VT, 3 ROUNDS
Control	TIME ON TARGET IS 10 MINUTES FROM ...... NOW

CHAPTER 10

ADJUSTMENT PROCEDURE BY GROUND OBSERVER

Section I. GENERAL

10–1. When to Adjust

When the observer cannot locate the target with sufficient accuracy to warrant firing for effect, he will 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. If, in his opinion, fire for effect can be delivered on the basis of the target location and surprise is desired, he will request FIRE FOR EFFECT (FFE) in his call for fire. If registration has not been accomplished recently, the fire direction officer may direct that an adjustment be conducted, regardless of the accuracy of the target location.

10–2. Adjusting Point

The observer must select a point upon which to adjust (adjusting point). In precision fire, the adjusting point is the target. In area fire, the adjusting point should be a well-defined point near the center of the area occupied by the target (fig 10–1).

10–3. Appearance of Bursts

The observer must be able to identify the type of shell and fuze used from the appearance of the burst(s). Descriptions of the types of shells and fuzes with which an observer normally will be concerned are given in *a* through *f* below, however, the sizes of the bursts will vary in accordance with the caliber of the weapon.

a. Shell HE, Airburst, Fuze Time or Fuze VT. A fuze time or fuze VT airburst is characterized by a flash, a sharp explosion, and a puff of black smoke that becomes elongated along the trajectory. 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 airburst characterized by a flash, a sharp explosion, and a ball of smoke (usually black). Dirt is kicked up by the shell fragments from the side and base spray. Burst appearance depends on 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 airburst are indications of an effective ricochet burst.

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 outward. If the impact occurs on a hard surface, such as a rock, a flash may also appear. Fuze quick fired into a wooded area will sometimes result in an airburst caused by the projectile striking the trees and detonating before it reaches the ground.

d. Shell HE, Fuze Delay, Mine Action. A mine action burst is characterized by the eruption of a vertical column of earth, often with clods of earth. There is very little smoke, and the explosion is muffled.

e. HC and Colored Smoke, Fuze Time. Functioning of an HC or a 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. As the canisters fall to the ground, they emit smoke in thin streams. The 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. Small particles of phosphorus are spread upward and outward as a pillar of smoke forms and rises.

10–4. Fuze Selection for High-Explosive Projectiles

The effect obtained with an HE projectile depends on the fuze action (fig 10–2). (For a detailed discussion of the effects of HE projectiles, see chapter 27.)

a. Fuze VT. A VT fuze is a radio-activated fuze that detonates the projectile automatically at a predetermined height above the earth's surface. Therefore, a height-of-burst adjustment is not required. There is a point detonating backup mechanism in case of failure of the radio

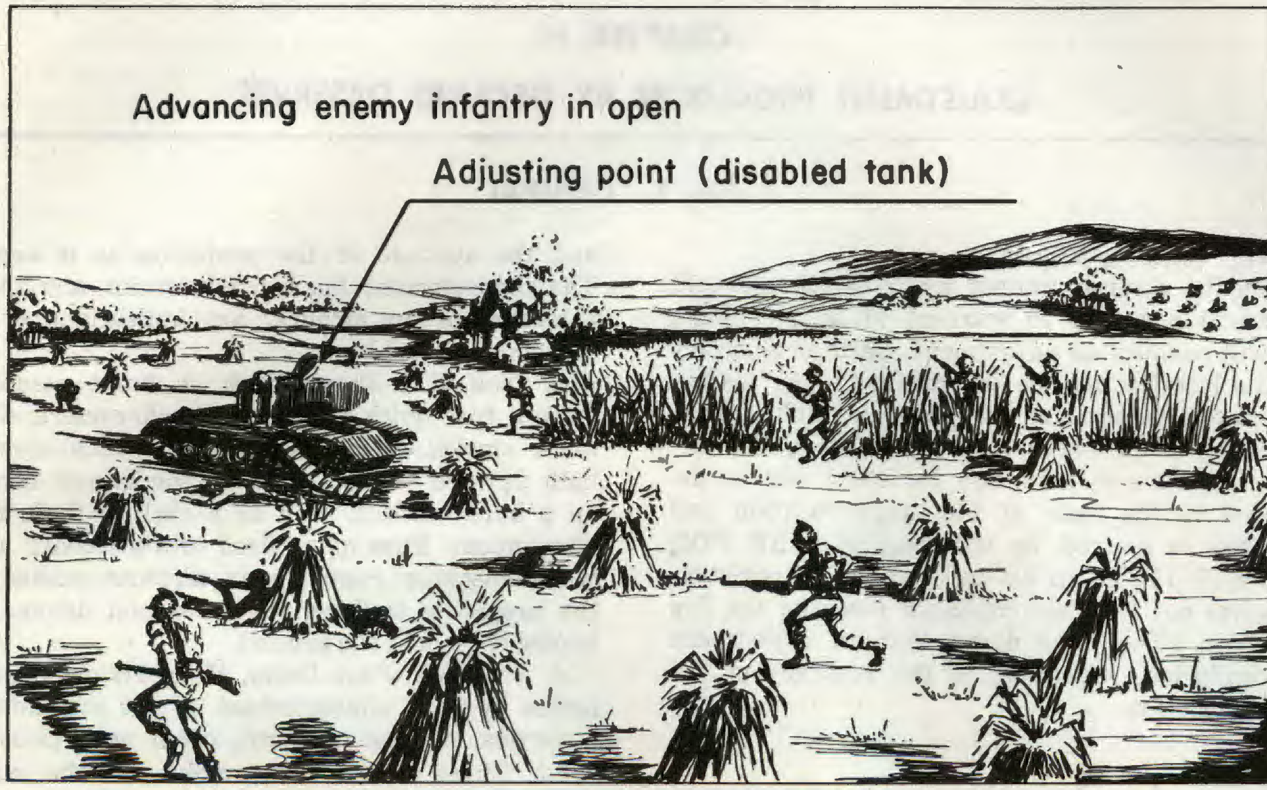


Figure 10–1. Adjusting point in area fire.

activation. During the adjustment, fuze quick normally is employed to obtain greater speed and to facilitate observer spottings. Fuze VT is suitable for use against—

(1) Personnel in the open.

(2) Personnel in entrenchments (low-angle fire only).

(3) Area targets when neutralization is desired.

b. Fuze Time. A time fuze detonates the projectile on operation of a preset time mechanism or on impact. The height of burst is controlled by the observer. Since the observer must adjust the height of burst, use of this fuze is more time consuming than use of fuze VT. However, with fuze time the observer may obtain any height of burst desired. Fuze time is ineffective in high-angle fire, because of the large height-of-burst probable error involved in the long time of flight. Fuze time is suitable for use against the same types of targets as those against which fuze VT is used, within the limits imposed by the vertical probable error of the fuze.

c. Fuze Delay. When delay action of the fuze is used, the projectile has time after impact and before detonation either to penetrate and produce mine action or to ricochet and produce a low airburst. Fuze delay is used with shell HE for destruction missions that require penetration and for ricochet fire.

(1) Factors which determine whether a shell will ricochet are the angle of impact; shape, weight, and terminal velocity of projectile; the use of fuze delay; and the condition of the surface of the ground, including the composition of the soil.

(2) When the angle of impact is small, the projectile tends to ricochet rather than to penetrate the ground. As the angle of impact increases the tendency to penetrate increases. When the projectile penetrates the ground, the burst will produce either a crater or a camouflet, depending on the depth of the burst, type of soil, and force of detonation. If the penetration is very great, the burst may produce a camouflet; that is, a hole will be formed underground, but the surface of the ground will remain uncratered.

(3) When penetration occurs and the shell is in the earth at the instant of detonation, frag-

mentation effect above the ground is very small. Penetration into a bunker or dugout will produce casualties by blast effect and fragmentation. Penetration into a structure built of logs, sandbags, or similar materials results in the blowing apart of constituent units. The effectiveness depends on the amount of high-explosive filler in the penetrating projectile. Use of concrete-piercing (CP) fuze increases the depth of penetration and the angle at which penetration may be obtained against reinforced concrete or heavy masonry targets.

(4) Ricochet fire should be used only against personnel in shallow foxholes or shallow trenches. The effect obtained with ricochet fire against these targets is somewhat better than the effect obtained with VT or time fuze because of the lower height of burst and the nose-up attitude of the projectile. The lowered height of burst reduces the effect obtained against deeply entrenched targets. In order for a given number of rounds fired with fuze delay to be as effective as the same number of rounds fired with fuze quick against troops prone in the open, 80 percent of the rounds fired with fuze delay must produce ricochet action. Therefore, ricochet fire is not used against troops in the open. Factors which determine whether a projectile will ricochet cannot be evaluated for a particular point of impact until the bursts are spotted. Ricochet fire must be observed. Another type of fuze must be used if ricochet action cannot be expected from at least 50 percent of the rounds fired in fire for effect.

d. Fuze Quick. Quick (superquick) 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 rapid adjustment. Fuze quick is suitable for use against—

(1) Personnel standing in the open (very effective in high-angle fire).

(2) Personnel in sparsely wooded terrain where tree bursts give the effect of low airbursts.

(3) Materiel when penetration of the material is not required for producing damage.

(4) Armored vehicles when the concussion effect of heavy artillery is sufficient for producing damage.

e. Combined Fuze Action in Fire for Effect. When the target is such that more than one type of fuze action will add to the effectiveness of fire for effect, the observer will include the fuzes desired in the call for fire or in subsequent corrections.

10-5. Spottings

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 spotting. Spottings are made for range, deviation, and height of burst. Spottings must be by the observer at the instant the burst occurs except when it is necessary to delay a spotting to take advantage of drifting smoke or dust.

a. The observer should be required to announce his spottings during his early training. As an observer gains experience, spottings need not be announced.

b. Under certain conditions the observer may be able to make a spotting even though he is unable to see the burst. For example, if the observer hears but does not see a burst and the only possible place where the burst could occur and not be visible to the observer is in a ravine beyond the adjusting point, then he should assume that the burst is beyond the adjusting point.

c. If visibility is temporarily impaired or if the observer is unable to obtain a spotting for a particular round, he reports UNOBSERVED, REPEAT.

10-6. Corrections

The observer causes the mean point of impact or burst to be placed on, or sufficiently close to, the target by making appropriate corrections during the adjustment. From his spottings, the observer determines deviation and range corrections in meters; he announces these corrections in that sequence as commands to bring the bursts onto the OT line and to establish the appropriate bracket of the adjusting point along the OT line.

Section II. ADJUSTMENT OF DEVIATION

10-7. Deviation Spottings

a. Deviation is the lateral distance from the burst center to the OT line. A deviation spotting is the angular amount and direction of the deviation. During the conduct of fires, the observer measures, in mils, the angular deviation from the OT line to the center of each burst or group of bursts (fig 10-3).

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. A deviation spotting is announced as LINE or (so much) RIGHT (LEFT). For example, the observer sees a burst and measures the angular deviation as 20 mils to the right of the OT line. His deviation spotting in this instance is 20 RIGHT.

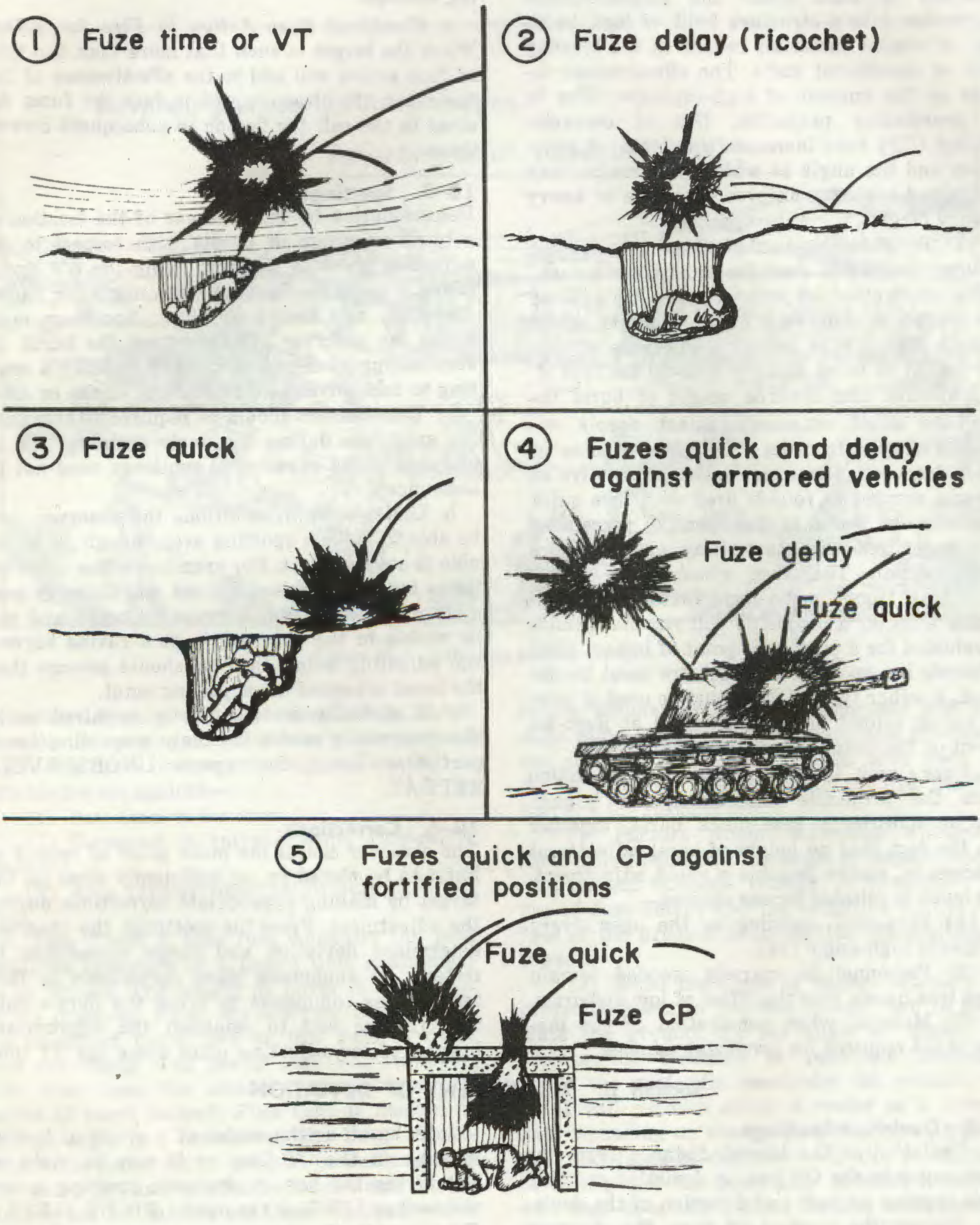


Figure 10-2. Effects of high-explosive bursts.

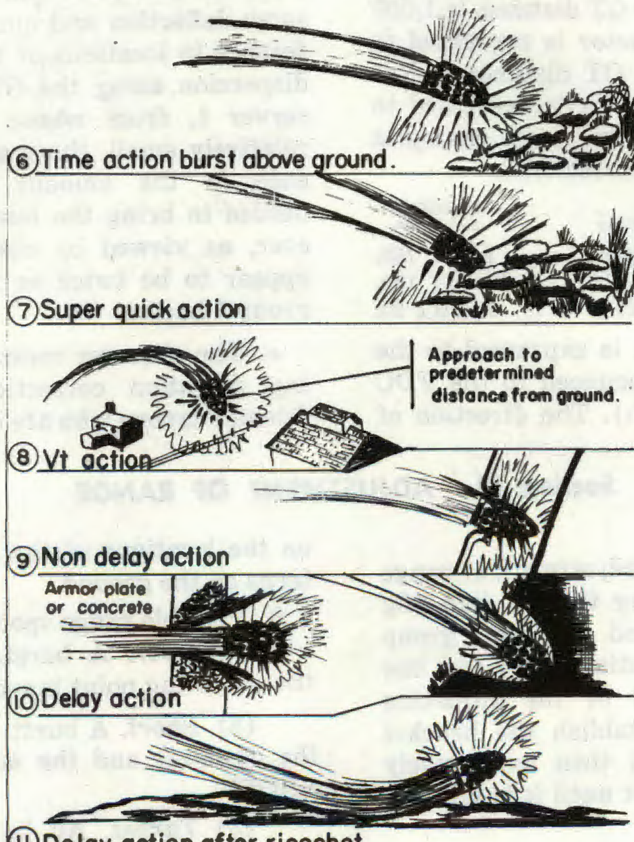


Figure 10–2—Continued.

10-8. Deviation Corrections

a. A deviation correction is the distance in meters perpendicular to the OT line required to move a subsequent group of bursts to the OT line. In the adjustment phase on an area mission, minor deviations (10 to 20 meters) should be ignored unless such action would preclude obtaining range spottings. In the adjustment phase of a precision mission, all deviations, however minor, must be corrected to the OT line.

b. The observer computes a deviation correction by multiplying the deviation spotting by the OT factor. The OT factor is the OT distance in thousands of meters. If the OT distance is 1,000 meters or greater, the OT factor is expressed to the nearest thousand. If the OT distance is less than 1,000 meters, the OT factor is expressed to the nearest hundred. The following are examples of computations of deviation corrections:

OT distance	OT factor	Spotting	Deviation correction
3600	4	40 RIGHT	LEFT 160.
3400	3	50 LEFT	RIGHT 150.
800	0.8	40 LEFT	RIGHT 30.

c. The deviation correction is expressed to the nearest 10 meters and is announced to the FDC as LEFT (RIGHT) (so much). The direction of the correction is always opposite the direction of the spotting.

d. When the angle between the OT line and the gun target (GT) line (angle T) is 500 mils or greater, the fire direction center will notify the observer of this fact after the first SHOT is given (fig 10-4). When the angle T is large, the observer should consider the range dispersion of the weapon when determining corrections. What the observer sees as deviation may be due, wholly or partly, to range dispersion, which cannot be corrected by deviation corrections. In figure 10-5 the two groups of rounds shown were fired at the same deflection and quadrant elevation. The difference in locations 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 the bursts to the OT line. However, as viewed by observer 2, group 2 bursts appear to be twice as far from the OT line as group 1 bursts.

e. The observer must exercise caution in making deviation corrections in the direction of friendly troops who are close to the target.

Section III. ADJUSTMENT OF RANGE

10-9. General

The normal procedure for the adjustment of range is to establish a bracket along the OT line (fig 10-6). A bracket is established when one group of rounds falls over the adjusting point and one group of rounds falls short of the adjusting point. The observer must establish the bracket early in the adjustment and then successively decrease the size of the bracket until it is appropriate to enter fire for effect.

10-10. Range Spottings

a. Definite range spottings are required for making a proper range adjustment. Any range spotting other than DOUBTFUL or LOST (UNOBSERVED) is definite.

(1) A burst or group of bursts on the OT line normally, gives a definite range spotting. Figure 10-7 is a guide showing approximate areas for the various spottings.

(2) The observer may make a definite range spotting when the burst(s) is not on the OT line by using his knowledge of the terrain, drifting smoke, shadows, and wind. However, even experienced observers must exercise caution and good judgment when making such spottings.

(3) Spottings of airbursts for range are based on the locations of the burst fragmentation patterns on the ground.

b. Possible range spottings are as follows:

(1) *Over.* A burst(s) that appears beyond the adjusting point is spotted OVER.

(2) *Short.* A burst (s) that appears between the observer and the adjusting point is spotted SHORT.

(3) *Target.* An impact burst that hits the target is spotted TARGET. This spotting is used *only in precision fire.*

(4) *Range correct.* A burst or center of a group of bursts that is at the proper range is spotted RANGE CORRECT. (This spotting is not used in the fire-for-effect phase of a precision mission.)

(5) *Doubtful.* A burst that can be observed but cannot be determined as over, short, target, or range correct is spotted DOUBTFUL. A burst that appears range correct in the fire-for-effect phase of a precision mission is spotted DOUBTFUL.

(6) *Lost.* A burst that is not observed and is not known to be definitely beyond or short of the adjusting point is reported as LOST. When

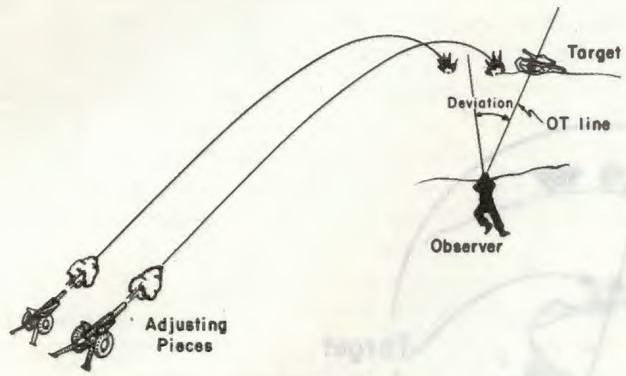


Figure 10–3. Deviation.

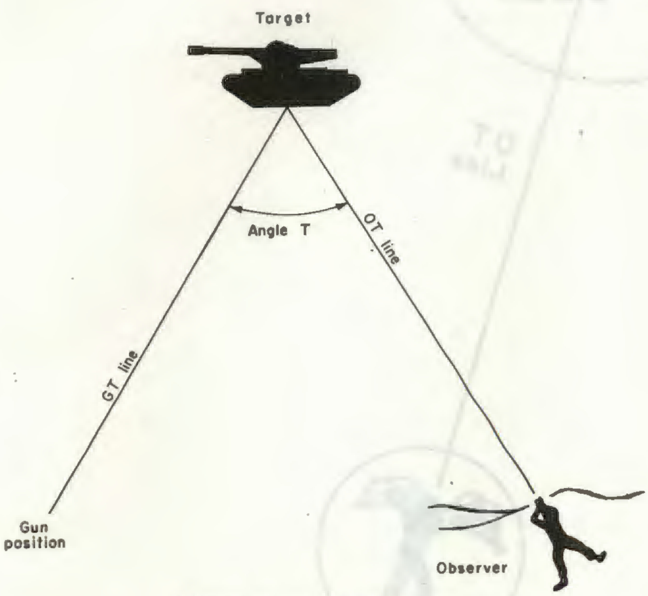


Figure 10–4. Angle T.

rounds are reported LOST, a bold shift in deviation or range should be made.

(7) *Lost over (short).* A burst that is not observed but is known to be definitely beyond or short of the adjusting point is reported as LOST OVER or LOST SHORT.

10–11. Bracketing

a. When the first definite range spotting is obtained, the observer should make a range correction that can be expected to result in a range spotting in the opposite direction; e.g., if the first definite range spotting is SHORT, the observer should add enough to obtain an OVER on the next round or group of rounds. As a guide, after the first definite range spotting, a range change of 400 meters is suggested if the initial target location is estimated, and a range change of 200 meters is suggested if the initial target location is surveyed.

b. Once a bracket has been established, it is successively decreased, normally by splitting, until it is appropriate to enter fire for effect. Fire for effect is normally asked for in area fire when a 100-meter bracket is split or when fire on the target is observed.

c. The procedures in *a* and *b* above are not to be considered inflexible. The observer must use his knowledge of the terrain, knowledge gained from previous firing and general experience, and good judgment in determining the size of the initial and subsequent range changes. For example, if the observer adds 800 after in initial range spotting of SHORT, and the second range spotting is OVER, but the bursts are much closer to the adjusting point then the initial rounds, a range change of DROP 200 would be appropriate.

d. When the observer requests an adjustment on a target close to friendly troops, he makes range corrections toward friendly elements in increments that he considers safe. He does not necessarily attempt to bracket the target with any successive corrections. As his corrections bring the bursts closer to the target, definite range spottings can be made easily. Making small, safe shifts rather than establishing the normal bracket may result in a greater expenditure of ammunition and time but may be necessary to insure safety (fig 10–8). An adjustment made in this manner is referred to as *creeping* and should be used exclusively during DANGER CLOSE missions.

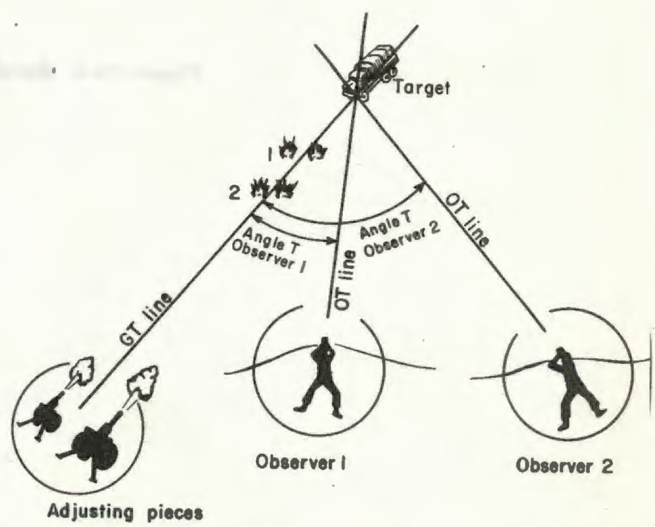


Figure 10–5. The effect of angle T when viewing range dispersion.

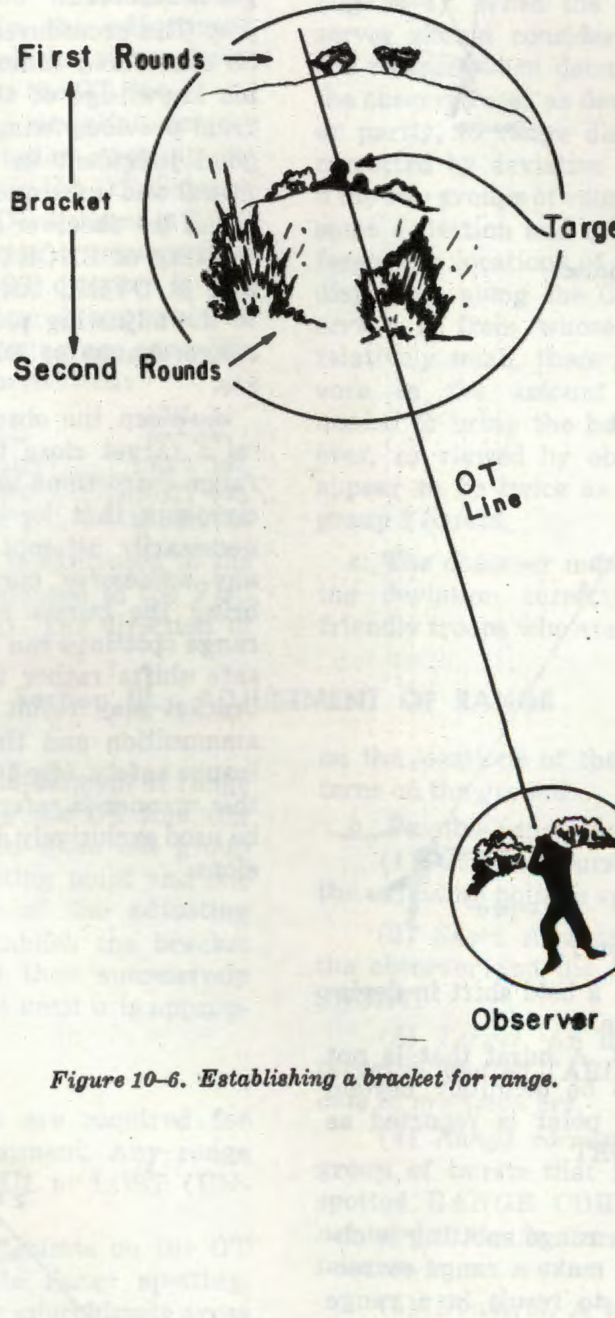


Figure 10–6. Establishing a bracket for range.

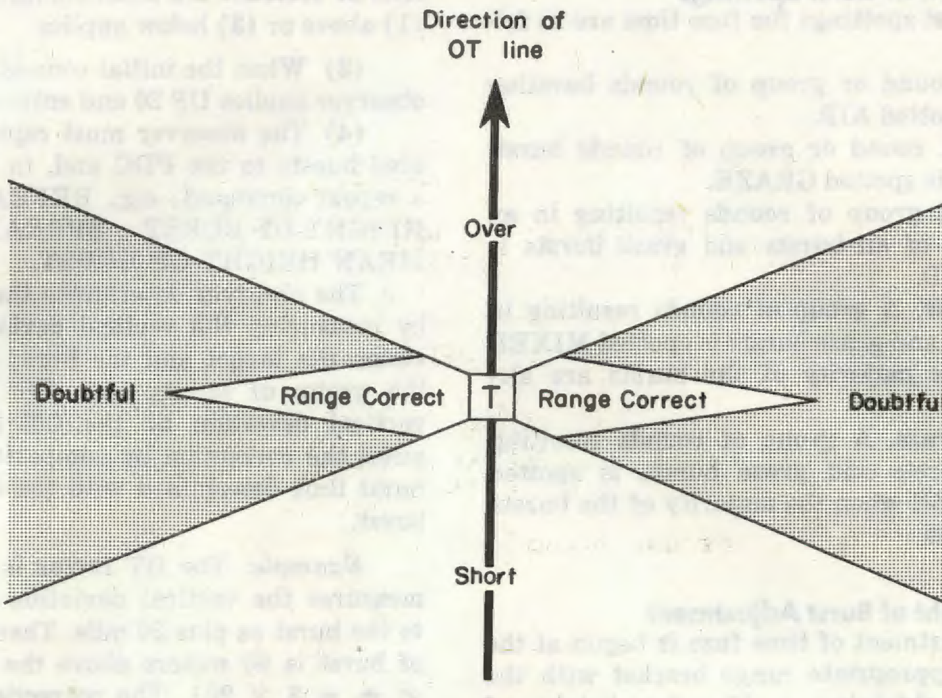


Figure 10-7. Range spottings.

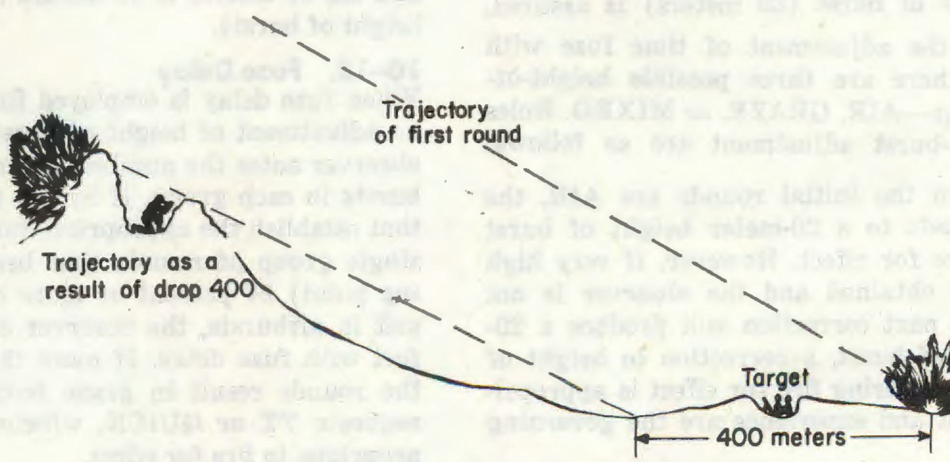


Figure 10-8. Need for creeping when close to friendly troops.

Section IV. ADJUSTMENT OF HEIGHT OF BURST

10-12. General

In firing fuze time in area fire, the observer must adjust the height of burst. The observer conducts the adjustment of deviation and range with fuze quick and then, upon splitting the appropriate range bracket, normally 100 meters, or obtaining a range correct spotting, begins the adjustment of height of burst. Normally, further corrections to deviation and range are not required. The observer spots height of burst and determines the correction ot the nearest 5 meters to raise or lower the bursts to the desired height. He announces the correction as UP (DOWN) (so much). He computes height-of-burst shifts by using the mil relation in the same manner as for deviation shifts. The proper height of burst for fire for effect is normally 20 meters above the target. Any time two bursts are widely separated in height, the observer must report this fact to the FDC. When fuze delay is being used for ricochet fire, no correction for height of burst can be made. When VT fuze is used, only malfunctions and graze bursts are reported.

10-13. Height-of-Burst Spottings

Height-of-burst spottings for fuze time are as follows:

a. Air. A round or group of rounds bursting in the air is spotted AIR.

b. Graze. A round or group of rounds bursting on impact is spotted GRAZE.

c. Mixed. A group of rounds resulting in an equal number of air-bursts and graze bursts is spotted MIXED.

d. Mixed Air. A group of rounds resulting in both airbursts and graze bursts is spotted MIXED AIR when the majority of the bursts are airbursts.

e. Mixed Graze. A group of rounds resulting in both airbursts and graze bursts is spotted MIXED GRAZE when the majority of the bursts are graze bursts.

10-14. Height of Burst Adjustment

a. The adjustment of time fuze is begun at the split of the appropriate range bracket with the objective of obtaining a 20-meter height of burst. Fire for effect is entered only when a correct height of burst (20 meters) is assured.

b. During the adjustment of time fuze with two pieces, there are three possible height-of-burst spottings—AIR, GRAZE, or MIXED. Rules for height-of-burst adjustment are as follows:

(1) When the initial rounds are AIR, the observer adjusts to a 20-meter height of burst and enters fire for effect. However, if very high airbursts are obtained and the observer is not sure that the next correction will produce a 20-meter height of burst, a correction to height of burst without entering fire for effect is appropriate (judgment and experience are the governing factors).

(2) When the initial rounds are GRAZE, the observer applies UP 40 and continues the asjustment. A 40-meter height-of-burst correction will be applied until spottings of AIR or MIXED are obtained and then the rule in (1) above or (3) below applies.

(3) When the initial rounds are MIXED, the observer applies UP 20 and enters fire for effect.

(4) The observer must report widely separated bursts to the FDC and, in most cases, give a repeat command; e.g., REPEAT, 100-METER HEIGHT-OF-BURST SPREAD; 60-METER MEAN HEIGHT OF BURST.

c. The observer determines the height of burst by measuring the vertical deviation in mils between the target and the burst or the center of the group of bursts and then multiplying the vertical deviation by the OT factor. He computes the correction by comparing the height of burst thus determined with the desired height of burst.

Example: The OT factor is 3. The observer measures the vertical deviation from the target to the burst as plus 20 mils. Therefore, the height of burst is 60 meters above the target ($W = R \times \text{\textmu} = 3 \times 20$). The correction is DOWN 40, FFE (the desired height of burst is 20 meters and the 60 meters is 40 meters above the desired height of burst).

10-15. Fuze Delay

When fuze delay is employed for ricochet action, no adjustment of height of burst is possible. The observer notes the number of airbursts and graze bursts in each group. If in two groups of rounds that establish the appropriate range bracket (or a single group of rounds that bracket the adjusting point) 50 percent or more of the rounds result in airbursts, the observer enters fire for effect with fuze delay. If more than 50 percent of the rounds result in graze bursts, the observer requests VT or QUICK, whichever is more appropriate, in fire for effect.

10-16. Fuze VT

No adjustment of height of burst is possible with fuze VT. Burst height is controlled by the mechanism within the fuze.

Section V. SUBSEQUENT CORRECTIONS

10–17. General

a. After the initial burst(s) appears, the observer transmits subsequent corrections until the mission is completed. These corrections include appropriate changes in elements previously transmitted and the necessary corrections for deviation, range, and height of burst. Elements that may require correcting and the order in which corrections are announced are as follows:

(1) Observer-target direction.
(2) Trajectory.
(3) Method of fire.
(4) Distribution.
(5) Projectile.
(6) Fuze.
(7) Deviation.
(8) Range.
(9) Height of burst.
(10) Control.

b. Any element for which a change or correction is not desired is omitted.

10–18. Change in Observer-Target Direction

A change in observer-target direction is given when it deviates from the announced direction by more than 100 mils. For example, an observer begins an adjustment on several self-propelled guns, using a tree at direction 5620 as the adjusting point. During the adjustment the self-propelled guns move to a new position an appreciable distance from the adjusting point. The observer selects a new adjusting point in the vicinity of the target and measures direction 5840 to that point. The first element of his next correction is DIRECTION 5840.

10–19. 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, an observer is making an adjustment on some moving armored personnel carriers. During the adjustment the carriers move into a deep gully for cover. Knowing from previous firing in the area that high-angle fire will be necessary to bring effective fire into the gully, the observer requests HIGH ANGLE. Conversely, an observer is making a high-angle adjustment on a column of vehicles halted in a town along a street with tall buildings. During the adjustment the vehicles move out toward the edge of town. As soon as he notices the vehicles emerging from the town, the observer should request CANCEL HIGH ANGLE to expedite the firing.

10–20. Change in Method of Fire

The observer must announce any change he desires in the method of fire. For example, in order to change from pieces firing simultaneously to pieces firing in order from left to right, the observer requests PLATOON LEFT. He may request this change to take advantage of the wind when smoke shells are bing fired or to clarify spottings when one burst is obscuring another. He cancels PLATOON LEFT by announcing CANCEL PLATOON LEFT.

10–21. Change in Distribution

If the observer desires a sheaf other than parallel, he must specify the type desired; e.g., CONVERGE (OPEN), SHEAF 100 METERS. If the observer wishes to change to a parallel sheaf during adjustment or fire for effect, he requests CANCEL CONVERGE (OPEN), SHEAF 100 METERS.

10–22. Change in Projectile

When the observer desires to change the type of projectile, he announces the desired change; e.g., WP or SMOKE.

10–23. Change in Fuze

When the observer desires to change the type of fuze or fuze action, he announces the desired change; e.g., VT or DELAY.

10–24. Correction for Deviation

The observer transmits deviation corrections to the nearest 10 meters as RIGHT (LEFT) (so much).

10–25. Correction for Range

The observer transmits range corrections as ADD (DROP) (so much).

a. ADD. ADD is used by the observer to move subsequent burst(s) away from the observer along or parallel to the OT line. If the burst(s) falls short of the target, the observer commands ADD (so much).

b. DROP. DROP is used by the observer to move subsequent burst(s) toward the observer along or parallel to the OT line. If the burst(s) appears beyond the target, the observer commands DROP (so much).

10–26. Correction for Height of Burst

The observer transmits height-of-burst corrections to the nearest 5 meters as UP (DOWN) (so much).

10-27. Change in Control

When the observer-desires to change the method of control (other than AT MY COMMAND, para 9-8*b*(1)), he announces the new method of control; e.g., FIRE FOR EFFECT.

10-28. Repeating Previously Fired Data

a. REPEAT is used by the observer to indicate that he desires a subsequent round or group of rounds fired with no corrections to deviation, range, or height of burst. For example, if several rounds burst in the area of observation simultaneously and the observer could not determine which rounds to observe, he would request REPEAT or WP REPEAT.

b. REPEAT is also used by the observer to indicate that he wants fire for effect repeated with or without changes or corrections to any of the elements; e.g., ADD 50, REPEAT.

10-29. Correction of Errors

If the observer discovers an error in the transmission or read-back of a subsequent correction, he corrects the error as outlined in paragraph 9-10.

10-30. Additional Information

If the observer desires to transmit information necessary to the conduct of a mission and there is no specific format prescribed, he should transmit the information in clear, concise language and in the sequence least likely to cause confusion and most likely to expedite the mission.

CHAPTER 11

FIRE FOR EFFECT

Section I. PRECISION FIRE

11-1. General

The adjustment in precision fire is conducted with a single piece. (See chapter 19 for FDC procedures.)

a. The observer requests fire for effect upon splitting the appropriate range bracket or upon spotting a range correct or target hit. The appropriate range bracket to be split upon entering fire for effect is usually 100 meters. However, when the range probable error of the weapon at registration point range is 38 meters or larger, the FDC will instruct the observer to enter fire for effect when a 200-meter bracket is split. If the observer spots a round as target hit during the adjustment phase, he will enter fire for effect by annocncing TARGET, FIRE FOR EFFECT.

b. Fire for effect consists of a number of rounds fired singly or in groups of two or three by the adjusting piece. The FDC informs 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 fire for effect in a precision mission but only announces spottings of bursts as they occur.

c. If the deviation or range spotting for a particular burst indicates to the observer the probability that the round was fired in error, the observer should report the magnitude of the deviation or range error to the fire direction center. For example, the observer spots a round in fire for effect as DOUBTFUL and estimates that it is 100 meters left of the registration point. The observer transmits a spotting of DOUBTFUL, 100 METERS LEFT. Since spottings normally are made in miles, the word "meters" is used to prevent any misunderstanding. The error is reported in meters because the OT distance may not be known at the fire direction center.

11-2. Registration With Fuze Quick

a. During fire for effect in a registration with fuze quick, the observer announces the range and deviation spottings of each burst. He announces spottings for range as OVER, SHORT, or DOUBTFUL and for deviations as RIGHT, LEFT, or LINE. He does not announce the magnitude of the deviation unless a round appears to be in error. A target hit is spotted as TARGET. These spottings are announced in the order of range and then deviation.

b. Fire for effect is continued until the FDC notifies the observer that the registration is complete.

c. For an example of a precision registration with fuze quick, see paragraph 14-2.

11-3. Registration With Time Fuze

a. After a registration has been conducted with fuze quick, a time registration may be initiated from the fire direction center. The FDC notifies the observer to OBSERVE TIME REGISTRATION.

b. The observer does not send corrections in a time registration but only announces his spotting of each burst as AIR or GRAZE. He records the height of burst of each round but does not report the height of burst unless he is requested to do so by the fire direction center or unless the height of burst of a round is in excess of 50 meters. For example, if the height of burst of a round is 75 meters, he reports AIR, 75 METERS. If a round is obviously in error for range of deflection, he must determine and report the amount of error. For example, the observer spots a round in fire for effect as GRAZE, LINE but estimates that it is 100 meters short of the target. The observer transmits GRAZE, 100 METERS SHORT, LINE. Rounds are fired singly until both an airburst and a graze burst have been obtained. The time registration is continued until it is terminated by the fire direction center.

c. For an example of a time registration, see paragraph 14-3.

11-4. Destruction Mission

a. In a destruction mission, the FDC will direct the use of fuze quick in the initial rounds of fire for effect as well as in the adjustment. This procedure facilitates valid spottings by the observer and expedites determination of an adjusted deflection and quadrant elevation at the fire direction center. Subsequently, the S3 directs the use of the fuze that will be most effective against the target; e.g., fuze delay or fuze concrete-piercing. If this subsequent fuze is not effective, the observer must request a type of fuze that, in his opinion, will be more effective.

b. During fire for effect, the observer announces spottings just as he does in a registration with fuze quick.

c. Fire for effect is continued until the observer notifies the FDC that the target has been destroyed.

Section II. AREA FIRE

11-5. General

a. In area fire, the observer normally requests fire for effect at the conclusion of an adjustment. However, he may fire for effect when his target location is accurate enough to preclude the need for adjustment.

b. The type and volume of fire delivered in fire for effect are determined by the S3. His decision is based on the observer's request, the description of the target, the effect sought, and the status of ammunition supply and on other considerations (chap. 27). If fire for effect is ineffective or insufficient, the necessary corrections are made and additional fire for effect is requested.

c. Upon completion of fire for effect, the observer sends refinement data and END OF MISSION. He reports the effect observed.

11-6. Fire for Effect After Adjustment

a. Deviation. Deviation errors of 30 meters or more are corrected during the adjustment by the observer. Therefore, it should not be necessary to make a large shift upon entering fire for effect.

b. Range. The adjustment of range is complete when the observer has obtained bursts at the same range as the adjusting point (range correct or target hit) or when he has split the appropriate range bracket. When the target is fixed, of little depth, and clearly visible or when the fires of more than one battery are massed on the target, it is appropriate to split a 100-meter range bracket. When the target is moving, is of substantial depth, or is poorly defined, it may be appropriate to enter fire for effect on splitting a 200-meter range bracket. When the range probable error is 38 meters or larger, the FDC will notify the observer to enter fire for effect on splitting a 200-meter range bracket.

c. Height of Burst. When time fuze is being used, fire for effect is not called for until the height of burst is correct or until a correction can be expected to result in the correct height of burst (para 10-14). When fuze delay is being used for ricochet fire, fire for effect is entered with fuze delay only if 50 percent or more of the bursts that established the final range bracket were airbursts.

11-7. Distribution

a. Normally, the S3 determines the proper distribution of fire for a target. His decision is based on the observer's call for fire and other available information. Unless the S3 directs, because of the nature and the size of the target, the use of a sheaf other than that normally fired, artillery fires are delivered at center range in a parallel sheaf. The S3 may also direct the battery or batteries to fire through different elevations for greater range coverage.

b. When appropriate, the observer may call for a special sheaf. This should be announced in the call for fire when possible. It may be announced in subsequent corrections if the sheaf being fired does not provide satisfactory distribution. In making such a request, the observer announces the type of sheaf desired; e.g., OPEN or SHEAF, 50 METERS.

c. When the number of pieces allocated to the mission is not adequate to cover the target with an open sheaf, the observer may make successive shifts in fire for effect to insure coverage of the target.

11-8. Surveillance of Fire for Effect

The observer carefully observes te results of the fire for effect 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 the mean point of impact (mean point of burst) is not directly on (20 meters above) the adjusting point, the observer will make a correction to improve the accuracy of the replot of the target and end the mission; e.g., LEFT 20, DOWN 5, immediately followed by END OF MISSION.

b. If the fire has been insufficient but accurate, including an effective height of burst, the ob-

server may request REPEAT to obtain additional fire.

***c.* If any element of the fire for effect (deviation, range, or height of burst) was sufficiently in error that the effect sought was not obtained, the observer should correct the element(s) in error and continue fire for effect; for example, ADD 50, DOWN 10, REPEAT.**

***d.* If ricochet action with fuze delay was desired, but was not obtained from at least 50 percent of the rounds fired in fire for effect, and additional fire is needed, the observer must request a change to fuze VT or time and repeat fire for effect.**

***e.* If the observer desires that the target be replotted for future use, he announces the appropriate corrections (e.g., RIGHT 10, RECORD AS TARGET, END OF MISSION) and reports the effect observed.**

***f.* For an example of an area mission, see paragraph 14–4.**

CHAPTER 12

ADJUSTMENT OF FIRE BY THE AIR OBSERVER

Section I. INTRODUCTION

12-1. General

Observation and adjustment of artillery fires may be accomplished from the air by use of organic Army aircraft or Air Force high-performance aircraft. An air observer normally is 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 in training a new air observer and enables the pilot to adjust fire in the event an observer is not available.

12-2. Observation From Army Aircraft

Observation from organic Army aircraft normally is limited to altitudes and locations that allow the aircraft to avoid enemy ground fire and enemy fighter aircraft.

12-3. 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 and the other to observe for hostile aircraft. Danger from both hostile air defense artillery and hostile planes usually increases as the duration of the flight and the depth into hostile territory increase. For this reason the air observer must minimize the time required for an adjustment.

Section II. PREFLIGHT PREPARATIONS

12-4. General

The air observer and pilot should be given a preflight briefing by the intelligence officer (S2) and operations officer (S3).

12-5. Preflight Briefing

a. All pilots and observers flying a mission should be briefed on all points pertinent to the mission, including—

(1) The locations of battery position areas, registration points, confirmed targets, known points, suspected targets, and areas to be searched and the spotting lines to be used in making corrections (if the GT line is not used).

(2) The tactical situation, to include the locations of friendly troops, no-fire and fire support coordination lines and the zones of action of supported troops.

(3) The surveillance required, the time of the mission, the type of adjustment to be made, the maps and photographs to be used, known enemy air defense, flight instructions, and security restrictions.

(4) The communication details, to include the locations of ground radios and panel stations, the channels to be used, the call signs to be used, the check-in time(s), and prearranged signals.

b. All important enemy locations, lines and areas discussed in the briefing are recorded on appropriate maps. Photographs, oblique or vertical, are gridded when possible and the direction and locations of critical points, lines, and areas are marked on the photographs.

Section III. DETERMINATION OF INITIAL DATA

12-6. Call for Fire

The procedures used by the air observer are similar to those used by the ground observer. (The air observer cannot locate a target by polar coordinates.) The call for fire and subsequent corrections from an air observer, the elements of which are identical with those of the ground observer, are transmitted in the same sequence as those from the ground observer.

12-7. Determination of the Spotting Line

Usually, the ground observer uses the observer-target line as a basis for locating a target by a shift from a known point and for making his spottings and corrections. Since the aircraft is constantly moving, the air observer must use as his basis for locating a target, a shift from a known point, and for making his spottings and corrections a spotting line other than the observer-target line. Fire direction procedures are based on the target grid method; therefore, the air observer's spotting line and its direction must be known by the FDC personnel of the unit for which the air observer is adjusting fire. Preferably, the air observer selects his spotting line and makes it known to the FDC personnel prior to flight. The air observer may select as his spotting line the gun-target line or some other line of known direction.

a. Gun-Target Line. The air observer may select as his spotting line the gun-target line. If he knows the location of the adjusting battery and can identify that location while in flight, he can easily visualize the gun-target line. If he does not know the location of the adjusting battery, he can request RANGING ROUNDS in his call for fire (distribution of fire). In such a case, the FDC personnel will cause the adjusting battery to fire two rounds at the same deflection but 400 meters apart in range so that the air observer can visualize the gun-target line. If fire direction personnel of the adjusting battery are conducting the mission and the air observer's aircraft is equipped with a homing device, the air observer can easily determine the gun-target line. The pilot maneuvers the aircraft over the target area and, at the observer's request, the adjusting battery radiotelephone operator keys his radio for 20 to 30 seconds. The pilot maneuvers the aircraft so that the on-course signal is indicated in the homing device, thus establishing the flight of the aircraft on the gun-target line. After the air observer has determined the gun-target line, he should select a terrain feature, such as a road, stream, or ridgeline, that will assist him in remembering the direction of the gun-target line. If the spotting line has not been prearranged with the FDC and the air observer does not indicate a spotting line in his call for fire, the gun-target line will be used.

b. Other Line of Known Direction. The air observer may select as his spotting line a terrain feature, such as a road, railroad, stream, or ridgeline, or a series of terrain features. The air observer, either prior to or during flight, must make known to the FDC personnel the identification of the feature(s) so that they can determine the direction established thereby. If the air observer can accurately visualize a cardinal compass direction on the ground, he may use the cardinal direction as a spotting line.

12-8. Location of Targets

When a target is observed, its location can be determined and indicated by grid coordinates, by a shift from a known point (marking round) or by a prearranged code.

a. Grid Coordinates. The observer locates the target on his map and transmits the grid coordinates of the location.

b. Shift from a Known Point (Marking Round) and a Spotting Line. The observer may indicate the location of a target by announcing a shift from a known point and a spotting 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 meters; e.g., FROM REGISTRATION POINT 1, RIGHT 400, ADD 800. If any spotting line other than the GT line is used, the observer must identify the spotting line; e.g., FROM TARGET AF7406, SPOTTING LINE NORTH-SOUTH HIGHWAY, RIGHT 400, ADD 800. Subsequent corrections, based on the announced spotting line are made in the normal manner. When no maps are available and there has been no previous firing in an area, the air observer may request MARK CENTER OF SECTOR and then shift from the marking rounds using an announced spotting line as the basis for corrections. 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. Another example is FROM REGISTRATION POINT 1, CARDINAL NORTH, 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 target number may be given to the target. In this case, the observer need only transmit the preassigned code name or target number to obtain fire on the target.

12-9. Determination of Distance

The observer can determine distance on the ground by requesting RANGING ROUNDS. The 400-meter range spread obtained from ranging rounds not only will allow accurate visualization of the GT line (para 12-7*a*) but also will establish a yardstick for estimating subsequent range and deviation corrections.

Section IV. ADJUSTMENT PROCEDURES

12-10. General

Adjustment procedures for the air observer are the same as those for the ground observer *except* as noted in paragraph 12-11.

a. Considerations for the selection of an adjusting point are the same for both air and ground observers.

b. The air observer can adjust artillery fire at night by using standard procedures. However, artificial illumination may be necessary to make the target area discernible. The illumination may be accomplished by searchlight, illuminating shells, or parachute flares. When parachute flares are used, the flares should be released from an aircraft other than the observer's aircraft so that the observer will not be looking into the target area directly past a burning flare. 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 checkpoints and for general terrain orientation. The air observer must consider the different shapes and shadows that 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 by a well-trained observer.

c. The air observer may use AT MY COMMAND during the adjustment so that the aircraft can be positioned for proper observation of each group of rounds. The time of flight is sent to the observer immediately following the message to the observer to facilitate aircraft orientation. A new time of flight will be announced when it changes more than 5 seconds from that originally announced. A 5-second splash warning is transmitted from the FDC to the observer for each group of rounds.

12-11. Adjustments

a. Adjustment of Deviation. The air observer determines deviation in meters, with respect to the spotting line, and announces corrections in meters. In some instances, it may be faster and more accurate to bracket the spotting line for deviation than to attempt precise deviation corrections to the spotting line.

b. Adjustment of Range. The air observer spots bursts for range with respect to the chosen spotting line and the target. Using the bracket method of adjustment, he announces range corrections in meters.

c. Adjustment of Height of Burst. The air observer cannot readily determine differences in height of burst, consequently, he seldom will be requested to adjust height of burst. He may be required to observe time registrations in which only spottings of AIR or GRAZE are transmitted.

12-12. Fire for Effect

The air observer calls for fire for effect and announces spottings during fire for effect in the manner described for a ground observer (para 11-6).

CHAPTER 13

ADJUSTMENT PROCEDURE FOR SPECIAL SITUATIONS

Section I. CONDUCT OF FIRE WITH CHEMICAL PROJECTILES

13-1. Chemical Projectiles

Chemical projectiles for cannon artillery consist of HC smoke projectiles, colored smoke projectiles, white phosphorus (WP) projectiles, and gas projectiles.

a. HC Smoke. HC (white) smoke is a base-ejection projectile that is fired with a time fuze. HC smoke is used primarily for screening against enemy observation; it produces no casualty effect. HC smoke may be used for signaling, for marking a target for an airstrike, and for aiding an observer in locating his rounds under difficult observing conditions.

b. Colored Smoke. Colored smoke also is a base-ejection projectile that is fired with a time fuze. The colors available are red, yellow, green, and violet. Colored smoke is used for signaling, for marking a target for an airstrike, and for aiding an observer in locating his rounds under difficult observing conditions. Normally, the observer does not adjust colored smoke. If adjustment onto a precise location is required, the observer adjusts deviation, range, and height of burst as appropriate.

c. White Phosphorus. White phosphorus is a burster-type projectile that usually is fired with an impact fuze. In some cases wherein white phosphorus is used for aiding an observer in locating his rounds under difficult observing conditions, it is fired with a time fuze. White phosphorus is very effective in the initial buildup of a smokescreen, but it is not as effective as HC smoke in maintaining a smokescreen because the white phosphorus smoke rises rapidly. Since white phosphorus possesses incendiary and casualty-producing effects as well as smoke effect, the proximity of friendly troops must be carefully considered when it is used for screening. When white phosphorous is used against frame houses or other objects of flammable material, some fuzes should be set at delay to effect penetration before bursting and thus increase the incendiary effect of the burning phosphorous particles. Casualties are caused by the small particles of phosphorous adhering to the clothing and skin, causing painful burns.

d. Gas. The gas projectile is a burster-type projectile that is fired with an impact fuze or a time fuze, depending on the type of filler. Gases available are irritant agents and lethal agents.

13-2. Smokescreening Missions

A smokescreen is employed to reduce the effectiveness of enemy visual observation. Visual observation is reduced by employing smoke on enemy observation posts, on friendly units or installations, or between enemy observation posts and friendly units or installations. A smoke mission must be coordinated with higher headquarters to insure that the mission does not interfere with other operations.

a. Effects of Weather on Smoke. The effects of weather conditions on the performance of both HC and WP smoke are similar in nature, though different in magnitude. The principal difference between HC and WP smoke is in the rate of fire needed to insure continuous screening. The rate of fire required for *WP smoke* is greater than that for *HC smoke*.

(1) *Wind strength.* A strong wind disperses the smoke quickly; however, if there is little or no wind, the smoke may thin out by natural dispersion before it has been effectively carried downwind. The best wind is a steady wind of about 4 to 10 knots.

(2) *Humidity of the atmosphere.* Smoke disperses more rapidly in a dry atmosphere than in a moist atmosphere.

(3) *Turbulence of the atmosphere.* Turbulence is caused by hot air rising from the ground and disturbing the atmosphere. Turbulence may cause the smoke to drift irregularly, may cause windows to develop, and, when severe, may cause pillaring.

(*a*) High turbulence occurs on calm, sunny days.

(*b*) Moderate turbulence occurs when the sky is overcast (cloudy). When the wind exceeds

10 knots, turbulence is always moderate regardless of existing weather conditions.

(*c*) Low turbulence occurs on clear nights and when the sky is clear and the wind is light, for about 1 hour before and after sunset.

b. Selection of Adjusting Point(s).

(1) Careful selection of the adjusting point(s) is necessary if full advantage is to be taken of the smokescreen. The factors that determine the selection of the adjusting point(s) are—

(*a*) The area to be blinded; i.e., the area in which the enemy is located.

(*b*) The area to be screened; i.e., the area over which our own troops must pass.

(*c*) The direction of the wind. (The strength of the wind affects only the rate of fire.)

(2) The areas to be blinded and screened (fig 13–1) will be pointed out on the ground or map by the supported unit commander or the artillery commander ordering the smokescreen. The direction of the wind is determined by the observer.

(*a*) In figure 13–1, it is clear that the smoke must be across the area DEFG and be effective between X and Y. Normally, line XY should be placed close to the area to be blinded so that the smoke causes the most inconvenience to the enemy and very little inconvenience to our own troops. However, there are occasions when the smokescreen should be close to the area to be screened; e.g., when the area to be screened is much smaller than the area to be blinded or when the altitude of the area to be blinded is much lower than that of the area to be screened.

(*b*) The number and locations of adjusting points, in order to produce an effective smokescreen along the line XY (YX) in figure 13–1, depends on the direction of the wind. Wind is classified, according to its direction in relation to the direction of line XY (YX), as a flank wind, an oblique wind, a tailwind, or a headwind.

1. Flank wind. A wind from a direction within 500 mils of the direction of line XY (YX) is considered a flank wind. The adjusting point(s) must be upwind of Y (X).

2. Oblique wind. A wind from a direction between 500 and 1,300 mils of the direction of line XY (YX) is considered an oblique wind. The adjusting point(s) must be upwind of line XY (YX).

3. Tailwind. A wind from a direction between 1,300 and 1,600 mils of the direction of the line XY (YX) and blowing from the area to be screened toward the area to be blinded is considered a tailwind. The adjusting point(s) must be upwind of line XY (YX) but does not need to be outside the area XYEF.

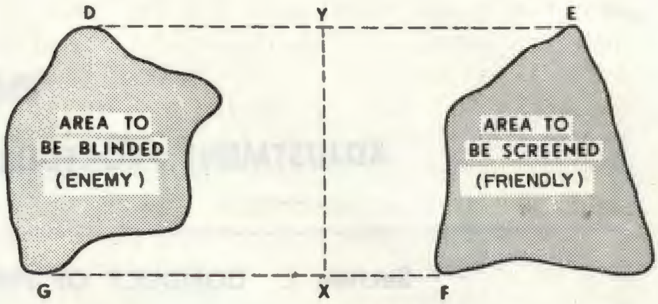


Figure 13–1. Selection of adjusting point(s).

4. Headwind. A wind from a direction between 1,300 and 1,600 mils of the direction of the line XY (YX) and blowing from the area to be blinded toward the area to be screened is considered a headwind. Since the wind is blowing from the enemy toward our troops, the smoke mission is likely to be unsuccessful because of the inconvenience caused our own troops by the smoke drifting toward them. If the smoke mission is undertaken, the adjusting point(s) must be upwind of the line XY (YX) and often must be inside the area to be blinded.

c. Conduct of a Quick Smoke Mission. The quick smoke mission usually is satisfactory when the area to be blinded is small, the observer is in the area to be screened, and the wind is from the flank or nearly so. In such circumstances, the smoke delivered from one gun normally will be sufficient. However, if the observer, after seeing the smoke pattern on the ground, determines that additional points are needed, he will locate these points by grid or by a shift from the last round fired. Smoke will be delivered on these points, and, if necessary, the observer will correct the placement of the smoke.

(1) *Call for fire.* When the observer desires to smoke an area quickly, he must select the adjusting point upwind from the area to be smoked. The call for fire includes the location of the adjusting point, the direction, the type of smoke mission, the length of the target (area to be smoked), the attitude of the target, the estimated number of points needed to adequately cover the target, and the time length of the smokescreen.

Example: FIRE MISSION, GRID 321546, DIRECTION 300, SMOKE, 200-METER FRONT, ATTITUDE 4800, ESTIMATE 2 POINTS FOR 30 MINUTES, ADJUST FIRE.

(2) *Adjustment.* The adjustment is begun on the adjusting point with one gun firing HE with fuze quick. When shell HE has been adjusted to within 100 meters of the adjusting point, the observer will call for smoke to complete the adjustment. The adjustment with smoke is continued until the observer has the proper height of burst (approximately 100 meters) and placement of the smoke on the ground.

(3) *Fire for effect.* Once fire for effect is begun, the observer must observe the effect of the smoke on the ground to determine whether adequate coverage is provided by one adjusting point. If the observer sees that he is not getting the needed coverage, he must select an additional adjusting point(s) with relation to the effect provided from the smoke already on the ground. To determine the number of points needed, the observer divides the width of the area to be blinded by the effective width of the smoke. The observer may request that the additional point(s) be located accurately by the use of HE and then, a 100-meter bracket is obtained, switch to smoke. However, if the observer is positive that his location of the additional adjusting point(s) is within 100 meters, he may request that smoke be fired immediately and, if necessary, adjust the smoke. Once the observer sees that he is getting adequate coverage, he must notify the FDC as to the length of time he desires the area to be smoked.

d. Conduct of a Deliberate Smoke Mission. The deliberate smoke mission is used when the area to be blinded or screened has a longer frontage than can be covered by the fire from a quick smoke mission. The smoke mission may be initiated by the observer, or it may be planned at the FDC and the observer instructed to observe the screen and make any corrections in sheaf, range spread, lateral spread, or rate of fire necessary to provide an adequate smokescreen.

(1) *Call for fire.* If the observer initiates the deliberate smoke mission, the call for fire will include the same elements as the call for fire for the quick smoke mission. A formal procedure may be impossible because of the number of adjusting points and the large area to be smoked. In this case, many exchanges of information will be informal.

(2) *Adjustment.* The adjustment is conducted as outlined in *c*(2) above. The observer evaluates the effect of the smoke on the ground and estimates any corrections necessary to produce an adequate smokescreen. The situation may arise in which the observer estimates that the entire battery is not required; in this case, he should notify the FDC that the right (left) platoon is not required in fire for effect. Whenever possible, adjustment with HE and fuze quick should be made just prior to the firing of the smokescreen.

(3) *Fire for effect.* Once fire for effect is begun, the observer must observe the effect of the smokescreen to determine whether an adequate screen is provided. If the entire area is not screened or if gaps are present in the screen, the observer should request any necessary sheaf, range spread, or lateral spread corrections to produce the necessary screen.

Note. The observer must bear in mind that the adjustment of a smoke mission is conducted with HE and fuze quick until rounds are within 100 meters of the desired adjusting point. This is particularly important when it is desired to smoke friendly positions. Great care must be taken to select an adjusting point so that friendly troops are not endangered during the HE adjustment.

Section II. BATTLEFIELD ILLUMINATION

13–3. General

The purpose of battlefield illumination is to provide friendly forces with light to assist them in night ground operations, offensive or defensive. The artillery observer is concerned primarily with two means of illumination—illuminating projectiles and searchlights. When properly used, night illumination increases the morale of friendly forces, facilitates operations, and harasses and blinds the enemy. The artillery is responsible for providing illumination with illuminating projectiles and searchlights. Any artillery observer may be called upon to conduct an illumination mission.

13–4. Conduct of Fire With Illuminating Projectile

a. Uses. Illuminating projectiles are used for—

(1) Illuminating areas of suspected enemy movements.

(2) Providing illumination for night adjustment or surveillance of artillery fire by an air observer or a ground observer.

(3) Harassing enemy positions or installations.

(4) Furnishing direction to friendly troops for attacks or patrol activities. (Illumination

flares must be placed well in advance of friendly troops to avoid illuminating the troops.)

(5) Guiding low-level tactical aircraft on important targets within artillery range.

b. Ammunition. Table 13-1 gives some of the factors to be considered in the employment of artillery illuminating projectiles. Data are approximate and vary with nonstandard conditions.

c. Call for Fire. When the observer desires to illuminate the battlefield using illuminating projectiles, he calls for fire, using the procedures described in chapters 8 and 9. The method of engagement element in the call for fire will require special consideration when determining the—

(1) *Type of projectile.* Illuminating must be specified.

(2) *Type of fuze.* Fuze time is used with illuminating projectile. Therefore, this element is omitted from the call for fire.

(3) *Distribution of fire.* The size and shape of the area to be illuminated, the OT distance, conditions of visibility, and the candlepower of the projectile influence the selection of the distribution of fire. Distribution of fire is indicated as follows:

(*a*) *One gun.* One round from one gun.

(*b*) *Two guns.* One round from each of two guns firing simultaneously with the same data and at approximately the same point in the air.

(*c*) *Two guns, lateral spread.* One round from each of two guns firing simultaneously at the same range but at different deflections. (For distances between bursts, see table 13-1.) All spreads are made with respect to the GT line.

(*d*) *Two guns, range spread.* One round from each of two guns firing simultaneously but at different ranges along the GT line. (For distances between bursts, see table 13-1.)

(*e*) *Four guns.* One round from each of four guns firing simultaneously in a diamond pattern (fig 13-2).

d. Adjustment.

(1) Range and deviation adjustments are made by using standard observed fire procedures, except that the adjustment is considered complete when the illumination is within 200 meters of the desired location. Normally, deviation, range, and height of burst are adjusted concurrently. If the height of burst is drastically in error, it may be necessary for the observer to adjust the height of burst before adjusting the other elements in order to have enough light to see the target.

(2) The correct position of the flare relative to the adjusting point depends on the terrain and the wind. Generally, 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 must be some distance from the adjusting point because of the 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 prominent target, better visibility may be obtained by placing the flare beyond the target so that the target is silhouetted.

(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 meters. Variations in the time of burning of flares cause any finer adjustment of the height of burst to be useless.

(4) When the point of burst is too high, the height-of-burst change is estimated from the height of the flare at the time it burned out. When the point of burst is too low, the change required is estimated from the length of time (T) in seconds that the flare burned on the ground. By multiplying T by the approximate rate of fall of the projectile flare, the observer can determine the approximate correction required.

Example: An M314A2 projectile flare burned 13 seconds on the ground; 13 × 10 = 130; the correction is UP 150 (answer rounded off to nearest 50 meters). (Refer to table 13-1 for rate of fall for different types of ammunition.)

(5) After the observer has adjusted the flare to the desired location, he should control the

Table 13-1. Illuminating Projectile Characteristics

Cannon	*Projectile*	*Initial height of illumination (meters)*	*Distance between burst (spread) (meters)*	*Burning time (seconds)*	*Rate of continuous illumination (rounds per minute)*	*Rate of fall (meters per second)*
105-mm	M314A2	750	800	60	2	10
105-mm	M314A2E1	750	800	70 to 75	2	10
155-mm	M118	750	800	60	2	10
155-mm	M485	600	1000	120	1	5

rate of fire and number of pieces firing to reduce ammunition expenditure to the minimum necessary for the required observation.

e. Illumination for HE Adjustment.

(1) If the adjustment of illuminating projectile 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 call for fire. 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.

(3) If the observer decides to adjust the illuminating fire and the HE fire concurrently, he prefaces the corrections 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. When this method is used, the observer usually includes AT MY COMMAND in the method of control.

(4) If the HE adjustment is made on an immobile target, such as a disabled tank or a bridge, 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 includes BY SHELL, AT MY COMMAND in the method of control. This indicates that both HE and illuminating rounds will be fired only at the observer's command. As soon as the FDC reports that illuminating and HE fires are ready, the observer gives the command to fire the illuminating round and then gives the command to fire the HE rounds so that the HE rounds will arrive during the period of maximum illumination of the target. As an alternate method, the observer may control only the firing of illuminating rounds and allow the FDC to command the firing of HE. When the illumination has been adjusted to yield the best light, the observer announces ILLUMINATION MARK to the FDC to notify the FDC of the exact time when the target is best illuminated. The FDC times the interval between the actual firing of the illuminating round and receipt of the observer's ILLUMINATION MARK. By comparison of this time interval with the time of flight of the HE, the FDC can control the firing of the rounds so that

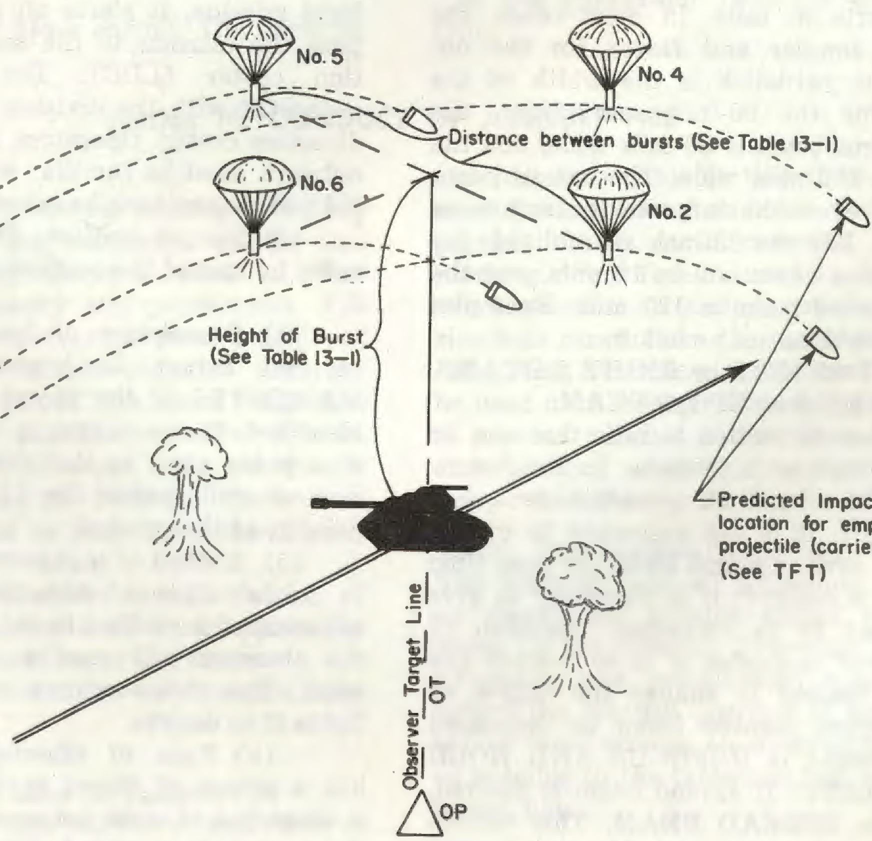


Figure 13-2. Field Artillery Illumination—Four Guns.

they arrive at the target during the period of maximum illumination.

f. Example Mission. See paragraph 14-5 for an example mission.

13-5. Conduct of Fire With Searchlight Illumination

a. The primary use of searchlights by the observer is for illumination of areas of suspected enemy movement for night adjustment or surveillance of artillery fire from air or ground observation posts. Searchlights are also used to guide friendly elements, mark coordinating lines, mark targets for close air support missions, and illuminate objectives in an attack (FM 6-115).

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. The observer procedure for the adjustment of the searchlight beam is similar to that employed in a fire mission. However, the observer makes the adjustment on the searchlight-target line in deviation and elevation. Corrections are made in one of two ways. The observer can move the beam right or left and up or down in increments of 1/4, 1/2 or 1 beam width or he may make these shifts in mils. In most cases, the beam-width is simpler and faster for the observer, since his yardstick is the width of the beam itself. For the 30-inch searchlight, the width of the focus beam is 30 mils wide, and the spread beam is 180 mils wide. The spread beam cannot be used when the infrared lenses are on the searchlight. For the 23-inch searchlight, the width of the focus beam is 9 to 13 mils, and the width of the spread beam is 120 mils. Examples of observer corrections are as follows:

(1) RIGHT 60 MILS or RIGHT 2 BEAMS.

(2) UP 15 MILS or UP 1/2 BEAM.

d. The smallest correction in mils that can be made by the observer is 5 mils. In the beam-width method, the smallest correction is a 1/4 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. Omission of the other element indicates it is to remain the same. If it is desired to change the degree of beam spread from focused beam to defocused beam, the command is DEFOCUS AND HOLD AT MY COMMAND. If spread beam is desired, the command is SPREAD BEAM. This correction precedes the deviation and elevation corrections.

e. On occasion, the searchlight may be used in a continuous sweep or in a sweep in one direction of the searchlight beam. The searchlight may be used in this manner in either the visible or infrared mode; however, infrared is the normal mode in which the sweep is made. If the observer wishes to exercise a greater degree of control, he may command SWEEP RIGHT (LEFT) AND HOLD AT MY COMMAND. Visible light is rarely used in this manner because potential targets can normally hide or conceal their locations as the light approaches. Infrared illumination may be employed in this manner unless the enemy is equipped with infrared viewers. When the searchlight is employed in a continuous sweep, the searchlight crew must observe the sweep so that they can keep the light on the terrain in the manner which best uses the infrared illumination.

f. Elements of the illumination request are as follows:

(1) *Identification of observer.* Identification of the observer in an illumination request is the same as that in a call for fire.

(2) *Warning order.* 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 normally is collocated with the division (corps) artillery fire direction center. Operators in the communication network must be familiar with this warning signal and the action to be taken.

(3) *Target location.* The target may be located by any of the methods described in chapter 8.

(4) *Description of target.* The description of the target is preceded by the word SUSPECTED if the target cannot be positively identified. If the target is identified, the procedure is the same as that for a call for fire. This element will enable the LDC to determine the priority of the mission.

(5) *Method of engagement.*

(*a*) *Type of adjustment.* If the type of adjustment is omitted in the illumination request, the observer will receive one light in adjustment. The observer may request two or more lights if he desires.

(*b*) *Type of illumination.* The observer has a choice of direct or indirect illumination. A clear line of sight between the searchlight and the target is required for direct illumination. Visibility into the illuminated area is nearly equivalent to daylight observation if the light source is behind the observer. With a single beam shining at a low angle 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 is easier to control but is 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 installations. The observer must avoid both of these situations. If the observer does not specify INDIRECT ILLUMINATION, it is assumed that he desires direct illumination. Indirect illumination utilizes the scattered or reflected light rays from the main searchlight beams. The diffused light of indirect illumination reaches into hollows, draws, and tree-lined roads. With the naked eye, an observer in an area illuminated by diffused light can detect a man standing at ranges up to 150 meters; with the aid of binoculars, he 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.

(*c*) *Degree of beam spread.* The observer requests the beam spread necessary to illuminate the area under observation. The degree of beam spread is designated in the illumination request as FOCUS, DEFOCUS, or SPREAD BEAM. If the observer omits this element, focus beam will be used.

(6) *Control.* ADJUST LIGHT is the only method of control used with searchlights. If the observer desires to control the time of turning the light on, he includes AT MY COMMAND immediately preceding ADJUST LIGHT. To prevent personnel from misinterpreting fire commands, the observer uses the command FLICK to order the lights turned on.

g. Some of the terms used in an illumination mission that are not common to field artillery are defined in (1) through (4) below.

(1) FLICK—Put light in action (corresponds to the command FIRE).

(2) ACTION COMPLETE—Pointing data have been set on light (corresponds to the command SHOT).

(3) CUT—Put light out of action (corresponds to the command CHECK FIRING).

(4) HOLD—Keep the light on the same azimuth, elevation, and beam spread (corresponds to the command REPEAT).

h. See paragraph 14–6 for an example mission.

Section III. CONDUCT OF ASSAULT FIRE

13–6. General

a. Assault fire is a special technique of indirect fire in which the maximum charge that will clear intervening crests is used to effect maximum muzzle velocity and penetration. Firing is conducted as short range from a defiladed weapon position to attain pinpoint accuracy against a stationary target. The short range and flat trajectory make possible successive hits on the same portion of the target. Only one gun is used on a mission, and the FDC for the mission normally is located at or near the weapon position.

b. Assault fire is used for the destruction of caves, pillboxes, or other fixed fortifications by firing on the vertical portion of the target.

c. See paragraph 14–7 for an example mission.

13–7. Ammunition Used for Assault Fire

a. Projectile. A high-explosive projectile is used for assault fire.

b. Fuzes. Concrete-piercing fuze is appropriate for destroying fortifications. Fuze quick is used for adjusting and for cutting through a parapet or an earth covering. Then conrcete-piercing delay fuze is used in fire for effect to effect penetration and destruction. If excessive ricochets result from the use of concrete-piercing delay fuze, concrete-piercing nondelay fuze should be used until enough cratering has been effected to prevent ricochet of the delay fuze. Also, concrete-piercing nondelay fuze may be used to clear away rubble during the fire for effect.

13–8. 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 as possible to the target and on or near the gun-target line.

13–9. Initial Data

Normally, personnel prepare initial data in advance by use of the best means available (usually survey) to locate the target with respect to the assault weapon position. Therefore, in most cases, a complete call for fire from the observer is not necessary.

13-10. Adjustment

The observer uses a modified adjustment procedure in which he exercises complete control of fire throughout the mission. He gives corrections in meters for each successive round until the point of impact is on the desired portion of the target. The observer corrects an off-line burst to bring subsequent bursts to the line through normal adjustment procedure except that he gives deviation corrections to the nearest meter. He brackets the target for range, and successively splits the bracket.

13-11. Fire for Effect

a. When the observer splits a 50-meter range bracket, he is in fire for effect although no announcement of fire for effect is made. At this time the observer normally is able to estimate vertical error more accurately than he can estimate range error. Therefore, the observer makes corrections for altitude rather than range. After a 50-meter range bracket has been split, the smallest appropriate correction in direction or altitude is one-half meter. The observer 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 observer is responsible for controlling and ending the mission.

b. The observer usually will be able to see each round in flight as it travels to the target. By noting the position of each round at the instant before the burst rather than by judging from the burst itself, the observer can make more accurate spottings and thus can make the small corrections necessary for pinpoint accuracy.

Section IV. CONDUCT OF FIRE BY USE OF COMBINED OBSERVATION

13-12. General

a. Combined observation is that type of observation in which two or more observers at different locations are employed to obtain spottings on the same target. For effective conduct of fire by use of combined observation, the angle of intersection of the OT lines should not be less than 150 mils. An angle of 300 to 500 mils is preferred.

b. Combined observation is used for the following types of missions:

(1) High-burst registration.

(2) Mean-point-of-impact registration.

(3) Fire to obtain surprise through use of fire-for-effect transfers.

(4) Surveillance of planned fires.

c. Observation posts should be established during daylight so that instruments may be oriented and a line materialized on the ground for orientation after dark. The OT directions of targets discovered during daylight are recorded by all observers. An observer may locate a target at night by placing the illuminated crosshairs of an observing instrument on the flash of an enemy weapon. The vertical angle and direction are recorded if adjustment is not started at once. As an expedient, the direction to a flash may be materialized on the ground by a piece of white tape or two stakes.

13-13. Equipment

a. To obtain optimum accuracy, each observer should be equipped with a BC scope or an aiming circle.

b. If a line of known direction is not available, initial direction to the target can be obtained by the use of a compass. Subsequent deviations from the OT line can be measured with binoculars if a BC scope or an aiming circle is not available. However, the use of a compass and binoculars for combined observation is inaccurate. Lack of a BC scope or an aiming circle may preclude the use of combined observation during darkness.

13-14. 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 areas often are not available. Special procedures have been developed to permit registration under these conditions. One such procedure is the high-burst registration in which time fuze is used. (For FDC procedures, see paragraphs 19-27 through 19-36.)

b. Orientation of Observer. In a high-burst registration, two observers (01 and 02) usually are employed. The location of each observer and the desired point of burst must be known at the fire diretcion center. The fire direction center will determine and furnish to each observer the direction and vertical angle to the excepted point of burst. A typical message to the observers from the FDC is as follows: OBSERVE HIGH-BURST REGISTRATION. 01 DIRECTION 1164, VERTICAL ANGLE PLUS 12, MEASURE THE VERTICAL ANGLE. 02 DIRECTION 718, VERTICAL ANGLE MINUS 3. REPORT WHEN READY TO OBSERVE.

c. Conduct of Registration. Each observer orients his instrument on the direction and vertical angle given and reports when ready to observe. (As soon as practicable after orientation of his instrument, the observer will set out, on a known direction, a stake that can be equipped with a light for night orientation.) The S3 directs the firing of one orienting round. The observer will orient 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, he combines the observed deviation on the reticle with the reading set on the azimuth scale and azimuth micrometer to derive the measured direction. The same general procedure is used to measure the vertical angle. Both observers report direction readings, but only the designated observer will report the vertical reading (e.g., on the message to the observers in *b* above, only 01 would report vertical angles.)

13–15. Mean-Point-of-Impact Registration

A mean-point-of-impact registration is conducted in the same manner as a high-burst registration (para 13–17) except that impact fuze is used instead of time fuze.

13–16. Combined Observation for Missions Other Than High-Burst or Mean Point of Impact Registration

a. General. At long OT distances (more than 4,000 meters), the use of combined observation may conserve ammunition. Combined observation is especially important for heavy artillery, since observing distances are normally so great that adjustment by normal procedure is very difficult. (For FDC procedures, see paragraphs 24–27 and 24–28.)

b. Procedures. After the observation posts are plotted on the FDC charts, the following procedures apply:

(1) *Target location and orientation of observation posts.*

(*a*) When an accurate target location is furnished by higher headquarters, the FDC, using the procedures described in paragraph 13–17*b*, orients the observation posts.

(*b*) When one observer locates the target accurately, the FDC, using the target location, orients the other observer.

(*c*) When one observer locates a target, he may orient the other observer on the location of the target. Both observers may then report directions to the target, and the FDC can locate the target by intersection.

(2) *Procedure during adjustment.* When both observers report READY TO OBSERVE, firing is begun. After each round is fired, each observer reports the direction, and the designated observer reports the vertical angle to each burst. If so directed, the observers report deviations (number of mils right or left of the OT line) rather than directions.

13–17. Target Area Base

A target area (short) base (fig 13–3) may be established to locate targets rapidly and accurately. A target area base consists of two observation posts from which points in the target area can be located by a combination of intersection and polar plotting. Distances are computed, but the targets are placed on the firing chart by polar plotting. The base must be long enough so that the apex angle (the angle at the target formed by the intersection of the lines of sight from the two observation posts) is at least 150 mils. The base should be as nearly perpendicular to the direction to the target area as possible. Both 01 and 02 must be plotted on the firing chart and the distance and direction between them determined.

a. When the ends of the base are intervisible, the observers measure the interior angles at 01 and 02. If the ends of the base are not intervisible, the target area base personnel compute the interior angles by comparing the direction of the base with the direction from each observation post to the point being located (FM 6–2).

b. The observers determine the apex angle by subtracting the sum of the interior angles at 01 and 02 from 3200.

c. The 01 observer solves the distance from 01 to the target by using the law of sines, as follows:

$$\frac{\text{Distance 01 to target}}{\text{Sin angle at 02}} = \frac{\text{length of base}}{\text{sin apex angle}}$$

When the law of sines is applied, the supplementary angle may be substituted for the interior angle at 02, since the sines of supplementary angles are equal.

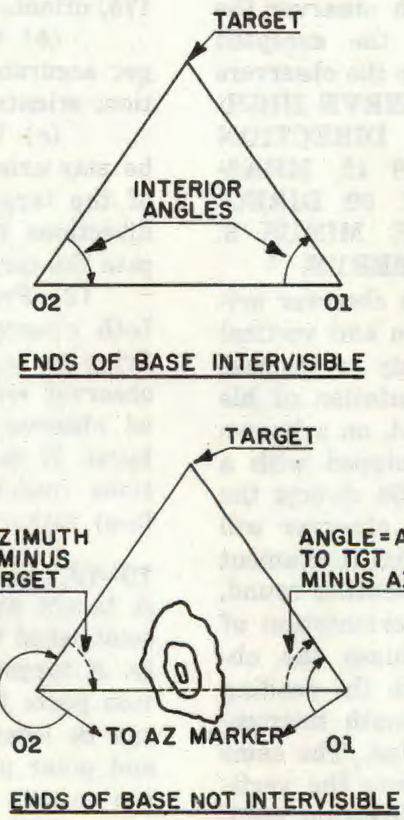


Figure 13–3. Target area (short base).

d. The military slide rule is arranged to provide a rapid and simple solution to the short base problem. The steps in the solution are as follows:

(1) Place the hairline of the cursor over the value of the angle at 02 on the scale marked "opposite angle."

(2) Move the slide until the value of the apex angle of the scale marked "apex angle" is under the hairline.

(3) Move the cursor until the hairline is over the length of the base on the C (base) scale.

(4) Read the distance from 01 to the target on the D (range) scale.

e. The observer reports the target location to the FDC by polar coordinates from 01 as DIRECTION (so much), DISTANCE (so much), UP (DOWN) (so much).

Section V. ADJUSTMENT OF HIGH-ANGLE FIRE AND AUXILIARY ADJUSTING POINT

13–18. 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 the 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 high-angle fire. Generally, those cannon with a maximum elevation substantially in excess of 800 mils have the capability of firing high-angle fire.

13–19. 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, he notifies the FDC that high-angle fire may be necessary. In that case, the S3 decides whether high-angle fire is to be used and notifies the observer.

13-20. Call for Fire

a. When high-angle fire is desired, the observer so indicates in his call for fire.

b. The excessive height-of-burst probable error associated with a long time of flight makes fire with mechanical time fuze undesirable for use in high-angle fire. Because of the steep angle of fall, ricochet fire is seldom possible.

c. Quick and VT fuzes give excellent effect from side spray because of the steep angle of fall. VT fuzes produce a lower height of burst than that normally obtained with low-angle fire.

13-21. Adjustment

a. The observer procedure for the adjustment of high-angle fire is the same as that for the adjustment of low-angle fire.

b. The observer must realize that small deviation corrections during adjustment may be unnecessary and time consuming because of 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 will announce SHOT when the round(s) is fired and will announce SPLASH 5 seconds before the burst(s) occurs.

13-22. Auxiliary Adjusting Point

In order to achieve surprise, the observer may decide not to adjust on the target but to adjust on a nearby point. This nearby point, the auxiliary adjusting point, must be far enough away from the target that the real purpose of the adjustment is obscured. At the same time, the auxiliary adjusting point must be so selected that an accurate (preferably lateral) shift to the target can be determined. When the adjustment on the auxiliary adjusting point is complete, the shift to the target is made.

Section VI. CONDUCT OF FIRE WHEN OBSERVER IS NOT ORIENTED

13-23. General

In a fast-moving situation, an observer may become confused and disoriented. An observer in a moving vehicle has a problem in orientation because his OT direction is constantly changing. To bring fire upon a target when the direction is changing rapidly or is unknown, both the observer and the FDC must exercise judgment and initiative.

13-24. Target Location

If possible, the target location is determined by use of the procedures prescribed in chapter 8. If target location by normal means is not possible, the observer must request that a round be fired at a point where he can identify it and use that round as his known point.

13-25. Gun-Target Line Method of Adjustment

When the observer cannot determine the OT direction or when the OT direction is changing frequently (for example, when the observer is with an armored or mechanized infantry unit), the observer may decide to adjust with respect to the gun-target line. To determine the direction of the GT line, it may be necessary for the observer to request ranging rounds (two rounds fired at the same deflection but 400 meters apart in range; corrections are made from the NEAR or FAR round). When the observer is adjusting with respect to the GT line, the S3 should select a unit to fire whose location will result in the smallest angle T.

Section VII. ADJUSTMENT OF FIRE BY SOUND

13-26. General

During operations when observer visibility is restricted, fire may be adjusted by the use of sound alone.

13-27. Adjustment of Fire by Sound

a. Target Location. Target locations may be reported to the observer by the supported unit, or they may be determined by the observer. If the observer can hear noises at the enemy position (for example, weapons firing, vehicles, or troop movement), he can estimate a direction and distance from his position.

b. The Call for Fire. When adjustment by sound is to be used, the observer so indicates in the call for fire.

c. Adjustment.

(1) Only one gun is used in the adjustment. Upon hearing the burst of the adjusting round, the observer estimates the direction to the burst and compares it with the direction to the target. He converts the deviation to a

lateral shift in meters by using the estimated distance from his position to the target.

(2) Distance to the adjusting burst is difficult to judge; therefore, it may be necessary for the observer to use creeping techniques to adjust onto the target. He can determine distance by measuring the time that it takes for the sound of the burst to reach him and multiplying the time interval by the speed of sound, which is 350 meters per second. (In this case, the time of impact must be announced by the fire direction center.)

(3) The observer must exercise caution in very broken terrain. In hills or mountains the sound may travel around a hill mass before it reaches the observer and thus produce a false direction to the burst. If this occurs, it may be necessary to fire a high airburst(s) initially.

d. Adjustment With More Than One Observer.

(1) A more accurate target location can be derived if two or more observers can hear the noises produced at the enemy location. Each observer reports an estimated direction to the enemy location. The FDC can plot the data and determine the ground location by intersection.

(2) During the adjustment, each observer reports the direction to the burst, and the FDC plots the data. The FDC determines the impact point of the round by intersection and applies the appropriate corrections to the subsequent round to bring it to the target.

Section VIII. AERIAL FIELD ARTILLERY

13–28. Adjustment

The adjustment of aerial field artillery is a responsibility of the forward observer. Adjustment procedures may be found in FM 1–40, and FM 6–102.

Section IX. ABCA PRECISION FIRE

13–29. General

a. This section describes the precision fire procedures that an observer from the army of one ABCA nation (United States, Great Britain, Canada, Australia) may use when observing for an FDC of the army of another ABCA nation. These procedures are used in joint operations. They may also be used, at the discretion of the US field artillery commander, as an alternate to the US procedures.

b. The ABCA precision fire procedures should provide results comparable to those obtained with the US procedures and may require less time and ammunition. Before using these procedures as an alternate to the US procedures, the US field artillery commander should consider the following:

(1) *Forward observer ability and judgment.* ABCA precision fire is controlled by the observer. Therefore, observer errors due to poor judgment or inexperience are more likely to cause an invalid registration or an ammunition-consuming destruction mission. The US commander, therefore, should be confident in the ability and judgment of forward observers who will use these procedures.

Note. Forward observers of the other ABCA nations also perform many of the functions normally performed by the US S3/fire direction officer. They are normally experienced field artillerymen of proven ability.

(2) *Spotting Conditions.* The ABCA precision fire procedures may be used under the same conditions as the US procedures. Where conditions of difficult terrain, limited visibility, or a large angle T increase the probability of misspottings, however, the risk of an invalid registration or an unsatisfactory destruction mission is greater with the ABCA procedures.

(3) *Air observers.* Since the air observer spots from a vantage point well above the terrain, the use of ABCA precision (impact) procedures by an air observer should consistently provide satisfactory results particularly in difficult terrain.

c. The adjustment in ABCA precision fire is conducted with a single piece. The adjustment procedures are the same as the US procedures.

d. Fire for effect in ABCA precision fire is begun when the observer splits the appropriate range bracket, obtains a range correct spotting, or obtains a target hit. The range bracket to be split is normally 100 meters. When the range probable error is 25 meters or greater, the FDC will notify the observer, and he will enter fire for effect when he splits a 200 meter range bracket.

e. In a time registration, the observer must adjust the mean height of burst of four rounds fired with the same data to a point 20 meters above the registration point.

13-30. Impact Registration

a. In the ABCA impact registration, the observer continues the fire for effect until he obtains a bracket; that is, two OVERS and two SHORTS fired at the same data or at data 25 meters apart. (When the range probable error is 25 meters or greater, the verified bracket is 50 meters.) In satisfying this criterion, a spotting of TARGET or RANGE CORRECT is considered an OVER and a SHORT. For firing purposes, range corrections are never less than 25 or 50 meters, depending on the range probable error. For refinement of the final bracket, the observer may order a 10-meter range correction, which is used to determine the adjusted data but is not fired.

b. During fire for effect, deviation corrections are made only when necessary to obtain definite range spottings. A deviation correction for two or more rounds fired at the same data is based on the average deviation of the rounds from the registration point. Deviation corrections are never less than 10 meters. A final deviation refinement may be made if necessary. It is based on the average deviation of the FFE rounds. Like a final range refinement, it is used in determining the adjusted data but is not fired.

c. After the observer obtains a verified bracket, he orders a final refinement, if necessary, and transmits RECORD AS REGISTRATION POINT (so and so), END OF MISSION. When the observer estimates that the registration point lies equidistant between the MPI of the two pairs of bracketing rounds, the observer orders a refinement of ADD (DROP) 10 so that the final adjusted data are determined near the midpoint of the bracket. When the observer estimates that the registration point lies nearer the last round(s) fired, no final refinement is required, and the last data fired are the adjusted data. When he estimates that the registration point lies nearer the mean of the pair of rounds at the opposite end of the bracket from the last round(s) fired, the observer orders ADD (DROP) 25 so that the adjusted data are determined at that point. When the range probable error is 25 meters or greater than 25 meters, final refinements of 25 and 50 meters are made in the same manner.

d. The sequential examples below list most of the combinations of spottings that may occur during fire for effect and the appropriate corrections required to obtain a verified bracket. The observer has split a 100-meter bracket by ordering ADD (DROP) 50. If he spots the next round as OVER or SHORT, he follows the procedures in (1) below. If he spots the next round as RANGE CORRECT or TARGET, he follows the procedures in (2) below.

(1) *OVER or SHORT.* The observer orders that a pair of rounds be fired opposite this spotting by transmitting 2 ROUNDS, ADD (DROP) 25, as appropriate. This splits the 50-meter fire-effect bracket. If necessary, he orders one or more additional rounds until two definite range spottings have been obtained. The following spotting combinations may occur:

(*a*) Both rounds opposite the initial spotting (OVER or SHORT). This pair of rounds establishes a preponderance of OVER or SHORT. The observer orders that a round be fired opposite the preponderance by transmitting 1 ROUND, ADD (DROP) 25, as appropriate.

1. If the round is opposite the preponderance, the observer ends the registration, since two pairs of rounds, fired at data 25 meters apart, bracketing the registration point have been obtained.

2. If the round is the same as the preponderance, the observer orders an additional round at the same data. If this round is spotted opposite the preponderance, the observer ends the registration as in *1* above. If it is spotted the same as the preponderance, the observer orders one or more 25-meter range corrections until a spotting of RANGE CORRECT or TARGET or a round opposite the preponderance is obtained. He then orders corrections as necessary to obtain a verified bracket. If two or three 25-meter range corrections result in the same spotting as the preponderance, the observer may assume that a false range bracket was obtained prior to fire for effect. The observer should continue the adjustment with appropriate range corrections until the proper range bracket is obtained and should then reenter fire for effect.

3. If the round is RANGE CORRECT or TARGET, the observer ends the registration, since the equivalent of two pairs of rounds fired at data 25 meters apart, bracketing the registration point have been obtained.

(*b*) *Both rounds the same as the initial spotting (OVER or SHORT).* The observer orders one or more 25-meter range corrections until a spotting of RANGE CORRECT or TARGET or a round opposite the preponderance is obtained. He then orders corrections as necessary to obtain a verified bracket. If two or three

25-meter range corrections result in the same spotting as the preponderance, the observer may assume that a false range bracket was obtained prior to fire for effect. The observer should adjust fire until the proper range bracket has been obtained and should then reenter fire for effect.

(*c*) *The two rounds bracket the registration point (one OVER and one SHORT).* The observer orders an additional round fired at the same data.

1. If the round is OVER or SHORT, the observer orders another round to be fired opposite the preponderance of the last three spottings. The observer ends the registration if this round is spotted opposite the preponderance. If the spotting is the same as the preponderance, the observer orders one or more 25-meter range corrections until a spotting of RANGE CORRECT or TARGET or a spotting opposite the preponderance is obtained. He then orders corrections as necessary to obtain a verified bracket. If two or three 25-meter range corrections result in spottings the same as the preponderance, the observer may assume that a false range bracket was obtained prior to fire for effect. The observer should continue the adjustment with appropriate range corrections until the proper range bracket is obtained and should then reenter fire for effect.

2. If the round is RANGE CORRECT or TARGET, the observer ends the registration, since the equivalent of two pairs of rounds, fired at the same data, bracketing the registration point has been obtained.

(2) *RANGE CORRECT or TARGET.* The observer orders that a round be fired at the same data by transmitting REPEAT. This will result in one of the following spottings:

(*a*) The same as the initial spotting RANGE CORRECT or TARGET. The observer ends the registration, since the equivalent of two pairs of rounds, fired at the same data, bracketing the registration point has been obtained.

(*b*) Opposite the initial spotting (OVER or SHORT). An OVER or a SHORT in combination with the initial spotting (RANGE CORRECT or TARGET) established a preponderance of OVER or SHORT. The observer orders one round fired opposite the preponderance by transmitting ADD (DROP) 25, as appropriate. This splits the 50-meter fire for effect bracket.

1. If the round is opposite the preponderance, the observer orders one or more rounds fired at the same data until one of the definite range spottings shown in (a), (b), or (c) below is obtained.

(a) RANGE CORRECT or TARGET. The observer ends the registration, since the equivalent of two pairs of rounds, fired at data 25 meters apart, bracketing the registration point has been obtained.

(b) Opposite the preponderance. The observer ends the registration, since two pairs of rounds, fired at data 25 meters apart, bracketing the registration point have been obtained.

(c) Same as the preponderance. The observer orders one or more 25-meter range corrections until a spotting of RANGE CORRECT or TARGET or a round opposite the preponderance is obtained. He then orders correction as necessary to obtain a verified bracket. If two or three 25-meter range corrections result in the same preponderance, the observer may assume that a false range bracket was obtained prior to fire for effect. The observer should continue the adjustment until the proper range bracket has been obtained and should then reenter fire for effect.

2. If the round is the same as the preponderance, the observer follows the procedure outlined in *1*(c) above.

3. If the round is RANGE CORRECT or TARGET, the observer ends the registration, since the equivalent of two pairs of rounds, at data 25 meters apart, bracketing the registration point has been obtained. (The OVER or SHORT obtained in (*b*) above with the previous data is disregarded.)

e. When DOUBTFUL range spottings are obtained, the observer may order another round(s) back on the line. Once a deviation correction has been made during fire for effect, however, an additional round(s) must be fired to insure that both rounds of a pair constituting one end of the final bracket are fired at the same data. For example, an observer splits a 100-meter bracket by ordering DROP 50, and obtains a SHORT. His next correction is 2 ROUNDS, ADD 25. He spots both of these rounds as DOUBTFUL for range. He determined their average deviation to be 30 meters left of the registration point. The observer orders RIGHT 30 and obtains two OVERS. If he had not made the deviation correction, his next correction would have been 1 ROUND, DROP 2 to verify the short end of the bracket established by the first round of fire for effect. Since the deviation correction was made, the first round in fire for effect is disregarded, the method of fire remains 2 ROUNDS, and the correction is DROP 25. If these two rounds are SHORT the impact registration is ended.

13-31. Time Registration

If a time registration is desired after the impact registration has been completed, the observer transmits any final refinements and orders RECORD AS REGISTRATION POINT 1, TIME, REPEAT.

a. The time registration is continued with a single piece. The observer adjusts the mean height of burst of four rounds fired with the same deflection and quadrant elevation to 20 meters above the registration point. The rules for the conduct of the time registration are as follows:

(1) If the first round is a graze burst, the height of burst is raised in 40-meter increments until an airburst is obtained.

(2) When an airburst is obtained, the observer will announce 3 ROUNDS, FIRE FOR EFFECT.

(3) When four rounds have been fired with the same data, the observer will end the time registration with the appropriate correction to height of burst, if required, to achieve a 20 meter mean height of burst; for example, RECORD AS TIME REGISTRATION POINT AT DOWN 10, END OF MISSION.

(4) The possible spottings and observer corrections for the four rounds are as follows:

(*a*) Four AIR. The height of burst is corrected to 20 meters.

(*b*) Three AIR and one GRAZE. The height of burst is assumed to be correct.

(*c*) Two AIR and two GRAZE. The height of burst corrected by UP 10.

(*d*) One AIR and three GRAZE. The height of burst is corrected by UP 20.

b. Corrections to height of burst are made in 10-meter increments. Check rounds may be fired from other weapons of the battery to verify the validity of the time registration.

13-32. ABCA Destruction Missions

The destruction mission is a continuation of an impact registration. At the final adjusted data determined from the impact registration, the observer continues the mission by firing single rounds, in three-round groups, until the target has been destroyed. Corrections to range and deviation, to the nearest 10 meters, are made after each three-round group.

Section X. MOVING TARGET MISSIONS

13-33. General

To bring fire on a moving target requires that both the observer and the FDC use procedures and techniques slightly different than those used when firing on stationary targets.

13-34. Advance Planning

Advance planning is necessary to be prepared for firing on moving targets. As time permits, the observer should make the following preparations:

a. Select intercept points (IP) along likely avenues of approach and determine the distance between each successive IP. Record the distances as they will be used in determining the target's rate of speed.

b. Notify the FDC of the location of each IP. The FDC will assign a target number to each IP and will determine and maintain updated firing data for each IP.

c. Check rounds should be fired on as many of the IP's as possible so that the probability of first round accuracy will be increased. Check rounds should be fired periodically to insure that firing data is current.

13-35. Conduct of Fire

a. Target Acquisition Identification. Since time is extremely critical in a moving target mission and weapons may have to be shifted, the following information must be sent to the FDC as soon as a moving target is detected:

(1) Identification of observer.

(2) Warning order.

(3) General location of the target (grid square, proximity to some known point, etc.).

(4) Nature of target. Notification that the target is moving will alert the FDC that a delay can be expected and that data for an "AT MY COMMAND, FIRE FOR EFFECT" mission will probably follow.

Example: ALWAYS CIVIL 18, THIS IS ALWAYS CIVIL 24, FIRE MISSION, VICINITY TARGET AF7002, THREE TANKS MOVING SOUTHEAST, OVER.

b. Target Location. Select an IP on which to fire that is along the moving target's route of march and through which it can be expected to pass. The IP selected must, given the target rate of speed, allow the firing unit sufficient time to be ready to fire.

c. Call for Fire. Send the complete call for fire to the FDC with "AT MY COMMAND, FIRE FOR EFFECT" as the method of fire and control.

d. Determining the Time to Fire. The elements of information required to determine the time to command firing are the projectile time of flight and the rate of speed of the target. These are determined as follows:

(1) Measure the distance between two points through which the target will pass.

(2) Record the time required for the target to pass between the two points and compute the rate of speed as follows:

$$\text{RATE} = \frac{\text{DISTANCE}}{\text{TIME}}$$

(3) Once the rate of speed of the target has been determined the rate is used to determine the distance the target must be from the IP when the command to fire is given. This distance may be determined as follows:

(*a*) Determine the TF, from the FDC, and add two seconds (transmission time).

(*b*) Determine the distance the target will travel during TF + 2 seconds as follows:

DISTANCE = RATE × TIME

(*c*) Back off the distance determined in (*b*) above from the IP and along the target's route of march and visually select a point on the ground. The command to fire is announced when the target reaches this point.

e. Adjustment. If the fire is not effective the fire-for-effect must be adjusted. Two distinct actions are required. First, determine the corrections required to place the MPI at the original IP and, second, determine a new IP as the target takes evasive action. For example, if the MPI of the fire-for-effect rounds was approximately 100 meters left and 200 meters short of the IP with respect to the OP line the observer would announce to the FDC "R100, + 200, new IP, GRID ______ DIR ______." A new time to fire must be determined and the mission continued.

CHAPTER 14

ILLUSTRATIVE EXAMPLES

14-1. General

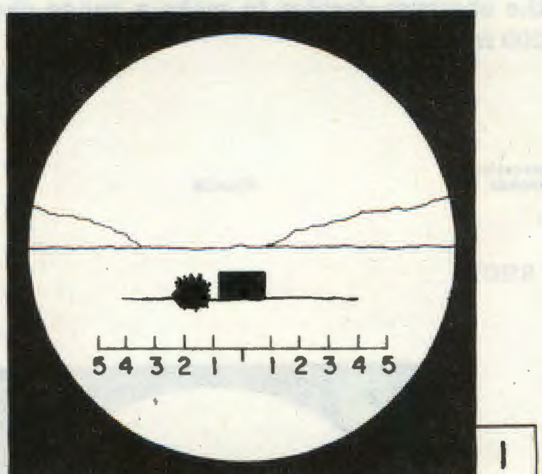
The examples of missions contained in this chapter are typical of those that an observer may be called upon to fire. In the examples in paragraphs 14-2 through 14-4, the symbols used are as follows: + indicates a spotting of OVER, − indicates a spotting of SHORT, ? indicates a spotting of DOUBTFUL, A indicates a spotting of AIR, G indicates a spotting of GRAZE, LN indicates a spotting of LINE, L indicates a spotting of LEFT, R indicates a spotting of RIGHT, and RG CORR indicates a spotting of RANGE CORRECT.

14-2. Precision Registration

The sample mission shown in figure 14-1 is an impact registration fired by a 155-mm howitzer (M109) on a surveyed registration point.

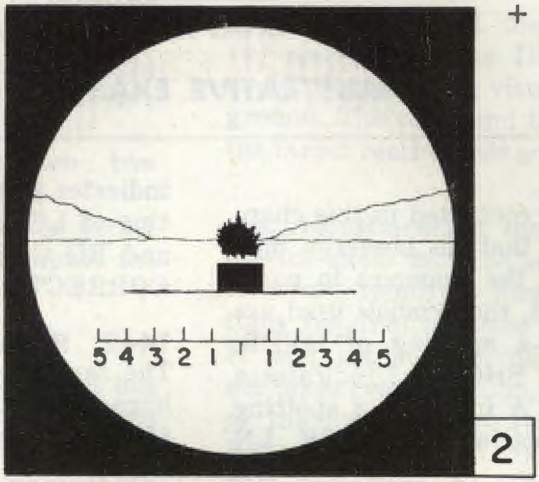
Results

Messages, corrections, and commands		*Observer spottings Rg*	*Dev*
Observer to FDC (call for fire): FIRE MISSION, REGISTRATION POINT 1, DIRECTION 4710, REGISTRATION, ADJUST FIRE. (The FDC will transmit to the observer those elements of the fire order that are of interest to him.)			
FDC to observer: SHOT.		?	15L



Remarks: The estimated OT distance is 3,000 meters. With binoculars, the observer measured the burst 15 mils left of the OT line. The observed deviation is 45 meters (15 × 3). No range spotting is obtained. The observer determined a shift of right 40 meters (45 rounded to the nearest 10 meters) to bring the next burst to the OT line.

Figure 14-1. Spotting the burst in impact registration.

Messages, corrections, and commands	*Results*	*Observer spottings Rg*	*Dev*
Observer to FDC: RIGHT 40. FDC to observer: SHOT.		+	LN

Remarks: The burst has been brought to the OT line. From this range spotting of OVER, the observer decides to make a range change of 200 meters.

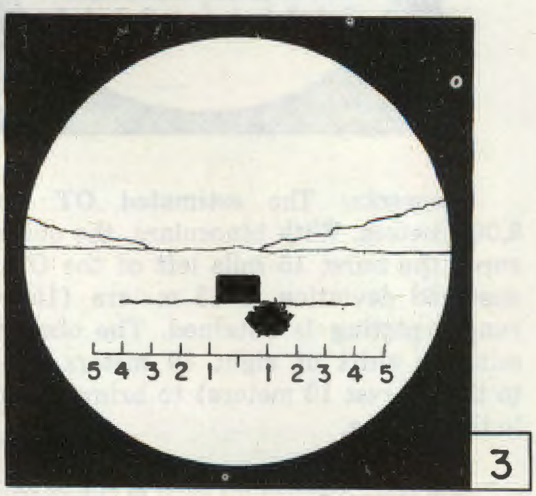
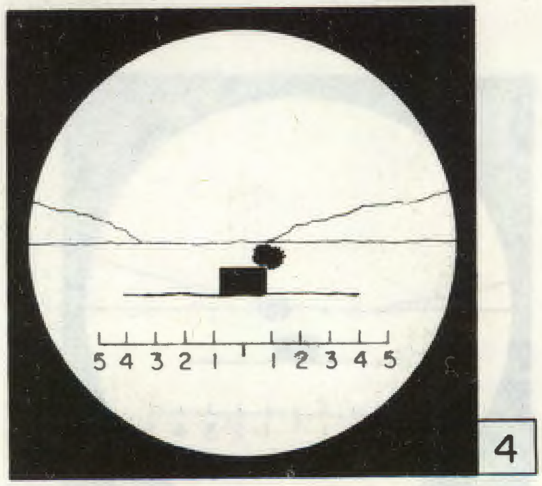
Messages, corrections, and commands	*Results*	*Observer spottings Rg*	*Dev*
Observer to FDC: DROP 200. FDC to observer: SHOT.		—	10R

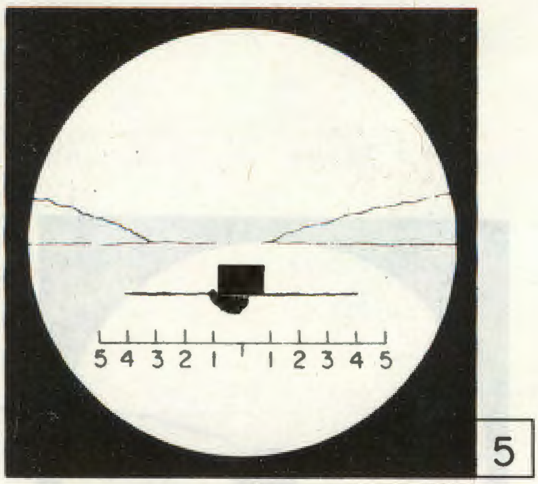
Figure 14-1—Continued.

Messages, corrections, and commands	***Results***	***Observer Spottings Rg***	***Dev***
Observer to FDC: LEFT 30 ADD 100. FDC to observer: SHOT.		+	10R



Remarks: A 100-meter range bracket has now been established along the OT line. The observer will request a range change of 50 meters for the next round, which will be the first round in fire for effect.

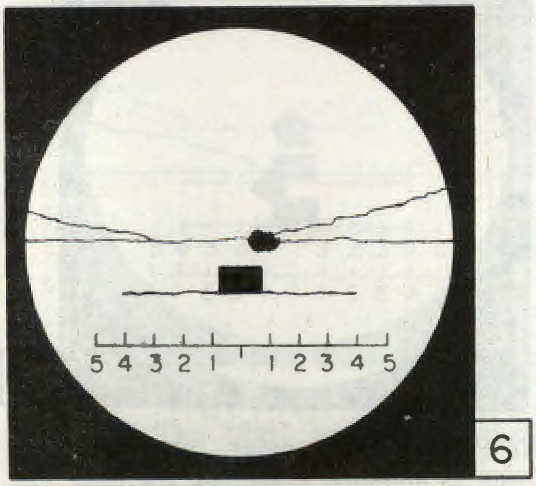
Messages, corrections, and commands	***Results***	***Observer spottings Rg***	***Dev***
Observer to FDC: L30 DROP 50, FIRE FOR EFFECT FDC to observer: SHOT. Observer to FDC: SHORT, LINE.		–	LN



Remarks: No further corrections are given by the observer. The FDC assumes control of the FFE phase and continues the mission until sufficient spottings from which to compute an adjusted elevation have been obtained. The observer reports only his spottings.

Figure 14–1—Continued

Messages, corrections, and commands	*Results*	*Observer spottings* Rg	Dev
FDC to observer: SHOT. Observer to FDC: OVER, RIGHT.		+	R



Messages, corrections, and commands	*Results*	*Observer Spottings* Rg	Dev
FDC to observer: SHOT. Observer to FDC: OVER, LINE.		+	LN

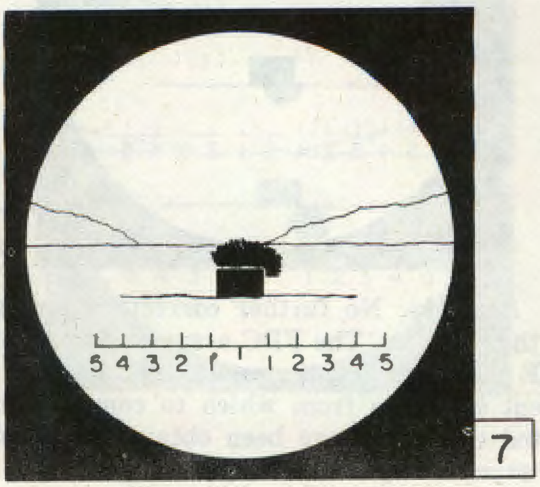
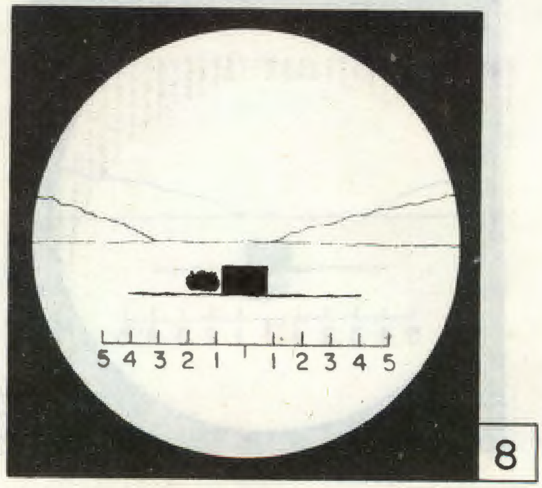


Figure 14-1—Continued

Messages, corrections, and commands	*Results*	*Observer Spottings Rg*	*Dev*
FDC to observer: SHOT. Observer to FDC: DOUBTFUL, LEFT.		?	L



Remarks: This round is not on the OT line. The observer spots the round as DOUBTFUL, LEFT.

Messages, corrections, and commands	*Results*	*Observer spottings Rg*	*Dev*
FDC to observer: SHOT. Observer to FDC: OVER, LINE.		+	LN

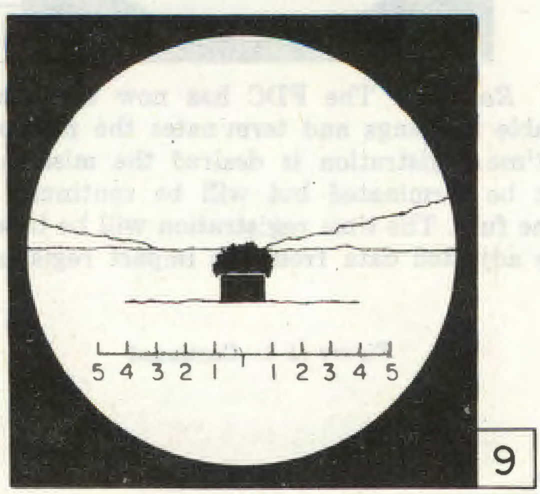
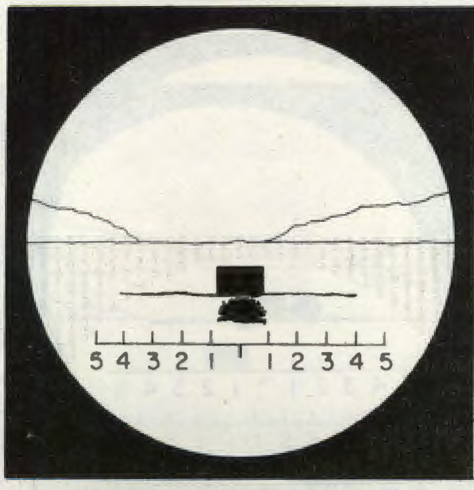


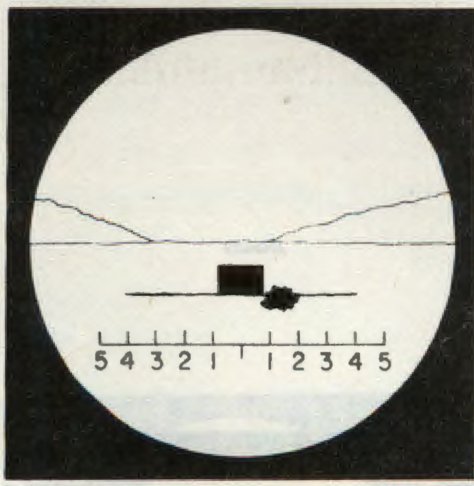
Figure 14–1—Continued

Messages, corrections, and commands	*Results*	*Observer spottings Rg*	*Dev*
FDC to observer: SHOT. Observer to FDC: SHORT, LINE.		—	LN



10

Messages, corrections, and commands	*Results*	*Observer Spottings Rg*	*Dev*
FDC to observer: SHOT. Observer to FDC: SHORT, RIGHT.		—	R



11

Remarks: The FDC has now obtained six usable spottings and terminates the mission. If a time registration is desired the mission will not be terminated but will be continued with time fuze. The time registration will be based on the adjusted data from the impact registration.

Figure 14–1—Continued

Messages corrections, and commands

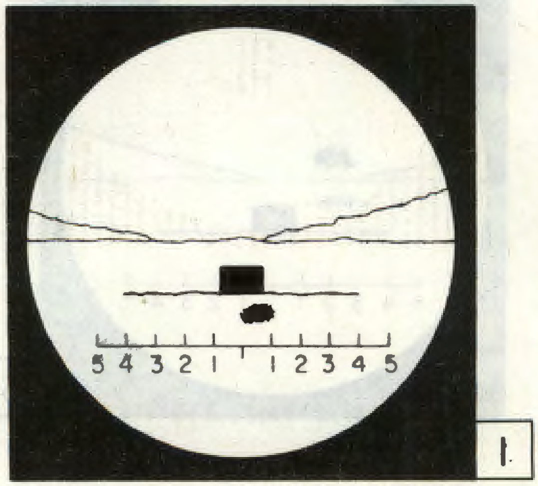
FDC to observer:
END OF MISSION.

Note. See chapter 19 for FDC impact registration procedures.

14–3. Time Registration

When a time registration is desired, it will be fired immediately following the impact registration. The sample mission shown in figure 14–2, illustrates the procedures used for a time registration. During a time registration the observer reports only spottings of AIR or GRAZE.

Messages, corrections, and commands	*Results*	*Observer spottings*
FDC to observer: OBSERVE TIME REGISTRATION. SHOT. Observer to FDC: GRAZE.		G



Messages, corrections, and commands	*Results*	*Observer Spottings*
FDC to observer: SHOT. Observer to FDC: AIR.		A

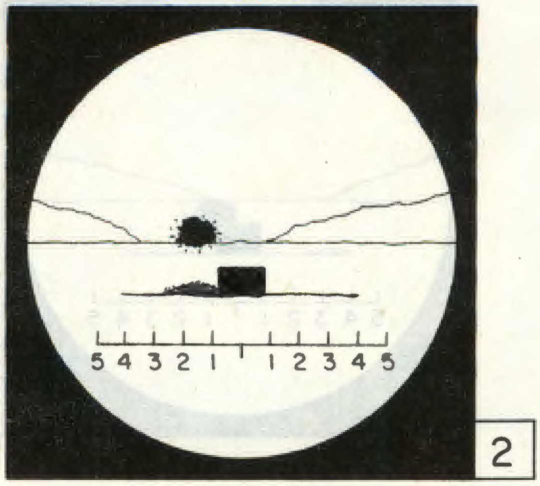


Figure 14–2. Spotting the burst in time registration.

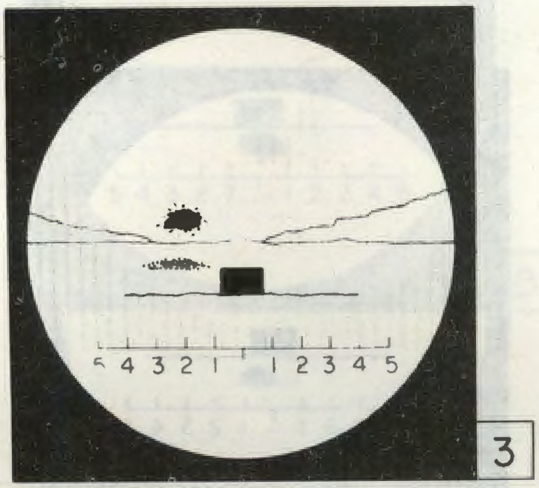
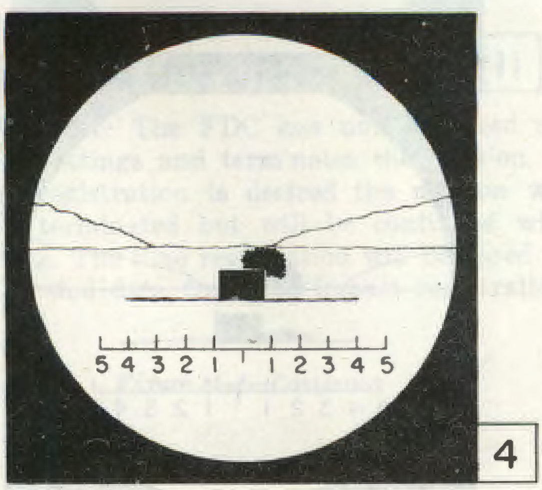
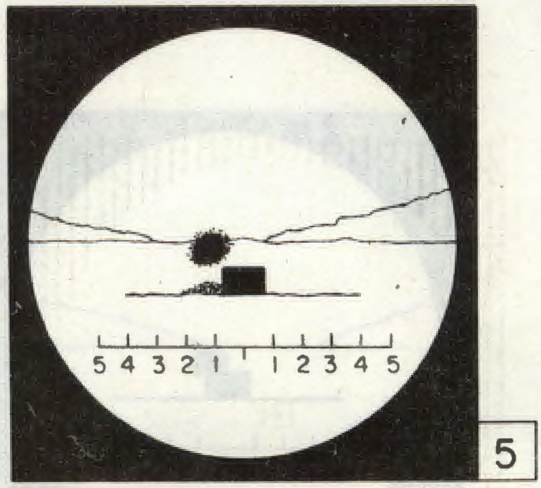
Messages, corrections, and commands	*Results*	*Observer Spottings*
FDC to observer: OBSERVE 3 ROUNDS, SHOT.		A
		G

Figure 14–2. Continued

Messages, corrections, and commands	*Results*	*Observer Spottings*
FDC to observer: ROUNDS COMPLETE. Observer to FDC: AIR, GRAZE, AIR.		A



Remarks: Two more rounds will be fired at the graze end of the time bracket to obtain six time spottings.

Messages, corrections, and commands	*Results*	*Observer spottings*
FDC to observer: OBSERVE 2 ROUNDS. SHOT.		A

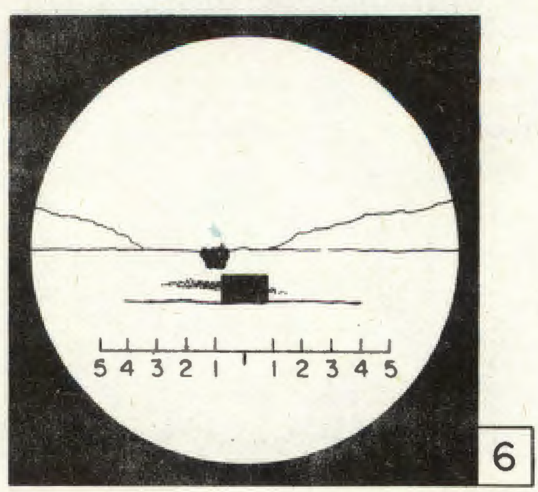
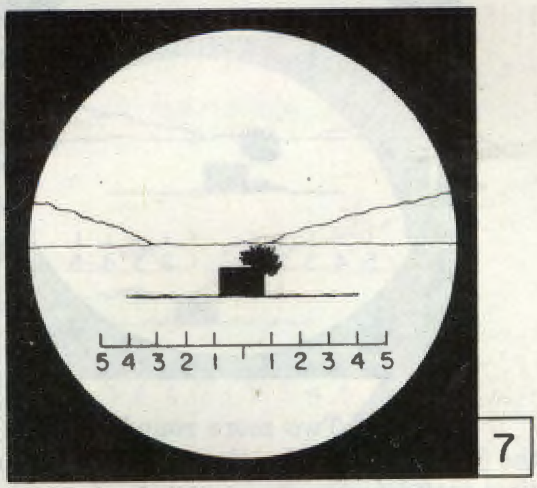


Figure 14–2. Continued

Messages, corrections, and commands	*Results*	*Observer spottings*
FDC to observer: ROUNDS COMPLETE. Observer to FDC: AIR, GRAZE.		G



Messages, corrections, and commands

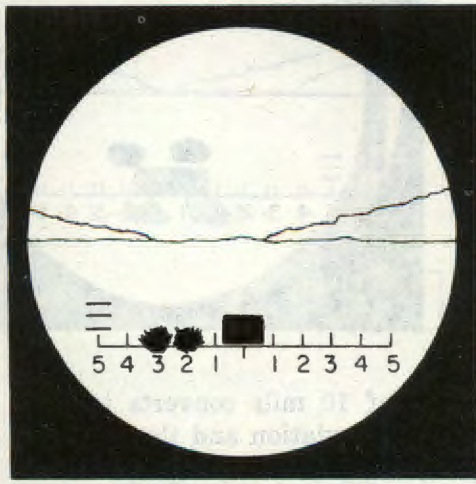
FDC to observer:
END OF MISSION.

Note. See chapter 19 for FDC time registration procedures.

Figure 14-2. Continued

14-4. Area Fuze Time Mission

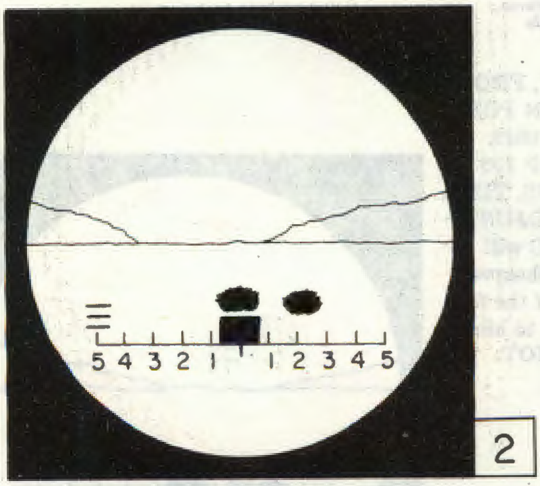
The sample mission shown in figure 14-3, illustrates the observer procedures used during an area mission with fuze time fired in effect. The procedures outlined are the same as those for a fuze quick area mission except for the height-of-burst adjustment phase required with fuze time.

Messages, corrections, and commands	*Results*	*Observer spottings Rg*	*Dev*
Observer to FDC: FIRE MISSION, FROM REGISTRATION POINT 1, DIRECTION 1880, LEFT 660, DROP 1000, MACHINEGUNS, TIME IN EFFECT, ADJUST FIRE. (The FDC will transmit to the observer those elements of the fire-order of interest to him.) FDC to observer: SHOT.		?	25L

Remarks: The estimated OT distance is 2,200 meters. With binoculars, the observer measures the center of the burst as 25 mils left of the OT line. The observed deviation is 50 meters (25 × 2). No range spotting is obtained.

Figure 14-3. Area mission using fuze time.

Messages, corrections, and commands	***Results***	***Observer spottings Rg***	***Dev***
Observer to FDC: RIGHT 50. FDC to observer: SHOT.		+	10R



Remarks: Deviation of 10 mils converts to 20 meters. This is a minor deviation and the observer elects to ignore it inasmuch as he is able to obtain a range spotting. If a range spotting were not obtainable, this deviation would be corrected.

Messages, corrections, and commands	***Results***	***Observer spottings Rg***	***Dev***
Observer to FDC: DROP 200. FDC to observer: SHOT.		—	10R

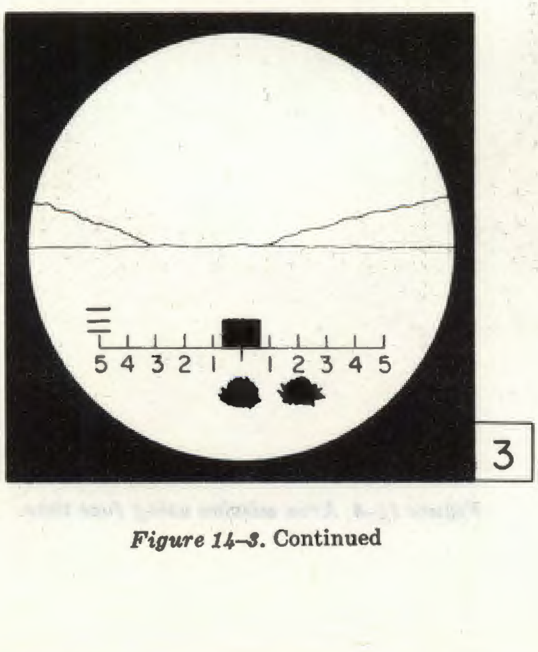
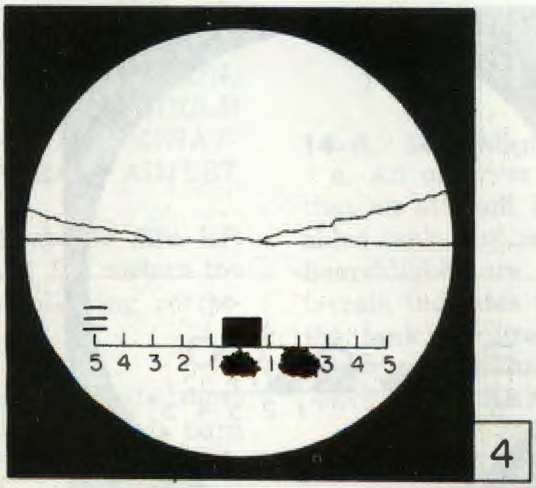
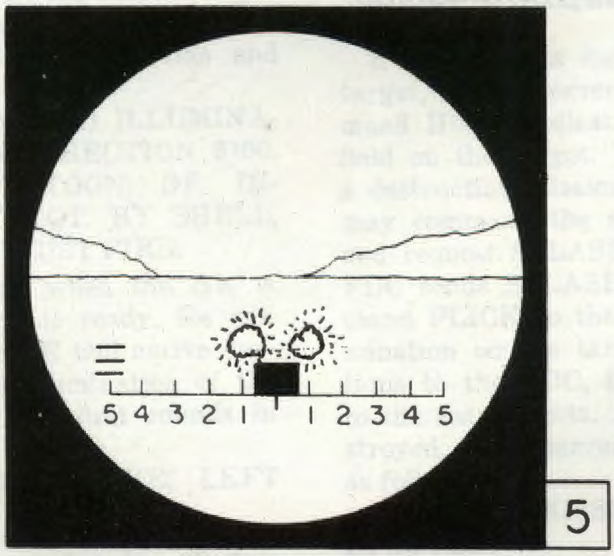


Figure 14–3. Continued

Messages, corrections, and commands	*Results*	*Observer Spottings Rg*	*Dev*
Observer to FDC: ADD 100. FDC to observer: SHOT.		—	10R



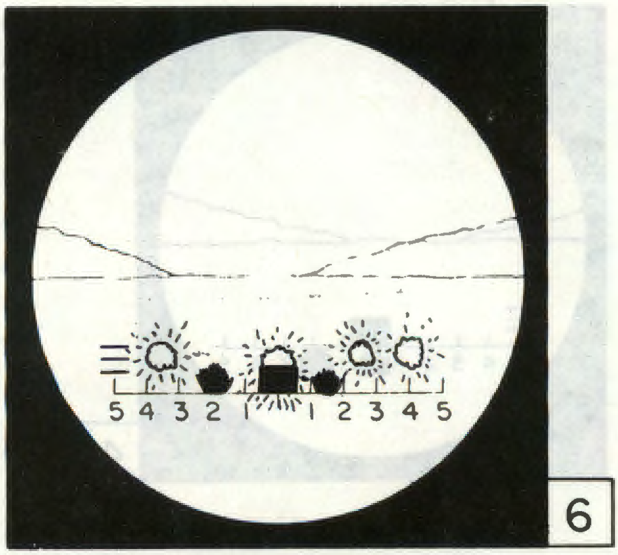
Messages, corrections, and commands	*Results*	*Observer Spotting HOB*
Observer to FDC: TIME, LEFT 20, ADD 50. FDC to observer: SHOT.		A (15 mils)



Remarks: The observer spotting of AIR 5 mils permits the observer to adjust the HOB to 20 meters and request fire for effect. The HOB correction is DOWN 10.

Figure 14–3. Continued

Messages, corrections, and commands	*Results*	*Observer spottings HOB Rg Dev*
Observer to FDC: DOWN 10, FIRE FOR EFFECT FDC to observer: SHOT.		Mixed A RG CORR LN



Remarks: Observer spottings of MIXED AIR, RANGE CORRECT, and LINE are considered adequate for the fire for effect and the observer ends the mission with END OF MISSION, MACHINEGUNS NEUTRALIZED.

Figure 14-3. Continued

14-5. Coordinated Illumination Mission

a. An observer hears a number of heavy vehicles at a direction estimated at 5,800 mils. He cannot detect any lights and the entire area is in complete darkness. Judging from the sound and the map study, the observer estimates the source of the noises to be grid 725365, which is about 2,000 meters from his position. He sends the following call for fire: BOLD RANGE 18, THIS IS BOLD RANGE 24, FIRE MISSION, GRID 725365, DIRECTION 5800, VEHICLE NOISES, SUSPECTED TANKS, ILLUMINATING, 2 GUNS LATERAL SPREAD, ADJUST FIRE.

b. The first rounds burst about 100 mils left of the suspected target area and 150 meters too high. The observer sends the following corrections:

RIGHT 200, DOWN 150.

c. The second group of rounds bursts short near the OT line but too low—the rounds burn 10 seconds on the ground. The observer sends the following corrections:

ADD 400, UP 50.

Note. The time of burning (T) on the ground (10 seconds) times the rate of descent (5 meters per second) equals the HOB correction (UP 50).

d. The third group of rounds bursts over the target area at the correct height and the observer notices two tanks and a number of infantrymen moving to the right at the extreme right edge of the illuminated area. He determines a shift from the center of the illumination and transmits the following:

RIGHT 400, COORDINATED ILLUMINATION, GRID 73113690, DIRECTION 6100. 2 TANKS AND PLATOON OF INFANTRY, VT IN EFFECT, BY SHELL, AT MY COMMAND, ADJUST FIRE.

e. The observer is notified when the HE is ready and when illuminating is ready. He will control the firing so that the HE will arrive during the period of maximum illumination of the target. The corrections for the first rounds in the adjustment of HE are as follows:

ILLUMINATING, REPEAT; HE, LEFT 70, ADD 100.

f. The observer's request to fire for effect is ILLUMINATING, REPEAT: HE, RIGHT 10, DROP 50, FIRE FOR EFFECT. He retains control of the time of firing to observe the effect.

g. The tanks and remaining infantrymen are moving out to the northwest away from the observer. It is necessary to shift illumination, and the observer desires to repeat fire for effect against the target. He sends the following corrections:

ILLUMINATING, ADD 400; HE, LEFT 50 REPEAT.

h. The tanks and infantrymen have moved out of the area of observation. The observer ends the mission as follows:

RECORD AS TARGET, END OF MISSION, TANKS AND INFANTRY DISPERSED TO NORTHWEST.

14-6. Searchlight Mission

a. An observer hears movement and suspects that an attempt is being made to repair a disabled tank that is blocking a road in his sector. Searchlights are available, and a study of the terrain indicates that it is possible to illuminate the tank by direct illumination. He sends the following illumination request:

EVER READY 18, THIS IS EVER READY 24, ILLUMINATION MISSION, GRID 67184437, DIRECTION 0780, SUSPECTED ACTIVITY AROUND DISABLED TANK, TWO LIGHTS DIRECT FOCUS BEAM, ADJUST LIGHTS.

b. The left beam appears below the target and the right beam is 2 beam widths to the left. The observer sends the following corrections:

NUMBER 1, RIGHT 2 BEAMS; NUMBER 2, UP 1/2 BEAM.

Note. Searchlights are numbered from right to left in their position.

c. Both beams having been centered on the target, the observer orders HOLD. The command HOLD indicates that the lights are to be held on the target. The observer then calls for a destruction mission on the tank. The observer may command the searchlights to CUT HOLD and request SPLASH from the FDC. When the FDC sends SPLASH, the observer should command FLICK to the searchlights to obtain illumination on the target. After he sends corrections to the FDC, he should send CUT HOLD to the searchlights. After the tank has been destroyed, the observer will terminate the mission as follows:

END OF MISSION, STALLED TANK DESTROYED.

d. Using these commands at AT MY COMMAND for the artillery fire, the observer is able to light the target for adjustment and surveillance and hold to a minimum the exposure of friendly searchlight positions.

14-7. Assault Fire Mission

The target is a cave in hard rock on a hillside.

An 8-inch howitzer section has been given the mission of sealing the cave entrance. The gun-target range is 1,500 meters and the observer-target distance is 1,000 meters. The mission has been prearranged in detail, and a complete call for fire is unnecessary. The observer reports when he is ready to observe, and the FDC, having prepared all data in advance, sends commands to the howitzer to fire the first round. Since the first round is fired at such short range with precise initial data, it should be close to the target.

a. The first round bursts 10 mils right of the OT line. The observer spots this round DOUBTFUL for range. He sends a correction of LEFT 10.

b. The second round bursts between the observer and the target. The observer sends a correction of ADD 50.

c. The third round bursts beyond the target. The observer sends the correction DROP 25.

d. The fourth round bursts just above the upper right corner of the entrance to the cave. Height changes are now appropriate instead of range changes. The observer sends the correction LEFT 1, DOWN 1.

e. The fifth round burst just below the left edge of the entrance to the cave. The observer sends the correction RIGHT 1/2, UP 1/2.

f. The sixth round bursts in the cave entrance. Fuze CP delay is now appropriate to penetrate the hard rock. No further changes in height or deflection are required. The observer sends the correction CONCRETE-PIERCING DELAY, REPEAT.

g. The seventh round also bursts in the cave entrance. The observer sees that the cave is almost completely sealed. He sends the correction REPEAT.

h. The eighth round strikes the cave entrance and completely seals the entrance with rubble. The observer terminates the mission by announcing END OF MISSION, CAVE ENTRANCE SEALED.

PART FOUR

FIRE DIRECTION

CHAPTER 15

FIRE DIRECTION, GENERAL

Section I. INTRODUCTION

15-1. Definitions

a. Fire Direction. Fire direction is the tactical employment to fire power and includes 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 incorporates the method and techniques used in fire direction centers to convert calls for fire into appropriate fire commands.

(1) *Tactical Fire Direction.* Tactical fire direction is the exercise of tactical command of one or more units in the selection of targets, the designation of units to fire, and the allocation of ammunition for each mission.

(2) *Technical Fire Direction.* Technical fire direction is the conversion of calls for fire to appropriate firing data and fire commands.

b. Fire Direction Center. The fire direction center (FDC) is the element to the artillery headquarters that consists of the operations, intelligence, and communications personnel and equipment with which the commander directs artillery fire.

15-2. Objectives of Fire Direction

The methods employed in fire direction must insure that the following objectives are met:

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 of the units.

d. Prompt distribution of fires simultaneously on numerous targets within range.

15-3. Command and Scope

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, and corps, and artillery headquarters are concerned primarily with tactical fire direction.

b. Fire direction, as exercised by a cannon artillery battalion, consists of technical fire direction as well as tactical fire direction. It is at the battalion that most technical fire direction occurs. However, when a battery is operating independently, fire direction is exercised by the battery commander through his executive officer and the fire direction personal at the battery fire direction center.

c. This manual is concerned primarily with technical fire direction for field artillery cannon battalions and batteries. For a discussion of tactical fire direction, see FM 6-20.

Section II. FIRE DIRECTION CENTER, GENERAL

15-4. Role of the Fire Direction Center

The fire direction center is the element of the gunnery team that receives the call for fire from the observer or higher headquarters, determines the firing data, and announces the fire commands to the firing battery. The fire direction center also determines and applies corrections to standard firing table values in order to achieve the accuracy in firing that is characteristic of field artillery.

15-5. Principles of Operation

a. Processing Fire Missions. Accuracy, flexibility, and speed in the execution of fire missions depend on:

(1) Accurate and rapid preparation of firing data and transmission of fire commands to the firing batteries.

(2) Accurate and rapid verification of firing data.

(3) Efficient division of duties among FDC personnel.

(4) Adherence to standard techniques and procedures.

(5) Efficient use of FDC plotting equipment and data-determining devices.

(6) Teamwork among FDC personnel.

(7) Efficient use of communication equipment, including radios and the battalion fire direction center switchboard.

b. Production of Firing Data. Observer fire missions are normally received and converted to firing data and fire commands in the battalion fire direction center. However, this process may be accomplished in a battery fire direction center under the following conditions:

(1) The battery is operating independently.

(2) The battery FDC is directed to process a mission. For example, if the battalion FDC is processing two missions simultaneously, the battery FDC may be directed to produce data for a mission.

15–6. Battalion S2

The battalion S2 is the intelligence officer. FM 6–20 contains a detailed discussion of his duties. Duties of the S2 that pertain to fire direction are to—

a. Locate likely targets and report them to the FDC with recommendations for their attack.

b. Advise the FDC on methods of attacking targets.

c. Obtain and distribute maps, photomaps, and aerial photographs and assist in target restitution.

Section III. FDC PERSONNEL IN THE BATTALION

15–7. Organization

The battalion FDC team is composed of the S3, the assistant S3, one chief fire direction computer, one assistant chief fire direction computer, one computer for each firing battery organic or attached to the battalion, one horizontal control operator (HCO), one vertical control operator (VCO), and the number of radiotelephone operators necessary to monitor and operate the radio and wire communication nets of the FDC. In addition to these personnel, a switchboard operator is assigned from the battalion communications platoon to install and operate the battalion FDC switchboard.

15–8. Battalion S3 (Assistant S3)

The S3 is the operations and training officer of the battalion. FM 6–20 contains a detailed discussion of his duties. The S3 is also the battalion gunnery officer. He plans, coordinates, and supervises the activities of the battalion and battery fire direction centers and is responsible for the training of the fire direction personnel. The assistant S3 assists the S3 in the performance of his duties and must be able to perform the duties of the S3. The duties of the S3 when engaged in fire direction are to—

a. Actively supervise the battalion fire direcion center.

b. Supervise the functioning of the battalion fire direction wire and radio nets.

c. Inspect the plot of each reported target, decide how to attack the target, and issue the fire order.

d. Direct and supervise the computation and transmission of corrections such as registration, meteorological and velocity error (VE) corrections.

e, Insure that appropriate fire direction records are maintained.

f. Supervise the preparation and execution of prearranged fires.

Note. In order to maintain continuous (24-hour) operation in the FDC, it is necessary to use officers other than the S3, the assistant S3, and the assistant executive officer in the battalion and battery fire direction centers. The term fire direction officer (FDO), as used in this manual, refers to the officer in charge of the FDC at that particular time.

15–9. Chief Fire Direction Computer (Assistant Chief Fire Direction Computer)

The chief fire direction computer is the senior enlisted member of the battalion fire direction center. He must be thoroughly proficient in both gunnery and communication procedures. He must be capable of operating and supervising the operation of the communication facilities within the fire direction center. His specific duties are to—

a. Supervise all enlisted members of the fire direction center.

b. Supervise the computation of registration, met, and velocity error corrections.

c. Inform the battalion S2 of the status of fire missions and render a report of firing to the S2 on the termination of each fire mission.

d. Insure proper maintenance of the necessary FDC records.

15–10. Computer

There is one fire direction computer for each battery in the battalion fire direction center. The duties of the computer are to—

a. Record calls for fire, fire orders, firing data, corrections, and all other data as directed by the fire direction officer.

b. Maintain the necessary FDC records.

c. Compute firing data, convert firing data to fire commands, and transmit the fire commands to the battery in the proper sequence.

d. Announce total height-of-burst correction to the nonadjusting battery computers when he is acting as the computer of the adjusting battery in a battalion mass mission.

e. Assist in the conduct of registrations and the determination and application of registration corrections.

f. Compute met, VE, and special corrections when so directed.

g. Determine data for replot, with the assistance of the vertical control operator and the horizontal control operator.

h. Transmit current chart data and corrections to the battery fire direction center.

i. Record the battery executive officer's report.

j. Prepare data sheets and maintain the record of data sheets for prearranged fires sent to the firing battery.

15–11. Horizontal Control Operator

The duties of the horizontal control operator are to—

a. Prepare and maintain the horizontal control chart.

b. Plot target locations.

c. Determine and announce chart data.

d. Determine the size of angle T and announce it when necessary.

e. Assist the computer and vertical control operator in determining replot data.

f. Operate the gun direction computer M18 (FADAC).

15–12. Vertical Control Operator

The specific duties of the vertical control operator are to—

a. Prepare and maintain the vertical control chart, normally a grid sheet supplemented by a 1:50,000 map.

b. Maintain overlays to include situation, fire capabilities, and dead space overlays.

c. Inform fire direction officer when calls for fire plot close to friendly locations or patrols or within no-fire lines.

d. Plot targets, record their altitudes, and announce the altitudes when required.

e. Compute the site for each battery, when necessary, and announce that site to the appropriate computer when requested.

f. Assist the computer and the horizontal control operator in determining replot data.

g. Act as the horizontal control operator in the event of multiple missions.

h. Provide a check for the horizontal control operator as time permits.

i. Assist the chief fire direction computer as directed.

15–13. Radio Telephone Operator(s)

The radiotelephone operator(s) must be trained in FDC communications procedures. His specific duties are to—

a. Operate a radio or telephone in the fire direction center.

b. Install remote control or radio-wire integration circuits from the radio vehicle to the fire direction center as necessary.

c. Repeat calls for fire received by telephone or radio and send the message to observer.

d. Make communications checks as directed.

15–14. Switchboard Operator

The switchboard operator must be trained in FDC communications procedures. His specific duties are to—

a. Install and operate the FDC switchboard.

b. Assist in the installation of radio-wire integration and local FDC circuits.

c. Prepare and maintain a traffic diagram.

d. Perform the necessary communications checks to insure that the FDC circuits operate properly.

15–15. Continuous FDC Operation

The fire direction center in any unit must be organized for 24-hour operation. This means that additional personnel must be trained in FDC procedures so that they may perform the duties of assigned FDC personnel when necessary. Allowing fatigued personnel to work in the FDC promotes the possibility of error. Personnel cross-trained in FDC procedures ordinarily are obtained from sections that perform similarly exacting work, such as the battalion target acquisition platoon.

15-16. Battery Fire Direction

The battery fire direction center is manned by personnel assigned to the firing battery headquarters. Its composition is similar to that of the battalion FDC except that it is organized on a smaller scale. The battery executive officer or, when directed, the assistant executive officer serves as the battery fire direction officer. There is only one fire direction computer, and in some cases one chart operator may serve as both the horizontal control operator and vertical control operator.

CHAPTER 16

CHART DATA

Section I. FIRING CHARTS

16-1. General

The firing chart is a photomap, a grid sheet, or a sheet of plain paper on which are shown the relative locations of batteries, registration points, and targets and other details needed in preparing firing data.

16-2. Map

A map is a graphic representation, drawn to scale, of a portion of the earth's surface as seen from above. Maps (normally 1:50,000) are used as supplements to firing charts. A map 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 for field artillery use. 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 accurate and adequate ground control, it should be used only for obtaining approximate locations and vertical control to supplement a grid sheet firing chart.

16-3. 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. A photomap must not be considered exact until its accuracy has been verified. Errors caused by tilt, distortion due to relief, and errors due to poor assembly may be present in photomaps. Points which cannot be located on the photomap by inspection may be located by survey. It will be necessary to determine the scale of the map before points can be located by survey. Normally vertical control can be established only by estimation. Some photomaps have spot elevations, but interpolation is 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.

16-4. Grid Sheet

A grid sheet is a sheet of plain 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, any scale desired may be used. Grid sheets used by the field artillery are normally printed to a scale of 1:25,000, with the distance between grid lines representing 1,000 meters. The locations of all points placed on the grid sheet must be determined either by survey or by firing. Horizontal and vertical control charts usually are grid sheets.

16-5. Purpose of Firing Chart

The firing chart is used for determining the range, direction, and vertical interval from the gun(s) to the target. The effectiveness of artillery fires depends, to a large degree, on the accuracy and completeness of the firing chart.

16-6. Type of Firing Charts

There are two types of firing charts used in an FDC—the surveyed firing chart and the observed firing chart. The procedures described in this chapter for determining data are applicable to both the surveyed firing chart and the observed firing chart.

a. The surveyed firing chart is a chart on which the locations of all critical points (battery positions, registration points, OP's) are based either on survey (FM 6-2) or on map inspection. 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.

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 be established only by the adjustment of fire, hence the name "observed firing chart." Details pertaining to construction of an observed firing chart are contained in chapter 26.

Section II. PLOTTING

16-7. General

Fire direction center personnel must make every effort to insure the accuracy of data shown on the firing chart. All firing charts in the battalion should be identical so that any chart can be used to mass the fires of the battalion.

16-8. FDC Equipment

The use of special equipment is required in the construction and use of a firing chart. 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. The 6H (hard lead) pencil (1, fig 16-1), sharpened to a wedge point, is used for drawing all lines from which measurements will be made. This procedure is required if the necessary accuracy is to be achieved.

b. The 4H Pencil. The 4H pencil (1, fig 16-1) is used for lettering and for accentuating tick marks. It should be sharpened to a conical point.

c. Map Pins. Map pins (2, fig 16-1), commonly referred to as plotting pins, are used for marking battery, radar, and OP positions and for plotting all points on the firing chart.

d. Plotting Scale. The plotting scale (3, fig 16-1) is used for measuring distances and for plotting and determining the coordinates of critical points such as batteries, radar, OP's and registration points, which must be located accurately. The scale should always be used in plotting coordinates determined by survey computations when the grid lines on the firing chart are not exactly 1,000 meters apart. The scale is graduated in meters, yards, and inches. The meter and yard graduations are at scales of 1:25,000, 1:50,000, and 1:62,500. The plotting scale should never be used as a straightedge for drawing lines.

e. Coordinate Scale (Aluminum). The aluminum coordinate scale (4, fig 16-1) is a square-shaped scale used for plotting and determining the grid coordinates of targets and critical points located by other than survey computations. It may also be used for plotting the coordinates of critical points determined by survey computations if the grid lines are exactly 1,000 meters apart. This is graduated in meters and yards at scales of 1:25,000 and 1:50,000. The scale has a projecting knob for ease of handling.

f. Coordinate Scale (Plastic). The plastic coordinate scale (5, fig 16-1) is a right-angled scale used for plotting and determining the coordinates of targets other than registration points and locations determined by survey computations. This scale is graduated in meters and yards at scales 1:25,000 and 1:50,000.

g. Protractor. The protractor (6, fig 16-1) is a plastic angle-measuring instrument made in the shape of a half circle. The arc of the half circle is graduated in 10-mil increments with each 100-mil graduation numbered in a clockwise sequence and a counter-clockwise sequence. The hairline connecting the 0 and 3200 mil graduations is used as a baseline for measuring angles. The straightedge of the protractor is graduated in meters at scales of 1:25,000 (black) and 1:50,000 (red).

h. Range-Deflection Protractor. The range-deflection protractor (RDP) (7, fig 16-1) is used for measuring angles and distances. It is used for measuring range and deflection from the battery to the target and for polar plotting. The left edge of the arm is graduated in 50 meter increments (1:25,000 scale) and is read to an accuracy of 10 meters, visually interpolating, if necessary. The arc of the range-deflecting protractor covers 1,000 mils and is graduated in 5-mil increments with each 50-mil increment indicated by a long line. It is read to an accuracy of one mil, visually interpolating, if necessary.

i. Military Slide Rule. The military slide rule (MSR) (8, fig 16-1) is discussed in paragraph 13-17.

j. Graphical Firing Table. The graphical firing table (GFT) (9, fig 16-1) is discussed in paragraph 17-10.

k. Graphical Site Table. The graphical site table (GST) (10, fig 16-1) is discussed in paragraph 17-7.

16-9. Tick Marks

a. The tick mark is the symbol used for marking the location of an installation or a target plotted on a firing chart. The tick mark (fig 16-2) is constructed in the form of a cross starting approximately 40 meters from the pinhole on the chart and extending approximately 150 meters in length (1:25,000 scale). Normally, the

Figure 16–1. FDC equipment.

lines of the tick mark are drawn parallel to the grid lines; however, if the plotted point falls on or very close to a grid line, the tick mark is drawn at a 45° angle to the grid lines. The tick mark for a point located by firing (recorded targets) is drawn in red.

b. The identification of the point is placed in the upper right quadrant of the tick mark. The installation or activity is indicated in the following manner (fig 16–2):

(1) *Battery.* The letter designation is shown in the appropriate color; i.e., A—red, B—black, C—blue, D—orange. If more than four lettered batteries are assigned to one battalion, the color coding starts again with red and continues in the same sequence. The pieces of an artillery battery are sometimes widely dispersed, and it may be necessary to plot the location of each piece or each platoon center.

(2) *Radar.* The military symbol is shown in green.

(3) *Forward observation post.* The military symbol and the call number of the observer are shown in black. (If the observer is from another unit, both the call sign and the call number will be used.)

(4) *Battalion observation post.* The assigned number of the observation post is shown in black; e.g., 02.

(5) *Registration points.* The registration point and the number assigned are shown in black; e.g., reg pt 3.

(6) *Targets.* The assigned target number is shown in black; e.g., AF7415.

c. The altitude, in meters, of the plotted point is placed in the lower left quadrant in black.

d. If the plotted point has been fired on, the fuze used in fire for effect may be placed in the lower right quadrant.

e. If the target has been fired on with high-angle fire, the letters HA may be placed in the upper left quadrant.

f. The charge fired may also be placed in the upper left quadrant.

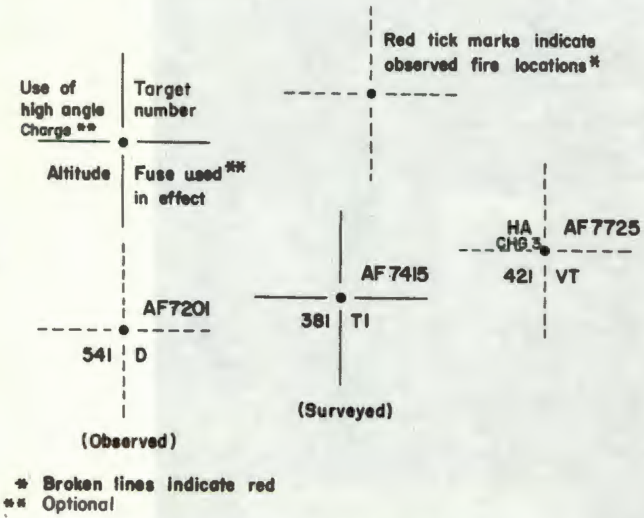


Figure 16-2. Marking plotted points.

16-10. Plotting a Point From Grid Coordinates With a Plotting Scale

a. A normal grid is defined as a grid that is printed to the exact scale of the plotting scale (fig 16-3). To plot a point on a normal grid, use the following procedure: Assume that the coordinates of the point are 6241937749. First locate grid square above 6237, place the 0 graduation of the plotting scale on the north-south line 62 and the 1,000-meter graduation on the north-south line 63. Mark off 419 meters with a plotting pin (1, fig 16-3). Move the scale one grid square below grid square 6237 and repeat the operation (2, fig 16-3). Remove the pins and, using a 6H pencil, connect the two pinholes with a fine, light line (3, fig 16-3). This will be the north-south line passing through the point. In a similar manner, determine the east-west line passing through the point (4, 5, 6, fig 16-3). The intersection of these lines (7, fig 16-3) is the desired point, which is indicated by a tick mark made with a 4H pencil.

b. Grid lines are sometimes closer together or farther apart than normal because of poor manufacturing processes or because of shrinking or stretching of the grid paper.

(1) When grid lines are closer than normal, plot the point in the same manner as described in *a* above. By inclining the scale so that the 0 of the scale is on one grid line and the 1,000-meter graduation is on the other grid line, the point will be plotted in its true relation to the grid.

(2) If the grid lines are farther apart than normal, measure the distance between the grid lines and find the difference from normal. Add proportional part of this difference to each 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 (400/1000) x 20, or 8 meters. The 400-meter measurement then is scaled as 408 meters (1, fig 16-5).

(3) You can obtain similar results by diagonally inclining the plotting scale so that one 1,000-meter graduation is on one grid line and the other 1,000 meter graduation is on the adjacent grid line. Multiply the distance to be plotted by 2, and scale the result. For example, when the easting coordinate is plotted (2, fig 16-5) the 400-meter measurement will be scaled as 800 on the inclined plotting scale.

16-11. Measuring Grid Coordinates of a Point With a Plotting Scale

Grid coordinates are measured in the same manner as that in which they are plotted, and the distance is read directly between the point and the grid line. The first digit(s) of the easting grid coordinate is the number appearing at the top or bottom of the north-south line west of the point. The balance of the easting grid coordinate is the distance of the point east of this north-south line as measured with the scale. The first digit(s) of the northing coordinate is obtained from the right or left of the east-west line south of the point. The balance of the northing grid coordinate is the distance of the point north of this line as measured with the scale. If the grid lines are closer together or farther apart than normal, measurements are made in the same manner as that in which points are plotted.

16-12. Use of Coordinate Scale

When rapid massing on targets of opportunity or rapid plotting of targets for an adjustment is necessary, plotting may be done with the coordinate scale (4 and 5, fig 16-1). To use a coordinate scale for determination of coordinates, place the 0 of the scale at the lower left corner of the grid square. Keeping the scale on the lower horizontal grid line, slide it to the right until the point for which coordinates are desired touches the edge of the scale. When reading coordinates, examine the two (four) sides of the coordinate scale to insure that the horizontal scale is alined with the east-west grid line and the vertical scale is parallel with the north-south grid line.

16-13. Measuring and Plotting an Angle With a Protractor

Angles may be measured or plotted with the plastic

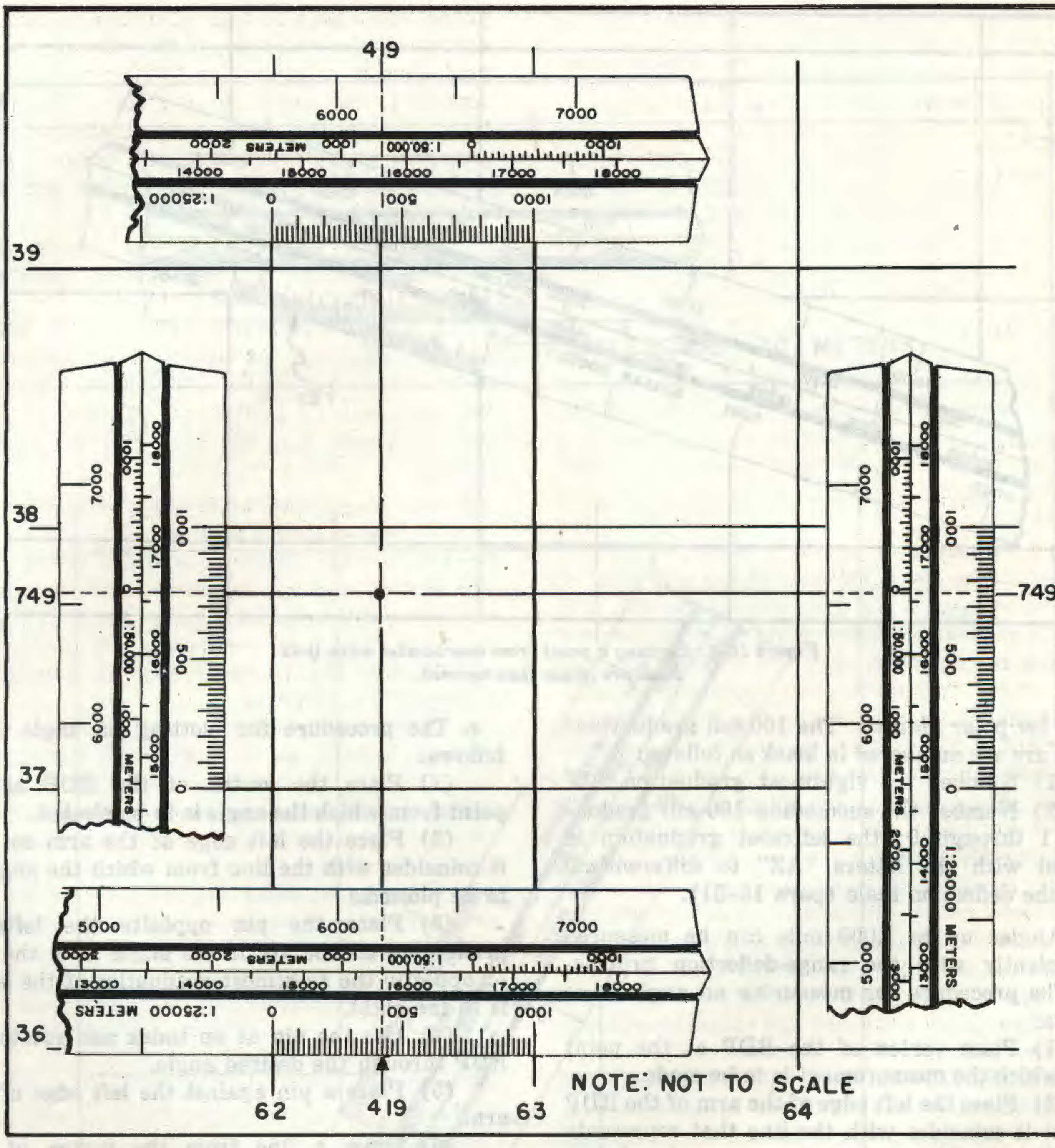


Figure 16–3. Plotting a point from coordinates on a normal grid.

protractor (6, fig 16–1). FM 21–26 describes the use of a plastic protractor graduated in degrees.

16–14. Measuring and Plotting Distance With a Plotting Scale

The most accurate device for determining the distance between two points plotted on a firing chart is the plotting scale. The chart operator must take care to use the correct scale on the plotting scale. After the direction of a line has been established on a chart, the length of the line may be plotted with the plotting scale.

16–15. Measuring and Plotting With a Range Deflection Protractor

a. When several angles and distances are to be plotted or measured from one point and one reference direction (e.g., polar plotting from radar), the procedure is facilitated by the use of the range-deflection protractor.

b. The range-deflection protractor must be pre-

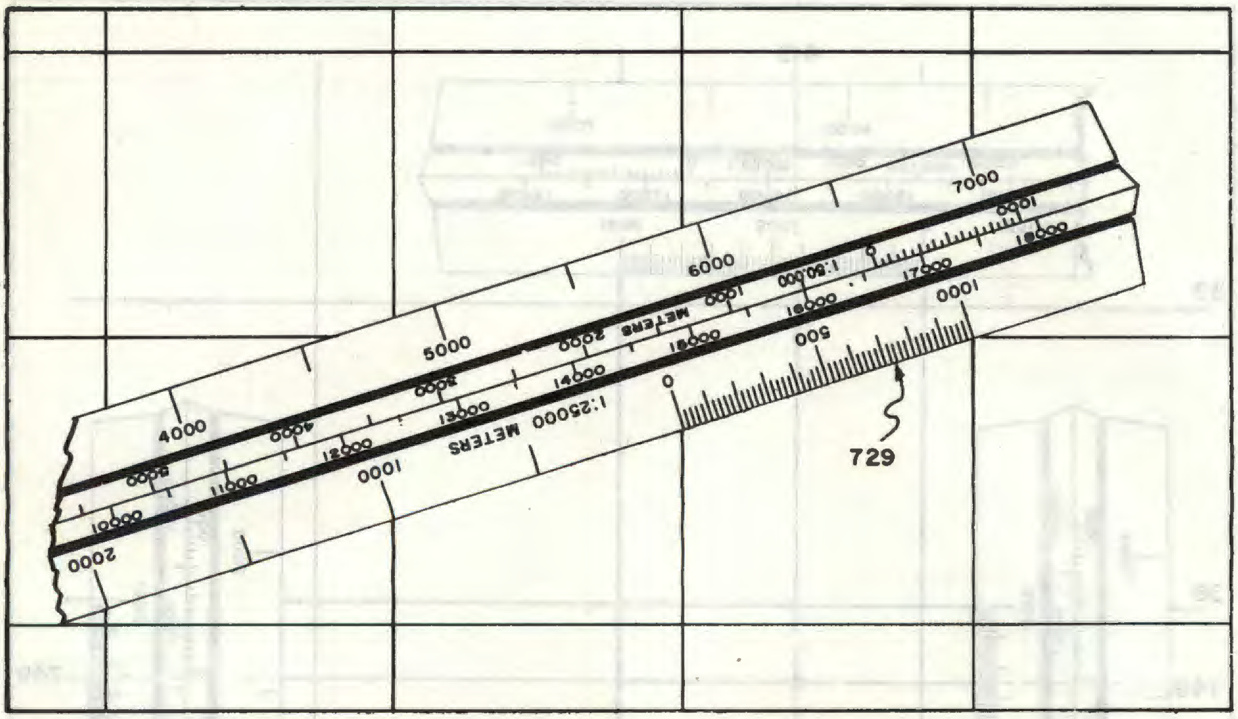


Figure 16–4. Plotting a point from coordinates when grid lines are closer than normal.

pared for polar plotting. The 100-mil graduations on the arc are numbered in black as follows:

(1) Number the rightmost graduation "0."

(2) Number the succeeding 100-mil graduations 1 through 9; the leftmost graduation is marked with the letters "AZ" to differentiate from the deflection scale (para 16–21).

c. Angles up to 1,000 mils can be measured conveniently with the range-deflection protractor. The procedure for measuring an angle is as follows:

(1) Place vertex of the RDP at the point from which the measurement is to be made.

(2) Place the left edge of the arm of the RDP so that it coincides with the line that represents the left limit of the angle to be measured and then place a pin at the right most graduation on the arc of the range-deflection protractor.

(3) Rotate the RDP until the left edge of the arm coincides with the line that represents the right limit of the angle and read the value of the angle from the azimuth scale opposite the pin placed along the arc.

d. To measure the distance in meters between two points, place the vertex of the RDP at one of the points and the left edge of the arm against the pin in the second point and read the distance opposite the pin in the second point.

e. The procedure for plotting an angle is as follows:

(1) Place the vertex of the RDP at the point from which the angle is to be plotted.

(2) Place the left edge of the arm so that it coincides with the line from which the angle is to be plotted.

(3) Place the pin opposite the leftmost graduation on the arc if the angle is to the left or opposite the rightmost graduation if the angle is to the right.

(4) Use the pin as an index and rotate the RDP through the desired angle.

(5) Place a pin against the left edge of the arm.

(6) Draw a line from the vertex of the angle through the pin location.

16–16. Preparing Chart With Polar Indexes for a Range-Deflection Protractor

a. The point from which polar plotting is to be performed must be plotted on the firing chart. If a large number of angles are to be measured or plotted from a point, the chart should be indexed.

b. Azimuth indexes are constructed on the firing chart at 1,000-mil intervals throughout the target area (fig 16–6). These indexes are constructed so that the left edge of the arm of the range-deflection protractor is alined on an azi-

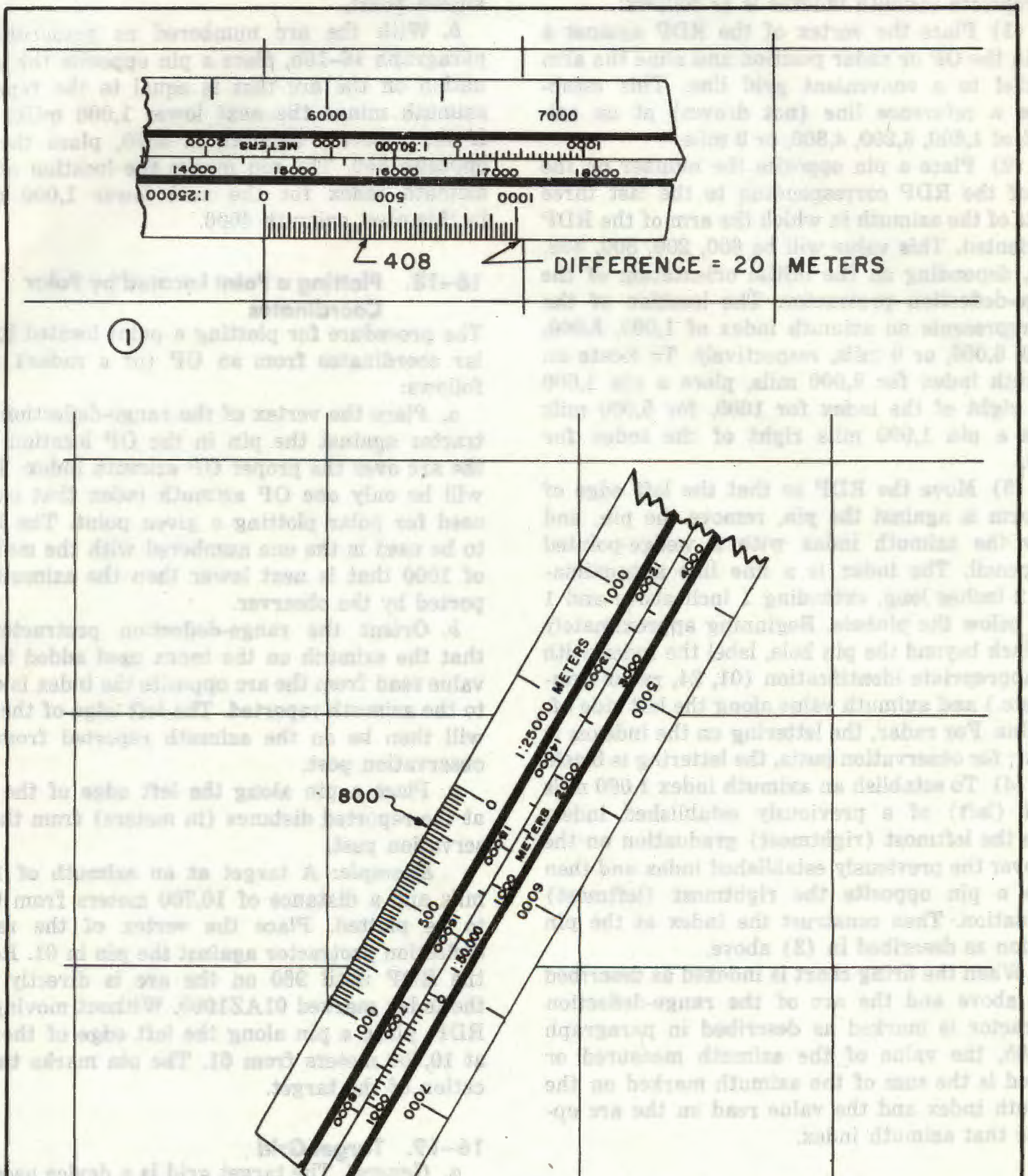


Figure 16–5. Plotting a point from coordinates when grid lines are farther apart than normal (two techniques).

muth that is a multiple of 1000 when the appropriate index is opposite the rightmost graduation on the arc. The procedure for establishing the appropriate azimuth indexes is as follows:

(1) Place the vertex of the RDP against a pin in the OP or radar position and aline the arm parallel to a convenient grid line. This establishes a reference line (not drawn) at an azimuth of 1,600, 3,200, 4,800, or 0 mils.

(2) Place a pin opposite the number on the arc of the RDP corresponding to the last three digits of the azimuth in which the arm of the RDP is oriented. This value will be 600, 200, 800, 400, or 0, depending on the initial orientation of the range-deflection protractor. The location of the pin represents an azimuth index of 1,000, 3,000, 4,000, 6,000, or 0 mils, respectively. To locate an azimuth index for 2,000 mils, place a pin 1,000 mils right of the index for 1000, for 5,000 mils place a pin 1,000 mils right of the index for 4000.

(3) Move the RDP so that the left edge of the arm is against the *pin*, remove the pin, and draw the azimuth index with a wedge-pointed 6H pencil. The index is a fine line approximately 2 inches long, extending 1 inch above and 1 inch below the pinhole. Beginning approximately 1/8 inch beyond the pin hole, label the index with the appropriate identification (01, 24, radar symbol, etc.) and aximuth value along the left side of the line. For radar, the lettering on the indexes is green; for observation posts, the lettering is black.

(4) To establish an aximuth index 1,000 mils right (left) of a previously established index, place the leftmost (rightmost) graduation on the arc over the previously established index and then place a pin opposite the rightmost (leftmost) graduation. Then construct the index at the pin location as described in (3) above.

c. When the firing chart is indexed as described in *b* above and the arc of the range-deflection protractor is marked as described in paragraph 16-15*b*, the value of the azimuth measured or plotted is the sum of the azimuth marked on the azimuth index and the value read on the arc opposite that azimuth index.

16-17. Preparing Chart When Azimuth to a Known Point Has Been Reported From a Radar Measurement

There will be occasions when the azimuth to a point plotted on the firing chart can be measured by radar. In such cases the procedure described in *a* and *b* below will be used for constructing the azimuth index.

a. Place the vertex of the range-deflection protractor against the pin in the radar location and the left edge of the arm against the pin in the known point.

b. With the arc numbered as prescribed in paragraph 16-15b, place a pin opposite the graduation on the arc that is equal to the reported azimuth minus the next lower 1,000 mils; e.g., if the reported azimuth is 4350, place the pin opposite 350. The pin marks the location of the azimuth index for the next lower 1,000 mils; in this case, azimuth 4000.

16-18. Plotting a Point Located by Polar Coordinates

The procedure for plotting a point located by polar coordinates from an OP (or a radar) is as follows:

a. Place the vertex of the range-deflection protractor against the pin in the OP location with the arc over the proper OP azimuth index. There will be only one OP azimuth index that can be used for polar plotting a given point. The index to be used is the one numbered with the multiple of 1000 that is next lower than the azimuth reported by the observer.

b. Orient the range-deflection protractor so that the azimuth on the index used added to the value read from the arc opposite the index is equal to the azimuth reported. The left edge of the arm will then be on the azimuth reported from the observation post.

c. Place a pin along the left edge of the arm at the reported distance (in meters) from the observation post.

Example: A target at an azimuth of 1,960 mils and a distance of 10,700 meters from 01 is to be plotted. Place the vertex of the range-deflection protractor against the pin in 01. Rotate the RDP until 960 on the arc is directly over the index marked 01AZ1000. Without moving the RDP, place a pin along the left edge of the arm at 10,700 meters from 01. The pin marks the location of the target.

16-19. Target Grid

a. General. The target grid is a device used for converting, by plotting, the observer's target locations and corrections with respect to the OT (observer-target) line (or some other line of known direction) to target locations and corrections with respect to the GT (gun-target) line. A target grid is operated in conjunction with each of the charts in the battalion to plot the observer's shift from a known point and his subsequent

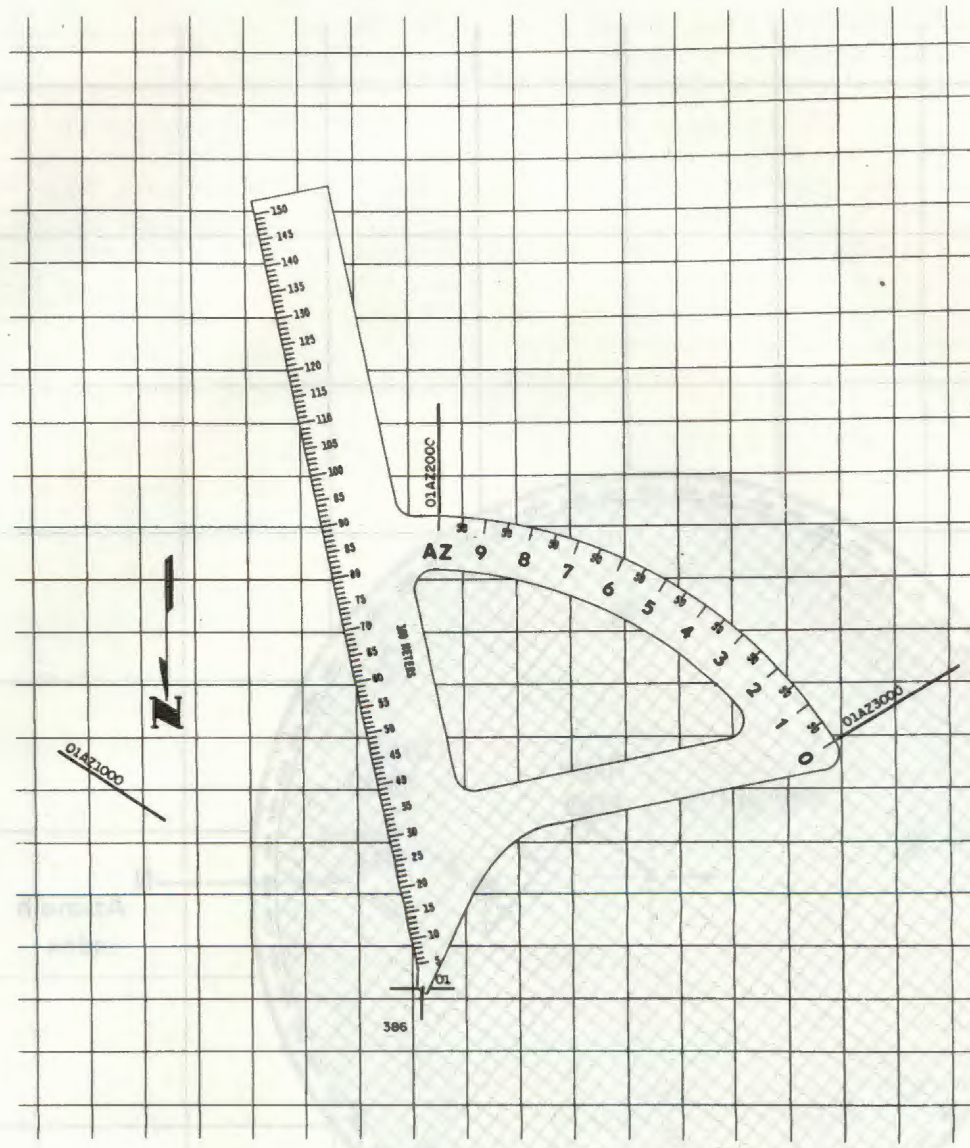


Figure 16–6. Range-deflection protractor and chart prepared for Polar-plotting.

corrections, and to measure rough angles. An arrow extends across the target grid, with the point of the arrow at the 0 mark of the azimuth circle. This arrow 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 mil graduation is numbered. The azimuth scale is numbered in a counterclockwise direction because the grid is rotated and the index is stationary. 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 with a scale of 1:25,000, the smallest graduation of the target grid represents a distance of 100 meters (fig 16–7).

b. Positioning the Target Grid. The chart operator places the center of the target grid over a point in the target area. This point may be the initial plotted location of the target to be adjusted on, a registration point, a meteorological checkpoint, a previously fired target, or an arbitrarily selected point, such as a grid intersection. If the chart operator selects a point other than the target to be plotted, he must insure that both the selected point and the target fall beneath the target grid. If subsequent corrections cause the target to plot off the target grid, the chart operator moves the target grid to a suitable new position and reorients it on the same azimuth given in the call for fire.

c. Orienting the Target Grid. To use the target

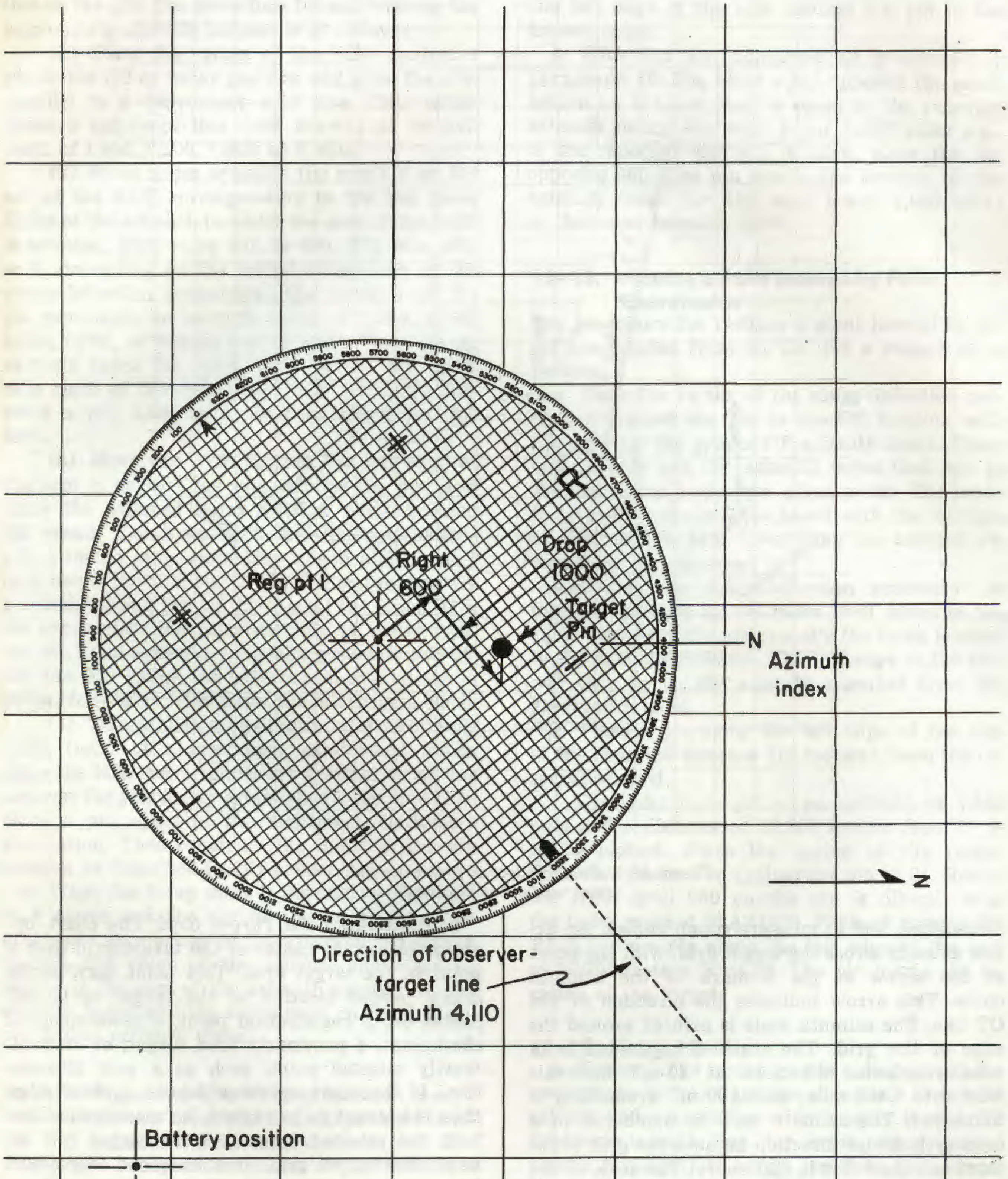


Figure 16–7. Plotting a target with the target grid by shift from a known point.

grid for plotting a shift from a known point or for plotting the observer's subsequent corrections, the chart operator constructs a north index on the chart at the edge of the target grid. He places the center of the target grid over the known point or target location and rotates it until the arrow (or a line on the target grid parallel to the arrow) is parallel to a north-south grid line and the arrowhead is pointing north. The chart operator constructs a permanent north index if the chart is being prepared to plot a shift from a known point. He draws the index at 0 azimuth on the chart 1 inch above and 1 inch below the edge of the target grid and marks the index "N" to prevent its being confused with other indexes on the chart. If subsequent corrections are to be plotted, the chart operator will not construct a permanent north index. A pin set out at 0 azimuth in the same manner as described above is sufficient since the initial target location is usually only transitory. The chart operator orients the target grid for both a shift from a known point and for subsequent corrections by rotating it until the figure opposite the north index is the same as the OT direction announced by the observer. This operation places the arrow and all lines parallel to it on the same direction as the OT line (fig 16–7).

d. Procedure to Correct a Misoriented Target Grid. If the observer sends a direction that is in error, the resulting error in orientation of the target grid should be corrected when it is large enough to cause the observer difficulty in adjusting. This procedure should be used only if the FDC is sure the observer is using the observer target line and not an arbitrary direction for adjusting.

(1) In figure 16–8, the observer's first correction is ADD 400. The chart operator moves the target pin to a point equivalent to 400 meters up the OT line, and a round is fired with the data obtained.

(2) The observer's next correction of RIGHT 200 indicates that the reported direction is in error. The chart operator moves the target pin to a point equivalent to 200 meters right of its last location and notes the position of the constructed line shot.

(3) While a round is being fired with these data, the chart operator rotates the target grid until the arrow is parallel to the line formed by the previous line shot and the constructed line shot. When the next observer correction is received, the chart operator moves the target pin from the chart location of the last round fired.

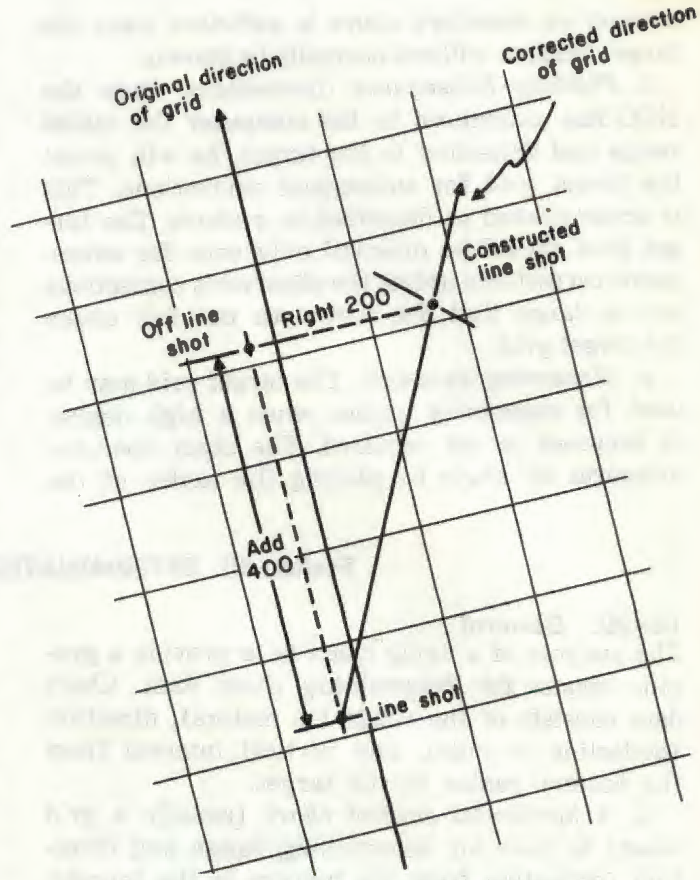


Figure 16–8. Correcting a misorientation of the target grid.

e. Plotting a Target by Shift From a Known Point.

(1) To use the target grid for plotting a target by the shift from a known point method, a north index must have been constructed for the known point. To construct the north index, the chart operator places the center of the target grid over the known point and rotates the target grid so that the arrow and all lines parallel to the arrow are parallel to the north-south grid lines on the firing chart. He draws the index on the chart, at 0 azimuth, extending 1 inch above and 1 inch below the edge of the target grid and labels it "N" to prevent its being confused with other indexes on the chart. The chart operator orients the target grid by rotating it until the azimuth reading opposite the north index is the same as the OT direction announced by the observer. This operation places the arrow and all lines parallel to it on the same direction as the OT line (fig 16–7).

(2) To use the target grid when targets are located by any means other than a shift from a known point, a north index need not be constructed. A pin set out at 0 azimuth in the same

manner as described above is sufficient since the target location will not normally be known.

f. Plotting Subsequent Corrections. Once the HCO has announced to the computer the initial range and deflection to the target, he will orient the target grid for subsequent corrections. This is accomplished as described in *c* above. The target grid should be oriented only once for subsequent corrections unless the observer's corrections are so large that the plot does not fall under the target grid.

g. Measuring an Angle. The target grid may be used for measuring angles when a high degree of accuracy is not required. The chart operator measures an angle by placing the center of the target grid over the apex of the angle to be measured and the 0 of the azimuth circle over the right side of the angle. He then reads the size of the angle at the point on the azimuth circle that is intersected by the left side of the angle. See paragraph 18–11 for a discussion on determination of angle T.

h. Marking the Target Grid. For convenience in plotting the chart the operator may mark the target with a plus sign in the first and fourth quadrants, a minus sign in the second and third quadrants, an R to the right of the arrow near 4800, and an L to the left of the arrow near 1600 (fig 16–7).

Section III. DETERMINATION OF CHART DATA

16–20. General

The purpose of a firing chart is to provide a graphic means for determining chart data. Chart data consists of the range (in meters), direction (deflection in mils), and vertical interval from the battery center to the target.

a. A horizontal control chart (usually a grid sheet) is used for determining range and direction (deflection from the battery to the target). The range-deflection protractor is the device used for measuring range and deflection.

b. A vertical control chart (usually a grid sheet supplemented by a 1:50,000 map) is used for determining the vertical interval between the battery and the target. It may also be used for determining range and direction.

16–21. Numbering the Range-Deflection Protractor for Deflection

Direction normally is measured and announced in terms of deflection. To facilitate the determination of deflection, number the mil scale on the arc of the range-deflection protractor as follows: Number the left graduation of the mil scale 0. Number the graduations in black to the right in 100-mil increments but omit the zeros representing hundreds,; for example, write the numbers 100, 200, and 300 as 1, 2, and 3, (fig 16–9). The last graduation on the right end of the arc is marked "DF" to differentiate from the azimuth scale.

16–22. Preparing the Firing Chart

Before the firing chart can be used for determining chart data, the battery center must be plotted, and the deflection indexes must be constructed. When each piece or each platoon center is plotted on the firing chart, tick marks and deflection indexes are identified by using the standard battery color code together with the number of the piece or platoon.

a. Deflection Index. The deflection index is used in conjunction with the range-deflection protractor for determining chart deflection (fig 16–10). This index is constructed as follows:

(1) With the vertex of the range-deflection protractor against the pin in the battery position, orient the left edge of the arm in the direction in which the battery is laid. If the battery is laid on a grid azimuth, plot the azimuth from the battery position. Using the procedure described in paragraph 16–16*b* (1) and (2), place a pin in the chart to represent the azimuth corresponding to the largest multiple of 1000 contained in the azimuth of fire. (Do not draw an index, since indexes are drawn only for OP's and radar positions.) Move the RDP until the last three digits of the azimuth of fire, as read from the azimuth scale of the RDP, are opposite the pin. The left edge of the RDP is now oriented on the direction in which the battery is laid. If the battery is laid on the registration point, place the left edge of the RDP against the pin in the registration point.

(2) Now place the pin in the chart at the 200-mil graduation. Move the RDP so that the left edge of the arm is against this pin, remove the pin, and draw a fine line (with a 6H pencil) on the chart along the range scale. Extend the line 1 inch above and 1 inch below the pinhole. Label this index with the appropriate battery designation and the number 3. The 3 represents 3,000 mils. (For referred deflections of 2400 and 2800 the pin would be placed at the 4 and 8, respective-

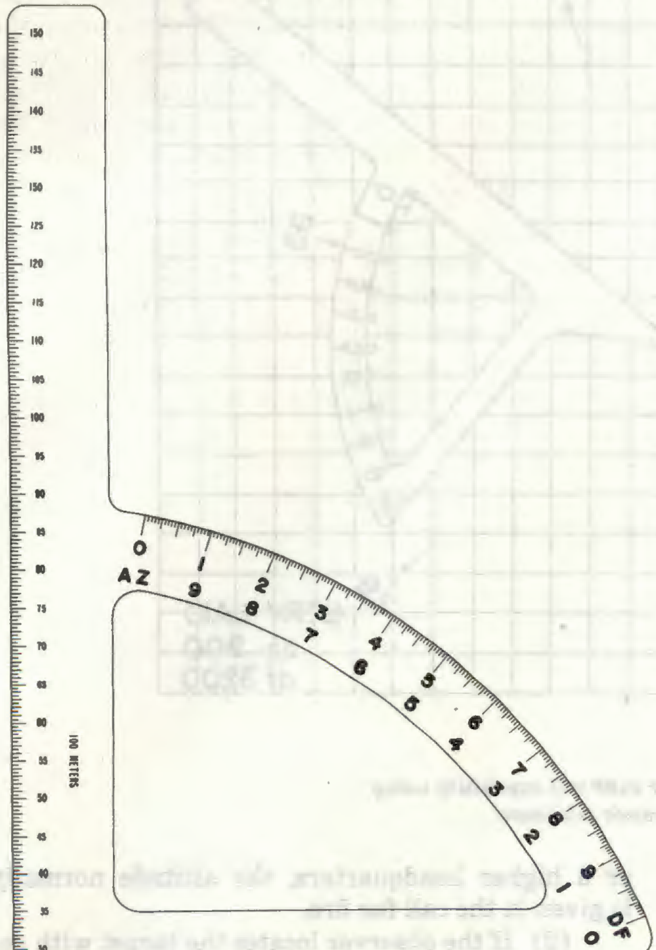


Figure 16–9. Range-deflection protractor numbered for measuring deflection and azimuth.

ly, and the index would be labeled 2 for 2,000 mils).

(3) Draw an arrowhead on the index pointing toward the battery at a point 1/8 inch beyond the pinhole. Use the appropriate battery color to mark the arrowhead, battery designation, and number.

b. Supplementary Deflection Indexes. Locate the right (left) supplementary index by placing the leftmost (rightmost) graduation on the arc of the range-deflection protractor over the deflection index and placing a pin opposite the rightmost (leftmost) graduation. Draw the index as described in *a*(2) and (3) above. For

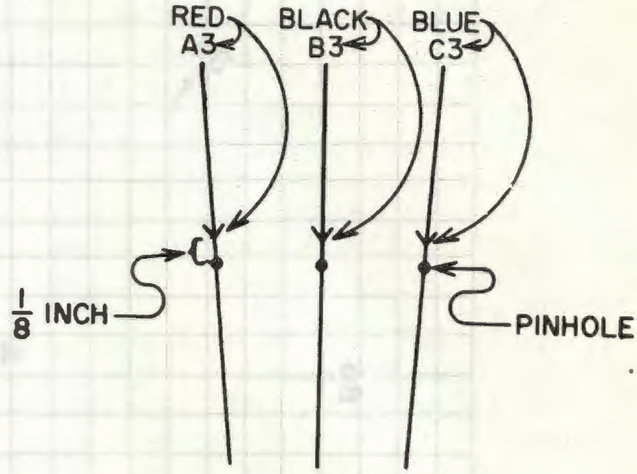


Figure 16–10. Deflection indexes.

weapons with referred deflection of 3200, label the left supplementary index with the battery designation and the number 4 and the right supplementary index with the battery designation and the number 2.

16–23. Preparing the Firing Chart for 6,400-Mil Capability

When firing in a 6,400-mil sector is required and the batteries are plotted in the center of the firing chart, the indexes are constructed and numbered as shown in figures 16–11 and 16–12.

a. Speed of adjustment is slowed somewhat by the large deflection shifts sometimes required in providing 6,400-mil coverage. The fire direction officer can minimize this loss of time caused by shifting trails by announcing a rough azimuth or a rough deflection immediately after the command BATTERY ADJUST. One method of determining and directing this rough orientation is as follows: The howitzer crew places azimuth stakes out in the firing battery for the cardinal directions. The HCO initially determines a rough azimuth by visual estimation or from a target grid placed face down over the battery position and oriented on grid north. The computer announces this azimuth in the special instructions. The howitzer crew, using the azimuth stakes, immediately begins pointing the weapon in the appropriate direction.

b. When indexing the firing chart for 6,400-mil capability, the chart operator may find that the RDP will measure a few mils more or less than 6,400 mils. When this is the case, he should apply a proportionate part of the error to each of the 1,000-mil deflection indexes. This will place

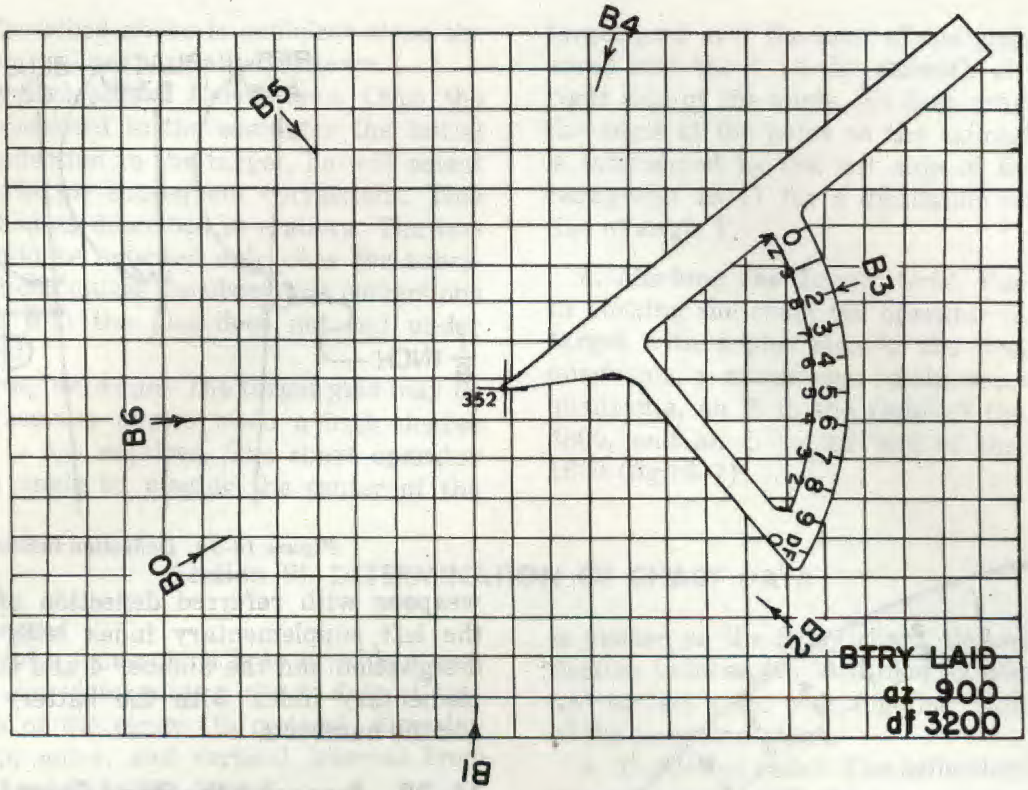


Figure 16-11. Firing chart for 6400 mil capability using the 0 to 6400 panoramic telescope.

a small error in each deflection index rather than place all the error at one point.

16-24. Determination of Chart Range and Deflection

Chart range and deflection are measured as follows:

a. Place the vertex of the range-deflection protractor against the pin in the battery position and the left edge of the arm against the pin in the target location.

b. Read the range, in meters, on the scale of the arm opposite site the pin in the target location. Measure and announce the range to the nearest 10 meters.

c. Read the chart deflection on the arc opposite the appropriate deflection index. Determine the value of this deflection by combining the reading on the arc at the deflection index with the 1,000-mil designation of that index.

16-25. Target Altitude and Vertical Interval

a. The altitude of the target may have been determined by survey, it may be given in the call for fire, or it may be determined by FDC personnel.

(1) If the call for fire is from another unit or a higher headquarters, the altitude normally is given in the call for fire.

(2) If the observer locates the target with reference to a known point, the vertical control operator determines the altitude of the target by applying the vertical shift to the altitude of the known point. If no vertical shift is specified, the altitude of the target is assumed to be the same as the altitude of the known point. (The map altitude is disregarded.) The observation post is the known point in a polar plot mission.

(3) If the observer locates the target by grid coordinates, the vertical control operator determines the altitude from a map.

b. The vertical control operator determines the vertical interval by subtracting the altitude of the battery from the altitude of the target. If the altitude of the target is greater than that of the battery, the sign of the vertical interval is plus. If the altitude of the target is less than that of the battery, the sign of the vertical interval is minus.

16-26. Charts

a. S3 Chart. If the S3 desires, a separate chart is constructed to show the fire capabilities and the locations of the firing batteries, foward

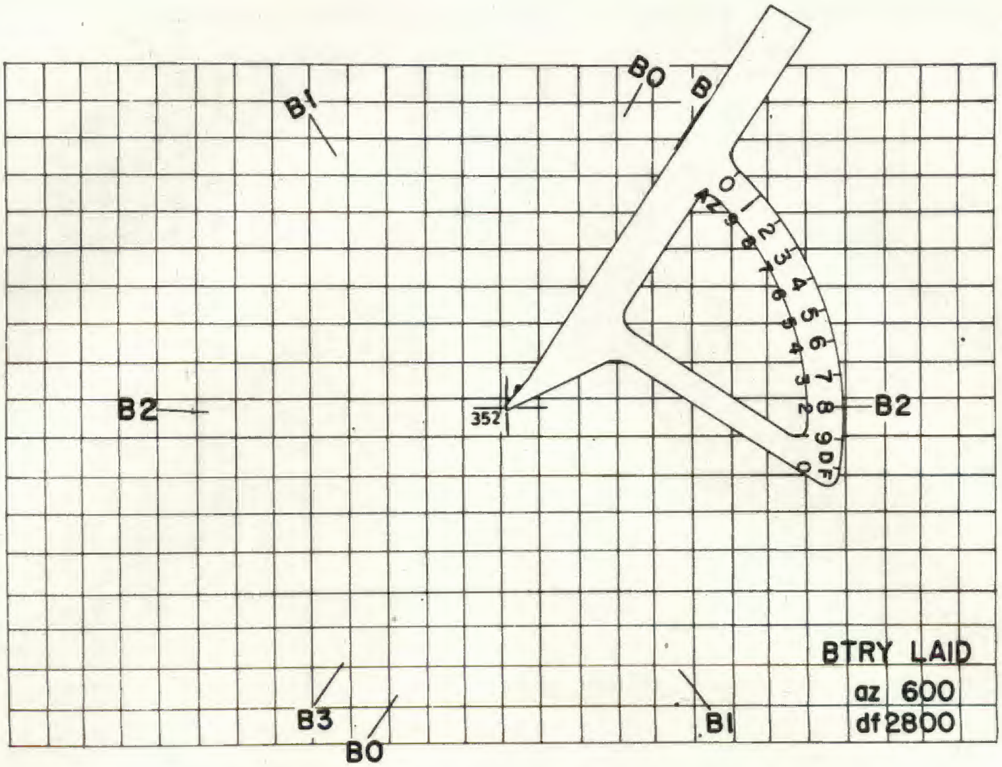


Figure 16-12. Firing chart for 6400 mil capability using the 0 to 3200 panoramic telescope.

troops, the no-fire line, registration points, and met checkpoints. This chart should be a map.

b. Horizontal Control Chart. The horizontal control chart is usually a grid sheet on which are plotted the locations of the firing batteries, surveyed observation posts, field artillery radars, registration points, met checkpoints, final protective fires, and targets as ordered by the S3 or requested by the observers. The horizontal control operator (HCO) maintains the horizontal control chart.

c. Vertical Control Chart. The vertical control chart is normally a grid sheet supplemented by a 1:50,000 map on which are plotted the locations of the firing batteries, surveyed observation posts, field artillery radars registration points, met checkpoints, final protective fires, and targets as ordered by the S3 or requested by the observers. The vertical control chart may be used during multiple missions to produce horizontal data. The vertical control operator (VCO) maintains the vertical control chart and the 1:50,000 map. He maintains the following overlays for use with the map:

(1) A fire capabilities overlay.

(2) A dead space overlay.

(3) A situation overlay on which are posted the no-fire line, friendly locations, routes of current and planned patrols, registration points, and recorded targets.

d. Report of Surveyed Data. For convenience, a sheet of paper on which are tabulated the grid coordinated and altitude of each firing battery and all critical points plotted on the chart should be attached to each chart. In addition, the azimuths on which the batteries are laid, the azimuth of the orienting lines, the orienting angles, and the reference direction for the surveyed observation posts should be recorded.

16-27. Equipment

a. Vertical Control Operator and Horizontal Control Operator. In addition to the more common equipment, such as plotting pin and colored pencils, each chart operator will have a coordinate scale and a range deflection protractor. The vertical control operator will also have a graphical site table for each caliber of weapon for which he must compute site.

b. Computer. Each computer will have a graphical firing table and a tabular firing table for the caliber and type of weapon for which he is computing.

CHAPTER 17

FIRING DATA

17-1. General

The data determined from the firing chart must be converted to settings to be placed on the cannon and ammunition so that the projectile may hit the point to which the chart data have been measured. These data, called firing data, normally are computed in the fire direction center. Firing data consists of the charge, deflection, fuze setting (when applicable), and quadrant elevation.

17-2. Charge

For cannons that fire semifixed or separate-loading ammunition, the amount of propellant may be varied. The propellant is packaged in increments, and the amount to be used is expressed in increments as, for example, CHARGE 5. Charge 5 contains increments 1 through 5. The selection of the charge is discussed in paragraph 18-5*c* (7).

17-3. Deflection

The deflection to be fired is termed the piece deflection. The computer determines the piece deflection by applying, according to the LARS rule, the total deflection correction determined from the deflection correction scale to the chart deflection announced by the horizontal control operator. The piece deflection is announced in the fire commands as DEFLECTION (so much).

17-4. Fuze Setting

a. When time fuze is to be fired, the computer will determine a fuze setting to be placed on the fuze to cause it to function at the desired point along the trajectory. The fuze setting is a function of elevation plus complementary angle of site. When the complementary angle of site is small, the fuze setting may be considered a function of elevation alone.

b. The fuze setting corresponding to the elevation (or elevation plus comp site) for fuze M564 may be determined from either the tabular or graphical firing tables.

c. The fuze setting is announced as TIME (so much).

17-5. Elevation

a. In order that an artillery piece, firing a given charge, may cause a projectile to achieve a prescribed range, the tube must be elevated from the horizontal to a vertical angle known as elevation. The elevation can be determined from the tabular or graphical firing tables.

b. In the tabular firing tables, range is listed every 100 meters and an elevation, valid under certain assumed standard conditions, is given for each listed range. Elevations corresponding to ranges between listed ranges are determined by interpolation.

c. On the graphical firing tables, elevation, valid under assumed standard conditions, is determined from the elevation scale. The hairline of the cursor is placed over the range in question and the elevation is read under the hairline on the elevation scale.

17-6. Site

a. If the target is at an altitude other than that of the artillery piece(s) to be fired, the trajectory may not pass through the target. This difference in altitude is a value known as the vertical interval (VI). The sign of the vertical interval depends on whether the target is above or below the weapon(s) (*e*, below).

b. The elevation from the firing tables compensates for the horizontal range (para 17-5*a*). The vertical interval must also be compensated for; otherwise, in the case of a positive VI, a round fired at the firing table elevation will fall short. The opposite is true of a negative vertical interval. The VI is compensated for by the computation of a vertical angle known as angle of site. The angle of site takes the algebraic sign of the vertical interval.

c. Another characteristic of the trajectory in the atmosphere is that of nonrigidity. Unless this is compensated for, a round fired from a tube raised to an angle the sum of elevation plus angle of site will not strike the target. The value of the angle which compensates for nonrigidity of the trajectory is the complementary angle of site or comp site. The comp site will also compensate for the slant range. The comp site is a signed value. In low angle fire it has the same sign as the angle of site. In high angle fire it always has the opposite sign.

d. The algebraic sum of the angle of site and the comp site is that value known as site. Site is defined as the angle formed by the base of the trajectory and the line of site.

e. The vertical control operator determines site. He may determine site by use of the tabular firing tables (*f* below) or by use of the graphical site table (GST) (para 17–8). Normally, the preferred method, because of its speed and accuracy, is by use of the graphical site table. Regardless of the method used, he must first determine the vertical interval. He determines the vertical interval by subtracting the altitude of the battery from the altitude of the target. If the altitude of the target is greater than that of the battery, the sign of the vertical interval is plus. If the altitude of the target is less than that of the battery, the sign of the vertical interval is minus.

f. Once the vertical control operator has determined the vertical interval, he may determine site by individually determining its component parts, angle of site and comp site, and then algebraically adding them together.

(1) Angle of site is determined to the nearest 1/10 mil. For angles of site of 100 mils or less, the VCO uses the mil relation $\not{h} = W/R$, in which $\not{h}$ = angle of site, W = vertical interval, and R = chart range in thousands to the nearest 100 (e.g., range 4060 is expressed as 4.1). For angles of site greater than 100 mils, he uses the formula tangent of the angle of site equals the vertical interval divided by the chart range. The angle of site takes the sign of the vertical interval.

(2) Comp site is determined to the nearest one-tenth mil. The VCO extracts the appropriate comp site factor from table G of the firing tables. He multiplies the angle of site ((1) above) by the comp site factor. The comp site takes the same sign as the comp site factor.

(3) Site is the sum of the angle of site and comp site. Site is expressed to the nearest mil.

17–7. Graphical Site Table (GST)

The determination of site by use of angle of site and the comp site factor from the tabular firing tables is time consuming. Use of the graphical site table facilitates the computation of angle of site (vertical angle) or site. The GST can also be used for determining the vertical interval when the site or angle of site (vertical angle) and the range (distance) are known. The GST consists of a base, a slide, and a cursor (a piece of clear plastic with a vertical hairline through the center).

a. The base contains the D scale, which is identical with that of any slide rule. The D scale is the base scale of the GST and is used in all computations made with the GST. A complete FDC spotting table, except for the observer spotting column (*b* below), is printed on the base beneath the slide.

b. The slide contains the C scale (range), yard (YD) and meter (M) gagepoints, and the site-range scales. The observer spotting column of the FDC spotting table is printed at each end on both sides of the slide.

(1) The C scale, which is identical with that on any slide rule, can be read in meters and yards.

(2) The M and YD gagepoints may be used for converting yards to meters or for converting meters to yards. To convert yards to meters (meters to yards), place the M gagepoint (YD gagepoint) opposite the range in yards (meters) on the D scale. Opposite the YD gagepoint (M gagepoint), read the range in meters (yards).

(3) Two site-range scales are provided for each charge—one in black, marked "TAG" (target above gun), and one in red, marked "TBG" (target below gun). The site-range scales are used, along with the D scale in computing site or vertical interval. The site-range scales include the effect of comp site. This is reflected in the spacing of the 100-meter graduations on each site-range scale. The TAG and TBG scales differ by small amounts because the comp site factor for a minus angle of site differs from that for a plus angle of site.

c. The GST possesses certain limitations, which are printed in red on the back of the GST. These limitations must not be exceeded or an error greater than 1 mil may be introduced into the computations. A short explanation of its use and illustrative examples are also printed on the back of the GST.

17–8. Computations With the GST

The GST may be used for computing angles of site of 100 mils or less, for computing site, or for computing vertical interval when the angle of site (vertical angle) or site and the range (distance) are known.

a. Angles of site of 100 mils or less are determined by use of the mil relation and the C and D scales. The procedure is as follows: Move the hairline to the vertical interval in meters on the

D scale, set the range in thousands of meters under the hairline on the C scale, and read the angle of site on the D scale opposite the M gagepoint. The angle of site is determined to the nearest whole mil. Reading the value of the angle of site under the meter gagepoint refines the error in the mil relation (1.0186) that would be incurred by straight division and, therefore, produces a more accurate solution. Angles of site greater than 100 mils must be computed by use of the military slide rule and tangent function.

b. The procedure for determining site is as follows: Move the hairline to the vertical interval in meters on the D scale, set the range in meters under the hairline on the appropriate site-range scale for the selected charge, and read the site on the D scale opposite the M gagepoint. (Use the TAG scale if the vertical interval is positive; use the TBG scale if the vertical interval is negative.) Since the site-range scales are graduated every 100 meters, visual interpolation is usually necessary for setting off the range. If the range for the charge being fired is not inincluded on the GST, site must be determined from the firing tables as explained in paragraph 17–6*f*.

c. The procedure for determining vertical interval when the angle of site and the range are known is as follows: Set the M gagepoint over the angle of site on the D scale, set the range under the hairline on the C scale and read the vertical interval under the hairline on the D scale. The procedure for determining vertical interval when the site and the range are known is as follows: Set the M gagepoint over the site on the D scale, set the range under the hairline on the appropriate site-range scale, and read the vertical interval under the hairline on the D scale. The vertical interval takes the sign of the angle of site.

17–9. Quadrant Elevation

Quadrant elevation is the sum of elevation and site or the sum of the angle of site and the elevation corresponding to range plus complementary range. Quadrant elevation is announced as QUADRANT (so much).

17–10. Firing Tables

The current tabular firing tables for each cannon constitute the basic source of ballistic data for that cannon and, in most cases, the required data can be extracted from the tables. However, determination of data from the tabular firing tables is time consuming. Graphical firing tables (GFT) provide a simple means of quickly determining firing data. Graphical firing tables are used principally for determining elevations for ranges determined from the firing chart. Each table consists of one or more rules, and each rule consists of a base and a cursor. The construction of the rules depends on whether the GFT is for low-angle or high-angle fire. The high-angle GFT is described in paragraph 25–2. The low-angle GFT is described in paragraph 17–11.

17–11. Low-Angle Graphical Firing Table

The base of the GFT is 18 inches long and 3 1/2 inches wide. On each side of the base are a set of ballistic scales for a single charge (discussed in order from top to bottom in *a* through *g* below), gagepoints (*h*, *i*, and *j* below), and a fuze *k* line (*l* below).

a. Deflection Correction/Drift Scale. The deflection correction/drift (DEFL CORR/DRIFT) scale shows projectile drift in mils, printed in black. Drift is always to the right. Elevations at which drift changes are printed in red above the scale.

b. 100/R Scale. The 100/R scale gives the number of mils necessary to shift the point of burst laterally or vertically 100 meters for a given range. The numbers on the scale are printed in red.

c. Range Scale. The range scale is the basic scale and all other scales are plotted with reference to it. Range is expressed logarithmically in meters and varies for each charge. The range scale is developed to give as large a range spread as possible and still permit graduations large enough for accurate readings. Range is read to the nearest 10 meters.

d. Elevation Scale. The elevation (ELEV) scale is graduated in mils to show elevation; elevation increases from left to right and is read to the nearest 1 mil. The numbers on this scale are printed in black and red. The red numbers denote the elevations that are within range transfer limits for the one-plot GFT setting. For the one-plot GFT setting, the range to the registration point or met checkpoint must be between the leftmost and rightmost red elevation numbers.

e. Fuze Setting Scale. The fuze setting (FS) scale gives the fuze setting for the M564 fuze and is read to the nearest 0.1 increment.

f. Fork Scale. The fork scale shows the change in elevation necessary to move the mean point of impact 4 range probable errors. The numbers on this scale are printed in red.

g. Change to Fuze Setting for a 10-Meter Change in Height of Burst Scale. The change to fuze setting for a 10-meter change in height of burst (Δ FS/ Δ 10 MHOB) scale is graduated in 0.1 increments and is read to the nearest 0.01 increment. This scale indicates the amount of correction that must be applied to the M564 fuze setting to raise or lower the height of burst 10 meters at a given range.

h. Met Check Gagepoints. Above the fuze setting line are red triangular gagepoints. The apex of each triangle points to the quadrant elevation that, under standard conditions, results in the maximum ordinate of the trajectory passing through a whole line number of a met message. The ranges and quadrant elevations at the met check gagepoints are preferred for met plus VE computations.

i. Height of-Burst Probable Error Gagepoints. Above the fork scale on all GFT's (except that for charge 1) are two red triangular gagepoints. The gagepoint on the right indicates the range and fuze setting at which the probable error in height of burst is 15 meters. Large height-of-burst dispersion must be expected when time fuze is used with a particular charge at ranges exceeding that indicated by the right gagepoint. The gagepoint on the left indicates the range at which the probable error in height of burst for the next lower charge is 15 meters.

j. Range Probable Error Gagepoint. Above the change in fuze setting for a 10-meter change in height of burst scale is a black triangular gagepoint. This gagepoint indicates the range and elevation at which the range probable error is 25 meters. If the rule for a charge has no range probable error gagepoint shown, the range probable error does not reach 25 meters for that charge.

k. Range K Line. The range K line is a broken black line near the right edge of the rule. The angle made by the range K line with the scales geometrically portrays the predicted rate at which the range K varies with range. An elevation gageline drawn on the cursor parallel to the range K line will indicate elevations that vary at the same rate as does range K.

l. Fuze K Line. The fuze K line is a broken black line near the left edge of the rule. The angle made by the fuze K line with the scales geometrically portrays the predicted rate at which the fuze K varies with range. A time gageline drawn on the cursor parallel to the fuze K line will indicate fuze settings that vary at the same predicted rate as does fuze K.

17–12. Determining Data With the GFT

a. The procedure for determining the elevation and fuze setting with the graphical firing table when no corrections are known is as follows:

(1) Place the hairline over the measured chart range.

(2) Read the elevation under the hairline from the elevation scale.

(3) Read the fuze setting under the hairline from the fuze setting scale.

b. Corrections determined from registration are applied to the GFT as described in chapter 20.

CHAPTER 18

FIRE DIRECTION PROCEDURES

Section I. BATTALION FDC PROCEDURES

18–1. General

The fire direction procedures presented in this section are for battalion fire direction. For battery fire direction, they must be slightly altered to conform to battery FDC organization. However, the basic principles remain the same.

18–2. FDC Organization

The personnel of the fire direction center are assigned specific duties. To provide efficient fire control, FDC personnel perform their duties in a prescribed sequence and manner. The organization of the FDC and duties of FDC personnel are covered in chapter 15.

18–3. Recording the Call for Fire

a. Most calls for fire will reach the FDC from an observer. Missions coming to the battalion FDC by wire or radio are recorded and read back by a radio telephone operator (RTO). The radio-telephone operator insures that all members of the FDC are alerted to the mission by announcing FIRE MISSION.

b. All computers not actively engaged in another mission record the call for fire on DA Form 3622 (FDC Computer's Record). (DA Form 3622 is available through normal AG publication supply channels.)

18–4. Plotting the Target Location

When a call for fire is received, each chart operator not engaged in another fire mission immediately plots the location of the new target.

18–5. Fire Order

a. When a target is plotted, the S3 examines the target plot. He analyzes the target on the basis of its location relative to friendly forces, the no-fire line, the zones of fire, registration points and the factors listed in chapter 27. From his analysis, he decides whether the mission should be fired, and if so, how the target should be attacked.

b. If the mission is to be fired, the S3 issues the fire order, which informs the FDC of the manner in which the mission will be fired. The fire order consists of some or all of the elements in (1) through (12) in the sequence in which they are transmitted. Inapplicable elements are omitted.

Element	*When announced*	*Example*
(1) Battery(ies) to fire	Always	BATTALION.
(2) Adjusting battery	When applicable	BRAVO.
(3) Method of fire of adjusting battery	When different from that in the observer's request.	CENTER LEFT.
(4) Basis for corrections	When applicable	USE GFT.
(5) Distribution	When applicable	SHEAF, 50 METERS.
(6) Projectile	When different from that in observer's request.	SHELL WP.
(7) Ammunition lot and charge	When applicable	LOT TZ, CHARGE 5.
(8) Fuze	When different from that in the observer's request.	FUZE TIME IN EFFECT.
(9) Number of rounds	Always in area fire; never in precision fire.	5 ROUNDS.

Element	When announced	Example
(10) Range spread, lateral spread, or zone	When different from that in the observer's request.	RANGE SPREAD.
(11) Time of opening fire	When different from that in the observer's request.	AT MY COMMAND.
(12) Target number	Always	TARGET ALFA FOXTROT 7413.

c. The considerations affecting the elements of the fire order are explained in (1) through (12) below.

(1) *Batteries to fire.* The selection of the battery or batteries to fire for effect in a mission depends on—

(*a*) The number of batteries available.

(*b*) The size of the area to be covered and the accuracy of the location.

(*c*) The caliber and type of weapons and the number of weapons per battery.

(*d*) Whether or not surprise fire is possible.

(*e*) The importance of the target.

(*f*) The locations of batteries relative to each other and to the target.

(*g*) The type of fire desired (destruction, neutralization, harassing or interdiction).

(*h*) The battery with the most recent or the best corrections in the zone to be covered.

(*i*) The status of ammunition.

(*j*) The policies of the commander.

(2) *Adjusting battery.* For registration and for missions requiring fires of the battalion, it is usually better to use the midrange battery as the adjusting battery. If a battalion consists of different caliber weapons, the battery with the smallest caliber weapons is normally chosen as the adjusting battery in an area mission.

(3) *Method of fire of adjusting battery.* Unless the observer requests a different method of fire, simultaneous fire by the center platoon is used during the adjustment.

(4) *Basic for corrections.* FADAC is the primary means of determining firing data. If firing data are to be determined graphically, the S3 will announce USE GFT as the basis for corrections. Omission of this element of the fire order indicates that FADAC is to be used.

(5) *Distribution.* When the S3 desires or the observer has requested a pattern of bursts other than that obtained from a parallel sheaf, the fire order must include a command for distribution. When special corrections are desired, the S3 commands SPECIAL CORRECTIONS followed by a description of the sheaf desired; e.g., SPECIAL CORRECTIONS, COVERGED SHEAF. When the S3 wishes to adjust only the width of the sheaf by the rapid computation and application of a deflection difference, he indicates that wish by announcing the desired width of sheaf; e.g., SHEAF 100 METERS.

(6) *Projectile.* The projectile or combination of projectiles selected depends on the mission and the nature of the target. If neither the observer's call for fire nor the fire order specifies the projectiles to be fired, shell HE is used.

(7) *Ammunition lot and charge.*

(*a*) There can be an appreciable difference in the ballistic characteristics of different propellant lots of ammunition. Disregard of propellant lot numbers can seriously impair the accuracy of fire. Mixing propellant lots in a single observed fire mission can materially increase the dispersion pattern and can even invalidate an adjustment. Large propellant lots normally are reserved for registrations and subsequent transfers (observed and unobserved). Small propellant lots are expended on battery missions when adjustment is necessary. Accurate ammunition records, to include a record of lot numbers, must be maintained at section, battery, and battalion levels.

(*b*) For fixed and semifixed ammunition, the ammunition lot number pertains to an assembled projectile-propellant combination. For simplicity, the lot number may be coded; e.g., lot X. Letters at the beginning of the alphabet are used as prefixes of target numbers and should not be used to designate lots. This will prevent confusion in the fire order. For separate-loading ammunition, the lot number pertains to a specific projectile-propellant combination. The lot may be coded, for example, as lot XY, with X designating the projectile lot and Y designating the propellant lot. Segregation and coding of fuzes by lot number is necessary for time fuzes only.

(*c*) The mission nature of the target and terrain, ammunition available, type of fuze to be used, range, and effects sought govern the selection of the charge to be used.

(*d*) If high angle fire is to be used, the S3 will replace the charge selection with the phrase HIGH ANGLE. The adjusting battery computer will then select the charge.

(*e*) Each computer will have readily available a list of GFT settings showing the lot numbers and charges used. If FADAC is to be used to determine the firing data, only the lot number need be designated in the fire order unless the S3 specifically desires that a certain charge be fired. If the GFT is to be used, the S3 will specify the lot number and charge to insure that the computer selects the most current corrections.

(*f*) When a mission requiring adjustment is to be fired by only one battery, the lot number specified should be one that implements the battery commander's plans and policies with respect to expenditure of lots on hand; e.g., consume the smallest of the odd lots first.

(*g*) If the battalion is composed of different caliber batteries, the lot number and the charge, when announced, are announced for each battery; for example, BATTALION, ALFA, USE GFT: ALFA, LOT XRAY, CHARGE 5; BRAVO, LOT XRAY, CHARGE 5; CHARLIE, LOT XRAY, CHARGE 5, DELTA, LOT XRAY YANKEE, CHARGE 4.

(8) *Fuze.* The mission, description of target and terrain fuzes available, range, and effects sought govern the selection of the fuze to be used. The omission of fuze in the fire order indicates agreement with the observer's selection of fuze.

(9) *Number of Rounds.* The mission, the description of target, the batteries and ammunition available, and pertinent orders from higher headquarters govern the number of rounds to be fired in fire for effect. Each cannon within the element *battery(ies) to fire* ((1) above) will fire the number of rounds specified.

(10) *Range spread, lateral 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, lateral spread, or zone to be used. Normally, a battalion should not fire with a range spread greater than 1 C (100 meters) between batteries, because a greater spread will not give uniform coverage of the target area. When a zone is to be fired, the fire order should specify the zone in terms of mils and quadrants; e.g., ZONE 5 MILS 5 QUADRANTS. If three quadrants are to be fired, only the zone need be stated; e.g., ZONE 5 MILS.

(11) *Time of opening fire.* The mission, the description of the target, and the effect desired govern the selection of time of opening fire. The time of opening fire may be stated as TIME ON TARGET (TOT), AT MY COMMAND, or any specific time according to a prearranged schedule. Unless the observer has requested a time of opening fire, the omission of this element indicates that the batteries should fire when ready.

(12) *Target number.* Unless a number has been specified by higher headquarters, a number for each target is selected from the block of numbers assigned to the battalion. The battalion, division artillery, artillery group, or corps artillery, may assign a number to a target. This number is combined with a two-letter prefix to indicate the unit that assigned the target number. The FDC will keep readily available the list of target numbers used, in order to avoid duplication (FM 6-20).

d. By omitting an element of the call for fire, the observer is, in effect, requesting the standard for that item. For example, by omitting a request for fuze, the observer is requesting fuze quick in effect. When the S3 cannot fulfill the requirements of the call for fire because of ammunition shortages or policies of the commander or for other reasons, he so specifies in the fire order. For example, the following call for fire is received in the FDC: GRID 41423617, DIRECTION 1460, INFANTRY PLATOON IN OPEN, PLATOON LEFT, VT IN EFFECT, ADJUST FIRE. The S3 decides that fuze time must be used in this mission. He issues the following fire order: BATTALION, ALFA, USE GFT, LOT XRAY YANKEE, CHARGE 5, FUZE TIME IN EFFECT, 4 ROUNDS, TARGET ALFA FOXTROT 7401. On the basis of the call for fire and fire order, each of the batteries will fire battery 4 rounds at center range in fire for effect; Battery A will conduct the adjustment and will fire the center two pieces sequentially from left to right using shell HE and fuze quick. Corrections known for lot xray yankee, charge 5, will be used and each round will be fired by the battery when ready.

e. The standards for those elements of the fire order that have standards are as follows:

Element	*Standard*
Method of fire of adjusting battery	CENTER 1 ROUND.
Distribution	PARALLEL.
Projectile	SHELL HE.
Fuze	FUZE QUICK.

Element	Standard
Range spread or zone	CENTER RANGE.
Lateral spread	CENTER DEFLECTION.
Time of opening fire	WHEN READY.

18-6. Announcing and Recording the Fire Order

a. The fire order is announced to all personnel in the fire direction center. Each computer not actively engaged in another mission records the fire order on DA Form 3622, as shown in figure 18-1.

b. In area fire, the batteries to fire in effect (para 18-5*b*(1)), the adjusting battery (para 18-5*b*(2)), the number of rounds (para 18-5*b*(9)), and the target number (para 18-5*b*(12)) and any element(s) of the fire order that differs from the corresponding element(s) of the call for fire are transmitted to the observer. In the example in paragraph 18-5*d* BATTALION, ALFA, TIME IN EFFECT, 4 ROUNDS, TARGET ALFA FOXTROT 7401, would be sent to the observer. In precision fire, only the unit firing and the target number are sent to the observer; e.g., BRAVO, REGISTRATION POINT 1.

c. When DANGER CLOSE is included in the call for fire, the range probable error, in meters, will be included as the last element of the message to observer.

18-7. Determining, Recording, and Transmitting Preliminary Fire Commands

Immediately upon receiving a call for fire and the fire order, each computer determines, transmits to the battery, and records all fire commands except those determined from the chart and graphical equipment. For example, the call for fire GRID 41231234, DIRECTION 1430, VEHICLE PARK, ADJUST FIRE is received and the fire order BATTALION, BRAVO, USE GFT, LOT XRAY YANKEE, CHARGE 5, 4 ROUNDS, TARGET ALFA FOXTROT 7432 is given.

a. The adjusting battery computer records the call for fire and the fire order on DA Form 3622. From the call for fire and fire order, he determines the initial fire commands and records them on the form (fig 18-1).

(1) *Battery adjust.* The fire order indicates that the battalion will fire and Battery B will adjust.

(2) *Shell HE.* Omission of the type of projectile from both the call for fire and the fire order implies the use of shell HE.

(3) *Lot XY.* The fire order indicates the use of shell HE.

(3) *Lot XY.* The fire order indicates the use of lot XY.

(4) *Charge 5.* The fire order indicates the use of charge 5.

(5) *Fuze quick.* Omission of fuze from both the call for fire and the fire order implies the use of fuze quick.

(6) *Center 1 round.* Omission of the method of fire from both the call for fire and the fire order implies the use of simultaneous fire by the center platoon of the adjusting battery. Battery B was designated in the fire order to conduct the adjustment. The computer designates the center two pieces to fire one round during the adjustment.

(7) *Battery 4 rounds in effect.* The fire order specifies four rounds in effect.

b. The procedure for the nonadjusting batteries is the same as that for the adjusting battery (*a* above) except that the fire commands must include DO NOT LOAD: e.g., BATTERY 4 ROUNDS, DO NOT LOAD. The transmission of commands to nonadjusting batteries together with DO NOT LOAD permits preparation of the ammunition and laying the pieces in the approximate direction to the target to minimize the time required for preparing to fire when the command to fire for effect is received.

c. The computer transmits all fire commands to the firing battery in the proper sequence as they are determined.

18-8. Determining and Recording Chart Data

a. Initial chart data for all batteries to fire are determined by the horizontal control operator. The HCO announces range and deflection to each computer concerned by saying, for example, BRAVO, RANGE 6600, DEFLECTION 3213.

b. The data for the adjusting battery are announced first. The SOP should designate the sequence to be followed in announcing data for the nonadjusting batteries.

c. During the adjustment, data are determined and announced for the adjusting battery only. When fire for effect is called for, corrected chart data are announced for all batteries.

18-9. Determining and Announcing Site

a. Using the graphical site table, the vertical control operator computes the site for each battery to fire and records the computed site.

b. When each computer desires site, he requests it by saying, for example, SITE BRAVO. The VCO announces the site to each computer as requested by saying, for example, SITE BRAVO,

FDC COMPUTER'S RECORD

For use of this form, see FM 6-40; the proponent agency is TRADOC.

BATTERY	DATE	TIME RECEIVED	TIME COMPLETED	TGT
B	12 FEB	0800	0815	AF 7432

CALL FOR FIRE 44, FM, GRID 42113616, DIR 420, SNIPER FIRING FROM WOOD LINE, AF

FIRE ORDER:
UNIT(S) B MF ____
BASIS FOR CORR USE GFT
DISTR ____ SH ____
LOT XY CHG 5 FZ ____
2 RDS; SPREAD ____
TIME ____ TGT AF 7432

TOT DF CORR L3
DF 3210
RG 6600 EL 336
SI +5
341

100/R	20/R	∢ SI	△ FS	10m SI
15	3			

INITIAL FIRE COMMANDS

BTRY ADJUST	SP INSTR
SH HE	LOT XY
CHG 5	FZ Q
MF C ① BTRY ② IN EFF	
DF 3213	TI
QE 341	AMMO EXP ②

OBSERVER CORRECTIONS / SUBSEQUENT FIRE COMMANDS

MF SH FZ	DEV	RG	HOB	SH,CHG FZ,MF	CHART RG	CHART DF	CORR (L3)	DF FIRED	FS CORR	TI	HOB CORR	SI (+5)	EL	QE	AMMO EXP
	L30	+200			6790	3218	L3	3221				+5	350	355	④
		-100			6700	3214	L3	3217				+5	343	348	⑥
	R10	+50	FFE	BTRY ②	6750	3212	L3	3215				+5	347	352	⑱ Q
				EM, SNIPER NEUT, EST 1 CAS											

DATA FOR REPLOT

GRID	ALT	FZ	TGT

AMMUNITION

TYPE	HE	HE	GB	WB	M557	M564	M514		
LOT	X	T	Y	W					
ON HAND	681	435	677	599	824	608	424		
RECEIVED	100	150	100	100	100	100	50		
TOTAL	781	585	777	699	924	708	474		
EXPENDED	18	0	18	0	18	0	0		
REMAINING	763	585	759	699	906	708	474		

DA FORM 3622, 1 Jan 74 REPLACES DA FORM 3622, 1 AUG 70, WHICH IS OBSOLETE.

Figure 18–1. Recording chart data and fire commands (adjusting battery).

PLUS 5. The computer repeats SITE BRAVO, PLUS 5 to insure he has received the correct site.

18-10. Determining and Recording Fire Commands Based on Chart Data

a. After receiving the chart data, the computer determines and announces the following data:

(1) *Deflection.* The computer applies the total deflection correction (if any) determined from the deflection correction scale to the chart deflection and announces the total as DEFLECTION (so much). The total deflection correction remains constant throughout a low-angle mission.

(2) *Quadrant elevation.* The computer determines the elevation by placing the hairline of the GFT over the chart range and reading the elevation under the elevation gageline. If no elevation gageline has been constructed, he reads the elevation under the hairline. He then adds the site, determined by the VCO, to the elevation and announces the sum as QUADRANT (so much).

b. The computer records on the FDC Computer's Record (DA Form 3622) (fig 18-1 and 18-2) the chart data announced by the HCO, the site announced by the VCO, and the fire commands determined by the computer.

18-11. Measuring and Announcing the Angle T

a. If an adjustment is to be made, the HCO determines to the nearest 10 mils the size of the angle T based on the direction given in the call for fire. This operation is performed after the initial data have been read from the chart. The HCO may determine the size of the angle T by measuring or computing it.

b. The size of the angle T, to the nearest 100 mils, is always announced to the observer when it is 500 mils or greater. The size of the angle T may be requested by the observer at any time.

18-12. Procedure During Fire for Effect

a. When fire for effect is requested, the HCO determines and announces chart data for all batteries that are to fire.

b. The adjusting battery computer announces to the nonadjusting battery computers any change in fuze and the total correction to height of burst made during adjustment. For example, if in a fuze time mission the observer's total height-of-burst correction during adjustment was down 10 meters, the adjusting battery computer would announce TOTAL HOB CORRECTION, DOWN 10. If no change in fuze or correction to height of burst was made, the adjusting battery computer would announce CORRECTIONS, NONE.

c. All computers convert the chart data to firing data. Fire commands, including the method of fire specified in the fire order and the firing data are announced to the firing battery.

d. When a range spread or 1/2 range spread has been directed in the fire order, the batteries will fire at different ranges. All chart data will be determined at center range. Normally, the adjusting battery computer will determine firing data based on the chart data announced by the horizontal control operator. One nonadjusting battery will fire beyond center range, and the other will fire short of center range. One nonadjusting battery computer will add 50 meters or 100 meters, whichever is appropriate, to the chart range announced by the horizontal control operator. The other nonadjusting battery computer will subtract 50 meters or 100 meters, whichever is appropriate, from the chart range announced by the horizontal control operator. The nonadjusting battery computers determine firing data based on the modified chart range and the announced chart deflection. A procedure for a two battery mission should be established so that all personnel, including observers, will know whether the non-adjusting battery is to fire beyond or short of the adjusting battery.

e. Each battery fires for effect as soon as it is ready, except when delayed fire for effect has been requested by the observer. Delayed fire for effect may be used advantageously when the personnel or vehicles constituting the target are not at the adjusting point but their arrival there at is anticipated; for example, at a construction site, bridge, or crossroad. Time-on-target procedures (para 18-20) can be used in such a situation.

f. When the first rounds are fired, the firing battery reports SHOT to the fire direction center. The fire direction center transmits shot to the observer, who reads back SHOT. When the last battery to fire has reported ROUNDS COMPLETE, the fire direction center transmits ROUNDS COMPLETE to the observer and he acknowledges with ROUNDS COMPLETE.

g. When the observer sends END OF MISSION (EM) and the results of the mission, the fire direction center reads back and records the message.

h. Each battery computer records the observer's report and, on completion of the mission,

FDC COMPUTER'S RECORD

For use of this form, see FM 6-40; the proponent agency is TRADOC.

BATTERY	DATE	TIME RECEIVED	TIME COMPLETED	TGT
A	12 FEB	0800	0815	AF7432

CALL FOR FIRE 44 FM, GRID 43211234, DIR 1430, VEHICLE PARK, AF

FIRE ORDER:
UNIT(S) BN, B MF
BASIS FOR CORR USE GFT
DISTR SH
LOT XY CHG 5 FZ
4 RDS; SPREAD
TIME TGT AF7432

TOT DF CORR 0
DF 3005
RG 5950 EL 293
SI +7
300

100/R	20/R	∡ SI	△ FS	10m SI
17	3			

INITIAL FIRE COMMANDS

BTRY ADJUST	SP INSTR
SH HE	LOT XY
CHG 5	FZ Q
MF BTRY (4) DNL IN EFF	
DF 3005	TI
QE 300	AMMO EXP —

OBSERVER CORRECTIONS / SUBSEQUENT FIRE COMMANDS

MF SH FZ	DEV	RG	HOB	SH,CHG FZ,MF	CHART RG	CHART DF	CORR (0)	DF FIRED	FS CORR	TI	HOB CORR	SI (+7)	EL	QE	AMMO EXP
				BTRY (4)	6100	3013	0	3013				+7	302	309	(24) Q
				EM, VEHICLE PARK NEUT, EST 8 CAS											

DATA FOR REPLOT

GRID	ALT	FZ	TGT

AMMUNITION

TYPE	HE	HE	GB	WB	M557	M564	M514		
LOT	X	T	Y	W					
ON HAND	604	482	633	582	801	611	433		
RECEIVED	100	150	100	100	100	100	50		
TOTAL	704	632	733	682	901	711	483		
EXPENDED	24	0	24	0	24	0	0		
REMAINING	680	632	709	682	877	711	483		

DA FORM 3622, 1 Jan 74 REPLACES DA FORM 3622, 1 AUG 70, WHICH IS OBSOLETE.

Figure 18–2. Recording Chart Data and Fire Commands (Nonadjusting Battery).

announces to the battery END OF MISSION, TARGET (so-and-so). The recorder enters END OF MISSION, TARGET (so-and-so) on the Firing Battery Recorders Sheet (DA Form 3623) for future reference. At the completion of a mission, the battery computers, using DA Form 3622, and the recorder, using DA Form 3623, complete the ammunition record.

18–13. Multiple Fire Missions

a. Two fire missions can be processed in the battalion FDC simultaneously. All calls for fire received at the FDC are acknowledged and recorded. When a battalion fire mission is in progress and another mission is received, the mission is recorded by a second radiotelephone operator and is plotted by the vertical control operator so that the S3 can examine the target plot and reach a decision to fire. If the target is suitable for attack by a battery, the S3 should assign the mission to a battery FDC to be processed. Since only two fire missions (one per chart) can be conveniently processed concurrently in the battalion FDC, the S3 must make a decision when two or more requests (requiring more than one battery) are received in the fire direction center. The S3 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 call on an attached or reinforcing battery, he may request the fire through higher headquarters, or he may decide that the target is not sufficiently important to be attacked and treat the call for fire only as intelligence information and so inform the observer.

b. If a battalion adjust fire mission is in progress and the FDC receives a call for fire that requires the use of only one battery, the S3 may assign the new mission to one of the nonadjusting batteries at once. The S3 would order the selected battery to SUSPEND ON TARGET ALFA FOXTROT 7205, FIRE MISSION. The call for fire, which has already been recorded, would be repeated to the selected battery computer. A fire order for the mission would be announced. END OF MISSION followed by the new call for fire would be announced by the computer to the firing battery. If the battery should complete this mission before the mission of target ALFA FOXTROT 7205 is in fire-for-effect status, the S3 might order this battery to RESUME ON TARGET ALFA FOXTROT 7205.

18–14. Registration

Normally, the S3 supervises registrations. When directed to do so by the battalion FDC, a battery may conduct a registration. To insure uniform application of corrections, the officer who conducts the registration will immediately transmit the corrections to all batteries and to the battalion fire direction center. The corrections are not applied until the S3 so directs. Each computer maintains a record of current GFT settings and total deflection corrections.

18–15. Procedure for Time Fuze Fire

A 20-meter height of burst is a mean height suitable for all cannon artillery and will produce effective results without an excessive number of graze bursts or high airbursts because of the vertical probable error. When time fuze is being used and a fire command including DO NOT LOAD is received at the firing battery, the fuze is not cut until a method of fire that permits loading the weapon has been received. This procedure will preclude the setting of the fuze more than once if a different fuze setting is required when the final time is announced.

a. When time fuze is to be used in fire for effect, the adjustment is conducted with fuze quick. When the appropriate range bracket (normally 100 meters) is split or when a range correct spotting is obtained, the observer will request time fuze and conduct the adjustment of height of burst.

b. The computer determines the fuze setting for time fuze by placing the hairline of the GFT over the chart range and reading the fuze setting under the time gageline. If no time gageline has been constructed, he reads the fuze setting corresponding to the elevation to be fired. He announces the fuze setting as TIME (so much).

c. For the initial rounds of time fuze, the computer must compute an angle of site, based on a vertical interval of 20 meters and the initial GT (chart) range and add the angle of site to the site determined for the ground location. (Complementary angle of site for the increased vertical interval is insignificant and is ignored.) Determination of this angle of site is simplified by use of the 100/R scale on the GFT. The value of 100/R is a function of range and indicates the number of mils required to move the burst 100 meters vertically or laterally. The value of 100/R is determined at the initial chart range. Since, only a 20-meter height of burst is desired in time fire, only 0.2, or 1/5, of 100/R (20/R) is required. For example, when the range to the target is 6,000 meters, the 100/R factor is 17 mils. One-fifth, or 0.2, of 17 is 3.4 mils; thus, 3 mils must be added to the site to achieve a 20-meter height of burst. The computer combines the angle of site for the height of burst with the site announced by the VCO and the elevation to determine the quadrant elevation. He announces quadrant elevation as QUADRANT (so much).

d. When a height-of-burst correction is given by the observer, the computer converts the correction to a correction to fuze setting by determining, from the GFT, the change to fuze setting for a 10-meter change in height of burst and multiplying it by the number of 10-meter increments in the observer correction. For example, for charge 5 and a fuze setting of 17.5, the change to fuze setting for a 10-meter change in height of burst is 0.12. Assuming a height-of-burst correction of UP 40, the correction to fuze setting is 4 × 0.2 = 0.48, or −0.5. Applying −0.5 to 17.5, the computer determines a fuze setting to fire of 17.0. Assuming the observer's next correction to be DOWN 20, FIRE FOR EFFECT, the correction to fuze setting is 2 × 0.12 = 0.24 or +0.2. Applying this correction to the last fuze setting fired, 17.0, the computer determines the new time to be fired to be 17.2 (17.0 + 0.2). Height of burst corrections by the observer are announced to the nearest 5 meters. The change to fuze setting for a 10-meter change in height of burst is determined at the initial fuze setting. In the case of a battalion mass mission, the nonadjusting batteries determine FS at the final pin location. This procedure is the same as that used by the adjusting battery. When the adjusting battery computer announces total height of burst corrections (para 18–12*b*), the nonadjusting battery computers determine the fire for effect time by applying the proper number of FS increments to the fuze setting to the final pin location.

e. Because fuze quick is used during the adjustment, the initial fire commands to the adjusting battery will state, as part of the method of fire, the number of time-fuzed rounds to be used in fire for effect. Typical fire commands for an adjusting battery would be BATTERY ADJUST, SHELL HE, LOT XRAY YANKEE, CHARGE 5, FUZE QUICK, CENTER 1 ROUND, BATTERY 3 ROUNDS TIME IN EFFECT, DEFLECTION 3132, QUADRANT 345.

f. For purposes of refinement data or repeating fire for effect, the observer may desire to change the mean burst location. When this is the case the following procedures will apply:

(1) *Range and/or deviation.* If the observer sends a correction for range or deviation or if he sends corrections for both range and deviation, the HCO will plot the correction(s) and determine new chart data. The computer will determine new firing data and will apply to the new fuze setting the total fuze setting correction determined during the adjustment.

(2) *Height of burst.* If the observer sends a correction for height of burst only, the correction is applied to the total site by use of the 100/R factor, because a change in fuze setting will cause both a range change and a deviation change. (The amounts of the changes depend on the size of the angle T.)

(3) *Range and/or deviation and height of burst.* If the observer sends a correction for range or deviation and a correction for height of burst or if he sends corrections for range, deviation, and height of burst, the procedures outlined in (1) and (2) above apply.

18–16. Procedure using VT fuze

a. When VT fuze is used, as when time fuze is used, an additional angle of site must be added to the site determined for the ground location. The additional angle of site for VT fuze is determined in the same manner as that for time fuze (para 18–15*c*). Application of this additional angle of site compensates for the shortened range that would result if the fuze functioned on a trajectory determined for a ground impact location (fig 18–3). The heights of burst (and, thus, the ranges) obtained with VT fuzes vary in different types of terrain. If an unsatisfactory range results, the observer must make a range correction to bring the effect to the desired location. For future missions in the same area, a similar correction may be applied for fire for effect with VT fuze. There is no need to compensate for the shortened range in high-angle fire, since the descending branch of the trajectory is nearly vertical.

b. When VT fuze is to be used in fire for effect, adjustment is made with fuze quick in order to facilitate spotting. The fire commands to the adjusting battery include, as a part of the method of fire, the number of VT-fuzed rounds to be used in fire for effect in order to expedite the delivery of fire for effect. Typical fire commands for an adjusting battery would be BATTERY ADJUST, SHELL HE, LOT XRAY ZULU, CHARGE 5, FUZE QUICK, CENTER 1 ROUND, BATTERY 3 ROUNDS VT IN EFFECT, DEFLECTION 3359, QUADRANT 352.

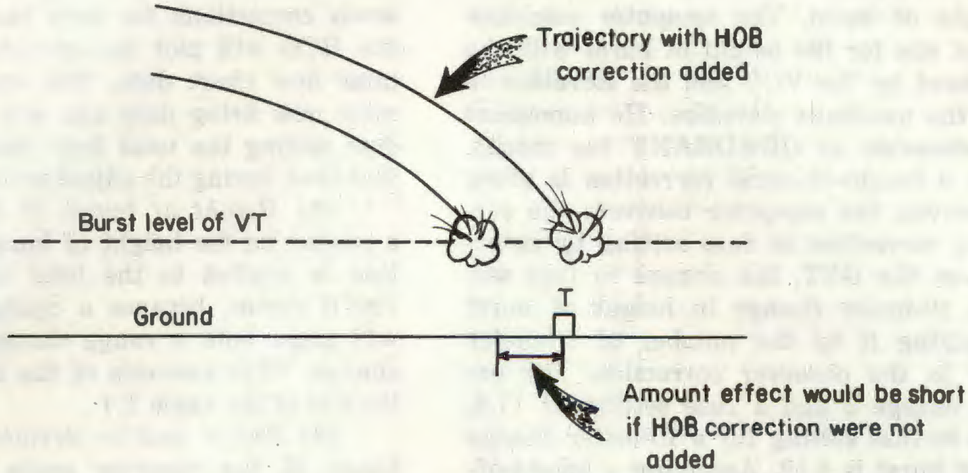


Figure 18-3. Result of height of burst correction to VT fuze effect.

c. The adjusting battery computer computes the height-of-burst correction (using 100/R at initial chart range) and applies it as part of site on entering fire for effect. The nonadjusting battery computers determine the height-of-burst correction and apply it in the initial commands, which are sent together with DO NOT LOAD as a part of the method of fire.

d. When VT fuzes are used and the source of data is tabular firing tables or graphical equipment that includes time-of-flight data, a fuze setting corresponding to the time of flight to the target is determined. The time of flight to the target is that corresponding to the elevation to be fired. If the time of flight to the target is not a whole number, the next lower whole number is used. For example, if the time of flight corresponding to the elevation to be fired is 24.2 seconds; the fuze setting for the VT fuze is 24 seconds. This is announced as TIME 24.0.

e. When VT fuzes are used and the sources of data is graphical equipment that does not include time-of-flight data, the fuze setting for the VT fuze is the fuze setting for MTSQ that corresponds to the elevation to be used. If this fuze setting is not a whole number, the next lower whole number is used.

f. Since fuze quick is used in adjustment, the fire commands for "FUZE VT" and "TIME" (so much)" are announced with fire for effect data for the adjusting battery. The command "FUZE VT" and "TIME (so much)" are included in the initial commands for nonadjusting batteries. However, the time they fire is that time corresponding to the elvation at the final pin location. If the observer reports that VT fuzes are bursting on impact, the fuze setting for the VT fuze is decreased by 1.0.

g. New types of VT fuzes are being developed that will produce a height of burst of approximately 5 meters. When firing these fuzes, it is not necessary to apply a correction to site to compensate for the shortened range as the amount of the shortened range is insignificant.

18-17. Procedure for Mission by Air Observer

a. The air observer, with no fixed location, normally omits direction in his call for fire. He usually adjusts with respect to the gun-target line. If grid coordinates are used initially to locate the target, the chart operator centers the target grid on this plot and orients the grid so that the 0 to 3200 line is parallel to the arm of the range-deflection protractor. The vertex of the range-deflection protractor is at the *adjusting battery* pin and the edge is against the pin at the initial target location. The chart operator plots the observer's first correction with the target grid oriented as described above, and determines the chart data. The target grid need not be reoriented after subsequent corrections unless there has been a change of 200 mils or more in direction of fire during the mission. If necessary, the chart operator may reorient the target grid (using the target pin location as a pivot point) by rotating the grid until the 0 to 3200 line is again parallel to the arm of the range-deflection protractor.

b. To plot a target location as a shift from a registration (known) point, the chart operator must center the target grid over the registration point and orient the 0 to 3200 line parallel to the center battery-registration point line. The chart operator plots the observer's shift and determines the chart data. He then reorients the target grid parallel to the *adjusting* battery-target line. Thereafter, the target grid need not be reoriented during the mission unless the direction of fire changes more than 200 mils.

c. The chart operator may also orient the target grid with respect to a spotting line, such as a railroad, or the direction announced by the observer. In this case, the chart operator centers the target grid over a predesignated point and orients the 0 to 3200 line parallel to the spotting line. The observer's corrections are with respect to the spotting line; so the target grid needs no reorientation.

d. When the observer's call for fire includes MARK CENTER OF SECTOR, the chart operator centers the target grid over the point selected as the center of sector and orients the grid so that the 0 to 3200 line is parallel to the adjusting battery-target line. After he has plotted the observer's shift from this point, he follows the procedures outlined in *b* above.

18–18. Procedure When Ground Observer is Moving Rapidly

a. Occasionally, a ground observer, especially one mounted in a tank, finds it necessary to adjust with respect to the gun-target line. The fire direction procedures involved are the same as those prescribed for the air observer (para 18–17*a* and *b*).

b. When an observer is moving rapidly while adjusting on the OT line, his OT direction may change considerably during a mission. If the observer does not change the direction in a subsequent correction, the FDC will change it, if necessary, by use of the procedure described in paragraph 16–19*d*.

18–19. Procedures When Engaging Moving Targets

a. Time is extremely important in the engagement of moving targets. The FDC should, as much as possible, prepare in advance for the attack of moving targets. For each likely intercept point (IP) received from the (firing officer) FO, a target number will be assigned. For each of its firing units the FDC (battalion and battery) should compute firing data to each IP. This data should be recorded to save time and should be updated immediately upon re-registration (chap 20), receipt of a new met message (chap 21), etc. Check rounds should be fired on as many IP's as possible. These points should be replotted (chap 20) if they are not surveyed locations. Check rounds should be fired for the observer to insure that firing data is correct.

b. The moving target mission will normally be fired as an "AT MY COMMAND, FIRE FOR EFFECT" mission. As standard procedure for moving target missions the FDC will include TF in the message to observer.

c. If the fire is not effective, the fire-for-effect must be adjusted. If the fires were accurate, the mission would continue on as before on a new IP. If the fires were inaccurate, a reasonably valid assumption (if the IP location was correct) may be made that conditions which caused the fire to miss the original IP will apply equally to the new IP, both in direction and amount. The procedure for repeating fire-for-effect would then essentially be a repetition of the initial fire-for-effect except that the correction to bring the fire to the first IP is applied to the grid of the new IP. The new IP is first plotted on the firing chart and then the observer corrections must be applied to this new point using the old OT direction. Once these corrections are applied, new firing data for each unit will be computed. Once the firing data has been computed, the new OT direction will be used.

18–20. Procedure for Time-on-Target Missions

a. The time-on-target (TOT) technique is a special technique of firing the pieces of several units so that the projectiles of all the units firing arrive at the target at the same time. This technique gains the full value of the element of surprise. The fire direction officer may set the time on target 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 IS 0905 ______ NOW). Time on target may also be ordered as TIME ON TARGET IS (so many) MINUTES FROM ______ NOW. Generally, 10 minutes advance notice will give all units sufficient time to prepare and execute a TOT mission.

b. In time-on-target missions, the target is plotted and firing data and fire commands are determined as usual except for the method of fire. The fire order includes AT MY COMMAND and TIME ON TARGET. The fire commands initially transmitted to the firing battery include DO NOT LOAD. At the appropriate time, the method of fire is changed to include AT MY COMMAND, TIME ON TARGET (so many) MINUTES FROM ______ NOW. Each battery executive officer coordinates the time of loading so that the rounds are in the chambers for the shortest possible time prior to firing and reports when the battery is ready. The appropriate time for the battery to load can be determined by subtracting the time of flight plus 30 seconds from the time on target. The time of flight should be sent to the executive officer if the fire commands do not include a fuze setting.

c. To coordinate the firing of all batteries, the battalion S3 initiates a count down approximately 10 seconds before the battery with the longest time of flight must fire. The count down is continued until all batteries have fired. Each battery is given the command FIRE when the battalion S3 announces the time in his counting which corresponds to the time of flight for the battery plus 2 seconds. This 2 seconds is added to the time of flight to allow for the interval 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, BATTALION, TARGET ALFA YANKEE 2101, INFANTRY BATTALION ASSEMBLY AREA, VT, 2 ROUNDS, TIME ON TARGET IS 10 MINUTES FROM ____ NOW.

The battalion S3 starts his stopwatch at the command NOW and begins his count by announcing, at the appropriate time, "TIME ON TARGET IS 60 SECONDS FROM NOW 50 ____ 40 ____ 30, 29, 28, 27, 26," etc., until all batteries have fired. The computer of a battery which has a time of flight of 13 seconds for this target would command fire at the announced count of 15.

18–21. Report on 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 48 ROUNDS ON 100 INFANTRY DIGGING IN AT 60053687, ESTIMATE 20 CASUALTIES, REMAINDER WITHDRAWING.

18–22. Records

a. The battery computers will maintain a temporary file of FDC Computer's Record (DA Form 3622) for possible future reference.

b. A blackboard or sheet of acetate may be used for posting current GFT settings, registration and met data, and any other information of immediate use to the fire direction personnel. A record of registration and met data as well as velocity errors developed with specific ammunition lots should be kept for reference.

c. The battalion chief computer and the battery computers should maintain a temporary file of records of precision fire.

d. The computer maintains a temporary file of data sheets for all prearranged fire sent to the battery.

e. The battery computers maintain a current record of all ammunition present in the battery. If necessary, the computer's record may be supplemented in order to make the record complete.

f. The battalion chief computer keeps a current master ammunition record that will be a consolidation of the ammunition records of the battery computers plus the amount of ammunition in the battalion train.

Section II. BATTERY FIRE DIRECTION

18–23. General

a. The battery executive officer is responsible for the control of the firing battery. This responsibility extends to the production of firing data and fire commands when the battery fire direction personnel are responsible for processing a mission. The executive officer exercises control of the firing battery area that he chooses to occupy.

b. The battery fire direction center is the installation within the firing battery where firing data is determined. The battery fire direction center is manned by personnel assigned to the firing battery headquarters.

c. A battery in a battalion that normally exercises technical fire direction will determine fire commands only when—

(1) Operating independently.

(2) Directed to do so by the S3.

d. Firing charts—one or two, the number being left to the discretion of the commander—are maintained at the battery. If only one chart is maintained, it should be a grid sheet supplemented by a 1:50,000 map.

18-24. Procedure at the Battery When the Battalion is Determining Fire Command

a. When fire commands are being produced at the battalion FDC, the commands are transmitted to the battery fire direction center by the computer at the battalion fire direction center. The executive officer is responsible for insuring that the fire commands are received, recorded, read back, and relayed to the pieces. Considering the state of training of his unit, the executive officer must organize his personnel so that the fire commands are relayed to the pieces rapidly and accurately. A wire bridge may connect the radiotelephone operator's telephone and the computer's telephone in the battery FDC, enabling the computer in the battalion FDC to send commands directly to the guns. If a wire bridge has not been established, or the radiotelephone operator is receiving commands over the radio, the radiotelephone operator reads back the commands to the battalion fire direction center. The computer in the battery FDC records the commands and relays them to the pieces. In any case, the recorder at the gun position records the commands and reads them back to the FDC so that the executive officer (XO) can hear the commands and thereby control the fire and the chiefs of sections can check their sections. The executive officer (or assistant executive officer or chief of firing battery) must supervise the operations of the computer and the recorder. The executive officer himself may transmit the fire commands to the pieces and may do so from any position in the firing battery area that affords him the best control of firing battery operations.

b. During lulls in firing, the battery chart operator(s) and computer receive, from the battalion FDC, data for the construction of the firing chart and current registration and met data. The GFT settings and deflection correction scales are kept current so that the battery can determine fire commands when required.

18-25. Procedures When the Battery is Producing Fire Commands

When the battery is required to produce fire commands, appropriate personnel of the firing battery headquarters constitute the FDC and assume the functions of their battalion counterparts; i.e., the executive officer (or whoever is in charge of the firing battery at the time) assumes the duties of the S3, the battery computer assumes the duties of the computer in the battalion FDC, and so forth.

Section III. COMMUNICATIONS

18-26. General

a. Separate radio and wire systems are installed to provide the communications necessary for fire direction. These systems should parallel each other so far as possible to provide an alternate means of communication if either system should fail. The radio and wire systems 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 can be considered the primary means of communication, since the presence of both types of communication permits a selection of the best means to meet any situation. Highest priority must be given to installing the wire lines between the battalion FDC and the fire direction centers in the firing batteries. For detailed instructions pertaining to wire and radio communications, see FM 6-10.

b. Maximum use will be made of fire direction personnel to set up the communications within the fire direction center. For example, wire personnel normally will lay wire to a terminal near the fire direction center. The FDC personnel are responsible for the communications from the terminal to and throughout the fire direction center. Radio operators will remote the radios. The switchboard operator will conduct the normal wire checks for those lines terminating in the switchboard.

18-27. 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, lack of time may preclude developing the wire system beyond installing the fire direction lines to the batteries. In this case, radio will carry traffic to fire support 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 expanded and improved until the unit displaces from the position. Wire circuits parallel the radio circuits. As the wire system is improved, radio traffic is reduced.

Section IV. SAMPLE MISSIONS

18-28. One Battery, Fuze Time

a. General. A 155-mm howitzer (M109) battalion has established OP's and a registration has been conducted. The GFT setting derived from the registration is GFT B: Charge 5, Lot XY, range 6900, elevation 380, time 24.4. The installation of wire lines to the OP's has not been completed.

b. Procedures During Mission. (As Prescribed by ACP 125). See figure 18-4.

FO radiotelephone operator:	ALWAYS CIVIL 18, THIS IS ALWAYS CIVIL 46, FIRE MISSION, OVER.
FDC radiotelephone operator [to alert FDC personnel]:	FIRE MISSION.
FDC radiotelephone operator:	ALWAYS CIVIL 46, THIS IS ALWAYS CIVIL 18, FIRE MISSION, OUT.
FO radiotelephone operator:	GRID 98336422, OVER.
FDC radiotelephone operator:	GRID 98336422, OUT.
FO radiotelephone operator:	DIRECTION 2140, OVER.
FDC radiotelephone operator:	DIRECTION 2140, OUT.
FO radiotelephone operator:	INFANTRY WEAPONS COMPANY DIGGING IN, TIME IN EFFECT, ADJUST FIRE, OVER.
FDC radiotelephone operator:	INFANTRY WEAPONS COMPANY DIGGING IN, TIME IN EFFECT, ADJUST FIRE, OUT.

The chart operators plot the target. The location of the target is checked against no-fire lines and the location of friendly troops. The S3 decides how to attack the target and issues the fire order.

S3:	BRAVO, USE GFT, LOT XRAY YANKEE, CHARGE 5, 5 ROUNDS, TARGET ALFA FOXTROT 7501.
FDC radiotelephone operator:	BRAVO, 5 ROUNDS, TARGET ALFA FOXTROT 7501, OVER.
FO radiotelephone operator:	BRAVO, 5 ROUNDS, TARGET ALFA FOXTROT 7501, OUT.
Battery B computer (to battery):	BATTERY ADJUST, SHELL HE, LOT XRAY YANKEE, CHARGE 5, FUZE QUICK, CENTER ONE ROUND, BATTERY 5 ROUNDS TIME IN EFFECT.
Battery B telephone operator:	BATTERY ADJUST, SHELL HE, LOT XRAY YANKEE, CHARGE 5, FUZE QUICK, CENTER ONE ROUND, BATTERY 5 ROUNDS TIME IN EFFECT.
HCO:	BRAVO RANGE 7240.
Battery B computer:	BRAVO RANGE 7240.
HCO:	DEFLECTION 3229.
Battery B computer:	DEFLECTION 3229.

Battery B computer determines and applies a deflection correction of L1.

Battery B computer (to battery):	DEFLECTION 3230.
Battery B telephone operator:	DEFLECTION 3230.
Battery B computer (to VCO):	SITE BRAVO?
VCO:	SITE BRAVO, PLUS 3.
Battery B computer:	SITE BRAVO, PLUS 3.

FDC COMPUTER'S RECORD

For use of this form, see FM 6-40; the proponent agency is TRADOC.

BATTERY	DATE	TIME RECEIVED	TIME COMPLETED	TGT
B	12 FEB	1025	1038	AF7501

CALL FOR FIRE 44 FM, GRID 9830 6420, DIR 2140, INF CO DIGGING IN, TIME IN EFF, AF

TOT DF CORR L1
DF 3229
RG 7240 EL 408
SI +3
411

100/R	20/R	∢ SI	△ FS	10m/SI
14	3		0.08	

INITIAL FIRE COMMANDS

BTRY ADJUST	SP INSTR
SH HE	LOT XY
CHG 5	FZ Q
MF C ① BTRY ⑤ TI IN EFF	
DF 3230	TI
QE 411	AMMO EXP ②

FIRE ORDER:
UNIT(S) B MF
BASIS FOR CORR USE GFT
DISTR SH
LOT XY CHG 5 FZ
5 RDS; SPREAD
TIME TGT

OBSERVER CORRECTIONS				SUBSEQUENT FIRE COMMANDS												
MF SH FZ	DEV	RG	HOB	SH,CHG FZ,MF	CHART RG	CHART DF	CORR (L1)	DF FIRED	FS CORR	TI	HOB CORR	SI (+3)	EL	QE	AMMO EXP	
		-200			7050	3219	L1	3220				+3	392	395	④	
	R30	+100			7140	3220	L1	3221				+3	400	403	⑥	Q
TI	L10	-50		FZ TI	7090	3219	L1	3220		25.3	+3	+6	395	401	②	
			D10 FFE	BTRY ⑤					+0.1	25.4				401	㉜	TI
				EM, EST 25 CAS, REMAINDER DISPERSED												

DATA FOR REPLOT

GRID	ALT	FZ	TGT

AMMUNITION

TYPE	HE	HE	GB	WB	M557	M564	M514			
LOT	X	T	Y	W						
ON HAND	287	450	450	287	350	337	96			
RECEIVED	—	—	—	—	—	—	—			
TOTAL	287	450	450	287	350	337	96			
EXPENDED	38	0	38	0	6	32	0			
REMAINING	249	450	412	287	344	305	96			

DA FORM 3622, 1 Jan 74 REPLACES DA FORM 3622, 1 AUG 70, WHICH IS OBSOLETE.

Figure 18–4. Completed computer's record fuze time mission.

Battery B computer adds the site, +3, to elevation 408 and announces the sum to the firing battery as quadrant.

Battery B computer (to battery):	QUADRANT 411.
Battery B telephone operator:	QUADRANT 411.

As time permits, Battery B computer will determine 100/R and 20/R and enter them on the computer's record for use during the adjustment of height of burst with time fuze.

Battery B telephone operator:	SHOT.
Battery B computer:	SHOT.
FDC radiotelephone operator:	SHOT, OVER.
FO radiotelephone operator:	SHOT, OUT . . . DROP 200, OVER.
FDC radiotelephone operator:	DROP 200, OUT.
HCO:	RANGE 7050.
Battery B computer:	RANGE 7050.
HCO:	DEFLECTION 3219.
Battery B computer:	DEFLECTION 3219.
Battery B computer (to battery):	DEFLECTION 3220.
Battery B telephone operator:	DEFLECTION 3220.
Battery B computer (to battery):	QUADRANT 395.
Battery B telephone operator:	QUADRANT 395 . . . SHOT.
Battery B computer:	SHOT.
FDC radiotelephone operator:	SHOT, OVER.
FO radiotelephone operator:	SHOT, OUT . . . RIGHT 30, ADD 100, OVER.
FDC radiotelephone operator:	RIGHT 30, ADD 100, OUT.
HCO:	RANGE 7140.
Battery B computer:	RANGE 7140.
HCO:	DEFLECTION 3220.
Battery B computer:	DEFLECTION 3220.
Battery B computer (to battery):	DEFLECTION 3221.
Battery B telephone operator:	DEFLECTION 3221.
Battery B computer (to battery):	QUADRANT 403.
Battery B telephone operator:	QUADRANT 403 . . . SHOT.
Battery B computer:	SHOT.
FDC radiotelephone operator:	SHOT, OVER.
FO radiotelephone operator:	SHOT, OUT . . . TIME, LEFT 10, DROP 50, OVER.
FDC radiotelephone operator:	TIME, LEFT 10, DROP 50, OUT.
Battery B computer (to battery):	FUZE TIME.
Battery B telephone operator:	FUZE TIME.
HCO:	RANGE 7090.
Battery B computer:	RANGE 7090.
HCO:	DEFLECTION 3219.
Battery B computer:	DEFLECTION 3219.

Battery B computer adds 20/R, site, and elevation together to determine the quadrant to fire (395 + (+3) + (+3) = 401). As soon as quadrant has been sent to the battery he will note and record in the appropriate block on the computer's record, the change to fuze setting for a 10-meter change in height of burst (0.08).

Battery B computer (to battery):	DEFLECTION 3220, TIME 25.8, QUADRANT 401.
Battery B telephone operator:	DEFLECTION 3220, TIME 25.8 QUADRANT 401. . . SHOT.
Battery B computer:	SHOT.
FDC radiotelephone operator:	SHOT, OVER.
FO radiotelephone operator:	SHOT, OUT . . . DOWN 10, FIRE FOR EFFECT, OVER.
FDC radiotelephone operator:	DOWN 10, FIRE FOR EFFECT, OUT.
Battery B computer (to battery):	BATTERY 5 ROUNDS.
Battery B telephone operator:	BATTERY 5 ROUNDS.

Battery B computer applies a correction of +0.1 to the last time fired.

Battery B computer:	TIME 25.9, QUADRANT 401.
Battery B telephone operator:	TIME 25.9, QUADRANT 401 . . . SHOT.
FDC radiotelephone operator:	SHOT, OVER.
FO radiotelephone operator:	SHOT, OUT.
Battery B telephone operator:	ROUNDS COMPLETE.
Battery B computer:	ROUNDS COMPLETE.
FDC radiotelephone operator:	ROUNDS COMPLETE, OVER.
FO radiotelephone operator:	ROUNDS COMPLETE, OUT . . . END OF MISSION, ESTIMATE 25 CASUALTIES, REMAINDER DISPERSED, OVER.
FDC radiotelephone operator:	END OF MISSION, ESTIMATE 25 CASUALTIES, REMAINDER DISPERSED, OUT.
Battery B computer (to battery):	END OF MISSION, TARGET ALFA FOXTROT 7501.
Battery B telephone operator:	END OF MISSION, TARGET ALFA FOXTROT 7501

18-29. Common Errors and Malpractices in the Fire Direction Center

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 an improper scale of the coordinate scale.

(2) Using the yard scale instead of the meter scale.

(3) Plotting the grid from the wrong grid line in the wrong direction, when the firing chart is so placed that north is toward the plotter.

(4) Reading azimuths 1,600 or 3,200 mils in error.

c. Common errors and malpractices pertaining to the range-deflection protractor, and the GFT are—

(1) Reading the wrong elevation or time gageline when more than one line is placed on a cursor.

(2) Failing to seat the vertex of the range-deflection protractor against the pin in the battery position when data are being determined or against the pin in an OP or radar position for polar plotting.

(3) Reading the data on the GFT from a position other than directly above the index and scale, thus introducing parallax errors.

(4) Reading deflections from the deflection index of the wrong battery.

(5) Misreading the deflection.

(6) Using the ballistic scale for the wrong charge.

(7) Reading drift instead of fork (F) or vice versa.

d. Common errors and malpractices with the target grid are—

(1) Miscounting in increments of 100 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 north index correctly. This error is especially common when direction of fire is other than north.

(4) Reversing the observer's target location; for example, plotting FROM REGISTRATION POINT, RIGHT 500 as 500 METERS LEFT (or over, or short) of the registration point.

CHAPTER 19
CONDUCT OF REGISTRATIONS

Section I. GENERAL

19–1. Introduction
If all conditions of materiel and weather were standard, firing a cannon at a particular elevation would cause the projectile to travel the distance shown in the firing table corresponding to that elevation. Similarly, if the proper deflection were 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 seldom exist simultaneously; thus, the projectile will rarely hit the target when fired with standard data for the chart range and deflection. Inaccuracies in survey and the firing chart and nonstandard conditions of material and the atmosphere may all contribute errors. The number of meters by which the projectile bursts over or short and right or left of the target is the combined effect of these errors. The magnitude of the cumulative errors and the corrections for those errors can be determined by registration.

19–2. Purpose of Registrations
The purpose of a registration is to determine the firing data (called adjusted data) that will place the mean burst location of rounds fired with that data at a point of known location. Registration data are used for determining correction which, when applied, will compensate for the cumulative errors caused by the factors listed in paragraph 19–1. Chapter 20 discusses the determination and application or registration corrections.

19–3. Types of Registrations
The types of registration are—

a. Precision Registration. Precision registration is a technique for determining, by adjustment, the firing data that will cause the mean point of impact of a group of rounds to occur at a point of known location, called a registration point.

b. High-Burst and Mean-Point-of-Impact Registrations. High-burst and mean-point-of-impact registrations are techniques for determining the mean burst location of a group of rounds fired with a single set of firing data.

Section II. PRECISION REGISTRATION

19–4. General
a. The precision registration is conducted on a clearly defined, accurately located registration point. The registration point must be a readily identifiable, permanent or semipermanent object or feature located close to the center of the target area or zone of action. If the target area is large, more than one registration point may be used. The location(s) of the registration point(s) must be plotted on the firing chart.

b. The registration is conducted with only one piece, normally the base piece.

c. During the registration, fire direction personnel compute and record data on DA Form 4198 (Record of Precision Fire). (DA Form 4198 is available through normal publication supply channels.)

d. A precision registration is conducted in two phases the adjustment phase and the fire-for-effect phase.

19–5. Adjustment Phase
a. The observer is normally directed to conduct a registration on a designated registration point. Occasionally, the observer may be required to select a registration point.

b. On receipt of the observer's call for fire, the horizontal control operator (HCO) determines and announces the chart range and deflection to the registration point. The vertical control operator (VCO) computes and announces site. The computer determining initial fire commands sends them to the battery. Fuze quick is used throughout the adjustment.

c. The HCO plots the observer's corrections, using the target grid and announces the chart data. The computer determines and announces the subsequent fire commands.

d. When the observer's correction is for range but not deviation, an observer deviation spotting of LINE is presumed at FDC. From this spotting an FDC deviation is determined and recorded. The FDC deflection spottings determined during the adjustment may be used during fire for effect to establish one limit of a deflection bracket.

e. The adjustment phase is ended and the fire-for-effect phase begun when any one of the following conditions exists:

(1) The observer splits the proper range bracket.

(2) A target hit occurs.

(3) A spotting of RANGE CORRECT is made by the observer.

19-6. Determination of Angle T

a. The angle T is the smaller angle formed at the target by the intersection of the gun-target line and the observer-target line.

b. At the beginning of a precision registration on a surveyed registration point, the HCO measures and announces the angle T to the nearest 10 mils. Normally, the announcement of the value of the angle T is made after the computer has sent the initial fire commands to the firing battery.

c. If the registration point is not accurately located (i.e., when an observed firing chart is used), the HCO determines the value of the angle T upon entering fire for effect.

d. If the target grid is centered over the registration point and oriented on the observer's direction, the HCO measures the angle T by placing the vertex of the range-deflection protractor against the battery pin and the left edge of the arm against the pin in the registration point. He determines the value of the angle T from the azimuth scale of the target grid between the point where the arm of the range-deflection protractor intersects the scale and 0 or 3200, whichever is appropriate.

e. The HCO may compute the angle T by comparing the azimuth from the observer to the registration point with the azimuth from the battery to the registration point.

Example: A call for fire has included an observer-target direction of 680 mils. The chart deflection to the target is 3463, the azimuth of lay is 1200, and the referred deflection is 3200. Deflection has increased from 3200 to 3463, or 263 mils, and, therefore, azimuth has decreased by the same amount (1200 − 263 = 937, or 940). The azimuth on which the weapon is pointing, or the gun-target direction is 940. Since the observer-target direction is 680, the angle T is 260 guns on the left (940 − 680 = 260).

19-7. Fire-For-Effect Phase

a. Fire for effect is begun upon completion of the adjustment phase. During fire for effect, the firing chart is not used. Firing data are computed from the spottings reported by the observer.

b. Fire for effect is conducted with fuze quick until the correct deflection and adjusted elevation have been obtained. When desired, a time registration is conducted with fuze time to determine the adjusted time (para 19-18 through 19-20).

19-8. Determination of FDC Spottings

The adjusted elevation and the correct deflection are determined with respect to the GT line. Observer spottings, which are made with respect to the OT line, must be converted to FDC spottings with respect to the GT line. The FDC spottings corresponding to a given observer spotting depend on the location of the observer with respect to the GT line (right or left) and the size of the angle T. Use of the FDC spotting table (fig 19-1) facilitates the determination of the FDC spottings.

19-9. Factor S

a. The factor S is the deflection change in mils between two rounds that are 100 meters apart on the OT line (fig 19-2). The value of the factor S depends on the range and the size of the angle T. A decrease in range will increase the factor S. An increase in the size of angle T will also increase the value of the factor S.

b. When the observer obtains a 100-meter bracket on the OT line, it is assumed that a 1 S deflection bracket exists. When the 100-meter bracket is split, the deflection read by the HCO should be within 1/2 S of the correct deflection.

c. The values of 1/2 S for all likely combinations of range and angle T have been computed and placed in the 1/2 S table (fig 19-3). The values of 1/2 S in the table are the computed values rounded to 2 or the nearest power of 2. The formula for the computation of 1/2 S is

$$\frac{S}{2} = \frac{50 \times \sin\angle T}{\text{rg in 1000's}}$$

d. The 1/2 S is determined as soon as the angle T for the mission has been determined.

19-10. Correct Deflection

a. Deflection is correct when one of the following conditions has been satisfied:

FDC SPOTTING — GUN ON LEFT OF OBSERVER (G, O)

OBSERVER SPOTTING	1-99m	100-499m	500-799m	800-1399m	1400-1600m	1601-1799m	1800-2399m	2400-2699m	2700-3099m	3100-3200m
?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 SPOTTING — GUN ON RIGHT OF OBSERVER (O, G)

OBSERVER SPOTTING	1-99m	100-499m	500-799m	800-1399m	1400-1600m	1601-1799m	1800-2399m	2400-2699m	2700-3099m	3100-3200m
?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 19–1. FDC spotting table.

(1) A target hit is obtained.

(2) A 2-mil deflection bracket is split.

(3) Deflection spottings of left and right are obtained from the same deflection setting.

(4) Deflection spottings of left and right are obtained from deflection settings 1 mil apart. (The last deflection is considered correct).

(5) A line shot is obtained when the observer is adjusting on the GT line.

b. The correct deflection is not necessarily the adjusted deflection (para 20–12).

19–11. Determination of the Correct Deflection

a. The correct deflection exists when one of the five conditions described in paragraph 19–10 exists. Following the rules in (1) through (5) below facilitates the determination of the correct deflection once fire for effect has been entered.

(1) Do not change deflection on a doubtful FDC-deflection spotting. There may be times when an excessive number of doubtful spottings, caused by such factors as a large angle T or excessive dispersion, may render determination of correct deflection difficult by use of the standard rules. Such situations are covered in *e* below.

(2) If not deflection bracket exists, move 1/2 S in the direction opposite the last definite deflection spotting.

(3) If a deflection bracket exists either split the bracket or move 1/2 S *toward the center of the bracket,* whichever is smaller.

(4) Always move from the last deflection fired.

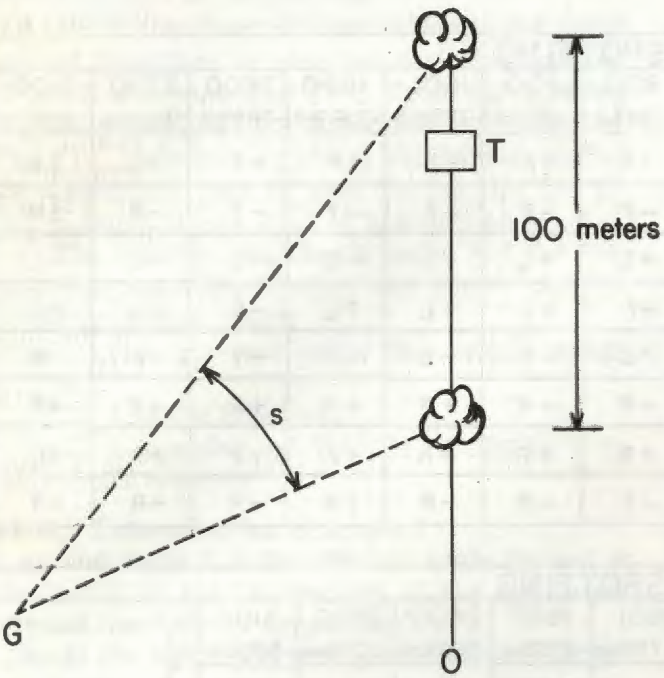


Figure 19-2. The Factor S

½ S TABLE

GT range in meters	Angle T in mils				
	0-99 3100-3200	100-499 2700-3099	500-799 2400-2699	800-1399 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	2	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 19-3. 1/2 S Table.

(5) Any FDC spotting from a line shot in the adjustment phase may be used to establish one end of the deflection bracket. The deflection spotting of the line shot thus obtained is determined by whether the guns are on the left or on the right of the observer.

b. Normally, the correct deflection can be determined prior to the determination of the adjusted elevation. However, if the correct deflection has not been determined prior to the determination of the adjusted elevation, fire for effect is continued at the adjusted quadrant elevation, and the observer is required to give range and deviation spottings in meters. After two successive FDC spottings of *doubtful* and based in information from the observer—

(1) The deflection may be considered correct.

(2) An arbitrary shift may be made. Frequently, an arbitrary shift will yield a definite FDC deflection spotting.

c. After an adjusted elevation, but not a correct deflection, has been obtained the center of a 4-mil deflection bracket may be accepted as correct when speed, not refined accuracy, is essential.

d. If a time registration is to be fired following completion of the impact phase, and the correct deflection has not yet been determined, the observer is instructed to spot graze bursts for range and deviation, since they may be used in determining the correct deflection. Time registration procedures are discussed in paragraph 19-19.

e. Frequently, the terrain and other factors, such as a large angle T, a small registration point, and wide dispersion, will present difficulties in the adjustment of deflection. In this instance, as in any other observed fire situation, the observer is usually the best qualified to take action. The observer may see more than he can convey in the normal spotting. The S3 must be prepared to ask for and rely on the observer's report and judgment.

19-12. Use of Fork

The fork is the change in elevation required to move the mean point of impact of a group of rounds a distance equal to 4 range probable errors. In a precision mission, the fork used is that corresponding to the first elevation fired in the fire-for-effect phase. If the value of the fork is an odd number, it is increased to the next higher even value to facilitate splitting. (The correct value of the fork must be used in computation of the adjusted elevation.)

19-13. Elevation in Fire for Effect

a. The observer may enter fire for effect in a precision registration when one of the three situations listed in paragraph 19-5*e* exists. Target hit contingencies with respect to elevation are covered in paragraph 19-16.

b. If the observer entered fire for effect in the registration by splitting the appropriate bracket or from a RANGE CORRECT spotting, the procedures for determining the adjusted elevation are:

(1) Obtain a definite FDC range spotting

in fire for effect. A definite FDC range spotting is either an OVER or a SHORT.

(2) Move in increments of a *full even* fork until a spotting in the opposite sense is obtained.

(3) Split the bracket and obtain three definite FDC range spottings.

(4) Determine the preponderance, move 1/2 fork away from the preponderance, and obtain two more definite FDC spottings at that quadrant. These two spottings will be obtained at the same quadrant as one of those which established the fork bracket.

(5) Consider the following six rounds in the computation of the adjusted quadrant elevation; the three rounds that yielded definite spottings at the center of the fork bracket, the last two rounds that yielded definite spottings, and the round that established the even fork bracket and was fired at the same quadrant elevation as the last two rounds.

19-14. Computation of Adjusted Elevation

a. The computation of the adjusted elevation is based on the assumption that the six rounds considered fell in a normal dispersion pattern. The location of the mean point of impact of the six rounds with respect to the registration point may be computed on the basis of the laws of probability and the size of the range probable error. A change in elevation that will place the mean point of impact at the registration point is computed.

b. The following formula is used for determining the elevation change to move the mean point of impact to the registration point:

$$\text{Elevation change} = \frac{\text{difference in number of overs and shorts} \times \text{fork.}}{2 \times \text{number or rounds considered}}$$

Example: The six FDC range spottings considered during fire for effect are four SHORT and two OVER. The fork is 6. The elevation change $= \frac{2}{(2 \times 6)} \times 6 = 1.0$ mil. The sign of the change is plus if the preponderance is SHORT and minus if the preponderance is OVER.

c. The elevation change is algebraically added to the mean of the quadrant elevations used during fire for effect, and the result is expressed to the nearest mil. Site is then algebraically subtracted from the adjusted quadrant elevation. The result is the adjusted elevation.

Example: During fire for effect, three spottings were determined at quadrant 316 and three at 313. The elevation change is algebraically added to the mean quadrant 314.5 $\frac{(316 + 313)}{2}$. The adjusted quadrant is 316 (314.5 + 1.0 = 315.5 or 316). Site is +3 mils. The adjustable elevation is 313.

19-15. Example of a Registration

Figure 19-4 is an example of the record of a registration with fuze quick. The registration was conducted with a 155-mm howitzer (M109), firing charge 4. There is no base piece displacement for range.

a. Comment 1. After the initial round has been fired, the HCO measures and announces the angle T as ANGLE T 430, GUNS ON THE LEFT. The computer then enters the 1/2 S table at the appropriate chart range (to the nearest listed value, 5000) and the appropriate angle T (100-499) and determines the 1/2 S to be 2 mils.

b. Comment 2. Firing data for rounds 2 through 4 are based on the HCO's plotting of the observer's corrections.

c. Comment 3. The observer's correction of ADD 100 from round 2 indicates that his spotting must have been SHORT LINE. From this observer spotting, the computer determines and records an FDC deflection spotting of RIGHT for round 2.

d. Comment 4. The computer determines the value of the fork at the first elevation in fire for effect—308 mils (QE 314—site + 6 = el 308). Fork is 4, and 1/2 fork is 2.

e. Comment 5. The fourth round (first round in fire for effect) yields a definite FDC range spotting of OVER; therefore, the fifth round is fired at a quadrant elevation 4 mils lower (1 even fork). This round yields a SHORT, which established the even fork bracket on the gun-target line. The bracket is split and rounds 6, 7, and 8 yield a preponderance of SHORT (−, +, −). The quadrant elevation is changed 1/2 fork opposite the preponderance toward the OVER, at quadrant elevation 314. Rounds 9 and 10 each yield a spotting of OVER. The computer determines the adjusted quadrant elevation from the three rounds fired at quadrant elevation 312 and the three rounds fired at quadrant elevation 314.

f. Comment 6. During fire for effect, the deflection 3216 is not changed until a definite FDC deflection spotting is obtained. The computer compares the FDC deflection spotting of RIGHT from round 6 with that obtained from round 2. Since no deflection bracket exists, the computer changes the deflection by 1/2 S in the direction opposite the last spotting obtained, and determines a deflection of 3218. Round 7 results in an FDC deflection spotting of LEFT. At this point, the re-

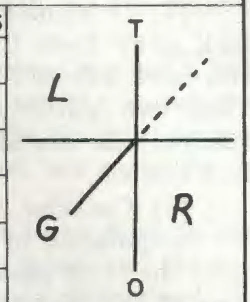
RECORD OF PRECISION FIRE

For use of this form, see FM 6-40; proponent agency is TRADOC.

BATTERY	DATE/TIME	OBSERVER	REG PT / TGT
B	10 JUN 0800	44	✓

GFT SETTING	TOTAL DF CORR
GFT: B CHG 4 LOT RS RG 5090 EL 306 TI —	

CHART DATA				INITIAL FIRE COMMANDS	
DF 3215	TOT DF CORR 0	BP DISP 0		BP	ADJUST
RG 5090	EL 313	ACH RG		SH HE	LOT RS
ADJUSTED DATA	SI +6	KN FZ CORR		CHG 4	FZ Q
DF 3217	½S= 2	∡SI		MF BP ①	
EL 306	F= 4	10m SI FAC		DF 3215	
TIME —	½F= 2	ANGLE T 430		QE 319	



RD NO	LOT, FZ, MF	CHART RG	CHART DF	CORR (◯)	DF FIRED	TIME FIRED	EL (+6)	QE	OBSR SPOTTING OR CORRECTION	FDC SPOTTING RG	FDC SPOTTING DF
1		5090	3215	0	3215		313	319	L10 -200		
2		4910	3199	0	3199		298	304	+100		R
3		4990	3208	0	3208		305	311	L20+50 FFE		
4		5030	3216	0	3216		308	314	+R	+	?
5					(3216)			310	-L	-	?
6					(3216)			312	-R	-	R
7					3218			312	+LN	+	L
8					(3217)			312	-L	-	CORR
9								314	+R	+	}
10								314	?R	+	
11								EM			
12	Δ EL =	2/2XC ×4	= -0.7								
13	MN QE	=	313.0				CORRECT	DF	3217		
14	+Δ EL		+(-0.7)				CORR FOR BP	DISP	0		
15	ADJ QE		312.3 =		312		ADJ	DF	3217		
16	-SITE				-(+6)						
17	ADJ EL				306						
18											
19											
20											
21											
22											
23											
24											

DA FORM 4198, 1 Jan 74 — REPLACES DA FORM 6-12, 1 OCT 64, WHICH IS OBSOLETE.

Figure 19–4. Record of impact registration.

gistration has resulted in FDC deflection spottings of RIGHT at deflection 3216 and LEFT at deflection 3218. The correct deflection is 3217 (a 2-mil deflection bracket has been split).

19-16. Target Hits

a. Occasionally, an observer may observe a target hit when spotting rounds in a registration. The target hit may occur during the adjustment, at the center of the fork bracket in fire for effect, or at the end of the fork bracket in fire for effect.

b. A spotting of TARGET by the observer warrants consideration of special contingencies by the FDC in computing firing data for subsequent rounds. These contingencies may be summarized by the following set of rules:

(1) If a target hit occurs during the adjustment, obtain two more definite FDC range spottings at the same quadrant. If a preponderance exists, move 1/2 fork away and obtain three definite FDC range spottings. If no preponderance exists, obtain three more definite range spottings at the same quadrant. Compute the mean quadrant and elevation change with the six spottings 1/2 fork apart or with the six spottings at the same quadrant.

(2) If a target hit occurs at the end of the fork bracket in fire for effect, follow the rules in (1) above.

(3) If a target hit occurs at the center of the fork bracket in fire for effect, obtain a total of three definite FDC range spottings at the center of the bracket. If a preponderance exists, move 1/2 fork away and obtain two more definite FDC range spottings at that quadrant. Compute the mean quadrant and elevation change in the usual manner. If no preponderance exists, obtain three more definite FDC spottings at the same quadrant and compute the mean quadrant and elevation change with the six rounds at the same quadrant.

c. Two examples of target hit contingencies are shown below.

Example 1:

Round No.	Deflection fired	Chart range	QE fired	Observer spottings or corrections	FDC spottings Range	FDC spottings Deflection
1	3215	5090	319	R50-200		
2	3189	4930	306	TGT, FFE	−+	CORR
3	----	----	306	−L	−	
4	----	----	306	−R		
5	----	----	308	+R	+	
6	----	----	308	?R	+	
7	----	----	308	+R	+	

Fork is 4.
Preponderance is one OVER.
Mean QE is 307.0.
Elevation change is −0.3.
Adjusted QE is 307 (307.0 + (−0.3) = 306.7).

Example 2:

Round No.	Deflection fired	Chart range	QE fired	Observer spottings or corrections	FDC spottings Range	FDC spottings Deflection
1	3215	5090	319	R50-200		
2	3189	4930	306	TGT, FFE	−+	CORR
3	----	----	306	−L	−	
4	----	----	306	+R	+	
5	----	----	306	?R	+	
6	----	----	306	−LN		
7	----	----	306	−R	−	

Fork is 4.
Preponderance is one SHORT.
Mean QE is 306.0.
Elevation change is +0.3.
Adjusted QE is 306 (306.0 + (+0.3) = 306.3).

19-17. PE_R Equal to or Greater than 38 Meters

In general, the same procedures apply to all artillery regardless of caliber; however, when the value of the PE_R is equal to or greater than 38 meters, rounds fired as a result of ADD (DROP) 50, FIRE FOR EFFECT, may be wasted because of the large range probable error. In such cases, the observer should be notified at the start of the mission to request for fire for effect when a 200-meter range bracket is split.

19-18. Purpose of a Time Registration

A zero height of burst is obtained when a number of rounds fired with the same fuze setting and quadrant elevation results in a mean height of burst at ground level. If nonstandard conditions affected time of flight and range at the same rate and if there were no variation in the functioning of time fuzes (no manufacturer's tolerance and no effects from storage), the fuze setting listed in the firing table corresponding to the adjusted elevation would be the adjusted time. A number of rounds fired with that fuze setting and with the adjusted quadrant elevation and correct deflection to the registration point would result in a zero height of burst. Because of the variation in functioning of time fuzes and because of the difference in rate at which nonstandard conditions affect time of flight and range, a time registration must be conducted to determine a fuze setting that will produce a zero height of burst for rounds fired with the adjusted elevation. The fuze setting determined from the time registration is the adjusted time.

19-19. Time Registration Procedures

a. If the S3 has so designated in the fire order, a time registration is fired at the completion of the impact registration. During the time registration, all rounds are fired at the adjusted quadrant elevation determined from the impact registration. All rounds are also fired at the correct deflection, if it has been determined. If it has not been determined, the observer is directed to spot all graze bursts for range and deviation. To initiate the time registration, FDC orders observer to OBSERVE TIME REGISTRATION. All rounds fired will be spotted by the observer as either "AIR" or "GRAZE." If the observer is to spot graze bursts for range and deviation, he is sent the message "OBSERVE TIME REGISTRATION SPOT GRAZE BURSTS". The observer will comply by spotting in the standard manner; e.g., GRAZE, OVER, LEFT.

b. The registering piece is ordered to fire fuze time. The fuze setting for the initial round is normally the fuze setting listed in the firing table corresponding to the adjusted elevation. However, if an experience fuze correction is known, the initial round should be fired with a fuze setting corresponding to the adjusted elevation plus the experience fuze correction.

c. After the observer's first spotting, the fuze setting is changed 0.4 in an attempt to obtain a spotting in the opposite sense. If the spotting is AIR, the fuze setting is too short and 0.4 is added to the fuze setting. If the spotting is GRAZE, the fuze setting is too great and 0.4 must be subtracted from the fuze setting. This procedure of changing the fuze setting 0.4 is continued until a spotting in the opposite sense has been obtained. A 0.4 time bracket is thus established.

d. If the observer reports a height of burst in excess of 50 meters prior to the establishment of a 0.4 time bracket, a change in fuze setting larger than 0.4 may be appropriate.

e. After a 0.4 time bracket has been obtained, the bracket is split and three rounds are fired at the center of the bracket. Because the spotting procedure in a time registration is relatively simple, the S3 should expedite the registration by changing the method of fire to "BASE PIECE 3 ROUNDS" and ordering the observer to "OBSERVE 3 ROUNDS". It should be noted that the method of fire is not changed in an impact registration at the center of the fork bracket. The method of fire remains "BASE PIECE 1 ROUND". This is because if three rounds are fired at once, the possibility of the observer's making a misspotting or of not observing one of the rounds are greatly increased. Such is not the case in a time registration, in which difficulty in spotting is not great.

f. After the observer has spotted the three rounds fired at the center of the time bracket the preponderance of the spottings is determined. The fuze setting is changed 0.2 in the direction opposite the preponderance and two rounds are fired. The method of fire should be changed to BASE PIECE 2 ROUNDS and the observer instructed to OBSERVE 2 ROUNDS. This procedure of adding 0.2 to or subtracting 0.2 from the center of the time bracket will always result in firing at the fuze setting which established the limit of the 0.4 time bracket in the direction opposite the preponderance at the trial time.

g. After the observer has spotted two rounds fired at the fuze setting 0.2 away from the center of the time bracket the adjusted time may be computed. The adjusted time is not a true time but is a term applied to a fuze setting. Henceforth, all fuze settings will be referred to as time; i.e., adjusted time or mean time. The six rounds considered in the computation of the adjusted time are the three rounds fired at the center of the time bracket, the last two rounds fired, and the round fired with the same time as the last two rounds that established one end of the 0.4 time bracket. The formula for the computation of the adjusted time is

$$\text{Adjusted time} = \text{mean time fired} \pm \frac{\text{difference in number of airs and grazes} \times 0.4}{2 \times \text{number or rounds considered}}$$

The value of the time change expressed to the nearest 0.1 will always be 0.1 if there is a preponderance. If the preponderance is AIR, the adjusted time is the mean time plus 0.1. If the preponderance is GRAZE, the adjusted time is mean time minus 0.1. If there is no preponderance (equal number of AIR and GRAZE), the adjusted time is the mean time.

19–20. Example of a Time Registration

The following is an example of a time registration with a 155-mm howitzer (M109), charge 5, correct deflection 3211, site +4, adjusted quadrant elevation 324. The fuze setting corresponding to elevation 320 is 21.3.

Round No.	*Deflection fired*	*Time fired*	*QE fired*	*Observer spotting*
12 FZ TIME	3211	21.3	324	A
13	----	21.7	324	A
14	----	22.1	324	G
15 BP ③	----	21.9	324	A
16	----	----	----	G
17	----	----	----	A
18 BP ②	----	22.1	324	G
19	----	----	----	G

Comments: The initial round is AIR; 0.4 is added to the time until a time bracket has been established (AIR at 21.7; GRAZE at 22.1). The bracket is split and three rounds are fired at 21.9. The three rounds result in two AIR and one GRAZE—a preponderance of AIR. The time is increased 0.2, and two more rounds are fired at 22.1 (the time that established the graze end of the time bracket). The six rounds in fire for effect are the three rounds fired at 21.9 and the three rounds fired at 22.1. The preponderance of the six rounds is GRAZE; 0.1 is subtracted from the mean time, 22.0, to arrive at the adjusted time of 21.9.

19–21. Abbreviated Procedure for a Time Registration

A technique known as the abbreviated procedure may be used when speed or economy of ammunition takes precedence over accuracy, when only missions requiring adjustment are to be fired, or when subsequent registrations are to be fired in the same position with the same fuze-ammunition lot combinations. The abbreviated procedure is appropriate when experienced personnel are firing under comparatively stable conditions and are able to judge the reliability of results.

a. The time bracket is established as prescribed in paragraph 19–19*a* through *e*.

b. Two rounds are fired at the center of the time bracket.

c. If the two rounds fired at the center of the time bracket result in mixed spottings, the time fired at the center of the time bracket is the adjusted time.

d. If the two rounds fired at the center of the bracket result in the same spotting, the time is changed 0.2 in the appropriate direction to the end of the 0.4 time bracket that resulted in a spotting opposite of the two rounds fired at the center of the bracket and one round is fired.

e. If the spotting of the round fired at the appropriate end of the time bracket is opposite that of the rounds fired at the center of the bracket the adjusted time is the mean time.

f. If the spotting of the round fired at the appropriate end of the time bracket is in the same sense as the rounds fired at the center of the bracket the registration may be invalid. (Procedures for determining the validity of an abbreviated time registration are discussed in paragraph 19–26.)

g. Examples of the abbreviated time registration are given in (1) and (2) below.

(1) *Example 1.*

Round No.	*Time*	*Spotting*	*Comment*
1	19.6	A	Add 0.4.
2	20.0	G	Split the 0.4 time bracket.
3, 4	19.8	A, G	Time at center of bracket (19.8) is the adjusted time.

(2) *Example 2.*

Round No.	*Time*	*Spotting*	*Comment*
1	19.6	G	Subtract 0.4.
2	19.2	A	Split the 0.4 time bracket.
3, 4	19.4	G, G	Subtract 0.2.
5	19.2	A	Adjusted time is 19.3.

Section III. VALIDITY OF REGISTRATIONS

19–22. General

a. The fork bracket method of determining adjusted data precludes the possibility of a 6 and 0 registration. However, it is possible that a 5 and 1 registration may occur. Any 5 and 1 registration (impact or time) must be verified. Current registration procedure is based on the assumption that the six usable rounds considered follow the normal dispersion pattern and that an elevation change of 1 fork will move the mean point of impact to the registration point. However, if the single round in the minority sense in a 5 and 1 registration falls outside the normal dispersion pattern, the mean point of impact is an indeterminate distance from the registration point and the registration is invalid. Verification procedures are those procedures for determining the validity of the registration.

b. An invalid registration may result from—

(1) An erroneous spotting by the observer, which may cause a false bracket in range, deflection, or fuze setting.

(2) Errors at the fire direction center.

(3) Errors at the piece.

(4) Excessive dispersion.

c. Whenever a registration does not meet the requirements for validity, it must be continued until it is valid.

19-23. Verification of an Impact Registration

a. An impact registration that results in only one spotting opposite that of the preponderance (that is five OVER and one SHORT, five SHORTS and one OVER, one TARGET and five OVER, one TARGET and five SHORT) should be verified. The rules for verifying an impact registration are as follows:

(1) Move 1/2 fork in the appropriate direction (add if the preponderance is SHORT; drop if the preponderance is OVER) from the last quadrant elevation fired and fire one verifying round.

(2) If the spotting of the verifying round is opposite that of the preponderance, consider the registration valid. The verifying round is not considered in computing the adjusted quadrant elevation.

(3) If the spotting of the verifying round is the same as that of the preponderance, fire two more rounds at the same quadrant elevation used to fire the verifying round. If the spotting of either of these two rounds is opposite that of the preponderance, compute the adjusted elevation from the last three rounds fired and the three rounds fired at the quadrant previous to the verifying round. If the spotting of both of these rounds are the same as that of the preponderance, the registration is invalid. Establish a new fork bracket, followed by fire for effect.

b. Examples of verifying an impact registration are given in (1), (2), and (3) below.

(1) *Example 1.*

Round number	*QE*	*FDC range spotting*	*Comment*
1	339	+	Fork is 7. Move 8 (even fork.
2	331	—	Split bracket. Fire ③.
3, 4, 5	335	+, +, +	All +. Drop ½ fork; fire ②.
6, 7	331	+, +	5 and 1. S3 decides to verify.
8	327	—	Registration is valid. Adjusted QE is 331.

(2) *Example 2.*

Round number	*QE*	*FDC range spotting*	*Comment*
1	339	+	Fork is 7. Move 8 (even fork).
2	331	—	Split bracket. Fire ③.
3, 4, 5	335	+, +, +	All +. Drop ½ fork; fire ②.
6, 7	331	+, +	5 and 1. S3 decides to verify.
8	327	+	Fire ②.
9, 10	327	+, —	Compute adjusted QE, from rounds fired at QE 327 and 331. Adjusted QE is 328.

(3) *Example 3.*

Round number	*QE*	*FDC range spotting*	*Comment*
1	339	+	Fork is 7. Drop 8 (even fork).
2	331	—	Split bracket. Fire ③.
3, 4, 5	335	+, +, +	All +. Drop ½ fork; fire ②.
6, 7	331	+, +	5 and 1. S3 decides to verify.
8	327	+	fire ②.
9, 10	327	+, +	Registration is invalid. Drop even fork.
11	319	—	Split bracket. Fire ③.
12, 13, 14	323	+, —, +	Drop ½ fork; fire ②.
15, 16	319	—, —	Compute adjusted QE, from rounds fired at QE 323 and 319. Adjusted QE is 322.

19-24. Valid Time Registrations

a. A time registration is considered valid if any of the following combinations of spottings are obtained in fire for effect:

(1) Three AIR and three GRAZE.

(2) Four AIR and two GRAZE.

(3) Two AIR and four GRAZE.

b. If the spottings in the fire-for-effect phase of a time registration are five AIR and one GRAZE, the S3 must request the observer to report the mean height of burst. If the observer reports a mean height of burst of 15 meters or less, the registration is valid. If he reports a height of burst greater than 15 meters, the registration must be verified.

19–25. Verification of a Time Registration

a. A time registration that results in either of the following combinations of spottings must be verified:

(1) Five GRAZE and one AIR.

(2) One GRAZE and five AIR (mean height of burst is greater than 15 meters).

b. The procedure for verification of a time registration is as follows:

(1) Change the time by 0.2 from the last time fired; and if the preponderance is AIR and subtract if the preponderance is GRAZE. Fire one verifying round.

(2) If the spotting of the verifying round is opposite that of the preponderance, consider the registration valid.

(3) If the spotting of the verifying round is the same as that of the preponderance, fire two more rounds with the same time as the verifying round. If the spotting of either of these rounds is opposite that of the preponderance, compute the adjusted time, from the last three rounds fired and the three rounds fired with a time 0.2 away from the time of the last three rounds. If the spotting of both of the rounds fired with the same time as the verifying round are the same as that of the preponderance, the registration is invalid. Establish a new 0.4 time bracket, followed by fire for effect.

c. Examples of verifying time registrations are given in (1), (2), and (3) below.

(1) *Example 1.*

Round	Time	Spotting	Comment
1	14.1	A	
2	14.5	G	0.4 time bracket is established.
3, 4, 5	14.3	G, G, G	
6, 7	14.1	G, G	Five G and one A. Must be verified; subtract 0.2.
8	13.9	A	Registration is valid. Adjusted time is 14.1.

(2) *Example 2.*

Round	Time	Spotting	Comment
1	14.1	A	
2	14.5	G	
3, 4, 5	14.3	G, G, G	
6, 7	14.1	G, G	Five G and one A. Must be verified.
8	13.9	G	Spotting of verifying round same as that of preponderance. Fire two more rounds at 13.9.
9, 10	13.9	G, A	Compute adjusted time based on rounds 1, 6, 7, 8, 9, and 10. Adjusted time is 13.9.

(3) *Example 3.*

Round	Time	Spotting	Comment
1	14.1	A	
2	14.5	G	
3, 4, 5	14.3	G, G, G	
6, 7	14.1	G, G	Five G and one A. Must be verified.
8	13.9	G	Spotting of verifying round same as that of preponderance. Fire two more rounds at 13.9.
9, 10	13.9	G, G	Registration is invalid. Re-establish 0.4 time bracket.
11	13.5	A	0.4 time bracket is established. Enter fire for effect.
12, 13, 14	13.7	A, G, G	Preponderance is G.
15, 16	13.5	A, A	Four A and two G. Adjusted time is 13.7.

19–26. Verification of an Abbreviated Time Registration

a. If the two rounds fired at the center of the time bracket and the subsequent round fired at the end of the bracket are all AIR and the mean height of burst is 15 meters or less, the registration is valid.

b. If the two rounds fired at the trial time and the subsequent round fired at the end of the bracket are all GRAZE or if they are all AIR and the mean height of burst is greater than 15 meters, the registration may be invalid. In this situation, the apparent adjusted time is the time that established the end of the 0.4 time bracket at which the last round was fired.

c. The FDC verifies the apparent adjusted time by changing the time 0.2 in the appropriate direction (adding if the last round is AIR and subtracting if the last round is GRAZE) and firing one verifying round.

d. If the spotting of the verifying round is opposite that of the last three rounds fired, the apparent adjusted time is considered verified.

e. If the spotting of the verifying round is the same as that of the last three rounds fired, one more round is fired with the same time as that of the verifying round. If the spotting of this round is opposite that of the preceding round, the adjusted time is the mean of the apparent adjusted time and the time at which the last two rounds were fired. If the spotting of this last round fired is the same as that of the four preceding rounds, a new 0.4 time bracket must be established, followed by fire for effect.

f. Examples of the procedure for verifying an abbreviation time registration are given in (1) and (2) below.

(1) *Example 1.*

Round	Time	Spotting	Comment
1	22.4	A	Add 0.4.
2	22.8	G	Split the 0.4 time bracket.
3, 4	22.6	G, G	Subtract 0.2.
5	22.4	G	Apparent adjusted time is 22.4. Must be verified.
6	22.2	A	Apparent adjusted time is considered verified. Adjusted time is 22.4.

(2) *Example 2.*

Round	Time	Spotting	Comment
1	21.8	G	Subtract 0.4.
2	21.4	A	Split the 0.4 time bracket.
3, 4	21.6	A, A	Add 0.2.
5	21.8	A	Mean height of burst reported is 25 meters. Apparent adjusted time is 21.8. Must be verified.
6	22.0	A	Fire another round.
7	22.0	G	Adjusted time is 21.9. (A and G at 21.8 and A and G at 22.0). If round 7 has been AIR, a new registration woud have been required.

Section IV. MEAN-POINT-OF-IMPACT AND HIGH-BURST REGISTRATIONS

19–27. General

a. The opportunities to conduct registrations on clearly defined, accurately located registration points in the target area may be limited. At night, the adjustment of fire on a registration point without some type of illumination is impossible. In desert, jungle, or arctic operations, clearly defined registration points normally are not available. Either of two alternate registration procedures may be used to overcome these limitations. These procedures are known as the mean-point-of-impact (MPI) registration, and the high-burst (HB) registration. In an MPI or HB registration, the mean burst location of a group of rounds (normally six) fired with a single set of data is determined. The HB and MPI registrations are very similar in that the six rounds considered must be visible to two surveyed observers, usually designated 01 and 02. This requirement for survey is the major limitation of the HB and MPI registrations.

b. An HB registration offers distinct advantages over an MPI registration because time fuze is employed. Since airbursts are used, deflection, range, and fuze corrections may be determined simultaneously. A HB registration is easier to observe than a MPI registration, especially at night, and corrections may be obtained for areas concealed from ground observation.

19–28. Selection of Point at Which to Register

a. The S3 selects the point toward which the HB/MPI registration will be fired. This point is known as the orienting point. For convenience, the S3 normally selects a grid intersection as the orienting point. Once he has selected the orienting point, the S3 initiates the registration by issuing the fire order; e.g., BRAVO, HIGH BURST AT GRID 6138, HEIGHT OF BURST 50 METERS, USE GFT, LOT XRAY YANKEE, CHARGE 4, AT MY COMMAND, HIGH-BURST REGISTRATION. The S3 will usually include AT MY COMMAND in the fire order because he must choose, from among the rounds fired, six usable rounds and, once they have been chosen, terminate the registration.

b. The point at which a mean-point-of impact registration is to be fired should be—

(1) Close to the center of the zone into which the unit is expected to fire.

(2) In a relatively level area, free of ravines and objects that might obscure bursts.

(3) In an area visible to the observers.

(4) Located so that the apex angle is at least 300 mils in order to provide the required survey accuracy.

c. The point at which a high-burst registration is to be fired should be—

(1) Over the center of the zone into which the unit is expected to fire.

(2) High enough to be visible to the observers.

(3) High enough that airbursts are assured but not so high that the quadrant elevation and the vertical interval to the predicted burst point computed from the battery exceed the limitations stated on the reverse side of the appropriate GST. Exceeding these limitations introduces unacceptable errors. Fifty meters above the ground is usually a good height of burst, but in no case should the predicted burst height be less than 2 height-of-burst probable errors.

(4) Located so that the apex angle is at least 300 mils in order to provide the required survey accuracy.

19–29. Orientation of the Observers

a. Once the orienting point has been selected the two observers, 01 and 02, must be oriented on it. Lines of known direction must be established on the ground. The observers must be furnished azimuth and vertical angles to the expected point of burst. The azimuths are usually determined graphically from the firing chart. The vertical angles normally are computed by use of the C and D scales of the GST.

b. A message to the observers prior to an MPI or HB registration contains a warning order, orientation data for each OP, a directive to observer 01 to measure and report vertical angles, and a directive to both observers to report when ready to observe. Since 01 is the control OP, vertical angles should be measured at 01.

Example: OBSERVE HIGH-BURST REGISTRATION 01, DIRECTION 1065, VERTICAL ANGLE PLUS 10, MEASURE THE VERTICAL ANGLE. 02, DIRECTION 485, VERTICAL ANGLE PLUS 8. REPORT WHEN READY TO OBSERVE.

c. Observer procedures are discussed in paragraphs 13–17 and 13–18.

19–30. Determination of Firing Data

a. The point at which the registration is to be fired is plotted on the firing charts. The horizontal control operator determines and announces the chart range and deflection to the selected point.

b. The vertical control operator determines the site to the selected point. He determines the vertical interval used in the determination of site for a high-burst registration by subtracting the altitude of the gun from the sum of the altitude of the ground under the selected point and the desired height of burst above the ground.

c. The computer determines the fire commands based on the announced chart data. The method of fire is BASE PIECE or NUMBER (so-and-so) 1 ROUND, AT MY COMMAND. In well-trained units, the method of fire may be changed BASE PIECE (so may) ROUNDS AT (so many) SECONDS after the observers have oriented on the initial round. When the method of fire is BASE PIECE (so many) ROUNDS AT (so many) SECONDS each observer must carefully identify the round to which each reading pertains.

d. Firing data are not changed during the registration unless a change is necessary to move the bursts to a point visible to the observers or to raise the height of burst if graze bursts occur during a high-burst registration. If the height of burst of the rounds is to be changed, the site must be recomputed. However, if firing data are changed during the firing of the registration, the registration must be continued until six usable rounds fired at the same data have been obtained.

19–31. Procedure During Firing of a High-Burst or Mean-Point-of-Impact Registration

a. When the battery has reported READY and the observers have reported READY TO OBSERVE, the S3 commands FIRE. The first round is used to orient the observers and normally is not considered as one of the usable rounds.

b. If either of the observers cannot observe the initial round, firing data may be changed to move the burst until both observers can see the bursts.

c. After the observers have located the burst, the registration is continued. One round at a time is fired until six usable rounds have been obtained. Each observer reports the direction to each burst, and the designated observer reports the vertical angle to each burst.

d. Any round that appears to be erratic is disregarded. In judging whether a round is erratic, the S3 must consider the locations of the observers with respect to the gun-target line and the size of the probable error. Any round not disregarded as erratic or erroneously spotted by an observer is considered usable.

19–32. Determination of the Location of the Mean Point of Impact or High Burst

a. When six usable rounds have been obtained, the average azimuth from each OP and the average vertical angle measured at 01 are determined. These are the averages for the six rounds considered.

b. Once these averages have been determined, they are used to determine the location of the mean point of impact or high burst. The three methods by which this may be done, are listed below in order of increasing accuracy but decreasing speed of computation.

(1) Graphic intersection. In the graphic intersection method the HCO uses the chart and his RDP to determine the mean location. He sets off the mean direction from each OP and with a 6H pencil draws a line along the left edge of the RDP. The point of intersection of the two lines is the burst location. The HCO uses the mean vertical angle from 01 in determining the burst altitude.

(2) *Polar plot.* In the polar plot method the HCO computes the distance from 01 to the mean burst location by use of the law of sines. The following data are required for use of this me-

thod: The mean azimuth from each OP to the mean location, the direction from 01 to 02, and the distance between 01 and 02. The HCO plots the mean burst location on the chart with his RDP by polar plotting from 01. He uses the mean direction of 01 and the distance determined by the law of sines. The VCO determines the altitude of the burst by using the mean vertical angle and the computed distance.

(3) *Computation of coordinates.* The computation of coordinates method is actually an extension of polar plotting, since a determination of the distance from 01 to the mean burst must be made. If the coordinates of 01 are known and the direction and distance from 01 to the mean burst are known, then the actual grid coordinates of the burst location may be determined by use of trigonometric functions. When the HCO has determined the coordinates he plots them on the chart. The VCO determines the altitude of the burst by using the tangent of the vertical angle and the computed distance from 01 to the mean burst location.

c. Computations for the polar plot and computation of coordinates methods are facilitated by use of DA Form 4201 (High-Burst (Mean Point of Impact) Registration) (fig 19-5). (DA Form 4201 is available through normal AG publication supply channels.)

d. The mean burst location is not tickmarked. The point is used only for determining corrections from the registration.

e. The plotted burst location is the actual "did hit" location of the six usable rounds and should not be confused with the orienting point (para 19-28). The orienting point is the "should hit" location of the six rounds and will not coincide with the plotted mean burst location unless the total effects of nonstandard conditions existing at the time of registration do not differ from those used to compute the firing data. The orienting point serves to provide the observers with orienting data and it serves as a basis for determining the firing data for the rounds in the registration.

19-33. Determination of Chart Data to the Mean Point of Impact or High Burst

a. After the location of the mean point of impact or high burst, has been determined and plotted on the chart, the HCD measures the range and deflection to the plotted point from the battery that fired the mission. The range and deflection measured are the chart range and chart deflection.

b. The VCO computes site by determining the vertical interval and dividing the vertical interval by the chart range (GST) for the appropriate charge. The vertical interval is determined by subtracting the altitude of the battery from the altitude of the mean point of impact or high burst. Site is *always* determined at chart range.

19-34. Determination of Adjusted Elevation and Adjusted Time

a. The quadrant elevation used to fire the six usable rounds in a mean-point-of-impact or high-burst registration is the adjusted quadrant elevation. The computer subtracts the site (para 19-33*b*) from the adjusted (fired) quadrant elevation to determine the adjusted elevation.

b. The fuze setting used to fire the six usable rounds in a high-burst registration is the adjusted time. When the vertical interval to the high-burst (para 19-33*b*) is small (100 meters or less), the fuze setting corresponding to the adjusted elevation is used in determining the total fuze correction. However, when the vertical interval is large (greater than 100 meters), the complementary angle of site should be added to the adjusted elevation in determining the total fuze correction. The procedure for determining the total fuze correction when the vertical interval is greater than 100 meters is explained in (1) through (5) below. (This procedure is illustrated in paragraph 19-38*f*.)

(1) Determine the angle of site and site to the reported mean location of the high burst (GST).

(2) Determine the complementary angle of site (site minus angle of site).

(3) Determine the fuze setting for the adjusted elevation plus the complementary angle of site (GFT).

(4) Determine the total fuze correction by subtracting the fuze setting for the adjusted elevation plus complementary angle of site from the fuze setting used to fire the high-burst registration.

(5) Add the total fuze correction to the fuze setting corresponding to the adjusted elevation. At this value (adjusted fuze setting at the level point), construct the time gageline on the cursor of the GFT. The GFT setting now permits accurate transfer of time fires within small vertical intervals (100 meters or less). When fuze time is being used and first-round accuracy is required for targets with large vertical intervals (greater than 100 meters) determine the fuze settings by applying the total fuze correc-

tion to the fuze setting corresponding to the elevation plus complementary angle of site to the target. This is done by placing the elevation gageline over the elevation plus comp site and reading the fuze setting under the time gageline (para 19-36, example problem 2).

19-35. Example High-Burst Registration

a. A 155-mm howitzer M109 battalion has just made a night occupation of position. Survey has been completed. In order to accurately fire a predawn preparation, the S3 decides to fire a high-burst registration (charge 5). After studying the map, the S3 decides to fire the high burst at grid intersection 6242 with a desired height of burst above the ground of 60 meters. The altitude at the grid intersection is 407 meters.

b. The survey officer has furnished the following data:

Coordinates of Battery B	5708538148
Altitude of Battery B	381 meters
Coordinates of 01	6159939123
Altitude of 01	436 meters
Coordinates of 02	6039639620
Altitude of 02	431 meters
Distance 01 to 02	1,302 meters
Azimuth 01 to 02	5,199 mils

c. The HCO constructs a firing chart and plots the location of 01, 02, and all batteries on the chart. He measures the aximuths and distances from 01 and 02 to the 6242 grid intersection.

(1) 01 to 6242—aximuth 141 mils, distance 2,900 meters.

(2) 02 to 6242—azimuth 604 mils, distance 2,870 meters.

d. The VCO computes the vertical angles from 01 to 02 to the desired location of the high burst.

(1) Desired altitude of the high burst is 467 meters (407 + 60).

(2) 01 vertical interval = +31 (467 −436). Vertical angle = 11 mils (31/2900, GST).

(3) 02 vertical interval = +36 (467 −431). Vertical angle = +13 mils (36/2870, GST).

e. The FDC sends the following message to the observers: OBSERVE HIGH-BURST REGISTRATION; 01, DIRECTION 141, VERTICAL ANGLE PLUS 11, MEASURE THE VERTICAL ANGLE; 02, DIRECTION 604, VERTICAL ANGLE PLUS 13, REPORT WHEN READY TO OBSERVE.

f. The HCO measures and announces the following chart data for Battery B: BRAVO, RANGE 6240, DEFLECTION 3177.

g. The VCO computes and announces site BRAVO, PLUS 15.

(1) Vertical interval = +86 (467 −381).

(2) Site = +15 mils (+86/6240, GST, charge 5).

h. The computer determines and sends to the battery the following fire commands: BASE PIECE ADJUST, SHELL HE, LOT ZULU TANGO, CHARGE 5, FUZE TIME, BASE PIECE 1 ROUND, AT MY COMMAND, DEFLECTION 3177, TIME 20.8, QUADRANT 327.

i. The base piece and both observers report READY, and firing is begun. (As each round is observed, the observers report in numerical order; e.g., 01, DIRECTION (So much), VERTICAL ANGLE (so much); 02, DIRECTION (so much). FDC Personnel record the directions and vertical angles, and the next round is fired. When six usable rounds have been observed, the mission is ended.)

j. The coordinates of the mean burst location are computed as shown in figure 19-5.

The grid coordinates of the high burst are 6190341930; the altitude is 455.

k. The chart operators plot the high-burst location and determine the following chart data:

(1) HCO: range 6130; deflection 3178.

(2) VCO: vertical interval +74 (455 − 381); site 13 mils (+74/6130, charge 5).

The following is a tabulation of the essential information derived from this registration:

Chart data	*Adjusted (fired) data*
Deflection 3,178 mils	Deflection 3,177 mils
Range 6,130 meters	QE 327 mils
Site +13 mils	Elevation 314 mils (327 − (+13))
	Time 20.8

19-36. Radar Registrations

a. General. The AN/MPQ-4A radar system is designed for employment in the countermortar and counterbattery role. However, the capabilities of this radar are such that it can be profitably employed in observing high-burst and mean-point-of-impact registrations. When proper techniques and procedures are employed, the accuracy of registration corrections obtained by the radar observed method is comparable to that of corrections obtained by other methods.

b. Employment. Employment and position requirements for the radar set depend on the tactical mission assigned the radar section and on certain technical and tactical factors that influence the operation of the equipment. The complete suitability of a radar site can be determined only by the accomplishment of the assigned mission from that site. The radar position should be located adjacent to one of the firing batteries.

HIGH BURST (MEAN POINT OF IMPACT) REGISTRATION

For use of this form, see FM 6-40; the proponent agency is US Army Training and Doctrine Command.

COMPUTATION OF HB (MPI) LOCATION

Message to Observers

OBSERVE HIGH BURST REGISTRATION, O1, DIRECTION 141, VERTICAL ANGLE +11, MEASURE THE VERTICAL ANGLE, O2, DIRECTION 604, VERTICAL ANGLE +13, REPORT WHEN READY TO OBSERVE.

Dis O1 → O2		
1302M	Az O1 → O2	5199
	⊖	3200
	Az O2 → O1	1999

Data Fired	Chg 5	Df 3177	FS 20.8	QE 327

Observer Readings

Rd No	O1 Az	O1 VA	O2 Az
1	~~96~~	~~+10~~	~~572~~
2	110	+8	590
3	108	+8	588
4	111	+7	589
5	115	+7	588
6	~~95~~	~~+9~~	~~570~~
7	107	+7	590
8	111	+7	590
9			
10			
Total	662	+44	3535
Average	110	+7	589

Interior Angles

O1 on Left		O1 on Right	
Az O1 → HB (MPI)		Az O2 → HB (MPI)	589
+6400 if necessary		+6400 if necessary	—
Total		Total	589
−Az O2 → HB (MPI)		−Az O1 → HB (MPI)	110
APEX ∠		APEX ∠	479
Az O2 → HB (MPI)		Az O2 → O1	1999
+6400 if necessary		+6400 if necessary	—
Total		Total	1999
−Az O2 → O1		−Az O2 → HB (MPI)	589
∠ at O2		∠ at O2	1410

Distance O1 HB (MPI)

Log base O1 → O2	3	114	611
+Log sin ∠ at O2	9	992	400
Sum	13	107	011
−Log sin Apex Angle	9	656	209
diff = Log dist O1 HB (MPI)	3	450	802
Dist O1 → HB (MPI)		2823.6M	

Bearing = 6400 − Az (dE −, dN +)	Bearing = Az (dE +, dN +)	Az O1 → HB (MPI) → Bearing
IV	I	110
III	II	
Bearing = Az − 3200 (dE −, dN −)	Bearing = 3200 − Az (dE +, dN −)	Bearing: N110E

Log of dE, dN, and dH

Log dist O1 → HB (MPI)	3 450	802	Log dist O1 → HB (MPI)	3 450	802	Log dist O1 → HB (MPI)	3 450	802
Log sin Bearing	9 032	548	Log cos Bearing	9 997	462	Log Tan Vert ∠	7 837	105
Sum = Log dE	2 483	350	Sum = Log dN	3 448	264	Sum = Log dH	1 287	907

Coordinates of O1	E	61 599	N	39 123	H	436
⊕	dE	304	dN	2807	dH	19
Location of HB (MPI)	E	61 903	N	41 930	H	455

COMPUTATION OF GFT SETTING

				Chart data to HB (MPI) location	Df corr
Alt HB (MPI)	455	QE fired	327	Deflection 3178 Range 6130 M	R1
−Alt Btry	381	− Site VI/HB (MPI) Rg	+ 13	GFT B Charge 5 Lot 2T	
VI	⊕ 74	Adj Elev	314	Range 6130 Elevation 314 Time 20.8	

DA FORM 1 JAN 74 4201 REPLACES DA FORM 6-55, 1 NOV 67, WHICH IS OBSOLETE.

Figure 19–5. Computation of high burst registration.

Such a location simplifies communications, survey, and logistics and enables the section to take advantage of an existing defensive perimeter. When selecting the optimum radar site, the radar officer should consider the range capabilities of the radar in order that as many batteries as possible may take advantage of the registration capabilities of the radar. This should be done without degradation of the countermortar or counterbattery role. The radar should be placed in defilade to afford personnel and equipment protection from hostile fire and to reduce the effects of electronic countermeasures.

c. Advantages and Disadvantages. A radar registration, when compared with other methods of conducting a registration, has certain advantages and disadvantages. The primary advantage is the reduction in the time required to prepare for observing the registration. Less survey is required for radar than is required for sound, flash, or target area bases, since only the radar and the registering piece must be on a common grid. Fewer communications facilities are required since only the radar, the FDC, and the registering battery need communicate. A radar-observed mean-point-of-impact (MPI) registration can be conducted by the radar, since accuracies are maintained within acceptable limits. High-angle registrations may be conducted by use of radar MPI techniques. Radar registrations can provide polar plot data from the radar to the mean location of six usable rounds to the high burst (MPI), which is the preferred technique, polar plot data for each round may be reported, or grid and altitude may be determined and reported by the radar section. Distances reported by the radar are slant distances, however, for plotting and computational purposes, the horizontal error introduced is insignificant and the radar distance is considered to be horizontal distance.

d. Selection of Orientation Point. Some coordination and mutual understanding must exist between the FDC and radar personnel in the choice of a high-burst (MPI) orientation point. The quadrant elevation and the vertical interval to the predicted burst point computed from the battery center must not exceed the limitations stated on the reverse of the appropriate GST. Exceeding these limitations introduces unacceptable errors.

(1) For a high-burst registration, the selected point must be optically visible from the radar. In order for the radar to optically observe elevation deviations below as well as above the selected point, the pointing elevation of the radar must be at least 10 mils above the elevation to the radar screening crest. The radar operator measures the elevation to the screening crest from the radar along the azimuth to the selected burst point by sighting through the optical telescope. The pointing elevation of the radar should not exceed 50 mils.

(2) For a radar MPI registration, only electrical line of sight is necessary. However, the pointing elevation to the selected point is determined in the same manner as for the high-burst registration to insure electrical beam clearance. A characteristic of the radar MPI registration is that the rounds normally cannot be observed at impact because the radar is usually sited behind a mask. Therefore, it is necessary that the radar observe the artillery rounds at some place in space where they all pass through the radar beam. This place in space is called the selected datum plane—the theoretical horizontal plane of the radar beam from which the radar personnel compute the "did hit," or chart, location of the six usable rounds (fig 19–6).

e. Message to Observer. If radar registrations are to be conducted efficiently and rapidly, certain data must be furnished to the radar section by the FDC. To provide these data, the FDC prepares a message to observer. The message to observer consists of five elements which are discussed below in the sequence in which they are transmitted.

(1) *Warning Order.* The element *warning order* must always be included. It consists of the order OBSERVE HIGH BURST (MPI) REGISTRATION. This element informs the radar section of the type of registration to be fired and that preparations are to begin immediately.

(2) *Unit to fire.* The element *unit to fire* may be eliminated by standing operating procedure when it is unnecessary for the radar section to contact the battery to fire or to know the battery location. It consists of the word FOR, and the call sign or code name of the unit to fire.

(3) *Orienting Data.* The element *orienting data* must always be included. It specifies the direction and distance of the orienting point from the radar location.

(4) *Vertical Angle Report.* The element *vertical angle report* must always be included and consists of the command REPORT VERTICAL ANGLE. The radar section will determine the vertical angle based on the radar elevation to a point 10 mils above the crest and on the direction announced in the message to observer. Using the vertical angle and the distance from

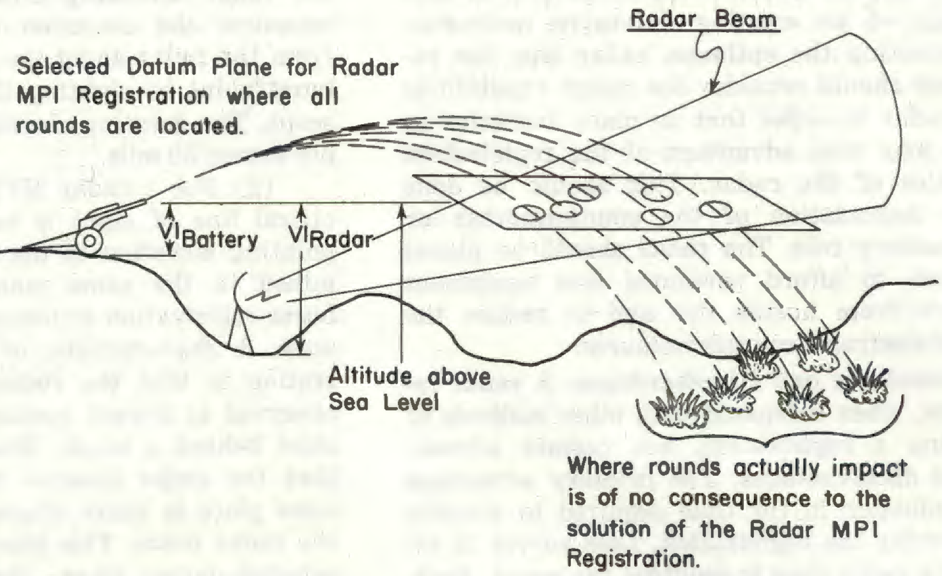


Figure 19-6. Theoretical MPI selected datum plane.

the radar to the orienting point, the FDC will determine the altitude of the orienting point. For a high burst registration the orienting point must be 2 PE_{HB} above the ground. If the altitude determined is not 2 PE_{HB} above the ground the FDC will raise the orienting point to that altitude required and determine and announce the new vertical angle to the radar. For an MPI registration the vertical angle reported by radar is the vertical angle determined for the selected datum plane.

(5) *Report order.* The element report order consists of the order REPORT WHEN READY TO OBSERVE. This element instructs the radar section to inform the FDC when the section is ready to observe the registration.

f. Conduct of Radar Registrations.

(1) Radar-observed MPI and high burst registration procedures are identical to standard MPI and high-burst registration procedures except as noted in *a* through *e* above and in the example in paragraphs 19-37, 19-38, and 19-39.

(2) In the conduct of radar high-burst registrations, large vertical intervals (greater than 100 meters) are frequently encountered because of the positioning requirements of the radar. Large vertical intervals necessitate the consideration of the complementary angle of site in the determination of the total fuze correction as described in paragraph 19-34*b* and illustrated in paragraph 19-38*f*.

19-37. Example 1—Radar Registration

Example Problem 1.

a. A 155-mm howitzer M109 battalion has just made a night occupation of position. Position area survey has been completed. There are no surveyed observation posts. An AN/MPQ-4A radar section is located in a nearby direct support artillery battalion perimeter. In order to accurately deliver unobserved fires from this new position, the S3 decides to have Battery B fire a radar-observed high-burst registration (charge 5 green bag). Upon inspection of the map, the S3 decides to fire the high burst at grid intersection 6237. The altitude of the battery is 352 meters and the altitude of the radar is 358 meters.

b. The HCO measures and announces the following data measured from Battery B to grid intersection 6237.

(1) RANGE 6420.

(2) DEFLECTION 3287.

c. The HCO measures and announces the direction and distance from the radar to grid intersection 6237 and the FDC sends the following message to observer: OBSERVE HIGH BURST REGISTRATION FOR LOUD THUNDER 18, DIRECTION 6275, DISTANCE 5890, REPORT VERTICAL ANGLE, REPORT WHEN READY TO OBSERVE.

d. Report from radar: VERTICAL ANGLE PLUS 17, AMC, REQUEST SPLASH, READY TO OBSERVE.

e. The VCO computes the altitude of the orienting point to be 456 meters and determines and announces, SITE BRAVO, PLUS 18 (VI +104/6.42, GST).

f. The computer determines and sends the following fire commands to the battery: BASE PIECE ADJUST, SHELL HE, LOT XRAY ZULU, CHARGE 5 FUZE TIME, BASE PIECE 1 ROUND, AT MY COMMAND, DEFLECTION 3287, TIME 21.6, QUADRANT 342.

g. When the radar reports READY TO OBSERVE and the base piece reports READY, firing is begun. If the first round is not visible in the telescope reticle and on the B-scope, the antenna will be reoriented to the center of the burst and the round will not be used. If the first round bursts more than 5 mils below the center of the reticle, the altitude must be increased and the round is not used. As each round is fired, the radar operator reports OBSERVED or UNOBSERVED. If the report OBSERVED is followed by REQUEST SITE INCREASE (DECREASE) early in the registration, the burst is occurring to low (HIGH). The quadrant elevation must be increased (decreased) by the number of mils necessary to raise (lower) the burst approximately 2 PE_{HB}.

(1) The computer determines the PE_H from the firing tables, interpolating with range to the nearest 100 meters: $PE_{HB} = 17$, $2\ PE_{HB} = 30$ $(17 \times 2 = 34)$. $100/R = 16.$ and Site increase $= +5$ mils $\left(\frac{30 \times 16}{100}\right)$.

(2) The quadrant previously fired is increased by 5 mils and the computer announces QUADRANT 347 (342+5).

(3) If the bursts continue to be either to low or to high, a further increase or decrease of the quadrant in smaller increments may be deemed necessary. This precludes further orientation of the radar and permits the radar section to provide optimum data to the mean location of the six usable rounds.

h. The radar observes six usable rounds, and the radar section ends the mission with the report END OF MISSION.

i. The radar section computes the mean burst location and sends the following message to the FDC: HIGH BURST REGISTRATION OBSERVED, AVERAGE DIRECTION 6225, AVERAGE DISTANCE 5840, AVERAGE VERTICAL ANGLE PLUS 14.

j. The chart operators polar plot the announced high-burst location from the radar location and determine and announce the following chart data:

(1) HCO: RANGE 6310, DEFLECTION 3282.

(2) VCO: SITE PLUS 15 (VI +86/6.31, GST).

Note. Since the vertical interval does not exceed 100 meters, standard procedures are followed.

k. The following data are derived from this registration:

Chart data		*Adjusted data*	
Deflection	3282	Deflection	3287
Range	6310	QE	347
Site	+15	Elevation (347 − (+15))	332
		Time	21.6

GFT B: Chg 5, lot XZ, rg 6310, el 332, ti 21.6. Total deflection correction L5.

19-38. Example 2—Radar Registration

The following problem illustrates the conduct of a high-burst registration and the determination of registration corrections when the vertical interval from the battery to the reported altitude of the radar high burst exceeds 100 meters.

a. The S3 decides to have Battery A fire a radar-observed high-burst registration at grid intersection 6337. The altitude of the battery is 355 meters and the altitude of the radar is 358 meters.

b. The HCO measures and announces the following data measured from Battery A to grid intersection 6337.

(1) RANGE 6530.

(2) DISTANCE 3198.

c. The HCO measures and announces the direction and distance from the radar to grid intersection 6337 and the FDC sends the following message to observer: OBSERVE HIGH BURST REGISTRATION FOR LOUD THUNDER 18, DIRECTION 6335, DISTANCE 6040, REPORT VERTICAL ANGLE, REPORT WHEN READY TO OBSERVE.

d. Report from radar: VERTICAL ANGLE PLUS 30, AMC, REQUEST SPLASH, READY TO OBSERVE.

e. The VCO computes the altitude of the orienting point to be 536 meters and determines and announces, SITE ALFA, PLUS 32 (VI +181/6.53, GST).

f. The computer determines and sends the following fire commands to the battery: BASE PIECE ADJUST, SHELL HE, LOT QUEBEC NOVEMBER, CHARGE 5, FUZE TIME, BASE PIECE 1 ROUND, AT MY COMMAND, DEFLECTION 3198, TIME 22.0, QUADRANT 363.

Note. The computed data cannot exceed the previously stated limitations.

g. The radar observes six usable rounds and the radar section ends the missions with the report END OF MISSION. The radar section computes the mean burst location and sends the following report to the FDC.

h. Message from radar: HIGH BURST REGISTRATION OBSERVED, AVERAGE DIRECTION 6310, AVERAGE DISTANCE 5850, AVERAGE VERTICAL ANGLE PLUS 28.

i. The chart operators polar plot the announced high-burst location from the radar location and announce the following chart data:

(1) HCO: RANGE 6340, DEFLECTION 3191.

(2) VCO: SITE PLUS 30 (VI +167/6.34, GST).

ANGLE OF SITE +27 (167/6.34, C and D scales, GST).

Note. Since the vertical interval exceeds 100 meters, the complementary angle of site must be considered in the determination of the total fuze correction.

j. The computer determines the total fuze correction and the adjusted fuze setting at the level point.

(1) Complementary angle of site is +3 (+30 − (+27)).

(2) Adjusted elevation is 333 (363 − (+30)).

(3) Adjusted elevation plus complementary angle of site is 336 (333 + (+3)).

(4) Fuze setting for adjusted elevation plus complementary angle of site is 22.3.

(5) Total fuze correction is −0.3 (22.0 −22.3).

(6) Fuze setting for adjusted elevation is 22.1.

(7) Adjusted fuze setting at the level point is 21.8 (22.1 + (−0.3)).

k. The following data are derived from this registration:

Chart data		*Adjusted data*	
Deflection	3,191 mils	Deflection	3,198 mils
Range	6,340 meters	QE	363 mils
Site	+30 mils	Elevation	333 mils
		Time	21.8
			(at level point)

GFT A: Chg 5, lot QN, rg 6340, el 333, ti 21.8. Total deflection correction L7.

19–39. Example 3—Radar Registration

a. Battery C (155-mm howitzer) has just occupied a position during an intense fog. Survey is complete but, because of the fog, the established OP's have very limited visibility. An AN/MPQ–4A radar section is located in an adjacent battery perimeter. The battery fire direction officer decides to fire a radar-observed mean-point-of-impact registration at grid intersection 6336 (charge 4). The altitude of the battery is 348 meters and the altitude of the radar is 358 meters.

b. The HCO measures and announces the following data measured from Battery C to grid intersection 6336.

(1) RANGE 5180.

(2) DEFLECTION 3047.

c. The HCO measures and announces the direction and distance from the radar to grid intersection 6336 and the FDC sends the following message to observer: OBSERVE MPI REGISTRATION FOR LOUD THUNDER 18, DIRECTION 5990, DISTANCE 4670, REPORT VERTICAL ANGLE, REPORT WHEN READY TO OBSERVE.

d. Report from radar: VERTICAL ANGLE PLUS 14, AMC, REQUEST SPLASH, READY TO OBSERVE.

e. The VCO computes the altitude of the selected datum plane to be 422 meters and determines and announces, SITE CHARLIE, PLUS 17 (VI +74/5.18, GST).

f. The computer determines the following fire commands and sends them to the firing battery: BASE PIECE ADJUST, SHELL HE, LOT LIMA SIERRA, CHARGE 4, FUZE QUICK, BASE PIECE 1 ROUND, AT MY COMMAND, DEFLECTION 3047, QUADRANT 337.

g. The radar observes six usable rounds and the radar section ends the mission with the report END OF MISSION.

h. The radar section computes the location of the mean point of impact in the selected datum plane and sends the following message to the fire direction center: MPI REGISTRATION OBSERVED, AVERAGE DIRECTION 6115, AVERAGE DISTANCE 4380, AVERAGE VERTICAL ANGLE PLUS 18.

i. The chart operators plot the announced MPI location and determine the following data:

(1) Horizontal control operator: Range 4830, deflection 3053.

(2) Vertical control operator: Vertical interval +86 (434 −348). Site +20 (+86/4.83, GST).

j. The following data are derived from this registration:

Chart data		*Adjusted data*	
Deflection	3,053 mils	Deflection	3,047 mils
Range	4,830 meters	QE	337 mils
Site	+20 mils	Elevation	317 mils
			(337 − (+20))

GFT C: CHARGE 4, LOT LS, RANGE 4830, ELEVATION 317.
Total deflection correction R6.

Section V. REGISTRATION WITH MORE THAN ONE AMMUNITION LOT

19-40. General

Although the ballistic characteristics of propellants vary from one lot to another, the ballistic differences between projectile lots are negligible. The corrections for difference in weight of projectile can be computed. Because of this, registration with the same propellant lot and different projectile lots provides no appreciable gain in accuracy and is not necessary. Only when a large quantity of propellant from a partcular lot is on hand should a registration be made with the lot. The procedure described in this section applies when more than one large quantity propellant lot is on hand.

19-41. Procedure for Registration With More Than One Lot

a. As soon as the adjusted quadrant elevation has been determined for the first lot, registration is begun with the second lot. The observer is sent the message OBSERVE SECOND LOT REGISTRATION, which notifies him that he should continue to spot for range and deviation as he did with the first lot.

b. The first round of the second lot is fired with the adjusted quadrant elevation of the first lot. As soon as a definite FDC range spotting has been obtained, the quadrant elevation is changed 1 even fork in the appropriate direction. The value of fork is the same as that determined initially for the first lot. This procedure is continued until an even fork bracket has been established. The fork bracket is then split. Procedures in paragraphs 19-13 and 19-14 are followed as in the registration with the first lot of ammunition.

c. The correct deflection established for one lot is used for all lots because deflection is not affected appreciably by the ballistic differences between lots. Therefore, if the correct deflection has not been established for the first lot by the time the adjusted elevation is determined, the registration with the second lot is begun and the deflection adjustment is continued during the second registration until the correct deflection has been established.

d. If a sufficient number of impact fuzes of one lot are available, fuzes of that lot should be used throughout the impact registrations with the first propellant lot and other propellant lots of multiple-lot registrations. However, the use of impact fuzes of different lots will not affect the impact registration.

e. Time fuzes of one lot must be used throughout a given time registration. However, if time fuzes of one lot are to be used with two or more propellant lots, the total fuze correction determined for that fuze lot with one of the propellant lots normally is valid for use with the other propellant lots.

Section VI. FIRE DIRECTION PROCEDURES FOR ABCA PRECISION FIRE

19-42. General

In order to obtain the desired results when using the ABCA registration procedures, the FDC must be as familiar with observer procedures as is the observer. These procedures are covered in paragraphs 13-29 through 13-32.

19-43. Impact Registration

In an ABCA impact registration the final pin location on the firing chart, as directed by the observer, is the location from which the adjusted data are determined. When a 1:50,000 chart is being used, refinement at the split of the 100-meter bracket may be accomplished with the M17 plotting board by use of the technique outlined in paragraphs 24-68 and 24-69. For an air observer mission, or any mission adjusted along the gun-target line, data may be determined by use of 100/R and the C factor as outlined in paragraph 24-70.

19-44. Time Registration

The initial round in the ABCA time registration is fired at the fuze setting corresponding to the adjusted elevation and the correct deflection and at the adjusted QE increased by 20/R. The FDC converts all observer HOB corrections to fuze setting corrections by use of the ΔFS factor. The final HOB correction is converted to an adjusted time that results in a height of burst 20 meters above the registration point.

CHAPTER 20

DETERMINATION AND APPLICATION OF REGISTRATION CORRECTIONS

Section I. INTRODUCTION

20-1. Determination of Registration Corrections

Registration corrections consist of total range, fuze, and deflection corrections. Fire direction center personnel compute these corrections by comparing the chart, or "should hit," data determined from the firing tables with the adjusted, or "did hit," data determined from the registration.

20-2. Application of Registration Corrections

When properly applied, registration corrections permit transfer of fires (i.e., firing for effect upon an accurately located target) without an adjustment. Registration corrections also facilitate accurate plotting of targets located by the adjustment of fire.

Section II. REGISTRATION RANGE CORRECTIONS

20-3. Computation of Total Range Correction

a. If standard conditions exist, the elevation to be fired to achieve the chart range is the elevation listed in the firing table for that range. When nonstandard conditions exist, the range achieved by firing a particular elevation differs from the range indicated in the firing tables by an amount equal to the cumulative effect of all nonstandard conditions.

b. The chart range for a registration is measured from the battery center to the registration point, mean point of impact, or high burst. If the registering piece is in front of or behind the battery center, the measured chart range is not the achieved range. The adjusted elevation from a registration is the elevation that achieved the range from the registering piece to the registration point. This achieved range is also the GFT setting range. The achieved range is equal to the chart range modified by the distance the base piece is in front of or behind the battery center, when the weapon is pointing on the initial azimuth of lay.

Example: A 155-mm howitzer M109 battery has registered with charge 5GB (M3 propellant). Chart range is 5,000 meters. The adjusted elevation is 245. The base piece is 30 meters behind the battery center (fig 20-1). The achieved range (GFT setting range) is 5,030 meters (5000 + 30).

c. The adjusted elevation is the sum of the elevation listed in the firing tables for the achieved range and the elevation correction necessary to compensate for the cumulative effect of all nonstandard conditions. The total range correction is the difference in meters between the achieved range and firing table range corresponding to the adjusted elevation. The total range correction is determined in the following manner:

(1) Determine, from the firing tables, the range corresponding to the adjusted elevation.

(2) Subtract the achieved range from the range corresponding to the adjusted elevation. The result is the total range correction.

d. The accuracy to which the total range correction is determined depends on whether the graphical firing table (GFT) or the tabular firing tables (TFT) are used in determining the range corresponding to the adjusted elevation. With the GFT, the range and the total range correction are determined to the nearest 10 meters. With the TFT the range and the total range correction are determined to the nearest meter. The total range correction is a signed value.

Example: Continuing the example in *b* above, the range corresponding to elevation 245 (GFT) is 5170 and the total range correction is +140 (5170 − 5030 = +140).

20-4. Determination and Application of Range K.

a. The range K is an expression of the total

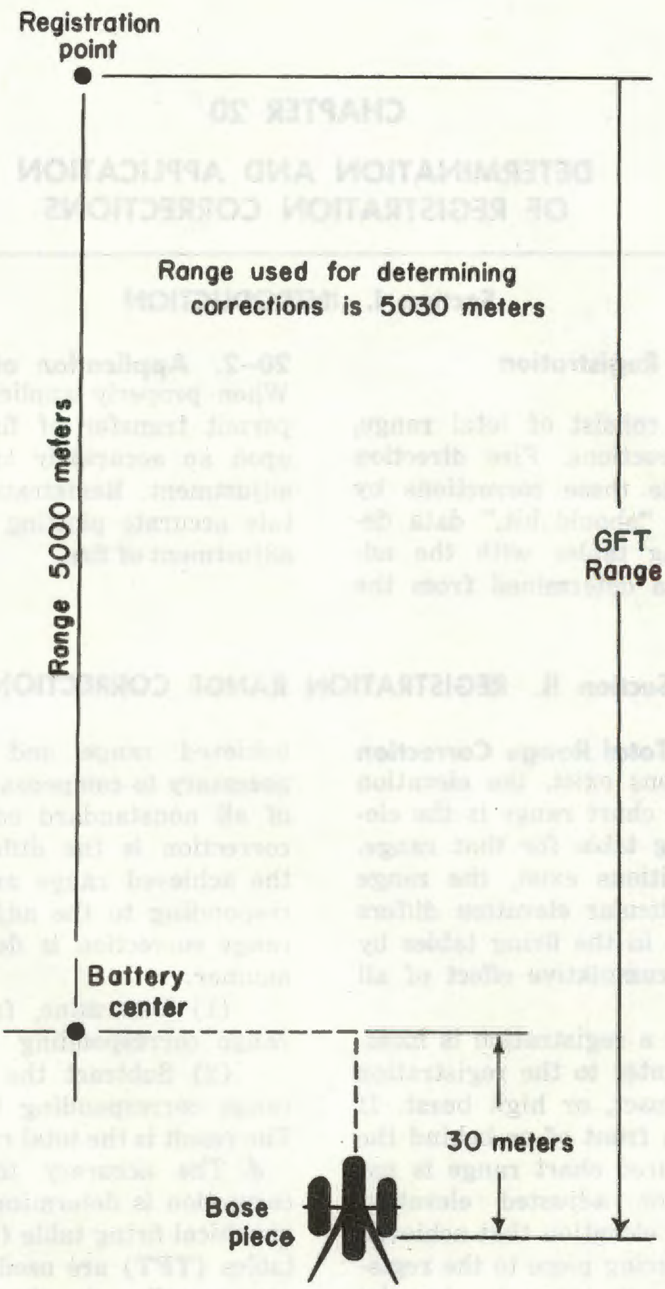


Figure 20-1. Base piece displacement correction—range.

range correction as a ratio of meters correction per thousands of meters in range. The range K is equal to the total range correction divided by the achieved range in thousands of meters (to the nearest 100 meters).

Example: Continuing the example in paragraph 20-3b, the range K is determined as follows:

Range K = $\frac{+140}{5.0}$ = +28.0, or +28 meters per 1,000 meters.

b. Within transfer limits, the total range correction is assumed to vary directly with chart range. The total range correction to be applied for a target within transfer limits is determined by multiplying the range K by the chart range to the target in thousands (to the nearest 100 meters).

c. The elevation to be fired is the elevation corresponding to the sum of the total range correction (*b* above) and the chart range, expressed to the nearest 10 meters.

Example: Continuing the example, the battery is to fire on a target at a chart range of 6,120 meters with charge 5 green bag with the range K computed in *a* above, the elevation to be fired is determined as follows:

Range correction =	
+28 × 6.1 = 171 ----	+170 meters
Chart range ----------	6,120 meters
	6,290 meters

Elevation corresponding to range 6290 = 314.9, or 315 mils.

d. Normally, a range K is computed and applied only when graphical equipment is not available. In the computation of the range K from the tabular firing tables interpolation for elevation and range is required. The table is entered with range to the nearest 10 meters. The discussion of the application of range K in *b* and *c* above assumes that range K is a constant. Range K is not a constant and the fact that it is a variable is taken into account in the construction of the slant scale GFT.

20–5. Total Fuze Correction

a. A time registration or a high-burst registration will yield an adjusted, or "did hit" time. If all conditions were standard and if there were no variation in the function of time fuzes (no manufacture's tolerance and no effects from handling and storage), the time corresponding to the adjusted elevation (or elevation plus comp site if the vertical interval exceeds 100 meters) would be the adjusted time. But this is not the case and registration is necessary. The time corresponding to the adjusted elevation is also known as the chart time. The correction necessary to correct for the combined effects of nonstandard conditions on fuze setting is called the total fuze correction.

b. The total fuze correction is equal to the adjusted time minus the fuze setting listed in the firing tables corresponding to the adjusted elevation (or elevation plus complementary angle of site). The total fuze correction is determined to the nearest 0.1 and is a signed value.

Example: Continuing the example in paragraph 20–3*b*, the adjusted time obtained was 16.3. The fuze setting corresponding to the adjusted elevation of 245 is 16.6. The total fuze correction is −0.3 (16.3 − 16.6).

20–6. Application of Total Range and Total Fuze Corrections

Use of total range and total fuze corrections as determined in paragraphs 20–3 and 20–5 is covered in chapter 21.

20–7. GFT Settings

a. Corrections determined by registration (or met plus VE computation) usually are portrayed graphically on the graphical firing table in the form of a GFT setting. GFT settings are of three types: one-plot, two-plot, and multiple-plot. The GFT setting contains the following elements (in the sequence indicated): The unit that registered, the charge fired, the ammunition lot, the achieved range (chart range modified by base piece displacement) to the nearest 10 meters, the adjusted elevation, and, if determined, the adjusted time.

Examples:

(1) One-plot GFT setting:
GFT B: Charge 5, lot XY,
range 5920, elevation 305, time 19.9

(2) Two-plot GFT setting:
GFT B: Charge 5, lot XY,
range 4510, elevation 207, time 13.7
range 7490, elevation 398, time 24.4

(3) Multiple-plot GFT setting:
GFT B: Charge 5, lot XY,
range 3500, elevation 151, time 10.0
range 5600, elevation 261, time 16.6
range 8390, elevation 434, time 26.1

b. One-Plot GFT Setting. Known corrections from one registration (or one met plus VE computation) are portrayed graphically on the GFT in the form of a one-plot GFT setting. For the one-plot GFT setting, the registration point (met checkpoint) must be selected so that the range to the registration point (met checkpoint) falls between the red numbered elevations on the elevation scale. Transfers may be made to all elevations within the red numbered elevations as described in paragraph 20–10.

(1) The one-plot GFT setting is placed on the GFT in the following manner:

(*a*) Place the hairline over the GFT setting range.

(*b*) Place a black dot on the cursor over the adjusted elevation.

(*c*) Place a red dot on the cursor over the adjusted time.

(*d*) Slide the cursor so that the black dot is over the black dashed line (RG K line) at the right end of the scale.

(*e*) Construct the elevation gageline by drawing on the cursor a fine black line over the dot at the same angle as the dashed line. Extend the elevation gageline from the top to the bottom of the cursor and label the gageline "EL."

(*f*) Slide the cursor so that the red dot is over the black dashed line (FZ K line) at the left end of the rule.

(*g*) Construct the time gageline by drawing on the cursor a fine red line over the red dot at the same angle as the dashed line. Extend the time gageline from the top to the bottom of the cursor and label the gageline "TI."

(2) Data are read from a one-plot GFT setting in the following manner:

(*a*) Place the hairline over the chart range.

(*b*) Read the elevation under the elevation gageline.

(*c*) Read 100/R under the hairline.

(*d*) Read fork or drift under a visually simulated line parallel to the hairline and through the intersection of the elevation gageline and the elevation scale.

(*e*) For the M564 fuze, read the fuze setting under the time gageline. For VT fuze, read the fuze setting under the simulated line ((*d*) above) at the point where the line crosses the fuze setting scale. If the fuze setting for the VT fuze is not a whole number, use the next lower whole number. For example, if the number is 25.8, use 25.0.

(*f*) Read the change in fuze setting for a 10-meter change in height of burst under a visually simulated line parallel to the hairline and through the intersection of the time gageline and the fuze setting scale.

Example: Assume that the chart range to the target is 7,120 meters. Use the one-plot GFT setting shown in the example in *a*(1) above. Place the hairline over 7120 on the range scale (①, fig 20–2) and read the following data:

Elevation	393 mils
100/R	14 mils
Fork	5 mils
Drift	7 mils
Fuze setting	25.0
Change to fuze setting of a 10-meter change in height of burst	0.08

c. Two-Plot GFT Setting. When corrections from two registrations, two met plus VE computations, or a combination thereof are known, a two-plot GFT setting can be constructed. The two-plot GFT setting is more accurate than the one-plot GFT setting and can be used for the full range of the GFT without regard to range transfer limits.

(1) The two-plot GFT setting is placed on the GFT in the following manner:

(*a*) Determine corrections in the lower third and in the upper third of the ranges of the GFT for the charge.

(*b*) Place the hairline over the GFT setting range to one of the registration points or met checkpoints.

(*c*) Place a black dot on the cursor over the adjusted elevation and a red dot over the adjusted time.

(*d*) Repeat the steps in (b) and (*c*) above for the other registration point or met checkpoint.

(*e*) Construct the elevation gageline by drawing on the cursor a fine black line connecting the two black elevation dots. Extend the elevation gageline from the top to the bottom of the cursor and label the gageline "EL."

(*f*) Construct the time gageline by drawing on the cursor a fine red line connecting the two red dots. Extend the time gageline from the top to the bottom of the cursor and label the gageline "TI."

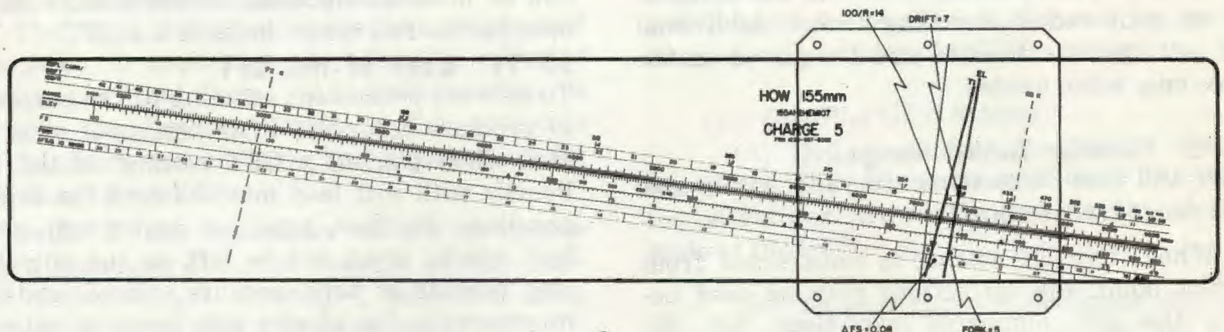
(2) Data from the two-plot GFT setting gagelines are read in the same manner as those from the one-plot GFT setting gageline (②, fig 20–2).

d. Multiple-Plot GFT Setting. If the situation permits determining corrections to three or more points, a multiple-plot GFT setting can be constructed. The multiple-plot GFT setting is even more accurate than the two-plot GFT setting and, like the two-plot GFT setting, can be used for the full range of the GFT without regards to range transfer limits. The multiple-plot GFT setting is constructed as follows: Assume that the gun direction computer M18 (FADAC) is available and the GFT is available, and the GFT is being used as a backup system. The FADAC operator has obtained the following chart ranges and corresponding adjusted elevations and adjusted times:

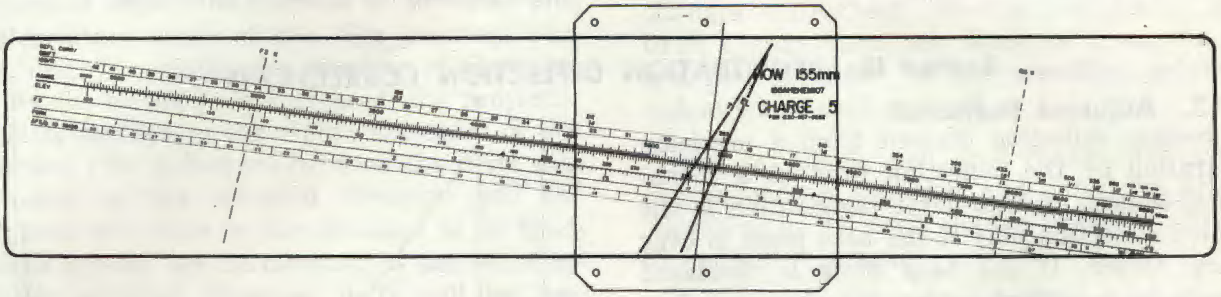
Range	*Elevation*	*Time*
2900	120	8.6
4300	185	13.1
5700	255	17.8
7100	330	22.6
8500	414	27.8

(1) For each plot move the hairline over the chart range and place a black dot on the cursor over the corresponding elevation and a red dot over the corresponding time.

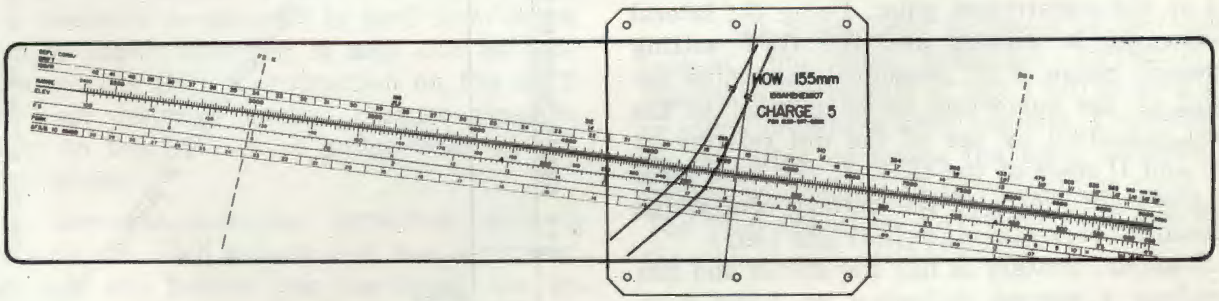
(2) Construct the elevation gageline by drawing a series of fine black lines connecting the black dots. Construct the time gageline by drawing a series of fine red lines connecting the red dots. The resulting elevation and time gagelines are more accurate than those of either the one- or two-plot GFT setting.



①
Figure 20–2. One-plot GFT setting.



②. Two-plot GFT Setting.
Figure 20–2—Continued.



③. Multiple-Plot GFT Setting.
Figure 20–2—Continued.

(3) Data from the multiple-plot GFT setting gagelines are read in the same manner as those from the one- and two-plot GFT setting gagelines (③, fig 20–2).

20–8. Selection of GFT Settings

a. When only one battery of a battalion has registered, the GFT setting of that battery will be used by nonregistering batteries of the same caliber. It is desirable, therefore, that the center battery conduct the registration unless it is greatly echeloned in range from the flank batteries, in which case the battery nearest the mean range to the registration point should conduct the registration. If the batteries are widely separated in range or direction of fire to the registration point, the common GFT setting will not accurately reflect corrections for the nonregistering batteries. However, in the absence of other registration data, it will provide the best firing data available. The FDC can improve the accuracy of the corrections for the nonregistering batteries by applying to the common GFT setting the differences in shooting strength between base pieces.

b. If all batteries have registered with the same charge and this charge is to be used in a mission, each computer uses the GFT setting established by the registration of his battery.

20–9. GFT Settings for More Than One Lot

If the same charge has been used for registration with more than one lot of ammunition, two GFT settings may be placed on the cursor. The gagelines may be marked with the lot designation or color coded according to lot. Additional GFT settings are recorded and are placed on the cursor only when needed.

20–10. Transfer Limits—Range

Range and fuze corrections are valid within specified range transfer limits.

a. When the GFT setting is constructed from one plot point, the corrections may be used between the red numbered elevations for the charge.

b. When the GFT setting is constructed from two or more plot points, the corrections may be used for the full range limits of the GFT.

20–11. Care of the GFT

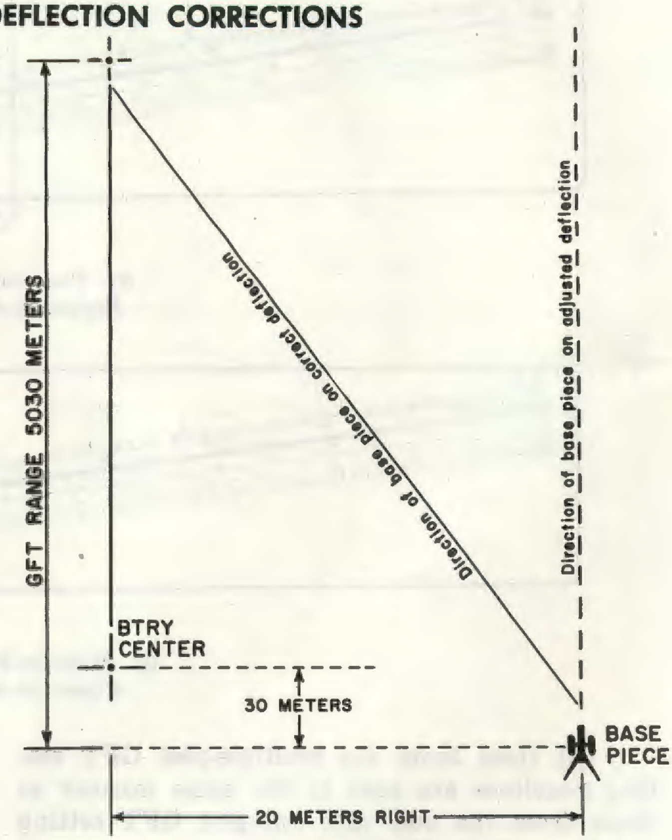
To prevent permanent scarring of the cursor and to promote accuracy, FDC personnel must take care when placing a GFT setting on the GFT. Pencils with soft lead must be used for drawing gagelines. Further, gagelines drawn with colored lead pencils must not be left on the cursor for long periods of time, because colored lead tends to penetrate the plastic and becomes extremely difficult to remove. It is to be emphasized that, for accuracy, pencils sharpened to a fine point must be used for drawing gagelines.

Section III. REGISTRATION DEFLECTION CORRECTIONS

20–12. Adjusted Deflection

The correct deflection derived from a precision registration or the deflection fired in a mean-point-of-impact or high-burst registration is the adjusted deflection only if the base piece is over battery center. If the base piece is displaced laterally from battery center, the correct deflection must be modified to compensate for the displacement so that the battery sheaf will be centered on the registration point. Using the lateral displacement in meters and the GFT setting (achieved) range, FDC personnel determine the amount of the correction to be applied to the correct deflection by use of the mil relation or the C and D scale of the GST. If the base piece is to the right (left) of the battery center, the displacement correction is to the right (left).

Example: Battery B has registered and has determined a correct deflection of 3,252 mils. The GFT setting range is 5,030 meters. The base piece is 20-meters to the right of the battery center (fig 20–3). The correction for base piece displacement is right 4 mils (20/5.03, GST). The adjusted deflection is 3,248 mils (3,252 −4).



Displacement correction for deflection = $\frac{\text{20 METERS RIGHT}}{5.030}$ = Right 4 mils

Figure 20–3. Base piece displacement correction-deflection.

20–13. Total Deflection Correction

The total deflection correction is the correction that must be applied to the chart deflection to a target in order to determine a deflection that will hit the target. The adjusted deflection determined from a registration is the deflection that placed the mean burst center of the rounds from all pieces in the battery at the registration point or the mean-point-of-impact or high-burst location. The numerical value of the total deflection correction for the registration point (mean-point-of-impact or high-burst location) is equal to the adjusted deflection minus the chart deflection. If the adjusted deflection is greater (less) than the chart deflection, the correction is plus (left) minus (right).

Example: A registration has been completed on registration point 1. The adjusted deflection is 3248. The chart deflection to registration point 1 is measured as 3,256 mils. The total deflection correction for registration point 1 is minus (right) 8 (3248–3256 = −(R)8).

20-14. Deflection Correction Scale

a. The total deflection correction determined to a point is applicable only for the adjusted elevation to that point. As the elevation is changed, the resultant drift of the projectile will change correspondingly and a correction for drift must be applied.

b. Drift is the departure of the projectile from a standard direction because of the combined action of air resistance, projectile spin, and gravity. Since all US cannons impart a right-hand spin to the projectile, the drift is always to the right. Drift is a function of time of flight, and time of flight is a function of elevation plus complementary angle of site. For practical purposes, drift is considered a function of elevation.

c. As the elevation is increased, the projectile will drift farther to the right; therefore, a left correction (the difference between the drift that will occur at the adjusted elevation and the drift that will occur at the elevation to be fired) must be applied. As the elevation is decreased below the adjusted elevation, drift will be less; therefore, the correction for its effect will be less.

d. For convenience, a deflection correction scale is normally constructed in card form or on a sheet of paper; however, it may also be constructed on the GFT. Construction on the GFT is the least desirable method because constant erasures on the GFT cause undue wear on the ballistic scales.

e. A separate deflection correction scale is constructed for each battery that has registered. When only one battery has registered, the deflection correction scale based on the GFT setting of the registering battery is used by all batteries of the same caliber.

20-15. Construction of the Deflection Correction Scale

a. Normally, the deflection correction scale is constructed by the computer. The procedure used will depend on whether it is based on one-plot, two-plot, or multiple-plot GFT settings.

(1) *One-Plot GFT Setting.*

(*a*) Deflection transfer limits for the one-plot GFT setting are applicable throughout the elevations printed in red on the elevation scale of the GFT.

(*b*) To construct the deflection correction scale, draw a line 4 to 5 inches long on a card or sheet of paper, then draw short lines perpendicular to the first line to represent the drift changes throughout the transfer limits. These drift change lines are obtained from the GFT and are identified by the elevation printed in red, at which drift changes.

(*c*) Mark each drift change line with its corresponding elevation and enter the adjusted elevation in the drift change block that brackets the adjusted elevation.

(*d*) Enter the total deflection correction from the registration below the adjusted elevation.

(*e*) Since drift increases as elevation increases, the total deflection correction will change in increments of left 1 mil at each greater elevation where drift changes. Conversely, as the elevation decreases the total deflection correction will change in increments of right 1 mil. The total deflection corrections are recorded on the scale in each drift block.

Example: Assume that a registration was conducted with charge 5, M3 propellant, that the adjusted elevation was 330, and that the total deflection correction was L8. The deflection correction scale is constructed in card form as follows:

200–212	212–263	263–310	310–354 (330)	354–395	395–433	433–470	470–500
L5	L6	L7	L8	L9	L10	L11	L12

(*f*) The deflection correction scale is constructed on the GFT by recording the total deflection correction in each drift block (fig 20-4).

(2) *Two-plot GFT setting.*

(*a*) When two total deflection corrections are determined from two registrations, or two met plus VE computations, or from one registration and one met plus VE computation for the same general direction (within 200 mils), a deflection correction graph that is valid for the full range of the charge is constructed. Each total deflection correction is plotted on the graph opposite the appropriate adjusted elevation and a straight line is drawn through the two points and extended to the limits of the elevation scale. Figure 20-5 illustrates a deflection

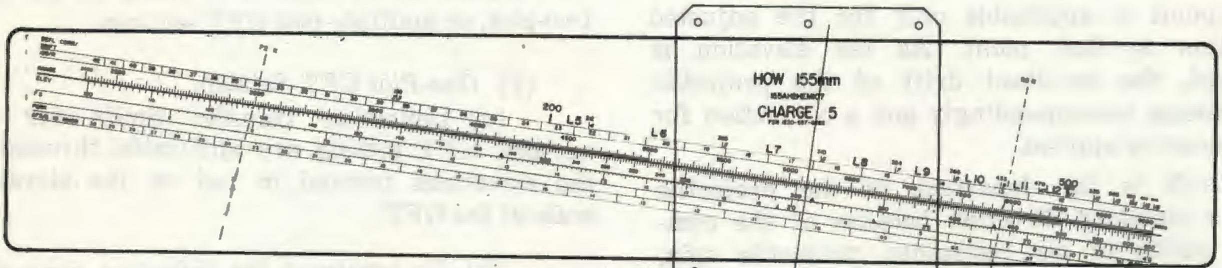


Figure 20–4. Deflection correction scale on the GFT.

correction graph constructed from the following adjusted data for charge 5, M3 propellant.

Elevation 190—total deflection correction R4

Elevation 438—total deflection correction L6

(*b*) When corrections are based on one registration and one met plus VE solution, the possibility exists that a position deflection correction is included in the total deflection correction to the registration point. This position deflection correction is isolated and then applied to the met deflection correction.

1. Assume that a registration and a concurrent met resulted in the following data:

Adjusted elevation ... 190

Total deflection correction R4

Met deflection correction R2

2. To isolate the position deflection correction, subtract the met deflection correction to the registration point (R2) from the total deflection correction (R4). The result is the position deflection correction.

Position deflection correction .... R2 (R4 − R2).

3. Assume that a met plus VE solution to a target in the same direction as the registration point but at a greater range resulted in the following data:

Adjusted elevation ... 358

Met deflection correction L8

4. To obtain the total deflection correction at elevation 358, add the position deflection correction, which is considered a constant, to the met deflection correction to the target (L8 + R2 = L6).

5. Using the two total deflection corrections (R4 and L6), follow the steps outlined for the two-plot deflection correction graph.

(3) *Multiple-plot GFT setting*. When three or more total deflection corrections are determined, each total deflection correction will be plotted on a deflection correction graph (as described in (2) above) at the corresponding adjusted elevation. A series of straight lines is used to connect all the total deflection corrections. The lines at the lowest and highest elevations are extended to the limits of the elevation scale.

b. After the deflection correction scale or graph has been constructed, the total deflection correction for any point within transfer limits can be determined by entering the scale or graph with the elevation to a point and extracting that total deflection correction corresponding to that elevation. This correction is applied to the chart deflection and the sum is the piece deflection.

c. An alternate method of determining the total deflection correction to be used for a given mission is by use of the GFT deflection

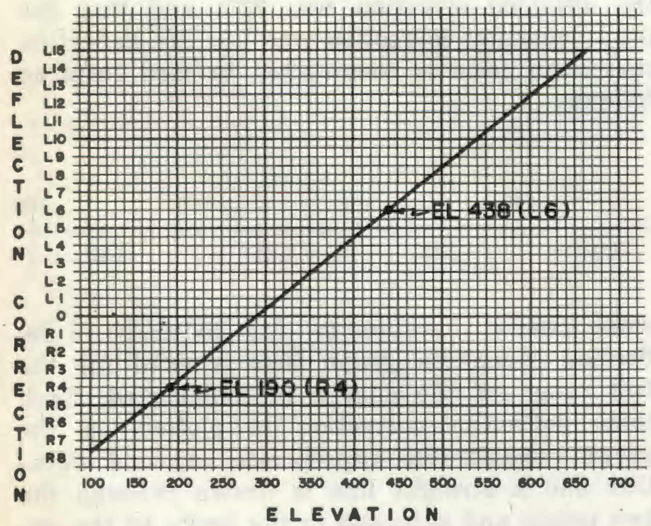


Figure 20–5. Two-plot deflection correction graph.

correction. (Use the data from the example following *a*(1)(*e*) above).

(1) Determine the drift block in which the adjusted elevation is located (el 330, drift block 6). The number 6 represents the number of mils the projectile will drift to the right between elevations 310 through 354. It is also the number of mils necessary to correct for drift.

(2) Subtract the drift correction (L6) from the total deflection correction (L8). The difference is the GFT deflection correction (L2). The GFT deflection correction can then be recorded with the GFT setting and placed on the cursor as a ready reference.

(3) To use the GFT deflection correction, determine the drift for the elevation to be fired and add the drift correction to the GFT deflection correction. The sum is the total deflection correction to be used.

Example: Using the data above, assume that a mission is to be fired and the drift for the elevation to be fired is R9. Drift correction L9 plus the GFT deflection correction L2 equals a total deflection correction of L11

20–16. Transfer Limits—Deflection

a. Deflection corrections determined by registration or met plus VE computation are valid within specified deflection transfer limits.

(1) When the GFT setting range is 10,000 meters or less, deflection corrections are valid between 400 mils left and 400 mils right of the battery-registration point line.

(2) When the GFT range is greater than 10,000 meters, deflection corrections are valid between 4000 meters left and 4000 meters right of the battery-registration point line.

b. Deflection corrections may be used throughout 6,400 mils if valid meteorological data have been determined and applied in the form of an 8-directional met. The 8-directional met technique is described in paragraph 21–16.

Section IV. REPLOTTING TARGETS

20–17. General

a. Fire-for-effect chart data, particularly altitude (site), sometimes are not precise. Within the battalion, fire-for-effect data, if used again without changing the ammunition lot, usually will cause effective fire to fall on the target. However, if the target location is to be sent outside the battalion, the coordinates and altitude sent must reflect the actual ground location as accurately as possible. These may be determined by a process known as *replot.* A valid GFT setting for the time at which the target was fired is required for accurately replotting a target. The degree to which the target data determined by replot correspond to the actual ground location of the target depends on the accuracy of the corrections applied—the more accurate the corrections, the more accurate the target data.

b. FDC personnel replot a target only when the observer has requested or the S3 has directed that the target be recorded. Replot data consist of the grid and altitude of the target, the type of fuze fired in effect, and the target number. The procedure used for determining replot data differs for each type of fuze used in fire for effect.

20–18. Point Detonating Fuze (Quick and Delay)

a. During the adjustment of point-detonating fuze, the observer seldom corrects for difference in altitude; therefore, the site fired is often not the true site to the target. Any error in site will be reflected as a range error on the firing chart. If the true site to the target is determined and then subtracted from the quadrant elevation used in fire-for-effect, the resulting elevation can be used to determine the true chart range to the target. FDC personnel, using a map, determine true site by successive approximation.

b. Since the total deflection correction may not have been applied during the mission, or if used, may not have been the most valid, a replot deflection must be determined that will reflect the actual chart deflection to the target. The replot deflection will be the fire-for-effect deflection to the final pin location minus the total deflection correction from the deflection correction scale that corresponds to the fire-for-effect elevation to the final pin location (*g* below).

c. The adjusting battery computer announces the replot deflection and range to the HCO. The replot deflection is determined as in *b* above and the replot range is the range read under the hairline when the elevation gageline is placed over the elevation corresponding to the final pin location. The HCO polar plots the target from the battery center of the adjusting battery at the range and deflection announced by the computer, and determines and announces the grid to the VCO. The VCO plots the grid and determines the map altitude at the replotted location. Using this altitude and the replot range last announced by the computer, the VCO computes the first apparent site and announces this site to the computer.

d. If the site announced by the VCO does not agree within 1 mil of the site fired, the computer subtracts the new site from the quadrant elevation and uses the resulting elevation to determine a new replot range. The replot deflection remains the same.

e. The HCO polar plots the new data and announces the grid to the vertical control operator. The VCO plots these grid coordinates and determines the map altitude of the replotted location. This procedure, referred to as successive approximation, is repeated until the site announced by the VCO agrees within 1 mil of the site previously computed.

f. When the site announced by the VCO agrees with, or within 1 mil of, the previous site computed, the computer uses the final site to compute the final replot elevation.

g. The computer announces the final replot range based on the final elevation. The HCO polar plots the target at the deflection and range announced by the computer. He then announces to the computer the grid to be recorded. The VCO announces the altitude used to determine the final site. The computer records on the computer's record the grid, altitude, fuze used in fire for effect, and target number.

Example: The GFT setting of Battery A (155-mm howitzer M109) is GFT A: Charge 4, lot ZT, range 5270, elevation 350. The total deflection correction from registration is left 8. The altitude of the battery is 405 meters.

Fire-for-effect data: Target AF7601 (charge 4, fuze quick).

Deflection fired	3,214 mils
Chart deflection	3,206 mils
Quadrant fired	373 mils
Site initially computed	−11 mils
Elevation corresponding to final pin location (373 − (−11))	384 mils
Computer to HCO:	
Replot deflection (fire-for-effect deflection minus total deflection correction L9)	3,205 mils
Replot range (range corresponding to elevation 384)	5,630 meters
The HCO polar plots deflection 3205 and range 5630. He reads and announces the grid 43713421 to the VCO. The VCO plots the grid and determines the altitude of the point to be	366 meters
The VCO computes the first apparent site and announces it to the computer (vertical interval −39 meters, range 5630)	−8 mils
The computer determines the second apparent elevation (373 − (−8))	381 mils
Computer to HCO:	
Replot deflection	3,205 mils
Replot range (range corresponding to elevation 381)	5,600 meters
The HCO polar plots, these data and announces grid 43743417 to the VCO. The VCO plots the grid and determines the altitude of this point to be	363 meters
The VCO computes the second apparent site and announces it to the computer (vertical interval −42 meters, range 5600)	−9 mils
Site agrees within 1 mil of last site computed. The computer determines the final replot elevation (373 − (−9))	382 mils
Computer to HCO:	
Replot deflection	3,205 mils
Replot range (range corresponding to elevation 382)	5,610 meters
The HCO polar plots these data and announces replot grid 43733416 to the computer. The VCO announces the altitude used to determine final site (−9 mils):	363 meters
Replot data are:	
Grid 43733416, altitude 363, fuze quick, target AF7601.	

20–19. Fuze VT

The procedure for replotting a target attacked with VT fuze is the same as that for replotting a target attacked with point-detonating fuze (para 20–18) except that the quadrant elevation and site used in the successive approximation are the quadrant elevation and site used in fire for effect minus the height-of-burst correction that was fired.

20–20. Fuze Time

a. The procedure for replotting a target attacked with fuze time is based on the assumption that the observer adjusted the height of burst to 20 meters and, thus, that the final fuze setting is accurate. Consequently, when the time gageline is over the fire-for-effect time, the range read under the hairline is assumed to be the correct range and the elevation read under the elevation gageline is assumed to be the correct elevation. Therefore, no successive approximation is required. To obtain replot data, the computer places the time gageline over the fire-for-effect time, reads 100/R and the range under the hairline, and reads the elevation under the elevation gageline.

b. The computer announces to the HCO the replot deflection (FFE deflection minus total deflection correction) and the range just determined (replot range). To determine total site, the computer subtracts the correct elevation just determined from the fire-for-effect quadrant elevation. This total site is the algebraic sum of ground site and 20/R. The computer determines ground site by subtracting the 20/R corresponding to the replot range from total site. He then announces ground site to the VCO.

c. The HCO announces to the computer the replot grid of the plotted pin location. Using the GST, the ground site announced by the computer, and the replot range, the VCO determines the vertical interval. He then algebraically adds the VI to the battery altitude and announces the sum to the computer as the target altitude.

Example: The GFT setting of Battery A (155-mm howitzer battalion (M109)) is:

GFT A: Charge 4, lot ZT, range 5270, elevation 350, time 19.9 deflection correction L7.

The altitude of the battery is 405 meters.

Fire-for-effect data: Target AF7602 (Charge 4, fuze time)

Deflection fired	3,218 mils
Chart deflection	3,211 mils
Quadrant fired	307 mils
Fire-for-effect time	16.8

The computer places the time gageline over the fire-for-effect time and reads the following data under the hairline: range = 4,590 meters, 100/R = 22 mils. Under the elevation gageline the computer determines the elevation to be 292 mils and the total deflection correction corresponding to elevation 292 to be L7:

Computer to HCO:

Replot deflection	3,211 mils (3218 − L7)
Replot range	4,590 meters

The HCO polar plots these data and announces the grid of the pin location to the computer: grid 43863427. The computer records the coordinates and determines the ground site as follows:

Quadrant elevation	307
Minus correct elevation	292
Total site	+15

100/R at replot range is 22 mils. Therefore 20/R is 4 mils.

Total site	+15
Minus 20/R	−(+4)
Ground site	+11

Computer to VCO: Site +11.

The VCO, using the GST, ground site, replot range, and altitude of the battery, determines the target altitude and announces it to the computer:

Vertical interval	+46 meters (+11 × 4.59)
Plus battery altitude	405 meters
Target altitude	451 meters

Replot data are: grid 43863427, altitude 451, fuze time, target AF7602.

20–21. Replotting Targets with Refinement Data

a. Point-Detonating Fuze. When a mission fired with point-detonating fuze is ended with refinement data, the corrections are plotted on the firing chart and new chart data are determined. A new FFE deflection and QE are determined and replot is performed as outlined in paragraph 20–18.

b. Proximity Fuze. The procedure for replotting a target fired with proximity fuze when refinement data are announced is the same as that described for a target fired with point-detonating fuze except that the quadrant elevation used in the successive approximation is the quadrant elevation determined to the final pin location minus the height-of-burst correction (20/R) that was fired.

c. Mechanical Time fuze. The procedure for replotting a target fired with mechanical time fuze when refinement data are announced depends on the type(s) of correction(s) included in the refinement data.

(1) *Range and/or deviation.* If the refinement data include a correction for range or deviation or corrections for both range and deviation, but no correction for height of burst, it must be assumed that the observer adjusted the height of burst to 20 meters. The horizontal control operator plots the corrections on the firing

chart and determines new firing data. The new deflection is the replot deflection. The computer determines a new fuze setting and a new quadrant elevation based on the new range. He applies the total fuze setting correction (determined during the adjustment) to the new fuze setting to determine the fuze setting that would be used if the data were to be fired. With the fuze setting, deflection and quadrant elevation to fire, the target is replotted as outlined in paragraph 20-20.

(2) *Range and/or deviation and height of burst.* If the refinement data include a correction for range or deviation (or corrections for both range and deviation) and a correction for height-of-burst, FDC personnel initially ignore the height-of-burst correction. If the height-of-burst correction were considered in determining a new fuze setting, an error would be introduced into the replot location by the Δ FS used. For example, the observer sends LEFT 20, ADD 30, DOWN 10, RECORD AS TARGET, END OF MISSION. FDC personnel plot the range and deviation corrections (ignoring the height-of-burst correction) and determine the deflection, quadrant elevation, and fuze setting as described in (1) above. It is assumed that these data will produce a mean burst location of range correct, line, and a height of burst of 30 meters. The computer now applies the height-of-burst correction (down 10) to the last site fired, using the 100/R factor, and applies the new total site to the refinement data elevation to determine the QE to fire. With the fuze setting, quadrant elevation, and deflection to fire, the target is replotted as outlined in paragraph 20-20.

(3) *Height of burst.* If the refinement data include a correction for height of burst only, it must be assumed that range and deviation are correct but that the height of burst is other than 20 meters. For example, the observer sends UP 10, RECORD AS TARGET, END OF MISSION. The computer applies the height-of-burst correction (up 10) to the last site fired, using the 100/R factor, to determine the quadrant to fire. The target is then replotted in the normal manner.

20-22. Use of Corrections

a. Valid corrections for nonstandard conditions must be available if replot is to be conducted. These corrections must be valid for the time at which the target to be replotted was fired upon. These corrections are not necessarily those that were used to fire on the target, since an outdated GFT setting or no GFT setting at all may have been used at that time. However, if valid corrections for the time of firing are determined after firing, they are used in replotting the target.

b. Similarly, if replot is to be conducted and the mission was fired with an outdated total deflection correction or with no total deflection correction, then the valid total deflection correction for the time of firing must be available. It is the total deflection correction corresponding to the fire-for-effect elevation from the mission and is determined from the deflection correction scale. The total deflection correction is subtracted from the fire-for-effect piece deflection. The result is the chart deflection and is used as the replot deflection.

CHAPTER 21
METEOROLOGICAL CORRECTIONS AND VELOCITY ERROR

Section I. THE METEOROLOGICAL MESSAGE

21–1. General

Among the conditions that affect a projectile after it leaves the tube is the state of the atmosphere through which the projectile passes. The three properties of the atmosphere that the United States field artillery units consider in gunnery computations are wind (direction and speed), air temperature, and air density. The meteorological (Met) message contains current information about atmospheric conditions.

21–2. Types of Meteorological Messages

a. Met messages provided for the field artillery are the Ballistic Met message, used for the manual computation of met corrections, and the computer met message, used with FADAC. This chapter will deal only with the ballistic met message.

b. Two types of ballistic met messages are provided for the artillery. The type 2 message is used with air defense artillery. The type 3 message is used with field artillery cannon and free rockets, firing on surface targets, and is the type with which the field artillery is concerned.

21–3. Ballistic Met Message

a. The data contained in cannon artillery firing tables are based on the International Civil Aviation Organization (ICAO) atmospheric structure. The firing tables are arranged in a sequence and a format that coincide with the sequence and format of the ballistic met message.

b: The met message is divided into an introduction and a body (fig 21–1).

(1) The introduction to the met message consists of four six-character groups.

(*a*) *Group 1.* The first three letters (MET) in group 1 designate the transmission as a met message. The fourth letter (B) indicates that it is a ballistic met message. The first digit (3) indicates that it is a type 3 met message. The last digit (0) designates the octant of the earth in which the met station is located. In this case, the met station is located in the Northern Hemisphere between 0° and 90° west longitude. The key to the octant designation code is as follows:

Code number	*Octant*
0	North latitude, 0° to 90° west longitude
1	North latitude, 90° to 180° west longitude
2	North latitude, 180° to 90° east longitude
3	North latitude, 90° to 0° east longitude
4	Not used
5	South latitude, 0° to 90° west longitude
6	South latitude, 90° to 180° west longitude
7	South latitude, 180° to 90° east longitude
8	South latitude, 90° to 0° east longitude
9	Used for coded identification

(*b*) *Group 2.* Group 2 (512018) designates the center of the area in which the met message is valid. This may be expressed in tens, units, and tenths of degrees of latitude and longitude (512 = 51.2° = 51° 12′ north latitude, and 018 = 01.8° = 01° 48′ west longitude). When octant code 9 is used in group 1, the six digits or letters represent the coded location of the meteorological unit that produced the met message.

(*c*) *Group 3.* The first two digits in group 3 (07) represent the day of the month on which the message becomes valid. The next three digits (095) indicate the hour at which the met message becomes valid in tens, units, and tenths of hours (0930). The hours refers to *Greenwich mean time.* (GMT). In a ballistic met message produced by some allied nations, the last digit in group 3 indicates the number of hours the message will remain valid. A 1 indicates 1 hour; a 2, 2 hour; and so on through 8. A 9 represents 12 hours. US met stations do not attempt to predict the number of hours a met message will remain valid. The last digit in group 3 of a met message produced by the US met station is always a 0. In combat, US forces normally receive met data on a 2-hour schedule.

(*d*) *Group 4.* The first three digits of group 4 (049) indicate the altitude of the met station meteorological datum plane (MDP) above mean sea level in tens of meters (490 meters). The next three digits (982) indicate the atmospheric pressure at the MDP, expressed as a percentage (to the nearest 0.1 percent) (98.2 percent) of the ICAO standard atmospheric pressure at mean sea level. When the value is 100 percent or greater, the initial digit 1 is omitted, e.g., 101.6 percent would be expressed as 016 in the met message.

(2) The body of the met message consists of up to 16 met message lines (00 through 15) and each line consists of two six-digit groups. Each line contains the ballistic weather data for a particular altitude zone. Ballistic data are weighted averages of the conditions that exist from the surface up through the altitude zone indicated by the line number.

(*a*) The first two digits of the first group constitute the met message line number which identifies the altitude zone. The lines are numbered in sequence from 00 (surface conditions) through 15 (18,000 meters). Line number 03 is used as an example in (*b*) through (*e*) below.

(*b*) The next two digits in this group (29) indicate the direction from which the ballistic wind is blowing expressed as hundreds of mils (2900) true azimuth.

(*c*) The last two digits in this group (24) indicate the speed of the ballistic wind expressed in knots.

(*d*) The first three digits of the second group (004) indicate the ballistic air temperature expressed as a percentage (to the nearest 0.1 percent) of the ICAO standard temperature. The initial digit 1 is omitted when the value is 100 percent or greater. Thus, 004 indicates an air temperature of 100.4 percent.

(*e*) The last three digits of this group (981) indicate the ballistic air density expressed as a percentage (to the nearest 0.1 percent) of

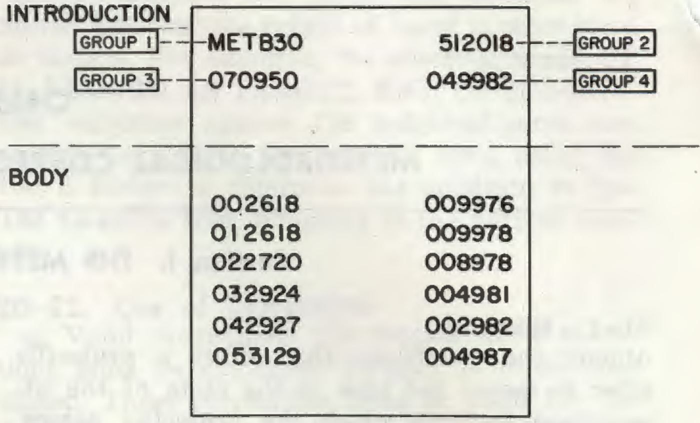


Figure 21-1. The ballastic met message.

the ICAO standard density. Thus, air density is 98.1 percent. If the value is 100 percent or greater, the initial digit 1 is omitted.

21-4. Selection of Meteorological Message Line

One of the keys to the proper solution of the met message is the selection of the proper line of the message. The proper line is that for the altitude closest to the summit of the trajectory.

a. The maximum ordinate (height of the summit of the trajectory above the gun) is a function of quadrant elevation and muzzle velocity (charge). The proper line number can be determined from the Line Numbers of Meteorological Message table (table A) for the appropriate charge. The table is entered with the adjusted quadrant elevation for the point for which the met message is to be solved.

b. If a met message is being solved prior to firing, no adjusted quadrant elevation is known and the line number is determined from the Complementary Range Line Number table (table B) for the appropriate charge. This table is entered at the chart range and height of target above gun, both to the nearest 100 meters.

Section II. POSITION VELOCITY ERROR

21-5. General

a. The best way to determine corrections is by registration. Corrections determined from a registration compensate for the combined effects of all nonstandard conditions that existed at the time of the registration. A portion of the registration corrections compensate for nonstandard conditions that can be determined at the time the registration is being fired. The nonstandard conditions that can be determined are—

(1) Ballistic wind (extracted from the met message).

(2) Ballistic air temperature (extracted from the met message).

(3) Ballistic air density (extracted from the met message).

(4) Weight of projectile (received from the firing battery).

(5) Drift (extracted from the firing tables).

(6) Propellant temperature (measured at the gun position).

(7) Rotation of the earth (extracted from the firing tables).

b. Corrections for the nonstandard conditions listed in *a* above can be computed by use of the firing tables.

c. There are ballistic variations from firing table standards that cannot be measured (for example, tube wear, moisture content of the propellant and shell surface finish). Corrections for these unknown variations are included in the corrections determined from a registration. For convenience, the total of the unknown variations are grouped together and termed position velocity error (position VE). The variations that compose position VE include—

(1) Factors affecting developed muzzle velocity.

(2) Factors affecting the ballistic coefficient of the projectile.

(3) Mechanical limitations and small errors in survey, charts, FDC equipment, met, and fire control instruments.

d. Position VE is a measure of weapon and ammunition performance expressed in terms of meters per second (m/s).

21-6. Determination of Position Velocity Error

The position velocity error can be determined only when the observations upon which the met message is based are concurrent with a registration. The procedure for determining position VE is accomplished by the following steps:

a. Determine the total range correction from the registration as described in paragraph 20-3.

Note. The total range correction may also be computed as follows: Subtract the entry range (para 21-7) (to the nearest meter) from the range corresponding to the adjusted elevation plus complementary angle of site.

b. Compute the met range correction as described in paragraph 21-8. For convenience, corrections for nonstandard projectile weight and rotation of the earth together with corrections for ballistic range wind, air temperature, and air density are considered in the met range corrections.

c. Determine the ΔV range correction by algebraically subtracting the range correction from the total range correction. The symbol "ΔV" is used to represent the total variation from standard muzzle velocity. In the present context, ΔV is the sum of VE and the change to muzzle velocity due to change in propellant temperature.

d. Convert the ΔV range correction to ΔV in meters per second by dividing the ΔV range correction by the muzzle velocity unit correction, which is determined from the Ground Data table (table F). The sign of the ΔV range correction is always opposite the sign of the ΔV. If the ΔV range correction is *plus,* extract the unit correction from the *Decrease* column. If the ΔV range correction is *minus,* extract the unit correction from the *Increase* column.

e. Compute the velocity error in meters per second by algebraically subtracting the change to muzzle velocity for propellant temperature (para 21-8) from ΔV (*d* above).

21-7. Entry Range

a. The range (entry range) at which to extract unit corrections from the firing tables must be determined. The entry range is the sum of the chart range to the point for which the met message is being solved and the complementary range. Complementary range is the range correction corresponding to the complementary angle of site and is determined from the firing tables. To determine complementary range, enter the Complementary Range Line Number table (table B) with the chart range to the nearest 100 meters and the height of target above the gun to the nearest meters. Interpolation for height of target above the gun may be necessary.

Example: 155-mm howitzer M109, charge 5 GB (M3 propellant), chart range 7020, altitude of battery, 237, altitude of target 500. There is no base piece displacement for range.

Height of target above gun is +263 meters. Enter table B at range 7000 and height of target above gun +263.

	Height of target above gun		
7000	+200	(+263)	+300
	54	(72.3)	83

Complementary range is +72 meters. Entry range is 7092 (7020 +72). For entry into tables F, H, and I, the nearest listed value to entry range is used.

b. If a met is being solved and speed of computation is of primary consideration, it may not be necessary to mathematically interpolate for comp range. Instead, it may only be necessary to visually interpolate table B in order to determine the value of entry range with which to enter the tables. However, care must be used if this visual interpolation is used in this table.

21-8. Computation of Meteorological Corrections

Met range and deflection corrections are computed concurrently. Firing table data are based on an assumed standard trajectory that exists under prescribed standard conditions of weather and materiel. Unit corrections for nonstandard conditions are contained in the firing tables. If the variation between an existing condition and the assumed standard condition has been measured, the FDC can determine a correction for that variation by multiplying the variation by the appropriate unit correction. The Met Data Correction Sheet (DA Form 4200) is used as an aid in computing met corrections. (DA Form 4200 is available through normal AG publication supply channels.) An example of the solution of a met message and the use of the met data correction sheet (fig 21-2) is shown below.

Example: Assume that a 155-mm howitzer M109 battery has registered and the following information is available:

Adjusted data to registration point:

Elevation	368 mils
Quadrant elevation	374 mils
Deflection	3,209 mils
Time	24.6

Chart data to registration point:

Range	7,230 meters
Deflection	3,220 mils
Site	+6 mils

Additional information:

Latitude of battery	34° N
Altitude of battery	321 meters
Altitude of registration point	358 meters
Azimuth to registration point	1,820 mils (nearest mil)
Weight of projectile	5 squares
Propellant temperature	62° F
Charge	5 GB (M3 propellant)
Lot	XY

Concurrent met message:

METB31	344983
120950	030031
004717	021016
014817	024018
025118	029019
035120	031021
045221	033023
055220	033022

a. Enter all known data in the proper spaces on the form, i.e., charge, adjusted quadrant elevation, chart range (achieved range) to the nearest 10 meters, altitude of battery, height of target above gun, latitude to the nearest 10°, direction of fire to the nearest 100 mils, propellant temperature, and weight of projectile.

b. Enter data from the introduction to the met message.

c. Determine the proper met message line number (para 21-4). Enter data from proper met message line on the form.

d. Determine the complementary range and enter it on the form. Add the complementary range to the chart range (achieved range) to determine the entry range (para 21-7). Enter the entry range on the form.

e. Since grid convergence seldom exceeds 50 mils and the ballistic wind is measured to the nearest 100 mils, the true azimuth given in the met message is considered to be the grid azimuth—it requires no conversion. Compute the chart direction of the wind by subtracting the direction of fire from the direction of the ballistic wind. Enter the Wind Components table (table C) with the chart direction of the wind and determine the components of a 1-knot wind. Enter the components on the form.

f. Compute the range wind and crosswind (to the nearest knot) and enter them in the appropriate spaces.

g. Determine the difference in altitude between the meteorological datum plane (MDP) and the battery (Δh). Enter the Temperature and Density Corrections table (table D) with Δh (to the nearest 10 meters) to determine the corrections to air temperature and density. Apply the corrections and enter the corrected temperature and density in the appropriate blocks.

h. Enter the Propellant Temperature table (table E) with propellant temperature to the nearest degree to determine the change to muzzle velocity (to the nearest 0.1 meter per second). Enter the muzzle velocity change (to be used later in determination of VE) on the form.

i. Compute the variations from standard for range wind, temperature, density, and projectile weight and enter them on the form.

j. Enter the Ground Data table (table F) at entry range (*d* above) rounded to nearest 100 meters and extract the unit corrections for drift, crosswind, muzzle velocity (extract both factors), range wind, air temperature, air density, projectile weight. Enter the unit corrections in the appropriate spaces on the form.

k. Determine the rotation corrections to range (table H) and azimuth (table I) and enter the corrections on the form. Rotation tables (H and I) are entered at entry range to the nearest listed range, azimuth of fire (expressed to the nearest 1 mil) to the nearest listed value, and latitude to the nearest 10°. If the azimuth of fire (nearest mil) is exactly halfway between listed values, use the higher entry argument. For example: if the direction of fire is exactly 1300 mils, enter table H at azimuth 1400.

MET DATA CORRECTION SHEET
For use of this form, see FM 6-40; proponent agency is TRADOC.

BATTERY DATA				MET MESSAGE		
CHARGE 56B	ADJ QE 374	CHART RG 7230	LATITUDE 30°N	TYPE MESSAGE METB 3	OCTANT 1	AREA/UNIT 344983
ALT OF BTRY (10 m)	320			DATE 12 / TIME 0930	ALT MDP 300	PRESSURE 109.1
ALT OF MDP	300			LINE NO. 03 / WIND DIR 5100 / WIND SPEED 20	AIR TEMP 103.1	AIR DENSITY 102.1
BTRY (ABOVE) / BELOW MDP (Δh)	+20			Δ h CORRECTION	± 0.0	⊖ 0.2
ALT OF TARGET (nearest meter)	358			CORRECTED VALUES	103.1	101.9
HEIGHT OF BURST ABOVE TARGET	- - -					
ALT OF BURST	358					
ALT OF BTRY (nearest meter)	321					
HEIGHT OF TARGET (burst) ABOVE GUN (M)	+37			COMP RG +10	CHART RG 7230	ENTRY RG 7240 — 7200

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400	
DIRECTION OF WIND	5100	
DIRECTION OF FIRE	(1820) 1800	
CHART DIRECTION OF WIND	3300	
CROSS WIND — WIND SPEED	20 × COMP ⓁR 0.10 = Ⓛ 2	KNOTS × 0.33 UNIT CORR
RANGE WIND — WIND SPEED	20 × COMP ⓉH 0.99 = ⓉAIL/HEAD 20	KNOTS

Total DF Corr R 11
Met DF Corr L 9
Pos DF Corr R 20

ROTATION CORR ⓁR	0.9
DRIFT CORR L	7.1
CROSS WIND CORR ⓁR	0.7
MET DEFL CORR ⓁR	8.7 — L9

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATIONS FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	ⓉH 20	0	20	-10.1		202.0
AIR TEMP	103.1	100%	Ⓘ 3.1	-23.1		71.6
AIR DENSITY	101.9	100%	Ⓘ 1.9	+13.9	26.4	
PROJ WEIGHT	5 ▣	4 ▣	Ⓘ 1	+26.0	26.0	
ROTATION	-25 x 0.87					21.8
					52.4	295.4
						52.4
				MET RANGE CORR		243.0 — -243

COMPUTATION OF VE

VE	-2.3	M/S D+19.3	TOTAL RANGE CORRECTION -190
PROP TEMP 62° °F	CHANGE TO MV FOR PROP TEMP -0.4	M/S I-18.4	MET RANGE CORRECTION -243
	ΔV -2.7	M/S MV UNIT CORRECTION +19.3	ΔV RANGE CORRECTION +53
			TOTAL RANGE CORRECTION

OLD VE ______ + NEW VE ______ = ______ ÷ 2 = AVG VE ______ M/S

TI 24

MET FUZE CORRECTION

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS	
ΔV	Ⓓ 2.7	-0.037		0.100	-190 ↗ 7040
RANGE WIND	ⓉH 20	+0.013	0.260		Rg 7230, el 368, Ti 24.6
AIR TEMP	Ⓘ 3.1	+0.037	0.115		+0.3
AIR DENSITY	Ⓘ 1.9	-0.015		0.028	24.3
PROJ WEIGHT	Ⓘ 1.0	-0.065		0.065	TOTAL FUZE CORRECTION +0.3
			0.375	0.193	MET FUZE CORRECTION +0.2
			0.193		FUZE CORRECTION +0.1
		MET FUZE CORR	0.182		TOTAL FUZE CORRECTION

OLD FZ CORR ______ + NEW FZ CORR ______ = ______ ÷ 2 = AVG FZ CORR ______

TARGET NO.	BATTERY	DATE/TIME 12 0430 MAR 70

DA FORM 1 JAN 74 4200 REPLACES DA FORM 6-15, 1 APR 67, WHICH IS OBSOLETE.

Figure 21–2. Solution of the met message (concurrent met).

l. Compute the crosswind correction and then add rotation correction for azimuth, dirft correction, and crosswind correction to determine the met deflection correction.

m. Enter the Fuze Setting Factors table (table J) at the chart time to the nearest listed value. (Chart time is the time corresponding to the adjusted elevation and is read under the hairline on the GFT.) For example, the time corresponding to adjusted elevation 368 mils is 24.3. Enter table J with a value of 24 and extract the unit corrections for muzzle velocity (extract both values), range wind, air temperature, air density, and projectile weight. Enter the unit corrections in the appropriate spaces on the form. (The procedure for determining the met fuze correction is explained in paragraph 21-10.)

n. Determine the met range correction as follows:

(1) Multiply the variations from standard by the unit corrections and enter the results under the column headed Plus or Minus, whichever is appropriate. The sign of each range correction is the same as the sign of the corresponding unit correction.

(2) Add the values in each column. Find the difference between the two columns (Plus and Minus) and round off to the nearest meter; the result is the met range correction.

Note. Exercise particular care in using the firing tables to insure that the correct values are extracted. For instructions regarding entry into tables A, D, H, and I, read the note at the bottom of each of those tables.

21-9. Average Position Velocity Error

a. A position VE is computed whenever a registration and a met message are concurrent. The position VE includes all nonmeasurable variations from standard conditions. Some variations are relatively constant (for example, tube wear and ballistic coefficient) whereas others are unpredictable (for example, propellant variation and minor weather variations). In order to smooth out these errors, FDC personnel average each new position VE determined with the previous velocity error (which may be an average VE) determined at the same position. This method gives most weight to the most recently determined VE but does not disregard the previous velocity errors.

Example:

VE determined at 0800 −3.2 m/s

VE determined at 1000 −3.8 m/s

Average VE to be used after 1000 −3.5 m/s

$$\frac{(-3.8) + (-3.2)}{(\quad 2 \quad)}$$

VE determined at 1400 −4.5 m/s

Average VE to be used after 1400 −4.0 m/s

$$\frac{(-4.5) + (-3.5)}{(\quad 2 \quad)}$$

b. A position VE is considered valid only for the position,. weapon, charge, and propellant for which it was determined. When a unit has displaced and cannot register immediately, the average VE from the previous position may be used but transfers may not be accurate. Where position VE for the new position has been determined, it is used while the unit is in that position. It is also averaged with VE's from previous positions for use in a future position when registration is not possible.

21-10. Computation of Meteorological Fuze Correction

a. The fuze setting corresponding to the adjusted elevation plus complementary angle of site approximates the correct fuze setting. In low-angle fire, comp site usually is negligible and has little effect on fuze setting. For this reason, comp site normally is considered only for nuclear fires or for firing large vertical angles or extreme ranges. Since, under nonstandard conditions, fuze setting varies at a slower rate than does elevation, a more accurate fuze setting can be obtained by correcting, for nonstandard conditions, the fuze setting corresponding to the adjusted elevation. The Fuze Setting Factors table (table J) is designed to compensate for the same nonstandard conditions that affect range.

(1) *Met fuze correction*. The met fuze correction is equal to the algebraic sum of the individual fuze setting corrections required to compensate for variations from standard conditions and is determined as follows: Extract the unit corrections from the firing tables. Multiply each variation from standard by the appropriate unit correction. Add separately those changes that increase and those that decrease the fuze setting. Subtract the smaller sum from the larger sum. The result expressed to the nearest tenth is the met fuze correction. The sign of the correction is that of the column with the larger sum.

(2) *Total fuze correction*. Determine the total fuze correction by subtracting the fuze setting corresponding to the adjusted elevation from the adjusted time.

(3) *Position fuze correction.* Determine the position fuze correction by subtracting the met fuze correction from the total fuze correction.

b. The use of the Fuze Setting Factors table eliminates the error in assuming that the total fuze correction is constant. The technique involved is similar to that for determining velocity error in that the effect of nonstandard conditions on fuze setting is computed at the time of the registration and subtracted from the total fuze correction. When a current met message is received, a met fuze correction is computed in much the same manner as a met range correction. The fuze setting corresponding to the new adjusted elevation is determined and the total fuze correction (met fuze correction plus the position fuze correction) is added to this fuze setting to obtain the new adjusted fuze setting.

Example: This is a continuation of the example in paragraph 21-8. GFT B: Charge 5, lot XY, range 7,230, elevation 368, time 24.6. The total fuze correction is +0.3(24.6 −24.3). The concurrent met message is solved and yields a met fuze correction of +0.2. This is subtracted from the total fuze correction and the resulting position fuze correction (+0.1) is filed for future use. Later, a new met message is received. This message is solved as described in paragraph 21-11, and results in the following GFT setting: GFT B: Charge 5, lot XY, range 7,230, elevation 370. The met fuze correction determined from the new met (+0.1) is added to the position fuze correction determined from the earlier met (+0.1) to obtain the total fuze correction (+0.2) to be applied to the fuze setting corresponding to the met corrected elevation (370). Thus, the GFT fuze setting is 24.6 (24.4 + (+0.2)).

MET DATA CORRECTION SHEET
For use of this form, see FM 6-40; proponent agency is TRADOC.

BATTERY DATA / **MET MESSAGE**

CHARGE	ADJ QE	CHART RG	LATITUDE	TYPE MESSAGE	OCTANT	AREA/UNIT
5GB	374	7230	30°N	METB 3	1	344983

BATTERY DATA		MET MESSAGE				
ALT OF BTRY (10 m)	320	DATE 12	TIME 1130		ALT MDP 300	PRESSURE 103.1
ALT OF MDP	300	LINE NO. 03	WIND DIR 4200	WIND SPEED 18	AIR TEMP 101.1	AIR DENSITY 96.6
BTRY ABOVE/BELOW MDP (Δh)	+20	Δh CORRECTION			± 0.0	⊖ 0.2
ALT OF TARGET (nearest meter)	358	CORRECTED VALUES			101.1	96.4
HEIGHT OF BURST ABOVE TARGET	---					
ALT OF BURST	358					
ALT OF BTRY (nearest meter)	321					
HEIGHT OF TARGET (burst) ABOVE GUN (M)	+37	COMP RG +10	CHART RG 7230	ENTRY RG 7240	7200	

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400	Pos DF Corr R 20
DIRECTION OF WIND	4200	Met DF Corr L 4
		Total DF Corr R 16
DIRECTION OF FIRE (1820)	1800	ROTATION (L) CORR R 0.9
CHART DIRECTION OF WIND	2400	DRIFT CORR L 7.1
CROSS WIND — WIND SPEED 18 × COMP (R) 0.71 = (L) 13 KNOTS × 0.33 UNIT CORR =		CROSS WIND L CORR (R) 4.3
RANGE WIND — WIND SPEED 18 × COMP (H) 0.71 = (TAIL) HEAD 13 KNOTS		MET DEFL (L) CORR R 3.7 — L4

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATIONS FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	(T) 13	0	(T) 13	-10.1		131.3
AIR TEMP	101.1	100%	(D) 1.1	-23.1		25.4
AIR DENSITY	96.4	100%	(D) 3.6	-13.8		49.7
PROJ WEIGHT	5 ▢	4 ▢	(I) 1	+26.0	26.0	
ROTATION	-25 × 0.87					21.8
					26.0	228.2
						26.0
				MET RANGE CORR		202.2 — -202

COMPUTATION OF VE

PROP TEMP 81° °F	VE	-2.3 M/S	D + 19.3	TOTAL RANGE CORRECTION		
	CHANGE TO MV FOR PROP TEMP	+ 0.5 M/S	I - 18.4	MET RANGE CORRECTION	-202	
	ΔV	-1.8 M/S	MV UNIT CORRECTION +19.3	ΔV RANGE CORRECTION	+ 35	
				TOTAL RANGE CORRECTION	-167	-170

OLD VE ______ + NEW VE ______ = ______ ÷ 2 = AVG VE ______ M/S

MET FUZE CORRECTION

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS	
ΔV	(I) 1.8	0.037		0.067	7060; -170
RANGE WIND	(T) 13	0.013	0.169		Rg 7230, el 370, Ti 24.6
AIR TEMP	(D) 1.1	0.037	0.041		+0.2
AIR DENSITY	(D) 3.6	0.016	0.058		24.4
PROJ WEIGHT	(I) 1.0	-0.065		0.065	TOTAL FUZE CORRECTION
			0.268	0.132	MET FUZE CORRECTION +0.1
			0.132		FUZE CORRECTION +0.1
MET FUZE CORR			0.136		TOTAL FUZE CORRECTION +0.2

OLD FZ CORR ______ + NEW FZ CORR ______ = ______ ÷ 2 = AVG FZ CORR ______

TARGET NO.	BATTERY	DATE/TIME
		12 0600 MAR 70

DA FORM 4200, 1 JAN 74 — REPLACES DA FORM 6-15, 1 APR 67, WHICH IS OBSOLETE.

Figure 21-3. Application of velocity error.

Section III. APPLICATION OF METEOROLOGICAL AND VELOCITY ERROR CORRECTIONS

21–11. Application of Velocity Error

Frequently, it is undesirable to register each time there is a significant change in weather. In order to keep corrections for nonstandard conditions current in such a situation, FDC personnel use a technique called met plus VE. The major changes in registration corrections are due to changes in met conditions and propellant temperature. A new met message will provide data on correct met conditions; position VE and position fuze correction are virtually constant.

a. Determine a new current total range correction by adding the current met range correction to a ΔV range correction determined from the position average VE in meters per second and the current correction to muzzle velocity for propellant temperature (*b* below). Determine a new current total fuze correction by algebraically adding the position fuze correction to the current met fuze correction. Now use the updated total range and total fuze corrections to determine an updated GFT setting (*c* below). A met message solved by the met plus VE technique is referred to as a subsequent met. (fig 21–3).

b. Convert the ΔV in meters per second to a ΔV range correction by multiplying the ΔV by the muzzle velocity unit correction; the result is always given the sign of the unit correction used. The unit correction is determined at the range used to solve the met message and is taken from the Decrease column if the ΔV is minus and from the Increase column if the ΔV is plus.

c. Use the total range and total fuze corrections to determine an updated GFT setting as follows: Algebraically add the total range correction to the GFT setting range. The result is the range corresponding to the adjusted elevation. Place the hairline on the GFT over this range and under the hairline read the elevation and the fuze setting. The elevation is the new adjusted elevation for the GFT setting. The fuze setting is the new chart time. Express the chart time to the nearest whole unit to determine the entry argument into table J. Determine the chart time before determining the met fuze correction. Algebraically add the met fuze correction to the position fuze correction to determine the current total fuze correction. Algebraically add this total fuze correction to the chart time to determine the new adjusted time for the GFT setting.

Example: 155-mm howitzer M109. A subsequent met is being solved for charge 5 green bag to determine an updated GFT setting. The GFT setting range is 5,880 meters. The total range correction is +110 meters. The range corresponding to the adjusted elevation is 5,990 meters (5880+(+110)). The hairline is placed over range 5,990, and elevation 295 and fuze setting 19.8 are read under the hairline. The elevation is the adjusted elevation and the time is the new chart time. Table J is entered with a value of 20 (19.8 ≈ 20). The met fuze correction is algebraically added to the position fuze correction to determine the total fuze correction (−0.2). This value is added to the chart time (19.8) to determine the new adjusted time of 19.6 (19.8 +(−0.2). Thus, the updated GFT setting is GFT A: Charge 5, lot XY, range 5880, elevation 295, time 19.6.

21–12. Determination of Range Corrections for Targets Outside Transfer Limits

a. The use of the position VE is not restricted to transfer limits of the point at which the VE was determined. However, corrections determined close to minimum and maximum usable ranges for the charge are less accurate.

b. Corrections for targets outside transfer limits can be computed by use of the met plus VE technique. The met corrections are determined by use of the chart range, vertical interval, and direction to the target in question. ΔV is converted to a ΔV range correction by use of the MV unit correction determined at the entry range for the target.

21–13. Deflection Corrections

a. Corrections for deflection and range are best determined from a registration. As a result of the initial registration, a deflection correction scale is constructed. The deflection correction scale indicates the total deflection correction for a given elevation. The total deflection correction is equal to the met deflection correction plus the position deflection correction.

b. A change of the total deflection correction as determined from a second registration or by the met plus VE technique will modify this deflection correction scale. To modify the total deflection correction by the correction determined from a met message FDC personnel must know the amount of the total deflection correction that was due to weather. This can be determined from a met message taken concurrently with the registration. If a later met message indicates a weather change, a new deflection correction scale must be constructed. The new total deflection correction will be the algebraic sum of the position deflection correction brought forward and the new met deflection correction.

c. For example, a registration has been conducted and a concurrent met message has been solved for a 155-mm howitzer M109 firing charge 5 green bag.

(1) Corrections from the registration and met message are as follows:

Chart deflection	3200 mils
Adjusted deflection (initial registration at 1600 hours	3186 mils
Total deflection correction at the adjusted elevation (1600 hours)	R 14 mils
Met deflection correction (1600 hours)	R 8 mils
Position deflection correction	R 6 mils

Note. The position deflection correction is held constant and used only in the position for which it was determined.

(2) At 2200 hours, a new met message is computed (no registration):

Met deflection correction (2200 hours)	R 10 mils
Position deflection correction	R 6 mils
Total deflection correction at met corrected elevation (R 10 + R 6)	R 16 mils

(3) The next morning at 0600 hours a second registration is conducted and a new met message is computed:

Chart Deflection (0600 hours)	3200 mils
Adjusted deflection	3191 mils
Total deflection correction at the adjusted elevation	R 9 mils
Met deflection correction at 0600 hours	R 1 mil
Position deflection correction	R 8 mils
Average position deflection correction (R6+R8=R14/2)	R 7 mils

Note. The position deflection corrections are averaged to give most weight to the most recently determined position deflection correction.

(4) At 1000 hours, new met corrections are computed (no registration):

Met deflection correction (1000 hours)	L 2 mils
Average position deflection correction	R 7 mils
Total deflection correction at met corrected elevation	R 5 mils

(5) At 1400 hours, a new message is computed (no registration):

Met deflection correction (1400 hours)	R 3 mils
Average position deflection correction	R 7 mils
Total deflection correction at met corrected elevation	R 10 mils

d. The data in *c* above may be tabulated for ready reference as follows:

Registration Data

Time	Chart df	Adj df	Regis df corr	Met df corr	Pos df corr	Avg pos df corr	Total df corr
1600	3200	3186	R14	R8	R6	--	R 14
2200	----	----	----	R10	R6	--	R 16
0600	3200	3191	R9	R1	R8	R7	R 9
1000	----	----	----	L2	--	R7	R 5
1400	----	----	----	R3	--	R7	R 10

21-14. Deflection Corrections Outside Transfer Limits

The FDC can determine a total deflection correction for an accurately located target outside transfer limits by solving the current met message and determining the met deflection correction to the target. The met deflection correction to the target is applied to the position deflection correction to the registration point. The result is the total deflection correction to the target.

Example:

Total deflection correction at registration point range	R 5
Met deflection correction at registration point range	R 2
Position deflection correction	R 3
Met deflection correction at target range	L 1
Total deflection correction at target range (R3 + L1)	R 2

21-15. Example—Met Plus VE

The following is an example of a met plus VE computation and is a continuation of the example presented in paragraph 21-8. The solution is shown in figure 21-3. Subsequent met message:

METB31	344983
121150	030031
004116	041963
014015	011964
024116	011964
034218	011966
043917	013966
054118	013968

Current propellant temperature: 81° F.

Met range correction	−202 meters
VE	−2.3 m/s
Change to MV for propellant temperature	+0.5 m/s
ΔV	−1.8 m/s
MV unit correction	+19.3 meters
ΔV range correction (19.3 × 1.8)	+35 meters
Total range correction (−202 + (+35) = −167)	−170 meters
GFT range	7,230 meters
Corrected range (7230 + (−170))	7,060 meters
Elevation for range 7060	370 mils
Fuze setting for elevation 370	24.4
Met fuze correction	+0.1
Position fuze correction	+0.1
Total fuze correction	+0.2
Corrected fuze setting (24.4 + (+0.2))	24.6
Position deflection correction	R 20 mils
Met deflection correction	L 4 mils
Total deflection correction	R 16 mils

GFT setting:

GFT B: Chg 5, lot XY, rg 7230, el 370, ti 24.6

21-16. 8-Direction Met Technique

a. Current doctrine requires that a firing unit provide accurate artillery support throughout a 6,400-mil zone. The current procedures for preparing firing charts were developed to enhance this 6,400-mil capability.

b. When available, FADAC is used for determining corrected firing data throughout 6,400 mils and can be used for determining a GFT setting for each 800-mil segment of the unit area of responsibility. When FADAC is not available, these data are determined graphically by means of the 8-direction met technique.

c. Traditional transfer limits define an area within which registrations are assumed to be valid. These transfer limits place a severe limitation on a 6,400-mil firing chart. The unit could obtain registration corrections by conducting a registration in each 800-mil sector of the unit area of responsibility, but at a tremendous cost in ammunition expenditure.

d. Corrections to range, deflection, and fuze setting to compensate for the effects of the variable ballistic wind direction and velocity and for earth rotation throughout the unit area of responsibility can be determined by use of the 8-direction met technique. When these corrections are combined with known position corrections, lateral transfer limits can be eliminated for ranges of 10,000 meters or less. For ranges greater than 10,000 meters, lateral transfer limits are valid 4,000 meters right and 4,000 meters left of the battery registration point line. Therefore, at these ranges, there will be areas between successive 800-mil segments that are not covered by valid deflection corrections. An additional met plus VE GFT setting must be determined to cover each area.

e. The procedure for application of the 8-direction met technique consists of four steps:

(1) Solution of a met message concurrent with a registration.

(2) Determination of a position VE, a position deflection correction, and a position fuze correction.

(3) Solution of the met message for each 800-mil segment with reference to the registration point direction.

(4) Application of the position corrections to met corrections for each 800-mil segment to determine valid GFT settings and deflection correction scales.

f. The position corrections (constants) determined from an initial registration and a concurrent met message will be used with subsequent met messages until a new registration has been conducted and average constants determined. Average constants will be used with all met messages subsequent to a registration for computing GFT settings in all 800-mil segments. Average constants determined from the met concurrent with a subsequent registration will be used in all 800-mil segments except the segment containing the registration point. The GFT setting determined from the registration will be used until a subsequent met message has been computed.

g. Because of the small effect that base piece displacement has on the azimuth to the registration point, the azimuth of fire need not be recomputed when base piece displacement is applied.

h. An example problem of an 8-direction met for a 155-mm howitzer (109) is as follows:

(1) *Data determined from the registration and concurrent met message.*

(*a*) *GFT setting from registration.*

GFT A: Chg 5, lot XY, rg 5350, el 263, ti 17.4

(*b*) *Total registration corrections.*

Range +130 meters
Deflection L 10 mils
Fuze −0.4

(*c*) *Concurrent met corrections.*

Range ---------- +156 meters
Deflection ---------- L 6 mils
Fuze ---------- −0.1

(*d*) *Position corrections (constants).*

ΔV range correction --- −26 meters
Deflection ---------- L 4 mils
Fuze ---------- −0.3

Note: When the direction of fire is changed in 800-mil increments, the resulting change in the chart direction of the wind will have an appreciable effect on met corrections and will result in different GFT settings for each 800-mil segment. Because chart direction of the wind has no effect on air temperature, air density, projectile weight, drift, and ΔV range correction, these elements remain constant for all computations.

(2) *Corrections 800-mils right of the registration point direction.*

(*a*) *Met corrections.*

Range ---------- +79 meters
Deflection ---------- L 9 mils
Fuze 0

(*b*) *Total corrections (met plus position)*

Range (+79 + (−26)) ---------- +50 meters
Deflection (L9+L4) L 13 mils
Fuze (0 + (−0.3)) -- −0.3

(*c*) *GFT setting.*

GFT A: Chg 5, lot XY, rg 5350, el 259, ti 17.2

(3) *Corrections 3,200 mils from the registration point direction.*

(*a*) *Met corrections.*

Range ---------- −76 meters
Deflection ---------- L 4 mils
Fuze ---------- +0.2

(*b*) *Total corrections (met plus position).*

Range (−76 + (−26)) ---------- −100 meters
Deflection (L4+L4) - L 8 mils
Fuze (+0.2 + (−0.3)) ---------- −0.1

(*c*) *GFT setting.*

GFT A: Chg 5, lot XY, rg 5350, el 250, ti 16.8.

Section IV. EXPERIENCE CORRECTIONS

21–17. General

Current registration or met corrections may not be known or obtainable in some situations; for example, when a unit makes a hasty occupation of position or when restrictions are placed on registration. In such a case, the S3 must decide what corrections, if any, are to be applied to data to improve the accuracy of fires. Except in unusual cases in which conditions of the weather, ammunition, and weapon are known, the S3 will resort to an analysis of experience corrections as a basis for applying corrections. These corrections are used until met or registration corrections are available.

21–18. Experience Velocity Error Corrections

The average VE or the latest VE will be used as the basis for a GFT setting. It is better to establish a GFT setting with this information than to ignore it until a registration has been conducted.

21–19. Experience Meteorological (Range) Corrections

If a current met message is not available, the data for a GFT setting may be improved by use of corrections for weather, ammunition, and weapon performance determined from previous met messages and registrations. Corrections based solely on such records should be used only with extreme caution.

21–20. Experience Fuze Correction

Evaluation of all previous time registrations of a specific fuze will invariably indicate that a relatively constant fuze correction is required for obtaining the proper height of burst. This factor is the average fuze correction. The average fuze correction, if applied to the fuze setting corresponding to the elevation for the initial round, should cause the round to burst at approximately the desired height. The fuze correction is considered a fuze characteristic, not a correction for weather conditions.

21-21. Position Deflection Correction

When a position deflection correction is determined, it may be due to one or more errors in plotting, laying, and/or survey. The S3 should keep in mind that errors causing the position deflection correction are difficult to isolate and remain relatively constant for a given position. Therefore, a position deflection correction for one position cannot be used in a new position.

CHAPTER 22

CALIBRATION

Section I. GENERAL

22–1. 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. Calibration makes it possible to group cannons of a given caliber and of nearly equal muzzle velocities into one battery so as to reduce the frequency with which individual piece corrections must be applied.

c. Calibration also permits the determination and application of corrections to compensate for variations in muzzle velocity developed by individual pieces.

d. The VE determined by absolute calibration may be used in computing a met plus VE GFT setting when no other data are available.

22–2. Ammunition

Muzzle velocity is a measure of the shooting strength of a weapon-ammunition-charge combination. The muzzle velocity of a given weapon varies from charge to charge. The only method of determining the muzzle velocity precisely with any particular charge is to calibrate with that charge. In order to obtain a valid sampling and to receive the maximum value from the calibration, the unit should insure that sufficient amounts of the same lot of propellant and projectile are available. The recommended number of rounds for each piece during the calibration is 8 rounds. This number includes two conditioning rounds (warming rounds), the result of which may be discarded if erratic readings are obtained. The calibration can be conducted with fewer rounds but with some sacrifice of accuracy and overall reliability. To eliminate velocity trends due to oil and dirt, the unit must insure that the tubes are clean and dry.

22–3. Optimum Charge

Usually, calibration is accomplished with only one charge and, hence, it is necessary to select the charge that 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 works fairly well as a basis for individual piece corrections for all other charges for howitzers but not too well for guns. Absolute calibration data are valid only for the specific charge fired.

22–4. Frequency of Calibration

a. 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 annually. If a great deal of firing takes place, recalibration may be needed more often. If an accurate and reliable record of the change in the position VE determined from registrations and concurrent met data is maintained, recalibration may not be necessary until the velocity loss becomes excessive (2 range probable errors). Wear tables can also give a general indication of the need for calibration.

b. Ordnance teams measure tube wear by means of 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, but they can be used to detect extremes in velocities within a group of weapons. However, there is little reliability in a VE determined from wear measurements. Pullover gage readings can be used for grouping weapons initially when immediate calibration is not feasible. Changes in the readings may be used as a guide in scheduling recalibration.

22–5. Wear Tables

Wear tables may prove helpful in filling in the gaps between calibrations. Wear tables estimate the erosion of a gun tube as a result of firing a certain number of rounds with specified charges. From this estimated erosion, the loss in muzzle velocity may be approximated.

22-6. Heavy Artillery

a. The procedures for calibrating, grouping the pieces, and computing and applying calibration corrections for heavy artillery are the same as those for light and medium artillery.

b. For the 175-mm gun equipped with the M113 cannon tube, the loss in muzzle velocity per round fired is significant. Unless an equal number of rounds are fired by all weapons of the battery, calibration data must be altered periodically. Therefore, an accurate record of calibration data, subsequent firing, and corrections applied to calibration data for these weapons is particularly important.

22-7. Records

a. The records of all firing, including calibration, is maintained in the equipment logbook on the Weapon Record Data (DA Form 2408-4).

b. A complete record of calibration data should be maintained by the battery and by battalion. A record of each lot number and the associated muzzle velocity data could be an aid to the operations officer. It is possible that the same lot could be issued after an interval of time has passed, and a knowledge of the performance of the lot may eliminate the need for calibration. This is particularly true when the unit does not fire sufficient full service rounds to materially decrease the shooting strengths of its pieces.

Section II. CHRONOGRAPH CALIBRATION

22-8. Chronograph Calibration Techniques

Chronograph support is provided by ordnance teams and by teams organic to field artillery units. When chronograph support organic to the field artillery is used, calibration should be conducted in coordination with other scheduled firings so that ammunition need not be expended specifically for calibration.

a. Skyscreen. The chronograph used by ordnance teams is usually the skyscreen. The skyscreen is a set of photoelectric cells that are placed along a carefully surveyed base. The base is established along a prolongation of the tube. Passage of the projectile overhead changes the light intensity striking the cells, which in turn activates an electric time counter. The ordnance team computes the mean developed muzzle velocity of the rounds fired from each weapon and then compensates for the effect of nonstandard conditions to determine the muzzle velocity. When calibration is to be conducted by an ordnance team using skyscreen, the procedures outlined in (1) and (2) below should be followed.

(1) A bench-checked (ordnance-tested) gunner's quadrant should be available and all propellant thermometers to be used should be calibrated. A firing point with no trees and a minimum of underbrush must be chosen; the area out to 200 meters in front of the weapon must be as level as possible. An area approximately 30 meters behind and slightly to one side of the firing point must be set aside for the calibration van. A traffic pattern must be laid out and enforced so that no traffic crosses the cables between the calibration van and the screens. The deflection and quadrant elevation chosen must be such that the rounds fall within safety limits. The selection of suitable firing data is important because, once the screens have been emplaced, even a small change in firing data requires repositioning of the screens, which takes as much time as the original positioning.

(2) It is preferable to fire all pieces successively from the same position while the skyscreens remain in place. The first piece to be calibrated is laid and its position staked so that subsequent pieces will stop on the same spot. The calibration team then emplaces the skyscreens by sighting through the tube. Once the skyscreens have been emplaced, there is no need to lay each subsequent piece by aiming circle. Each weapon pulls into the position marked by the stake; the crew lays the piece by sighting through the tube directly over the screens, takes a sight picture, and corrects aiming post displacement. Since the piece is centered over the skyscreens, which have not been moved, it is laid on the selected azimuth and is, therefore, safe. The logbook for each weapon is delivered to the ordnance team as the piece comes to the firing point.

b. Radar Chronograph M36. Chronographs of the radar doppler type are organic to field artillery units. They are more flexible than skyscreen equipment and are capable of day and night operation. Radar doppler chronographs operate on the principle that the frequency of the transmitted radio waves will change when reflected from a moving projectile.

(1) The chronograph organic to field artillery units is the radar chronograph M36. It is a

portable electronic instrument and is ideally suited for use during tactical operations. The M36 operates from a vehicle mount or a ground mount to the side of the piece. It measures velocities from 75 to 1,860 meters per second. It is laid parallel to the weapon being calibrated in the normal manner; i.e., by aiming circle, by reciprocal laying, or by laying on a common aiming point.

(2) After each round fired, the M36 chronograph measures the difference in frequencies between the transmitted and received signals and converts the difference to an indicated velocity, which is displayed directly in meters per second. The readout indicates the velocity of the projectile at some point along the trajectory as determined by the delay selector switch. The readout velocity must be corrected to a muzzle velocity under standard conditions of gravity, surface air density, propellant temperature, and projectile weight. The corrected velocity is the muzzle velocity achieved by the weapon with the propellant lot and charge used for the calibration. If FADAC has been programmed with the appropriate tape, it will perform the necessary extrapolation and display the corrected muzzle velocity. Otherwise the chronograph team corrects the readout velocity manually by means of the special extrapolation tables in TM 9-1290-325-12/2.

(3) The chronograph can follow changes in direction and elevation as fast as the piece can be laid. Because of this speed and the lack of intensive preparation required, calibration can be performed whenever firing is conducted and an M36 chronograph is available. For a more detailed discussion of the M36, see TM 9-1290-325-12/1 and TM 9-1290-325-12/2.

22-9. Application of Muzzle Velocity

a. Grouping of Weapons. Weapons are grouped by muzzle velocity so that the pieces in each firing battery are as close to each other in shooting strength as the situation permits. In some instances in which one or more pieces vary considerably in muzzle velocity, the next higher artillery headquarters may arrange for appropriate transfer of weapons between battalions having the same caliber.

b. Selection of Base Piece. Once the pieces within the battalion have been grouped, each battery selects a weapon as the base piece. The muzzle velocity of the base piece must be near the average of the battery and must be such that the muzzle velocities of the greatest number of other battery pieces are within ±1.5 meters per second of the muzzle velocity of the base piece.

c. Computation of Firing Data.

(1) The average MV determined by chronograph calibration for each battery is used as an MV input to the gun direction computer M18 (FADAC). For a more detailed explanation, see FM 6-40-3.

(2) The average MV determined by chronograph calibration for each battery may be used in determining a GFT setting as outlined in paragraph 23-2. When a position VE or an average position VE is available from prior registrations and concurrent met messages, the VE is preferred to the MVV in making the GFT setting.

22-10. Example

a. A 155-mm howitzer M109 battalion has been issued 18 weapons. Pullover gage readings provided by ordnance furnish data to permit an interim distribution of pieces to each battery. This initial distribution is temporary, since the wear measurement is only a slight indication of muzzle velocity and is used only until calibration has been accomplished.

b. An ordnance calibration team and sufficient ammunition of one lot are arranged for and the decision is made to calibrate all weapons. The S3 determines that charge 4 GB (M3 propellant) provides the best range coverage for this and future firings.

c. All weapons of the battalion are calibrated, and the readings obtained for piece number 1 of Battery A are as follows:

Round number	*Reported MV (m/s)*
1	311.7
2	315.9
3	316.0
4	316.8
5	316.6
6	316.1
7	318.8
8	317.0

(1) Rounds number 1 and 7 are discarded as erratic and the remaining six rounds are retained. Round number 2 is used, even though it is a warming round, since it appears to be consistent with the other rounds. The readings of the six rounds are averaged, and the result (316.4) is the MV for this weapon and ammunition lot.

(2) The muzzle velocities are computed in the same manner for the other 17 pieces in the battalion and the results tabulated.

Battery	*Piece number*	*MV (m/s)*
A	1	316.4
	2	311.5
	3	312.7
	4	314.2

Battery	Piece number	MV (m/s)
	5	315.7
	6	314.6
B	1	310.4
	2	307.3
	3	309.3
	4	308.5
	5	313.6
	6	309.7
C	1	304.1
	2	309.1
	3	306.8
	4	305.0
	5	309.0
	6	306.4

(3) The weapons are listed in order of decreasing muzzle velocity.

Piece number	MV (m/s)
A1	316.4
A5	315.7
A6	314.6
A4	314.2
B5	313.6
A3	312.7
A2	311.5
B1	310.4
B6	309.7
B3	309.3
C2	309.1
C5	309.0
B4	308.5
B2	307.3
C3	306.8
C6	306.4
C4	305.0
C1	304.1

(4) The final muzzle velocities form the basis for regrouping the weapons. The unit SOP requires that long-shooting weapons be placed in Battery A, medium-shooting weapons in Battery B, and short-shooting weapons in Battery C. The weapons ((3) above) are regrouped as follows: The first six are placed in Battery A, the next six in Battery B, and the last six in Battery C. Most of the weapons were properly grouped on the basis of pullover gage readings but some transferring was required. Battery A weapons now consist of the following:

Piece number	MV (m/s)
A1	316.4
A2 (formerly A5)	315.7
A3 (formerly A6)	314.6
A4	314.2
A5 (formerly B5)	313.6
A6 (formerly A3)	312.7

(5) Piece number A4 is designated the base piece. The muzzle velocity of A4 is close to the average MV of the battery, and this arrangement requires that only A1 have special corrections applied, since A1 is the only weapon with a MV that varies by more than ±1.5 m/s from the MV of the base piece. The exchange of piece numbers between A3 and A6 as shown is not absolutely necessary. It is done in this case to show that the weapon closest in shooting strength to the base piece should be in the center platoon with the base piece. Such an arrangement provides a close grouping in the adjustment phase of observer-adjusted missions.

Section III. FALL-OF-SHOT COMPARATIVE CALIBRATION

22-11. 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 location of the mean point of impact of each piece. This premise assumes that the difference in range between mean points of impact 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. Calibration should be conducted only when the wind is relatively stable, and a fall-of-shot calibration, either comparative or absolute, should not be attempted during the passage of a weather front.

b. Quadrant Elevation. When fall-of-shot calibration is being conducted, the weapon should be calibrated at a quadrant elevation between the leftmost and rightmost red numbered elevations. (The red numbered elevations are an indication of the transfer limits for a one-plot GFT setting; they also help to show the normal operating limits for each weapon/charge combination. The old limits of a quadrant elevation between 240 and 460 was not weapon/charge associated and, therefore, in most cases was more restrictive than necessary.) A low quadrant elevation minimizes the effect of nonvelocity elements absorbed into the velocity error. The firing data (deflection and quadrant elevation) must be such that all observers can see the bursts and that the rounds fall within safety limits.

c. Emplacement of Weapons. The weapons to be calibrated should be employed in a level position area. When the trails are spread, there should be about 2 feet between the trails of adjacent pieces. Cant must be eliminated. The weapons may be laid for direction by any of the methods described in chapter 4. 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 fifth-order survey accuracy (FM 6-2).

d. Observation. If possible, the target acquisition battalion should provide the required flash base from which the mean point 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, each equipped with a battery commander's telescope or an aiming circle, should be installed. The OP's must be located to a survey accuracy of not less than 1:1,000 (fifth order) and tied to a common reference point of the same accuracy (FM 6-2). Each observer records direction 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 that falls more than 4 range probable errors away from the mean point of impact of the rounds fired. A round that 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 mean point of impact. This necessitates a quick check of directions recorded by the two flank observers before a piece is released from the calibration site. If, for the same round, both of these observers recorded a direction quite different from all others in that group, then an additional round should be fired from that piece. The decision to fire additional rounds is made by the officer in charge.

e. Accuracy. To insure maximum accuracy, the officer in charge should brief all personnel on the importance of the calibration. A reliable system of communications and exchange of commands, data, and information should be developed for the conduct of firing. It is especially important that bubbles be centered exactly before each round is fired. The pieces should be serviced and checked to insure that they are in proper firing condition. One bench-checked (ordnance-tested) gunner's quadrant should be used on all pieces. At least one calibrated powder thermometer per piece should be obtained before the firing.

22-12. Conduct of Firing

a. Each piece is placed over its surveyed stake. Trunnions are leveled, and the pieces are boresighted and then laid. Tubes must be cleansed of all oil film and then dried.

b. Orienting data (direction and vertical angle to the desired MPI) for each OP are determined and announced to the observer.

c. Chart data from the center of the position area to the desired point of impact are measured from a map. A common deflection and a common quadrant elevation are determined and are used for all pieces throughout the firing. Fuze quick is always used for calibration.

d. Ammunition should be prepared sufficiently in advance of firing to insure uniform weather conditioning. Propellant temperatures of at least four rounds at each piece are measured and recorded immediately prior to firing.

e. Observers are alerted before firing is begun. For each round fired, the number of the piece firing and SHOT are announced when the piece is fired. SPLASH is announced 5 seconds before impact.

f. Each piece is laid for quadrant elevation with the same gunner's quadrant. Battery right (left) is used in order to equalize the weather conditions under which each piece is fired. Sufficient time between rounds must be allowed to enable the observers to locate the round, record the data for that round, and change the orienting data for the next round if necessary. (About 30 seconds is sufficient for the average crew.)

g. The first two rounds from each piece are conditioning rounds but the observers should pick up the round and report and record data as a check of the system and procedures.

h. Firing should be completed as rapidly as possible. If a piece misfires, that piece is called out, the observers are notified, and firing of the other pieces is continued.

i. Before the pieces are released, a check with the observers should be made to make sure that data for all rounds have been recorded and to see if any rounds were erratic. If any rounds were erratic or if the observers missed any rounds, additional rounds should be fired immediately.

22-13. Determination of Range To and Altitude Of the Mean Point of Impact for Each Piece

a. When the target acquisition battalion provides the flash base, it furnishes the grid coordinates and altitude of the mean point of impact for each piece. When the unit provides its own observers, the S3 must examine the observers' recorded data in order to detect erratic rounds and questionable observer data.

b. When sufficient usable rounds have been obtained, the MPI range for each piece is determined by the following procedures:

(1) Compute the average azimuth from each OP for each piece.

(2) Form three target area bases by using selected pairs of OP's (fig 22-1).

(3) Compute three sets of grid coordinates for each mean point of impact, one from each of the three bases.

(4) If there is an appreciable difference in the three sets of coordinates (20 meters or more radially), perform a graphic check (*d* below).

(5) Average the three sets of coordinates to arrive at the mean MPI location.

(6) Using the coordinates of the piece and the MPI location for that piece, compute the range to the mean point of impact for each piece.

c. The altitude of the MPI is determined as follows: Compute the altitude of the MPI from each OP and average the four altitudes to determine the mean altitude. (If accurate maps are available, the MPI altitude may be measured from the map.)

d. If survey, observer orientation, and observer readings are correct, all rays, as plotted from the respective OP's, will theoretically intersect at a common point. Normally, however, the rays, either for a single round or a mean point of impact, will not intersect but will form a polygon of error. If observer data appear to be of questionable accuracy, a graphical check on the magnitude and nature of the polygon of error should be made as follows: Plot all OP's on a gridded sheet to a scale of 1:6,250 and plot the azimuth of the round or mean point of impact in question as rays from the respective observation posts. 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 in error, consider the data from all observers to be 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. The smaller the polygon, the more accurate the calibration. A graphical check should be made on the common reference point before firing begins.

22-14. Adjustment of Ranges for Differences in Altitude

a. A valid comparison of the ranges achieved by the pieces being calibrated could be obtained if all pieces were at the same altitude and if all mean points of impact were at the same altitude. The unit can establish a common altitude for the pieces by selecting a level position

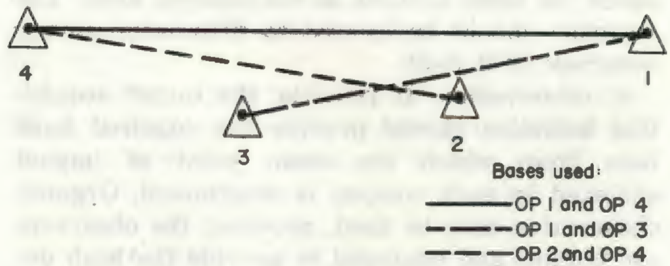


Figure 22-1. Target area bases.

area. However, the altitude of the mean points of impact may vary even though a relatively level impact area is selected. Therefore, to obtain a valid comparison of the ranges achieved by *each piece,* the unit must correct the measured ranges to the ranges that would have been achieved had all rounds landed at a common altitude.

b. The procedure for correcting the measured ranges for differences in altitudes of the MPI is as follows:

(1) Select a reference altitude. Any convenient altitude may be used. The lowest MPI altitude is commonly used as the reference altitude.

(2) Subtract the reference altitude from the altitude of the mean point of impact.

(3) Multiply the difference in altitude by the cotangent of the angle of fall. (The cotangent of the angle of fall is determined from the Supplementary Data table (table G) at the measured range to the MPI rounded to the nearest 100 meters.) If the altitude of the MPI is greater (less) than the reference altitude, the sign of the correction is plus (minus) (fig 22-2).

(4) Add the range correction determined in (3) above to the measured range to determine the corrected range.

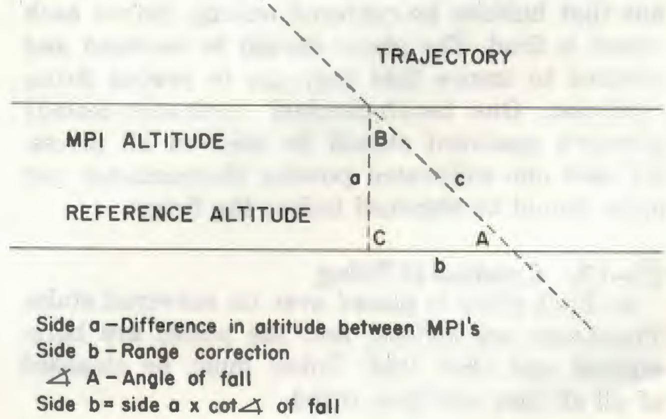


Figure 22-2. Correction for difference in altitude.

22-15. Selection of the Standard Piece

In a comparative calibration, the piece that achieved the longest corrected range is chosen as the standard piece. Its corrected range is the standard with which the corrected ranges of the other pieces are compared. The comparative VE assigned to the standard piece is 0 meters per second.

22-16. Determination of Comparative Velocity Error

The procedure for determining the comparative VE of a piece is as follows:

a. Determine the difference between the corrected range of the piece in question and the corrected range of the standard piece.

b. Enter the Ground Data table (table F) at the corrected range (rounded to the nearest 100 meters) of the piece in question. Determine the correction for a *decrease* in muzzle velocity of 1 meter per second.

c. Divide the difference in range (*a* above) by the muzzle velocity unit correction (*b* above). The result is the comparative VE. The sign of the comparative VE is always minus, since the longest shooting piece is the standard.

22-17. Correction of Velocity Error for Propellant Temperature Variations

A valid comparative VE can be determined only if all weapons fire ammunition with the same propellant temperature. Precautions should be taken to keep all propellants at the same temperature. If there is any variation in the average propellant temperatures of the individual weapons, the comparative VE's determined (para 22-14) must be corrected. The final comparative VE of a particular piece is the VE that would have been attained if the ammunition fired by that weapon had the same propellant temperature as the ammunition of the standard piece. The procedure for correcting the VE for propellant temperature variations is as follows:

a. Enter the Propellant Temperature table (table E) and determine the change to muzzle velocity for propellant temperature for each piece.

b. To determine the correction to VE for each piece, subtract (algebraically) the change to muzzle velocity for propellant temperature from that of the standard piece.

c. For each piece, add the correction (*b* above) to the VE determined as prescribed in paragraph 22-16. The result is the final comparative VE.

22-18. Example

A 155-mm howitzer M109 battalion has completed firing a fall-of-shot comparative calibration with charge 7, quadrant elevation 310. All pieces were at the same altitude. The following data have been determined (data for only four pieces are shown):

Piece number	*Computed range (meters)*	*Altitude of MPI (meters)*	*Average propellant temperature (Fahrenheit)*
1 ------	9665	320	83°
2 ------	9710	316	80°
3 ------	9790	321	80°
4 ------	9610	325	78°

a. The MPI ranges are corrected for differences in altitudes between mean points of impact. The lowest MPI altitude (316 meters) is selected as the reference altitude.

Piece number	*Computed range (meters)*	*Altitude of MPI (meters)*	*Difference in altitude (meters)*	*Cotangent of angle of fall*	*Range correction (meters)*	*Correc- range (meters)*
1 ----------------------------	9665	320	+4	2.1	+8	9673
2 ----------------------------	9710	316	0	2.1	0	9710
3 ----------------------------	9790	321	+5	2.1	+10	9800
4 ----------------------------	9610	325	+9	2.2	+20	9630

b. Piece number 3 is selected as the standard piece because it is the piece with the greatest corrected range (9800).

c. The VE's are determined as follows:

Piece number	*Corrected range*	*Difference from std rg*	*MV unit correction*	*VE*
1 ------------------------	9673	-127	21.1	-6.0 m/s
2 ------------------------	9710	-90	21.1	-4.3 m/s
3 ------------------------	9800	0		0 m/s
4 ------------------------	9630	-170	21.0	-8.1 m/s

d. The VE's are corrected for differences in propellant temperature between the standard piece and all other pieces. The final comparative VE's are shown below.

Piece number	*PT*	*Change to MV for PT*	*Correction to VE for PT*	*VE*	*Final VE*
1	83° F	+2.2	−0.5	−6.0	−6.5 m/s
2	80° F	+1.7	0	−4.3	−4.3 m/s
3	80° F	+1.7	0	0	0 m/s
4	78° F	+1.4	+0.3	−8.1	−7.8 m/s

22-19. Comparative Calibration by Battery

At times calibration of all batteries on the same day may not be practicable. In such cases, each battery conducts a separate calibration. The data from the separate calibrations are then adjusted to a common level so that the weapons can be properly grouped within the battalion.

a. The first battery to calibrate its weapons also calibrates one piece from each of the other two batteries. These pieces are later used as control pieces by their respective batteries.

b. The separate calibrations are conducted and data computed as outlined in paragraphs 22-12 through 22-18.

c. The different sets of data are adjusted to a common level by application of a correction to the VE's of the second and third batteries to calibrate. The correction to be applied to the VE's of each battery is number of meters 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.

(1) Example: Battery A is calibrated first; Battery B, second; and Battery C, third. The VE's determined from the separate calibrations are as follows:

A		B		C	
Weapon	VE	Weapon	VE	Weapon	VE
A1—	−0	B1*	−2.4	C1**	−1.5
A2—	−1.2	B2	−0.9	C2	−0.3
A3—	−2.1	B3	0	C3	−1.8
A4—	−2.4	B4	−1.5	C4	−2.1
A5—	−3.7	B5	−2.7	C5	0
A6—	−4.6	B6	−3.4	C6	−1.2
B1*—	−0.6				
C1**—	−2.7				

*Battery B control weapon.
**Battery C control weapon.

(2) A correction of +1.8 m/s must be applied to the VE for B1 obtained with Battery B to bring it to the VE obtained with Battery A; hence, +1.8 m/s must be applied to all VE's in Battery B.

(3) Similarly, a correction of −1.2 m/s must be applied to the VE for C1 obtained with Battery C to bring it to the VE obtained with Battery A; hence −1.2 m/s must be applied to all VE's in Battery C.

(4) When the correction factors ((2) and (3) above) have been applied, the calibration data can be rewritten (adjusted to a common level) as follows:

A		B		C	
Weapon	VE	Weapon	VE	Weapon	VE
A1	0	B1	−0.6	C1	−2.7
A2	−1.2	B2	+0.9	C2	−1.5
A3	−2.1	B3	+1.8	C3	−3.0
A4	−2.4	B4	+0.3	C4	−3.3
A5	−3.7	B5	−0.9	C5	−1.2
A6	−4.6	B6	−1.6	C6	−2.4

(5) The weapons can now be listed in order of decreasing shooting strength and the VE's adjusted so that the longest shooting weapon has a VE of 0; the correction required to bring the longest shooting piece to 0 must be applied similarly to all weapons.

Order of strength	First adjusted VE	Final adjusted VE
B3	+1.8	0
B2	+0.9	−0.9
B4	+0.3	−1.5
A1	0	−1.8
B1	−0.6	−2.4
B5	−0.9	−2.7
A2	−1.2	−3.0
C5	−1.2	−3.0
C2	−1.5	−3.3
B6	−1.6	−3.4
A3	−2.1	−3.9
A4	−2.4	−4.2
C6	−2.4	−4.2
C1	−2.7	−4.5
C3	−3.0	−4.8
C4	−3.3	−5.1
A5	−3.7	−5.5
A6	−4.6	−6.4

(6) The final adjusted VE's are the basis for regrouping the weapons. They represent comparative calibration VE's equal to battalion calibration VE's.

Section IV. FALL-OF-SHOT ABSOLUTE CALIBRATION

22-20. 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. 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. Ideally, the location of the met station should be a point between the weapon and target and should be such that the balloon would pass as near the summit of the trajectory as possible. The time of the met passage and the time of firing should be coordinated.

b. Selecting the Quadrant Elevation. The QE fired should be such that the maximum ordinate will coincide with an altitude represented by a line number of the met message. The method of bringing an acceptable QE (240 to 460 mils) into agreement with a line number of the met message involves the use of the Supplementary Data table of the firing table. The following example illustrates the method of selecting the QE to be fired in calibrating a 155-mm howitzer M109 with charge 5 GB, M3 propellant.

Altitudes represented by met line numbers

Line 02	500 meters
Line 03	1,000 meters
Line 04	1,500 meters
Line 05	2,000 meters

From the Supplementary Data table, a maximum ordinate of 500 meters results in a horizontal range of approximately 6,000 meters. The quadrant elevations for ranges in the vicinity of 6,000 meters are in the vicinity of 296 mils, a good QE for calibration. The range corresponding to a maximum ordinate of 500 meters is 6,037 meters. The corresponding QE is 298.3 mils. For convenience, this QE can be rounded to 300 mils for firing the calibration.

Note. The GFT provides a more rapid solution to the choice of the QE to fire. This is accomplished by placing the manufacturer's hairline over one of the met check gagepoints between the red numbered elevation limits. The QE is then read from the elevation scale under the hairline.

c. Selecting Pieces for Calibration. It is sometimes desirable to bring only a limited number of pieces into a state of absolute calibration. Preferably, three pieces per battalion are selected, although one is sufficient. The base piece, or a piece with average wear measurement within each battery should be selected. If comparative calibration data are known or later determined, all pieces can be brought into an acceptable state of absolute calibration as shown in the example in paragraph 22-23*a*.

d. Other Considerations. Other preliminary considerations for absolute calibration are the same as those for comparative calibration.

22-21. Conduct of Firing

An absolute calibration is conducted in the same manner as a comparative calibration except that fire by battery right (left) is not used. Each piece will complete firing before the next piece fires. Each piece should be fired as rapidly as possible consistent with the capabilities of the weapon and personnel involved so that range effects due to changes in weather are minimized. Speed should not, however, take precedence over accuracy.

22-22. Computation of Absolute Velocity Error

a. To compute the VE, first locate the MPI for each weapon by using the method described in paragraph 22-13. Then compute site by using the difference in altitude between the piece and the mean point of impact. Subtract the site from the QE fired to determine the elevation fired. Enter the Ground Data table and interpolate for the range corresponding to the elevation. This is the standard horizontal range that would have been achieved if all conditions had been standard at the time of firing. Subtract the developed MPI range from the standard (firing table) range. The resultant difference in range is the range correction necessary to compensate for all nonstandard conditions at the time of firing.

b. Compute range corrections for all known nonstandard conditions except propellant temperature by using met data taken at the time of firing. All unit corrections are determined at the range (nearest 100 meters) to the mean point of impact. The line number is that corresponding to the QE fired.

c. Subtract the met range correction from the total range correction determined as described in *a* above. The result is the correction in meters to compensate for ΔV. Compute the ΔV by dividing the ΔV range correction by the MV unit correction (determined at MPI range). If the ΔV range correction is plus (minus), the MV unit correction is taken from the *Decrease (Increase)* column. Determine the VE by subtracting the muzzle velocity change for propellant temperature from ΔV. The propellant temperature used is the average of all propellant temperatures recorded at the piece.

Example: 155-mm howitzer M109, charge 5 GB, M3 propellant:

MPI range	5,630 meters
Site	+6.4 mils
QE fired	300 mils
Elevation	293.6 mils (300−6.4)

The range corresponding to elevation 293.6 mils is 5,964 meters.

The total range correction to compensate for all nonstandard conditions is +334 meters (5964 −5630).

Assume that a met message has been solved and a met range correction of +172 meters has been determined.

The ΔV range correction is +162 meters (334 − 172).

The unit correction for muzzle velocity (*Decrease* column, range 5600) is +15.8 (meters).

The ΔV = +162/15.8 = 10.3 m/s.

The propellant temperature is 53° F.

The change to muzzle velocity for propellant temperature is −0.8 m/s. The VE is −9.5 m/s (−10.3 − (−0.8)).

d. The VE of −9.5 m/s in the example in *c* 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 muzzle velocity variation computed is of a different magnitude. Such a difference can be caused by—

(1) A difference in projectile lot efficiency (overcoming air resistance) between the lot used in the calibration and the lot used in constructing the firing tables. The difference in projectile lot efficiency may show up as an increase or a decrease in range not otherwise accounted for.

(2) Limitations in accurately determining met data.

(3) Limitations of computational procedures and firing tables.

(4) Errors in survey.

(5) Errors in the QE used (to include barrel curvature).

e. 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 number	*VE*	*MVV*	*Difference*
1	−7.3	−5.5	−1.8
2	−9.1	−7.6	−1.5
3	−6.7	−4.6	−2.1
4	−11.3	−6.4	−4.9
5	−8.2	−7.0	−1.2
6	−7.6	−6.1	−1.5

Section V. REDISTRIBUTION OF WEAPONS

22–23. Grouping of Pieces According to Velocity

a. Grouping After Calibration by Fall of Shot. A list by tube number of all pieces calibrated, ranging in order from the strongest shooting piece to the weakest, should be prepared for grouping the pieces. These pieces should then be assigned to batteries on the basis of their shooting strengths; i.e., the strongest 1/3 in one battery (normally Battery A), the weakest 1/3 in another battery (normally Battery C), and the remaining 1/3 in the remaining battery (normally Battery B). Within batteries, the base piece should be the piece with the shooting strength nearest the battery average. The unit can equalize wear among the tubes in service by habitually assigning to the longest shooting pieces missions that do not require all the pieces of the battery. The following examples illustrate the method of grouping pieces according to shooting strength:

Tube number	VE comparative calibration	Adjustment of VE's to absolute scale	Battery*
51180	0	−3.4	A1
51242	−0.3	−3.7	A2
51177**	−0.9	−4.3	A3 (base piece)***
51359	−1.2	−4.6	A4
51628	−1.5	−4.9	A5
51032	−1.5	−4.9	A6
51768	−1.8	−5.2	B1

Tube number	VE comparative calibration	Adjustment of VE's to absolute scale	Battery*
51535	−2.4	−5.8	B2
51640	−3.0	−6.4	B3 (base piece)***
51819	−3.4	−6.8	B4
51225	−3.7	−7.1	B5
51275	−4.0	−7.4	B6
51393	−4.3	−7.7	C1
51410	−4.3	−7.7	C2
51733	−4.6	−8.0	C3
51366	−4.9	−8.3	C4
51136	−5.8	−9.2	C5 (base piece)***
51250	−6.7	−10.1	C6

*Assignment to batteries only; does not imply piece numbering within batteries.

**Absolute calibration performed with this tube.

***If the designation of the average piece as the base piece causes calibration corrections to be carried on one or more of the pieces, another piece may be designated as the base piece.

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 number	Comparative VE	Absolute VE	Difference
1	0	−3.7	−3.7
2	−0.3	−4.3	−4.0
3	−0.9	−4.3	−3.4
		Mean	−3.7

Therefore, −3.7 meters per second should be applied to the comparative VE's of all weapons to adjust to the absolute scale. This includes applying the mean difference to the comparative VE's of the weapons that fired the absolute calibration and thereby reduces the errors caused by nonvelocity elements that are contained in the absolute VE's determined by firing.

b. Grouping After Calibration by Chronograph. The results of chronograph calibration (MVV's) are absolute calibration data. These data permit the most effective grouping and are also the basis for the most reliable corrections for variations in shooting strength between weapons. When MVV's or 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.

22–24. Computation and Application of Calibration Corrections

a. Once the weapons have been calibrated and grouped, corrections must be applied to compensate for the differences in shooting strength between the base pieces of the batteries within the battalion and for the differences in shooting strength between the base piece and other weapons within each battery. The computation and application of these corrections are explained in chapter 23.

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 technique, the following factors should be considered:

(1) When both MVV's and VE's are available from the same calibration, the VE's normally will prove more successful in present techniques. The VE's at least partly compensate for variations in projectile lot efficiency (from the firing table lot) and in barrel curvature, whereas the MVV's do not.

(2) Velocity errors are subject to errors of met data and survey. They are also subject to limitations of present computing procedures.

(3) The MVV or VE used in this respect is valid only for the weapon-ammunition combination for which it has been determined.

c. The following rules should be used as a guide in applying calibration data when MVV's and VE's are both available:

(1) Muzzle velocity variations are preferred to either type of fall-of-shot calibration data for grouping pieces and computing individual piece corrections. An absolute calibration should not be conducted for the sole purpose of grouping piece or computing individual piece corrections.

(2) Velocity errors of the type obtained from registration and concurrent met are preferred to absolute VE's for computing corrections to firing data (and determining GFT settings), as in the met plus VE technique. In the absence of absolute VE's, MVV's can be used for met plus VE computations; comparative VE's cannot be used for this purpose.

(3) If MVV's and comparative VE's only are available, the MVV's are preferred for grouping pieces and for computing individual piece corrections and corrections to firing data.

CHAPTER 23

CALIBRATION, POSITION, AND SPECIAL CORRECTIONS

Section I. CALIBRATION CORRECTIONS

23–1. General

Calibration corrections are corrections to compensate for the variations in the shooting strengths of the pieces in a unit. Calibration corrections are used primarily—

a. For deriving GFT settings for nonregistering batteries from the registration of one battery.

b. In combination with position corrections for deriving special corrections.

c. For correcting firing data for those weapons whose shooting strengths vary by more than ±1.5 meters per second from that of the base piece.

23–2. Determination of GFT Settings for Nonregistering Batteries

a. When only one battery of a battalion equipped with weapons of the same caliber is allowed to register, the GFT setting of the registering battery is used by the nonregistering batteries in the absence of any better information. If calibration VE's of the base piece of the batteries are known, these VE's may be used in obtaining the nonregistering batteries GFT settings of an accuracy that will approach the accuracy of GFT settings that would have been obtained if all batteries had registered.

b. The procedure for determining the GFT setting for a nonregistering battery is as follows:

(1) Determine the comparative VE of the base piece of each nonregistering battery by subtracting the VE of the base piece of the registering battery from the VE of the base piece of the battery in question.

(2) Determine a VE range correction by multiplying the comparative VE ((1) above) by the muzzle velocity unit correction corresponding to the entry range for the registering battery.

(3) Determine the VE corrected range for the nonregistering battery by algebraically adding the VE range correction to the GFT range of the registering batttery.

(4) Using the GFT setting for the registering battery, determine the elevation and fuze setting corresponding to the VE corrected range ((3) above).

(5) Construct the GFT setting for the nonregistering battery as follows:

(*a*) Place the hairline over the GFT range to the registration point for the registering battery and draw the elevation gageline over the elevation determined in (4) above.

(*b*) Draw the time gageline over the fuze setting obtained. This applies the registration total fuze correction to the fuze setting corresponding to the elevation determined in (4) above.

Example: Battery B (155-mm howitzer M109) has registered and determined the following GFT settting: GFT B: Charge 5, lot YS (GB, M3 propellant), range 6820, elevation 368, time 23.8. The VE's for the base pieces are—

A: −0.9 m/s.
B: −3.0 m/s.
C: −5.0 m/s.

The comparative VE's of the base pieces for A and C are—

A: +2.1 m/s (−0.9 − (−3.0)).
C: −2.0 m/s (−5.0 − (−3.0)).

The muzzle velocity unit corrections are—

A: −17.7 (Increase column)
C: +18.4 (Decrease column)

The VE range corrections are—

A: −40 meters (−17.7 × +2.1 = −37).
C: +40 meters (+18.4 × −2.0 = +37).

The VE corrected ranges for Batteries A and C are—

A: 6780 (6820 −40).
C: 6860 (6820 +40).

Using the GFT setting for Battery B and the corrected ranges determined for Batteries A and C, read the elevation and fuze setting under the appropriate gagelines. The GFT settings are—

GFT A: Charge 5, lot YS, range 6820, elevation 365, time 23.6.

GFT C: Charge 5, lot YS, range 6820, elevation 371, time 24.0.

c. The procedure for determining GFT settings for nonregistering batteries by use of calibration corrections is based on the assumption that if different weapons fire a registration from the same location, at the same time, and on the same registration point, the differences in adjusted data would be caused by the differences in shooting strength of the invididual weapons. Therefore, the FDC can determine the GFT setting for each nonregistering battery by compensating for the difference between the comparative VE's of the base pieces. (Since it is assumed that the weapons fired the same registration, then the GFT setting range for the nonregistering batteries will be the same as that of the registering battery.)

23-3. Calibration Corrections for Individual Pieces of a Battery

a. Calibration corrections to compensate for the variations in shooting strength of the pieces of a battery are applied to the quadrant elevation. The individual piece correction is based on the variation of the shooting strength of each piece compared with that of the base piece.

b. In area fire, calibration corrections should be applied to any piece whose VE varies by more than ±1.5 meters per second from that of the base piece. Calibration corrections for various ranges may be computed and tabulated on a card, which is furnished to the chief of section. The chief of section determines the appropriate correction and applies it to the announced quadrant elevation.

c. When special corrections are to be used for achieving a particular burst pattern, calibration corrections are determined and applied to all pieces in the battery.

d. The procedure for determining the calibration correction for an individual piece of a battery is as follows:

(1) Determine the comparative VE of the piece with respect to the base piece by subtracting the calibration VE of the base piece from that of the piece in question.

(2) Determine the muzzle velocity unit correction from the Ground Data table at the entry range (to the nearest 100 meters). Extracting the unit correction from the Decrease (Increase) column if the sign of the comparative VE ((1) above) is minus (plus).

(3) Determine the calibration correction in meters by multiplying the comparative VE by the muzzle velocity unit correction.

(4) Determine the calibration correction in mils by dividing the calibration correction in meters by the change in range for a 1-mil change in elevation (m/mil). Determine the meters per mil factor from the Ground Data table at the entry range to the nearest 100 meters.

Example: A 155-mm howitzer M109 battery has been assigned a final protective fire at a chart range of 7,130 meters. Calibration corrections are to be applied. The comparative VE's from a calibration with charge 5 GB (M3 propellant) are as follows:

Piece number	*Calibration VE*
1	−2.1 m/s
2	−2.7 m/s
3 (base piece)	−3.0 m/s
4	−3.4 m/s
5	−4.3 m/s
6	−4.3 m/s

Following the procedure described in *d* above, compute the calibration correction as follows:

Piece No.	*Comparative VE*		*MV unit corrections*		*Calibration correction (meters)*		*Meters per mil factor*	*Calibration correction (mils)*
1	+0.9	×	−18.2	=	−16	÷	13	−1
2	+0.3	×	−18.2	=	−5	÷	13	0
3	0	×	------	=	----	÷	--	0
4	−0.4	×	+19.0	=	+8	÷	13	+1
5	−1.3	×	+19.0	=	+25	÷	13	+2
6	−1.3	×	+19.0	=	+25	÷	13	+2

Note. **The calibration correction in meters takes the sign of the MV unit correction factor.**

e. If time fuze is to be used, a calibration fuze correction corresponding to the calibration correction for range (elevation) must be determined and applied. Use the following proportion for determining the time correction:

$$\frac{\text{Calibration fuze correction}}{\text{difference in fuze setting for 100-meter range change}} = \frac{\text{calibration correction in meters}}{\text{100 meters}}$$

Determine the difference in fuze setting for a 100-meter range change from the Ground Data table at the elevation for the base piece. Extract the fuze settings corresponding to the two listed elevations that bracket the base piece elevation and determine the difference in the two fuze settings. If the base piece elevation is listed in the firing table, use the fuze setting corresponding to the base piece elevation and that corresponding to the next higher (lower) listed elevation when the calibration correction in meters is plus (minus).

f. When a GFT with a current GFT setting is available, determine the corrections for each piece as described in *d*(3) above and algebraically add the corrections to the GFT range. Place the hairline of the GFT over the corrected range and read the elevation and fuze setting under the appropriate gagelines.

Section II. POSITION CORRECTIONS

23-4. General

a. Position corrrections are corrections for individual pieces to compensate for the difference between the pattern formed by the pieces in the position area and the desired pattern of burst at the target. Position corrections may be required because of abnormal dispersion or concentration of the pieces or because of the location, size, or shape of the target.

b. Generally, position corrections are applied in area missions only if the depth of the position is abnormally great. A deflection difference is usually used in an area mission to correct for an abnormal width of battery.

c. In rare cases, corrections may be needed for differences in the altitudes of the pieces. The correction for vertical displacement will be negligible and is ignored unless the terrain is extremely rugged. The correction for the range effect is determined as follows: Use the GST to compute the amount of site necessary to correct for vertical displacement of the piece from the battery center. Multiply this change in site by the meters per mil factor from the tabular firing tables or, using the GFT, apply the site as a change in elevation to determine the equivalent range correction. Combine the range correction obtained with other position corrections to determine the total correction.

23-5. Preparation of M10 or M17 Plotting Board for Determining Position Corrections

When the M10 or M17 plotting board is used for determining position corrections, the piece locations and the desired sheaf must be plotted to scale on the transparent disk of the plotting board. The piece locations are given in the battery executive officer's report (oral or sketch (fig 23-1)).

a. Aline the centerline of the transparent disk (red 32 at the top) so that it coincides with the arrow on the gridded base of the board. The center of the board represents the battery center.

b. To facilitate measurement, assign each small square of the base of value of 5 meters. If, for example, a piece is 30 meters right of, and 20 meters behind, the battery center, plot the piece location 6 squares right of, and 4 squares below, the center of the board.

c. Place an index for reading deflections on the base opposite the referred deflection. For weapons that are equipped with the 0 to 6400 mil panoramic telescope, use the red arrow at the 0 index for reading deflections and renumber the scale as indicated in figure 23-2.

d. For an open sheaf, draw on the base, lines parallel to the direction-of-fire arrow (fig 23-2). Draw the lines to the same scale as that used for plotting the piece locations and equally spaced according to the effective width of the burst. For a converged sheaf, the center of the board represents the point of convergence of the sheaf. For a special sheaf, plot each desired point of burst.

23-6. Computation and Application of Position Corrections

After the plotting board has been prepared, position corrections in meters for deflection and range for each piece of the battery may be graphically obtained for any desired direction of fire. The plotted positions represent not only the piece positions but also the uncorrected burst positions in the target area.

a. Set off the direction of fire on the plotting board by rotating the transparent disk until the desired deflection is opposite the index.

b. The deflection correction in meters for each piece (burst) corresponds to the distance and direction (right or left) between the plotted burst and its appropriate place in the constructed sheaf. Starting with the right burst, move each burst to the nearest sheaf line, with no more than one burst to a line. The bursts need not be placed in the sheaf in the numerical order of piece num-

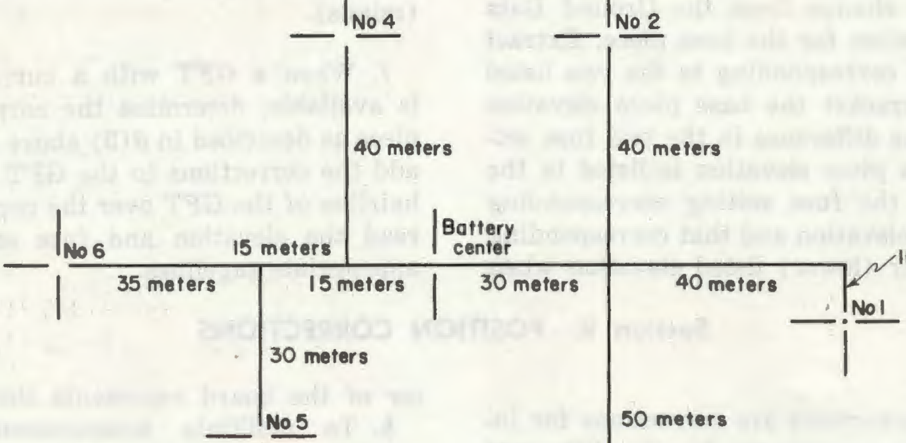


Figure 23-1. Executive officer's sketch of an abnormal battery position.

bers. Convert the correction in meters to a correction in mils by dividing the shift in meters by the chart range in thousands to the nearest hundred meters (mil relation). If a GST is available, divide the shift in meters by the chart range in thousands to the nearest 10 meters by use of the C and D scales and the M gage point (*e*(1) below). Use procedures outlined in paragraph *f*(1) below whenever the GST is available.

c. The range correction in meters for each piece (burst) corresponds to the distance and direction (over or short) between the plotted burst and the line at chart range (center of board) perpendicular to the direction of fire.

(1) Convert the range correction in meters to a correction in mils of elevation by dividing the correction in meters by the meters per mil factor.

(2) Convert the range correction to a time correction in the manner described in paragraph 23-3*e*.

d. The following example illustrates the procedure for computing and applying position corrections by use of the plotting board. A 155-mm howitzer M109 battery has been laid, collimators have been emplaced, and deflection has been reset to 3200. The pieces are distributed as shown in figure 23-1. The final protective fire assigned to the battery is at a chart range of 5,710 meters. The chart deflection to the FPF is 2,850 mils. The long axis of the FPF is perpendicular to the direction of fire. Determine position corrections for charge 5, GB, (M3 propellant), fuze quick, open sheaf.

(1) Remove the disk from the plotting board and draw six lines parallel to the arrow 50 meters apart, with one of the two centerlines 25 meters right and the other 25 meters left of the arrow. (Scale is one small square = 5 meters.)

(2) Replace the disk and orient the 0-3200 line of the disk over the arrow, with the red 32 on the disk at the head of the arrow.

(3) Plot the pieces on the disk.

(4) Rotate the disk until 2850 (red scale) is opposite the red arrow.

(5) Determine the deflection correction in meters required to move each burst to the appropriate place in the sheaf.

Number 1 right 55 meters
Number 2 right 10 meters
Number 3 right 30 meters
Number 4 left 47 meters
Number 5 left 6 meters
Number 6 left 64 meters

(6) Convert the deflection correction in meters to a correction in mils by dividing the correction in meters by the chart range in thousands to the nearest hundred meters.

Number 1 right 10 (55/5.7)
Number 2 right 2 (10/5.7)
Number 3 right 5 (30/5.7)
Number 4 left 8 (47/5.7)
Number 5 left 1 (6/5.7)
Number 6 left 11 (64/5.7)

(7) Determine the range correction in meters required to bring each burst to the line at chart range perpendicular to the direction of fire.

Number 1 −14 meters
Number 2 −48 meters
Number 3 +37 meters
Number 4 −33 meters
Number 5+38 meters
Number 6 +1 mil (+22/16)

(8) Convert the range correction in meters to a correction in mils of elevation by dividing the correction in meters by the meters per mil factor for the chart range to the nearest 100 meters.

Number 1 −1 mil (−14/16)
Number 2 −3 mils (−48/16)
Number 3 +2 mils (+37/16)
Number 4 −2 mils (−33/16)
Number 5 +2 mils (+38/16)
Number 6 + 1 mil (+ 22/16)

e. Position corrections may also be applied by using the GFT in conjunction with the M17 plotting board. This method should be employed whenever possible, and especially when a valid GFT setting is being used. If a valid deflection correction scale is available, the total deflection correction must be determined and algebraically applied to the position correction for deflection.

(1) The deflection correction for each piece is determined as in *b* above except that the correction in meters is converted to mils, using the GST, by dividing the shift in meters by the chart range in thousands to the nearest 10 meters. The total deflection correction (determined from the deflection correction scale at the elevation corresponding to the target range and using the GFT setting) is algebraically added to the correction determined above. The result is applied to the chart deflection using the LARS rule.

(2) The individual elevations and times to be fired are obtained by applying the range corrections determined from the plotting board to the chart ranges. The hairline is placed over these corrected ranges and the corrected elevations and times are read under their respective gagelines.

f. The following example illustrates the procedure for applying position corrections by use of the GFT in conjunction with the plotting board. Battery and target data are the same as those in the example in *d* above. The GFT setting in use is GFT B: Chg 5, lot XY, rg 6360, el 344, ti 21.8.

(1) Prepare the plotting board by following the steps in *d*(1) through (4) above.

(2) Determine the deflection correction in meters for each piece (*d*(5) above).

(3) Convert each deflection correction in meters to a deflection correction in mils by use of the C and D scales and M gagepoint on the GST.

Number 1 R10 (R55/5.71)
Number 2 R2 (R10/5.71)
Number 3 R5 (R30/5.71)
Number 4 L8 (L47/5.71)
Number 5 L1 (L6/5.71)
Number 6 L11 (L64/5.71)

(4) Determine the deflection correction to be applied in the following manner. With the manufacture's hairline over the chart range (5710) the elevation (298) is read under the elevation gageline. Enter the deflection correction scale and extract the total deflection correction (L2). This value is then applied as follows:

Number 1 R10 + L2 = R8
Number 2 R2 + L2 = 0
Number 3 R5 + L2 = R3
Number 4 L8 + L2 = L10
Number 5 L1 + L2 = L3
Number 6 L11 + L2 = L13

The corrections just determined are applied to the chart deflection (2850) to determine the deflection to fire each piece:

Number 1 2850 + R8 = 2842
Number 2 2850 + 0 = 2850
Number 3 2850 + R3 = 2847
Number 4 2850 + L10 = 2860
Number 5 2850 + L3 = 2853
Number 6 2850 + L13 = 2863

(5) Determine the range correction in meters for each piece (*d*(7) above).

(6) Determine the corrected range for each piece by applying the range correction to the nearest 10 meters to the chart range.

Number 1 −14 (−10)
Number 2 −48 (−50)
Number 3 +37 (+40)
Number 4 −33 (−30)
Number 5 +38 (+40)
Number 6 +22 (+20)

Note. Since chart range is determined to the nearest 10 meters each range correction is also expressed to this accuracy.

(7) Determine the elevation and times for each piece (*e*(2) above).

	Elevation	*Time*
Number 1	297	19.1
Number 2	295	18.9
Number 3	300	19.3
Number 4	296	19.0
Number 5	300	19.3
Number 6	299	19.2

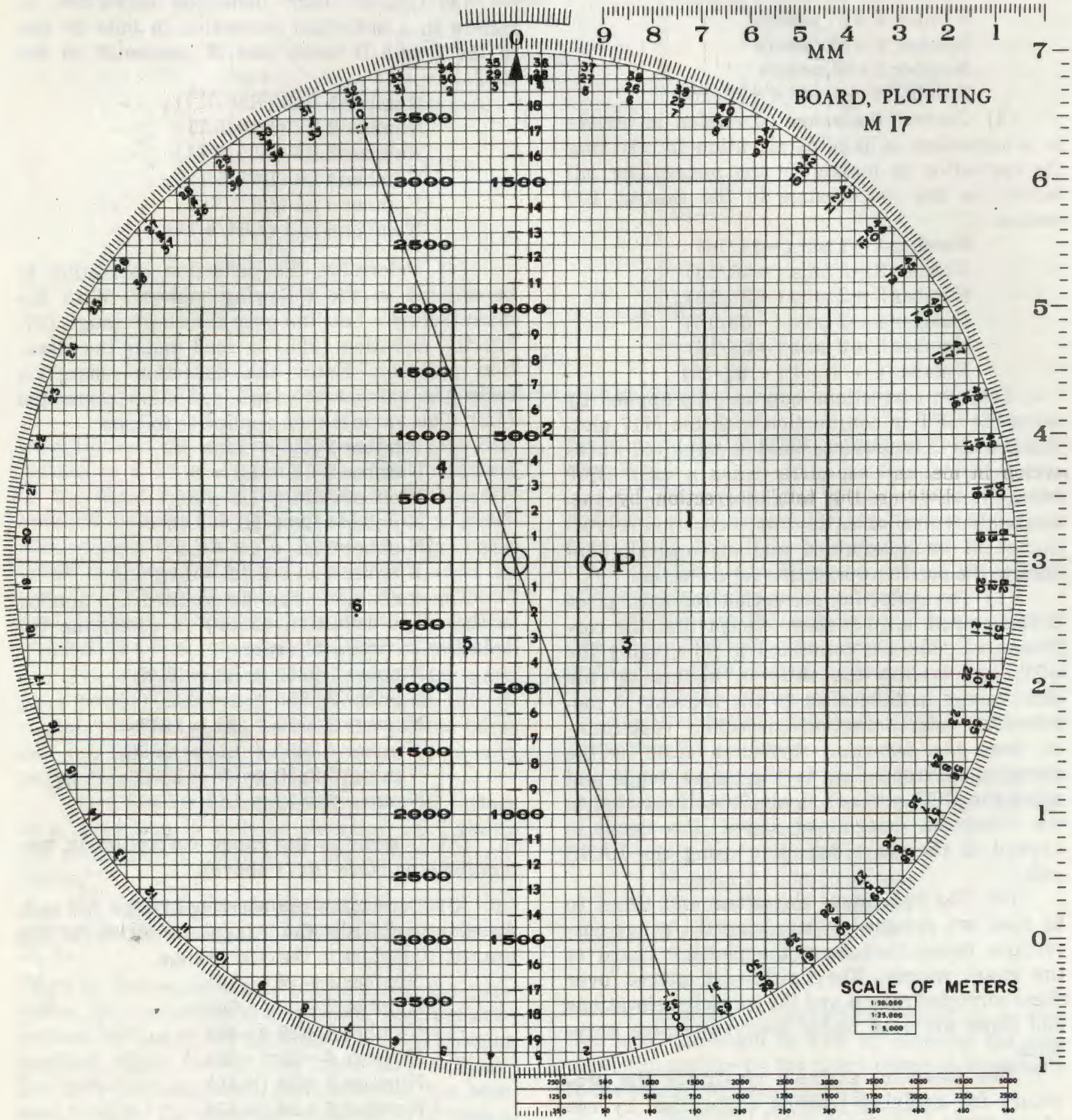


Figure 23–2. Use of the M17 plotting board.

Section III. SPECIAL CORRECTIONS

23-7. General

Special corrections are individual piece corrections applied to deflection, fuze setting, and quadrant elevation to place the burst in a precise pattern so that the burst of each piece falls (theoretically) at a planned point on the target. In the rare cases in which they are used, special corrections normally are computed at the battalion fire direction center. Special corrections are a combination of calibration corrections and position corrections.

23-8. Determination of Special Corrections

a. Deflection. The special correction for deflection is solely a position correction and is determined as described in paragraph 23-6*b*. If a total deflection correction can be determined it is applied as outlined in paragraph 23-6*f*.

b. Range. To determine the special correction for range for each piece, add the calibration correction in meters and the position correction for range in meters. Then, convert the total correction in meters to a correction in mils of elevation by dividing the total correction by the meters per mil factor determined at chart range. When the GFT is being used, add the special correction for range in meters to the chart range to determine the corrected range. To determine the elevation and time for each piece, place the hairline of the GFT over the corrected range and read the elevation and time under the hairline or, if a GFT setting has been constructed, under the respective gagelines.

c. Time. The special correction for fuze setting is determined by the following formula:

$$\frac{\text{Special fuze correction}}{\text{difference in fuze setting for a 100-meter change in range}} = \frac{\text{Special correction for range in meters}}{\text{100 meters}}$$

Use the procedure described in paragraph 23-6*e*, determine the difference in fuze setting for a 100-meter change in range at the elevation to the target before special corrections are applied.

23-9. Application of Special Corrections

a. Deflection. The position correction for deflection is added to the chart deflection and total deflection correction, and the total deflection for each piece is announced.

b. Time. The special correction for time is applied to the common fuze setting, and the total time for each piece is announced.

c. Elevation. The special correction for elevation is added to the common quadrant elevation and the total quadrant elevation for each piece is announced.

d. Example. The following is an example of the commands for special corrections:

BATTERY ADJUST.
SPECIAL CORRECTIONS.
SHELL HE, LOT XRAY YANKEE, CHARGE 5.
FUZE TIME.
BATTERY 1 ROUND.
DEFLECTION, NUMBER 1, 3249; NUMBER 2, 3250; NUMBER 3, 3250; NUMBER 4, 3253, NUMBER 5, 3249; NUMBER 6, 3252.
TIME, NUMBER 1, 23.9; NUMBER 2, 24.2; NUMBER 3, 23.8; NUMBER 4, 23.9; NUMBER 5, 24.4; NUMBER 6, 24.4.
QUADRANT, NUMBER 1, 371; NUMBER 2, 376; NUMBER 3, 369; NUMBER 4, 371; NUMBER 5, 380; NUMBER 6, 379.

CHAPTER 24

FDC PROCEDURES FOR SPECIAL SITUATIONS

Section I. INTRODUCTION

24–1. General

a. The characteristics of different types of projectiles and certain types of missions require special consideration by the FDC. Consideration must be given to differences in projectile weight and changes in the effects of drag (dependent upon specific projectile-fuze combinations).

b. Observer procedures for special situations are discussed in chapter 13.

24–2. Entry Range

The entry range for extracting unit correction factors from the firing tables will be the chart range determined to the point at which the observer desires special ammunition fired (usually fire-for-effect range). Normally, it is not necessary or practical to determine complementary range because the possible increased accuracy does not justify the additional time required for computing complementary range. However, complementary range should be considered for missions that do not require an adjustment and when the adjustment phase is conducted with the same projectile-fuze combination that is to be fired in effect.

Section II. CHEMICAL PROJECTILES

24–3. General

a. Chemical agents may be used to kill, injure, or harass personnel, to deny observation or use of an area, or to burn materiel. The fire direction procedures discussed in this section are applicable to chemical agents fired in chemical projectiles.

b. Paragraphs 13–1 through 13–5 describe the uses of chemical projectiles and prescribe observer procedures for the adjustment of chemical projectiles.

24–4. Smoke Projectiles

a. White Phosphorus. Projectile WP is a bursting projectile that produces smoke, incendiary effect, and casualty effect. Against most targets, superquick fuze action is used. The action of the fuze and burster charge breaks the projectile and scatters the phosphorus particles above the ground. Since WP smoke rises, or pillars, it is not suited for maintaining a smokescreen; however, it is excellent for the initial buildup of a smokescreen.

b. Smoke HC. Projectile smoke HC is a base-ejection projectile that produces white smoke. It is used primarily for screening. Smoke HC is always fired with time fuze. Smoke HC is an effective screening agent but produces no casualty effect. Smoke HC readily absorbs and retains moisture; it is more effective in rain or mist than it is in dry air.

c. Colored Smoke. Colored smoke is a base-ejection projectile that is normally used for prearranged signals or for aiding the observer in identifying his rounds. Colored smoke is fired with time fuze. Except for the color of the smoke (red, green, or yellow), colored smoke is similar to HC smoke (white).

24–5. FDC Procedures for Adjustment of Projectile, WP

a. When fire for effect is to be fired with white phosphorus, the adjustment is conducted with HE, fuze quick.

b. WP projectiles are heavier than HE projectiles. Therefore, when a change is made from HE to WP, the FDC must apply a correction to compensate for the difference in the weights of the projectiles. The correction is determined in the following manner:

(1) Determine the difference in the weights (squares) of the projectiles by subtracting the weight of the HE used in the adjustment from the weight of the WP.

(2) Determine, from the Ground Data Table, the correction for an *increase* in projectile weight of 1 square at fire-for-effect chart range.

(3) Determine the correction by multiplying the difference in projectile weight ((1) above) by the unit correction ((2) above). Express the result to the nearest 10 meters.

(4) Apply the correction to fire-for-effect chart range. Place the hairline of the GFT over the corrected range and read the elevation under the elevation gageline.

Example: 155-mm howitzer M109, charge 5 GB (M3 propellant)

Fire-for-effect chart range	6,040 meters
Comp range (VI + 30 meters)	+6 meters
Entry range (6040 + (+6) = 6046 = 6000)	6,000 meters
Weight of projectile HE	4 squares
Weight of projectile WP	7 squares
Difference in weights of projectiles	+3 squares
Weight of projectile unit correction (range 6000)	+25 meters
Range correction (+25) × 3) = +75 or 80)	+80 meters
Corrected range (6040 + 80)	6,120 meters

Place the hairline over 6,120 meters and read the elevation under the elevation gageline.

c. When necessary, the adjustment may be continued with one piece firing WP until it is in the proper place. The correction for projectile weight is considered constant for a particular mission and need not be changed during the adjustment.

24–6. FDC Procedure for Adjustment of HC Smoke

a. When HC smoke is to be used, the adjustment is begun with one piece firing HE, fuze quick, and the lowest practical charge. Using the lowest practical charge reduces the possibility of rupturing the canisters or scattering them on impact. An interior piece should be used in the adjustment. This will facilitate adjustment on additional points left or right of the initial adjusting point if they are needed.

b. When the observer has adjusted to within 100 meters of the adjusting point, he usually requests smoke and continues the adjustment until the smoke is at the proper location and height of burst. If more than one point is needed for screening an area, the FDC may apply special corrections by using the M17 plotting board or the observer may adjust smoke onto each point. The procedure for firing base-ejection smoke is as follows:

(1) Determine the fuze setting for fuze time by subtracting 2.0 from the fuze setting read under the time gageline.

(2) Adjust the height of burst by increasing or decreasing site in accordance with the observer's correction. (No height-of-burst correction (20/R) is applied when the adjustment with fuze time is begun.)

c. Base-ejection smoke HC normally is the same weight as HE; therefore, a weight correction is not required for smoke HC. However, base-ejection colored smoke is considerably lighter than HE and the FDC can improve the accuracy of colored smoke by applying a weight correction.

24–7. Building and Maintaining a Smokescreen (Smoke HC)

a. The unit should fire two rounds per point of impact as rapidly as possible to form an adequate smokescreen quickly and then maintain the smokescreen by firing at the minimum rate necessary. The minimum rate of fire is governed largely by the velocity of the wind. A guide for selecting the rate of fire for the 105-mm and 155-mm howitzers in maintaining a screen is shown below.

Wind velocity (miles per hour)	*Rate of fire per point of impact (number of seconds between rounds)*	
	105-mm howitzer	*155-mm howitzer*
3	60	120
10	40	80
15	30	60

Note. The above rates must be modified according to what the observer sees on the ground.

b. The spacing of the points of fall, which may be as great as 400 meters or as small as 30 meters, depends on the speed and direction of the wind and the size of the front to be screened. The points of fall are based on the observer's request and are changed as necessary to correct for changes in weather and the tactical situation.

24–8. Toxic Chemical Projectile

a. When toxic chemical projectiles are used, particular attention must be given to selection of the area into which the chemical projectiles will be fired. Wind direction and velocity and temperature gradient are factors of great importance in this selection and determine the number of chemical projectiles required for achieving the desired results. If friendly troops are downwind from the target area, they must mask. See FM 3-10 for information concerning the computation of safety distance.

b. Toxic chemical agents are employed in either a vapor (nonpersistent) form or a liquid droplet (persistent) form. A different fire direction technique is required for achieving the best results with each form.

(1) When a chemical projectile is used for producing a nonpersistent vapor hazard in the target area—

(*a*) A point-detonating fuze normally should be used.

(*b*) Surprise fire is essential. Sufficient artillery must be used so that all rounds impact within 30 seconds.

(*c*) A separate point of impact is assigned to each battery-size unit.

(2) When a chemical projectile is used for contaminating the target area with persistent liquid droplets—

(*a*) A low airburst normally should be used.

(*b*) Surprise fire is not essential.

(*c*) Each group of rounds is fired at a different point of impact. Normally, zone fire will give the best coverage.

c. In computing firing data for transfer of fire, the FDC must apply a correction to the HE GFT setting to compensate for the increased weight of the toxic chemical projectile and must apply an additional correction to compensate for the increased drag (based on a 1 1/2 percent increase in air density). These corrections are determined as shown in the example below.

Example: 155-mm howitzer M109, charge 5 GB (M3 propellant).

Fire-for-effect chart range	6,040 meters
Weight of projectile HE	4 squares
Weight of projectile GB	7 squares
Difference in weights of projectiles	+3 squares
Weight of projectile unit correction (range 6000)	+25 meters
Range correction (25 × 3)	+75 meters
Air density correction for 1 percent (range 6000)	+10.0 meters
Range correction (10.0 × 1½)	+15.0 meters
Corrected range (6040 + 90)	6,130 meters

Place the hairline over 6,130 meters and read the elevation under the elevation gageline.

Note. Refer to the introductory portion of the appropriate firing table for other projectile-fuze combinations that require air density corrections because of the increased effect of drag.

Section III. ILLUMINATNG PROJECTILES

24-9. General

a. Illuminating projectiles are provided for the 105-mm and 155-mm howitzers. The uses of illuminating projectiles and the procedures for the adjustment of these projectiles are covered in paragraphs 13-6 and 13-7.

b. This section is devoted primarily to the FDC procedures applicable to the 155-mm howitzer firing illuminating projectile M485 and fuze M565. FDC procedures for the 105-mm howitzer are the same except as otherwise indicated in this discussion.

c. The major improvements in the M485 projectile over other illuminating projectiles are greater illumination, a longer burning time, and a slower rate of descent. In addition, the M485 employs a drogue chute, which reduces chute failures; however, use of the drogue chute requires fuze activation prior to main chute deployment.

24-10. Selection of Charge

When an illuminating projectile is to be fired, the lowest possible charge should be selected in order to reduce the possibility of ripping the parachute when the flare is ejected from the projectile.

24-11. Chart Data

a. The HCO plots the location and announces chart data as in any other mission.

b. The VCO determines and announces the vertical interval between the battery and the ground level in the area to be illuminated.

24-12. Firing Data

In converting chart data to firing data, the computer must consider the type of adjustment to be conducted.

a. Deflection. Deflection corrections determined by firing HE are disregarded. The deflection to be fired depends on the type of adjustment.

(1) *One gun.* The chart deflection is fired.

(2) *Two guns.* The chart deflection is fired by both pieces.

(3) *Two guns, range spread.* The chart deflection is fired by both pieces.

(4) *Two guns, lateral spread.* The chart deflection minus 5 times 100/R is fired by the right piece. The chart deflection plus 5 times 100/R is fired by the left piece.

(5) *Four guns.* The chart deflection is fired by the two interior pieces. The chart deflection minus 5 times 100/R is fired by the right piece. The chart deflection plus 5 times 100/R is fired by the left piece.

b. Elevation and Fuze Setting. Range corrections determined from firing HE may be used (para 24-14*d*). The range at which elevation and fuze setting for each piece are determined depends on the type of adjustment.

(1) *One gun.* The chart range is fired.

(2) *Two guns.* The chart range is fired by both pieces.

(3) *Two guns, lateral spread.* The chart range is fired by both pieces.

(4) *Two guns, range spread.* The chart range plus 500 meters is fired by one piece and the chart range minus 500 meters is fired by the other piece.

(5) *Four guns.* The chart range is fired by the flank pieces. The chart range plus 500 meters is fired by one interior piece and the chart range minus 500 meters is fired by the other interior piece.

Note. **When illuminating projectiles other than M485 are fired, the lateral spread is plus and minus 4 times 100/R and the range spread is plus and minus 400 meters.**

24-13. Illuminating Graphical Firing Table

a. General. Graphical firing tables have been developed for use with illuminating projectiles M118 and M485 (155-mm) and M314 and M314-A2E1 (105-mm). The description of the scales (*b* below) and the determination of firing data (para 24-14 and 24-15) are basically the same for all models of illuminating graphical firing tables.

b. Description of the Graphical Firing Tables. The graphical firing table for the M485 is designated scale, graphical firing, 155AH-2ILLM485. A complete set of GFT's consists of two rules. Each rule consists of a cursor and a base, which is 18 inches long and 3 1/2 inches wide. A set of scales for a single charge is inscribed on each side of a base. The scales for charges 1 and 3 are on rule 1. The scales for charges 5 and 7 are on rule 2. There is sufficient overlap between these four charges to permit the elimination of charges 2, 4, and 6. Charge 1 data start at a range of 500 meters; thus it is possible to illuminate the firing position and the area immediately in front of the firing position. Fuze activation and parachute deployment at the shorter ranges of charge 1 occur on the ascending leg of the trajectory. The scales on the GFT, from top to bottom, are as follows:

(1) *100/R scale.* The 100/R scale denotes the number of mils necessary to shift the burst 100 meters laterally for a given range.

(2) *Range scale.* The range scale is the basic scale on the GFT and all other scales are plotted with reference to it. Range is read to the nearest 10 meters.

(3) *Elevation-to-impact scale.* The elevation-to-impact scale is graduated in mils. Low-angle elevations increase from left to right and are read to the nearest mil. For charge 1 only, high angle elevations to impact are printed on the right side of the scale. The high-angle elevations increase from right to left and are printed in red. The elevation-to-impact scale is used for determining the range (on the range scale) to which a nonfunctioning projectile (dud) will travel.

(4) *Height-of-burst scales.* At the left and right of the main body of each set of scales are the height-of-burst scales, which are graduated in 50-meter increments. For all charges except charge 1, the scales extend from 350 meters to 950 meters. The scales for charge 1 extend from 350 meters to 900 meters. (At the lowest range for charge 1, the QE required to reach 950 meters exceeds the capability of the weapon.)

(5) *Quadrant elevation scale.* The quadrant elevation scale indicates for each listed height of burst the QE necessary to achieve that height of burst and the desired range. The QE scale is graduated in mils and is read to the nearest mil. The QE's for charge 1 are for both low-angle fire and high-angle fire, depending on the range and the height of burst desired. The QE's for charges 3, 5, and 7 are for low-angle fire only.

(6) *Fuze setting scale.* The fuze set-

ting (FS) scale consists of a red line for each full fuze setting for the M565 fuze. The value of each line is printed in red at the bottom of the scale. Fuze setting is read for the desired range and height of burst to 0.1 accuracy by interpolation.

24–14. Determination of Data with the Illuminating Graphical Firing Table

a. Quadrant elevation and fuze setting for a given range and charge are determined as follows: Place the hairline over the range to the point to be illuminated. Determine the height-of-burst scale to use by adding the vertical interval to the nearest 50 meters to the optimum height of burst. Read the quadrant elevation at the intersection of the hairline and the selected height-of-burst scale. Determine the fuze setting to fire by interpolating between the red fuze setting arcs for the point of intersection of the hairline and the selected quadrant elevation.

b. A heavy black arrow on the quadrant elevation scale indicates the part of the trajectory which is at or near the summit and which does not exceed by 50 meters the height of burst which it represents.

c. The optimum height of burst for all other illuminating projectiles is 750 meters, the M485, because of the longer burning time and slower rate of descent, has an optimum height of illumination of 600 meters above the area to be illuminated.

d. The M485 is ballistically similar to the M107 HE projectile. If a current HE GFT setting is available, the FDC can achieve greater initial accuracy with the M485 by constructing the HE GFT setting on the illuminating GFT. This is possible because the range scales are constructed logarithmically rather than linearly. On the illuminating GFT, the GFT setting geometrically applies a constant range K instead of a variable range K, which is possible on the slant scale GFT's; however, the error is negligible, considering the size of the area of illumination. Construct the GFT setting on the illuminating GFT by placing the hairline of the cursor over the adjusted elevation on the elevation-to-impact scale and draw on the cursor a gageline parallel to the hairline and through the GFT setting range on the range scale. Mark this gageline RG. Determine data by placing the range gageline over the range to the point to be illuminated on the range scale and reading the quadrant elevation and fuze setting at the intersection of the selected quadrant elevation scale and the hairline.

Example: The following example illustrates the construction of the GFT setting and the determination of quadrant elevation and fuze setting:

HE GFT setting: GFT B: Chg 5, lot XY, rg 5840, el 302

Chart range to the point to be illuminated: 7,260 meters

Vertical interval: +60 meters.

(1) Place the hairline of the cursor over adjusted elevation 302 on the elevation-to-impact scale.

(2) Draw the range gageline over the GFT setting range (5,840 meters) and mark the gageline RG.

(3) Place the range gageline over the chart range (7,260 meters) to the point to be illuminated.

(4) Determine the height-of-burst scale to use.

(*a*) Optimum HOB: 600 meters.

(*b*) Vertical interval: +50 meters (nearest 50-meter increment).

(*c*) Height-of-burst scale to use: 650 (600 + (+50)).

(5) Read, at the intersection of the hairline and the 650-meter quadrant elevation scale, the quadrant elevation to fire: QE 547.

(6) Interpolate between the red fuze setting arcs bracketing the point of intersection of the hairline and the 650-meter quadrant elevation scale to obtain the fuze setting to fire: 26.6.

Note. The procedure for determining the quadrant elevation and fuze setting for the ascending branch is the same as the procedure for the descending branch.

24–15. Determination of Firing Data Based on Subsequent Observer Height-of-Burst Corrections

Data based on subsequent height-of-burst corrections are determined in the following manner:

a. Determine the height-of-burst scale to use.

(1) The observer always gives corrections to height of burst in multiples of 50 meters.

(2) The computer algebraically adds observer corrections to the height of burst previously used to obtain the height of burst for the next round(s).

b. Using the appropriate quadrant elevation scale, determine the quadrant elevation and fuze setting as outlined in paragraph 24–14.

24–16. Determination of Firing Data with the Tabular Firing Tables

a. Elevation and Fuze Setting. For each 100 meters in range, change 1 to the firing tables shows the elevation and fuze setting for the optimum height of illumination (600 meters above the pieces) and the change in elevation and fuze setting for a 50-meter change in height of burst. (Chart range is rounded to the nearest 100 meters in all cases.)

b. Height-of-Burst Correction. The observer may make height-of-burst corrections in increments of 50 meters during adjustment. To determine the total height-of-burst correction, the computer adds the observer's cumulative height-of-burst correction and the vertical interval (para 24–11*b*) rounded to the nearest 50 meters. The corrections to elevation and fuze setting are determined as follows:

(1) Divide the total height-of-burst correction by 50. This gives the number of 50-meter increments.

(2) Determine from the firing tables the changes in elevation and fuze setting for a 50-meter change in height of burst corresponding to the new chart range.

(3) Multiply the number of 50-meter increments from (1) above by the values from (2) above.

c. Data to be Fired. The fuze setting to be fired is the sum of the fuze setting (*a* above) and the fuze setting correction for height of burst (*b* above). The quadrant elevation to be fired is the sum of the elevation (*a* above) and the elevation correction for height of burst.

24–17. Corrections

The proper height of burst, time of burning, and distance between bursts of adjacent rounds may vary from one projectile lot to another because of variations in the illuminant. Storage conditions and extended periods of storage may cause variations in performance of the illuminant. Large variations from the optimum height of burst can be expected. To prevent waste of ammunition, the FDC personnel must record the corrections from all adjustments and determine the best height of burst for each ammunition lot. A correction to obtain the best height of burst should be applied at the start of the adjustment.

24–18. Example

This example illustrates the manner in which initial and subsequent fire commands are determined for illuminating projectile. The computer's record for this mission is shown in figure 24–1. The GFT setting given in the example in paragraph 24–14*d* will be used for this mission. Although this problem illustrates the techniques used for four guns (range and lateral spread), a separate study of the data used for pieces number 1 and number 6 will illustrate the techniques used for two guns, lateral spread and study of the data used for number 2 and number 5 will illustrate the techniques used for two guns, range spread.

a. Known Data.

Shell	M485
Lot	ZW
Charge	5 GB (M3 propellant)
Altitude of battery	352 meters

b. Chart Data.

Deflection to target	3496
Range to target	6630
Altitude of target	413

c. Determination of Deflection to Fire.

100/R corresponding to range 6630	15
500/R (5 × 15 = 75)	75
Number 1 deflection (3496 + R75)	3421
Number 2 and 5 deflection (chart df)	3496
Number 6 deflection (3496 + L75)	3571

d. Determination of Quadrant Elevation.

Optimum HOB	600 meters
Vertical interval (413 − 352 = +61)	+50 meters (nearest 50-meter increment)
Height-of-burst scale (600 + (+50))	650 meters
Number 1 QE (rg 6630)	498 mils
Number 2 QE (rg 6630 − 500 = rg 6130)	467 mils
Number 5 QE (rg 6630 + 500 = rg 7130)	536 mils
Number 6 QE (rg 6630)	498 mils

e. Determination of Fuze Setting.

Number 1 time (el 498)	23.1
Number 2 time (el 467)	20.6
Number 5 time (el 536)	25.9
Number 6 time (el 498)	23.1
Height-of-burst scale	650

f. Subsequent Fire Commands. When the observer has been able to identify a target, he initiates another call for fire for HE and continues using the illumination as described in paragraph 13–7.

FDC COMPUTER'S RECORD

For use of this form, see FM 6-40; the proponent agency is TRADOC.

BATTERY	DATE	TIME RECEIVED	TIME COMPLETED	TGT
B	19 NOV	2110	2135	AF 7501

CALL FOR FIRE 44 FM, GRID 725365, DIR 5800, VEH. NOISES, SUSPECTED TANKS, ILLUM, ADJUST FIRE

FIRE ORDER:
UNIT(S) B MF L+R PLT
BASIS FOR CORR USE GFT
DISTR ___ SH ___
LOT ZW CHG 5 FZ ___
___ RDS; SPREAD ___
TIME ___ TGT AF 7501

TOT DF CORR 0
DF 3496
RG 6630 EL
TGT 413 SI
BTRY 353
+61

100/R	50/R (60)	∡ SI	△ FS	10m/SI
15	75			

INITIAL FIRE COMMANDS

L+R ADJUST	SP INSTR SP CORR
SH ILLUM	LOT ZW
CHG 5	FZ TI
MF L+R ① IN EFF	
DF SEE BELOW	TI
QE	AMMO EXP

OBSERVER CORRECTIONS / SUBSEQUENT FIRE COMMANDS

MF SH FZ	DEV	RG	HOB	SH,CHG FZ,MF	CHART RG	CHART DF	CORR	DF FIRED	FS CORR	TI	HOB CORR	SI	EL	QE	AMMO EXP
				#1	6630	3496	R75	3421		23.1				498	
				2	6130		—	3496		20.6				467	
				5	7130		—	3496		25.9				536	
				6	6630		L75	3571		23.1				498	(4)
	R400	+400	U150	#1	7200	3480	R75	3405		26.7				567	
				2	6700		—	3480		23.8				529	
				5	7700		—	3480		30.1				616	
				6	7200		L75	3555		26.7				567	(8)
	L100	+200	D50	#1	6980	3479	R75	3404		25.2				541	
COORD	ILLUM			2	6480		—	3479		22.6				506	
				5	7480		—	3479		28.4				584	
				6	6980		L75	3554		25.2				541	(12)

EM, ILLUM EFFECTIVE

DATA FOR REPLOT

GRID	ALT	FZ	TGT

AMMUNITION

TYPE												
LOT												
ON HAND												
RECEIVED												
TOTAL												
EXPENDED												
REMAINING												

DA FORM 3622, 1 Jan 74 REPLACES DA FORM 3622, 1 AUG 70, WHICH IS OBSOLETE.

Figure 24–1. Completed computer's record, illumination mission.

Section IV. PROPAGANDA PROJECTILE

24-19. General

a. Artillery may be used for delivering psychological warfare leaflets. Pinpoint accuracy is not required for propaganda missions. Twenty-five rounds from a 105-mm howitzer normally will cover an area 500 by 500 meters. Corps artillery or higher headquarters normally issue the order to fire propaganda projectile and specify the area to be covered and the amount of ammunition to be expended.

b. There is no standard propaganda projectile. Ordnance prepares and issues the ammunition. Usually, an HC smoke projectile with the filler and booster replaced by leaflets is used. Ordnance must weigh the projectile and mark the weight on the projectile.

24-20. FDC Procedure for Firing Propaganda Projectile

The data for firing propaganda projectile are determined in the same manner as that for an HE mission with the following exceptions:

a. The height of burst above ground is initially 100 meters. Wind velocity and direction may affect the leaflets in such a way that a lower height of burst may be requested by the observer.

b. A correction to compensate for the variation in weight from that of a standard projectile must be determined and applied to chart range. Elevation and fuze setting are determined at the corrected range by use of the GFT. If available, a GFT setting for HE should be used.

Section V. ASSAULT FIRE

24-21. General

a. Assault fire is a special technique of indirect fire. One weapon, emplaced in defilade, fires on a target at a short range with the maximum charge that will clear the intervening crests. Because of the small vertical probable error of artillery weapons, assault fire is most effective against a target with a significant vertical dimension.

b. The FDC for the mission normally is located at or near the weapon. Observer procedures for assault fire are discussed in paragraphs 13-9 through 13-14.

c. The assault fire mission must be carefully planned and executed. FDC personnel, as part of the assault fire team, plot the target on the firing charts, compute initial data, and prepare deflection shift and quadrant change cards. Careful preparations and planning and accurate initial data result in a short adjustment phase in an assault fire mission.

24-22. FDC Procedures for Assault Fire

a. Normal observed fire and FDC procedures are used during the adjustment of an assault fire mission. If FADAC is not available, the tabular firing tables normally are used for determining initial firing data because the shorter ranges for the higher charges are not shown on the graphical firing tables.

b. After the initial firing data have been determined, the M17 (M10) plotting board is used for determining corrections until the observer announces vertical corrections rather than range corrections. During the remainder of the mission, a two-man team, consisting of a deflection computer and a quadrant computer, determines the data that will place the burst directly on the target.

Note. If the angle T is less than 100 mils, the FDC team may use the 100/R and C factors during the adjustment phase rather than plot the observer's corrections on the M17 plotting board.

(1) Before the start of the mission, the deflection computer prepares a deflection shift card (fig 24-2) for the chart range to the target as an aid in computing the required deflection changes. He prepares the card by using the C and D scales and M gagepoint of any GST. He sets

Deflection shift card	Chart range 1,500 meters
Observer's deflection Correction (in meters)	Deflection shift (in mils)
1/2	1/4
1	3/4
2	1 1/4
3	2
4	3
5	3
6	4
7	5
8	5
9	6
10	7

Figure 24-2. Deflection shift card.

the range to the target on the C scale opposite the observer's correction on the D scale and reads the deflection shift in mils opposite the M gagepoint. Deflection shifts in mils are rounded to the nearest whole mil for observer corrections greater than 2 meters and to the nearest 1/4 mil for observer corrections of 2 meters or less.

(2) Deflections can be set off to 1/4 mil on weapons equipped with the M100-series sights. The use of a deflection board (fig 4–15) is required for other sights. The deflection board (fig 4–15) is used for setting off deflection in units of 1/4 mil. To determine a new deflection to include the observer's corrections, the computer applies the required deflection shift to the previous deflection by use of the LARS rule (left, add; right, subtract).

Example: Chart range 1,500 meters.

Previous deflection fired	*Observer's correction (meters)*	*Deflection shift from card (mils)*	*New deflection command*
3210	Right 7	Right 5	3205
3205	Left 4	Left 3	3208
3208	Left 2	Left 1 1/4	3209 1/4
3209 1/4	Right 1	Right 3/4	3208 1/2
3208 1/2	Left 1/2	Left 1/4	3208 3/4

(3) The quadrant computer prepares in advance a quadrant change card (fig 24–3) for the chart range to the target as an aid in computing the required quadrant change (to the nearest 1/10 mil). The quadrant card is prepared in the same manner as the deflection shift card. Quadrant changes in mils are rounded to the nearest whole mil for observer corrections greater than 2 meters and to the nearest 1/10 mil for observer corrections of 2 meters or less. The gunner's quadrant is used throughout the mission. To determine a new quadrant to include the observer's correction, the computer applies the required quadrant change to the previous quadrant fired.

Quadrant change card	Chart range 1,500 meters
Observer's site Correction (in meters)	Quadrant change (in mils)
1/2	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 24–3. Quadrant change card.

Example: Chart range 1,500 meters.

Previous QE fired	*Observer's correction (meters)*	*QE change from card (mils)*	*New QE command*
30.0	Up 4	+3	33.0
33.0	Down 2	−1.4	31.6
31.6	Up 1/2	+0.3	31.9

Section VI. DESTRUCTION MISSIONS

24–23. General

a. The purpose of a destruction mission is to destroy a target by one or more direct hits. There are two primary considerations in the selection of the weapon—charge combination to be used: The projectile must be large enough to accomplish the mission and the weapon-charge combination should give the smallest PE_R possible. Most destruction missions should be fired by medium or heavy artillery; however, in some situations light artillery can be effective. The 8-inch howitzer is an excellent weapon for a destruction mission because of its small probable error and the effectiveness of its projectile.

b. A destruction mission is a precision mission. Because the destruction of the target is the objective, the observer, not the S3, will terminate the mission as soon as destruction of the target has been accomplished.

24–24. FDC Procedures for Destruction Mission

a. The correct deflection for a destruction mission is determined in the same manner as that for a precision registration.

b. An adjusted quadrant elevation is determined after six definite FDC spottings in fire for effect have been obtained. The adjusted QE is computed and used to the nearest 0.1 mil. Firing is continued, if necessary, with the adjusted QE (nearest 0.1 mil). A new adjusted QE is computed after each succeeding group of six definite FDC range spottings. If a second adjusted QE is required, 1/2 of the computed elevation change is applied to the previous adjusted quadrant elevation. If a third adjusted QE is required, 1/3 of the computed elevation change is applied. If a fourth adjusted QE or succeeding adjusted QE's are required, 1/4 of the computed elevation change is applied.

c. When a projectile-fuze combination other than HE, fuze quick, is desired, the change is made after the first adjusted QE has been computed. If the ballistic properties of the desired combination are different from those of the original combination, appropriate corrections for the nearest listed chart range must be applied.

Example: 155-mm howitzer (M109), charge 5 GB (M3 propellant), shell HE, fuze quick, range 5040.

The first adjusted QE is 244.5 mils.

The S3 directs the use of fuze concrete-piercing.

FT 155–AH–2 data:

Correction for fuze CP (1 percent increase in air density) = +7.4 meters

C factor = 5.8 mils

Correction to be applied:

$+7.4/100 \times 5.8 = 0.43$

Increase in QE = +0.4 mil

Section VII. FINAL PROTECTIVE FIRES

24–25. General

A final protective fire (FPF) is an immediately available prearranged barrier of fire designed to impede enemy movement across defensive lines or areas. The FPF is used for establishing prearranged close-in defensive fires in coordination with other means including other artillery fires, minefields, obstacles, final protective machinegun fires, and mortar final protective fires. Each battery is assigned one final protective fire. The battery is normally laid on the FPF when it is not firing other missions. The FPF may be fired on prearranged signal or on call as often as necessary. When possible, the data for the FPF should be verified or corrected by the firing of check rounds.

24–26. Characteristics of Final Protective Fires

The firing of a battery final protective fire, either individually or in coordination with final protective fires of other batteries, is based on the following:

a. Width of Final Protective Fire. The width (or the length of the FPF (fig 24–4) assigned to a battery should not exceed the width that can be covered by a single battery without shifting its fire. That is, the width of the FPF should not exceed the width of an open sheaf (as shown in table 2–1). If the width (length) of the area to be covered exceeds the width of an open sheaf, greater protection is obtained if sufficient reinforcing artillery is emplaced so that each battery can limit its fire to the width of an open sheaf. Assigning a battery a final protective fire that necessitates shifting fires greatly reduces the effectiveness of the FPF as a barrier of fire.

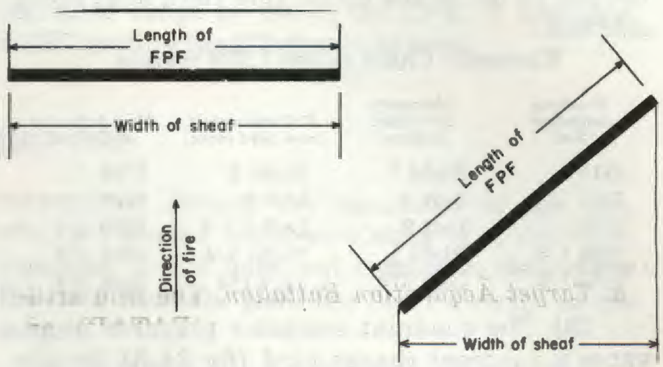


Figure 24–4. Final protective fire.

b. Preparation of Data. The final protective fire may be at an angle to the direction of fire. Special corrections to place each burst in the proper position normally are used. Map data for an FPF are taken from the center point of the FPF line. The computer determines corrections for each piece by use of the M17 plotting board and base their corrections on the angle between the FPF and the direction of fire. Firing data are determined by use of normal procedures except for—

(1) *Distribution.* A final protective fire is fired with special corrections.

(2) *Method of fire.* The method of fire is continuous fire at maximum rate.

Section VIII. COMBINED ADJUSTMENT

24–27. General

a. Observer procedures for combined adjustments are described in paragraphs 13–15 through 13–20.

b. Targets or adjusting points may be designated by one observer or the S3. When direct communications between observers is impossible, the FDC must coordinate the operations for the observers.

c. Only one piece is used in adjustment.

24-28. FDC Procedure for Combined Adjustments, Observation Posts Plotted

a. For combined adjustments, the target is plotted and firing data are determined in the normal manner. Orientation data for the OP's may be determined in the manner prescribed in paragraph 19-29.

b. After the initial round has been fired and the observers have reported the directions (or deviations), rays are drawn from each OP at the reported directions. The intersection of the rays is the location of the burst. Range and deflection corrections to place the burst at the target are measured. New firing data are computed and fired.

Example: 155-mm howitzers M109, charge 5 GB (M3 propellant).

Chart range to target	5,900 meters
Chart deflection	3,427 mils
QE fired (el 289) + site (+6))	295 mils
Deflection fired (df corr 0)	3,427 mils
Measured range to burst location	5,790 meters
Correction for range (5900 − 5790)	+110 meters
Corrected range (5900 + 110)	6,010 meters
Elevation corresponding to 6,010 meters	297 mils
New QE (297 + (+6))	303 mils
Measured deflection to burst location	3,433 mils
Deflection correction (3427 − 3433)	R6 mils
New deflection (3427 + R6)	3,421 mils

Section IX. SOUND, FLASH, AND RADAR MISSIONS

24-29. Target Acquisition Elements

a. Target Acquisition Battalion. The field artillery target acquisition battalion (FATAB) assigned to corp artillery has the means for locating targets, adjusting and registering friendly artillery fire, and assisting in the calibration of artillery. The target acquisition batteries of the battalion contain sound, flash, and radar platoons, which are deployed to cover common areas in support of the corps artillery mission.

b. Target Acquisition Platoon. The target acquisition platoon organic to the direct support battalion has the means for locating targets and adjusting and registering friendly artillery and mortars.

24-30. Target Acquisition Techniques

The techniques employed by sound, flash, and radar units are covered in FM 6-122 and FM 6-161.

24-31. Capabilities and Limitations

The capabilities of sound, flash, and radar complement each other.

a. Sound. The operation of sound ranging equipment is not affected by poor visibility; however, high winds interfere with the operation of sound ranging equipment. Sound ranging is employed for locating hostile artillery and registering friendly artillery.

b. Flash. Flash ranging is the most accurate means of locating targets; however, the efficiency of the flash ranging observation posts may at times be limited by poor visibility and adverse terrain. The flash ranging platoon is used for—

(1) Locating hostile artillery and other hostile targets in the area.

(2) Adjusting and registering friendly artillery.

(3) Assisting in the performance of comparative calibration of cannon artillery by providing the mean burst location.

c. Radar. The AN/MPQ-4A radar is organic to the target acquisition battery, field artillery target acquisition battalion (FATAB), and performs the counterbattery role. It is also organic to the target acquisition platoon of the direct support artillery battalions and performs the countermortar role. Radar operations are not affected by poor visibility due to darkness or fog; however, heavy rain or snow can reduce the capability of radar. Although the mobility of the radar is somewhat reduced in mountainous terrain, radar can be effective in such terrain because of the high angle of fire used. The AN/MPQ-4A is used for locating hostile artillery and mortars and for registering and adjusting friendly artillery and mortars. This radar also has the capability of providing survey information when normal survey means are not available. The AN/MPQ-4A is limited in its ability to locate hostile field artilliery firing low trajectory because of the inherent countermortar design features of the radar. Radars are subject to detection and electronic countermeasures i.e., jamming and deception.

These vulnerabilities are minimized by the application of appropriate electronic security (ELSEC) and electronic counter-countermeasure (ECCM) procedures. FM 32-5 and FM 32-20 contain pertinent details.

24-32. Target Designation

a. Target location reports normally include the coordinates (grid or polar) and altitude of the target, the times the target was active, the accuracy of the location, and a description of the target. In the absence of survey control, target acquisition elements can report targets in relation to a reference point, previous targets, or a registration point that has been located relative to both the firing unit and the locating agency. Sound and radar units must determine the altitudes of targets from maps; however, flash platoons can always determine relative altitudes.

b. The location of a target or registration point can be given to a target acquisition agency either as grid coordinates or as a shift from a known point.

24-33. Adjustment of Fire

a. The accuracy of the location, the type of target, and the time available determine whether a target 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 fire-for-effect mission. The sound ranging platoon may request that one round be fired after the fire for effect to plot the location of the effect, because sound tapes are difficult to read when many rounds are bursting at one time.

c. When sound, flash, or radar is used for conducting the adjustment of fire on a target, the FDC will receive a standard call for fire and subsequent corrections. The procedures are the same as those used in a normal adjustment by an observer except as indicated in (1) through (5) below.

(1) Time of flight is given to the adjusting agency (e.g., sound platoon) before firing commences. The commands SHOT and SPLASH are always given for each round.

(2) All adjustments are conducted with one weapon.

(3) The adjusting agency may give refined corrections (e.g., RIGHT 110, ADD 550), which would not be given by a ground observer, because the burst is located accurately.

(4) Sound-on-sound adjustments must be conducted with fuze quick.

(5) Normally, an adjustment by sound, flash, or radar will require less ammunition but the adjustment may be slower than an adjustment by conventional means, since each round must be plotted before corrections are determined.

24-34. Conduct of Registration

a. Artillery can be registered by means of sound ranging, flash ranging, and radar. However, sound ranging can be used only for an MPI registration and, since sound ranging is the least accurate of the three means, it should be used only when the other means cannot be used.

b. The coordinates and altitude of the registration point (point selected for HB or MPI) should be determined by the firing battalion in coordination with the target acquisition element. For a high-burst or mean-point-of impact registration, the number of rounds fired is determined at the FDC; however, the target acquisition element may request one or more rounds fired AT MY COMMAND in order to orient the observers or, in the case of sound ranging or radar, to insure positive identification. A specified interval between rounds may also be requested. For each round fired, the target acquisition element determines the location of the round and reports this location to the FDC. This enables the FDC to determine the validity of each round. Sound and flash elements report the location of each round by grid coordinates, whereas radar elements report the location either by grid coordinates or by polar coordinates.

Section X. GUNNERY PROCEDURES FOR IMPROVED CONVENTIONAL MUNITIONS

24-35. General

Gunnery procedures for the delivery of improved conventional munitions (ICM) can be broken down into three areas—firing battery, observer, and fire direction center. Basic gunnery procedures for standard HE ammunition also apply to ICM; however, there are some variations with which personnel must become familiar.

a. Firing Battery.

(1) A major consideration of ICM is identification. The projectile is painted olive drab and is marked with the model number and, normally, a band of yellow diamonds around the ogive. For some 105-mm projectiles, the container and the ammunition box, rather than the projectile, will be marked with the band of diamonds. Strict

segregation must be maintained because these markings may become obscured by dirt.

(2) Fuzes used with ICM are the M548 and the M565 fuzes only. In all fire commands, the fuze must be specified by model number. Fuzes M548 and M565 are identical except that the M548 has a point-detonating mode and the M565 does not. Neither fuze has a booster. The M63 and XM34 fuze setters are used to place settings on these fuzes. The fuze setting for firing ICM is critical; therefore, extreme care must be taken in setting the fuze.

(3) Normal storage, handling, and emergency destruction procedures also apply to ICM.

(4) ICM cannot be fired in direct fire as that term is presently defined. However, direct fire tables are included in the addenda to certain firing tables and are used by the chief of section for firing ICM in close-in battery defensive fires. These tables contain the quadrant and fuze setting for estimated ranges between 300 and 3,000 meters. Wind direction and speed must be considered when ICM is fired in close-in battery defensive fires in order to preclude danger to friendly troops. Also included in the addenda are tables designed to provide rapid response indirect fire that can be used for close-in battery defensive fires. For actual direct fire in battery defensive fires, the Beehive round is still preferred.

b. Observer.

(1) In order to aid the FDC, the observer may include an estimation of wind direction and speed in the call for fire. An accuracy of 100 mils in direction and 5 knots in velocity is desirable. A smoke or WP round may aid the observer in making his estimation.

(2) ICM is most effective against soft targets, such as troops in the open. The observer must be familiar with and must be capable of advising the supported commander on the effects produced by HE, and those produced by ICM and the effectiveness of ICM in various types of terrain.

(3) Some malfunctions (duds) do occur with ICM, particularly from low air bursts. The observer must report all duds and erratic rounds. Duds should be treated as potential mines or boobytraps.

(4) Surprise fire is most effective and desirable with ICM. When current corrections are not available, the observer should adjust with HE on a point near the target and then shift and fire for effect with ICM on the target.

(5) Procedures for the adjustment of ICM are similar to those for the adjustment of HE. Range and deviation are corrected from the center of the effects pattern. Height of burst is corrected in 50-meter increments. How far UP or DOWN the observer should go depends on the experience gained with adjustment of this round. The basic criterion is that if a large number of duds are observed or if the effects pattern appears too small, the observer should give an UP correction. This correction should not exceed 100 meters until the observer becomes familiar with the effects of changes in height of burst.

(6) When adjusting close-in fires with ICM, the observer must start the adjustment at least 600 meters from friendly troops, depending on the relative positioning of the weapons, target, and friendly troops and on the wind direction and speed. The adjustment should be made with the entire battery and corrections should be made from the near edge of the effects pattern.

c. Fire Direction Center.

(1) The procedure for computing data for firing ICM is applicable under the following conditions:

(*a*) *Observer adjustment.* The adjustment may be conducted with either HE or ICM. Adjustment with ICM is not recommended since it eliminates the element of surprise.

(*b*) *Met plus VE.* Current met corrections must be available.

(*c*) *K-transfer.* Current registration corrections must be available.

(2) FDC procedures for ICM involve the use of appropriate firing table addenda for determining low-level wind corrections and ballistic corrections to give the proper trajectory for ICM.

24–36. Example

The following example illustrates the procedures for firing ICM. Although the M449A1 projectile and M109 howitzer are used in the example, these procedures are applicable to all weapons when firing ICM (fig 24–5).

a. Known Conditions.

Battery coordinates	3971016255
Battery altitude	432 meters
Target coordinates	3873023200
Target altitude	451 meters
Battery laying:	
Azimuth	350 mils
Referred deflection	3,200 mils
GFT setting:	
GFT A: Chg 5, lot YZ, rg 6480, el 344, ti 22.4	
Total deflection correction	R10

FDC COMPUTER'S RECORD

For use of this form, see FM 6-40; the proponent agency is TRADOC.

BATTERY	DATE	TIME RECEIVED	TIME COMPLETED	TGT
A	26 MAY	0645	0655	AF 7326

CALL FOR FIRE 24 FM, GRID 3873 2320, DIR 610, INF COMPANY IN OPEN, VT, FFE

TOT DF CORR R9
DF 3696
RG 6970 EL 381
SI +3
TGT 451
BTRY 432
VI +19

100/R	20/R	±SI	△FS	10m/SI

FIRE ORDER:
UNIT(S) A MF
BASIS FOR CORR USE GFT
DISTR SH ICM
LOT UY CHG 5 FZ M548
3 RDS; SPREAD
TIME TGT AF 7326

INITIAL FIRE COMMANDS

BTRY ADJUST	SP INSTR AZ 6000
SH ICM	LOT UY
CHG 5	FZ M548
MF BTRY (3)	IN EFF
DF 3687	TI 23.5
QE 417	AMMO EXP (18)

OBSERVER CORRECTIONS / **SUBSEQUENT FIRE COMMANDS**

MF SH FZ	DEV	RG	HOB	SH,CHG FZ,MF	CHART RG	CHART DF	CORR	DF FIRED	FS CORR	TI	HOB CORR	SI	EL	QE	AMMO EXP
CORR	FOR	LOW		LEVEL WIND					QE	CORR					
CHRT	RG			7030					QE	SH	HE			384	
SITE				+3					QE	CORR				+33	
EL				386					QE	SH	ICM			417	
QE				389											
CORR	FAC			3.8					FZ	CORR					
WIND	SPEED			18											
TGT	DISPL			68.4	=70M				FZ	M564				24.6	
									FZ	CORR				−1.1	
									FS	FZ M548				23.5	
					EM,	INF	DISP,	EST	60	CAS					

DATA FOR REPLOT

GRID	ALT	FZ	TGT

AMMUNITION

TYPE									
LOT									
ON HAND									
RECEIVED									
TOTAL									
EXPENDED									
REMAINING									

DA FORM 3622, 1 Jan 74 REPLACES DA FORM 3622, 1 AUG 70, WHICH IS OBSOLETE.

Figure 24–5. Computer's record, ICM.

Line 01 of a current met message 013418 947115

b. Determination of QE to Target for HE Projectile.

Chart range	7,030 meters
Site	+3 mils
Elevation	386 mils
QE	389 mils

c. Correction for Low-Level Wind.

(1) Determine wind direction and speed from line 01 of the met message or from the observer's estimate.

Wind direction	3,400 mils
Wind speed	18 knots

(2) Enter column 1, table A, FT 155–ADD–E–1, charge 5G, with the HE QE to the nearest listed value (390) and determine the low-level wind correction factor from column 7.

Low-level wind correction factor .... 3.8 m/knot

(3) To determine the targe displacement for low-level wind, multiply the wind speed by the low-level wind correction factor and express the result to the nearest 10 meters.

Target displacement (18 × 3.8 = 68.4) .. 70 meters

d. Target Displacement. Place the center of the target grid over the target and set off the met wind direction (3400) opposite the north index. This places the arrow pointing into the wind. Displace the target plot toward the arrowhead (into the wind) by 70 meters. Measure chart data to the wind-displaced plot:

Range	6,970 meters
Deflection	3,696 mils

e. Determination of QE and Fuze Setting. Using the GFT and the GFT setting, determine the QE and fuze setting to the wind-displaced plot for projectile HE M107.

Elevation	381 mils
Site	+3 mils
QE	384 mils
Fuze setting	24.6

f. Firing Data for Projectile M449A1.

(1) Apply the total deflection correction to the target to the chart deflection to determine the deflection to fire.

Total deflection correction for elevation 381 .... R9

Deflection to fire (3696 + R(−)9) ... 3,687

(2) Enter column 1, table A, at the value nearest the adjusted QE (385) to obtain the correction to QE from column 2. Express the correction to the nearest mil and add it algebraically to the adjusted QE.

Adjusted QE	384
Correction to QE	+33
QE to fire	417

(3) Enter column 1, table B, with the adjusted fuze setting (24.6) to obtain the correction to fuze setting from column 2. Algebraically add the correction to fuze setting to the adjusted fuze setting to obtain the fuze setting to fire.

Adjusted fuze setting	24.6
Correction to fuze setting	−1.1
Fuze setting to fire	23.5

(4) Data to fire are as follows:

Deflection	3,687
Time	23.5
Quadrant	417

Note. Additional information concerning improved conventional munitions is contained in FM 6–141–1.

Section XI. DEAD SPACE

24–37. General

Dead space is the area within the maximum range of a weapon that cannot be covered by fire from a particular position because of intervening obstacles, the nature of the ground, the characteristics of the trajectory, or the mechanical limitations of elevating and depressing the tube. Dead space areas can be determined only with an accurate contour map. Trajectories for all charges, low- and high-angle fire, must be considered in the computation of dead space. Dead space is a more serious problem for guns than it is for howitzers.

24–38. Limits

The near limit for any dead space area is the grazing point of the trajectory; i.e., the point nearest the battery where the trajectory intersects the ground (fig 24–6). 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 as follows:

a. VT fuzes have 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.

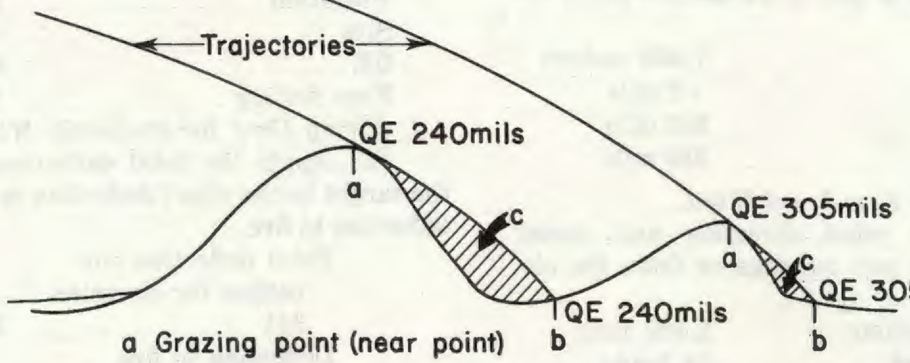


Figure 24-6. Dead space profile.

24-39. Determination of Dead Space

Dead space may be determined by the 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) Draw a ray on a map overlay from the plotted position of the piece through the desired point on the intervening terrain feature. Determine by inspection the highest point of the crest considered. Determine the quadrant elevations of this point and other points on the ray that are 50 to 100 meters beyond the highest point of the crest. The point requiring the greatest quadrant elevation marks the beginning of the dead space and is known as the grazing point.

(2) Determine the point of impact, or far limit of dead space, by finding a point beyond the crest that requires the same quadrant elevation as the grazing point. The process is one of trial and error. Select by inspection a test point of impact based on the range corresponding to the quadrant elevation for the grazing point and determine the quadrant elevation for the test point. If the quadrant elevation is less than that for the grazing point, the point is in dead space; if the quadrant elevation is greater than that for the grazing point, the point is beyond dead space. Repeat the process until the point of impact is located to the 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 meters (or the proper vertical clearance for fuze VT) at piece-crest range (para 4-9).

(4) Determine additional dead space areas along the ray in the same manner as that described in (1) and (2) above.

b. Adjacent rays should form an angle no greater than 100 mils except in very symmetrical terrain. In extremely hilly terrain, it may be necessary to determine dead space at 50-mil or smaller increments. The smaller the increments, the more accurate the dead space diagram. Dead space for additional rays is determined in the same manner as that described in *a* above.

24-40. Dead Space Chart

a. FDC personnel may outline the area of dead space on a chart or map by connecting points of determined quadrant elevation, corresponding to the same hill crest, on adjacent rays. Dead space is shaded or labeled.

b. Unless directed otherwise, dead space charts forwarded to higher headquarters need show only dead space areas for low-angle and high-angle fires without regard to charge. Dead space charts for the 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.

c. In rugged terrain, it may be necessary to determine whether a target is in dead space prior to the completion of a dead space chart. The procedure described in paragraph 24-39*a* is used for determining the dead space on a ray drawn from the battery to the target.

Section XII. MISCELLANEOUS

24–41. Data Sheets

Since prearranged fires are fire-for-effect missions, the FDC must determine and maintain current corrections to chart data and correct fire commands for these missions. To facilitate maintaining current chart and firing data for prearranged fires, battalion FDC personnel normally predetermine these data and enter them on the Firing Battery Data Sheet (DA Form 4199). (DA Form 4199 is available through normal AG publication supply channels.) If time permits, the computer at the battery fire direction center converts the data from the battery data sheet to individual piece data and enters these data on the Firing Battery Section Data Sheet. (DA Form 4007). A sample firing battery data sheet is shown in figure 24–7. The form is self-explanatory except for the following:

a. The times entered indicate when firing is started and lifted.

b. Time of flight normally is omitted. When time of flight is significant, as it is for fires on positions about to be assaulted by infantry, TOT fire, high-angle fire, or fires at extreme ranges, time of flight is entered and is used at the battery to modify the listed time of firing.

c. Columns for special corrections and zone using the common UTM zone junction longitudinal

d. The remarks column contains any special instructions.

e. When new corrections are obtained, the old commands are lined out and the change is entered.

24–42. Fire Capabilities Overlay

The fire capabilities overlay of the battalion shows the area that can be reached by the combined capabilities of the batteries of the battalion as directed. The area that can be reached by 2/3 of the pieces in deflection and range is the fire capability of the battery. The fire capabilities overlay of the battalion, as reported to higher artillery headquarters, may show the area that can be reached by each battery or may show the combined coverage of all the batteries. The overlay is used in conjunction with the dead space overlay for determining areas not covered by units to fire on targets. For detailed information and illustrations of the fire capabilities overlay, see FM 6–20.

24–43. Universal Transverse Mercator Grid Zone Transformation

a. General. Occasionally, throughout the world, operations may take place in an area where artillery is required to fire from one grid zone into another. When this situation occurs, the grid coordinates of points and the azimuth of lines from the grid of one zone must be transformed to the grid of the adjacent zone. This transformation will put the target and the firing unit on a common grid. Transformation of grid coordinates and azimuths can be accomplished by means of computations as outlined in FM 6–2 graphically as outlined in *b* below, or by FADAC as outlined in FM 6–40–3.

b. Graphical Zone to Zone Transformation.

(1) *Map construction.* Each US military map that covers an area within 25 miles of a UTM grid zone junction has printed around the border two sets of grid line numbers. One set is printed in black and the other, corresponding to the adjoining zone, is printed in blue. The marginal information indicates the color that applies to each zone.

(2) *Designation of the primary zone.*

(*a*) Either of the two adjoining zones may be designated as the primary zone.

(*b*) Designation of the primary zone is dependent on one or more of the following:

1. Where most of the action is expected to occur.

2. Unit SOP.

3. The commander's guidance.

4. Anticipated future operations.

(*c*) Generally, unit SOP dictates how the primary zone will be designated and which procedure will be used to determine the grid convergence factor; however, in the absence of an SOP, these decisions are made by the controlling artillery headquarters.

(3) *Preparation of the maps.*

(*a*) Once the primary zone has been designated, the map is prepared for transformation of data from one zone to another. If more than one map is used, fasten the two maps together, using the common UTM zone junction longitudinal line for orientation.

(*b*) Superimpose the grid of the primary zone over the adjacent zone by use of a straightedge.

(*c*) Draw the east-west grid lines into the adjacent zone by alining the straightedge with the tick marks around the border and number the grid lines with the appropriate values.

(*d*) Draw the north-south grid lines by alining the straightedge with the appropriate

FIRING BATTERY DATA SHEET

For use of this form, see FM 6-40; the proponent agency is US Army Training and Doctrine Command.

BATTERY	COORDINATES	ALTITUDE OF BATTERY	TIME	DATE	PAGE NO.
C	5736038479	397	2000	1 JUN 73	1

	CHART DATA											FIRE COMMANDS					
TGT NO.	COORDINATES	TIME FROM	TIME TO	TIME OF FLIGHT (Sec)	DEFLECTION CORR	DEFLECTION CHART DF	RANGE EL	ALT DIFF ALT HT OF BURST	SITE DIFF ALT SITE HT OF BURST	SP CORR SH LOT	CHG FZ MF	CORR INDIVIDUAL SHEAF CORRECTION	DF	TI INDIV CORR	ZONE	QE	REMARKS
AF 2103	53395 39542	0530	0532		L1	3277	4490 280	401 +4 20/R	+1 +5	HE QX	4 Ti		3278	16.9		286	
AF 2101	53843 37558	0534	0537		O	3403	3970 324	410 +13	+4	HE QY	D B④		3403			328	
AF 2104 200 METER ZONE	50631 36525	0539	0541		L4	3431	7660 314	437 +40 20/R	+6 +3	HE QY	6 VT B②		3435	24.0	3 m/	323	FIRE 5 ELEVATION
AF 2102	52440 37802	0543			L2	3282	5440 360	380 -17 20/R	-4 +4	HE QX	4 T! B⑤		3284	21.3		360	TOT 0543

DA FORM 1 JAN 74 4199 REPLACES DA FORM 6-14, 1 NOV 63, WHICH IS OBSOLETE.

Figure 24–7. Firing battery data sheet.

tick marks along the border of the map and number the grid lines with the appropriate values.

Note. Use a distinctive colored line in drawing the superimposed grid to facilitate rapid transformation of data and to reduce the possibility of error.

(4) *Determination of the grid convergence factor.* The grid convergence factor is used for converting an azimuth from the grid of one grid zone to that of an adjacent grid zone. This factor is determined from the marginal information of the maps or from a current Army Ephemeris.

(*a*) The marginal information printed on US military maps gives the grid convergence (grid declination) at the center of the map sheet. When the map sheet is within 25 miles of a grid junction, the grid convergence for each zone is given. One convergence is easterly and one westerly. The grid convergence factor is the sum of these two figures expressed to the nearest 10 mils.

(*b*) The convergence factor may also be computed by use of table 15, TM 6-300-(current year) (Army Ephemeris).

1. Determine the northing coordinate of the firing unit by using the grids of both the primary and the secondary zones.

2. Add these two values and divide by 2 to obtain the average northing. This is the argument for entry into the table.

3. Enter the appropriate table for the latitude of the area. Use the average northing coordinate and enter column N to the nearest listed value and determine the correction factor in mils from column G.

(*c*) The sign of the convergence factor can be determined from the following chart:

Northern Hemisphere	*Southern Hemisphere*
East to west, sign is —	East to west, sign is +
West to east, sign is +	West to east, sign is —

Note. In the Southern Hemisphere, subtract the average northing coordinate from 10,000,000 before entering the table.

c. Gunnery Procedures.

(1) *General.* The fire direction procedures necessary to rapidly calculate accurate firing data across a UTM grid zone junction are based on three primary considerations.

(*a*) Standard or normal call for fire procedures are utilized.

(*b*) The firing charts should remain as simple and uncluttered as possible.

(*c*) The system should be capable of easily controlling a number of firing units.

(2) *Observer procedures.* The observer sends the target location in the normal manner by using grid coordinates, polar plot, or shift from a known point. His map will require no superimposed grid lines and his azimuth-measuring instruments should be declinated for the same grid line as the location used in his call for fire.

(3) *FDC procedures.*

(*a*) In the FDC, all grid coordinates and azimuths should be in terms of the primary zone.

(*b*) The firing charts which may be used as the primary method of computing firing data or used in conjunction with FADAC, should also be in terms of the primary zone.

(*c*) On the battle map, the primary zone should be superimposed over the secondary zone. The battle map is used for converting grid coordinates from the secondary zone into grid coordinates of the primary zone. First, plot the grid coordinates, using the printed grid lines of the secondary zone, and then read the new grid coordinates for this point, using the superimposed grid lines of the primary zone.

(*d*) The grid convergence factor is determined to the nearest mil and expressed to the nearest 10 mils. It is generally determined only, once for a firing position.

(4) *FDC operation.* For a target that falls in the primary zone, the mission is processed by standard gunnery procedures as outlined herein. For a target that falls in the secondary zone, the procedures are modified as outlined in (*a*) and (*b*) below.

(*a*) *Target location by grid coordinates.* When grid coordinates of a target in the secondary zone are received by the FDC, they must be transformed into the primary zone.

1. The VCO plots the secondary zone grid coordinates on his battle map and reads the corresponding primary zone grid coordinates from the map.

2. The HCO plots the grid coordinates of the primary zone.

3. The computer applies the grid convergence factor to the reported OT azimuth and announces the converted azimuth to the HCO. The HCO orients the target grid over the target on the converted azimuth.

4. At this point, the target location has been completely transformed into the primary zone and the remainder of the mission is computed in the standard manner.

(*b*) *Target location by polar plot or shift from a known point.* When an observer in the secondary zone locates a target by polar plot or by a shift from a known point, the observer's location or the known point must be plotted on the chart. Therefore, the grid coordinates have already been converted to the primary zone and the HCO moves the RDP to the plot on the chart.

1. The computer applies the grid convergence factor to the observer's OT azimuth and announces the converted azimuth to the HCO. The HCO orients the target grid over the known point on the converted azimuth.

2. Again, the target location has been completely transformed into the primary zone and the remainder of the mission is processed in the standard manner.

Section XIII. 8-INCH HOWITZER—NUCLEAR DELIVERY

24-44. General

a. Procedure. This section describes fire direction techniques for delivery of the 8-inch howitzer nuclear round. Delivery techniques for the 8-inch howitzer nuclear round are the same as standard gunnery procedures with the exception of the determination of the fuze setting and the addition of ballistic corrections for the nuclear round.

b. Nomenclature.

(1) The high-explosive spotting round (HES M424) is used for registrations and adjustments.

(2) The nuclear round (NUC M422) is used for fire for effect.

c. Preferred Techniques. The two preferred techniques for the delivery of nuclear rounds from an 8-inch howitzer are—

(1) The met plus VE technique.

(2) The K-transfer (GFT) technique.

d. Observer's Adjustment Technique. If the information necessary for the employment of a preferred technique is not available, an adjustment and fire-for-effect (observer adjustment) technique may be used.

24-45. Requirements for Delivery Techniques

The requirements for the use of the various delivery techniques of 8-inch nuclear rounds are as follows:

a. Met Plus VE. The following data must be available:

(1) Accurate survey data for the gun and target.

(2) Registration data for shell HES.

(*a*) Valid position VE.

(*b*) Valid deflection correction.

(*c*) Valid position fuze correction.

(3) Current met data.

b. K-transfer (GFT). The following data must be available:

(1) Accurate survey data for the gun and target.

(2) Valid GFT setting, and total deflection correction.

c. Observer Adjustment. The observer must be in a position from which he can observe and adjust the rounds.

24-46. Accuracy

All firing data are determined to the same accuracy as that required for standard gunnery procedures.

24-47. Selection of Delivery Technique

a. Considerations in Selection of Delivery Technique. Listed below are some of the considerations in the selection of a delivery technique. The S3 must evaluate all considerations in making his decision.

(1) The tactical situation.

(2) The commander's guidance.

(3) The desirability of surprise.

(4) The weather conditions.

(5) The availability of spotting rounds.

(6) The time available.

(7) Restrictions on registrations.

(8) Survey.

(9) The validity of the GFT setting, velocity error, deflection, and total fuze correction.

b. Registrations. In a nuclear war, it is anticipated that the unit will register (three-round high burst) at least one weapon with shell HES immediately after occupying the position. This registration will establish a position VE to be used for the met plus VE technique and a GFT setting to be used for the K-transfer technique.

c. Accuracy of Techniques. The accuracy of each technique depends on the situation and the available data. There are so many variables that one technique cannot be considered the most accurate technique under all conditions. General guides are as follows:

(1) The met plus VE technique will probably be the most accurate method under most conditions, particularly when the target is in a fringe area or outside the transfer limits or when the registration data are not current. The accuracy of this technique depends on the validity of the met messages and the accuracy of the target location.

(2) The K-transfer method will yield an accurate solution if concurrent registration data are used. If the target is accurately located and in proximity to the high-burst registration, the

accuracy should equal or, possibly, exceed that of the met plus VE technique. In the fringe areas of the transfer limits, the accuracy can be expected to decrease. The principal disadvantage of this system is that the unit usually must fire a registration in order to develop current data.

(3) The observer adjustment technique is the least desirable method for several reasons. The accuracy of this technique depends on the ability of the observer to see the effect of the burst on the ground and on the size of the observer's bracket. This technique is used when the other techniques cannot be used. The disadvantages are the time consumed, loss of surprise, requirement for an observer to be in position, inaccuracy of fire (normally, a 100-meter bracket is split), and number of rounds (HES) used in adjustment.

d. Time Requirements. The time required to prepare the fire commands for delivery of a nuclear round depends on the situation and the data available. If a current GFT setting is available, the K-transfer technique will be the fastest. The next most rapid solution is met plus VE. The K-transfer technique will be the slowest if a registration must be fired, because of the time required to register. The time required for the observer adjustment technique depends on the speed of adjustment.

e. Ballistic Correction. Except for table M, the firing tables used for determing firing data for delivery of the 8-inch nuclear round (projectile NUC M422) are based on firing of the spotting round (projectile HES M424). Table M is based on comparative firing of projectile HES M424 and projectile NUC M422. Because of ballistic differences, a spotting round and a nuclear round fired with the same data will not burst at the same point. Therefore, when a nuclear round is to be fired, corrections to quadrant elevation and fuze setting must be determined. For each quadrant elevation listed, table M gives a correction for quadrant elevation and a correction for fuze setting to compensate for the ballistic differences between the two rounds. To determine the corrections, enter table M with the final quadrant elevation determined for projectile HES M424 to the nearest listed value and the height of burst above gun to the nearest 1 meter. The values of the corrections can usually be determined by visual interpolation.

f. Determination of Total Fuze Correction.

(1) Because of the large vertical intervals involved in the delivery of nuclear rounds, complementary angle of site (complementary range) must be considered in the determination of the total fuze correction. A greater fuze setting is required for delivering a projectile to a point at a given range plus a 200-meter vertical interval than to a point at the same range but at the same altitude as the weapon. This difference in fuze setting is in direct relationship to the complementary angle of site (complementary range). (This is also true in the delivery of conventional high-explosive projectiles for all weapons. However, in firing conventional HE projectiles, the vertical intervals and complementary angles of site are normally small and, consequently, have a negligible effect on the fuze setting.) The procedure for determining the total fuze correction is as follows:

(*a*) Determine the angle of site and site (GST).

(*b*) Determine the complementary angle of site (site minus angle of site).

(*c*) Determine the fuze setting for the adjusted elevation plus the complementary angle of site (GFT).

(*d*) Subtract the fuze setting for the adjusted elevation plus the complementary angle of site from the adjusted fuze setting.

Note. When using the tabular firing tables for determining the total fuze correction, add the complementary range to the chart range for the achieved high-burst location and then interpolating for elevation plus complementary angle of site in table F of the firing tables.

(2) The following example illustrates the determination of the total fuze correction with the GFT and GST (charge 1, projectile HES): Chart data to high-burst location:

Range ---------------- 3,490 meters
Height of burst
above gun ---------- +162 meters
Adjusted Data for the
high burst:
QE ---------------- 389 mils
Fuze setting ------ 15.9
Total fuze correction:
Fuze setting fired --- 15.9
Site to high burst
(+162/3490; chg
1, TAG, GST) ---- +53 mils
Angle of site (+162/
3490; C and D
scales GST) ------ +47 mils
Comp site (+53 −
(+47)) ------------ +6 mils
Adjusted elevation
(389 − (+53)) ----- 336 mils

Adjusted elevation plus comp site (336 + (+6)) .... 342 mils
Fuze setting for adjusted elevation plus comp site (GFT) 16.5
Total fuze correction (15.9 − 16.5) ...... −0.6

(3) The total fuze correction is added to the fuze setting for the elevation plus complementary angle of site to the target.

g. Position Velocity Error.

(1) Position VE includes the total deviation from standard for the weapon, ammunition, firing chart, and survey which cannot be accounted for and for which corrections cannot be determined except by firing. The following factors in relation to position VE for nuclear delivery must be considered:

(*a*) Nuclear delivery units will have a higher survey priority than other units.

(*b*) If registration is permitted, only one registration may be fired for each position.

(*c*) Manufacturer's tolerances are less for the spotting and nuclear rounds than for conventional ammunition.

(2) Accordingly, the position VE is continually averaged at every opportunity. Judgment must be used in the continual averaging of these velocity errors. A large deviation of a new position VE from the average position VE should be viewed critically, and the reason for the deviation should be determined and isolated. If the reason cannot be determined, it is usually better to omit this position VE when the average is being computed.

24-48. Met Plus VE

a. Determination of Position Velocity Error, and Total Deflection Correction. The procedures for determining the position VE and total deflection correction for shell HES are the same as those for determining the position VE and total deflection correction for HE as described in chapter 21. The position VE and total deflection correction for nuclear delivery should be determined as soon as possible after occupation of position and should not be delayed until the receipt of a nuclear mission.

b. Determination of the Total Fuze Correction. The procedure for determining the total fuze correction for shell HES is the same as that for determining the fuze correction for HE as outlined in chapter 21 except that comp site must be taken into account as outlined in paragraph 24-47*f*.

24-49. Example—Determination of Position VE, Position Deflection Correction, and Position Fuze Correction

a. Chart Data to Point Selected for High Burst.

Deflection .... 3,148 mils
Range .... 9,820 meters
Height above gun .... +180 meters

b. Determination of Firing Data for High-Burst Registration (Charge 3, Shell HES). It is mandatory that the first round of the high-burst registration be observed. Therefore, the firing data for the high-burst registration must reflect as many of the known nonstandard conditions as possible. The average position VE of the weapon and current met data should be applied to the firing data.

(1) *QE to be fired.*

Total range correction based on the average position VE and current met .... −160 meters
Elevation for corrected range (9820 + −160) .... 306 mils
Site (+180/9820; chg 3, TAG, GST) ...... +20 mils
QE (306 + (+20)) .... 326 mils

(2) *Fuze setting to be fired.*

Angle of site (+180/9820; C and D scales, GST) .... +19 mils
Comp site (+20 − (+19)) .... +1 mil
Elevation plus comp site (306 + (+1)) .. 307 mils
Fuze setting 27.3
Met fuze correction 0
Average position fuze correction .... +0.1
Fuze setting to fire 27.4

(3) *Deflection to be fired.*

Current met deflection correction .... R4 mils
Deflection (3148 + R4) .... 3,144 mils

Note. When using the tabular firing tables for determining the quadrant elevation and fuze setting to be fired, determine the entry range from the complementary range table. Use the entry range to determine the elevation plus complementary angle of site to determine the quadrant elevation.

c. Chart Data to the Achieved High-Burst Location (Graphic Solution or Computed).

Deflection .... 3,147 mils
Range .... 9,520 meters
Height of burst above gun .. +157 meters

d. Determination of the Total Range Correction.

QE fired	326 mils
Site (+157/9520, chg 3, TAG, GST)	+18 mils
Adjusted elevation (326 − (+18))	308 mils
Range for elevation 308 (GFT)	9,700 meters
Total range correction (9700 − 9520)	+180 meters

Note. When determining the total range correction from the tabular firing tables subtract the range corresponding to the elevation plus complementary angle of site from the entry range to the achieved high burst.

e. Determination of the Total Fuze Correction.

Fuze setting fired	27.4
Angle of site (+157/9.52, GST)	+17 mils
Comp site (+18 − (+17))	+ 1 mil
Elevation + Comp (site 308 + (+1))	309 mils
Fuze setting corresponding to elevation plus comp site (309)	27.5
Total fuze correction (27.4 − 27.5)	− 0.1

f. Determination of the Total Deflection Correction.

Deflection fired	3,144 mils
Deflection to chart location of high burst	3,147 mils
HB registration deflection correction (total deflection correction)	R3 mils

g. Determination of the Met Range Correction, Met Deflection Correction, and Met Fuze Correction. The met corrections are determined as shown in figure 24-8.

Battery laid on azimuth, 2000, deflection 3200	
Azimuth fired	2,053 mils
Weight of projectile	244 pounds
Altitude of gun	326 meters
Altitude of burst	483 meters
Propellant temperature	66° F
Latitude of gun	34° N
Concurrent ballistic met message:	

METB39	MIFMIF	070550	049982
002618	009976	012618	009978
022720	009978	032927	004981
042928	002982	053129	004987

h. Determination of Position VE and Position Fuze Correction. The position VE and position fuze correction are determined as shown in figure 24-8.

i. Determination of Position Deflection Correction.

Total deflection correction	R3 mils
Met deflection correction	R4 mils
Position deflection correction	L1 mil

j. Results.

Position VE	−1.3 m/s
Position fuze correction	0
Position deflection correction	L1 mil

24-50. Application of MET Plus VE

a. The application of met plus VE is the same as that for shell HE (chap 21) except for the fuze setting (use elevation plus comp site) and the ballistic corrections. When the met plus VE technique is used, the data will be computed to the target. The GFT setting will be kept current by use of met plus VE for emergencies; for example, when there is insufficient time to compute met plus VE to the target.

b. The ballistic corrections are determined as indicated in the example in paragraph 24-51.

24-51. Example—Application of Met Plus VE

This example is a continuation of the example in paragraph 24-49. The worksheet for the computations (DA Form 4207) is shown in figure 24-10. DA Form 4207 is attached to the DA Form 3622, on which are recorded the fire mission, the fire order, the initial fire commands, and the statement "See attached nuclear worksheet."

a. Chart Data to Target.

Range	10,520 meters
Desired height of burst above gun	+150 meters
Deflection	3,248 mils

b. Solution of Met Message for Met Range Correction, Met Deflection Correction, and Met Fuze Correction. The met message is solved as shown in figure 24-9.

Weight of projectile	241 pounds
Propellant temperature	75° F
Altitude of battery	326 meters
Altitude of target	336 meters
Height of burst above target	+140 meters
Chart deflection to target	3,248 mils
Battery laid on azimuth	2,000 mils
Referred deflection	3,200 mils
Position VE	−1.3 m/s

MET DATA CORRECTION SHEET
For use of this form, see FM 6-40; proponent agency is TRADOC.

BATTERY DATA | **MET MESSAGE**

CHARGE	ADJ QE	CHART RG	LATITUDE	TYPE MESSAGE	OCTANT	AREA/UNIT
3	326	9520	30°N	METB 3	9	MIFMIF

ALT OF BTRY (10 m)	330	DATE 07	TIME 0530	ALT MDP 490	PRESSURE 98.2
ALT OF MDP	490	LINE NO. 03	WIND DIR 2900	WIND SPEED 27	AIR TEMP 100.4	AIR DENSITY 98.1
BTRY ABOVE/BELOW MDP (Δh)	-160	Δh CORRECTION			⊖ 0.3	⊕ 1.6
ALT OF TARGET (nearest meter)	483	CORRECTED VALUES			100.7	99.7
HEIGHT OF BURST ABOVE TARGET	–					
ALT OF BURST	483					
ALT OF BTRY (nearest meter)	326					
HEIGHT OF TARGET (burst) ABOVE GUN (M)	+157	COMP RG +22	CHART RG 9520	ENTRY RG 9542	9500	

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400	Total DF Corr	R3
DIRECTION OF WIND	2900	Met DF Corr	R4
		Pos DF Corr	L1
DIRECTION OF FIRE (2053)	2100	ROTATION CORR	R ⊕ 0.9
CHART DIRECTION OF WIND	800	DRIFT CORR	L 4.6
CROSS WIND: WIND SPEED 27 × COMP L ⊕ 0.71 = ⊕ 19	KNOTS × 0.48 UNIT CORR =	CROSS WIND L CORR	⊕ 9.1
RANGE WIND: WIND SPEED 27 × COMP T ⊕ 0.71 = TAIL/HEAD 19	KNOTS	MET DEFL CORR	⊕ 3.6 R4

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATIONS FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	T ⊕ 19	0	⊕ 19	+9.1	172.9	
AIR TEMP	100.7	100%	⊕ 0.7	-5.6		3.9
AIR DENSITY	99.7	100%	⊖ 0.3	-33.5		10.0
PROJ WEIGHT	244 lbs	242 lbs	⊕ 2	+2.0	4.0	
ROTATION				-33 × 0.87		28.7
					176.9	42.6
					42.6	
				MET RANGE CORR	134.3	+134

COMPUTATION OF VE

	VE	-1.3 M/S	D +21.9	TOTAL RANGE CORRECTION	+180
PROP TEMP 66 °F	CHANGE TO MV FOR PROP TEMP	-0.8 M/S	I -21.3	MET RANGE CORRECTION	+134
	ΔV	-2.1 M/S	MV UNIT CORRECTION ±21.9	ΔV RANGE CORRECTION	+46
				TOTAL RANGE CORRECTION	

OLD VE ______ + NEW VE ______ = ______ ÷ 2 = AVG VE ______ M/S

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MET FUZE CORRECTION

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS		
ΔV	⊖ 2.1	-0.039		0.082	EL	308
RANGE WIND	T ⊕ 19	-0.002		0.038	+CAS	+ (+) 1
AIR TEMP	⊕ 0.7	-0.005		0.004	EL+CAS	309
AIR DENSITY	⊖ 0.3	+0.046	0.014		FS ~ EL+CAS =	27.5 ≈ 28
PROJ WEIGHT	⊕ 2	-0.011		0.022	TOTAL FUZE CORRECTION	-0.1
			0.014	0.146	MET FUZE CORRECTION	-0.1
				0.014	FUZE CORRECTION	0
		MET FUZE CORR		0.132	TOTAL FUZE CORRECTION	

OLD FZ CORR ______ + NEW FZ CORR ______ = ______ ÷ 2 = AVG FZ CORR ______

TARGET NO.	BATTERY	DATE/TIME
	B	07 0030 Mar 70

DA FORM 4200 JAN 74 — REPLACES DA FORM 6-15, 1 APR 67, WHICH IS OBSOLETE.

Figure 24–8. Met data correction sheet (DA Form 4208) (K-transfer, 8-inch nuclear round).

MET DATA CORRECTION SHEET
For use of this form, see FM 6-40; proponent agency is TRADOC.

BATTERY DATA

CHARGE	ADJ QE	CHART RG	LATITUDE
3	381	10,520	30°N

ALT OF BTRY (10 m)	330
ALT OF MDP	490
BTRY ABOVE/BELOW (BELOW circled) MDP (ΔH)	-160
ALT OF TARGET (nearest meter)	336
HEIGHT OF BURST ABOVE TARGET	+140
ALT OF BURST	476
ALT OF BTRY (nearest meter)	326
HEIGHT OF TARGET (burst) ABOVE GUN (M)	+150

MET MESSAGE

TYPE MESSAGE	OCTANT	AREA/UNIT	
MET B 3	9	MIF MIF	
DATE 07	TIME 0730	ALT MDP 490	PRESSURE 98.0
LINE NO. 04	WIND DIR 4200 / WIND SPEED 25	AIR TEMP 100.8	AIR DENSITY 97.3
Δ% CORRECTION		⊕ 0.3	⊕ 1.6
CORRECTED VALUES		101.1	98.9

COMP RG	CHART RG	ENTRY RG	
+24	10,520	10,544	10,500

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400
DIRECTION OF WIND	4200
DIRECTION OF FIRE (1952)	2000
CHART DIRECTION OF WIND	2200

Pos DF CORR L1
MET DF CORR R4
TOT DF CORR R3

ROTATION CORR	Ⓛ/R	1.1
DRIFT CORR	L	5.5
CROSS WIND CORR	L/Ⓡ	10.9
MET DEFL CORR	L/Ⓡ	4.3 — R4

CROSS WIND: WIND SPEED 25 × COMP L/Ⓡ 0.83 = Ⓡ 21 KNOTS × 0.52 UNIT CORR =

RANGE WIND: WIND SPEED 25 × COMP Ⓣ/H 0.56 = ⓉAIL/HEAD 14 KNOTS

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATIONS FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	Ⓣ 14	0	Ⓣ 14	-9.6		134.4
AIR TEMP	101.1	100%	Ⓘ 1.1	-8.5		9.4
AIR DENSITY	98.9	100%	Ⓓ 1.1	-37.9		41.7
PROJ WEIGHT	241 lbs	242 lbs	Ⓓ 1	-1.0		1.0
ROTATION	-35 x	0.87				30.4
						216.9
				MET RANGE CORR		216.9 — -217

COMPUTATION OF VE

	VE	-1.3 M/S	D+23.0	TOTAL RANGE CORRECTION	
PROP TEMP 73° °F	CHANGE TO MV FOR PROP TEMP	+0.6 M/S	1-22.4	MET RANGE CORRECTION	-217
	ΔV	-0.7 M/S	MV UNIT CORRECTION +23.0	ΔV RANGE CORRECTION	+16
				TOTAL RANGE CORRECTION	-201 — -200

OLD VE ______ + NEW VE ______ = ______ ÷ 2 = AVG VE ______ M/S

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MET FUZE CORRECTION

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS
ΔV	Ⓓ 0.7	-0.041		0.029
RANGE WIND	Ⓣ 14	+0.004	0.056	
AIR TEMP	Ⓘ 1.1	-0.003		0.003
AIR DENSITY	Ⓓ 1.1	+0.050	0.055	
PROJ WEIGHT	Ⓓ 1	+0.010	0.010	
			0.121	0.032
			0.032	
		MET FUZE CORR	0.089	

-200 → 10,320
Rg 10520, EL 342
+2
30.0

TOTAL FUZE CORRECTION	
MET FUZE CORRECTION	+0.1
FUZE CORRECTION	0
TOTAL FUZE CORRECTION	+0.1

OLD FZ CORR ______ + NEW FZ CORR ______ = ______ ÷ 2 = AVG FZ CORR ______

TARGET NO.	BATTERY	DATE/TIME
	B	07 0200MAR 72

DA FORM 4200 1 JAN 74 — REPLACES DA FORM 6-15, 1 APR 67, WHICH IS OBSOLETE.

Figure 24-9. Met data correction sheet (DA Form 4207) (met plus VE, 8-inch nuclear round) plus VE.

Position deflection correction .... L1 mil
Position fuze correction 0
Charge 3
Current ballistic message:

METB39	MIFMIF	070750	049980
004211	011970	014214	011971
024320	009971	034422	009973
044225	008973	054229	008972

Note. The line number to be used in solving the met message can be determined by use of table B. However, a more accurate determination can be made by use of an inferred QE and table A. A QE can be inferred from the current GFT setting and the chart data to the target.

c. Application of Position VE. The application of position VE to determine the total range correction is shown in figure 24-9.

d. Determination of Quadrant Elevation.

Total range correction ..... −200 meters
Chart range .... 10,520 meters
Corrected range (10,520 + −200) .... 10,320 meters
Elevation for corrected range .... 342 mils
Site (+150/10,520, GST) .. +16 mils
QE .... 358 mils
QE correction for ballistic difference .... +9 mils

(Enter the ballistic correction table, table M, in the tabular firing table with the nearest listed QE and the height of burst above gun to the nearest meter. If the QE falls exactly halfway between two listed values, the more even entry argument is selected. For example, HES QE 315 falls halfway between listed values 310 and 320. Therefore, 320 is selected as the entry argument into table M).

QE to be fired .... 367 mils

Note. When determining the QE from the tabular firing tables, obtain the elevation plus complementary angle of site for the total range correction plus the entry range (chart range plus complementary range) to the target and add the angle of site and the ballistic correction to determine the quadrant elevation to be fired.

e. Determination of the Fuze Setting.

Angle of site (+150/10,520; C and D scales .... +15 mils
Comp site (+16 − (+15)) . +1 mil
Elevation plus comp site ... 343 mils
Fuze setting for elevation plus comp site 30.0
Position fuze correction ... 0
Met fuze correction .... +0.1
Total fuze correction ...... +0.1
Fuze setting (30.0 + 0.1) .. 30.1
Fuze correction for the ballistic difference ...... +0.4

(Enter the ballistic correction table, table M, in the tabular firing table, with the nearest listed QE and the height of burst above gun to the nearest meter. These are the same entry arguments used to obtain the ballistic correction for QE).

Fuze setting to be fired 30.5

Note. When determining the fuze setting from the tabular firing tables, add the fuze setting corresponding to the elevation plus complementary angle of site (*d* above) to the total fuze correction and the fuze correction for the ballistic difference.

f. Determination of Deflection.

Chart deflection .... 3,248 mils
Position deflection correction .... L1 mil
Met deflection correction R4 mils
Total deflection correction R3 mils
Deflection to be fired ...... 3,245 mils

g. Firing Data.

Deflection .... 3,245 mils
Fuze setting 30.5
QE .... 367 mils

24-52. K-Transfer GFT Technique

a. General. The K-transfer GFT technique is based on a GFT setting, and a total deflection correction. Corrections are determined from an HB registration, normally with three rounds of HES shell. The ballistic difference between the spotting round and the nuclear round must be applied in the same manner as in the met plus VE technique. The difference, if any, between the projectile weights and the propellant temperatures of the spotting round and the nuclear round must also be applied.

b. Determination of GFT Setting. The procedure for determining the GFT setting is the same as that for HE ammunition except in the construction of the time gageline which is constructed as follows:

(1) Determine the complementary angle of site.

(2) Determine the fuze setting for the adjusted elevation plus comp site.

(3) Determine the total fuze correction by subtracting the fuze setting corresponding to elevation plus comp site from the fuze setting used to fire the high-burst registration.

(4) Add the total fuze correction to the fuze setting corresponding to the adjusted elevation. The result is the adjusted (GFT) fuze setting at the level point. Move the hairline of the cursor

8–INCH NUCLEAR COMPUTATION

MET PLUS VE

For use of this form, see FM 6-40; the proponent agency is TRADOC.

BATTERY B	DATE 12 NOV	PIECE NUMBER 2	TARGET NUMBER YX 1100
ITEM			
1. HOB ABOVE GUN (from met form)	+150		
2. CHART RG TO TGT		10,520	
3. TOTAL RG CORR (from met)		−200	
4. CORR RG, 2 plus 3 (10m)		10,320	
5. EL ~ 4 (MHL)	342		
6. SITE (VI 1 AT RG 2)	+16		
7. ANGLE OF SITE (C & D SCALES)	+15		
8. QE FOR SPOTTER, 5 plus 6	358		
9. BAL CORR FOR NUC (TABLE M) (1ṁ)	+9		
10. QE TO FIRE, 8 plus 9		367	
11. COMP SITE, 6 minus 7	+1		
12. EL 5	342		
13. EL plus COMP SITE, 11 plus 12	343		
14. FS ~ 13 (MHL)		30.0	
15. TOTAL FZ CORR (to tgt)		+0.1	
16. FS FOR SPOTTER, 14 plus 15	30.1		
17. BAL FZ CORR FOR NUC (TABLE M)		+0.4	
18. FS TO FIRE, 16 plus 17		30.5	
19. DF TO TGT		3248	
20. TOTAL DF CORR (to tgt)		R3	
21. DF TO FIRE, 19 plus 20		3245	

DA FORM 4207, 1 Jan 74

Figure 24–10. DA Form 4207, 8-inch nuclear met plus VE worksheet.

to the GFT setting range and construct the elevation gageline at the adjusted elevation and the time gageline at the adjusted fuze setting to the level point.

c. Determination of Total Deflection Correction. The total deflection correction is determined in the normal manner; that is, go from chart deflection to adjusted deflection and establish a deflection correction scale. The transfer limits are the same as those for conventional HE ammunition.

d. Application of Data to a Target. The GFT setting is used in the normal manner for determining the elevation. The fuze setting is determined by placing the elevation gageline over the elevation plus comp site and reading the fuze setting under the time gageline. The QE and fuze setting are corrected for the ballistic differences as indicated in paragraph 24-47*e*. The total deflection correction is determined from the deflection correction scale.

24-53. Example—Determination of GFT Setting, and Total Deflection Correction

a. Known Data.

Shell	HES
Lot	XY
Charges	3
Weight of projectile	241 pounds
Propellant temperature	66° F
Altitude of battery	318 meters

b. Fired (Adjusted) Data for High-Burst Registration.

Deflection	3,239 mils
Fuze setting	26.7
QE	325 mils

c. Chart Data to High-Burst Location.

Deflection	3,235 mils
Range	9,370 meters
Height of burst above gun	+184 meters

d. Determination of Adjusted Elevation.

Site (+184/9370; chg 3, TAG, GST)	+21 mils
Elevation (325 − (+21)	304 mils

e. Determination of GFT Fuze Setting.

Site	+21
Angle of site (+185/9370 C and D scales, GST)	+20 mils
Comp site (+21 − (+20))	+1 mil
Adjusted elevation	304 mils
Adjusted elevation plus comp site (304 + (+1))	305 mils
Fuze setting fired	26.7
Fuze setting for elevation plus comp site	27.1
Total fuze correction (26.7 − 27.1)	0.4
Fuze setting for adjusted elevation	27.1
GFT fuze setting	26.7

f. Determination of Total Deflection Correction.

Adjusted deflection	3,239 mils
Chart deflection	3,235 mils
Registration deflection corrections (center of the deflection correction scale)	Left 4 mils

g. Results.

GFT B: Chg 3, lot XY, rg 9370, el 304, ti 26.7

Total deflection correction ... Left 4 mils

The worksheet (DA Form 4208) for the computations used in determining the GFT setting, total fuze correction, and total deflection correction is illustrated in figure 24-11.

24-54. Example—Application of K-Transfer Technique

This problem is a continuation of the problem in paragraph 24-53. Projectile weight (shell nuclear) is 240 pounds; current propellent temperature is 74° F.

a. Chart Data to Target.

Range	10,470 meters
Deflection	3,132 mils
Altitude of target	341 meters
Desired height of burst above target	+150 meters

b. Determination of Entry Range. Entry range is necessary for determination of unit corrections for projectile weight and propellant temperature (*c* below). Visual interpolation usually is possible because entry range is used to the nearest 100 meters.

Complementary range (Enter table B at chart range and height of burst above gun)	+28 meters
Chart range	10,470 meters
Entry range	10,498 meters

c. Determination of Corrections for Difference in Projectile Weight and Propellant Temperature.

(1) *Correction for projectile weight.*

Weight of projectile (nuclear)	240 pounds
Weight of projectile used for registration	241 pounds
Variation from registration value	Decrease/1 pound
Unit correction determined at entry range (10,500)	−1 meter
Correction	−1 meter

(2) *Correction for propellant temperature.*

Change to muzzle velocity for current propellant temperature (74° F)	+0.8 m/s
Change to muzzle velocity for propellant temperature at registration (66° F)	−0.8 m/s
Variation from registration value	Increase 1.6 m/s
Unit correction (determined at entry range)	−22.4 meters
Correction	−36 meters

(3) *Total range correction for projectile weight and propellant temperature.*

Correction for projectile weight plus correction for propellant temperature ((−1) + (−36) = −37 or −40.)	

d. Determination of Quadrant Elevation.

Range plus projectile weight and propellant temperature differences (10,470 + (−40))	10,430 meters
Elevation (use GFT with GFT setting)	364 mils
Site (+173/10,470; chg 3, TAG, GST)	+19 mils
QE shell HES (364 + (+19))	383 mils
QE ballistic correction (Enter the ballistic correction table in the tabular firing tables with the QE to the nearest listed value and the HOB above gun to the nearest meter.)	+10 mils
QE to be fired	393 mils

e. Determination of Fuze Setting.

Site	+19 mils
Angle of site (+173/10,470 C and D scales, GST)	+17 mils
Comp site ((+19) − (+17))	+2 mils
Elevation	364 mils
Elevation plus comp site (364 + (+2))	366 mils
Fuze setting for elevation plus comp site (time gageline)	31.3
Ballistic fuze correction (table M)	+0.5
Fuze setting to be fired	31.8

f. Determination of Deflection to be Fired.

Chart deflection	3,132 mils
Total deflection correction (deflection correction scale)	Left 5 mils
Deflection to be fired	3,137 mils

g. Firing Data.

Target	YX1101
Shell	Nuclear
Lot	WY
Charge	3
Deflection	3,137 mils
Fuze setting	31.8
QE	393 mils

h. Computation of the K-transfer problem is simplified by use of a K-transfer worksheet (DA Form 4208) (fig 24–11).

24–55. Observer Adjustment

a. General. If the information necessary to employ either the met plus VE or the K-transfer technique is not available, an adjustment may be made with shell HES followed by fire for effect with shell NUC. The procedure will differ from the normal HE adjustment in that the observer must conduct a simultaneous adjustment of deviation, range, and height of burst to the normal 20 meters. Deflection, elevation, site, 100/R, and fuze setting are determined in the same manner as those for the HE projectile. The fuze setting is not determined by use of the elevation plus comp site method during the adjustment phase because the vertical interval will automatically correct for small errors during the adjustment.

b. Initial Data. For the first spotting round, an angle of site based on a vertical interval of 20 meters and the GT range must be computed and added to the site for the ground location in the same manner as that for conventional time fire. When a subsequent height of burst correction is given by the observer, the computer uses the 100/R factor to determine the height-of-burst correction in mils which is applied to the previous site. For example, the observer's height-of-burst correction is UP 20, 100/R is 29 mils, and the previous site is +8 mils. Multiply 29 mils by 0.2 and determine a height-of-burst correction of +5.8 mils, or +6 mils. Combine this with the previous site and determine a new site of +14 mils.

c. Fire-for-Effect Data.

(1) The chart data are determined in the same manner as in the adjustment phase. The observer's fire-for-effect request should place the burst over the target with a height of burst of 20 meters. The height above the target must be corrected by the difference between the height of the last round in the adjustment and the desired height above target for the nuclear round. For example if the observer requests LEFT 20, ADD 50, UP 5, FIRE FOR EFFECT and the desired height of burst above target for the nuclear round is +180 meters, a height-of-burst correction of UP 165 must be applied. Since the observer is striving for a 20-meter height of burst, the request for UP 5 indicates that the last round was 15 meters (20 − 5 = 15) above the target. Subtracting the 15 meters already achieved from the desired 180 meters results in a height-of-burst

8–INCH NUCLEAR COMPUTATION

K–TRANSFER

For use of this form, see FM 6-40; the proponent agency is TRADOC.

BATTERY B	DATE 12 NOV	PIECE NUMBER 2	TARGET NUMBER YX 1101

ITEM			Entry	Remarks
1.	ALT OF TGT	341		
2.	ALT OF BURST ABOVE TGT	+150		
3.	ALT OF BURST, 1 plus 2	491		
4.	ALT OF BTRY	318		
5	VI, 3 minus 4	+173		
6.	CHART RG TO TGT		10,470	(COMP RG +28)
7.	ENTRY RG (TABLE B, VI 5) (10,498)	10,500		
8.	NUC WT	240		
9.	SPOTTER WT	241		
10.	DIFFERENCE, 8 minus 9	DEC 1		
11.	UNIT CORR (TABLE F)	−1		
12.	CORR FOR PROJ WT, 10 X 11 (1m)		−1	
13.	NUC TEMP CORR (TABLE E) +74	+0.8		
14.	SPOTTER TEMP CORR (TABLE E) +66	−0.8		
15.	DIFFERENCE, 13 minus 14	INC 1.6		
16.	UNIT CORR (TABLE F)	−22.4		
17.	CORR FOR PROP TEMP, 15 X 16 (1m)		−36	(−1) + (−36) = −37 ≈ −40
18.	CORR RG, 6 plus (12 plus 17 (10m))		10,430	
19.	EL ~ 18 (GFT)	364		
20.	SITE (VI 5 AT RG 6)	+19		
21.	ANGLE OF SITE (C & D SCALES)	+17		
22.	QE FOR SPOTTER, 19 plus 20	383		
23.	BAL CORR FOR NUC (TABLE M) (1m)	+10		
24.	QE TO FIRE, 22 plus 23		393	
25.	COMP SITE, 20 minus 21	+2		
26.	EL 19	364		
27.	EL plus COMP SITE, 25 plus 26	366		
28.	FS ~ 27 (GFT)		31.3	
29.	BAL CORR FOR NUC (TABLE M)		+0.5	
30.	FS TO FIRE, 28 plus 29		31.8	
31.	DF TO TGT		3132	
32.	DF CORR (FROM SCALE USING EL 19)		L5	
33.	DF TO FIRE 31 plus 32		3137	

DA FORM 4208, 1 Jan 74

Figure 24–11. DA Form 4208, 8-inch nuclear (K-transfer) worksheet.

correction of UP 165 meters. If the observer requests LEFT 20, ADD 50, FIRE FOR EFFECT and the desired height above target is +180 meters, a height-of-burst correction of UP 160 must be applied (180 − 20 = 160). Since the observer did not make a height-of-burst correction, the height of burst is correct (20 meters).

(2) Because of the large height-of-burst correction required, site (angle of site plus comp site) instead of the 100/R value (which is only an angle of site) must be considered. Also, the fuze setting must be corrected by the amount of comp site involved. Therefore, both site and angle of site must be computed by use of the height-of-burst correction and the fire-for-effect range. The site is included as the height-of-burst correction to the last site fired. The comp site is determined (site minus angle of site) and added to the elevation for the fire-for-effect range in determining the fuze setting. A range correction for the differences in projectile weight and in propellant temperature must be applied, if appropriate, before the elevation and the fuze setting are determined.

(3) The QE for the spotting round is the elevation corresponding to the chart range plus the range corrections for propellant temperature and the projectile weight, plus the site for the additional height above target, plus the last site fired.

(4) Ballistic corrections to QE and fuze setting are determined at the QE for the spotting round and the total height of burst above gun (sum of initial vertical interval, the observer's net height-of-burst corrections, and the desired height of burst above the target).

(5) The QE to be fired is the QE for the spotting round ((3) above) plus the ballistic QE correction.

(6) The fire-for-effect deflection is the chart deflection to the final target pin location.

(7) The time to be fired is the fuze setting corresponding to the elevation plus comp site, plus the total fuze correction (if any), plus the ballistic correction ((4) above).

24-56. Example—Observer Adjustment Technique

The FDC computer's record for an observer adjusted mission is shown in figure 24-12.

a. Chart data to Initial Location Requested by Observer.

Range	3,460 meters
Deflection	3,289 mils
Altitude of the battery	318 meters
Map altitude of the target	336 meters
Desired height of burst above target	+180 meters
Projectile weight (HES and NUC)	242 pounds
Projectile temperature (HES and NUC)	70° F

b. Determination of Initial Data For Charge 1. The initial data for charge 1 are shown in figure 24-12.

c. Determination of Subsequent Data. Subsequent data are shown in figure 24-12.

d. Determination of Fire-for-Effect Data. Fire-for-effect data are shown in figure 24-12.

(1) *Determination of quadrant elevation.*

Height of burst in relation to the target and the last round fired (20−5)	+15 meters
Desired height of burst above target	+180 meters
Height-of-burst correction (180 − 15)	+165 meters
Site correction (+165/3500; chg 1, TAG, GST)	+54 mils
Entry range (3500 + (+52)) (not required in this example because PT and PW corrections are not necessary	3,552 meters
Elevation for range 3500 (GFT)	319 mils
Site (last site fired (+9) + site correction (+54))	+63 mils
QE for spotting round	382 mils
Total target height above gun (desired HOB above target (+180) + vertical interval (+18) + observer's net correction (−5))	+193 meters
QE ballistic correction (+193 HOB and 380 QE)	+10 mils
QE to fire nuclear round	392 mils

(2) *Determination of fuze setting.*

Angle of site for HOB correction (+165/3500; C and D scales, GST)	+48 mils

FDC COMPUTER'S RECORD

For use of this form, see FM 6-40; the proponent agency is TRADOC.

BATTERY	DATE	TIME RECEIVED	TIME COMPLETED	TGT
B	31 MAR	1420	1450	AZ - - - -

CALL FOR FIRE		INITIAL FIRE COMMANDS	
44 FM, GRID 41863795, DIR 4170 INF BN ASSEMBLY AREA, AF- - - -	TOT DF CORR 0	#1 ADJUST	SP INSTR
	DF 3289	SH HE,S	LOT XY
	RG 3460 EL 314	CHG 1	FZ TI
FIRE ORDER: UNIT(S) B MF #1 ①	SI +6	MF #1 ① #1 ① NUC	IN EFF
BASIS FOR CORR USE GFT, SH HES	20/R +6	DF 3289	TI 15.2
DISTR LOT XY SH NUC	326	QE 326	AMMO EXP ①
LOT WY CHG 1 FZ TI	100/R 29; 20/R 6; ∡ SI; △ FS; 10m/SI		
1 RDS; SPREAD			
TIME ____ TGT AZ - - - -			

OBSERVER CORRECTIONS				SUBSEQUENT FIRE COMMANDS											
MF SH FZ	DEV	RG	HOB	SH,CHG FZ,MF	CHART RG	CHART DF	CORR (0)	DF FIRED	FS CORR	TI	HOB CORR	SI (+12)	EL	QE	AMMO EXP
	L30	+200	D20		3630	3306	0	3306		16.1	−6	+6	334	340	②
	R20	−100	U10		3540	3298	0	3298		15.6	+3	+9	323	332	③
	L10	−50	U5 FFE	SH NUC LOT WY	3500	3297	0	3297		15.7	+54	+63	319	382	
									+	0.3			+	10	
										16.0				392	①
	HOB	CORRECTION						QE	BAL CORRECTION						
+	180	DESIRED HOB													
−	(+15)	ACHIEVED HOB (20−5)						+180	DESIRED HOB						
+	165							+18	INITIAL VI						
+	54							(−5)	NET HOB CORR						
−	(+48)	ANGLE OF SITE (165/3500)						+193	HOB ABOVE LEVEL POINT						
+	6	COMP SITE						+10	BAL QE CORR (+193 +380)						
	319	ELEVATION						+0.3	BAL FZ CORR (+193 +380)						
	325	EL PLUS COMP SITE													
	15.7	FZ SETTING FOR													
		EL PLUS COMPSITE													

DATA FOR REPLOT

GRID	ALT	FZ	TGT

AMMUNITION

TYPE									
LOT									
ON HAND									
RECEIVED									
TOTAL									
EXPENDED									
REMAINING									

DA FORM 3622, 1 Jan 74 REPLACES DA FORM 3622, 1 AUG 70, WHICH IS OBSOLETE.

Figure 24–12. Observer adjustment techniques.

Comp site for HOB correction (+54 − (+48)) .... +6 mils
Elevation + comp site (319 + 6) .... 325 mils
Fuze setting for elevation plus comp site, (325) 15.7
Ballistic fuze correction (+193 HOB and 380 QE) .... +0.3
Fuze setting to fire (+15.7 + (+0.3)) .. 16.0

(3) *Determination of deflection.*
Deflection (chart deflection to FFE location) 3,297 mils

(4) *Fire-for-effect data.*
Deflection .... 3,297 mils
Fuze setting 16.0
QE .... 392 mils

Section XIV. 155-MM HOWITZER—NUCLEAR DELIVERY

24–57. General

a. Procedure. This section describes the fire direction techniques for delivery of the 155-mm howitzer nuclear round. Nuclear delivery techniques for the 155-mm howitzer parallel standard gunnery procedures whenever possible; however, the lack of a ballistically matched spotting round requires modifications to normal procedures. Test firings have indicated that corrections derived from a high-burst registration with projectile HE M107 introduce errors when these corrections are applied to data for the nuclear round. The magnitude of these errors is comparable to that of errors introduced when the position VE and position fuze correction for the nuclear rounds are assumed to be zero. When the met correction technique is used, all nonmeasurable conditions (position VE and position fuze correction) are assumed to be standard and corrections are computed only for those conditions which are reported in a met message and by the firing battery. In those cases in which survey or met data are not available, an adjustment may be conducted on the target with HE projectiles armed with mechanical time fuzes. When the adjustment phase is completed, the ballistic corrections are added to the HE data and the nuclear round is fired in effect. If current met data are not available but a valid HE GFT setting exists, the K-transfer procedure can be used when weapon and target locations are known and the target is within transfer limits. The HE data to the target are computed, ballistic corrections are added, and the nuclear round is fired in effect.

b. Nomenclature. The 155-mm nuclear round consists of the XM454 projectile, the XM32E1 sequential timer, the T361 VT fuze, and the XM72 propellant.

c. Preferred Technique. The preferred technique for the delivery of nuclear rounds from a 155-mm howitzer is the met correction technique, in which position VE and position fuze corrections are assumed to be zero.

d. Alternate Techniques. If the information for the employment of the preferred technique is not available, the following techniques may be used:

(1) Adjustment with HE rounds and fire for effect with nuclear rounds.

(2) K-transfer (HE GFT setting).

24–58. Requirements for Delivery Techniques

The requirements for the use of the various delivery techniques for 155-mm nuclear rounds are as follows:

a. Met Correction Techniques. The following data must be available:

(1) Accurate survey data for the gun and target.

(2) Current met data.

b. Observer Adjustment. The observer must be in a position from which he can observe and adjust the rounds.

c. K-Transfer (HE GFT Setting).

(1) A valid GFT setting and a valid deflection correction must be available.

(2) The target location must be accurate.

(3) The target must be within transfer limits.

24–59. Accuracy

All data are determined to the same accuracy as that for standard gunnery procedures.

24–60. Selection of Delivery Technique

a. Considerations in Selection of Delivery Technique. Listed below are some of the considerations in the selection of a delivery technique. The S3 must evaluate all considerations in making his decision.

(1) The tactical situation.

(2) The commander's guidance.

(3) The desirability of surprise.

(4) The availability of met.

(5) The time available.

(6) Restrictions on registration.

(7) Survey.

(8) The validity of the GFT setting and deflection correction.

b. Registrations. It is anticipated that the unit will have adequate met support and will obtain a valid HE GFT setting and a total deflection correction by registering or by computation.

c. Accuracy of Techniques. The accuracy of each technique depends on the situation and the available data. There are so many variables that one technique cannot be considered the most accurate technique under all conditions. General guides are as follows:

(1) The met correction technique will probably be the most accurate method under most conditions. Even though a current met message and an HE deflection correction are available, the assumption that the VE and fuze correction are zero introduces some errors into the met correction technique. These errors are approximately the same as those that would occur if corrections obtained from registering with HE projectile, M3 or M3A1 propellant (charges 4 and 5), and fuze time were applied to nuclear data (charges 1 and 2). These errors are less than those that would occur if corrections obtained from registering with HE projectile and M4A1 or M4A2 propellant (charge 7) were applied to nuclear data (charge 3). The accuracy of this technique depends on the amount (unknown) by which the VE varies from standard, on the validity of the met message, and on the accuracy of the target location.

(2) The observer adjustment technique is required when a current met message is not available or when the battery or target is not accurately located. The disadvantages are the time and HE ammunition consumed, the loss of surprise, the inaccuracy of applying HE data to the nuclear round, and the inaccuracy of fire (normally, a 100-meter bracket is split).

(3) The accuracy of the K-transfer technique when current registration data are used depends on the validity of applying HE data to the nuclear round. If the target is accurately located and is in proximity to the registration point, the accuracy should approximate that of the observer adjustment technique. In the fringe areas of the transfer limits or outside the transfer limits, the accuracy can be expected to decrease. The principal advantages are the capability of delivering nuclear fires without adjustment and elimination of the requirement for a current met message and computation of corrections for the target.

d. Time Requirements. The time required to prepare fire commands for firing a nuclear round depends on the situation and the data available. If a current GFT setting is available, the K-transfer technique will be the fastest. The next most rapid solution is the met correction technique. The K-transfer technique will be the slowest if a registration must be fired, because of the time required to register. The time required for the observer adjustment technique depends on the speed of adjustment.

e. Ballistic Corrections. The 155-mm howitzer firing tables used for nuclear delivery are constructed for projectile, atomic, XM454. When HE projectile M107 is used in the observer adjustment technique or when an HE GFT setting is used for determining corrections, correction for deflection, fuze setting, and quadrant elevation to compensate for ballistic differences between the HE projectile and the nuclear projectile must be determined from table 0 of the firing tables. Table 0 is entered with the final QE for projectile HE.

24-61. Example—Met Correction Technique

The met data correction sheet and the FDC computer's record for the following sample mission are shown in figure 24-13 and figure 24-14, respectively.

a. Weapon-Ammunition Data.

155-mm howitzer M109

Altitude of battery	273 meters
Latitude of battery	34° N
Laying information:	
Azimuth	5,700 mils
Deflection	3,200 mils
Propellant temperature	54° F
Projectile weight	118.5 pounds
Charge	3 GB (M3 propellant)
Timer temperature	54° F

b. Chart Data.

Deflection to registration point	3,180 mils
Deflection to target	3,014 mils
Azimuth to target	5,886 mils
Range to target	11,440 meters
Altitude of target	342 meters
Height of burst above target	+25 meters

c. Data from Registration.

Adjusted deflection	3,176 mils
Met deflection correction	R6 mils

Total deflection correction -- R4 mils
Position deflection correction L2 mils

d. Recent Ballistic Meteorological Message.

METB31	344983	260750	021982
001409	984017	011312	984025
021115	968031	031217	959026
041422	942017	051527	920009

e. Qudrant Elevation. Add the entry range to the total range correction (fig 24-13) to determine the corrected entry range. Determine the elevation plus comp site for the corrected entry range and the angle of site to obtain the quadrant elevation.

Corrected entry range (11,458 + (+187)) ------ 11,640 meters
Elevation plus comp site for corrected entry range --- 405.8 mils
Angle of site ------------- +8.4 mils
Quadrant elevation -------- 414.2, or 414 mils

f. Deflection. Add the new met deflection correction and the position deflection correction at the registration point to the chart deflection.

Corrected deflection ------- 3,017 mils

g. Timer Setting.

Timer setting for 11,640 meters ---------------- 35.1
Intermediate timer setting (35.1 + (−0.2)) ------- 34.9
Correction for timer temperature ---------------- 0
Timer setting ------------ 34.9

h. Fire-For-Effect Data.

Deflection --------------- 3,017 mils
Timer setting ------------ 34.9
QE ---------------------- 414 mils

24-62. Example—Observer Adjustment Technique

The FDC computer's record for the following sample mission is shown in figure 24-15.

a. Weapon-Ammunition Data.

155-mm howitzer M109
Laying information:
Azimuth ------------- 800 mils
Deflection ------------ 3,200 mils
M107 charge --------- 7
XM454 charge -------- 3
Timer temperature -------- 85° F

b. Chart Data.

Deflection to target -------- 3,327 mils
Range to target ----------- 8,780 meters
Site to target ------------- +7 mils
100/R ------------------ 12 mils
Desired height of burst (XM454) ------------- +30 meters

c. Adjustment with Projectile M107, Fuze Time, for 20-Meter Height of Burst.

1	−400
2	+200
3	−100
4	Time R10 + 50
5	U10, FFE

d. Data Obtained from Round 5.

Projectile --------------- M107
Fuze ------------------ M564
Deflection -------------- 3,324 mils
Time ------------------ 23.1
QE -------------------- 259 mils

e. Site Correction for 30-Meter Height of Burst for Projectile XM454.

+10 (12/100) = +1 mil

f. Corrected QE for Projectile M107.

258 + (+1) = 259 mils

g. Corrections from Table 0, FT 155AJ-2.

Deflection --------------- L1 mils
Timer setting ------------ −0.4
QE -------------------- −5 mils

h. Corrections from Table K, FT 155-AJ-2.

Correction to timer for timer temperature ------------ 0

i. Fire-for-Effect Data for Projectile XM454.

Deflection --------------- 3,325 mils
Timer setting ------------ 22.7
QE -------------------- 254 mils

24-63. Example—K-Transfer Technique

The FDC computer's record for the following sample mission is shown in figure 24-16.

a. Weapon-Ammunition Data.

155-mm howitzer M109
Laying information:
Azimuth ------------- 6,200 mils
Deflection ------------ 3,200 mils
XM454 charge -------- 3
Timer temperature -------- 60° F

b. Chart Data.

Deflection to target -------- 3,142 mils
Range to target ----------- 9,910 meters
Vertical interval ----------- +47 meters
Desired height of burst ---- 30 meters

c. GFT Setting and Total Deflection Correction.

GFT B: Chg 7, lot XY, rg 10,420, el 354, ti 30.8
Total deflection correction to target ---------------- L4 mils

d. Data for Projectile M107.

Site ------------------- +9 mils
Deflection -------------- 3146 mils

MET DATA CORRECTION SHEET
For use of this form, see FM 6-40; proponent agency is TRADOC.

BATTERY DATA / **MET MESSAGE**

CHARGE	ADJ QE	CHART RG	LATITUDE	TYPE MESSAGE		OCTANT	AREA/UNIT
3		11,440	30°N	METB 3		1	344983

ALT OF BTRY (10 m)	270	DATE 26	TIME 0730	ALT MDP 210	PRESSURE 98.2
ALT OF MDP	210	LINE NO. 04	WIND DIR 1400	WIND SPEED 22 / AIR TEMP 94.2	AIR DENSITY 101.7
BTRY (ABOVE/BELOW) MDP (ΔH)	+60	Δ h CORRECTION		(-) 0.1	(-) 0.6
ALT OF TARGET (nearest meter)	342	CORRECTED VALUES		94.1	101.1
HEIGHT OF BURST ABOVE TARGET	+25				
ALT OF BURST	367				
ALT OF BTRY (nearest meter)	273				
HEIGHT OF TARGET (burst) ABOVE GUN (M)	+94	COMP RG +18	CHART RG 11,440	ENTRY RG 11,458	11,500

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400	POS DF CORR L2
DIRECTION OF WIND	1400	MET DF CORR L1
	7800	TOTAL DF CORR L3
DIRECTION OF FIRE (5886)	5900	ROTATION CORR (L) R 0.9
CHART DIRECTION OF WIND	1900	DRIFT CORR L 11.7
CROSS WIND — WIND SPEED 22 × COMP (C) 0.96 = (L) 21	KNOTS × 0.54 UNIT CORR =	CROSS WIND L CORR (R) 11.3
RANGE WIND — WIND SPEED 22 × COMP H (T) 0.29 = (TAIL)/HEAD 6 KNOTS		MET DEFL CORR (L) R 1.3 — L1

MET RANGE CORRECTION

		KNOWN VALUES	STANDARD VALUES	VARIATIONS FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	(T) H	6	0	(T) H 6	-11.0		66.0
AIR TEMP		94.1	100%	(-) 5.9	+7.8	46.0	
AIR DENSITY		101.1	100%	(+) 1.1	+41.7	45.9	
PROJ WEIGHT		118.5	120.4	(-) 1.9	+10.0	19.0	
ROTATION		+22 ×	0.87			19.1	
						130.0	66.0
						66.0	
					MET RANGE CORR	64.0	+64

COMPUTATION OF VE

	VE	m/s	D = +24.6	TOTAL RANGE CORRECTION
PROP TEMP 54° F	CHANGE TO MV FOR PROP TEMP	-5.0 m/s	I = -24.0	MET RANGE CORRECTION +65
	ΔV	-5.0 m/s	MV UNIT CORRECTION +24.6	ΔV RANGE CORRECTION +123
				TOTAL RANGE CORRECTION +188

OLD VE ____ + NEW VE ____ = ____ ÷ 2 = AVG VE ____ m/s

TI 35 — **MET FUZE CORRECTION**

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS	
ΔV	(-) 50	-0.046		0.230	
RANGE WIND	(T) H 6	+0.006	0.036		
AIR TEMP	(-) 5.9	+0.005	0.030		
AIR DENSITY	(+) 1.1	-0.051		0.056	
PROJ WEIGHT	(-) 1.9	+0.002	0.004		TOTAL FUZE CORRECTION
			0.070	0.286	MET FUZE CORRECTION -0.2
				0.070	FUZE CORRECTION
		MET FUZE CORR		0.216	TOTAL FUZE CORRECTION

OLD FZ CORR ____ + NEW FZ CORR ____ = ____ ÷ 2 = AVG FZ CORR ____

TARGET NO.	BATTERY	DATE/TIME

DA FORM 4200, 1 JAN 74 — REPLACES DA FORM 6-15, 1 APR 67, WHICH IS OBSOLETE.

Figure 24-13. Met data correction sheet.

FDC COMPUTER'S RECORD

For use of this form, see FM 6-40; the proponent agency is TRADOC.

BATTERY	DATE	TIME RECEIVED	TIME COMPLETED	TGT
B	22 APR	0600	0630	N- - - -

CALL FOR FIRE MADDOG 18, FM GRID 6329 4198, ALT 342, HOB +25, INF BN ASSY AREA, NUC, TI, FFE

FIRE ORDER:
UNIT(S) B MF #6
BASIS FOR CORR USE GFT
DISTR ______ SH NUC
LOT QZ CHG 3 FZ ______
1 RDS; SPREAD ______
TIME AMC TGT N- - - -

TOT DF CORR L3
DF 3014
RG 11, 440 EL 405.8

TGT 342 SI + 8.4
HOB +25 414.2
367
BTRY 273
VI +94

100/R	20/R	∡ SI	△ FS	10m/SI

INITIAL FIRE COMMANDS

#6 ADJUST	SP INSTR
SH NUC	LOT QZ
CHG 3	FZ TI
MF #6 ① AMC IN EFF	
DF 3017	TI 34.9
QE 414	AMMO EXP ①

OBSERVER CORRECTIONS / **SUBSEQUENT FIRE COMMANDS**

MF SH FZ	DEV	RG	HOB	SH,CHG FZ,MF	CHART RG	CHART DF	CORR	DF FIRED	FS CORR	TI	HOB CORR	SI	EL	QE	AMMO EXP
	QE	BAL	CORR				TIMER SETTING								
ENTRY RG				11,458		TS FOR RG 11,640							35.1		
TOT RG CORR			+	187		MET FZ CORR						+	(-0.2)		
CORR ENTRY RG				11,645		INTERMEDIATE TS							34.9		
				11,640		CORR FOR TIMER TEMP							0		
EL FOR 11,640 =				405.8		TIMER SETTING							34.9		

DATA FOR REPLOT

GRID	ALT	FZ	TGT

AMMUNITION

TYPE										
LOT										
ON HAND										
RECEIVED										
TOTAL										
EXPENDED										
REMAINING										

DA FORM 3622, 1 Jan 74 REPLACES DA FORM 3622, 1 AUG 70, WHICH IS OBSOLETE.

Figure 24–14. 155-mm NUC met plus VE mission.

FDC COMPUTER'S RECORD

For use of this form, see FM 6-40; the proponent agency is TRADOC.

BATTERY B	DATE 12DEC	TIME RECEIVED 0530	TIME COMPLETED 0600	TGT N- - - -

CALL FOR FIRE 24 FM, BN, GRID 61994873, DIR 780, INF BN ASSY AREA, ICM IN EFF, AF

FIRE ORDER:
UNIT(S) B #1 MF #1 SH NUC
BASIS FOR CORR IN EFF, LOT QZ
DISTR USE GFT SH HE
LOT XY CHG 7 FZ
1 RDS; SPREAD
TIME TGT N- - - -

TOT DF CORR	0
DF	3327
RG	8780
EL	260
SI	+7
	267

100/R	20/R	∡ SI	△ FS	10m/SI
12	2		0.09	

INITIAL FIRE COMMANDS

#1 ADJUST	SP INSTR
SH HE	LOT XY
CHG 7	FZ Q
MF #1 (1) #1(1) NUC IN EFF	
DF 3327	TI
QE 267	AMMO EXP (1)

OBSERVER CORRECTIONS / **SUBSEQUENT FIRE COMMANDS**

MF SH FZ	DEV	RG	HOB	SH,CHG FZ,MF	CHART RG	CHART DF	CORR (0)	DF FIRED	FS CORR	TI	HOB CORR	SI (+7)	EL	QE	AMMO EXP
		-400			8400	3323	0	3323				+7	242	249	(2)
		+200			8590	3326	0	3326				+7	251	258	(3)
		-100			8510	3325	0	3325				+7	247	254	(4) Q
TI	R10	+50		FZ TI	8560	3324	0	3324		23.2	+2	+9	249	258	(1) TI
			U10 FFE					(3324)	-0.1	(23.1)	+1	+10		(259)	
				SH NUC			L1	3325	-0.4	22.7				254	
	DF	CORR				TS	CORR					QE	CORR		
HE	DF		3324		M564 FS			23.1			HE	QE		259	
NUC	CORR		L1		NUC BAL CORR		+	-0.4			NUC	BAL	CORR	-5	
NUC	DF		3326		TS			22.7			NUC	QE		254	
					TEMP CORR			0							
					TS			22.7							

DATA FOR REPLOT

GRID	ALT	FZ	TGT

AMMUNITION

TYPE										
LOT										
ON HAND										
RECEIVED										
TOTAL										
EXPENDED										
REMAINING										

DA FORM 3622, 1 Jan 74 REPLACES DA FORM 3622, 1 AUG 70, WHICH IS OBSOLETE.

Figure 24–15. 155-mm nuclear mission (observer adjustment).

Time 28.7
QE .... 335 mils

e. Corrections from Table O, FT 155-AJ-2.

Deflection .... L1 mils
Timer setting .... −0.6
QE .... −10 mils

f. Corrections from Table K, FT 155-AJ-2.

Correction to timer for timer temperature 0

g. Corrections from Table L, FT 155-AJ-2.

Backoff time for VT fuze 1.8

h. Fire-for-Effect Data for Projectile XM454.

Deflection .... 3,147 mils
Timer setting 26.3
QE .... 325 mils

24-64. VT Fuze

Firing the XM454 projectile with the variable time option provides a higher probability of achieving the desired height of burst than firing the projectile with the sequential timer option. When the variable time option is used, the T361-E2 VT fuze is armed by the XM32E1 sequential timer at a predetermined time. Establish this predetermined time by subtracting a back-off time from the fuze setting computed for the XM32E1 sequential timer. The back-off time varies with the fuze temperature. Table L of the XM454 firing tables lists the value to be subtracted from the computed time in determining the time to be set on the XM32E1 sequential timer.

FDC COMPUTER'S RECORD

For use of this form, see FM 6-40; the proponent agency is TRADOC.

BATTERY	DATE	TIME RECEIVED	TIME COMPLETED	TGT
B	6 DEC	0700	0730	N----

CALL FOR FIRE 18, FM, GRID 5872 3913, ALT 421, HOB +30, DIV CP, NUC, VT, FFE

TOT DF CORR L4 + L1 = L5

DF 3142

RG 9910 EL 326

SI +9
333
NUC CORR -10
NUC QE 325

100/R	20/R	∡ SI	△ FS	10 m/SI

FIRE ORDER:
UNIT(S) B MF #1
BASIS FOR CORR USE GFT
DISTR ____ SH ____
LOT ZN CHG 3 FZ ____
____ RDS; SPREAD ____
TIME AMC TGT N----

INITIAL FIRE COMMANDS

#1 ADJUST	SP INSTR
SH NUC	LOT ZN
CHG 3	FZ VT
MF #1 ① AMC	IN EFF
DF 3147	TI 26.3
QE 325	AMMO EXP ①

OBSERVER CORRECTIONS				SUBSEQUENT FIRE COMMANDS											
MF SH FZ	DEV	RG	HOB	SH,CHG FZ,MF	CHART RG	CHART DF	CORR	DF FIRED	FS CORR	TI	HOB CORR	SI	EL	QE	AMMO EXP
	DF	CORR							TS	CORR					
CHT	DF			3142				TI	HE					28.7	
TOT	DF	CORR		L4				NUC	TI	CORR				-0.6	
	HE	DF		3146				INTERMEDIATE TI						28.1	
	NUC	DF CORR		L1				CORR FOR TIMER TEMP						0	
	NUC	DF		3147										28.1	
								BACKOFF TIME						-1.8	
								VT	TS					26.3	
						QE	CORR								
					HE	QE		335							
					NUC	CORR		-10							
					NUC	QE		325							

DATA FOR REPLOT

GRID	ALT	FZ	TGT

AMMUNITION

TYPE									
LOT									
ON HAND									
RECEIVED									
TOTAL									
EXPENDED									
REMAINING									

DA FORM 3622, 1 Jan 74 REPLACES DA FORM 3622, 1 AUG 70, WHICH IS OBSOLETE.

Figure 24–16. 155 NUC K-transfer mission.

Section XV. FIRING WITHOUT A FIRING CHART

24-65. Introduction

a. A field artillery battery must be able to deliver timely fire even though a fire direction center is not available to produce firing data. There are numerous solutions for converting the observer's call for fire to fire commands without a complete set of fire direction equipment and a firing chart. The solution presented in this section is simple and rapid.

b. Actions that must be taken in preparation for firing without a firing chart fall into three phases—

(1) Determination of data with which to fire the initial round(s).

(2) Conversion of the subsequent corrections announced by the observer with respect to the observer-target (OT) line to corrections (in meters) with respect to the gun-target (GT) line.

(3) Determination of firing data.

24-66. Occupation of Position

The firing battery occupies position and is laid by use of the procedures described in paragraphs 4-1 through 4-8. The executive officer estimates the azimuth on which to lay the battery from his knowledge of the situation or determines the azimuth from a map (if available).

24-67. Determination of Firing Data for Initial Round(s)

Firing data for initial round(s) are determined as follows:

a. The observer sends the call for fire, following the procedures described in chapter 9. The target may be located by any of the methods described in chapter 8.

b. On receipt of the call for fire, the executive officer determines the direction and range to the target.

(1) The executive officer may estimate the direction (azimuth) and range on the basis of his knowledge of this situation.

(2) The executive officer may measure direction (azimuth) and range from a map, if available.

c. The executive officer determines deflection by comparing the azimuth to the target with the azimuth on which the battery was initially laid and applying the difference to the referred deflection.

d. Site can be ignored unless the map (if available) indicates an appreciable difference in altitude between the battery position and the target.

e. Elevation can be determined from either the tabular firing tables or the graphical firing table.

f. Initial fire commands are given in the prescribed manner (para 4-28 through 4-49).

24-68. Determination of Angle T

a. The chart operator prepares the M17 plotting board for use by initially placing the 0-0-32 graduation on the disk opposite the center of the vernier scale. A mark is then placed on the rotating disk opposite the number representing the observer-target azimuth (labeling it 0) and another mark is placed on the disk opposite the number representing the gun-target azimuth (labeling it G) (fig 24-17).

b. When the 0 is opposite the red arrow at the top of the board, the board is oriented in the OT position (fig 24-18). When the G is opposite the red arrow, the board is in the GT position (fig 24-17).

c. The angle T determined initially is retained throughout the mission unless the weapons shift more than 200 mils from the deflection fired on the initial round.

24-69. Conversion of Observer's Subsequent Corrections To Corrections With Respect to the Gun-Target Line

a. During the adjustment, the observer follows normal observer procedures.

b. The chart operator converts the observer's shifts to corrections with respect to the GT line, by use of the M17 plotting board.

(1) The center of the plotting board always represents the location of the last burst.

(2) The chart operator places the rotating disk in the OT position and plots the observer's shift on the disk. Any convenient scale may be used. Most shifts can be plotted when a value of 10 or 20 meters is assigned to each small square of the grid.

(3) The chart operator now rotates the disk to the GT position. As the disk is rotated, the plot of the observer's shift with respect to the OT line is unchanged. The chart operator then measures the shift with respect to the GT line (center line of board) from the center of the board. This shift is in meters.

Example: OT azimuth is 6400; GT azimuth is 0500. The observer's shift is RIGHT 120, DROP 400. With the disk in the OT position and each small square representing 20 meters, plot the shift 6 small squares to the right and 20

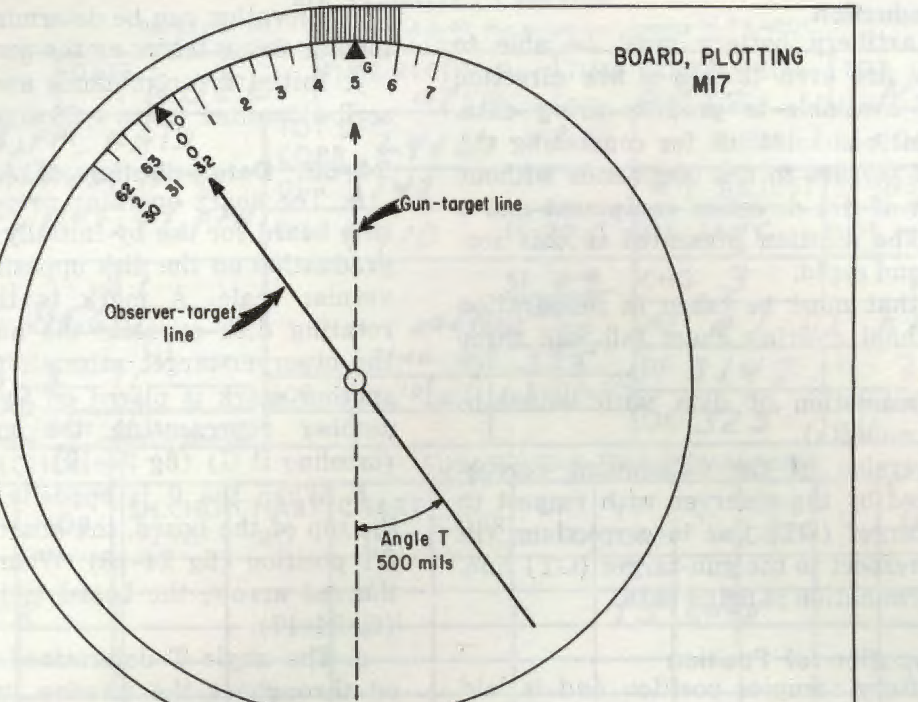


Figure 24-17. GT position.

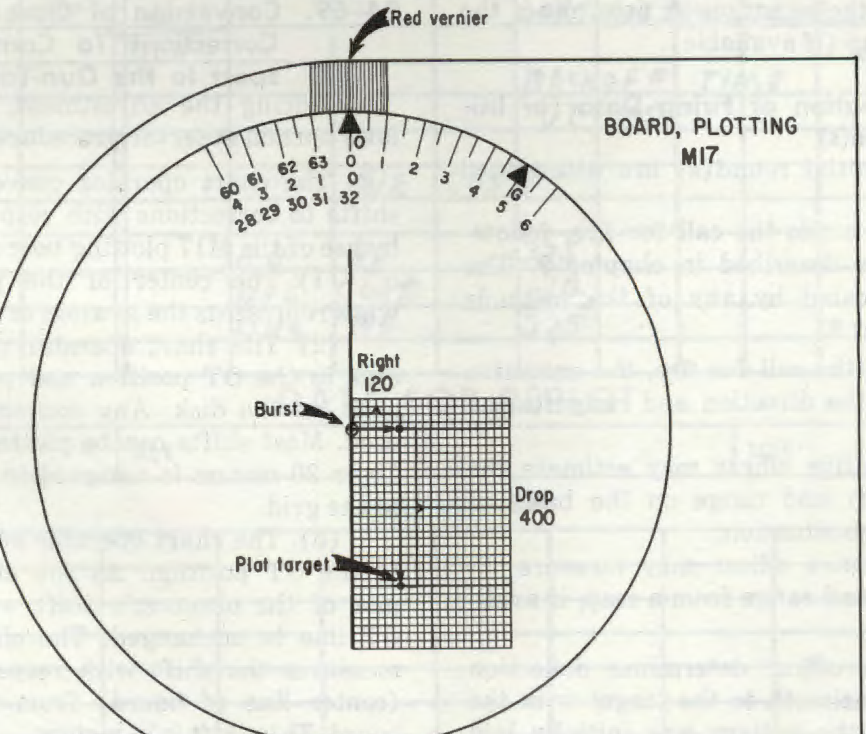


Figure 24-18. OT position.

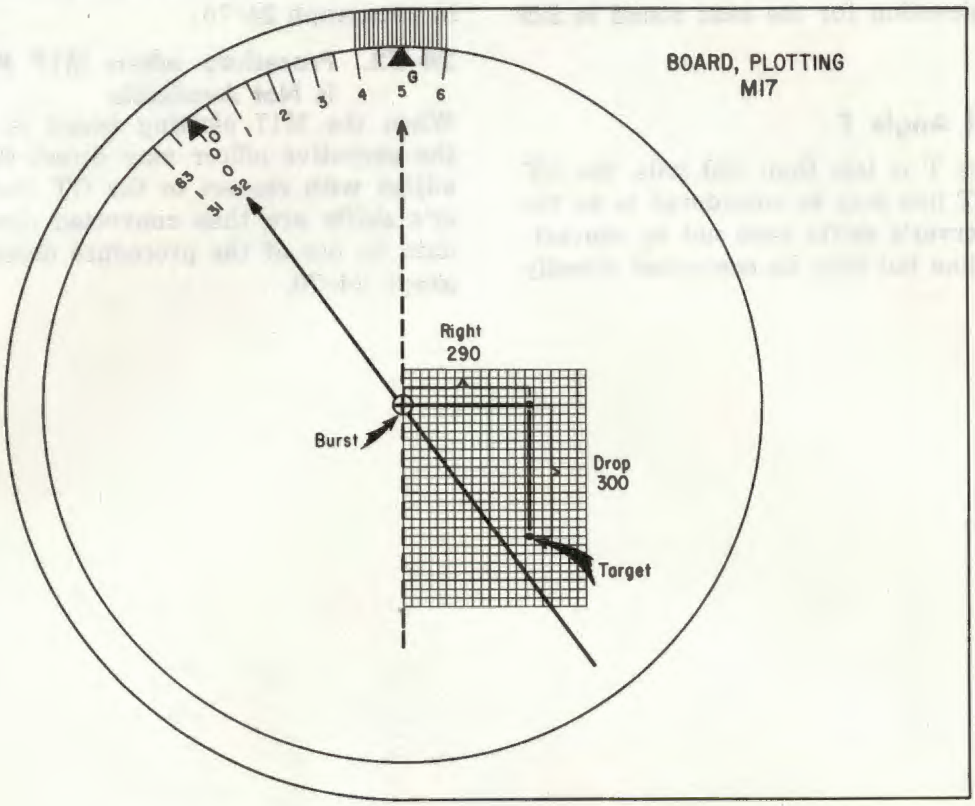


Figure 24-19. Determining corrections with respect to gun-target line.

small squares toward the bottom of the board from the center (fig 24-18). Rotate the disk to the GT position and measure the shift with respect to the GT line as RIGHT 290, DROP 300 (fig 24-19).

24-70. Determination of Firing Data for Subsequent Rounds

a. Deflection. In determining the deflection for subsequent rounds, it is necessary to convert the deviation corrections (in meters) with respect to the GT line to mils and apply the correction in mils to the previously red deflection. To convert deviation in meters to deviations in mils, multiply the 100/R value for the range to the target by the meter deviation divided by 100. Compute the 100/R value (100 divided by the range in thousands of meters) or set the hairline of the GFT over the range and read 100/R under the hairline.

Example: Continuing the example in paragraph 24-69, determine the 100/R to be 20 mils. Convert the deviation correction in meters, RIGHT 290, to a deviation correction in mils, RIGHT 58 (290/100 = 2.9 × 20). The deflection announced to the weapons is DEFLECTION 3142 (3200 + R 58, or 3200 −58).

b. Elevation. Elevation is determined by one of the following methods:

(1) *Graphical firing table.* When a graphical firing table is used for determining elevation, move the hairline of the cursor from the last range fired an amount equal to the range correction along the GT line and read a new elevation under the hairline (under the elevation gageline if a GFT setting has been constructed).

(2) *Tabular firing tables.* When the tabular firing tables are used for determining elevation, determine the C (change in elevation for a 100-meter change in range) at the initial range and use this value throughout the mission. The C used is the tabular value rounded to the nearest even mil. When the range correction along the GT line has been determined, compute an elevation change by multiplying the C by the range change divided by 100. Apply the elevation change to the last elevation fired in order to determine the elevation for the next round.

Example: Weapon, 155-mm howitzer M109, charge 5 green bag, initial range 5200, initial elevation 247. C is determined to be 6 mils. The range change with respect to the GT line is determined to be DROP 300. The elevation change is computed to be −18 mils (300/100 = 3 × 6). The elevation for the next round is 229 (247 −18).

24-71. Small Angle T

When the angle T is less than 100 mils, the OT line and the GT line may be considered to be the same. The observer's shifts need not be converted to the GT line but may be converted directly to firing data by use of the procedure described in paragraph 24-70.

24-72. Procedure when M17 Plotting Board is Not Available

When the M17 plotting board is not available, the executive officer may direct the observer to adjust with respect to the GT line. The observer's shifts are then converted directly to firing data by use of the procedure described in paragraph 24-70.

CHAPTER 25

FDC PROCEDURES FOR HIGH-ANGLE FIRE

25-1. General

a. High-angle fire is fire delivered at elevations greater than the elevation corresponding to the maximum range for a charge. Consequently, within the high-angle elevations for charge, range decreases with an increase of elevation and increases with a decrease of elevation. High-angle fire is used in firing into or out of deep defilade. It may be requested by the observer or ordered by the S3.

b. Most howitzers are capable of attacking targets effectively with high-angle fire. High-velocity weapons (guns) normally are not used for high-angle fire because their high velocities result in extremely high maximum ordinates, long times of flight, and large probable errors. Even with howitzers, high-angle fire results in high maximum ordinate• and correspondingly long times of flight.

c. To assist the observer in identifying his rounds, FDC personnel will announce SPLASH 5 seconds prior to impact. They may give the time of flight when they announce SHOT. They must always announce time of flight to an air observer. To provide security for the battery location, the FDC may code the time of flight.

d. The principal difference between low-angle fire and high-angle fire is that in high-angle fire an *increase* in elevation will cause a *decrease* in range.

25-2. High-Angle GFT

In high-angle fire, as in low angle fire, the basic sources of ballistic data are the current tabular firing tables for each cannon. To simplify the determination of firing data FDC personnel may use the high-angle GFT. The high-angle GFT consists of one rule, with ballistic data for charges 1 through 5 on one side and data for charges 5 through 7 on the other side. Data for charge 5 is included on both sides to facilitate changing charges during a mission. The scales on the high-angle GFT, from top to bottom, are as follows:

a. 100/R. The high-angle 100/R scale is identical to the low-angle 100/R scale.

b. Range. The range scale, on which range is expressed logarithmically in meters, is applicable to all charges appearing on one side of the base. Range is read to the nearest 10 meters.

c. Elevaiton. Elevation is expressed in mils and increases from right to left. Elevation is read to the nearest mil.

d. 10-mil site. The values on the 10-mil site scale denotes the site for each 10-mil angle of site for the elevation and charge selected. Numbers are printed in red. The sign of the site is opposite that of the angle of site.

e. Drift. The values on the drift scale are expressed in mils and denote projectile drift. Drift is always to the right.

f. Time of flight. The time of flight scale is graduated in seconds and indicates projectile time of flight.

g. Care must be taken in reading the high-angle GFT so as not to read the scales incorrectly. On the high-angle GFT, the elevation, drift, and time of flight scales increase in the direction opposite to the range scale.

25-3. Fire Order

When high-angle fire is to be used, the S3 will omit the charge from the fire order. The charge is determined by the adjusting battery computer (para 25-5). If the decision to fire highangel is made by the S3, based on his estimate of the situation, the words "high angle" will be substituted in the fire order for charge; however, if high-angle fire is included in the observer's call for fire, it need not be repeated in the fire order.

25-4. Fire Commands

a. 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 in a precision mission and the commands for the adjusting battery in an area mission are the same as those for low-angle fire.

b. The charge (which may change during the adjustment), the fuze setting (for VT fuze), and the quadrant elevation (which cannot be used until the piece is to be loaded) are omitted in the initial fire commands to the nonadjusting batteries. For example—

Adjusting Battery	*Nonadjusting Battery*
BATTERY ADJUST	BATTERY ADJUST.
SHELL HE	SHELL HE.
LOT XRAY YANKEE	LOT XRAY YANKEE.
HIGH ANGLE, CHARGE 4	HIGH ANGLE (charge is omitted).
FUZE QUICK	FUZE QUICK.
CENTER 1 ROUND, BATTERY 4 ROUNDS IN EFFECT	BATTERY 4 ROUNDS.
DEFLECTION 2992	DEFLECTION 2847.
	WAIT, OUT (further commands are not given until fire for effect).
QUADRANT 1173.	

c. The charge, the fuze setting (if any), and the quadrant elevation for the nonadjusting batteries are determined and announced when fire for effect is ordered.

25-5. Selection of Charge

In selecting the charge to be used, the adjusting battery computer, supervised by the S3, selects the charge that is least likely to require changing because of subsequent corrections from the observer. There is some degree of overlap in ranges covered by various charges. If there appears to be a choice between two charges, the computer selects the lower charge in order to reduce time of flight and tube wear. It may be necessary to change charges during an adjustment if the observer's initial target location was inaccurate.

25-6. Fuze

The most effective fragmentation of any burst occurs in a plane at approximately right angles to the line of fall. This fragmentation is almost parallel to the ground in high-angle fire. Consequently, if time fuze is fired, a very slight error in height of burst may result in a burst sufficiently high to cause significant loss of fragmentation effect. Because of the large height-of-burst probable error, time fuze normally is not employed in 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 fragmentation, the effect is a spray in all directions out from the point of impact approximately parallel to, and very near, the ground.

b. The maximum lethality against personnel in the open is attained with high-explosive projectile and fuze VT. This combination has the advantages of a lateral spray effect obtained with fuze quick and the effectiveness of a very low airburst.

c. Because the side spray is horizontal, high-angle fire normally is less effective than low-angle fire against personnel in trenches or foxholes, regardless of the fuze used.

25-7. Deflection

a. Drift is a function of time of flight. (For convenience in low-angle fire, drift is considered a function of elevation.) Thus, drift is appreciably greater in high-angle fire than in low-angle fire because of the increased time of flight.

b. In high-angle fire, drift changes too rapidly to permit the use of a deflection correction scale such as that used in a low-angle fire. Because drift changes a great amount for a relatively small range change, 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 is to the right, the correction is always to the left. The correction is always applied to the sum of the chart deflection and the deflection correction (if any).

Example: 155-mm howitzer, charge 5, high angle.

Range	*Elevation*	*Chart deflection*	*Deflection correction*	*Drift correction*	*Piece deflection*
8500	1062	3200	0	L45	3245

25-8. Site

Although site has a relatively small effect because of the large angle of fall in high-angle fire, site always is included in a registration, in a transfer mission, and in a mass mission. In other high-angle missions, site is ignored if the angle of site is no larger than plus or minus 30 mils. Since in high-angle fire range decreases as elevation increases and range increases as elevation decreases, a minus site must be used to compensate for a plus vertical interval and a plus site must be used to compensate for a minus vertical interval.

a. Standard FDC procedures concerning site in high-angle fire are as follows:

(1) The VCO computes and announces the angle of site for each high-angle mission. Since there is no GST for high-angle fire, the VCO computes the angle of site by use of the C and D scales of any graphical site table.

(2) Considering the size of the angle of site and the type of mission to be fired, the computer decides whether site will be included.

(3) Regardless of whether site is included, the computer does not include the height-of-burst correction (20/R) when VT fuze is to be fired because the decending branch of the trajectory in high-angle fire is almost vertical.

b. When the tabular firing tables are used in computing site, the computer extracts from the supplementary data table for the charge the complementary angle of site factor corresponding to the initial elevation to be fired. The sign of the complementary angle of site factor for a plus angle of site is minus; for a minus angle of site, it is plus. Because the complementary angle of site factor in high-angle fire always is greater than 1 mil, the complementary angle of site always will be greater than the angle of site. To determine the site, the computer algebraically adds the complementary angle of site to the angle of site, which produces a site with sign opposite that of the angle of site.

c. Use of a special site scale on the high-angle graphical firing table simplifies the determination of site for high-angle fire. The site scale is located just below the elevation scale. This scale is referred to as the 10-mil site scale. The reading obtained from this scale gives the site for a 10-mils angle of site at the elevation and charge that is being used. To determine the site for any point, divide the angle of site to that point by 10 and multiply the quotient by the factor read from the 10-mil site scale. The value obtained will be slightly less accurate than the value computed from the tabular tables. The 10-mil site factor, considered negative, when multiplied by the angle of the site and divided by 10, will produce the proper sign and amount of the site. The sign of the site will be opposite that of the angle of site.

Example: 155-mm howitzer M109, charge 5 (GFT).

Chart range .... 8,500 meters
Elevation corresponding to chart range ...... 1,062 mils
Altitude of battery .... 400 meters
Altitude of target ..... 509 meters
Vertical interval ...... +109 meters
Angle of site (C and D scales, GST) .... +13 mils
10-mil site factor (GFT) .... −4.1
Site (13/10 × (−4.1) . −5 mils
Quadrant elevation (1062 + (−5)) ...... 1,057 mils

d. If a change in charge is required during the conduct of the mission, site should be recomputed for the new charge.

25–9. Precision Registration

High-angle precision registration procedures differ from low-angle precision registration procedures in several respects.

a. Since range increases (decreases) as elevation decreases (increases) in high-angle fire, the fork and elevation change are applied accordingly.

b. High-angle fire introduces large amounts of drift into the trajectory. Additionally, the value of drift changes with each small change in range. This increased rate of change in drift introduces a unique situation whereby deflections fired at various elevations contain different amounts of drift. In order to minimize the error caused by this condition the FDC must give special consideration to the computation of the correct deflection.

(1) During the adjustment phase, no use is made of line shots.

(2) No attempt is made to change the value of deflection until after the full even fork bracket has been established. At this time, the normal procedure would apply. Definite deflection spottings determined at either end or both ends of the fork bracket may be utilized.

c. Site must be algebraically subtracted from the adjusted quadrant elevation to determine the adjusted elevation. The correct site can be derived only by successive approximation, since comp site is a function of elevation and not of chart range. Correct site is determined when the site computed agrees with or is within 1 mil of the previously computed site. The last site computed is the correct site.

Example: 155-mm howitzer M109, charge 3 (fig 25–1) (DA Form 4198 (Record of Precision Fire)).

Angle of site .... +26 mils
Adjusted QE .... 1074 mils
Site fired during registration .... −9 mils
10-mil site factor corresponding to elevation 1083 .... −4.0 mils
First apparent site (26/10 × (−4.0)) = −10.4 .... −10 mils

(First apparent site is within 1 mil of site fired.)
Adjusted elevation ----- 1,084 mils

d. GFT settings for high-angle fire are established in the same manner as those for low-angle fire. For the example in c above, the GFT setting is GFT B: Charge 3, lot ZT, range 5420, elevation 1084.

e. Standard transfer limits are not applicable to high-angle fire because of the short range span of each charge. Corrections are considered valid for the charge used in determining the corrections and are considered valid for other charges as shown in table 25-1.

Table 25-1. Transfer Limits, High Angle

Weapon	Charge registered with	Transfer limits
105-mm how	1, 2, 3, 4, 5	All ranges, charges 1 through 5.
	6	Charge 6 only, ± 1,500 meters.*
	7	Charge 7 only, ± 1,500 meters.*
155-mm how and 8-inch how.	1, 2, 3, 4	All ranges, charges 1 through 5.
	5	Charge 5 only, ± 1,500 meters.*
	6	Charge 6 only, ± 1,500 meters.*
	7	Charge 7 only, ± 1,500 meters.*

*±2,000 meters for registration point ranges greater than 10,000 meters.

f. The adjusted deflection is equal to the correct deflection plus the correction for lateral base piece displacement. The total deflection correction is determined by subtracting the chart deflection from the adjusted deflection. Because drift is so large and changes so rapidly, construction of a deflection correction scale is not considered practical for high-angle fire. Instead, the correction for drift corresponding to the adjusted elevation is algebraically subtracted from the total deflection correction. The result is called the GFT deflection correction and is considered to be a constant for all factors except drift.

Example: 155-mm howitzer M109, charge 3, high angle.

Adjusted elevation ---- 1,084 mils
Correct deflection ------ 3,188 mils
Correction for BP displacement ----------- R6 mils
Adjusted deflection ---- 3,182 mils
Chart deflection -------- 3,142 mils
Total deflection correction ------------ L40 mils
Drift correction corresponding to adjusted elevation ----------- L48 mils
GFT Deflection correction ------------ R8 mils

g. If no high-angle registration has been conducted, a GFT deflection correction of zero will be used. If a charge other than that with which the registration was conducted is to be fired, the GFT deflection correction for the charge nearest the charge to be fired is used.

25-10. Preparation of Graphical Equipment

a. Construct the GFT setting by placing the hairline over the adjusted elevation for the charge and drawing a range gageline through the GFT setting range. This will facilitate using the GFT setting for other charges when only one high-angle registration has been conducted.

b. The GFT deflection correction for each charge is placed on the GFT adjacent to the data for that charge. It is used in a fire mission by algebraically adding it to the value of drift for each round to be fired to determine the total deflection correction.

25-11. Data for Replot

a. The purpose of replot in high-angle fire is the same as that in low-angle fire (para 20-15).

b. Regardless of whether site is included during the adjustment, the correct site must be algebraically subtracted from the adjusted (fire-for-effect) quadrant elevation to obtain the adjusted (fire-for-effect) 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. Therefore, the effective site at the end of the adjustment will be different from that used in the initial firing data. This error must be corrected if the target is to be plotted at its correct range.

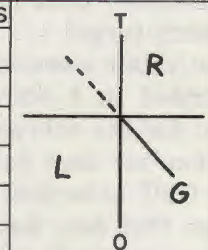
Example: 155-mm howitzer M109, GFT setting (from prior registration is GFT B: Charge 5, lot WY, range 7050, elevation 1145.

Angle of site -------- +20 mils
Adjusted QE --------- 1,162 mils
10-mil site factor corresponding to elevation 1162 ------------- −2.0 mils
First apparent site (+2.0) × (−2.0) = −4.0 -------------- −4 mils

RECORD OF PRECISION FIRE
For use of this form, see FM 6-40; proponent agency is TRADOC.

BATTERY	DATE/TIME	OBSERVER	(REG PT) TGT
B	14 OCT 1530	44	1
GFT SETTING GFT: B CHG 3 LOT ZT RG 5420 EL 1084 TI			TOTAL DF CORR R8

CHART DATA				INITIAL FIRE COMMANDS			
DF 3142	TOT DF CORR L51	BP DISP R6		BP	ADJUST		
RG 5430	EL 1105	ACH RG		SH	HE	LOT	ZT HA
ADJUSTED DATA	SI -9	KN FZ CORR		CHG	3	FZ	Q
DF 3182	½S= 2	∡SI	+26	MF	BP (1)		
EL 1084	F= 16	10 mil SI FAC	-3.4	DF	3193		
TIME	½F= 8	ANGLE T	120	QE	1096		



RD NO	LOT, FZ, MF	CHART RG	CHART DF	CORR (0)	DF FIRED	TIME FIRED	EL (-9)	QE	OBSR SPOTTING OR CORRECTION	FDC SPOTTING RG	FDC SPOTTING DF
(1)		5430	3142	L51	3193		1105	1096	L30 + 400		
(2)		5800	3144	L44	3188		1054	1045	-100		
(3)		5710	3146	L46	3192		1067	1058	R10 + 50 FFE		
(4)		5760	3144	L45	3189		1060	1051	+R	+	R
(5)					(3189)			1067	+L	+	?
(6)					(3189)			1083	-R	−	?
(7)					(3189)			1075	-L	−	L
(8)					3187			1075	-R	−	?
(9)					(3187)			1075	+R	+	R
(10)					(3188)			1067	+L	+	CORR
(11)								1067	+LN	+	?
12								EM			
13	MEAN QE				1071.0						
14	ΔEL = +2/(2×6) × 16				+2.7				CORR DF		3188
15	ADJ QE				1073.7 =		1074		CORR FOR BP DISP		R6
16	SITE FIRED						-(-9)		ADJ DF		3182
17	1ST APP EL						1083		CHART DF		3142
18	10 mil SI FAC FOR 1083 = -40								TOT DF CORR		L40
19	1ST APP SI (26/10 × -40)						-10		DRFT CORR		L48
20	AGREES WITHIN 1 mil OF SITE FIRED								GFT DF CORR		R8
21	ADJ EL (1074-(-10))						1084				
22											
23											
24											

DA FORM 4198, 1 Jan 74 — REPLACES DA FORM 6-12, 1 OCT 64, WHICH IS OBSOLETE.

Figure 25–1. Record of precision registration, high-angle fire

First apparent adjusted elevation (1162 − (−4)) .... 1,166 mils

10-mil site factor corresponding to elevation 1166 .... −1.9 mils

Second apparent site (+2.0) × (−1.9) = −3.8 .... −4 mils

Second apparent site agrees with first apparent site

Adjusted elevation (1162 − (−4)) ..... 1,166 mils
Range corresponding to elevation 1166 (use GFT setting) used in replotting target .... 6,780 meters

c. After the adjusted elevation has been determined as described in *b* above, the GFT deflection correction for the charge (or, if no GFT deflection correction has been determined for the charge fired, the GFT deflection correction from the nearest charge that does have a GFT deflection correction) and the drift correction are subtracted from the fire-for-effect piece deflection. If no GFT deflection correction has been determined, only the drift correction is subtracted from the fire-for-effect piece deflection. The result is the deflection for replotting the target.

Example: 155-mm howitzer M109, charge 5.

FFE piece deflection ...	3,245 mils
Adjusted elevation	1,166 mils
Drift correction corresponding to adjusted elevation	L62 mils
GFT deflection correction for charge 5 ..	L15 mils
Total deflection correction (L62 + L15)	L77 mils
Replot deflection (3245 − L77)	3,168 mils

d. If the terrain is rugged or if a large range change has been made since the angle of site was first computed (the angle of site may be first computed at the beginning of the mission or at the onset of determining replot data), the angle of site is recomputed for the replotted location of the target. The new map altitude is used in determining the new angle of site. If the new angle of site differs by more than 1 mil from the angle of site previously computed, a new adjusted elevation and a corrected range for replotting the target must be obtained. This process is repeated until the correct angle of site (one that agrees with or is within 1 mil of that previously computed) and adjusted elevation have been determined. The procedure for reporting data is the same as that used for low-angle fire except that the type of fire and charge used are included: for example, GRID ________, ALTITUDE ________, FUZE ________, HIGH ANGLE, CHARGE ________, TARGET ________.

25-12. Massing and Transfers

a. Because of the high maximum ordinates and long times of flight encountered in high-angle fire, massing or transfer of fire is less reliable in high-angle fire than in low-angle fire. However, under stable weather conditions, successful transfers of fire within a single charge 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 that is to fire on the target.

b. If several batteries are to mass on a target when only one battery is to adjust, site should be computed at the initial range for each battery. Site should be recomputed for the nonadjusting batteries whenever it is necessary to recompute site for the adjusting battery (e.g., when the adjusting battery changes charges) or should be recomputed for an individual nonadjusting battery when it changes charges.

c. During an adjustment, the 10-mil site factor may change considerably. As a result, the site at the end of the adjustment will differ from that used in the initial commands. However, the error in range due to false site will be essentially the same for all batteries.

25-13. Duties of Fire Direction Personnel

The duties of fire direction personnel in high-angle fire are the same as those in low-angle fire except for minor modifications as shown below:

a. If the observer does not request high-angle fire but the S3 decides that high-angle fire will be used, the command HIGH ANGLE will be given in lieu of the charge in the fire order.

Example: BATTALION, BRAVO, USE GFT, LOT ZULU TANGO, HIGH ANGLE FUZE VT IN EFFECT, 2 ROUNDS, TARGET ALFA FOXTROT 7604.

b. When adjustment is required before massing the battalion, the battery that is centrally located should normally be designated as the adjusting battery to eliminate large differences in range.

c. For all mass missions, batteries should fire center range, since large range dispersion can be expected.

d. The VCO determines and announces angle of site for all missions.

e. The computer—

(1) Selects the charge to be fired.

(2) Combines the drift correction, the GFT deflection correction, and the chart deflection to determine the deflection to fire.

(3) Determines site when the angle of site is larger than a plus or minus 30 mils or when a registration, transfer mission, or mass fire mission is to be fired.

CHAPTER 26

OBSERVED FIRING CHARTS

Section I. INTRODUCTION

26-1. General

Immediate delivery of supporting fires must not be delayed because of incomplete survey or the lack of suitable maps. When survey control and maps are not available, an observed firing chart is constructed. An observed firing chart is a chart on which the relative locations of the battery position(s) and targets are established by the adjustment of fires. An observed firing chart normally is constructed on a grid sheet.

26-2. Initial Observed Firing Charts

a. If the battery initial chart is an observed firing chart, the battery center is assigned assumed grid coordinates and an assumed altitude; e.g., grid 20004000, altitude 400 meters. The grid sheet is appropriately numbered based on the assumed battery location and a deflection index is constructed based on the azimuth of lay. The relative location of the battery and target can now be established by the adjustment of fire.

b. The observer's call for fire must include MARK CENTER OF SECTOR as the target location if no other method of locating the target is feasible. The fire direction officer determines the direction of fire and a safe range based on his knowledge of the situation. The chart operators determine the data for the initial round from the estimated direction and range to the center of the observer's sector. To assist the observer in locating the first round, the battery may fire white phosphorous, colored smoke, or a high airburst (HE or WP). Subsequent firing data are based on the observer's corrections. Fire direction procedures in the conduct of fire are generally the same as those used with a surveyed firing chart. After the mission has been completed, the observer may use the target as a known point in reporting other target locations.

c. As long as the ballistic variable of weather, materiel, and ammunition remain constant, any previously fired target may be refired with the same data. If the ballistic conditions do not remain constant inaccuracies will occur in subsequent firing. The battery should conduct a registration as soon as possible in order to provide a means of determining subsequent ballistic changes and to increase the accuracy of relative locations.

d. The FDC should plot on the firing chart targets fired in order to provide additional means of target location. The last pinhole will provide sufficient accuracy and should be noted with tick marks and a target number.

e. In situations in which survey control does not exist and maps are either inaccurate or nonexistent, the countermortar or counterbattery radar can be used to place the artillery battalion on a common grid and provide common direction for the massing of fires. Detailed information regarding radar charts is given in paragraphs 26-31 and 26-32 and FM 6-161.

Section II. BATTERY OBSERVED FIRING CHARTS

26-3. General

The procedure for constructing an observed firing chart consists of the following steps:

a. Have the observer select a registration point in the center of the zone of fire.

b. Assign this point assumed grid coordinates and an assumed altitude and plot it on the firing chart. Since this point is completely arbitrary, a grid intersection is preferred. (Example: Grid 2000040000, altitude 400 meters, long axis of the grid sheet north-south, southwest corner 1833.)

c. Conduct a precision registration (fuze time, if possible) on the registration point.

d. Determine the adjusted data.

e. From the adjusted data, determine the direction (azimuth) and distance (range) from the registration point to the battery.

f. Polar plot the battery center from the registration point.

26-4. Construction of the Observed Firing Chart

a. The battery is plotted on the back-azimuth of the azimuth of fire. If an impact registration is fired and site cannot be approximated, the battery is plotted at a range corresponding to the adjusted quadrant elevation. If a time registration is fired, the range corresponding to the adjusted time is used. The derived site is used for determining the relative altitude of the battery. The deflection index is constructed at the adjusted deflection and a deflection correction scale is prepared so that large deflection corrections are not required.

b. One of the sources of inaccuracy in an observed firing chart is the inclusion of false site which results in a corresponding error in the polar plot range. Errors due to false site can be reduced by use of time fuze and by selection of the charge that minimizes the height-of-burst probable error.

c. The battery observed firing chart may be consolidated into a battalion chart if all batteries register on the same registration point (para 26-12 through 26-15) or if the batteries have been tied together by survey with respect to one another (para 26-26).

26-5. Determination of Direction for Polar Plotting

a. At the completion of the registration, the battery executive officer measures the azimuth or the orienting angle (if an orienting line has been established).

b. When an orienting line has not been established, the executive officer measures the azimuth of fire after registration. The battery center is polar plotted on the back-azimuth of the measured azimuth.

c. When an orienting line has been established, the battery executive officer will measure the orienting angle after the registration. The azimuth of fire is then computed (azimuth of orienting line minus the orienting angle equals the azimuth of fire). The battery center is then polar plotted from the registration point on the back-azimuth of the azimuth of fire.

26-6. Determination of Range and Altitude, Percussion Plot

a. When maps and survey data are not available the determination of accurate site is impossible. However, every effort must be made to determine the approximate site. If the determination of even an approximate site is not feasible, the site is assumed to be zero.
The range for polar plotting is the range corresponding to the adjusted elevation (adjusted QE minus the site); the hairline of the GFT is placed over the adjusted elevation and the range is read under the hairline.

b. The vertical interval between the battery and the registration point should be estimated if possible. The estimated vertical interval is used in determining site (by successive approximation) and the battery altitude in the following manner:

(1) Determine the range corresponding to the adjusted quadrant.

(2) Use this range and the estimated vertical interval to compute a first apparent site.

(3) Apply the site to the adjusted QE to determine an elevation.

(4) Determine the range corresponding to this elevation.

(5) Use this range and the estimated vertical interval to compute a second apparent site.

(6) Continue successive approximation until the site agrees with or is within 1 mil of the previously computed site. Use last site computed to determine the adjusted elevation and use the adjusted elevation to determine the back plot range.

(7) Apply the vertical interval to the assumed altitude of the registration point to determine the altitude of the battery.

26-7. Determination of Range and Altitude, Time Plot, Site Unknown

a. The major sources of error in range in an observed firing chart, percussion plot, are the lack of an accurate site and the effects of unknown variations from standard conditions. If the site is unknown or incorrect, the derived adjusted elevation is in error by the amount of the error in site. Determining the polar plot range from a false elevation introduces a false range. However, the effect of site on the fuze setting is usually small. Therefore, the adjusted time can be used as a good indicator of the adjusted elevation and the polar plot range.

b. Derive a site by subtracting the elevation corresponding to the adjusted time (minus the average fuze correction, if any) from the adjusted quadrant elevation. Using the GST, determine the vertical interval by multiplying the polar plot range by the derived site. Determine the altitude of the battery by applying the vertical interval to the assumed altitude of the registration point.

Example: Time plot, site unknown. A 155-mm howitzer M109 battery using charge 5 has registered on a registration point.

Adjusted QE	315
Adjusted time	20.4
Average fuze correction	None

Range corresponding to time 20.4 (polar plot range).	6,140
Elevation corresponding to time 20.4	305
Derived site (315 − 305)	+10
Vertical interval (+10 × 6140) (GST)	+55
Altitude of registration point (assumed)	400
Altitude of battery (400 − 55)	345

c. When an average fuze correction is known, the accuracy of site and elevation is increased by determining the adjusted elevation in the following manner:

(1) Subtract the average fuze correction from the adjusted time.

(2) Read the adjusted elevation corresponding to the adjusted time.

26–8. Determination of Range and Altitude, Time Plot, Site Known

If an approximate site is known, data are determined as follows:

a. Determine the polar plot range in the same manner as described in paragraph 26–7.

b. Use the known site to determine the altitude of the battery.

c. Derive the elevation by subtracting the known site from the adjusted quadrant of elevation.

26–9. Determination of Site by Firing (Executive's High Burst)

An approximate site of an accuracy approaching survey accuracy may be determined from a modified high-burst registration fired after a precision registration.

a. Fuze setting (time), for a given charge, is a function of elevation plus complementary angle of site. Therefore, if the fuze setting is kept constant but the quadrant elevation is varied, the *elevation plus comp site* to each of the resulting points of burst is constant.

b. If, after a registration, a group of rounds is fired with the adjusted time but with a quadrant elevation large enough to raise the point of burst so that the burst is visible from the gun position, the angle of site to the burst can be measured. The measured angle of site is subtracted from the fired quadrant elevation. The result is the elevation plus comp site to the burst (QE = elevation + angle of site + comp site). The elevation plus comp site thus determined corresponds to the fuze setting fired (adjusted time) and is equal to the elevation plus the comp site to the registration point. Subtracting the elevation plus comp site from the adjusted quadrant elevation for the registration point gives the angle of site to the registration point. The angle of site thus determined and the range corresponding to the adjusted time can be used in computing the vertical interval and the site to the registration point.

c. The procedure for conducting an executive's high burst is as follows:

(1) After the time registration, the battery executive officer is sent the following command: OBSERVE HIGH BURST REGISTRATION, MEASURE ANGLE OF SITE, 3 ROUNDS, ADJUSTED DEFLECTION (so much), ADJUSTED TIME (so much), ADJUSTED QUADRANT ELEVATION (so much). The executive officer estimates the increase in site necessary to cause the bursts to be visible from the battery position and adds it to the announced quadrant elevation. He then has the base piece fire three rounds at the adjusted deflection, the adjusted time, and the increased quadrant elevation. The executive officer measures the angle of site to each burst with an aiming circle or a BC scope (battery commander's telescope) set up in the vicinity of the base piece. He then reports the average observed angle of site and the quadrant elevation fired.

(2) The FDC determines the site to the registration point, the adjusted elevation, and the vertical interval between the battery and the registration point in the following manner:

(*a*) Determine the elevation plus comp site for the executive's high burst by subtracting the average angle of site reported by the battery executive officer from the quadrant elevation fired. The elevation plus comp site thus determined is also the elevation plus comp site to the registration point.

(*b*) Determine the angle of site to the registration point by subtracting the elevation plus comp site from the adjusted quadrant elevation to the registration point.

(*c*) Using the C and D scales of the GST, determine the vertical interval between the battery and the registration point by multiplying the angle of site ((*b*) above) by the range to the registration point in thousands to the nearest 10 meters.

(*d*) Using the appropriate site range scale of the GST, determine the site to the registration point by dividing the vertical interval by the range to the registration point. Do not move the cursor of the GST from the position it was in when the VI was determined in (*c*) above.

(*e*) Derive the adjusted elevation by subtracting the site ((*d*) above) from the adjusted quadrant elevation.

Example: A 155-mm howitzer M109 registered on a point with charge 5. The adjusted data for the registration point included adjusted time (fz M564) 19.7 and adjusted quadrant elevation 302 mils. The report from the executive officer following the high burst was OBSERVED ANGLE OF SITE PLUS 14, QUADRANT FIRED 325. The registration point site, adjusted elevation, and vertical interval are determined as follows:

Range corresponding to adjusted time (19.7)	5960
QE fired for high burst	325
Average angle of site to high burst	+14
Elevation plus comp site to high burst	311
Adjusted QE to registration point	302
Elevation plus comp site to registration point	311
Angle of site to registration point (302–311)	−9
Vertical interval (−9 × 5.96, C and D scales, GST)	−53
Site (−52.6/5960, GST)	−10
Adjusted elevation (302 − (−10))	312

Note. If graphical equipment is not available, site may be determined in the following manner:

Comp site factor for range 5960 (6000)	−0.070
Comp site (9 × (−0.070))	−0.6
Site (−9) + (−0.6) = (−9.6)	−10

d. After understanding the theory on which the determination of site by firing is based, it may be easier to use the "got minus asked for" rule (fig 26–1) in computing the angle of site. For the example in *c* above, if the angle of site to the registration point had been zero, the increase in quadrant elevation to 325 (increase of +23 mils "asked for") would have caused the burst to occur at a measured angle of site +23 mils. Since the bursts actually occurred at a measured angle of site +14 mils ("got"), the angle of site to the registration point must be −9 mils. The formula (fig 26–1) used is angle of site to registration point = got minus asked for = +14 −(+23) = −9. Convert this angle of site to site in the manner described in *c* above.

26–10. Deflection Index

After the battery has been polar plotted on the chart, the deflection index is constructed at the adjusted deflection.

26–11. GFT Settings

The GFT setting for a battery using an observed firing chart is made in the usual manner. Place the hairline over the chart range (polar plot range) and draw the elevation gageline through the adjusted (derived) elevation and time gageline through the adjusted time. Elevation and time gagelines will be constructed even though they are located on the hairline.

Section III. BATTALION OBSERVED FIRING CHART

26–12. General

a. A battalion observed firing chart is based on the concept that points located with respect to a common point are located with respect to each other. If each firing battery of a battalion has registered on the same registration point and has been located on the firing chart using the procedures outlined in paragraphs 26–4 through 26–11, the batteries are then considered to be plotted in correct relationship to each other. Because the batteries are located correctly with respect to each other, the fires of the battalion may be massed on any target located by the adjustment of one of the batteries.

b. The principles involved in the construction of a battalion observed firing chart are the same as those for the construction of a battery observed firing chart. This section will describe the techniques used in the construction of the battalion chart.

26–13. Determination of Direction for Polar Plotting

The direction used for polar plotting each battery is determined in the manner prescribed in paragraph 26–5.

26–14. Determination of Range and Altitude Percussion Plot

a. Range and altitude for each battery may be determined in the manner described in paragraph 26–6.

b. If the relative altitudes of the batteries of

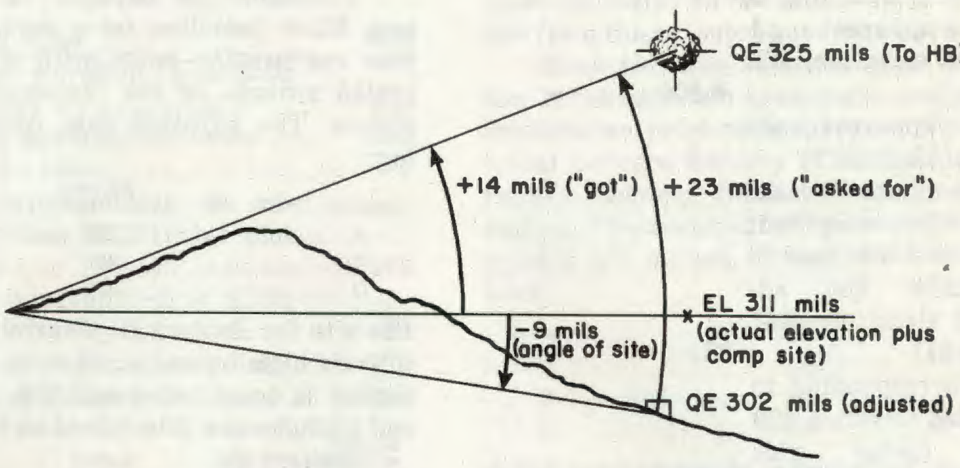


Figure 26-1. "Got minus asked for" diagram.

the battalion can be determined, the accuracy of the firing chart can be improved. One battery is selected as a reference battery and its polar plot range and altitude are determined in the manner described in paragraph 26-6. The altitude and range for each of the other batteries are determined in the following manner:

(1) Compute the vertical interval between the battery in question and the registration point by applying the difference in altitude between the battery in question and the reference battery to the vertical interval from the reference battery to the registration point.

(2) Compute an apparent site for the battery in question by using the vertical interval ((1) above) and the range corresponding to the adjusted quadrant elevation for the battery.

(3) Derive an apparent adjusted elevation by subtracting the apparent site from the adjusted quadrant elevation.

(4) Compute a new site by using the vertical interval and the range corresponding to the apparent adjusted elevation and determine a new adjusted elevation. If the new site varies by more than 1 mil from the apparent site, continue successive approximation until two successive sites agree or are within 1 mil.

(5) When the apparent site is within 1 mil of the last site computed, determine the adjusted elevation. The polar plot range is the range corresponding to this adjusted elevation.

Example: The batteries of a 155-mm howitzer M109 battalion have registered on a common registration point with charge 5 green bag. The assumed altitude of the registration point and Battery B, the reference battery, is 500 meters. The vertical intervals between the other batteries and Battery B are as follows: Battery A, −48 meters; Battery C, +34 meters. The adjusted data included the following:

Battery	*Adjusted QE*
A	337
B	323
C	320

Determine the battery altitudes and polar plot ranges as follows:

Battery B:

Altitude of registration point	500
Altitude of Battery B	500
Vertical interval	0
Site	0
Adjusted elevation (323–0)	323
Range corresponding to adjusted elevation 323 (polar plot range)	6,410

Battery A:

Altitude of Battery B	500
Vertical interval (with respect to Battery B)	−48
Altitude of Battery A	452
Altitude of registration point	500
Vertical interval	+48
Range corresponding to adjusted quadrant elevation 337 mils	6,620
First apparent site (+48/6620, GST)	+8
First apparent adjusted elevation (337 − (+8))	329

Range corresponding to first apparent adjusted elevation, 329 mils 6,500
Second apparent site (+48/6500, GST) ... +8
This site agrees with the last site computed; therefore, it is used to determine the adjusted elevation (337 − (+8)) 329
Range corresponding to adjusted elevation 329 mils (polar plot range) 6,500

Battery C

Altitude of Battery B .. 500
Vertical interval (with respect to Battery B) +34
Altitude of Battery C ... 534
Altitude of registration point 500
Vertical interval ...... −34
Range corresponding to adjusted quadrant elevation, 320 mils 6,370
First apparent site (−34/6370, GST) .. −6
First apparent adjusted elevation (320 − (−6)) 326
Range corresponding to first apparent adjusted elevation, 326 mils 6,460
Second apparent site (−34/6460, GST) .. −6
This site agrees with the last site computed. Therefore, the adjusted elevation is 326 mils. Range corresponding to adjusted elevation 326 mils (polar plot range) .. 6,460

26–15. Determination of Range and Altitude, Time Plot

a. The range and altitude for each battery may be determined as described in paragraph 26–7.

b. If the site for one battery can be determined by an executive's high burst, a common GFT setting can be constructed and used for determining the sites for the other batteries of the same caliber.

Example: The batteries of a 155-mm howitzer M109 battalion have registered on a common registration point with charge 5. The assumed altitude of the registration point is 400 meters. The adjusted data included the following:

Battery	*Adjusted QE*	*Adjusted time*
A	327	21.0
B	330	21.7
C	339	22.2

The site for Battery B, determined from an executive's high burst, is −5 mils. A common GFT setting is constructed and the polar plot ranges and altitudes are determined as follows:

Battery B

Adjusted quadrant elevation 330
Site (executive's high burst) .... −5
Adjusted elevation (330 − (−5)) 335
Range corresponding to adjusted time 21.7 .. 6,460 (polar plot range)
Vertical interval (−5 × 6460, GST) .... −29

Note. Since a common GFT setting is to be used in determining site for the other batteries and since the vertical intervals for these batteries will be based on site, the vertical interval computed for the battery that fires the executive's high burst is also based on site, not angle of site.

Altitude of registration point 400
Altitude of Battery B 429
The common GFT setting constructed from these data is GFT B: Chg 5, lot ____, rg 6460, el 335, ti 21.7.

Battery A: Note: To derive site for the other batteries, move the hairline to the adjusted time for the battery in question, read the elevation under the elevation gageline of the common GFT setting, and substract this elevation from the adjusted QE.

Adjusted time 21.0
Adjusted elevation (elevation gageline) 323
Adjusted quadrant elevation ... 327
Site (327–323) .... +4
Range corresponding to adjusted time 21.0 (polar plot range) 6,290
Vertical interval (+4 × 6.29, GST) .... +22
Altitude of registration point ... 400
Altitude of Battery A 378

Battery C

Adjusted time	22.2
Adjusted elevation (elevation gageline)	344
Adjusted quadrant elevation	339
Site (339−344)	−5
Range corresponding to adjusted time 22.2 (polar plot range)	6,570
Vertical interval (−5 × 6570, GST)	−29
Altitude of registration point	400
Altitude of Battery C	429

Battery	*Range*	*Altitude (meters)*	*Site (mils)*	*Adjusted Elevation (mils)*
A	6290	378	+4	323
B	6460	429	−5	335
C	6570	429	−5	344

c. If the relative altitudes of the batteries are known by survey, one battery may fire an executive's high burst to determine its site and altitude with respect to the registration point. The altitudes of the other batteries with respect to the registration point may then be computed. Compute site by using the vertical interval between the battery and the registration point and the range corresponding to the adjusted time. Derive the adjusted elevation by subtracting the site from the adjusted quadrant elevation.

Example: The batteries of a 155-mm howitzer M109 battalion have registered on a common registration point with charge 5. The vertical interval between Battery A and Battery B is +9 meters; between Battery C and Battery B, −6 meters. The assumed altitude of the registration point is 400 meters. The adjusted data are as follows:

Battery	*Adjusted QE*	*Adjusted time*
A	330	20.8
B	323	20.5
C	320	20.0

After conducting its registration, Battery B fired an executive's high burst and determined the site to the registration point to be +9 mils and the vertical interval to be +50 meters.

Battery	*Range*	*Altitude*	*Site*	*Adjusted elevation*
A	6240	359	+7	323
B	6160	350	+9	314
C	6040	344	+10	310

d. Each battery may fire an executive's high burst to determine the site to the registration point (para 26–9). Range, altitude, and adjusted elevation are determined as described in paragraph 26–8.

Section IV. REPLOTTING TARGETS ON THE OBSERVED FIRING CHART

26–16. General

The considerations for replotting targets on the observed firing chart are the same as those for replotting targets on the surveyed firing chart (para 20–17) except that the target coordinates will not be sent outside the battalion that has established its own arbitrary grid system.

26–17. Replotting Targets with Refinement Data

a. The observer must give refinement data whenever the mean burst location is not on the adjusting point. All refinement data are plotted and converted into firing data regardless of whether the observer requests additional fires, requests recording of the target, or announces END OF MISSION.

b. For the discussion in the following paragraphs, the terms FFE deflection and FFE elevation refer to the final firing data or the firing data determined from refinement data.

26–18. Replot Deflection

The target is plotted on the observed firing chart at the FFE deflection minus the total deflection correction at the FFE elevation (determined by replot).

26–19. Point-Detonation Fuze

Targets fired with point-detonating fuze are replotted on the observed firing chart in the same manner as on the surveyed firing chart, except that, since maps normally are not available, any information indicating the altitude of the target, such as the observer's up or down corrections, is used in determining the vertical interval. The site (the vertical interval will not change) and the adjusted elevation are then determined by successive approximation (para 26–14*b*.)

26–20. Fuze VT

Targets fired with fuze VT are plotted on the observed firing chart in the manner described in paragraph 26–19.

Targets fired with fuze time are replotted on the observed firing chart in the manner described in paragraph 20–20.

Section V. OBSERVED FIRING CHART FOR MORE THAN ONE BATTALION

26-22. General

Massing the fires of more than one battalion by use of an observed firing chart is possible provided common control can be established. Common control can be achieved if aiming circles are uniformly declinated. A common registration point with assumed grid coordinates and an assumed altitude 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 great distance between battalions will introduce errors that increase as the distance between the common registration point and the target increases. The relative altitudes of the common registration point and the battalion position areas must be known if several widespread battalions are to mass their fires effectively. Higher headquarters is responsible for selecting the registration point, assigning the arbitrary grid coordinates and altitude, and coordinating registration. Registration may be coordinated by assigning times for conducting registrations or by requiring a single battalion to register one battery of its own and one battery from each of the other battalions involved.

26-23. Construction of Observed Firing Chart for More Than One Battalion

The plotting method of constructing each battalion observed firing chart is as follows (fig 26-2).

a. Polar plot the registering battery from the common registration point designated by higher headquarters. The back-azimuth of the adjusted azimuth and the distance derived from the adjusted data are used in polar plotting.

b. Polar plot the battalion registration point from the registering battery position. The azimuth and distance (to the battalion registration point) that were determined previously from registration on the battalion registration point are used in polar plotting.

c. Register the other batteries of the battalion and then polar plot the batteries from the battalion registration point in the normal manner.

d. If the battalion registration point and the common registration point are not within transfer limits or if different charges are used, establish separate GFT settings and separate deflection correction scales.

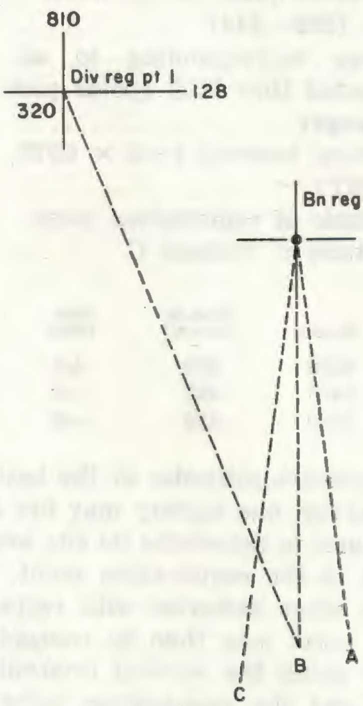


Figure 26-2. Battalion observed firing chart based on registration on a division artillery registration point.

26-24. 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.* The chart is constructed as follows:

a. Plot the battalion registration point, the batteries, and fired targets on the battalion chart. After registration, polar plot the common registration point from the registering battery on the battalion chart. Compute the altitude of the common registration point.

b. Make an overlay of the battalion chart including all points plotted on the battalion chart.

c. Plot the common registration point on the chart for more than one battalion at the grid coordinates specified by the higher headquarters.

d. Draw a ray on the chart for more than one battalion in the direction of the back-azimuth of the adjusted azimuth from the registration on the common registration point.

e. Place the overlay over the chart for more than one battalion and orient the overlay so that the common registration point is over its chart location and the registering battery is over the ray (*d* above).

f. Pinprick the locations of the batteries, battalion registration point, and targets through the overlay onto the chart for more than one battalion.

g. Reconcile all altitudes with the altitude assigned to the common registration point.

h. Construct on the chart for more than one battalion deflection indexes based on the adjusted data for the battalion chart.

Section VI. OBSERVED FIRING CHART WITH INCOMPLETE SURVEY

26–25. General

a. A position area survey may sometimes be used in conjunction with the observed firing chart until the surveyed firing chart is available. That part of the chart established by firing must be plotted to the same scale as that part obtained by survey.

b. The following typical situations might necessitate the use of an observed firing chart based on the registration of one battery and a position area survey:

(1) Lack of time or ammunition precludes registering all three batteries.

(2) The battalion displaces by echelon. Data can be ready for the remaining batteries when they arrive at the new position.

(3) The battalion is to displace after dark. A single howitzer can be brought up and registered during daylight so that data can be ready for the entire battalion when it arrives.

(4) Alternate positions have been occupied and firing must begin without registration from those positions.

(5) Fire from positions to be occupied is not permitted before a certain hour but massing is required immediately after that time. In such a situation a single registration may be performed from an alternate position. Data can then be prepared for the nonregistering battery positions after they have been connected to the registering battery position by means of a position area survey.

26–26. Procedure for Construction of Observed Firing Chart, Position Area Survey Only

The procedure for constructing a battalion observed firing chart based on the registration of one battery and a position area survey is as follows:

a. Establish a common orienting line (OL) for the battalion, if possible; otherwise, establish an orienting line for each battery.

b. Starting from any convenient point, run a traverse to locate all battery positions horizontally and vertically with respect to each other and to establish common directional control for all orienting lines.

c. Plot the battery positions, altitudes, and orienting lines on tracing paper to the same scale as that for the chart to be used. This overlay, including the measured grid azimuth of the orienting lines, constitutes the position area survey as delivered to the fire direction center.

d. Register one battery on the registration point; from the adjusted data, start the observed firing chart by plotting the registering battery.

e. Derive the azimuth of fire from the measured orienting angle of the registering battery and use the derived azimuth of fire for the direction-of-fire line of the battery on the overlay of the position area survey.

f. Orient the overlay so that the battery center on the overlay is over the registering battery center on the firing chart. Rotate the overlay until the direction-of-fire lines on the chart and the overlay coincide. Pinprick the locations of the nonregistering batteries and then label the locations with the proper altitudes in relation to the registering battery.

g. Measure the azimuth from each nonregistering battery to the registration point. The azimuth of each battery orienting line minus the determined direction of fire equals the orienting angle for laying the battery.

Section VII. RADAR FIRING CHARTS

26–27. General

Three techniques can be used in conjunction with radar-observed high-burst registration in constructing a firing chart. The techniques are as follows:

a. Observed firing chart improved by radar (time plot).

b. Radar chart, no maps or survey.

c. Radar chart, relative location of registering piece and radar determined.

26–28. Time Plot Observed Firing Chart Improved by Radar

In most cases the radar is in position and ready to observe by the time the firing batteries have completed registration. The time plot chart improved by radar may be constructed as soon as the registration of all batteries and a radar-observed high-burst registration by one of the batteries have been completed. The radar will supply data for an accurate GFT setting and deflection correction. The time plot observed firing chart improved by radar is the most accurate type of observed firing chart that can be constructed. Construction of a firing chart must not be delayed to await the availability of a radar.

26-29. Advantages of Radar Improved Chart

The radar-improved chart has the following advantages over a time plot observed firing chart:

a. An accurate range and an accurate vertical interval can be obtained from the radar location of the high burst. An accurate site can be determined and then used in deriving an accurate adjusted elevation (the site is subtracted from the QE fired). When the GFT setting derived from the radar-observed high-burst registration is applied to the adjusted data from a registration on the registration point, polar plot range and altitude can be determined accurately.

b. The direction in which the batteries are polar plotted from the registration point is improved by the amount of the deflection correction determined from the radar-observed high-burst registration.

26-30. Procedure for Construction of Radar-Improved Chart

a. All batteries are registered on a common registration point and an adjusted deflection, an adjusted azimuth or orienting angle, an adjusted time, and an adjusted quadrant elevation are determined.

b. The radar is located by survey with respect to one battery, and the locations of the battery and radar are plotted on a firing chart. The battery fires a high-burst registration observed by the radar using the same procedures outline in paragraphs 19-36 through 19-39. The point selected for the high burst should be—

(1) As close as possible to the common registration point.

(2) Low enough that the site is less than 50 mils.

c. The radar section provides the FDC with the average direction, the average distance, and the average vertical angle from the radar to the high burst location.

d. The high burst location is polar plotted from the radar location on the firing chart by the fire direction center.

e. Chart data consisting of range, deflection, and site are then determined from the battery to the high-burst location.

f. The GFT setting is determined. The GFT setting range is the chart range (*e* above). The adjusted elevation is the quadrant elevation fired in the radar-observed high-burst registration minus the site (*e* above). The adjusted time is the fuze setting fired in the radar-observed high-burst registration.

g. The total deflection correction is computed. The total deflection correction is equal to the deflection fired in the radar-observed high-burst registration minus the chart deflection. The total deflection correction is used by all batteries to modify their adjusted azimuths.

h. The common registration point is plotted on another chart at an assumed grid and an assumed altitude. The batteries will be polar plotted from the common registration point.

i. The polar plot direction is determined as follows:

(1) The azimuth of fire for each battery is determined in the manner described in paragraph 26-5.

(2) The azimuth of fire for each battery is then modified by the total deflection correction (*g* above). Since azimuth increases as deflection decreases, the azimuth of fire must be corrected in the opposite direction of the total deflection correction and by the same amount of the total deflection correction.

(3) The polar plot direction for each battery is the back-azimuth of the corrected azimuth of fire ((2) above).

j. The polar plot range is determined by use of the GFT setting from the radar-observed high-burst registration. The time gageline is placed over the adjusted time to the registration point, and the range is read under the hairline.

k. With the time gageline over the adjusted time, the adjusted elevation to the registration point is read under the elevation gageline. The site to the registration point is determined. The site is equal to the adjusted quadrant elevation minus the derived adjusted elevation. The vertical interval and altitude of the battery are computed.

l. The deflection index is constructed at the adjusted deflection.

m. The GFT setting from the radar-observed high-burst registration is used for all firing from the radar-improved charts.

Example: All batteries of a 155-mm howitzer M109 battalion have registered on a common registration point (assumed altitude 400 meters) with charge 5, lot WZ. Adjusted data are shown below:

Battery	Adjusted azimuth	Adjusted deflection	Adjusted QE	Adjusted time
A	6046	3151	280	18.0
B	6134	3166	274	17.6
C	6229	3171	269	17.2

(1) A traverse is run between the radar antenna and the base piece of Battery B. The locations of the radar antenna and Battery B are plotted on a firing chart. The radar is 6 meters above the base piece of Battery B.

(2) Battery B fires a high-burst registration over the registration point with the following data: charge 5, lot WZ, deflection 3166, time 17.6, quadrant 287.

(3) The radar section reports the data to the high burst location as AVERAGE DIRECTION 6074, AVERAGE DISTANCE 4360, AVERAGE VERTICAL ANGLE PLUS 17. The high burst location is polar plotted from the radar. The high burst location is 73 meters above the radar (+17 ×4.36, GST).

(4) Chart data from Battery B to the high-burst location are measured as deflection 3,181 mils, range 5,320 meters.

(5) The GFT setting is determined as follows:

Height of high burst with respect to radar	+73
Height of radar with respect to Battery B	+6
Height of high burst with respect to Battery B	+79
Chart range, Battery B to high burst	5,320
Site, Battery B to high burst (GST: Chg 5; +79/5320)	+16
Adjusted elevation (287−16)	271
GFT B: Charge 5, lot WZ, range 5320, elevation 271, time 17.6.	

(6) The total deflection correction is determined as follows:

Chart deflection, Battery B to high burst	3,181
Adjusted deflection	3,166
Total deflection correction	R15

(7) The polar plot data are computed by use of the GFT setting ((5) above), the total deflection correction ((6) above), and the adjusted data from the common registration point.

	Battery A	Battery B	Battery C
Adjusted azimuth to registration point	6046	6134	6229
Total deflection correction	R15	R15	R15
Corrected azimuth to registration point	6031	6119	6214
Polar plot azimuth	2831	2919	3014
Range (corresponding adjusted time)	5420	5320	5220
Elevation	277	271	264
Adjusted quadrant elevation	280	274	269
Site (adj QE−el)	+3	+3	+5
Vertical interval	+15	+15	+24
Altitude	385	385	376
Deflection index constructed at deflection	3151	3166	3171

26–31. Radar Chart

When radar is not available, 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, the FDC can construct an observed firing chart, called a *radar chart,* that will permit the battalion to mass fire effectively. The radar chart is not as accurate as an observed firing chart improved by radar. The construction of the radar chart is based on the firing of a high-burst registration by each battery.

26–32. Construction of Radar Chart

The procedures for construction of the radar chart are as follows:

a. The radar is oriented by use of the aiming circle and the radar location is plotted on the firing chart at assumed grid coordinates and an assumed altitude.

b. The 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 by the base piece of each battery at a safe range and a safe fuze setting.

d. The average direction, average distance, and average vertical angle, to each of the high-burst registrations are reported to the FDC.

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 use of the radar range and vertical angle.

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 that fired the high burst.

(2) The battery is polar plotted from its

mination of adjusted data and replot data is discussed in paragraph 26–39.)

(1) The target is plotted on the surveyed firing chart at the FFE deflection from the observed firing chart minus the total deflection correction at the FFE elevation. The total deflection correction is obtained from the surveyed chart deflection correction scale.

(2) If a map is not available, any information indicating the altitude of the target, such as the observer's up or down correction, is used for determining the vertical interval. The site and the adjusted elevation are determined by successive approximation (para 26–14*b*).

(3) The surveyed firing chart GFT setting is used in deriving the range from the adjusted elevation.

b. When more than one registration has been conducted, the elevation used in establishing the GFT setting is selected from the registration that most nearly coincides with the time of firing on the targets.

26–38. 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 targets 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 time gageline is placed over the adjusted time. Range is read under the hairline, and the adjusted elevation is read under the elevation gageline.

c. The adjusted elevation is subtracted from the quadrant elevation (minus 20/R at fire-for-effect range) in determining the site. The site and the range (*b* above) are used in determining the vertical interval.

26–39. Transfer to Surveyed Firing Chart, Computer Records Available

When the computer's records are available, the data for replotting targets on the surveyed firing chart are determined as described in *a* through *d* below:

a. Deflection. Determine the deflection at which to replot the target on the surveyed firing chart in the manner described in paragraph 26–37*a*(1).

b. Range. Determine range with the GFT setting for the surveyed firing chart. For a target fired with percussion fuze, place the elevation gageline over the adjusted elevation and read the range under the hairline. For a target fired with time fuze, place the time gageline over the adjusted time and read the range under the hairline.

c. Site and Elevation (Percussion Fuze).

(1) Determine the altitude of the target from a map or from the observer's call for fire. For example, the observer requested FROM REGISTRATION POINT 1, RIGHT 350, ADD 400, UP 20. The target is 20 meters above the registration point.

(2) Determine the site by successive approximation. Site is based on the vertical interval (difference in the altitude of the battery and target) and fire-for-effect range.

(3) Use the final adjusted elevation in determining the final plot range.

d. Site and Elevation (Time Fuze). The adjusted elevation must be determined for each target. Determine the adjusted elevation by placing the surveyed GFT setting time gageline over the adjusted time and reading the elevation under the gageline. Derive the site by subtracting the elevation from the adjusted quadrant elevation (minus 20/R at fire-for-effect range).

Example: Personnel of a 155-mm howitzer battalion have completed a survey and are transferring targets from an observed firing chart (percusssion fuze) to a surveyed firing chart. The surveyed firing chart GFT setting is GFT B: Charge 5, lot XT, range 6070, elevation 310. Target AF7401 is to be replotted on the surveyed firing chart. No map is available.

Date from computer's record				
	Fire-for-effect data			*Observer's vertical correction*
Fuze	*Deflection*	*Range*	*QE*	
Q	3216	6400	354	From Reg Pt 1, UP 70

Total deflection correction from deflection correction scale	L7
Altitude of battery	420
Altitude of registration point (survey)	438
Altitude of target (438 + 70)	508
Vertical interval	+88
Apparent site of target (GST) (88/6400)	+15
Quadrant elevation fired	354
Apparent adjusted elevation (354 − (+15))	339
Apparent range for replot (GFT)	6,490
Site (GST) (88/6490)	+15
Replot range	6,490
Replot deflection (3216 − L7)	3,209

*Agrees with first apparent site.

PART FIVE
MISCELLANEOUS
CHAPTER 27
TARGET ANALYSIS AND ATTACK

27–1. 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 unit and evaluation of the enemy are factors of primary concern. For detailed information concerning field artillery tactics, see FM 6–20. For detailed information concerning nonnuclear lethality and effects, see the FM 6–141-series manuals.

27–2. Description of Target

The method of attacking a target depends largely on the description of the target. The description of the target includes type, size, density, cover, mobility, and importance. To determine the proper type of projectile, fuze, caliber of weapon, and necessary ammunition expenditure, the observer and the S3 must consider carefully the description of the target. The description of the target is also a guiding factor in determining the type of adjustment and the speed of attack.

a. Fortified targets or armor must be destroyed by precision fire, assault fire, or direct fire in which projectiles and fuzes appropriate for penetration are used. The highest practicable charge should be used in assault fire and direct fire to increase penetration and to decrease vertical dispersion. The charge with the smallest probable error (PE), should be used in precision fire to decrease horizontal dispersion. If the target is flammable, projectile WP should be mixed with projectile HE—WP to ignite materiel and HE to cause fragmentation damage.

b. A target consisting of both personnel and materiel normally is attacked by area fire, in which airbursts or impact bursts are used to neutralize the area. The selection of caliber, projectile, and fuze is influenced by the extent of damage desired.

c. Since the precision with which the observer (or other target acquisition agency) can determine the dimensions of the target is limited and since area targets are seldom precisely delineated, standard terms have been adopted for convenience in target reporting.

(1) *Target depth.* All area targets are assumed to be approximately 250 meters in depth; unless otherwise specified by the observer 250 meters is the depth of battery three rounds from a 105-mm howitzer battery and is approximately the depth of battery one round from a 155-mm howitzer battery. A target greater than 300 meters in depth may be attacked as two targets. No special corrections are required for achieving a standard depth.

(2) *Scales.* Three scale designations for targets have been selected.

(*a*) *Scale 0.* Scale 0 designates those targets ranging from a virtual point to approximately 100 meters in width. Scale 0 targets can be assumed to be 75 meters wide. It is assumed that a parallel or an open sheaf of any caliber will more than cover a scale 0 target. A situation in which it can not be predicted that the mean point of impact will fall on the center of the target (e.g., unobserved fires) may dictate the use of a parallel or open sheaf with a scale 0 target. If the mean point of impact is adjusted onto a scale 0 target, ammunition will be wasted during fire for effect if a parallel or open sheaf is used. The observer should normally use a converged sheaf when adjusting onto a scale 0 target.

(*b*) *Scale 1.* Scale 1 designates targets that are wider than scale 0 and up to 300 meters in width; scale 1 targets are assumed to be 250 meters in width. This figure has been chosen because it bears a convenient relationship to the effective front covered by the parallel sheaf of a 105-mm, a 155-mm, or an 8-inch howitzer battery.

(*c*) *Scale 2.* Scale 2 designates targets that are greater than 300 meters and up to 450 meters in width; scale 2 targets are assumed to be 350 meters in width. This figure has been chosen because it represents the effective front covered by the 105-mm, 155-mm, or 8-inch howitzer battalion firing one round, parallel sheaf, at the target center.

(3) *Standard target sizes.* Standard target sizes of any dimensions may be adopted to satis-

fy conditions encountered. The dimensions of a target are needed for computations in determining the type and volume of fire required to achieve the desired results. A few fixed sizes meet the requirement.

27-3. Results Desired

The method of attacking a target is influenced by the results desired. Results are of four types—destruction, neutralization, harassing, and interdiction. The methods of attacking targets to achieve the desired results are as follows:

a. Destruction fire—Fire delivered for the sole purpose of destroying materiel.

b. Neutralization fire—Fire delivered for the purpose of reducing the combat efficiency of the enemy by hampering and interrupting the fire of his weapons, by reducing his freedom of action, by reducing his ability to inflict casualties on our troops, and by severely reducing his movement within an area. Most artillery fire missions seek to neutralize the target. Neutralization is often maintained by the use of fires of less intensity at varying intervals following the initial fires.

c. Harassing fire—Fire delivered for the purpose of disturbing the rest, curtailing the movement, and lowering the morale of enemy troops by the threat of casualties or losses in materiel.

d. Interdiction fire—Fire delivered for the purpose of denying the enemy the unrestricted use of an area or a point. Interdiction fire is usually of less intensity than neutralization fire.

27-4. Registration and Survey Control

a. Effective transfers are accomplished best when data from survey and current registrations are available or when current met messages and muzzle velocity data are available. When survey, registration, and met data are not available or are inadequate, targets should be attacked with observed fires, since unobserved fires may be ineffective in such cases.

b. To the extent posssible, surveillance to determine the results of fire for effect should be obtained on all missions. Accurate fire for effect without adjustment is highly effective against targets composed of personnel or mobile equipment. All destruction missions and missions fired at moving tagrets must be observed and fire for effect adjusted to the target.

27-5. 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.

b. Normally, a battalion should not fire with a range spread greater than 1 C (100 meters), since a greater spread will not give uniform coverage of the target. When choosing the range spread to be used, the S3 should consider the probable error, the lethality of the weapon-ammunition combination, and the effect desired.

27-6. Maximum Rate of Fire

a. The greatest effect is achieved when surprise fire is delivered with maximum intensity. Maximum intensity is best secured by massing the fires of several batteries or battalions using time-on-target (TOT) procedures. The intensity of fires available by firing many rounds from a few units is limited by the maximum rate of fire (*b* below).

b. The maximum rates of fire shown in table 1-1 are guides. These rates cannot be exceeded without danger of damaging the tube. To maintain these rates (either to maintain neutralization on one target or to attack a series of targets), the pieces must 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 higher charges.

27-7. Amount and Type of Ammunition

a. The amount of ammunition available is an important consideration in the attack of targets. The available supply rate will not be exceeded except by authority of higher headquarters. When the available supply rate is low, missions should be limited to those that contribute the most to the mission of supported units. When the available supply rate is high, missions that may affect planned or future operations and some missions that require massing of fires without adjustment may be fired.

b. The selection of a charge with which to attack a target depends on the range, the terrain, and the type of ammunition to be used. The maximum range for the charge selected for an adjustment should be at least 1/3 greater than the range to the target when data are obtained by precise methods to insure that the target can be reached. If possible, a charge giving an elevation to the target of 240 to 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 on the characteristics of the ammunition available for the cannon to be used.

d. The effects of HE ammunition vary with the fuze employed.

(1) Since the effective fragmentation of an HE projectile fired with an impact fuze is greatest if the projectile 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 27-1). When the projectile passes through trees, the detonation may occur in the foliage and effectiveness may be either improved or lost, depending on the density of the foliage and the nature of the target.

(2) The three types of fuzes that are used with HE ammunition to obtain airbursts are proximity (VT) fuze, time fuze, and delay fuze fired to ricochet. These fuzes are discussed below in order of effectiveness.

(*a*) *Fuze VT.* Fuze VT detonates automatically upon approach to a reflective object. Fuze VT is used to obtain airbursts (fig 27-2) without the necessity of adjusting height of burst. If the VT element fails to function, fuze quick action occurs upon impact. The height of burst of fuze VT varies 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, but heavy foliage will increase the height of burst by about the height of the foliage. Since VT fuze is not limited by range and since the height-of-burst probable error for VT fuze is smaller than that for time fuzes, VT fuze is preferred to time fuze for long-range targets and for targets that must be attacked with high-angle fire or that must be attacked at night. The greater the angle of fall, the closer the burst will be to the ground. When the target is close to friendly troops, the lowest practicable charge should be used to obtain a large angle of fall.

(*b*) *Fuze time.* Airbursts may be obtained by the use of fuze time (fig 27-2). The height of burst is determined by the quadrant elevation, charge, and fuze setting. If the time element fails to function with fuze time, fuze quick action occurs upon impact. When fuze time is used, the height of burst can be adjusted, but, because of dispersion, not all bursts will be at the desired height. The highest practicable charge should be used with fuze time to minimize the height-of-burst probable error. A height-of-burst probable error greater than 15 meters is considered excessive.

(*c*) *Fuze delay.* Fuze delay may be used to obtain airbursts by ricochet. If the angle of impact is small and the surface the projectile strikes is firm, the projectile will ricochet before detonating and produce airbursts (fig 27-3). Because of the uncertainty of ricochet actions, fuze delay to obtain ricochets should not be fired without observation. The highest practicable charge should be used to obtain ricochet bursts with fuze delay. If the angle of impact is too great, the projectile will penetrate before detonating and produce mine action (fig 27-4). Fuze delay can be used to destroy earth and log fortifications and is effective against some masonry and concrete targets. Fuze delay should not be used against heavy armor.

(3) Greater penetration against masonry or concrete can be obtained with HE ammunition by use of a concrete-piercing fuze. There are two types of concrete-piercing fuzes: nondelay, used primarily for clearing rubble, and delay, used for greater penetration. The HE projectile with fuze delay 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 27-1.

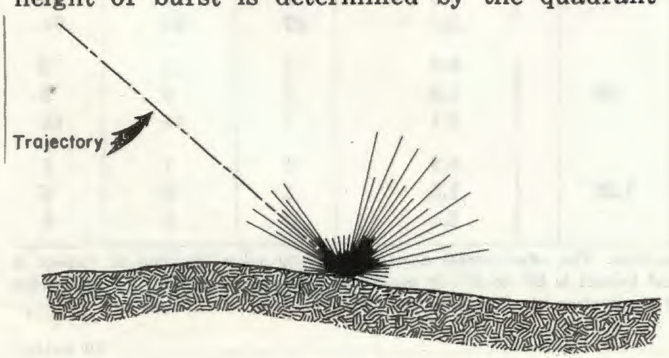


Figure 27-1. Effect of impact burst with fuze quick.

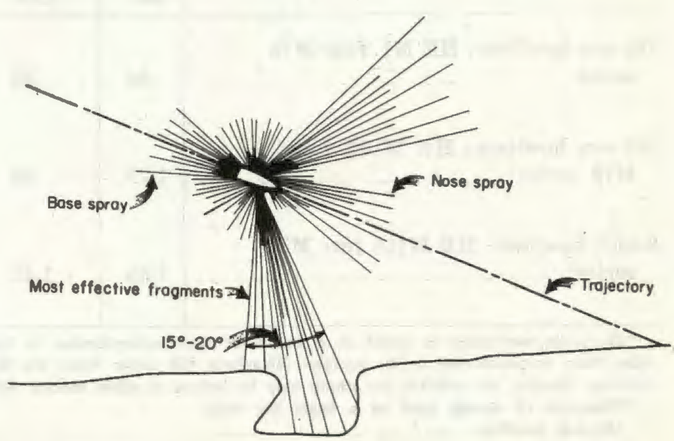


Figure 27-2. Effect of airburst with VT or time fuze.

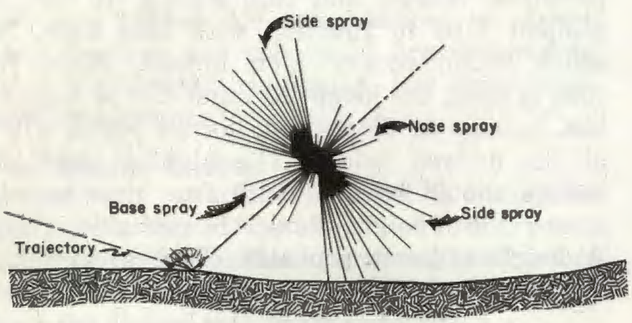


Figure 27-3. Effect of airburst with fuze delay (ricochet).

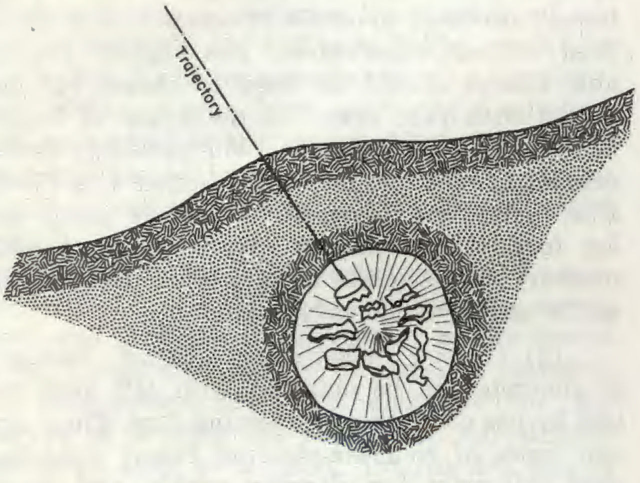


Figure 27-4. Mine action, fuze delay.

e. High-explosive antitank projectiles are designed for attacking armor targets.

(1) The HEP-T M327 projectile is available for the 105-mm howitzer. The physical characteristics and functioning of this projectile are classified and are covered in TM 9-1300-203-2.

(2) The 155-mm howitzer and larger weapons using HE ammunition with fuze quick with direct hits in the direct fire role are effective against armor because of the size and explosive power of the projectiles.

f. Chemical ammunition is used for producing casualties and for incendiary, screening, and marking purposes. Among the types of fillers used in chemical projectiles are toxic agents, white phosphorus, smoke HC, and colored smoke.

(1) Projectiles filled with toxic agents are particularly useful for causing casualties in fortified positions or installations. See FM 3-10 for detailed information on the use of chemical projectiles. Toxic chemicals may be used at low expenditure rates to harass the enemy and require them to wear protective masks for prolonged periods.

(2) The influence of weather (direction and speed of wind, temperature gradient) has a great deal to do with the effectiveness and tactical desirability of chemical agents. If favorable weather conditions exist, toxic agents will be more effective than HE on a round for round basis in some situations.

Table 27-1. Effect on Concrete

Cannon and projectile (maximum charge)	Thickness* of concrete perforated by single round (face perpendicular to line of impact) (M) Range (meters) 900	2,700	3,600	Thickness (meters)	Number of rounds falling in circle of given diameter** necessary to perforate various thicknesses* of concrete at given ranges Range (meters) 900	2,700	3,600
105-mm howitzer; HE M1, fuze M78 series	.64	.48	.46	0.9	5	10	12
				1.5	14	27	33
				2.1	27	53	64
155-mm howitzer; HE M107, fuze M78 series	1.19	.98	.82	0.9	1	1	2
				1.5	3	5	9
				2.1	7	11	18
8-inch howitzer; HE M106 fuze M78 series	1.68	1.43	1.22	0.9	1	1	1
				1.5	1	2	4
				2.1	3	5	8

*Thickness perforated is based on a line of impact perpendicular 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° or more from the perpendicular. The higher the striking velocity, the greater the angle may be before ricochet occurs. After the surface has been chipped, the angle may be still greater.

**Diameter of circle used as a basis for data.

105-mm howitzer .... 0.9 meter.
155-mm howitzer .... 1.2 meters.
8-inch howitzer .... 1.5 meters.

27-8. Considerations in Selection of Units for Fire

a. The unit selected for a mission must have cannons of the proper size and caliber to cover the target area quickly, effectively, and economically. Many 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 the desired effect. The decision of whether to have many units firing a few rounds on a large target or a few units firing many rounds is often a critical one (*b* below).

b. Many overlapping factors affect the selection of units and the number of rounds to fire on a target. Some of these factors are discussed in (1) through (10) below.

(1) *Availability of artillery.* When the number of available artillery fire units is small, more targets must be assigned to each artillery unit.

(2) *Size of the area to be covered.* The size of the area to be covered must be compared with the effective depth and width of sheaf to be used by the battery or batteries available.

(3) *Increased area coverage.* Targets greater in depth and width than the standard sizes discussed in paragraph 27-2*c* can be covered by—

(*a*) Increasing the number of batteries firing.

(*b*) Dividing the target into several targets and assigning portions to different batteries.

(*c*) Shifting fire laterally or using zone fire with a single battery or with a number of batteries controlled as a single fire unit.

(4) *Caliber and type of unit.* The projectiles of larger calibers are most effective for destruction missions. High-velocity guns are desired for maximum penetration of fortifications.

(5) *Surprise.* For surprise, a few rounds from many pieces are preferred to many rounds from a few pieces.

(6) *Accuracy of target location.* The importance of certain targets that are not accurately located may justify the fire of several units to insure coverage.

(7) *Critical targets.* The emergency nature of certain targets may justify the use of all available artillery fire. Enemy counterattack formations are such targets.

(8) *Dispersion.* At extreme ranges for a given cannon and charge, fire is less dense. More ammunition is required to effectively cover the target. The selection of a unit to fire along the long axis of the target in order to obtain the maximum effect from dispersion may be required when the target is at an extreme range. At normal elevations, probable error and dispersion do not present a serious problem.

(9) *Maintenance of neutralization and interdiction.* Neutralization and interdiction fires may be maintained by the use of a few small units rather than all the units that fired for effect. A unit may be able to fire other missions during the same period that it is maintaining neutralization or interdiction fires.

(10) *Vulnerability of targets.* Some targets should be attacked rapidly with massed fire while they are vulnerable. Examples of such targets are truck parks or personnel in the open.

27-9. Technique of Attack

The technique of attack is determined by an analysis of the capabilities of the cannons and ammunition available and the terrain in the target area. High-angle fire may be needed for firing into or out of defiladed positions.

27-10. Typical Targets and Method of Attack

a. Enemy material and fortifications and personnel in sufficient numbers to justify ammunition expenditure are generally artillery targets. However, artillery is not effective against minefields and barbed wire.

(1) *Minefields.* HE ammunition is ineffective for clearing minefields. The mines are detonated only by direct hits. Artillery fire fails to clear the minefields and only increases the problem of locating and removing the mines by hand and of moving equipment across the mined area.

(2) *Barbed wire.* The employment of artillery to breach wire requires extravagant use of ammunition.

b. Typical targets and suggested methods of attack are listed in table 27-2.

Table 27–2. Typical Targets and Suggested Methods of Attack

Type of target	Type of adjustment	Weapon	Projectile	Fuze	Type of fire	Remarks
Group I						
Armored vehicles (rendezvous).	Observed, unobserved.	All (pref 155-mm or larger).	HE, HEAT, HEP.	VT, ti, Q	Neutralization, destruction, assault.	(1), (2), (3).
Armored vehicles (moving).	Observed	All (pref 155-mm or larger).	HE, WP, HEAT, HEP.	VT, ti	Neutralization, destruction, assault.	Projectile HE to force tanks to "button up," and personnel outside the tank to take cover or disperse. WP may blind vehicle drivers and fires may be started from the incendiary effect on outside fuel tanks, but it may also obscure adjustment. (3).
Vehicles (rendezvous).	Observed, unobserved.	All	HE, WP	Q, VT, ti	Neutralization, destruction.	(1), (2), (4).
Vehicles (moving).	Observed	All	HE, WP	Q, VT, ti	Neutralization, destruction.	(2), (4), (6).
Weapons (fortified).	Observed	All (pref 155-mm or larger).	HE	Q, CP, delay	Destruction, neutralization.	Airbursts are desirable if weapon is firing. After weapon has been 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	Neutralization, destruction.	(1), (3), (4).
Group II						
Boats	Observed	All	HE	VT, ti	Neutralization, direct.	Airbursts 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 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, HE (large caliber) HEP.	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, 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.	Airbursts 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.	([2]), ([4]).

[1] Area is neutralized with projectile HE (airbursts if practical). Surprise is essential to produce casualties.

[2] Materiel remaining in area should be attacked for destruction by use of appropriate projectile and fuze.

[3] Projectile HEAT may be used in fire for effect provided that ranges and observing distances are short enough to permit spotting rounds.

[4] Projectile WP should be combined with HE when the target contains flammable material and the smoke will not obscure adjustment.

[5] Projectile 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. A firing unit or several units, if available, may fire at different points on the road simultaneously.

[7] Other references:—

a. (C) FM 6–141–1, Nonnuclear Employment of Field Artillery Weapons Systems (U).

b. (S) FM 6–141–2, Nonnuclear Employment of Field Artillery Weapons Systems (U).

c. Graphical Effects Table, Artillery Weapons (USAFAS).

CHAPTER 28

SERVICE PRACTICE

Section I. SERVICE PRACTICE PROCEDURES

28–1. General

a. Service practice is a practical exercise in which all elements of the gunnery team are trained in the use of service ammunition. Each service practice should begin with a tactical situation given by the officer in charge of firing. The primary purpose of service practice is to train artillerymen to adjust artillery fire. Fire direction personnel and the firing battery are also trained in their duties during service practice. Prescribed gunnery procedures and techniques should be used except when judgment clearly indicates that a departure from normal procedure will expedite the mission.

b. The service practice is part of the tactical field training of field artillery units. All elements of training, to include mobility, communication, tactical employment, and conduct of fire, should be combined in the service practice.

c. A service practice is an instructional medium and, like any military drill, should be conducted with briskness and precision. The officer in charge of firing must make full use of the service practice and must allow no lulls in the exercise. Observers must conduct each mission in a brisk, businesslike manner.

d. This chapter will serve as a guide in training personnel in observer procedures for the conduct of fire.

28–2. Roles of Key Personnel

a. Installation Commander. The commanding officer of an installation is responsible for the maintenance and the assignment of the firing ranges allotted to his command. He must insure that the safety precautions prescribed in AR 385–63 are followed. A range officer assists the commanding officer in all matters pertaining to firing ranges.

b. Range Officer. The range officer is responsible to the commanding officer for the preparation and maintenance of the firing ranges. Among his responsibilities are the preparation, authentication, and distribution of safety cards. The safety card is prepared in accordance with AR 385–63.

c. Officer in Charge of Firing. The officer in charge of firing is responsible for all aspects of a training exercise that involves firing live ammunition. He is responsible for safety. Normally, he has safety officers to assist him.

d. Safety Officer. The safety officer at the firing point represents the officer in charge of firing. Orders prohibiting firing that are issued by the safety officer can be rescinded only by the officer in charge of firing. The safety officer should interfere as little as possible with the delivery of fire. The safety officer will not be detailed to check or correct errors in laying or servicing the pieces that do not affect safety nor will he be assigned any additional duties during firing.

28–3. Training Prior to Service Practice

a. The gunnery techniques and procedures involved in a service practice must be taught before the unit conducts service practice.

b. The service practice OP is not the place to learn conduct of fire procedure. All participating personnel should be thoroughly familiar with the procedures before going to the observation post. They can learn these procedures by firing simulated missions. A simple and effective method for practicing simulated missions is the "match box 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 to represent the scale of the reticle in the binoculars. At least two persons, one acting as the observer and the other as the instructor, should work together. The observer faces the target and mil scale and announces the call for fire and the OT distance to the instructor; the instructor stands beside the table and announces the message to observer and SHOT. After announcing SHOT, the instructor places the top of a pencil on the table for a moment to simulate the burst. The observer spots the burst for range (OVER or SHORT) and for deviation (the number of mils, in relation to the mil scale, the burst is right or left of the OT line). He announces his spotting (e.g., LEFT 40, ADD 400). This procedure is continued until the mission is completed. The instructor critiques the mission. The instructor and the observer then change places and conduct another mission.

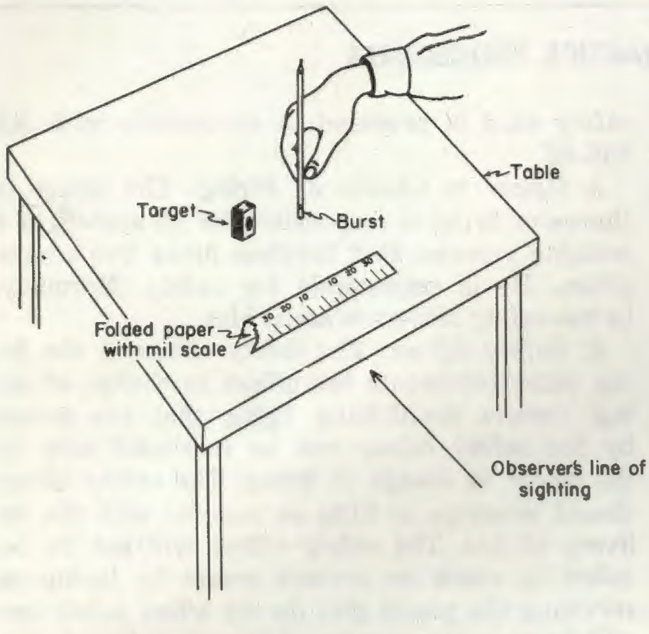


Figure 28–1. Matchbox problem setup.

28–4. 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 and select an observation post that will give the desired angle T and provide observation.

b. Prepare a map and plot the locations of the batteries, observation post, safety limits, and registration points.

c. Select appropriate reference points and targets.

d. Obtain the safety card from the range officer. The officer in charge of firing must check the safety card and, if it is not correct, he must reconcile the differences with the range officer. One copy of the approved safety card is delivered to the safety officer(s) prior to the service practice, and one copy is retained by the officer in charge of firing.

28–5. Procedures at the Observation Post

a. The officer in charge of firing must arrive at the OP sufficiently in advance of the participating personnel to insure that the observation post is properly organized and that all observers will have a good view of the target area. Figure 28–2 depicts a typical nontactical observation post arrangement. Preparation must include a thorough check of communications and a check with range control to insure that the range is clear and that it is safe to fire.

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 the location of friendly troops, zones of action, and final objective. For subsequent target designation, the orientation should define reference points and the direction to 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 that will assist them in calling for fire. Types of fuzes and projectiles available should not be given at this time. The observer should be told to consider all types of fuzes and projectiles authorized in the basic load in selecting the ammunition for his mission.

28–6. Designation of Targets

a. Targets should be designated in a uniform manner. This enables the personnel to become accustomed to a routine and to devote their efforts to making precise measurements. The officer in charge should designate each target by announcing the size and nature of the target and its location relative to the nearest reference point and the skyline. The targets should be realistically described in a sound tactical location; e.g., observation post 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 before he designates a target, the officer in charge should verify his description of the target by observing the target through his fieldglasses.

c. The types of targets selected must be varied so that observers must consider selection of the proper fuze and projectile. Each target must be described realistically. The following are examples of proper designations or targets:

(1) WITH YOUR GLASSES—TO IDENTIFY TWO MORTARS FIRING, FROM THE LONE TREE GO LEFT 85 MILS AND DOWN FROM THE SKYLINE 15 MILS. THIS WILL PLACE YOU ON YELLOW MATERIEL. THAT IS THE ADJUSTING POINT. IS THERE ANYONE WHO DOES NOT IDENTI-

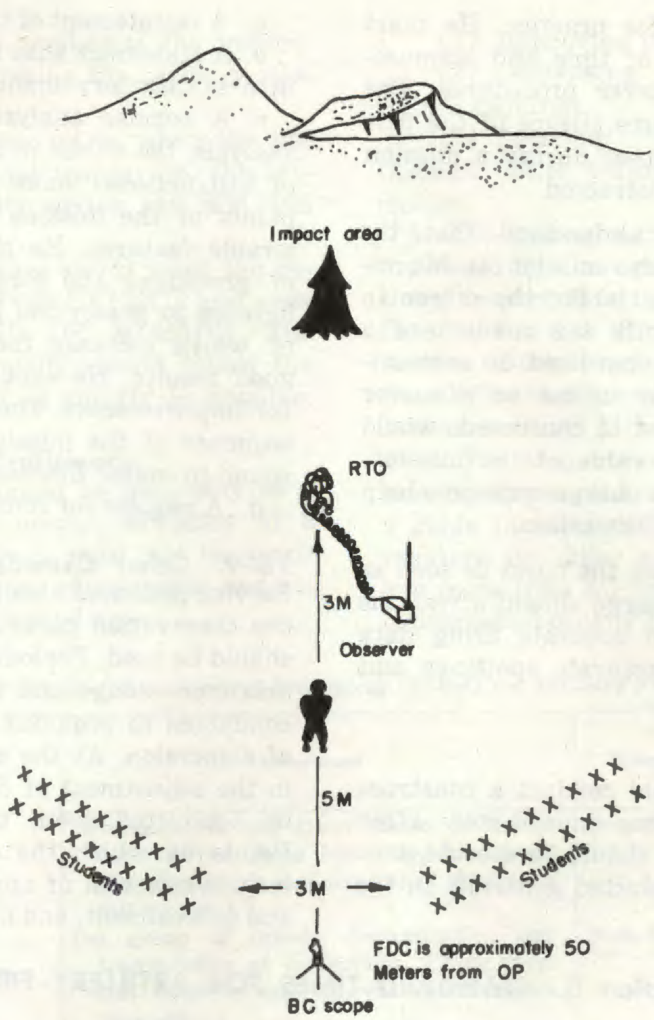


Figure 28-2. Typical nontactical observation post arrangement.

FY THE ADJUSTING POINT? PREPARE YOUR CALL FOR FIRE.

(2) WITH YOUR GLASSES—TO IDENTIFY A STALLED TANK, FROM MARKER GO LEFT 70 MILS AND DOWN FROM THE SKYLINE 12 MILS. THIS WILL PLACE YOU ON WHITE MATERIEL. THAT IS THE TARGET. IS THERE ANYONE WHO DOES NOT IDENTIFY THE TARGET? PREPARE YOUR CALL FOR FIRE.

d. When targets are being selected, careful consideration should be given to prescribed safety limits. No target should be assigned so close to a boundary that a reasonable bracket (200 meters) cannot be obtained. 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 conditions may at times exceed 10 percent of range. This potential error also makes the use of time fire hazardous until after registration corrections have been obtained. The best data available should always be used.

e. After the target has been identified, the observer should be given enough time to prepare initial data; 1 minute is normally adequate in the early stage of training. The first mission should be fired against a target of opportunity to create an air of realism. Registration can follow. For safety reasons, targets selected prior to a registration should be located near the center of the impact area. All observer personnel should prepare initial data for each mission and keep a record of the missions fired.

28-7. Supervision of Firing

a. The officer in charge must instill confidence in observer personnel and arouse and maintain their interest in the service practice. He must take maximum advantage of time and ammunition to teach proper observer procedures. The officer in charge must enforce silence of the personnel on the observation post during a mission so that the observer is not distracted.

b. The observer must understand that the successful completion of the mission is his responsibility. A good policy is for the officer in charge not to interfere with the conduct of a mission unless safety is jeopardized or ammunition is in short supply or unless an observer makes repeated errors that 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 observer must spot the burst as soon as it occurs. The officer in charge should stress the fact that determination of accurate firing data by the FDC depends on accurate spottings and corrections by the observer.

28–8. Critiques

The officer in charge should conduct a constructive and impersonal critique immediately after each mission. The critique should be specific, limited to essentials, and conducted generally in the following order:

a. A restatement of the assigned mission.

b. A statement that the mission was completed in a satisfactory manner or was not completed.

c. A concise analysis of the mission. In his analysis, the officer in charge should stress points of instructional value. He should state the good points of the mission and then state teh undesirable features. He should point out violations of procedure and stress the importance of adherence to prescribed procedures, the observance of which increase the probability of obtaining good results. He should make recommendations for improvements. The analysis should follow the sequence of the mission, but it should not be a round-by-round discussion.

d. A request for comments or questions.

28–9. Other Considerations

Service practices should be conducted from various observation posts and different impact areas should be used. Periodically, service practice with maximum range and a large angle T should be conducted to acquaint observers with the effects of dispersion. As the observer becomes proficient in the adjustment of fire, service practice should be conducted from tactical observation posts. Points on which the observer is graded should include selection of approach routes, use of cover and concealment, and firing of the mission.

Section II. STANDARD TIMES FOR ARTILLERY FIRE

28–10. General

The mission of the artillery is to deliver accurate and timely fire in support of infantry and armor. If the mission is to be accomplished, certain standards of accuracy and speed must be met. Total times required for a mission measure the efficiency of a unit as a whole. A continuous program of timing by commanders should assist in locating and eliminating time losses. The ultimate goal must be to reduce the time required for an adjustment to the absolute minimum to make it closely approximate the effectiveness of fire without adjustment. This goal can be accomplished if commanders will constantly stress the necessity for timely determination of accurate initial data and for smooth, efficient functioning of all members of the artillery team.

28–11. Fire Mission Phases

The mission requiring an adjustment is only a substitute for the more effective surprise mission. The adjustment results in a loss of surprise and, consequently, the kill capabilities of a sudden volume of accurately placed fire. Adjustment requires prolgoned use of wire and radio communication and thus invites enemy jamming of radio, which results in overloading of wire lines. In addition, as time for firing increases, exposure time to enemy counterbattery measures is increased. The mission requiring adjustment can be divided into three phases—the initial data phase; the adjustment phase; and the fire-for-effect phase.

a. 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 faster reaction time is required for attacking a column of infantry than for attacking a command post. More time spent in this phase may reflect better initial data and, consequently, less time and fewer rounds for completion of the mission. However, when personnel are being trained 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.

b. The *adjustment phase* starts when the initial rounds land. From that instant on, the target is warned and evasive action can and will be taken.

c. The *fire-for-effect phase* starts when the observer announces FIRE FOR EFFECT and ends when he announces END OF MISSION. The fire-for-effect rounds normally should follow the last rounds of adjustment as quickly as possible.

28–12. Standards of Proficiency

a. Timing standards should be used only 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 required.

(3) Speeding the action of personnel through better training and elimination of lost motion.

b. The timing standards shown in table 28–1 are based on average terrain and weather conditions, impact fuze in adjustment, impact or VT fuze in fire for effect, initial data within 400 meters of the target, a time of flight not greater than 25 seconds, and observer distance of 3,000 meters or less. Although no standard times are given for weapons other than 105-mm and 155-mm howitzers, the times listed can be used as a guide for all artillery pieces. The only change required for other artillery pieces will be to allow more time for loading and laying the larger cannons and usually for longer times of flight.

Table 28–1. Standards of Proficiency (Speed) for Artillery Fires

Type of fire	Element	Event timed	Weapon	Standards—minutes and seconds: 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 call for fire.)	Note 3	01 00	01 30	02 00	02 30
		Per group of rounds, determination and transmission of corrections. (Time from last burst 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 rounds. (Time from last element of observer's call for fire to quadrant command to battery.)	Note 3	00 30	00 45	01 00	01 15
		Per group of rounds, determination of firing data subsequent to initial rounds. (Time from last element of observer's correction to quadrant command to battery.)	Note 3	00 15	00 20	00 25	00 30
		Mass battalion after FFE is ordered by observer. (Time from observer's FFE to SHOT for the last battery.)	Note 1 Note 2	00 42 00 57	00 52 01 07	01 02 01 17	01 12 01 27
	Firing battery.	Initial rounds in adjustment. (Time from FDC quadrant to SHOT.)	Note 1 Note 2	00 15 00 30	00 20 00 35	00 25 00 40	00 30 00 45
		Per group of rounds, subsequent to initial rounds. (Time from FDC quadrant to SHOT.)	Note 1 Note 2	00 10 00 25	00 15 00 30	00 20 00 35	00 25 00 40
		FFE, battery one round. (Time from FDC quadrant to SHOT for the last round.)	Note 1 Note 2	00 15 00 30	00 20 00 35	00 25 00 40	00 30 00 45
	Overall firing time.	Time from first SHOT to SHOT for the last round in FFE. (Based on four groups of rounds in adjustment.)	Note 1 Note 2	04 40 05 55	06 37 06 52	07 14 08 28	08 11 09 27

Type of fire	Element	Event timed	Weapon	Standards—minutes and seconds: Superior	Excellent	Very satisfactory	Satisfactory
Precision registration.	Observer	Determination and transmission of initial data. (Time from last word of target identification to last element of observer's call for fire.)	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 spotting. (Time from burst to last element of observer's spotting.)	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 call for fire to quadrant command to battery.)	Note 3	00 30	00 45	01 00	01 05
		Per round, determination of firing data subsequent to initial round. (Time from last element of observer's correction to quadrant command to battery.)	Note 3	00 15	00 20	00 25	00 30
	Firing battery.	Initial round in adjustment. (Time from FDC quadrant to SHOT.)	Note 1	00 15	00 20	00 25	00 30
			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. (Time from first SHOT to SHOT for first round in FFE (based on four rounds in adjustment).)	Note 1	04 00	04 52	05 44	06 36
			Note 2	05 00	05 52	06 44	07 36
MPI or HB registration.	Overall firing time.	Per round fired. (Time from SHOT to next SHOT. Includes report of instrument readings from two OP's.)	Note 1	01 00	01 15	01 30	01 45
			Note 2	01 15	01 30	01 45	02 00
		Total registration time. (Time from first SHOT to last OP report of registration.)	Note 1	07 00	08 45	10 30	12 15
			Note 2	08 45	10 30	12 15	14 00
Fire for effect without adjustment.	Overall problem time.	Battery mission. (Time from last element of call for fire to SHOT.)	Note 1	00 45	01 00	01 15	01 30
			Note 2	01 00	01 15	01 30	01 45
		Battalion mission. (Time from last element of call for fire to SHOT for last battery to fire.)	Note 1	00 57	01 12	01 27	01 42
			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.

Note. The standards in table 28-1 do not separate telephone and radio operator time intervals. The efficiency of operators can be judged by the number of read-backs required. If communications personnel are not efficient, the total time standards will not be met.

c. Table 28-2 is a detailed breakdown of timing averaged for the "excellent" column for area fire in table 28-1.

Table 28-2. Service Practice Timing

From—	To—	Time interval (in seconds)
Target identified	Observer ready with call for fire	74
Observer initiates call for fire	Observer completes call for fire	16
Observer completes call for fire	Deflection sent to pieces	38
Deflection sent to pieces	Quadrant sent to pieces	7
Quadrant sent to pieces	Quadrant announced by chiefs of sections	5
Quadrant announced by chiefs of sections	Last chief of section reports READY	13
Last chief of section reports READY	Pieces are fired	2
(Pieces are fired.)	(SHOT announced to observer.)	(4)
Target identified	Pieces are fired	155
Initial rounds burst in target area	Observer completes subsequent corrections	15
Observer completes subsequent corrections	Deflection sent to pieces	14
Deflection sent to pieces	Quadrant sent to pieces	6
Quadrant sent to pieces	Quadrant announced by chiefs of sections	4
Quadrant announced by chiefs of sections	Last chief of section reports READY	8
Last chief of section reports READY	Pieces are fired	3
Initial rounds burst in target area	Subsequent rounds or fire-for-effect rounds are fired	50

CHAPTER 29
NAVAL GUNFIRE SUPPORT

Section I. INTRODUCTION

29-1. General
Naval gunfire (NGF) and close air support are employed in amphibious operations prior to the landing of artillery units and in coastal operations for reinforcing artillery. When naval gunfire is used in support of land forces, the Navy is responsible for control and command. Naval gunfire should be requested only for attacking targets that cannot be engaged adequately by the artillery and for supplementing artillery fires.

29-2. Characteristics of Naval Gunfire Weapons
Naval gunfire weapon characteristics are shown in table 29-1.

29-3. Communication Procedure
Normal artillery communication procedure is used in requesting naval gunfire.

Section II. CALL FOR FIRE

29-4. General
Normally, the call for fire for NGF support follows the same format as that for artillery support. However, in the first call for fire to a particular ship, the observer must specify the unit of measure to be used (i.e., meters or yards).

29-5. Elements and Sequence of Call for Fire
The following elements are transmitted in the sequence indicated.

a. Observer Identification—Same as that for artillery fires.

b. Warning Order—Same as that for artillery fires except that a target number is sent by the observer as part of the warning order.

c. Location of Target—Same as that for artillery fires except that the observer may shift to a new target from the target being fired on provided the new target is within 1,000 meters of the target from which the shift is made and END OF MISSION has not been given. To shift to a new target, the observer precedes his call for fire with FRESH TARGET. The command FRESH TARGET insures that the information gained from previous adjustments is not lost and normally bracketing may not be necessary.

d. Description of Target—Same as that for artillery fires.

e. Method of Engagement—Same as that for artillery fires with the following exceptions:

(1) *Trajectory.* Naval gunfire trajectories are quite flat and there is no high angle capability. However, by requesting REDUCED CHARGE the chances of engaging are increased due to the trajectory being steeper on the descending branch.

(2) *Ammunition.* Ammunition for naval gunfire is similar to standard ammunition for artillery; however, the terminology is different. Shell high-capacity or antiaircraft common, fuze quick, will be used, as appropriate, if the type of projectile and/or fuze action are not specified by the observer.

(*a*) *High Capacity (HC).* Equates to HE, fuze quick.

(*b*) *Anti-Aircraft Common (fuze quick),* Equates to HE, fuze quick.

(*c*) *Anti-Aircraft Common (fuze time).* Equates to HE, fuze time.

(3) *Distribution of fire.* Distribution of fire is not given by the observer for naval gunfire.

(4) *Danger.* The observer announces DANGER followed by the direction and distance of friendly forces from the target whenever any friendly forces are within 1,500 meters of the target. If friendly forces are within 600 meters of the target, the observer announces DANGER CLOSE.

For example: "DANGER CLOSE 500 SOUTHEAST"

f. Method of Fire and Control—Same as that for artillery fires with the following exceptions:

(1) *Method of fire.*

(*a*) Salvo fire is used for all missions. Because the ship is moving, it cannot fire battery right/left.

(*b*) Normally, the observer requests the number of guns for use during adjustment and the armament to be used. Normally, fire is opened with one gun for destruction fires and two guns for neutralization fires.

(2) *Control.* When the observer wants the ship to adjust the fire, he identifies the target and specifies the effect desired and, as the final element of the call for fire, announces SHIP ADJUST.

Table 29–1. Characteristics of Naval Gunfire Weapons

Ship	Class	Armament*	Rate of fire (rounds/min)	Types of ammunition	Types of fuzes	Maximum effective range (yards)	Maximum effective range (meters)
Heavy cruiser (CA)	Baltimore	9—8″/55	3–4	HC, AP	Q, D, ti	26,000	23,800
		12—5″/38	15	HC, illum, WP	Q, D, ti, VT	15,000	13,700
	Salem	9—8″/55	10	HC, AP	Q, D, ti	26,000	23,800
		12—5″/38	12–15	HC, illum, WP	Q, D, ti, VT	15,000	13,700
Guided missile heavy cruiser (CAC).		6—8″/55	3–4	HC, AP	Q, D, ti	26,000	23,800
		10—5″/38	15	HC, illum, WP	Q, D, ti, VT	15,000	13,700
		2—S-A** missile launchers					
Light cruiser (CL)		12—6″/47	10	HC, AP	Q, D, ti, VT	21,000	17,200
		12—5″/38	15	HC, illum, WP	Q, D, ti, VT	15,000	13,700
Guided missile light cruiser (CLG).		3 to 6—6″/47	4	HC, AP	Q, D, ti, VT	21,000	17,200
		2 to 6—5″/38	15	HC, illum, WP	Q, D, ti, VT	15,000	13,700
Destroyer (DD)	Sumner	6—5″/38	15	HC, illum, WP	Q, D, ti, VT	15,000	13,700
	Sherman	3—5″/54	20	HC, illum, WP	Q, D, ti, VT	22,500	20,600
Rocket ships	Landing ship med rocket (LSMR)	10—5″ S-S***	30/barrel	HC	----------	5 to 10,000	9,100 max
	Inshore fire support ship	8—5″ S-S*** rocket launchers	35	HC	Q, D, VT	5 to 10,000	9,100 max

*Number of tubes—diameter of bore/number of calibers.
**Surface to air.
***Surface to surface.

Section III. ADJUSTMENT PROCEDURE

29-6. General

The procedures used in the adjustment of naval gunfire are essentially the same as those used in field artillery fire. All terms used in field artillery adjustment are also used in the adjustment of naval gunfire.

29-7. Terms

Terms used in the adjustment of naval gunfire that are uncommon to the field artillery observer are given in *a* through *j* below.

a. Delay—The term used to indicate that the ship is not ready to fire. The term "delay" is followed by an estimated time at which the ship will be ready.

b. Straddle—The term used to indicate that multigun fires straddle the target.

c. Large Spread—The term used to indicate that the distance between bursts is excessive.

d. Trend—The term used to indicate that fires are creeping off the target. It is followed by an indication of direction and distance; for example, TREND SOUTHWEST, 50 meters per salvo.

e. Fresh Target—The term used by the observer to indicate that he wishes to shift to a new target within 1,000 meters of the target being fired on.

f. Neglect—The term used to inform the observer that the last rounds were fired with incorrect settings.

g. Will Not Fire—The term used to indicate that, for safety or other reasons, the ship is unable to fire; for example, the ship is under attack.

h. Salvo Fire—The term used to describe the method of fire in which a number of weapons are fired at the same target simultaneously.

i. Danger—The term used to indicate that friendly forces are within 1500 meters from the target.

j. Spreading Fire—The term used by the observer to inform the ship that fire is about to be distributed over an area target. It is followed by an appropriate correction.

CHAPTER 30

ARMOR EMPLOYED IN A FIELD ARTILLERY MISSION

30-1. General

a. Tank guns normally are not used in the field artillery (indirect fire) role because of tank guns and the smal bursting radius of the high velocity, flat trajectory and short tube life of tank guns and the small bursting radisu of the ammunition. However, under exceptional circumstances, the force commander may decide to employ tanks in an indirect fire role under the operational control of the supporting field artillery. The tank unit may be either attached to the field artillery units or given a reinforcing mission. The field artillery unit is responsible for fire control, communication, and survey. If the tank unit is attached, the field artillery unit is also responsible for ammunition, fuel, rations, and other supplies. Whether attached or reinforcing, the tank unit must retain the capability of immediately reverting to its primary role.

b. This chapter 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, on the characteristics of tanks and tank fire control equipment, and on direct fire with tank weapons, see the 17-series field manuals.

30-2. Ammunition

a. HE and WP projectiles are available for firing in 90-mm tank guns (M48A3 tank). HEP and WP projectiles are available for 105-mm tank guns (M60 and M60A1 tanks).

b. A typical basic load will include approximately 25 percent HE or HEP, 15 percent WP, and 60 percent antitank ammunition. Since a tank unit can be committed to mobile combat at any time, this basic load should not be used in the indirect fire role. If possible, ammunition should be prestocked for this purpose.

c. HE projectiles (90-mm tank guns) are issued with combination superquick and delay fuzes. Combination mechanical time and superquick or concrete-piercing fuzes may be obtained and substituted for the issued fuzes if required. Separate fuzes are not available for the 105-mm tank guns (M60 and M60A1).

Note. **See TM 9-1300-203 and table 1-2 for further information on ammunition.**

30-3. Observer Procedure

Field artillery observer procedures as covered in part three of this manual are used in conducting indirect fire with tanks.

30-4. Fire Direction

a. Firing Chart. The location of each tank platoon is plotted on the field artillery firing chart. A deflection index is constructed at zero deflection by orienting the left edge of the arm of the range-deflection protractor in the direction on which the tanks are laid and drawing the index on the chart at the center graduation of the mil scale on the arc. The RDP is numbered for reading shifts of 500 mils right or left of the direction of lay as follows:

(1) Number the center graduation 0.

(2) Number each succeeding 100 mil graduation to the right "L1" through "L4" and each succeeding graduation to the left "R1" through "R4". The last graduation on each end need not be numbered. For reading shifts greater than 500 mils, additional indexes must be constructed. If tank weapon firing tables are not available to the fire direction center, the tank unit normally fires only observed fires in the indirect role. If tabular or graphical firing tables are available, a registration should be conducted and corrections applied as outlined in chapter 20. Corrections sent by the observer during adjustment are plotted using the target grid as outlined in chapter 16.

b. Fire Commands.

(1) Fire command information is sent from the fire direction center to the tank unit fire control officer (FCO), who is responsible for tank fire. The FCO converts this information to a platoon fire command and sends it to the tanks. The FCO requires the range from the platoon target, the difference in elevation, the direction, and target description. An example is shown:

12,000 UP 10
FROM REFERENCE POINT, RIGHT 115
MORTARS FIRING

(*a*) 12,000, UP 10. The range information (12,000) is given to the nearest 100 meters.

When the target is at a different altitude from that of the tank, an angle of sight is computed in mils and included as part of the information (UP 10). The complementary angle of sight for high-velocity guns is negligible and is ignored.

(*b*) *From Reference Point, Right 115.* The direction information is given in terms of a reference point. In the indirect fire role, the tanks are laid in an azimuth, and this azimuth is considered the reference point. When the tank is laid, the azimuth indicator is zeroed. Directions 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 at zero, or 2,600 or 2,800 mils to the right front. Since the tank does not have a panoramic sight, the aiming post deflection is merely an offset angle. During lulls in the firing, the gunner checks a tanks displacement by using the aiming posts without traversing the turret (tube) back to the aiming circle.

(*c*) *Mortars Firing.* The nature of the target is announced to the tanks as a portion of their fire command.

(2) Once the fire control officer has the firing information of range, elevation, direction, and target description, he must convert this data so that a fire command can be sent to the tanks. The tanks must receive the range information as a quadrant reading, which includes the angle of sight and the elevation for range. The tank weapons may be laid for elevation by using either the gunner's quadrant or the elevation quadrant. Likewise, the direction command must be modified so this data can be placed on the tanks instruments. An example of a platoon fire command issued by the fire control officer, is shown in the following fire command.

PLATOON
HEP
MORTARS FIRING
3127 RIGHT
QUADRANT + 430
AT MY COMMAND. FIRE.

(*a*) *Platoon.* The normal method of employing tanks in an indirect fire role is by platoon (fire tank guns). To alert all fire weapons that they will fire the command is PLATOON. To alert all pieces to follow with one tank firing in adjustment, the command is PLATOON ADJUST, NUMBER THREE (The number three piece firing in adjustment).

(*b*) *HEP.* 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 if firing a round with an adjustable fuze other than fuze quick; e.g., HE DELAY.

(*c*) *Mortars Firing.* The nature of the target is announced to the tank unit as a portion of the fire command.

(*d*). *Deflection 3127 RIGHT.* This portion of the fire command is the direction and must be computed by the FCO using the direction information sent from the FDC and drift data contained in tank firing tables. Once the direction of the gun has been computed, and drift accounted for, it must be converted to a reading that can be applied to the tank azimuth indicator. The tank azimuth indicator is numbered left, from zero to 3,200 mils, and from that point again from zero to 3,200 mils. Because of this, a direction and an azimuth to the left of the reference point are the same, but to the right the two numbers are different, and always sum up to 3200. A direction "RIGHT" or "LEFT" must be included in the command since this determines which direction along an axis the tubes point.

(*e*) *Quadrant +430.* The FCO obtains the superelevation angle from the fire tables and combines it with the angle of sight announced by the FDC. 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 the inability to elevate to high angles, it may be necessary either to dig in the rear of the tanks or to place the tanks on a ramp which slopes away from the direction of fire.

(*f*) *At My Command. Fire.* The command to signal when a tank is ready is AT MY COMMAND. The command to open fire is FIRE. In tank gunnery, this command is the last element in the sequence of fire command because the tank gunner is trained to hold his fire until the command FIRE is received.

Note. **When required, other fire commands used by the artillery (e.g., pieces to fire, method of fire) are sent to the tanks in the simplest and most understandable manner. Commonsense 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 meters. For tanks armed with 90-mm guns, a parallel 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.

30–5. Alternate Methods

Other methods, that may be employed in controlling the indirect fire of tanks are as follows:

a. Independent Method. The tank unit uses fire direction equipment and personnel organic to the tank battalion to form, with artillery assistance, a fire direction center.

b. Semi-Independent Method. The tank unit handles its own indirect fire missions from prearragned data sheets. Survey control, meteorological computations, prearranged data sheets, and assistance in laying the tanks may be provided by the supported artillery. Interdiction and harassing missions are the types of mission most effectively handled by use of data sheets.

30–6. Survey

The survey necessary for the indirect firing of the tanks, such as the establishment of their position area locations, is performed by the field artillery battalion before the arrival of the tanks or as soon after their arrival as possible.

APPENDIX A

REFERENCES

A–1. Publication 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.

A–2. Army Regulations

75–1	Malfunctions Involving Ammunition and Explosives, Reports Control Symbol AMC–132 (MIN)
310–25	Dictionary of United States Army Terms
310–50	Authorized Abbreviations and Brevity Codes
385–63	Regulations for Firing Ammunition for Training, Target Practice, and Combat

A–3. Department of Army Pamphlets (DAPam)

108–1	Index of Army Motion Pictures and Related Audio-Visual Aids.
310-series	Index of Military Publications

A–4. Field Manuals (FM)

6–2	Field Artillery Survey
6–20	Field Artillery Tactics and Operations
6–70	105-mm Howitzer, Light, M102, Towed
6–75	105-mm Howitzer M101 Series, Towed
6–77	105-mm Howitzer M52, Self-Propelled
6–79	105-mm Howitzer M108, Self-Propelled
6–81	155-mm Howitzer M114, Towed
6–88	155-mm Howitzer M109, Self-Propelled
6–90	8-inch Howitzer M2, Towed
6–92	155-mm Howitzer M44, Self-Propelled
6–94	175-mm Gun M107, Self-Propelled and 8-inch Howitzer M110, Self-Propelled
6–115	The Field Artillery Searchlight Battery
6–120	The Field Artillery Target Acquisition Battalion and Batteries
6–122	Artillery Sound Ranging and Flash Ranging
6–125	Qualification Tests for Specialists, Field Artillery
6–140	Field Artillery Organizations
6–160	Counterbattery Radar Set AN/MPQ–10A
6–161	Radar Set AN/MPQ–4A
11–40	Signal Corps Pictorial Operations
17–12	Tank Gunnery
21–5	Military Training Management
21–6	Techniques of Military Instruction
21–26	Map Reading
21–30	Military Symbols
23–92	4.2-inch Mortar M30
(C) 32–5	Signal Security (SIGSEC) (U)
(C) 32–20	Electronic Warfare (U)
100–5	Operations of Army Forces in the Field

A-5. Technical Manuals (TM)

5-581A	General Drafting
6-230	Logarithmic and Mathematical Tables
6-240	Slide Rule, Military, Field Artillery
9-325	Operator and Organizational Maintenance Manual: Howitzer, Light, Towed, 105-mm M101 and M101A1.
9-1015-215-12	Operator and Organizational Maintenance Manual: Mortar 4.2-inch: Cannon M30 on Mount M24 or M24A1; and Mortar, Sub-caliber, 60-mm: M31
9-1015-234-12	Operator and Organizational Maintenance Manual: (Including Repair Parts and Special Tools Lists) Howitzer, Light, Towed: 105-mm, M102
9-1025-200-12	Operator and Organizational Maintennce Manual: Howitzer, Medium, Towed: 155-mm M114 and M114A1; and Howitzer, Medium, Towed, Auxiliary Propelled, 155-mm, M123A1
9-1300-200	Ammunition, General
9-1300-203	Artillery Ammunition
9-2300-216-10	Operator's Manual, Gun, FA, SP, 175-mm, M107 (2350-436-6635) and Howitzer, Heavy, SP, 8-Inch, M110 (2350-439-6243)
9-2300-216-20	Organizational Maintenance Manual, Gun, FA, SP, 175-mm, M107 (2350-436-6635) and Howitzer, Heavy, SP, 8-Inch, M110 (2350-439-6243)
9-2350-217-10	Operator's Manual, Howitzer, Light, SP, 105-mm, M108 (2350-440-8810) and Howitzer, Medium, SP, 155-mm, M109 (2350-440-8811)
9-2350-217-20	Organizational Maintenance Manual, Howitzer, Light, SP, 105-mm, M108 (2350-440-8810) and Howitzer, Medium, SP, 155-mm, M109 (2350-440-8811)
11-287	Radio Sets AN/VRQ-1, AN/VRQ-2, and AN/VRQ-3
30-245	Image Interpretation Handbook
38-750	The Army Maintenance Management System

A-6. Firing Tables (FT)

8-J-4	Cannon, 8-inch Howitzer; M2 and M2A1 on Howitzer, Heavy, Towed: 8-inch, M114 Cannon, 8-inch Howitzer; M47 on Howitzer, Heavy, Self-Propelled, Full-Tracked: 8-inch, M55 Cannon, 8-inch Howitzer: M2A1E1 on Howitzer, Heavy, Self-Propelled: 8-inch, M110 Firing Projectile, HE, M106, Projectile, Chemical, M426.
8-ADD-A-1	Firing Table Addendum to FT 8-J-4 for Projectile HE, M404
8-0-4	Cannon, 8-inch Howitzer: M2 and M2A1 on Howitzer, Heavy, Towed: 8-inch, M115, Cannon, 8-inch Howitzer: M2A1E1 on Howitzer, Heavy, Self-Propelled: 8-inch, M110 Cannon, 8-inch, Howitzer: M47 on Howitzer, Heavy, Self-Propelled, Full-Tracked: 8-inch, M55; Firing Projectile HES, M424, Projectile, Atomic, M422.
105-H-7	Cannon, 105-mm Howitzer, M2A2 and M2A1 on Howitzer, Light, Towed, 105-mm, M101A1 and M101 and Cannon, 105-mm Howitzer, M49 on Howitzer, Light, Self-Propelled, Full-Tracked, 105-mm, M52A1 and M52, Firing Cartridge, HE, M1; Cartridge, Gas, Persistent H and HB, M60, Cartridge, Gas, Nonpersistent, GB, M360, Cartridge, Smoke, WP, M60, Cartridge, Smoke, BE, M84 and M84B1 (HC and Colored), Cartridge, Illuminating, M314A2E1; Cartridge, HEP-T, M327 Cartridge, Antipersonnel, XM546
105-ADD-B-2	Firing Table Addendum to FT 105-H-6 for Cartridge, HE, M444
155-ADD-E-1	Projectile, HE, M449A1 (M449E2); Projectile HE, M449 (T379), Projectile, HE, M449E1
155-ADD-F-1	Addendum to FT 155-Q-4 for Projectile, HE, M449A1 (M449E2), Projectile, HE, M449 (T379) Projectile, HE, M449E1
155-AH-2	Cannon, 155-mm Howitzer, M126E1 and M126 on Howitzer, Medium, Self-Propelled: 155-mm, M109, Firing Projectile, HE, M107; Projectile,

	Smoke, WP, M110; Projectile, Smoke, BE, M116 and M116B1 (HC and Colored); Projectile, Gas, Persistent, HD, M110; Projectile, Gas, Persistent, H, M110; Projectile, Gas, Nonpersistent, GB, M121A1; Projectile, Gas Persistent, VX, M121A1; Projectile, Illuminating, M118, M118A1, M118A1B1, M118A2 and M118A2B1; Projectile, Illuminating, M485E2, M485E1 and M485
155–AJ–2	Firing Tables for Cannon, 155-mm, Howitzer, M126E1 and M126 on Howitzer, Medium, Self-Propelled
155–AM–1	Firing Tables for Cannon, 155-mm Howitzer, M185 on Howitzer, Medium, Self-Propelled, 155-mm, M109A1 and Howitzer, Medium, Self-Propelled, 155-mm M109A1B Firing Projectile, HE M107 Projectile, Smoke, WP, M110 Projectile, Smoke BE, M116, M116B1 (HC and Colored/Projectile); Projectile, Gas,Persistent, H and HD, M110 projectile, gas, nonpersistent, GB, M121A1 Projectile, Gas Persistent, VX, M121A1 Projectile Illuminating, M485A2 and M485A1
105–AS–2	Cannon, 105-mm Howitzer, M103, on Howitzer, Light, Self-Propelled: 105-mm, M108, Firing Cartridge, HE, M1; Cartridge, Gas, Persistent, H, M60; Cartridge, Gas, Persistent, HD, M60; Cartridge, Gas, Nonpersistent, GB, M360; Cartridge, Smoke, WP, M60; Cartridge, Smoke, BE, M84 and M84B1, (HC and Colored); Cartridge, Illuminating, M314A2E1; cartridge, HEP–T, M327 (Also Applicable to Howitzer, Light, Towed: 105-mm, M102)
105–ADD–F–1	Firing table Addendum to FT 105–AS–2 for Cartridge, HE, M444
155–Q–4	Howitzer, Medium, Towed, 155-mm, M114A1 and M114; Howitzer, Medium, Self-Propelled, Full-Tracked, 155-mm M44A1 and M44; Howitzer, medium, Towed, Auxiliary Propelled, 155-mm, M123A1; Firing Projectile, HE, M107; Projectile, Smoke, WP, M110; Projectile, Smoke, BE, M116 and M116B1 (HC and Colored); Projectile, Gas, Persistent, HD, M110; Projectile, Gas, Persistent, H, M110, Projectile, Gas, Non-Persistent, GB, M121A1; Projectiles, Gas Persistent, VX, M121A1; Projectile, Illuminating, M485E2, M485E1 and M485.
175–A–1	Cannon, 175-mm gun: M113, M113E1 on gun, Field Artillery, Self-Propelled: 175-mm, M107 Firing Projectile, HE, M437A2, M437A1.

A–7. DA Forms (Available through normal AF publications supply channels.)

2408–4	Weapon Record Data
3622	FDC Computer's Record
3623	Firing Battery Recorder's Sheet
4007	Firing Battery Section Data Sheet
4176	Target Grid, Scale 1:25,000 Meters
4198	Record of Precision Fire
4199	Firing Battery Data Sheet
4200	Met Data Correction Sheet
4201	High-Burst (Mean Point of Impact) Registration Computation of HB (MPI) Location
4207	8-inch Nuclear Computation—Met Plus VE
4208	8-inch Nuclear Computation—K Transfer

A–8. Miscellaneous Publications

164	Joint Radio and Telephone Procedure for Conduct of Artillery and Naval Gunfire
QSTAG 224	Manual Fire Direction Equipment, Target Classification and Methods of Engagement for Post—1970
QSTAG 225	Call for Fire Formats
QSTAG 246	Radio Telephone Procedures for the Conduct of Artillery Fire

APPENDIX B

CALL FOR FIRE FORMATS

(QSTAG 225)

CHAPTER 1

OBSERVER'S CALL FOR FIRE FORMAT

ELEMENTS OF A CALL FOR FIRE

B-1. The Elements of a Call for Fire Are:

a. Observer identification.

b. Warning order.

c. Location of target.

d. Description of target.

e. Method of engagement.

f. Method of fire and control.

OBSERVER IDENTIFICATION

B-2. This is the establishment of communication between the observer and the Fire Direction Center/Command Post (FDC/CP).

WARNING ORDER

B-3. The basic warning order is "Fire Mission." One of the following may be included to indicate the number of guns:

a. If less than a battery is desired—the number of guns is specified with Right, Left or Centre, if applicable.

b. Battery.

c. Battalion/Regiment.

d. Division.

e. All available.

Examples:

(1) "Fire Mission—One Gun."

(2) "Fire Mission—Two Guns Left."

(3) "Fire Mission—Regiment/Battalion."

B-4. The Warning Order is a request unless prior authority has been granted to order calls for fire. If the number of guns is not indicated the FDC/CP will allocate the number of guns.

LOCATION OF TARGET

B-5. The location of the target may be given in one of the following ways and is amplified in the succeeding paragraphs:

a. By a grid.

b. By a target number or a known point.

c. By a reference from a known point.

d. By polar coordinates.

B-6. *By a Grid.*

a. The grid will be given in terms of eastings and northings to the degree of accuracy required by the type of engagement.

Example:

(1) "Grid 321654."

(2) "Grid 42137856."

b. Altitude is normally given by the observer. If it is not given it is determined in the FDC/CP.

B–7. *By a Target Number or a Known Point.* The recorded target or the known point must be known to both the observer and the FDC/CP.

Examples:

(1) "ZT 1242."

(2) "AB 1014."

(3) "Registration Point1."

B–8. *By Reference From a Known Point.*

a. The designation and location of the known point must be known to both the observer and the FDC/CP. This may be a registration point, a recorded target, or a prominent terrain feature.

b. The reference from the known point will include the direction, horizontal correction (shift) and the vertical correction (shift) if any, to the new target.

Examples:

(1) "From ZT 1234, Direction 1200,
Right 400, Drop 200, Up 50."

(2) "From Registration Point 1,
Direction 2610, Left 600, Add 400, Down 20."

B–9. *By Polar Coordinates.* (To be used only when the position of the observer is known by the FDC/CP.) Polar coordinates consist of the direction, distance and vertical correction (shift) if any, from the observer's position to the target. A vertical correction (shift) is accepted as being metres unless mils are specified.

Examples:

(1) "Direction 1240, distance 2000,
Up 50."

(2) "Direction 1240, distance 2000.
Up 25 Mils."

B–10. *Direction.*

a. When the observer anticipates that he will be required to adjust or correct the fire, he will send a direction.

b. The direction is normally the horizontal clockwise angle measured by the observer from grid north to the target and is ordered to the nearest 10 mils, e.g., "Direction 1240."

c. If the ground observer wishes to use the line GT as a reference line he will order "Direction GT". If direction is not ordered by the air observer, the line GT is understood.

d. If the observer wishes to use an arbitrary reference line other than the line observer-target or gun-target, he will order it in the normal way, e.g., "Direction 1440."

DESCRIPTION OF TARGET

B–11. The observer indicates any or all of the following target features:

a. Target Type. Provides information as to type of target, e.g., battalion assembly area.

b. Degree of Protection. Provides information relative to the target protection, e.g., company dug in along ridge.

c. Approximate Size. Provides dimensions of the target in metres e.g., 200 by 100.

d. Attitude. Provides information relative to the longer axis of the target and given to the nearest 50 mils, e.g., attitude 2450.

METHOD OF ENGAGEMENT

B-12. The method of engagement of the target includes:

a. Type of engagement.

b. Trajectory.

c. Ammunition.

d. Distribution of fire.

B-13. *Type of Engagement.* This indicates to the FDC/CP any special procedures. If the type of engagement is not given, the convention is that an area neutralization mission is required. Types of special engagement which may be given are:

a. "Registration"—a fire mission conducted to determine the correction for shooting.

b. "Mark"—to indicate that the observer is going to fire rounds either:

(1) To orient himself in his zone of observation, or

(2) To indicate targets to ground troops, aircraft, or fire support ships.

c. "Destruction"—the engagement of a target with the purpose of destroying it.

d. "Danger Close"—when the target is within 600 metres of friendly personnel. The limits and special procedures are designed to insure the safety of friendly personnel.

B-14. *Trajectory.* This is the determination to use high or low angle. The order will be "High Angle"—if no order is given the convention is to fire at low angle.

B-15. *Ammunition.* This element indicates the type of ammunition and may include the volume required.

a. Type. If a type of ammunition is not specified it is assumed that HE fuze quick is required. Ammunition is specified as follows:

(1) The ammunition required in adjustment and in fire for effect is specified by the shell or fuze as shown below:

(*a*) *Shell.* "HE." "Illuminating," "WP," or "Smoke" (including colour other than white).

(*b*) *Fuze.* "Quick," "VT," "Time," "Delay" or "Concrete Piercing."

(2) If the type of ammunition required in adjustment and in fire for effect is different, this is stated by specifying the type of ammunition together with the terms, "in adjustment" or "in effect" as applicable. When HE fuze quick is to be used in either phase it need not be stated.

(3) *Examples:*

(*a*) "Delay"—HE Delay is fired during adjustment and fire for effect.

(*b*) "VT in Effect"—HE fuze quick is used in adjustment and VT at fire for effect.

(*c*) "WP in Adjustment"—WP is used in adjustment and HE fuze quick at fire for effect.

(*d*) "WP in Adjustment, HE Time in Effect"—WP is used in adjustment and HE fuze time at fire for effect.

b. Volume: The volume is a request for the number of rounds to be fired from each gun in fire for effect and, in addition, serves as a warning for the preparation of an unusual quantity or special type of ammunition.

B-16. Distribution of Fire. Orders are necessary to insure that fire is distributed adequately to cover any given target. If no specific order is given, batteries will fire with planes (lines) of fire parallel. Orders which may be used include:

a. "Converge"—Planes (lines) of fire and range are concentrated on a point.

terminated by the command "End of mission" or temporarily suspended by the command "Cease loading" or "Check firing."

n. "Followed by . . . ." Part of a term used to indicate a change in the rate of fire.

o. "Ready." The term to indicate that a weapon or weapons are aimed, loaded and/or prepared to fire.

p. "Repeat." A command or request to fire again the same number of rounds with the same method of fire.

CANCELLATION OF ORDERS

B-19. All fire orders are cancelled by "Cancel—" except when they contain a quantity or type of ammunition. Orders containing a quantity or type of ammunition are cancelled by a new order for quantity or type of ammunition, and the new order takes effect immediately.

REPORTS TO OBSERVER

B-20. *Message to Observer.* When the observer's call for fire is received, the FDC/CP to which it has been directed will prepare and transmit a "Message to Observer" as soon as possible. The "Message to Observer" may include the elements shown in the table below. When any element has been specified by the observer in his call for fire, it may be omitted from the "Message to Observer," providing the FDC/CP can meet the observer's requirements, otherwise it must be included.

Serial	*Element*	*Remarks*
1	Units to fire	
2	Projectile and/or fuze	The standard projectile is HE and the standard fuze is Quick. If this element is omitted in the observer's call for fire and the standard is provided, no report of this element is required.
3	Number of rounds from each gun for fire for effect.	
2	Projectile and/or fuze	The standard projectile is HE and the standard fuze is Quick. If this element is omitted in the observer's call for fire and the standard is provided, no report of this element is required.
3	Number of rounds from each gun for fire for effect.	
4	Target number	1. *UK/CA/ASCP* where appropriate. 2. *US FDC* will always send a target number.

Examples:

(1) Battalion, WP, five rounds, target AG 1428.

(2) Regiment, VT, three rounds, target ZT 1462.

B-21. *Shot*

a. Adjustment by the center gun(s) of the battery/troop is standard.

b. The observer will be informed of the guns used in adjustment by UK/CA/AS CPs.

c. During "Battery Right/Left" individual guns may be reported shot e.g. "Shot 1," "Shot 2" etc.

B-22. *Splash**. Splash is always reported during high angle fire, when shooting with air observers and when requested by the ground observer.

B-23. *Time of Flight.* Reported when requested by observer.

*The United States will use the following definition for "Splash." "Splash is always reported, *five seconds prior to predicted impact* during high angle fire, when shooting with air observers and when requested by the ground observer."

B-24. *Neglect.* Neglect is reported when for any reason a shell is fired with incorrect data. Another shell is fired at the correct data without any order from the observer.

B-25. *Rounds Complete.* Rounds complete is always reported when fire for effect is completed.

B-26. *Target—Recorded.* This may be reported by the FDC/CP when it has recorded the data of the fire mission.

CHAPTER 2

ARTILLERY HEADQUARTERS CALL FOR FIRE FORMAT

FORMAT

B–27. A format is required to enable an artillery headquarters to send calls for fire to higher, lower and adjacent artillery headquarters.

B–28. The format follows closely the observer's call for fire format. The elements are:

a. Identification.

b. Warning order and size of fire unit to engage.

c. Target location.

d. Description of target.

e. Method of engagement. The following elements are sent if they are different from standard.

(1) Type of engagement.

(2) Trajectory.

(3) Ammunition.

(*a*) Type of shell and/or fuze.

(*b*) Volume to be fired from each gun.

(4) Distribution of fire.

f. Method of fire and control.

(1) Fire for Effect.

(2) TOT.

B–29. Example of a divisional call for fire.

Fire Mission Division
ZU 2714
Brigade Headquarters
High Angle
VT 5 rounds
TOT 1325

ANNEX A TO QSTAG–225

AN AREA TARGET ENGAGED BY A BATTERY

Observer : US
Guns : UK/CA/AS

SERIAL	OBSERVER'S ORDERS	REPORTS TO OBSERVER
1	Observer's identification	
2	Fire Mission.	
3	Grid 456123 Altitude 120	
4	Direction 4790.	
5	Vehicle park in wood. 200 by 100, Attitude 800.	
6	Adjust Fire.	
7		Battery 5 rounds.
8		Shot 5.[a]
9	Right 200.	
10		Shot.
11	Drop 400.	
12		Shot.
13	Add 200.	
14		Shot.
15	Drop 100	
16		Shot.
17	Drop 50 FFE.	
18		Shot.
19		Rounds complete.
20	End of Mission. Three vehicles burning.	

[a] Identification of adjusting gun.

AN AREA TARGET ENGAGED BY A BATTERY

ANNEX B TO QSTAG–225

Observer : UK/CA/AS
Guns : US

SERIAL	OBSERVER'S ORDERS	REPORTS TO OBSERVER
1	Observer's identification.	
2	Fire Mission Battery.	
3	Grid 456123 Altitude 120	
4	Direction 4790.	
5	Vehicle park in wood. 200 by 100 Attitude 800.	
6	Adjust Fire.	
7		Battery identification 6 rounds. AG 7115.
8		Shot.
9	Right 100. Add 400.	
10		Shot.
11	Drop 200.	
12		Shot.
13	Drop 100.	
14		Shot.
15	Drop 50. 1 round, FFE.	
16		Shot.
17		Rounds complete.
18	5 rounds, FFE	
19		Shot.
20		Rounds complete.
21	Record as target.[a] End of Mission. Three vehicles burning.	

[a] Request by observer for target to be recorded.

ANNEX C TO QSTAG-225

AREA TARGET ENGAGED BY BATTERY FIRING TIME IN EFFECT

Observer : US
Guns : UK/CA/AS

SERIAL	OBSERVER'S ORDERS	REPORTS TO OBSERVER
1	Observer's identification.	
2	Fire Mission.	
3	Grid 341652 Altitude 120	
4	Direction 1690.	
5	Platoon in open, radius 150.	
6	Time in effect.	
7	Adjust Fire.	
8		Battery 4 rounds.
9		Shot 3.
10	Add 200.	
11		Shot.
12	Right 40. Drop 100.	
13		Shot.[a]
14	Time. Add 50.[b]	
15		Shot.
16	Up 40.[c]	
17		Shot.
18	Down 10 FFE.	
19		Shot.
20		Rounds complete.
21	Record as target. End of Mission. Platoon dispersed.	
22		Target ZP 1040 recorded.

[a] Adjustment to 100 metre bracket is done with fuze quick.

[b] On the request for fuze time the CP orders three guns in adjustment with fuze setting predicted and 20/R applied.

[c] The observer makes correction to HOB by ordering Up/Down. These corrections are converted by the CP to corrections to fuze setting.

ANNEX D TO QSTAG-225

AREA TARGET ENGAGED BY A BATTALION FIRING VT IN EFFECT

Observer : UK/CA/AS
Guns : US

SERIAL	OBSERVER'S ORDERS	REPORTS TO OBSERVER
1	Observer's identification	
2	Fire Mission Battalion	
3	Grid 432176 Altitude 120	
4	Direction 4420	
5	Battalion assembly area 300 by 200, Attitude 4200	
6	VT in effect, 8 rounds	
7	Adjust Fire [a]	
8	Report time of flight	
9		Battalion, Adjusting battery identification, 4 rounds, AB 1420.
10		Shot, time of flight 27 seconds.
11	Drop 400.	
12		Shot.
13	Add 200.	
14		Shot.
15	At my command FFE	
16		Battalion Ready.
17	Fire.	
18		Shot
19		Rounds complete.
20	Cancel at my command Repeat.	
21		Shot.
22		Rounds complete.
23	Record as target. End of Mission. Heavy casualties, Battalion dispersed.	

[a] Adjustment is done with fuze quick by two guns.

ANNEX E TO QSTAG–225

AREA TARGET ENGAGED BY A REGIMENT FIRING VT IN EFFECT

Observer : UK/CA/AS
Guns : US

SERIAL	OBSERVER'S ORDERS	REPORTS TO OBSERVER
1	Observer's identification.	
2	Fire Mission.	
3	Grid 432176 Altitude 120	
4	Direction 4420.	
5	Company assembly area. Radius 200.	
6	VT in effect.	
7	Adjust fire.[a]	
8		Regiment 6 rounds. ZT 1764.
9		Battery identification. Shot 4.
10	Drop 400.	
11		Shot.
12	Add 200.	
13		Shot.
14	Drop 100.	
15		Shot.
16	FFE.	
17		Shot.
18		Rounds complete.
19	Repeat.	
20		4 rounds.[b]
21		Shot.
22		Rounds complete.
23	Record as target. End of Mission. Heavy casualties. Company dispersed.	
24		Target ZT 1764 recorded.

[a] Adjustment is done with fuze quick by one gun.
[b] CP has allowed only an additional 4 rounds.

ANNEX F TO QSTAG-225

REGISTRATION

SERIAL	OBSERVER'S ORDERS	REPORTS TO OBSERVER
1	Observer's identification.	
2	Fire Mission (one gun)[a]	
3	Registration point 1.	
4	Direction 1240.	
5	Registration [b]	
6	Adjust Fire.	
7		Shot [c]
8	Right 70, add 200	
9		Shot.
10	Drop 100.	
11		Shot.
12	Add 50.[d]	
13		Shot.
14	Add 25.	
15		Shot.
16	Repeat.	
17		Shot.
18	Drop 25.[e]	
19		Shot.
20	Record as registration point 1 at Add 10.[f]	
21	Time Repeat.[g]	
22		Shot.[h]
23	Up 40.	
24		Shot.
25	3 Rounds FFE.	
26		Shot.
27		Rounds Complete.
28	Record as time registration point at Down 10. End of Mission.	

[a] Additional guns may be ordered/requested to verify the validity of the registration.
[b] Converge by SOP (Piece displacement).
[c] If the PEr is 25 meters or more, this will be reported to the observer.

[d] The observer now obtains a verified 25m bracket or bracketing rounds unless a report has been made from the FDC/CP that the PEr is in excess of 25m (see *c.* above) when a verified 50m bracket is used. A verified bracket consists of two pairs of rounds fired at the same data or at data 25m apart bracketing the registration point. A target hit or range correct spotting may be considered equivalent to a pair of rounds at the same data bracketing the registration point. Corrections for deviation are made after the split of the 50m bracket only when a shift is necessary to obtain positive range spottings. Deviation corrections for rounds fired at the same data should be made with respect to their estimated mean point of impact. When a deviation correction causes a second round at one end of a 25m bracket to be fired at data different from the first round, an additional round should be fired at the new data to verify the bracket.

[e] A verified 25m bracket has been established by observation on serials 12, 14, 16 and 18.

[f] As the registration point is equidistant between the two pairs of rounds which established the 25m bracket, the registration point is recorded at the mid-point. If it is found that the registration point lies nearer the last pair of rounds fired, this data is recorded without command. If it is found that the registration point lies nearer to the pair of rounds previously fired, this data is recordered by ordering Add/or Drop 25, as appropriate. A final refinement in deviation may be made if necessary, to move the mean point of impact of the adjusting rounds over the registration point.

[g] On the order "Time Repeat," using the predicted fuze setting, a round is fired at the data recorded to the registration point with the elevation increased by the equivalent of 20/R.

[h] The fuze length is adjusted by ordering corrections to the height of burst (HOB) until the mpb of four rounds fired at the same data is 20 meters above the registration point. The rules for the adjustment of the fuze are:

(1) If a groundburst is obtained, the HOB is raised 40 meters. This is repeated if necessary, until an airburst is obtained.

(2) Three further rounds are then fired at the same data. If three airbursts are obtained the HOB of the mpb of these three rounds and the previous round is assessed and a correction is ordered to bring the HOB to the correct height, i.e., 20 meters. If two airburst and one groundburst are obtained, the HOB is correct. If three groundburst are obtained, the HOB is correct at Up 20. If two groundburst and one airburst are obtained, the HOB is corerct at Up 10. Corrections to the HOB are ordered to the nearest 10 meters.

See footnotes at end of annex F.

ANNEX G TO QSTAG-225

DESTRUCTION

SERIAL	OBSERVER'S ORDERS	REPORTS TO OBSERVER
1	Observer's identification.	
2	Fire Mission (one gun).	
3	Grid 723459 Altitude 120	
4	Direction 1680	
5	Stalled tank.	
6	Destruction.	
7	Adjust Fire.	
8		Shot.[a]
9	Right 40, add 200.	
10		Shot.
11	Drop 100	
12		Shot.
13	Add 50.	
14		Shot.
15	Drop 25.	
16		Shot.
17	Repeat.	
18		Shot.
19	Add 25.[b]	
20		Shot.
21	Drop 10 3 rounds FFE 40 seconds.[c]	
22		Shot.
23		Shot.
24		Shot.
25		Rounds complete.
26	Repeat.	
27		Shot.
28		Shot.
29		Shot.
30		Rounds complete.
31	Repeat.	
32		Shot.
33		Shot.
34		Shot.
35		Rounds complete.
36	End of Mission. Tank destroyed.	

[a] If the PEr is 25 m or more this will be reported to the observer.

[b] A verified 25m bracket is obtained, unless the observer is informed that the PEr is in excess of 25m when a verified 50m bracket is established.

[c] A group of rounds is ordered to be fired at the split of the bracket. If it is found that the target lies nearer to one of the pair of rounds which established the bracket, FFE is opened at this data.

During FFE the observer makes any necessary correction to fire based on the observation of a previous group or groups of rounds.

A report of shot will be made for each round fired.

The observer may specify the interval of time between each round in the group.

See footnotes at end of Annex G.

ANNEX H TO QSTAG–225

QUICK/DELIBERATE SMOKE

SERIAL	OBSERVER'S ORDERS	REPORTS TO OBSERVER
1	Observer's identification	
2	Fire mission 5 guns.[a]	
3	Grid 123456.[b] Altitude 120	
4	Direction 1260.	
5	Screening 4 minutes.[c]	
6	Smoke in effect 10 rds.[d]	
7	Linear 1000 attitude 1750.[e]	
8	Adjust fire.	
9		Shot.
10	Left 150, add 400.	
11		Shot.
12	Drop 200.	
13		Shot.
14	Smoke, add 100.	
15		Shot.
16	Up 100.	
17		Shot.
18	At my command (2 rds followed by 8 rds) FFE (30 sec).[f]	
19		Ready.
20	Fire.	
21		Shot.
22		Rounds complete.
23	End of mission.	

[a] Indication of number of guns required to take part and hence the number of points.

[b] Grid reference of the up-wind point. (Point 1). The adjusting gun is directed at this point.

[c] The observer's estimate of the length of time screening if required.

[d] The observer's estimate of the total ammunition requirement. May be omitted by the US observer.

[e] This indicates that five points with 200 meters between each point are required. The grid reference, or the point at which adjustment is finished, is always Point 1. Point 2 is 200 metres from Point 1 on the indicated attitude of 1750 mils; point 3 is 200 meters from Point 2, etc. Guns engage the appropriately numbered points. May be omitted in Quick Smoke Missions.

[f] Items in brackets may be omitted by the US observer. The interval is that required to provide a continuous screen under prevailing conditions. At this point and throughout the FFE phase, the observer may order/request a round of smoke or HE to be fired on one of the other points, or other changes as necessary to maintain an effective smoke screen.

APPENDIX C
RADIO TELEPHONE PROCEDURES FOR THE CONDUCT OF ARTILLERY FIRE (QSTAG 246)

CHAPTER 1
INTRODUCTION

C–1. *Purpose*
Radiotelephone Procedures for the Conduct of Artillery Fire has been prepared to describe the use of radiotelephone procedures as it shall be employed for radiotelephone communications between Field Artillery Forward Observer and Field Artillery Fire Direction Centers.

C–2. *Publications* (Reserved for National References)

C–3. *Phonetic Alphabet*
When necessary to identify any letter of the alphabet, the standard phonetic alphabet shall be used. The phonetic alphabet is published in ACP 125.

C–4. *Pronunciation of Numerals*
When numerals are transmitted by radiotelephone, the rules for pronunciation of numerals, published in ACP 125, will be observed.

C–5. *Precedence*
Calls for fire will be considered equivalent to IMMEDIATE messages and will be accorded the considerations of that precedence classification. Fire missions, once in progress, will be interrupted only by FLASH messages.

CHAPTER 2
APPLICATION

C–6. *General*

The radiotelephone procedure used for the adjustment of field artillery fire deviates somewhat from communication procedures published in ACP 122 and ACP 125 in that abbreviated procedure is used in those instances where no confusion will exist. The deviations normally consist of one or more of the following:

a. Elimination of call signs (call words) after identities have been established. Under certain circumstances, when identification is required, transmissions are identified by the use of call sign suffix words, letters or numbers only.

b. A short phrase read-back method of transmission is automatically accomplished without the special operating instructions of "READ BACK".

c. Divergence from the normal or abbreviated normal message format. Examples of radiotelephone procedures used for the adjustment of field artillery are given in the following articles.

C–7. *Short Phrase Read-Back Procedures*

a. To facilitate the transmission of firing data and to minimize requests for repetitions which otherwise might be necessary, the call for fire, message to observer, subsequent corrections and fire commands will, where applicable, be transmitted in short phrases consisting of one or more elements of firing data.

b. Each phrase is read-back by the receiving operator, without operating instructions to do so, exactly as it was received.

c. The length of each phrase, or the number of elements of firing data included in each transmission should be commensurate with the state of training and experience of the individuals concerned and established procedure.

Example 1—Preliminary Call. The Field Artillery Forward Observer (FO) should make a preliminary call to the Fire Direction Centre (FDC): thereby establishing communication, before tranmitting the call for fire.

FO	DARK ERRAND 18, THIS IS DARK ERRAND 44, FIRE MISSION, OVER
FDC	DARK ERRAND 44, THIS IS DARK ERRAND 18, FIRE MISSION, OUT

Note. US call signs are used for illustrative purposes only. It is not the intention of this document to indicate that the US call sign procedure is to be adcpted by the BCA nations. Additionally, all examples are based on a US artillery battalion organization. It is not the intention of this document to indicate that such organization be adopted by the BCA nations.

Example 2—Call for Fire. Communication now established, the FO continues with the call for fire.

FO	FROM REGISTRATION POINT 1, DIRECTION 5940, OVER
FDC	FROM REGISTRATION POINT 1, DIRECTION 5940, OUT
FO	RIGHT 600, ADD 800, UP 20, OVER
FDC	RIGHT 600, ADD 800, UP 20, OUT
FO	COMPANY ASSEMBLING, ADJUST FIRE, OVER

FDC COMPANY ASSEMBLING,
ADJUST FIRE, OUT

Explanation:

a. Voice call signs are dropped after communication has been established.

b. When there is an alternative means of communication or a separate fire direction channel available to the observer, fire direction center, and the firing battery(s), the transmission of call signs is unnecessary.

c. When radio is the only means of communication and a separate fire direction channel is not available to the observer, fire direction center, and the firing battery(s), or when communications are difficult or multiple missions are being fired, the transmission of call sign suffix words, letters is mandatory.

Example 3—Message to Observer

FDC BATTALION, BRAVO, 5 ROUNDS
TARGET AF 7214, OVER
FO BATTALION, BRAVO, 5 ROUNDS
TARGET AF 7214, OUT

Explanation:
Type of fuze to be fired is not announced by FDC to FO unless it differs from that requested.

Example 4—Subsequent Corrections. Assume that the firing batteries received their fire commands over another means of communication. The adjusting battery has notified the FDC, SHOT.

FDC SHOT, OVER
FO SHOT, OUT
FO LEFT 100, DROP 400, OVER
FDC LEFT 100, DROP 400, OUT
FDC SHOT, OVER
FO SHOT, OUT
FO ADD 200, OVER
FDC ADD 200, OUT
FDC SHOT, OVER
FO SHOT, OUT
FO ADD 100, OVER
FDC ADD 100, OUT
FDC SHOT, OVER
FO SHOT, OUT
FO DROP 50, FIRE FOR EFFECT, OVER
FDC DROP 50, FIRE FOR EFFECT, OUT

Example 5—Fire for Effect

FDC SHOT, OVER
FO SHOT, OUT
FDC ROUNDS COMPLETE, OVER
FO ROUNDS COMPLETE, OUT

Explanation:
The FDC notifies the FO when the guns begin firing for effect and when they have completed firing for effect.

Example 6—End of Mission; Reporting Effect on Target

FO END OF MISSION, 50 CASUALTIES,
COMPANY DISPERSED, OVER
FDC END OF MISSION, 50 CASUALTIES,
COMPANY DISPERSED, OUT

CHAPTER 3

SPECIAL APPLICATION

C–8. *General*

There are four instances of special application of the use of radiotelephone in the adjusting of field artillery fire of sufficient note to warrant illustrating their use. The first is the use of a relay station between the Field Artillery Forward Observer and the Fire Direction Center. The second is the use of SPLASH. The third is radiotelephone procedure used in conducting a simultaneous mission. The fourth is the transmission of fire commands between the Fire Direction Center and the Firing Battery(s).

C–9. *Relay Procedure*

In circumstances where direct radio contact between the Forward Observer and the Fire Direction Center cannot be established because of distance, terrain, etc., and pending the availability of automatic retransmission equipment, the following relay procedure is prescribed and will be used by all concerned as applicable.

Example 7—Relay Procedure. Assume that direct radio contact cannot be established between the FO and the FDC. However, for example, the Artillery Liaison Officer (DARK ERRAND) is able to contact both the FO and the FDC. Hearing no reply to the preliminary call, the Liaison Officer will, without instructions or request, transmit as follows:

LO DARK ERRAND 18, THIS IS DARK ERRAND 76,
FROM DARK ERRAND 64, FIRE MISSION, OVER
FDC DARK ERRAND 76, THIS IS DARK ERRAND 18,
FIRE MISSION, OUT
LO 76, OUT

Communication now established the FO continues with the call for fire. To permit the originator to correct any mistake by the relay a pause of 5 seconds should be made between the relay station transmission and the check back.

FO FROM REGISTRATION POINT 1
DIRECTION 940, RIGHT 600, OVER
LO 76, FROM REGISTRATION POINT 1,
DIRECTION 940, RIGHT 600, OVER
FDC FROM REGISTRATION POINT 1,
DIRECTION 940, RIGHT 600, OUT
LO 76, OUT

The mission will continue to be sent in this manner until all elements of the call for fire have been received and read back by the FDC.
The relaying station reads back that portion of the call for fire request transmitted by the FO and transmits the information to the FDC. The suffix number of the relay station is retained to ensure that the originating and receiving stations are not confused.

FDC BATTALION, BRAVO 5 ROUNDS,
TARGET BG 7112, OVER
LO 76, BATTALION, BRAVO 5 ROUNDS,
TARGET BG 7112, OVER
FO BATTALION, BRAVO 5 ROUNDS
TARGET BG 7112, OUT
LO 76, OUT

The mission continues to be sent, relayed and acknowledged in this manner until it is completed.

Explanation:
The relay procedure described above illustrates the method employed by an intermediate station in relaying a call for fire. The relay was accomplished without the aid of operating instructions, address designations, etc. However, when necessary, the originating station will use whatever transmission instructions are required to accomplish the mission.

Example 8—Correcting a Mistake During the Relay Procedure. If the relay station answers back incorrectly, the originator immediately sends "WRONG, OVER", which is answered back "76 WRONG, OVER". The correct order is then sent, again preceded by "WRONG . . . . ." and thereafter the normal rules of correction procedure apply.

FDC BATTALION, BRAVO, 5 ROUNDS
TARGET BG 7112, OVER
LO 76, BATTALION, BRAVO, 5 ROUNDS
TARGET BG 7211, OVER
FDC WRONG, OVER
LO 76, WRONG OVER
FDC WRONG, BATTALION, BRAVO, 5 ROUNDS
TARGET BG 7112, OVER
LO 76, WRONG, BATTALION, BRAVO, 5 ROUNDS
TARGET BG 7112, OVER
FO WRONG BATTALION, BRAVO 5 ROUNDS
TARGET BG 7112, OUT
LO 76, OUT

Example 9—Correcting a Mistake by a Transmitting Operator.
If a transmitting operator makes an error, he transmits the proword "CORRECTION" followed by the last word, group, proword or phrase correctly transmitted. Transmission then continues.

FO RIGHT 100, ADD 200,
CORRECTION
RIGHT 100, DROP 200, OVER
LO 76, RIGHT 100, DROP 200, OVER
FDC RIGHT 100, DROP 200, OUT
LO 76, OUT

C-10. *Splash.*
In the circumstances where the warning "SPLASH" must be transmitted to the Forward Observer the following radiotelephone procedure will apply.

Example 10—SPLASH Procedure. Assume that the FO has requested "SPLASH" from the FDC. When the guns have been fired, the following will be transmitted:

FDC SHOT OVER
FO SHOT, OUT
FDC SPLASH, OVER
SPLASH is transmitted 5 seconds prior to the burst of the projectile.
FO SPLASH, OUT
FO LEFT 100, DROP 400, OVER
FDC LEFT 100, DROP 400, OUT
FDC SHOT, OVER
FO SHOT, OUT
FDC SPLASH, OVER
FO SPLASH, OUT

C-11. *Simultaneous Missions*
There are times when it becomes necessary to fire two or more missions simultaneously on the same fire direction net. When this situation arises,

it is necessary that stations identify their transmissions in order to avoid confusion. The battalion fire direction center controls all simultaneous missions. *All stations,* when sending or transmitting, *use their own suffix* number. In the following example, the battalion fire direction center indicates that Alpha Battery will fire for FO 1 (24) and that Bravo Battery will fire for FO 2 (25). The transmissions will be made on Fire Direction Net 1.

Interruptions should only be made in this procedure during a natural pause. Such pauses are:

a. After the call for fire and before firing the first round.

b. After a report of shot, i.e., during the time of flight.

Example 11—Simultaneous Mission

FO 1	DARK ERRAND 18, THIS IS DARK ERRAND 24, FIRE MISSION, OVER
BN FDC	DARK ERRAND 24, THIS IS DARK ERRAND 18, FIRE MISSION, 29 AVAILABLE, OVER
FO 1	29 AVAILABLE, OUT
FO 1	DARK ERRAND 29, THIS IS DARK ERRAND 24, FIRE MISSION, OVER
'A' FDC	DARK ERRAND, 24, THIS IS DARK ERRAND 29, FIRE MISSION, OUT
FO 1	GRID 432181, DIRECTION 800, OVER
'A' FDC	GRID 432181, DIRECTION 800, OVER
FO 1	TWO MGs FIRING, VT ADJUST FIRE, OVER
'A' FDC	TWO MGs FIRING, VT ADJUST FIRE, OUT
'A' FDC	ALPHA, 5 ROUNDS, TARGET BJ 7829, OVER
FO 1	ALPHA, 5 ROUNDS, TARGET BJ 7829, OUT
'A' FDC	SHOT, OVER
FO 1	SHOT, OUT
FO 2	DARK ERRAND 18, THIS IS DARK ERRAND 25, FIRE MISSION, OVER
BN FDC	DARK ERRAND 25, THIS IS DARK ERRAND 18, FIRE MISSION, 49 AVAILABLE, OVER
FO 2	25, 49 AVAILABLE, OUT
FO 2	DARKERRAND 49, THIS IS DARK ERRAND 25, FIRE MISSION OVER
'B' FDC	DARK ERRAND 25, THIS IS DARK ERRAND 49, FIRE MISSION, OUT
FO 2	25, GRID 422189, DIRECTION 980, SURVEY PARTY IN OPEN ADJUST FIRE, OVER
'B' FDC	49, GRID 422189, DIRECTION 980, SURVEY PARTY IN OPEN, ADJUST FIRE, OUT
FO 1	24, RIGHT 100, DROP 200, OVER
'A' FDC	29, RIGHT 100, DROP 200, OUT
'B' FDC	49, BRAVO, 3 ROUNDS, TARGET BJ 7716, OVER
FO 2	25, BRAVO, 3 ROUNDS, TARGET BJ 7716, OUT
FO 1	24, ADD 100, OVER
'A' FDC	29, SHOT, OVER
FO 1	24, SHOT, OUT
FO 2	25, LEFT 50, ADD 100, OVER
'B' FDC	49, LEFT 50, ADD 100, OVER
'B' FDC	49, SHOT, OVER
FO 2	25, SHOT, OUT

Explanation:

The missions continue in this manner until one firing unit has completed its task. Thereafter, suffix numbers are omitted.

C-12. *Fire Commands.*

(Fire Commands between the fire direction center and the firing batteries —national procedures).

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